IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF PENNSYLVANIA

DAMASCUS CITIZENS FOR SUSTAINABILITY, *Plaintiffs,* v. THE DELAWARE RIVER BASIN COMMISSION, *Defendant.*	No.: 2:23-cv-00061

EXHIBIT INDEX TO COMPLAINT

Exhibit A	Delaware River Basin Compact
Exhibit B	Pa. Bulletin Notice of DRBC Proposed Rulemaking (51 Pa. Bull. 7471 et seq.)
Exhibit C	DRBC Redline Comparison of Proposed Changes to Section 2.30 of the Delaware River Basin Water Code to Final Rule Version
Exhibit D	DRBC Redline Comparison of Proposed Changes to Part 440 of DRBC's Special Regulations at Title 18 to Final Rule Version
Exhibit E	DRBC Comment Response Document ("CRD") on Final Rule – dated December 7, 2022
Exhibit F	Table from PADEP Oil and Gas Bureau Waste/Wastewater Database Identifying Roadspreading "Waste Facilities"
Exhibit G	Bryce F. Payne, Jr., Ph.D. – "Oil and Gas Well Brines for Dust Control on Unpaved Roads – Part 1: Ineffectiveness" - European Scientific Journal, Sept. 2018
Exhibit H	Bryce F. Payne, Jr., Ph.D. – "Oil and Gas Well Brines for Dust Control on Unpaved Roads - Part 2: Environmental and Health Impacts, European Scientific Journal, Oct. 2018

Exhibit I	"Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater," Nancy Lauer, Nathaniel Warner, Avner Vengosh, *Environmental Science and Technology*, Jan, 4, 2018, DOI: 10.1021/acs.est.7b04952
Exhibit J	2-25-2021 Minutes Resolution
Exhibit K	DRBC Notice of Final Rules – December 7, 2022
Exhibit L	DRBC FAQs on Final Rules
Exhibit M	DRBC FAQs on *Proposed* Rules
Exhibit N	Penn State May 26, 2022 Brine Study Commissioned by PADEP ("Evaluation Of Environmental Impacts From Dust Suppressants Used On Gravel Roads", Burgos, et al.)
Exhibit O	"Efficacy of oil and gas produced water as a dust suppressant", Stallworth et al., Science of the Total Environment, Dec. 10, 2021
Exhibit P	DCS Amicus Brief Supporting Appellant Siri Lawson in EHB Docket No. 2017-051-B (with Appendices)
Exhibit Q	Catskill Mountainkeeper Comment Letter with Hydroquest Report and Addenda
Exhibit R	Excerpt from PADEP Oil and Gas Reports Data Dictionary
Exhibit S	Reid Frazier, StateImpact PA article on Belle Vernon sewage treatment plant

EXHIBIT A

DELAWARE RIVER BASIN COMPACT

Delaware River Basin Commission

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PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

1961

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United States: Public Law 87-328,
Approved September 27, 1961, 75 Statutes at Large 688

Delaware: 53 Delaware Laws, Chapter 71,
Approved May 26, 1961

New Jersey: Laws of 1961, Chapter 13,
Approved May 1, 1961

New York: Laws of 1961, Chapter 148,
Approved March 17, 1961

Pennsylvania: Acts of 1961, Act No. 268,
Approved July 7, 1961

PART I

COMPACT

Whereas the signatory parties recognize the water and related resources of the Delaware River Basin as regional assets vested with local, State, and National interests, for which they have a joint responsibility; and

Whereas the conservation, utilization, development, management, and control of the water and related resources of the Delaware River Basin under a comprehensive multipurpose plan will bring the greatest benefits and produce the most efficient service in the public welfare; and

Whereas such a comprehensive plan administered by a basin wide agency will provide effective flood damage reduction; conservation and development of ground and surface water supply for municipal, industrial, and agricultural uses; development of recreational facilities in relation to reservoirs, lakes, and streams; propagation of fish and game; promotion of related forestry, soil conservation, and watershed projects; protection and aid to fisheries dependent upon water resources; development of hydroelectric power potentialities; improved navigation; control of the movement of salt water; abatement and control of stream pollution; and regulation of stream flows toward the attainment of these goals; and

Whereas decisions of the United States Supreme Court relating to the waters of the basin have confirmed the interstate regional character of the water resources of the Delaware River Basin, and the United States Corps of Engineers has in a prior report on the Delaware River Basin (House Document 179, Seventy-third Congress, second session) officially recognized the need for an interstate agency and the economies that can result from unified development and control of the water resources of the basin; and

Whereas the water resources of the basin are presently subject to the duplicating, overlapping, and uncoordinated administration of some forty-three State agencies, fourteen interstate agencies, and nineteen Federal agencies which exercise a multiplicity of powers and duties resulting in a splintering of authority and responsibilities; and

Whereas the joint advisory body known as the Interstate Commission on the Delaware River Basin (INCODEL), created by the respective commissions or Committee on Interstate Cooperation of the States of Delaware, New Jersey, New York, and Pennsylvania, has on the basis of its extensive investigations, surveys, and studies concluded that regional development of the

Delaware River Basin is feasible, advisable, and urgently needed; and has recommended that an interstate compact with Federal participation be consummated to this end; and

Whereas the Congress of the United States and the executive branch of the Government have recognized the national interest in the Delaware River Basin by authorizing and directing the Corps of Engineers, Department of the Army, to make a comprehensive survey and report on the water and related resources of the Delaware River Basin, enlisting the technical aid and planning participation of many Federal, State, and municipal agencies dealing with the waters of the basin, and in particular the Federal Departments of Agriculture, Commerce, Health, Education, and Welfare, and Interior, and the Federal Power Commission; and

Whereas some twenty-two million people of the United States at present live and work in the region of the Delaware River Basin and its environs, and the government, employment, industry, and economic development of the entire region and the health, safety, and general welfare of its population are and will continue to be vitally affected by the use, conservation, management, and control of the water and related resources of the Delaware River Basin; and

Whereas demands upon the waters and related resources of the basin are expected to mount rapidly because of the anticipated increase in the population of the region projected to reach thirty million by 1980 and forty million by 2010, and because of the anticipated increase in industrial growth projected to double by 1980; and

Whereas water resources planning and development is technical, complex, and expensive, and has often required fifteen to twenty years from the conception to the completion of a large dam and reservoir; and

Whereas the public interest requires that facilities must be ready and operative when needed, to avoid the catastrophe of unexpected floods or prolonged drought, and for other purposes; and

Whereas the Delaware River Basin Advisory Committee, a temporary body constituted by the Governors of the four basin States and the mayors of the cities of New York and Philadelphia, has prepared a draft of an interstate-Federal compact for the creation of a basin agency, and the signatory parties desire to effectuate the purposes thereof: Now therefore

The states of Delaware, New Jersey and New York and the Commonwealth of Pennsylvania, and the United States of America hereby solemnly covenant and agree with each other, upon the enactment of concurrent legislation by the Congress of the United States and by the respective state legislatures, having the same effect as this Part, to the following Compact:

ARTICLE 1

SHORT TITLE, DEFINITIONS, PURPOSE AND LIMITATIONS

Section 1.1 Short Title.

This Act shall be known and may be cited as the Delaware River Basin Compact.

Section 1.2 Definitions.

For the purposes of this Compact, and of any supplemental or concurring legislation enacted pursuant thereto, except as may be otherwise required by the context:

(a) "Basin" shall mean the area of drainage into the Delaware River and its tributaries, including Delaware Bay;

(b) "Commission" shall mean the Delaware River Basin Commission created and constituted by this Compact;

(c) "Compact" shall mean Part I of this act;

(d) "Cost" shall mean direct and indirect expenditures, commitment, and net induced adverse effects, whether or not compensated for, used or incurred in connection with the establishment, acquisition, construction, maintenance and operation of a project;

(e) "Facility" shall mean any real or personal property, within or without the basin, and improvements thereof or thereon, and any and all rights of way, water, water rights, plants, structures, machinery and equipment, acquired, constructed, operated or maintained for the beneficial use of water resources or related land uses including, without limiting the generality of the foregoing, any and all things and appurtenances necessary, useful or convenient for the control, collection, storage, withdrawal, diversion, release, treatment, transmission, sale or exchange of water; or for navigation thereon, or the development and use of hydroelectric energy and power, and public recreational facilities; or the propagation of fish and wildlife; or to conserve and protect the water resources of the basin or any existing or future water supply source, or to facilitate any other uses of any of them;

(f) "Federal government" shall mean the government of the United States of America, and any appropriate branch, department, bureau or division thereof, as the case may be;

(g) "Project" shall mean any work, service or activity which is separately planned, financed, or identified by the commission, or any separate facility undertaken or to be undertaken within a specified area, for the conservation, utilization, control, development or management of water resources which can be established and utilized independently or as an addition to an existing facility, and can be considered as a separate entity for purposes of evaluation;

(h) "Signatory party" shall mean a state or commonwealth party to this Compact, and the federal government;

(i) "Water resources" shall include water and related natural resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership or control.

Section 1.3 Purpose and Findings.

The legislative bodies of the respective signatory parties hereby find and declare:

(a) The water resources of the basin are affected with a local, state, regional and national interest and their planning, conservation, utilization, development, management and control, under appropriate arrangements for intergovernmental cooperation, are public purposes of the respective signatory parties.

(b) The water resources of the basin are subject to the sovereign right and responsibility of the signatory parties, and it is the purpose of this Compact to provide for a joint exercise of such powers of sovereignty in the common interests of the people of the region.

(c) The water resources of the basin are functionally inter-related, and the uses of these resources are interdependent. A single administrative agency is therefore essential for effective and economical direction, supervision and coordination of efforts and programs of federal, state and local governments and of private enterprise.

(d) The water resources of the Delaware River Basin, if properly planned and utilized, are ample to meet all presently projected demands, including existing and added diversions in future years and ever increasing economies and efficiencies in the use and reuse of water resources can be brought about by comprehensive planning, programming and management.

(e) In general, the purposes of this Compact are to promote interstate comity; to remove causes of present and future controversy; to make secure and protect present developments within the states; to encourage and provide for the planning, conservation, utilization, development, management and control of the water resources of the basin; to provide for cooperative planning and action by the signatory parties with respect to such water resources; and to apply the principle of equal and uniform treatment to all water users who are similarly situated and to all users of related facilities, without regard to established political boundaries.

Section 1.4 Powers of Congress; Withdrawal.

Nothing in this Compact shall be construed to relinquish the functions, powers or duties of the Congress of the United States with respect to the control of any navigable waters within the basin, nor shall any provision hereof be construed in derogation of any of thefe constitutional powers of the Congress to regulate commerce among the states and with foreign nations. The power and right of the Congress to withdraw the federal government as a party to this Compact or to revise or modify the terms, conditions and provisions under which it may remain a party by amendment, repeal or modification of any federal statute applicable thereto is recognized by the signatory parties.

Section 1.5 Existing Agencies; Construction.

It is the purpose of the signatory parties to preserve and utilize the functions, powers and duties of existing offices and agencies of government to the extent not inconsistent with the Compact, and the commission is authorized and directed to utilize and employ such offices and agencies for the purpose of this Compact to the fullest extent it finds feasible and advantageous.

Section 1.6 Duration of Compact.

(a) The duration of this Compact shall be for an initial period of 100 years from its effective date, and it shall be continued for additional periods of 100 years if not later than 20 years nor sooner than 25 years prior to the termination of the initial period or any succeeding period none of the signatory states, by authority of an act of its legislature, notifies the commission of intention to terminate the Compact at the end of the then current 100 year period.

(b) In the event that this Compact should be terminated by operation of paragraph (a) above, the commission shall be dissolved, its assets and liabilities transferred, and its corporate affairs wound up, in such manner as may be provided by act of the Congress.

ARTICLE 2

ORGANIZATION AND AREA

Section 2.1 Commission Created.

The Delaware River Basin Commission is hereby created as a body politic and corporate, with succession for the duration of this Compact, as an agency and instrumentality of the governments of the respective signatory parties.

Section 2.2 Commission Membership.[1]

The commission shall consist of the Governors of the signatory states, *ex officio*, and one commissioner to be appointed by the President of the United States to serve during the term of office of the President.

Section 2.3 Alternates.

Each member of the commission shall appoint an alternate to act in his place and stead, with authority to attend all meetings of the commission, and with power to vote in the absence of the member. Unless otherwise provided by law of the signatory party for which he is appointed, each alternate shall serve during the term of the member appointing him, subject to removal at the pleasure of the member. In the event of a vacancy in the office of alternate, it shall be filled in the same manner as an original appointment for the unexpired term only.

Section 2.4 Compensation.

Members of the commission and alternates shall serve without compensation but may be reimbursed for necessary expenses incurred in and incident to the performance of their duties.

Section 2.5 Voting Power.

Each member shall be entitled to one vote on all matters which may come before the commission. No action of the commission shall be taken at any meeting unless a majority of the membership shall vote in favor thereof.

Section 2.6 Organization and Procedure.

The commission shall provide for its own organization and procedure, and shall adopt rules and regulations governing its meetings and transactions. It shall organize annually by the election of a chairman and vice-chairman from among its members. It shall provide by its rules for the appointment by each member in his discretion of an advisor to serve without compensation, who may attend all meetings of the commission and its committees.

[1] Section 2.2 is as enacted in 1961. See Editor's Note regarding subsequent changes.

Section 2.7 Jurisdiction of the Commission.

The commission shall have, exercise and discharge its functions, powers and duties within the limits of the basin, except that it may in its discretion act outside the basin whenever such action may be necessary or convenient to effectuate its powers or duties within the basin, or to sell or dispose of water, hydroelectric power or other water resources within or without the basin. The commission shall exercise such power outside the basin only upon the consent of the state in which it proposes to act.

ARTICLE 3

POWERS AND DUTIES OF THE COMMISSION

Section 3.1 Purpose and Policy.

The commission shall develop and effectuate plans, policies and projects relating to the water resources of the basin. It shall adopt and promote uniform and coordinated policies for water conservation, control, use and management in the basin. It shall encourage the planning, development and financing of water resources projects according to such plans and policies.

Section 3.2 Comprehensive Plan, Program and Budgets.

The commission shall, in accordance with Article 13 of this Compact, formulate and adopt:

(a) A comprehensive plan, after consultation with water users and interested public bodies, for the immediate and long range development and uses of the water resources of the basin;

(b) A water resources program, based upon the comprehensive plan, which shall include a systematic presentation of the quantity and quality of water resources needs of the area to be served for such reasonably foreseeable period as the commission may determine, balanced by existing and proposed projects required to satisfy such needs, including all public and private projects affecting the basin, together with a separate statement of the projects proposed to be undertaken by the commission during such period; and

(c) An annual current expense budget and an annual capital budget consistent with the water resources program covering the commission's projects and facilities for the budget period.

Section 3.3 Allocations, Diversions and Releases.

The commission shall have the power from time to time as need appears, in accordance with the doctrine of equitable apportionment, to allocate the waters of the basin to and among the states signatory to this Compact and to and among their respective political subdivisions, and to impose conditions, obligations and release requirements related thereto, subject to the following limitations:

(a) The commission, without the unanimous consent of the parties to the United States Supreme Court decree in *New Jersey v. New York, 347 U.S. 995 (1954)*, shall not impair, diminish or otherwise adversely affect the diversions, compensating releases, rights, conditions, obligations, and provisions for the administration thereof as provided in said decree; provided, however, that after consultation with the river master under said decree the commission may find and declare a state of emergency resulting from a drought or catastrophe and it may thereupon by unanimous consent of its members authorize and direct an increase or decrease in any allocation or diversion permitted or releases required by the decree, in such manner and for such limited time as may be necessary to meet such an emergency condition.

(b) No allocation of waters hereafter made pursuant to this section shall constitute a prior appropriation of the waters of the basin or confer any superiority of right in respect to the use of those waters, nor shall any such action be deemed to constitute an apportionment of the waters of the basin among the parties hereto: Provided, That this paragraph shall not be deemed to limit or restrict the power of the commission to enter into covenants with respect to water supply, with a duration not exceeding the life of this Compact, as it may deem necessary for a benefit or development of the water resources of the basin.

(c) Any proper party deeming itself aggrieved by action of the commission with respect to an out-of-basin diversion or compensating releases in connection therewith, notwithstanding the powers delegated to the commission by this Compact may invoke the original jurisdiction of the United States Supreme Court within one year after such action for an adjudication and determination thereof de novo. Any other action of the commission pursuant to this section shall be subject to judicial review in any court of competent jurisdiction.

Section 3.4 Supreme Court Decree; Waivers.

Each of the signatory states and their respective political subdivisions, in consideration of like action by the others, and in recognition of reciprocal benefits, hereby waives and relinquishes for the duration of this Compact any right, privilege or power it may have to apply for any modification of the terms of the decree of the United States Supreme Court in *New Jersey v. New York, 347 U.S. 995 (1954)* which would increase or decrease the diversions authorized or increase or decrease the releases required thereunder, except that a proceeding to modify such decree to increase diversions or compensating releases in connection with such increased diversions may be prosecuted by a proper party to effectuate rights, powers, duties and obligations under Section 3.3 of this Compact, and except as may be required to effectuate the provisions of paragraphs IIIB3 and VB of said decree.

Section 3.5 Supreme Court Decree; Specific Limitations on Commission.

Except as specifically provided in Sections 3.3 and 3.4 of this article, nothing in this Compact shall be construed in any way to impair, diminish or otherwise adversely affect the rights, powers, privileges, conditions and obligations contained in the decree of the United States Supreme Court in *New Jersey v. New York, 347 U.S. 995 (1954).* To this end and without limitation thereto, the commission shall not:

(a) Acquire, construct or operate any project or facility or make any order or take any action which would impede or interfere with the rights, powers, privileges, conditions or obligations contained in said decree;

(b) Impose or collect any fee, charge or assessment with respect to diversions of waters of the basin permitted by said decree;

(c) Exercise any jurisdiction, except upon consent of all the parties to said decree, over the planning, design, construction, operation or control of any projects, structures or facilities constructed or used in connection with withdrawals, diversions and releases of waters of the basin authorized by said decree or of the withdrawals, diversions or releases to be made thereunder; or

(d) Serve as river master under said decree, except upon consent of all the parties thereto.

Section 3.6 General Powers.

The commission may:

(a) Plan, design, acquire, construct, reconstruct, complete, own, improve, extend, develop, operate and maintain any and all projects, facilities, properties, activities and services, determined by the commission to be necessary, convenient or useful for the purposes of this Compact;

(b) Establish standards of planning, design and operation of all projects and facilities in the basin which affect its water resources, including without limitation thereto water and waste treatment plants, stream and lake recreational facilities, trunk mains for water distribution, local flood protection works, small watershed management programs, and ground water recharging operations;

(c) Conduct and sponsor research on water resources, their planning, use, conservation, management, development, control and protection, and the capacity, adaptability and best utility of each facility thereof, and collect, compile, correlate, analyze, report and interpret data on water resources and uses in the basin, including without limitation thereto the relation of water to other resources, industrial water technology, ground water movement, relation between water price and water demand, and general hydrological conditions;

(d) Compile and coordinate systematic stream stage and ground water level forecasting data, and publicize such information when and as needed for water uses, flood warning, quality maintenance or other purposes;

(e) Conduct such special ground water investigations, tests, and operations and compile such data relating thereto as may be required to formulate and administer the comprehensive plan;

(f) Prepare, publish and disseminate information and reports with respect to the water problems of the basin and for the presentation of the needs, resources and policies of the basin to executive and legislative branches of the signatory parties;

(g) Negotiate for such loans, grants, services or other aids as may be lawfully available from public or private sources to finance or assist in effectuating any of the purposes of this Compact; and to receive and accept such aid upon such terms and conditions, and subject to such provisions for repayment as may be required by federal or state law or as the commission may deem necessary or desirable;

(h) Exercise such other and different powers as may be delegated to it by this Compact or otherwise pursuant to law and have and exercise all powers necessary or convenient to carry out its express powers or which may be reasonably implied therefrom.

Section 3.7 Rates and Charges.

The commission may from time to time after public notice and hearing fix, alter and revise rates, rentals, charges and tolls and classifications thereof, for the use of facilities which it may own or operate and for products and services rendered thereby, without regulation or control by any department, office or agency of any signatory party.

Section 3.8 Referral and Review.

No project having a substantial effect on the water resources of the basin shall hereafter be undertaken by any person, corporation or governmental authority unless it shall have been first submitted to and approved by the commission, subject to the provisions of Sections 3.3 and 3.5. The commission shall approve a project whenever it finds and determines that such project would not substantially impair or conflict with the comprehensive plan and may modify and approve as modified, or may disapprove any such project whenever it finds and determines that the project would substantially impair or conflict with such plan. The commission shall provide by regulation for the procedure of submission, review and consideration of projects, and for its determinations pursuant to this section. Any determination of the commission hereunder shall be subject to judicial review in any court of competent jurisdiction.

Section 3.9 Coordination and Cooperation.

The commission shall promote and aid the coordination of the activities and programs of federal, state, municipal and private agencies concerned with water resources administration in the basin. To this end, but without limitation thereto, the commission may:

(a) Advise, consult, contract, financially assist, or otherwise cooperate with any and all such agencies;

(b) Employ any other agency or instrumentality of any of the signatory parties or of any political subdivision thereof, in the design, construction, operation and maintenance of structures, and the installation and management of river control systems, or for any other purpose;

(c) Develop and adopt plans and specifications for particular water resources projects and facilities which so far as consistent with the comprehensive plan incorporate any separate plans of other public and private organizations operating in the basin, and permit the decentralized administration thereof;

(d) Qualify as a sponsoring agency under any federal legislation heretofore or hereafter enacted to provide financial or other assistance for the planning, conservation, utilization, development, management or control of water resources.

Section 3.10 Advisory Committees.

The commission may constitute and empower advisory committees, which may be comprised of representatives of the public and of federal, state, county and municipal governments, water resources agencies, water-using industries, water-interest groups, labor and agriculture.

ARTICLE 4

WATER SUPPLY

Section 4.1 Generally.

The commission shall have power to develop, implement and effectuate plans and projects for the use of the water of the basin for domestic, municipal, agricultural and industrial water supply. To this end, without limitation thereto, it may provide for, construct, acquire, operate and maintain dams, reservoirs and other facilities for utilization of surface and ground water resources, and all related structures, appurtenances and equipment on the river and its tributaries and at such off-river sites as it may find appropriate, and may regulate and control the use thereof.

Section 4.2 Storage and Release of Waters.

(a) The commission shall have power to acquire, operate and control projects and facilities for the storage and release of waters, for the regulation of flows and supplies of surface and ground waters of the basin, for the protection of public health, stream quality control, economic development, improvement of fisheries, recreation, dilution and abatement of pollution, the prevention of undue salinity and other purposes.

(b) No signatory party shall permit any augmentation of flow to be diminished by the diversion of any water of the basin during any period in which waters are being released from storage under the direction of the commission for the purpose of augmenting such flow, except in cases where such diversion is duly authorized by this Compact, or by the commission pursuant thereto, or by the judgment, order or decree of a court of competent jurisdiction.

Section 4.3 Assessable Improvements.

The commission may undertake to provide stream regulation in the main stream or any tributary in the basin and may assess on an annual basis or otherwise the cost thereof upon water users or any classification of them specially benefited thereby to a measurable extent, provided that no such assessment shall exceed the actual benefit to any water user. Any such assessment shall follow the procedure prescribed by law for local improvement assessments and shall be subject to judicial review in any court of competent jurisdiction.

Section 4.4 Coordination.

Prior to entering upon the execution of any project authorized by this article, the commission shall review and consider all existing rights, plans and programs of the signatory parties, their political subdivisions, private parties, and water users which are pertinent to such project, and shall hold a public hearing on each proposed project.

Section 4.5 Additional Powers.

In connection with any project authorized by this article, the commission shall have power to provide storage, treatment, pumping and transmission facilities, but nothing herein shall be construed to authorize the commission to engage in the business of distributing water.

ARTICLE 5

POLLUTION CONTROL

Section 5.1 General Powers.

The commission may undertake investigations and surveys, and acquire, construct, operate and maintain projects and facilities to control potential pollution and abate or dilute existing pollution of the water resources of the basin. It may invoke as complainant the power and jurisdiction of water pollution abatement agencies of the signatory parties.

Section 5.2 Policy and Standards.

The commission may assume jurisdiction to control future pollution and abate existing pollution in the waters of the basin, whenever it determines after investigation and public hearing upon due notice that the effectuation of the comprehensive plan so requires. The standard of such control shall be that pollution by sewage or industrial or other waste originating within a signatory state shall not injuriously affect waters of the basin as contemplated by the comprehensive plan. The commission, after such public hearing may classify the waters of the basin and establish standards of treatment of sewage, industrial or other waste, according to such classes including allowance for the variable factors of surface and ground waters, such as size of the stream, flow, movement, location, character, self-purification, and usage of the waters affected. After such investigation, notice and hearing the commission may adopt and from time to time amend and repeal rules, regulations and standards to control such future pollution and abate existing pollution, and to require such treatment of sewage, industrial or other waste within a time reasonable for the construction of the necessary works, as may be required to protect the public health or to preserve the waters of the basin for uses in accordance with the comprehensive plan.

Section 5.3 Cooperative Legislation and Administration.

Each of the signatory parties covenants and agrees to prohibit and control pollution of the waters of the basin according to the requirements of this Compact and to cooperate faithfully in the control of future pollution in and abatement of existing pollution from the rivers, streams, and waters in the basin which flow through, under, into or border upon any of such signatory states, and in order to effect such object, agrees to enact any necessary legislation to enable each such party to place and maintain the waters of said basin in a satisfactory condition, available for safe and satisfactory use as public and industrial water supplies after reasonable treatment, suitable for recreational usage, capable of maintaining fish and other aquatic life, free from unsightly or malodorous nuisances due to floating solids or sludge deposits and adaptable to such other uses as may be provided by the comprehensive plan.

Section 5.4 Enforcement.

The commission may, after investigation and hearing, issue an order or orders upon any person or public or private corporation, or other entity, to cease the discharge of sewage, industrial or other waste into waters of the basin which it determines to be in violation of such rules and regulations as it shall have adopted for the prevention and abatement of pollution. Any such order or orders may prescribe the date, including a reasonable time for the construction of any necessary works, on or before which such discharge shall be wholly or partially discontinued, modified or treated, or otherwise conformed to the requirements of such rules and regulations. Such order shall be reviewable in any court of competent jurisdiction. The courts of the signatory parties shall have jurisdiction to enforce against any person, public or private corporation, or other entity, any and all provisions of this article or of any such order. The commission may bring an action in its own name in any such court of competent jurisdiction to compel compliance with any provision of this article, or any rule or regulation issued pursuant thereto or of any such order, according to the practice and procedure of the court.

Section 5.5 Further Jurisdiction.

Nothing in this Compact shall be construed to repeal, modify or qualify the authority of any signatory party to enact any legislation or enforce any additional conditions and restrictions to lessen or prevent the pollution of waters within its jurisdiction.

ARTICLE 6

FLOOD PROTECTION

Section 6.1 General Powers.

The commission may plan, design, construct and operate and maintain projects and facilities, as it may deem necessary or desirable for flood damage reduction. It shall have power to operate such facilities and to store and release waters on the Delaware River and its tributaries and elsewhere within the basin, in such manner, at such times, and under such regulations as the commission may deem appropriate to meet flood conditions as they may arise.

Section 6.2 Flood Plain Zoning.

(a) The commission shall have power to adopt, amend and repeal recommended standards, in the manner provided by this section, relating to the nature and extent of the uses of land in areas subject to flooding by waters of the Delaware River and its tributaries. Such standards shall not be deemed to impair or restrict the power of the signatory parties or their political subdivisions to adopt zoning and other land use regulations not inconsistent therewith.

(b) The commission may study and determine the nature and extent of the flood plains of the Delaware River and its tributaries. Upon the basis of such studies, it may establish encroachment lines and delineate the areas subject to flood, including a classification of lands with reference to relative risk of flood and the establishment of standards for flood plain use which will safeguard the public health, safety and property. Prior to the adoption of any standards delineating such area or defining such use, the commission shall hold public hearings, in the manner provided by Article 14, with respect to the substance of such standards. At or before such public hearings the proposed standards shall be available and all interested persons shall be given an opportunity to be heard thereon at the hearing. Upon the adoption and promulgation of such standards, the commission may enter into agreements to provide technical and financial aid to any municipal corporation for the administration and enforcement of any local land use ordinances or regulations giving effect to such standards.

Section 6.3 Flood Lands Acquisition.

The commission shall have power to acquire the fee or any lesser interest in lands and improvements thereon within the area of a flood plain for the purpose of restricting the use of such property so as to minimize the flood hazard, converting property to uses appropriate to flood plain conditions, or preventing unwarranted constrictions that reduce the ability of the river channel to carry flood water. Any such action shall be in accord with the standards adopted and promulgated pursuant to Section 6.2.

Section 6.4 Flood and Stream Stage Warnings and Posting.

The commission may cause lands particularly subject to flood to be posted with flood hazard warnings, and may from time to time cause flood advisory notices to be published and circulated as conditions may warrant.

ARTICLE 7

WATERSHED MANAGEMENT

Section 7.1 Watersheds Generally.

The commission shall promote sound practices of watershed management in the basin, including projects and facilities to retard runoff and waterflow and prevent soil erosion.

Section 7.2 Soil Conservation and Forestry.

The commission may acquire, sponsor or operate facilities and projects to encourage soil conservation, prevent and control erosion, and to promote land reclamation and sound forestry practices.

Section 7.3 Fish and Wildlife.

The commission may acquire, sponsor or operate projects and facilities for the maintenance and improvement of fish and wildlife habitats related to the water resources of the basin.

Section 7.4 Cooperative Planning and Operation.

(a) The commission shall cooperate with the appropriate agencies of the signatory parties and with other public and private agencies in the planning and effectuation of a coordinated program of facilities and projects authorized by this article.

(b) The commission shall not operate any such project or facility unless it has first found and determined that no other suitable unit or agency of government is available to operate the same upon reasonable conditions, in accordance with the intent and purpose expressed in Section 1.5 of this Compact.

ARTICLE 8

RECREATION

Section 8.1 Development.

The commission shall provide for the development of water related public sports and recreational facilities. The commission on its own account or in cooperation with a signatory party, political subdivision or any agency thereof, may provide for the construction, maintenance and administration of such facilities, subject to the provisions of Section 8.2 hereof.

Section 8.2 Cooperative Planning and Operation.

(a) The commission shall cooperate with the appropriate agencies of the signatory parties and with other public and private agencies in the planning and effectuation of a coordinated program of facilities and projects authorized by this article.

(b) The commission shall not operate any such project or facility unless it has first found and determined that no other suitable unit or agency of government is available to operate the same upon reasonable conditions, in accordance with the intent and purpose expressed in Section 1.5 of this Compact.

Section 8.3 Operation and Maintenance.

The commission, within limits prescribed by this article, shall:

(a) Encourage activities of other public agencies having water related recreational interests and assist in the coordination thereof;

(b) Recommend standards for the development and administration of water related recreational facilities;

(c) Provide for the administration, operation and maintenance of recreational facilities owned or controlled by the commission and for the letting and supervision of private concessions in accordance with this article.

Section 8.4 Concessions.

The commission shall after notice and public hearing provide by regulation for the award of contracts for private concessions in connection with recreational facilities, including any renewal or extension thereof, upon sealed competitive bids after public advertisement therefore.

ARTICLE 9

HYDROELECTRIC POWER

Section 9.1 Development.

The waters of the Delaware River and its tributaries may be impounded and used by or under authority of the commission for the generation of hydroelectric power and hydroelectric energy, in accordance with the comprehensive plan.

Section 9.2 Power Generation.

The commission may develop and operate, or authorize to be developed and operated, dams and related facilities and appurtenances for the purpose of generating hydroelectric power and hydroelectric energy.

Section 9.3 Transmission.

The commission may provide facilities for the transmission of hydroelectric power and hydroelectric energy produced by it where such facilities are not otherwise available upon reasonable terms, for the purpose of wholesale marketing of power and nothing herein shall be construed to authorize the commission to engage in the business of direct sale to consumers.

Section 9.4 Development Contracts.

The commission may after public notice and hearing enter into contracts on reasonable terms, consideration and duration under which public utilities or public agencies may develop hydroelectric power and hydroelectric energy through the use of dams, related facilities and appurtenances.

Section 9.5 Rates and Charges.

Rates and charges fixed by the commission for power which is produced by its facilities shall be reasonable, nondiscriminatory, and just.

ARTICLE 10

REGULATION OF WITHDRAWALS AND DIVERSIONS

Section 10.1 Power of Regulation.

The commission may regulate and control withdrawals and diversions from surface waters and ground waters of the basin, as provided by this article. The commission may enter into agreements with the signatory parties relating to the exercise of such power or regulation or control and may delegate to any of them such powers of the commission as it may deem necessary or desirable.

Section 10.2 Determination of Protected Areas.

The commission may from time to time after public hearing upon due notice determine and delineate such areas within the basin wherein the demands upon supply made by water users have developed or threaten to develop to such a degree as to create a water shortage or to impair or conflict with the requirements or effectuation of the comprehensive plan, and any such areas may be designated as "protected areas." The commission, whenever it determines that such shortage no longer exists, shall terminate the protected status of such area and shall give public notice of such termination.

Section 10.3 Withdrawal Permits.

In any protected areas so determined and delineated, no person, firm, corporation or other entity shall divert or withdraw water for domestic, municipal, agricultural or industrial uses in excess of such quantities as the commission may prescribe by general regulation, except (i) pursuant to a permit granted under this article, or (ii) pursuant to a permit or approval heretofore granted under the laws of any of the signatory states.

Section 10.4 Emergency.

In the event of a drought or other condition which may cause an actual and immediate shortage of available water supply within the basin, or within any part thereof, the commission may, after public hearing, determine and delineate the area of such shortage and declare a water supply emergency therein. For the duration of such emergency as determined by the commission no person, firm, corporation or other public or private entity shall divert or withdraw water for any purpose, in excess of such quantities as the commission may prescribe by general regulation or authorize by special permit granted hereunder.

Section 10.5 Standards.

Permits shall be granted, modified or denied as the case may be so as to avoid such depletion of the natural stream flows and ground waters in the protected area or in an emergency area as will adversely affect the comprehensive plan or the just and equitable interests and rights of other lawful users of the same source, giving due regard to the need to balance and reconcile alternative and conflicting uses in the event of an actual or threatened shortage of water of the quality required.

Section 10.6 Judicial Review.

The determinations and delineations of the commission pursuant to Section 10.2 and the granting, modification or denial of permits pursuant to Section 10.3 through 10.5 shall be subject to judicial review in any court of competent jurisdiction.

Section 10.7 Maintenance of Records.

Each state shall provide for the maintenance and preservation of such records of authorized diversions and withdrawals and the annual volume thereof as the commission shall prescribe. Such records and supplementary reports shall be furnished to the commission at its request.

Section 10.8 Existing State Systems.

Whenever the commission finds it necessary or desirable to exercise the powers conferred by this article any diversion or withdrawal permits authorized or issued under the laws of any of the signatory states shall be superseded to the extent of any conflict with the control and regulation exercised by the commission.

ARTICLE 11

INTERGOVERNMENTAL RELATIONS

Section 11.1 Federal Agencies and Projects.

For the purposes of avoiding conflicts of jurisdiction and of giving full effect to the commission as a regional agency of the signatory parties, the following rules shall govern federal projects affecting the water resources of the basin, subject in each case to the provisions of Section 1.4 of this Compact:

(a) The planning of all projects related to powers delegated to the commission by this Compact shall be undertaken in consultation with the commission;

(b) No expenditure or commitment shall be made for or on account of the construction, acquisition or operation of any project or facility nor shall it be deemed authorized, unless it shall have first been included by the commission in the comprehensive plan;

(c) Each federal agency otherwise authorized by law to plan, design, construct, operate or maintain any project or facility in or for the basin shall continue to have, exercise and discharge such authority except as specifically provided by this section.

Section 11.2 State and Local Agencies and Projects.

For the purposes of avoiding conflicts of jurisdiction and of giving full effect to the commission as a regional agency of the signatory parties, the following rules shall govern projects of the signatory states, their political subdivisions and public corporations affecting water resources of the basin:

(a) The planning of all projects related to powers delegated to the commission by this Compact shall be undertaken in consultation with the commission;

(b) No expenditure or commitment shall be made for or on account of the construction, acquisition or operation of any project or facility unless it shall have first been included by the commission in the comprehensive plan;

(c) Each state and local agency otherwise authorized by law to plan, design, construct, operate or maintain any project or facility in or for the basin shall continue to have, exercise and discharge such authority, except as specifically provided by this section.

Section 11.3 Reserved Taxing Powers of States.

Each of the signatory parties reserves the right to levy, assess and collect fees, charges and taxes on or measured by the withdrawal or diversion of waters of the basin for use within the jurisdictions of the respective signatory parties.

Section 11.4 Project Costs and Evaluation Standards.

The commission shall establish uniform standards and procedures for the evaluation, determination of benefits, and cost allocations of projects affecting the basin, and for the determination of project priorities, pursuant to the requirements of the comprehensive plan and its water resources program. The commission shall develop equitable cost sharing and reimbursement formulas for the signatory parties including:

(a) Uniform and consistent procedures for the allocation of project costs among purposes included in multiple-purpose programs;

(b) Contracts and arrangements for sharing financial responsibility among and with signatory parties, public bodies, groups and private enterprise, and for the supervision of their performance;

(c) Establishment and supervision of a system of accounts for reimbursable purposes and directing the payments and charges to be made from such accounts;

(d) Determining the basis and apportioning amounts (i) of reimbursable revenues to be paid signatory parties or their political subdivisions, and (ii) of payments in lieu of taxes to any of them.

Section 11.5 Cooperative Services.

The commission shall furnish technical services, advice and consultation to authorized agencies of the signatory parties with respect to the water resources of the basin, and each of the signatory parties pledges itself to provide technical and administrative services to the commission upon request, within the limits of available appropriations and to cooperate generally with the commission for the purposes of this Compact, and the cost of such services may be reimbursable whenever the parties deem appropriate.

ARTICLE 12

CAPITAL FINANCING

Section 12.1 Borrowing Power.

The commission may borrow money for any of the purposes of this Compact, and may issue its negotiable bonds and other evidences of indebtedness in respect thereto.

All such bonds and evidences of indebtedness shall be payable solely out of the properties and revenues of the commission without recourse to taxation. The bonds and other obligations of the commission, except as may be otherwise provided in the indenture under which they were issued, shall be direct and general obligations of the commission and the full faith and credit of the commission are hereby pledged for the prompt payment of the debt service thereon and for the fulfillment of all other undertakings of the commission assumed by it to or for the benefit of the holders thereof.

Section 12.2 Funds and Expenses.

The purpose of this Compact shall include without limitation thereto all costs of any project or facility or any part thereof, including interest during a period of construction and a reasonable time thereafter and any incidental expenses (legal, engineering, fiscal, financial consultant and other expenses) connected with issuing and disposing of the bonds; all amounts required for the creation of an operating fund, construction fund, reserve fund, sinking fund, or other special fund; all other expenses connected with the planning, design, acquisition, construction, completion, improvement or reconstruction of any facility or any part thereof; and reimbursement of advances by the commission or by others for such purposes and for working capital.

Section 12.3 Credit Excluded; Officers, State and Municipal.

The commission shall have no power to pledge the credit of any signatory party, or of any county or municipality, or to impose any obligation for payment of the bonds upon any signatory party or any county or municipality. Neither the commissioners nor any person executing the bonds shall be liable personally on the bonds of the commission or be subject to any personal liability or accountability by reason of the issuance thereof.

Section 12.4 Funding and Refunding.

Whenever the commission deems it expedient, it may fund and refund its bonds and other obligations whether or not such bonds and obligations have matured. It may provide for the issuance, sale or exchange of refunding bonds for the purpose of redeeming or retiring any bonds (including the payment of any premium, duplicate interest or cash adjustment required in connection therewith) issued by the commission or issued by any other issuing body, the proceeds of the sale of which have been applied to any facility acquired by the commission or which are payable out of the revenues of any facility acquired by the commission. Bonds may be issued partly to refund bonds and other obligations then outstanding, and partly for any other purpose of the commission. All provisions of this Compact applicable to the issuance of bonds are applicable to refunding bonds and to the issuance, sale or exchange thereof.

Section 12.5 Bonds; Authorization Generally.

Bonds and other indebtedness of the commission shall be authorized by resolution of the commission. The validity of the authorization and issuance of any bonds by the commission shall not be dependent upon nor affected in any way by: (i) the disposition of bond proceeds by the commission or by contract, commitment or action taken with respect to such proceeds; or (ii) the failure to complete any part of the project for which bonds are authorized to be issued. The commission may issue bonds in one or more series and may provide for one or more consolidated bond issues, in such principal amounts and with such terms and provisions as the commission may deem necessary. The bonds may be secured by a pledge of all or any part of the property, revenues and franchises under its control. Bonds may be issued by the commission in such amount, with such maturities and in such denominations and form or forms, whether coupon or registered, as to both principal and interest, as may be determined by the commission. The commission may provide for redemption of bonds prior to maturity on such notice and at such time or times and with such redemption provisions, including premiums, as the commission may determine.

Section 12.6 Bonds; Resolutions and Indentures Generally.

The commission may determine and enter into indentures providing for the principal amount, date or dates, maturities, interest rate, denominations, form, registration, transfer, interchange and other provisions of the bonds and coupons and the terms and conditions upon which the same shall be executed, issued, secured, sold, paid, redeemed, funded and refunded. The resolution of the commission authorizing any bond or any indenture so authorized under which the bonds are issued may include all such covenants and other provisions other than any restriction on the regulatory powers vested in the commission by this Compact as the commission may deem necessary or desirable for the issue, payment, security, protection or marketing of the bonds, including without limitation covenants and other provisions as to the rates or amounts of fees, rents and other charges to be charged or made for use of the facilities; the use, pledge, custody, securing, application and disposition of such revenues, of the proceeds of the bonds, and of any other moneys of the commission; the operation, maintenance, repair and reconstruction of the facilities and the amounts which may be expended therefor; the sale, lease or other disposition of the facilities; the insuring of the facilities and of the revenues derived therefrom; the construction or other acquisition of other facilities; the issuance of additional bonds or other indebtedness; the rights of the bondholders and of any trustee for the bondholders upon default by the commission or otherwise; and the modification of the provisions of the indenture and of the bonds. Reference on the face of the bonds to such resolution or indenture by its date of adoption or the apparent date on the face thereof is sufficient to incorporate all of the provisions thereof and of this Compact into the body of the bonds and their appurtenant coupons. Each taker and subsequent holder of the bonds or coupons, whether the coupons are attached to or detached from the bonds, has recourse to all of the provisions of the indenture and of this Compact and is bound thereby.

Section 12.7 Maximum Maturity.

No bond or its terms shall mature in more than fifty years from its own date and in the event any authorized issue is divided into two or more series or divisions, the maximum maturity date herein authorized shall be calculated from the date on the face of each bond separately, irrespective of the fact that different dates may be prescribed for the bonds of each separate series or division of any authorized issue.

Section 12.8 Tax Exemption.

All bonds issued by the commission under the provisions of this Compact and the interest thereof shall at all times be free and exempt from all taxation by or under authority of any of the signatory parties, except for transfer, inheritance and estate taxes.

Section 12.9 Interest.[2]

Bonds shall bear interest at a rate determined by the commission, payable annually or semi-annually.

[2] Section 12.9 appears as amended on October 17, 1984.

Section 12.10 Place of Payment.

The commission may provide for the payment of the principal and interest of bonds at any place or places within or without the signatory states, and in any specified lawful coin or currency of the United States of America.

Section 12.11 Execution.

The commission may provide for the execution and authentication of bonds by the manual, lithographed or printed facsimile signature of officers of the commission, and by additional authentication by a trustee or fiscal agent appointed by the commission. If any of the officers whose signatures or counter signatures appear upon the bonds or coupons cease to be officers before the delivery of the bonds or coupons, their signatures or counter signatures are nevertheless valid and of the same force and effect as if the officers had remained in office until the delivery of the bonds and coupons.

Section 12.12 Holding Own Bonds.

The commission shall have power out of any funds available therefor to purchase its bonds and may hold, cancel or resell such bonds.

Section 12.13 Sale.

The commission may fix terms and conditions for the sale or other disposition of any authorized issue of bonds. The commission may sell bonds at less than their par or face value but no issue of bonds may be sold at an aggregate price below the par or face value thereof if such sale would result in a net interest cost to the commission calculated upon the entire issue so sold of more than six percent per annum payable semi-annually, according to standard tables of bond values. All bonds issued and sold for cash pursuant to this act shall be sold on sealed proposals to the highest bidder. Prior to such sale, the commission shall advertise for bids by publication of a notice of sale not less than ten days prior to the date of sale, at least once in a newspaper of general circulation printed and published in New York City carrying municipal bond notices and devoted primarily to financial news. The commission may reject any and all bids submitted and may thereafter sell the bonds so advertised for sale at private sale to any financially responsible bidder under such terms and conditions as it deems most advantageous to the public interest, but the bonds shall not be sold at a net interest cost calculated upon the entire issue so advertised, greater than the lowest bid which was rejected. In the event the commission desires to issue its bonds in exchange for an existing facility or portion thereof, or in exchange for bonds secured by the revenues of an existing facility, it may exchange such bonds for the existing facility or portion thereof or for the bonds so secured, plus an additional amount of cash, without advertising such bonds for sale.

Section 12.14 Negotiability.

All bonds issued under the provisions of this Compact are negotiable instruments, except when registered in the name of a registered owner.

Section 12.15 Legal Investments.

Bonds of the commission shall be legal investments for savings banks, fiduciaries and public funds in each of the signatory states.

Section 12.16 Validation Proceedings.

Prior to the issuance of any bonds, the commission may institute a special proceeding to determine the legality of proceedings to issue the bonds and their validity under the laws of any of the signatory parties. Such proceeding shall be instituted and prosecuted *in rem* and the judgment rendered therein shall be conclusive against all persons whomsoever and against each of the signatory parties.

Section 12.17 Recording.

No indenture need be recorded or filed in any public office, other than the office of the commission. The pledge of revenues provided in any indenture shall take effect forthwith as provided therein and irrespective of the date of receipts of such revenues by the commission or the indenture trustee. Such pledge shall be effective as provided in the indenture without physical delivery of the revenues to the commission or to the indenture trustee.

Section 12.18 Pledged Revenues.

Bond redemption and interest payments shall, to the extent provided in the resolution or indenture, constitute a first, direct and exclusive charge and lien on all such rates, rents, tolls, fees and charges and other revenues and interest thereon received from the use and operation of the facility, and on any sinking or other funds created therefrom. All such rates, rents, tolls, fees, charges and other revenues, together with interest thereon, shall constitute a trust fund for the security and payment of such bonds and except as and to the extent provided in the indenture with respect to the payment therefrom of expenses for other purposes including administration, operation, maintenance, improvements or extensions of the facilities or other purposes shall not be used or pledged for any other purpose so long as such bonds, or any of them, are outstanding and unpaid.

Section 12.19 Remedies.

The holder of any bond may for the equal benefit and protection of all holders of bonds similarly situated:

(a) by mandamus or other appropriate proceedings require and compel the performance of any of the duties imposed upon the commission or assumed by it, its officers, agents or employees under the provisions of any indenture, in connection with the acquisition, construction, operation, maintenance, repair, reconstruction or insurance of the facilities, or in connection with the collection, deposit, investment, application and disbursement of the rates, rents, tolls, fees, charges and other revenues derived from the operation and use of the facilities, or in connection with the deposit, investment and disbursement of the proceeds received from the sale of bonds; or (b) by action or suit in a court of competent jurisdiction of any signatory party require the commission to account as if it were the trustee of an express trust, or enjoin any acts or things which may be unlawful or in violation of the rights of the holders of the bonds. The enumeration of such rights and remedies does not, however, exclude the exercise or prosecution of any other rights or remedies available to the holders of bonds.

Section 12.20 Capital Financing by Signatory Parties; Guarantees.

(a) The signatory parties will provide such capital funds required for projects of the commission as may be authorized by their respective statutes in accordance with a cost sharing plan prepared pursuant to Article 11 of this Compact; but nothing in this section shall be deemed to impose any mandatory obligation on any of the signatory parties other than such obligations as may be assumed by a signatory party in connection with a specific project or facility.

(b) Bonds of the commission, notwithstanding any other provision of this Compact, may be executed and delivered to any duly authorized agency of any of the signatory parties without public offering and may be sold and resold with or without the guaranty of such signatory party, subject to and in accordance with the constitutions of the respective signatory parties.

(c) The commission may receive and accept, and the signatory parties may make, loans, grants, appropriations, advances and payments of reimbursable or non-reimbursable funds or property in any form for the capital or operating purposes of the commission.

ARTICLE 13

PLAN, PROGRAM AND BUDGETS

Section 13.1 Comprehensive Plan.

The commission shall develop and adopt, and may from time to time review and revise, a comprehensive plan for the immediate and long range development and use of the water resources of the basin. The plan shall include all public and private projects and facilities which are required, in the judgment of the commission, for the optimum planning, development, conservation, utilization, management and control of the water resources of the basin to meet present and future needs; provided that the plan shall include any projects required to conform with any present or future decree or judgment of any court of competent jurisdiction. The commission may adopt a comprehensive plan or any revision thereof in such part or parts as it may deem appropriate, provided that before the adoption of the plan or any part or revision thereof the commission shall consult with water users and interested public bodies and public utilities and shall consider and give due regard to the findings and recommendations of the various agencies of the signatory parties and their political subdivisions. The commission shall conduct public hearings with respect to the comprehensive plan prior to the adoption of the plan or any part of the revision thereof.

Section 13.2 Water Resources Program.

The commission shall annually adopt a water resources program, based upon the comprehensive plan, consisting of the projects and facilities which the commission proposes to be undertaken by the commission and by other authorized governmental and private agencies, organizations and persons during the ensuing six years or such other reasonably foreseeable period as the commission may determine. The water resources program shall include a systematic presentation of:

(1) the quantity and quality of water resources needs for such period;

(2) the existing and proposed projects and facilities required to satisfy such needs, including all public and private projects to be anticipated;

(3) a separate statement of the projects proposed to be undertaken by the commission during such period.

Section 13.3 Annual Current Expense and Capital Budgets.

(a) The commission shall annually adopt a capital budget including all capital projects it proposes to undertake or continue during the budget period containing a statement of the estimated cost of each project and the method of financing thereof.

(b) The commission shall annually adopt a current expense budget for each fiscal year. Such budget shall include the commission's estimated expenses for administration, operation, maintenance and repairs, including a separate statement thereof for each project, together with its cost allocation. The total of such expenses shall be balanced by the commission's estimated revenues from all sources, including the cost allocations undertaken by any of the signatory parties in connection with any project. Following the adoption of the annual current expense budget by the commission, the executive director of the commission shall:

(1) certify to the respective signatory parties the amounts due in accordance with existing cost sharing established for each project; and

(2) transmit certified copies of such budget to the principal budget officer of the respective signatory parties at such time and in such manner as may be required under their respective budgetary procedures. The amount required to balance the current expense budget in addition to the aggregate amount of item (1) above and all other revenues available to the commission shall be apportioned equitably among the signatory parties by unanimous vote of the commission, and the amount of such apportionment to each signatory party shall be certified together with the budget.

(c) The respective signatory parties covenant and agree to include the amounts so apportioned for the support of the current expense budget in their respective budgets next to be adopted, subject to such review and approval as may be required by their respective budgetary processes. Such amounts shall be due and payable to the commission in quarterly installments during its fiscal year, provided that the commission may draw upon its working capital to finance its current expense budget pending remittances by the signatory parties.

ARTICLE 14

GENERAL PROVISIONS

Section 14.1 Auxiliary Powers of Commission; Functions of Commissioners.

(a) The commission, for the purposes of this Compact, may:

(1) Adopt and use a corporate seal, enter into contracts, sue and be sued in all courts of competent jurisdiction;

(2) Receive and accept such payments, appropriations, grants, gifts, loans, advances and other funds, properties and services as may be transferred or made available to it by any signatory party or by any other public or private corporation or individual, and enter into agreements to make reimbursement for all or part thereof;

(3) Provide for, acquire and adopt detailed engineering, administrative, financial and operating plans and specifications to effectuate, maintain or develop any facility or project;

(4) Control and regulate the use of facilities owned or operated by the commission;

(5) Acquire, own, operate, maintain, control, sell and convey real and personal property and any interest therein by contract, purchase, lease, license, mortgage or otherwise as it may deem necessary for any project or facility, including any and all appurtenances thereto necessary, useful or convenient for such ownership, operation, control, maintenance or conveyance;

(6) Have and exercise all corporate powers essential to the declared objects and purposes of the commission.

(b) The commissioners, subject to the provisions of this Compact, shall:

(1) Serve as the governing body of the commission and exercise and discharge its powers and duties except as otherwise provided by or pursuant to this Compact;

(2) Determine the character of and the necessity for its obligations and expenditures and the manner in which they shall be incurred, allowed, and paid subject to any provisions of law specifically applicable to agencies or instrumentalities created by Compact;

(3) Provide for the internal organization and administration of the commission;

(4) Appoint the principal officers of the commission and delegate to and allocate among them administrative functions, powers and duties;

(5) Create and abolish offices, employments and positions as it deems necessary for the purposes of the commission, and subject to the provisions of this article, fix and provide for the qualification, appointment, removal, term, tenure, compensation, pension and retirement rights of its officers and employees;

(6) Let and execute contracts to carry out the powers of the commission.

Section 14.2 Regulations; Enforcement.

The commission may:

(a) Make and enforce reasonable rules and regulations for the effectuation, application and enforcement of this Compact; and it may adopt and enforce practices and schedules for or in connection with the use, maintenance and administration of projects and facilities it may own or operate and any product or service rendered thereby; provided that any rule or regulation, other than one which deals solely with the internal management of the commission, shall be adopted only after public hearing and shall not be effective unless and until filed in accordance with the law of the respective signatory parties applicable to administrative rules and regulations generally; and

(b) Designate any officer, agent or employee of the commission to be an investigator or watchman and such person shall be vested with the powers of a peace officer of the state in which he is duly assigned to perform his duties.

Section 14.3 Tax Exemption.

The commission, its property, functions, and activities shall be exempt from taxation by or under the authority of any of the signatory parties or any political subdivision thereof; provided that in lieu of property taxes the commission shall, as to specific projects, make payments to local taxing districts in annual amounts which shall equal the taxes lawfully assessed upon property for the tax year next prior to its acquisition by the commission for a period of ten years. The nature and amount of such payments shall be reviewed by the commission at the end of ten years, and from time to time thereafter, upon reasonable notice and opportunity to be heard to the affected taxing district, and the payments may be thereupon terminated or continued in such reasonable amount as may be necessary or desirable to take into account hardships incurred and benefits received by the taxing jurisdiction which are attributable to the project.

Section 14.4 Meetings; Public Hearing; Records, Minutes.

(a) All meetings of the commission shall be open to the public.

(b) The commission shall conduct at least one public hearing prior to the adoption of the comprehensive plan, water resources program, annual capital and current expense budgets, the letting of any contract for the sale or other disposition by the commission of hydroelectric energy or water resources to any person, corporation or entity, and in all other cases wherein this Compact requires a public hearing. Such hearing shall be held upon at least ten days public notice given by posting at the offices of the commission. The commission shall also provide forthwith for distribution of such notice to the press and by the mailing of a copy thereof to any person who shall request such notices.

(c) The minutes of the commission shall be a public record open to inspection at its offices during regular business hours.

Section 14.5 Officers Generally.

(a) The officers of the commission shall consist of an executive director and such additional officers, deputies and assistants as the commission may determine. The executive director shall be appointed and may be removed by the affirmative vote of a majority of the full membership of the commission. All other officers and employees shall be appointed by the executive director under such rules of procedure as the commission may determine.

(b) In the appointment and promotion of officers and employees for the commission, no political, racial, religious or residence test or qualification shall be permitted or given consideration, but all such appointments and promotions shall be solely on the basis of merit and fitness. Any officer or employee of the commission who is found by the commission to be guilty of a violation of this section shall be removed from office by the commission.

Section 14.6 Oath of Office.

An oath of office in such form as the commission shall prescribe shall be taken, subscribed and filed with the commission by the executive director and by each officer appointed by him not later than fifteen days after the appointment.

Section 14.7 Bond.

Each officer shall give such bond and in such form and amount as the commission may require for which the commission may pay the premium.

Section 14.8 Prohibited Activities.

(a) No commissioner, officer or employee shall:

(1) be financially interested, either directly or indirectly, in any contract, sale, purchase, lease or transfer of real or personal property to which the commission is a party;

(2) solicit or accept money or any other thing of value in addition to the compensation or expenses paid him by the commission for services performed within the scope of his official duties;

(3) offer money or anything of value for or in consideration of obtaining an appointment, promotion or privilege in his employment with the commission.

(b) Any officer or employee who shall willfully violate any of the provisions of this section shall forfeit his office or employment.

(c) Any contract or agreement knowingly made in contravention of this section is void.

(d) Officers and employees of the commission shall be subject in addition to the provisions of this section to such criminal and civil sanctions for misconduct in office as may be imposed by federal law and the law of the signatory state in which such misconduct occurs.

Section 14.9 Purchasing.

Contract for the construction, reconstruction or improvement of any facility when the expenditure required exceeds ten thousand dollars and contracts for the purchase of services, supplies, equipment and materials when the expenditure required exceeds two thousand five hundred dollars shall be advertised and let upon sealed bids to the lowest responsible bidder. Notice requesting such bids shall be published in a manner reasonably likely to attract prospective bidders, which publication shall be made at least ten days before bids are received and in at least two newspapers of general circulation in the basin. The commission may reject any and all bids and readvertise in its discretion. If after rejecting bids the commission determines and resolves that in its opinion the supplies, equipment and materials may be purchased at a lower price in the open market, the commission may give each responsible bidder an opportunity to negotiate a price and may proceed to purchase the supplies, equipment and materials in the open market at a negotiated price which is lower than the lowest rejected bid of a responsible bidder, without further observance of the provisions requiring bids or notice. The commission shall adopt rules and regulations to provide for purchasing from the lowest responsible bidder when sealed bids, notice and publication are not required by this section. The commission may suspend and waive the provisions of this section requiring competitive bids whenever:

(1) the purchase is to be made from or the contract to be made with the federal or any state government or any agency or political subdivision thereof or pursuant to any open end bulk purchase contract of any of them;

(2) the public exigency requires the immediate delivery of the articles or performance of the service;

(3) only one source of supply is available;

(4) the equipment to be purchased is of a technical nature and the procurement thereof without advertising is necessary in order to assure standardization of equipment and interchangeability of parts in the public interest; or

(5) services are to be provided of a specialized or professional nature.

Section 14.10 Insurance.

The commission may self-insure or purchase insurance and pay the premiums therefore against loss or damage to any of its properties; against liability for injury to persons or property; and against loss of revenue from any cause whatsoever. Such insurance coverage shall be in such form and amount as the commission may determine, subject to the requirements of any agreement arising out of the issuance of bonds by the commission.

Section 14.11 Annual Independent Audit.

(a) As soon as practical after the closing of the fiscal year, an audit shall be made of the financial accounts of the commission. The audit shall be made by qualified certified public accountants selected by the commission, who have no personal interest direct or indirect in the financial affairs of the commission or any of its officers or employees. The report of audit shall be prepared in accordance with accepted accounting practices and shall be filed with the chairman and such other officers as the commission shall direct. Copies of the report shall be distributed to each commissioner and shall be made available for public distribution.

(b) Each signatory party by its duly authorized officers shall be entitled to examine and audit at any time all of the books, documents, records, files and accounts and all other papers, things or property of the commission. The representatives of the signatory parties shall have access to all books, documents, records, accounts, reports, files and all other papers, things or property belonging to or in use by the commission and necessary to facilitate the audit and they shall be afforded full facilities for verifying transactions with the balances or securities held by depositaries, fiscal agents and custodians.

(c) The financial transactions of the commission shall be subject to audit by the general accounting office in accordance with the principles and procedures applicable to commercial corporate transactions and under such rules and regulations as may be prescribed by the comptroller general of the United States. The audit shall be conducted at the place or places where the accounts of the commission are kept.

(d) Any officer or employee who shall refuse to give all require assistance and information to the accountants selected by the commission or to the authorized officers of any signatory party or who shall refuse to submit to them for examination such books, documents, records, files, accounts, papers, things or property as may be requested shall forfeit his office.

Section 14.12 Reports.

The commission shall make and publish an annual report to the legislative bodies of the signatory parties and to the public reporting on its programs, operations and finances. It may also prepare, publish and distribute such other public reports and informational materials as it may deem necessary or desirable.

Section 14.13 Grants, Loans or Payments by States or Political Subdivisions.

(a) Any or all of the signatory parties or any political subdivision thereof may:

1) Appropriate to the commission such funds as may be necessary to pay preliminary expenses such as the expenses incurred in the making of borings, and other studies of subsurface conditions, in the preparation of contracts for the sale of water and in the preparation of detailed plans and estimates required for the financing of a project;

2) Advance to the commission, either as grants or loans, such funds as may be necessary or convenient to finance the operation and management of or construction by the commission of any facility or project;

3) Make payments to the commission for benefits received or to be received from the operation of any of the projects or facilities of the commission.

(b) Any funds which may be loaned to the commission either by a signatory party or a political subdivision thereof shall be repaid by the commission through the issuance of bonds or out of other income of the commission, such repayment to be made within such period and upon such terms as may be agreed upon between the commission and the signatory party or political subdivision making the loan.

Section 14.14 Condemnation Proceedings.

(a) The commission shall have the power to acquire by condemnation the fee or any lesser interest in lands, lands lying under water, development rights in land, riparian rights, water rights, waters and other real or personal property within the basin for any project or facility authorized pursuant to this Compact. This grant of power of eminent domain includes but is not limited to the power to condemn for the purposes of this Compact any property already devoted to a public use, by whomsoever owned or held, other than property of a signatory party and any property held, constructed, operated or maintained in connection with a diversion authorized by a United States Supreme Court decree. Any condemnation of any property or franchises owned or used by a municipal or privately owned public utility, unless the affected public utility facility is to be relocated or replaced, shall be subject to the authority of such state board, commission or other body as may have regulatory jurisdiction over such public utility.

(b) Such power of condemnation shall be exercised in accordance with the provisions of any federal law applicable to the commission; provided that if there is no such applicable federal law, condemnation proceedings shall be in accordance with the provisions of such general state condemnation law as may be in force in the signatory state in which the property is located.

(c) Any award or compensation for the taking of property pursuant to this article shall be paid by the commission, and none of the signatory parties nor any other agency, instrumentality or political subdivision thereof shall be liable for such award or compensation.

Section 14.15 Conveyance of Lands and Relocation of Public Facilities.

(a) The respective officers, agencies, departments, commissions or bodies having jurisdiction and control over real and personal property owned by the signatory parties are authorized and empowered to transfer and convey in accordance with the laws of the respective parties to the commission any such property as may be necessary or convenient to the effectuation of the authorized purposes of the commission.

(b) Each political subdivision of each of the signatory parties is authorized and empowered, notwithstanding any contrary provision of law, to grant and convey to the commission, upon the commission's request, any real property or any interest therein owned by such political subdivisions including lands lying under water and lands already devoted to public use which may be necessary or convenient to the effectuation of the authorized purposes of the commission.

(c) Any highway, public utility or other public facility which will be dislocated by reason of a project deemed necessary by the commission to effectuate the authorized purposes of this Compact shall be relocated and the cost thereof shall be paid in accordance with the law of the state in which the facility is located; provided that the cost of such relocation payable by the commission shall not in any event exceed the expenditure required to serve the public convenience and necessity.

Section 14.16 Rights of Way.

Permission is hereby granted to the commission to locate, construct and maintain any aqueducts, lines, pipes, conduits and auxiliary facilities authorized to be acquired, constructed, owned, operated or maintained by the commission in, over, under or across any streets and highways now or hereafter owned, opened or dedicated to or for public use, subject to such reasonable conditions as the highway department of the signatory party may require.

Section 14.17 Penal Sanction.

Any person, association or corporation who violates or attempts or conspires to violate any provision of this Compact or any rule, regulation or order of the commission duly made, promulgated or issued pursuant to the Compact in addition to any other remedy, penalty or consequence provided by law shall be punishable as may be provided by statute of any of the signatory parties within which the offense is committed; provided that in the absence of such provision any such person, association or corporation shall be liable to a penalty of not less than $50 nor more than $1,000 for each such offense to be fixed by the court which the commission may recover in its own name in any court of competent jurisdiction, and in a summary proceeding where available under the practice and procedure of such court. For the purposes of this section in the event of a continuing offense each day of such violation, attempt or conspiracy shall constitute a separate offense.

Section 14.18 Tort Liability.

The commission shall be responsible for claims arising out of the negligent acts or omissions of its officers, agents and employees only to the extent and subject to the procedures prescribed by law generally with respect to officers, agents and employees of the government of the United States.

Section 14.19 Effect on Riparian Rights.

Nothing contained in this Compact shall be construed as affecting or intending to affect or in any way to interfere with the law of the respective signatory parties relating to riparian rights.

Section 14.20 Amendments and Supplements.

Amendments and supplements to this Compact to implement the purposes thereof may be adopted by legislative action of any of the signatory parties concurred in by all of the others.

Section 14.21 Construction and Severability.

The provisions of this Act and of agreements thereunder shall be severable and if any phrase, clause, sentence or provision of the Delaware River Basin Compact or such agreement is declared to be unconstitutional or the applicability thereof to any signatory party, agency or person is held invalid, the constitutionality of the remainder of such Compact or such agreement and the applicability thereof to any other signatory party, agency, person or circumstance shall not be affected thereby. It is the legislative intent that the provisions of such Compact be reasonably and liberally construed.

Section 14.22 Effective Date; Execution.

This Compact shall become binding and effective thirty days after the enactment of concurring legislation by the federal government, the states of Delaware, New Jersey and New York, and the Commonwealth of Pennsylvania. The Compact shall be signed and sealed in six duplicate original copies by the respective chief executives of the signatory parties. One such copy shall be filed with the Secretary of State of each of the signatory parties or in accordance with the laws of the state in which the filing is made, and one copy shall be filed and retained in the archives of the commission upon its organization.

IN WITNESS WHEREOF, and in evidence of the adoption and enactment into law of this Compact by the Congress and legislatures, respectively, of the signatory parties, the President of the United States and the respective Governors do hereby, in accordance with authority conferred by law, sign this Compact in six duplicate original copies, as attested by the respective secretaries of state, and have caused the seals of the United States and of the respective states to be hereunto affixed this **2nd** day of **November, 1961**.

s/ **JOHN F. KENNEDY**
PRESIDENT OF THE UNITED STATES

Attest:

s/ **DEAN RUSK**
SECRETARY OF STATE

s/ **ELBERT N. CARVEL**
GOVERNOR OF
THE STATE OF DELAWARE

Attest:

s/ **ELISHA C. DUKES**
SECRETARY OF STATE

s/ **ROBERT B. MEYNER**
GOVERNOR OF
THE STATE OF NEW JERSEY

Attest:

s/ **EDWARD J. PATTEN**
SECRETARY OF STATE

s/ **NELSON A. ROCKEFELLER**
GOVERNOR OF
THE STATE OF NEW YORK

Attest:

s/ **CAROLINE K. SIMON**
SECRETARY OF STATE

s/ **DAVID L. LAWRENCE**
GOVERNOR OF
THE COMMONWEALTH OF PENNSYLVANIA

Attest:

s/ **E. JAMES TRIMARCHI, JR.**
SECRETARY OFTHE COMMONWEALTH

PART II

EFFECTUATION

UNITED STATES: (from Public Law 87-328, 75 Stat. 688)

Section 15.1 Reservations.

In the exercise of the powers reserved to the Congress, pursuant to Section 1.4 of the Compact, the consent to and participation in the Compact by the United States is subject to the following conditions and reservations:

(a) Notwithstanding any provision of the Delaware River Basin Compact the Delaware River Basin Commission shall not undertake any project (as defined in such Compact), other than a project for which State supplied funds only will be used, beyond the planning stage until –

(1) such commission has submitted to the Congress such complete plans and estimates for such project as may be necessary to make an engineering evaluation of such project, including–

(A) where the project will serve more than one purpose, an allocation of costs among the purposes served and an estimate of the ratio of benefits to costs for each such purpose.

(B) an apportionment of costs among the beneficiaries of the project, including the portion of the costs to be borne by the Federal Government and by State and local governments, and

(C) a proposal for financing the project, including the terms of any proposed bonds or other evidences of indebtedness to be used for such purposes; and

(2) such project has been authorized by Act of Congress.

(b) No provision of Section 3.7 of the Compact shall be deemed to authorize the commission to impose any charge for water withdrawals or diversions from the Basin if such withdrawals or diversions could lawfully have been made without charge on the effective date of the Compact; or to impose any charges with respect to commercial navigation within the Basin, jurisdiction over which is reserved to the Federal Government: provided, that this paragraph shall be applicable to the extent not inconsistent with Section 1.4 of this Compact.

(c) Nothing contained in the Compact shall be deemed to restrict the executive powers of the President in the event of a national emergency.

(d) Notwithstanding the provisions of Article 2, Section 2.2 of the Compact, the member of the commission appointed by the President of the United States and his alternate shall serve at the pleasure of the President.[3]

[3] Section 15.1(d) is as enacted in 1961. This section was subsequently repealed by Public Law 105-18 in June of 1997. Also see Editor's Note on this subject.

(e) Nothing contained in the Compact shall be construed as impairing or in any manner affecting the applicability to all Federal funds budgeted and appropriated for use by the commission, or such authority over budgetary and appropriation matters as the President and Congress may have with respect to agencies in the Executive Branch of the Federal Government.

(f) Except to the same extent that state bonds are or may continue to be free or exempt from Federal taxation under the internal revenue laws of the United States, nothing contained in the Compact shall be construed as freeing or exempting from internal revenue taxation in any manner whatsoever any bonds issued by the commission, their transfer, or the income therefrom (including any profits made on the sale thereon).

(g) Nothing contained in the Compact shall be construed to obligate the United States legally or morally to pay the principal or interest on any bonds issued by the Delaware River Basin Commission.

(h) Notwithstanding the provisions of Section 11.5 or any other provision of the Compact, the furnishing of technical services to the commission by agencies of the Executive Branch of the Government of the United States is pledged only to the extent that the respective agencies shall from time to time agree thereto or to the extent that the President may from time to time direct such agencies to perform such services for the commission. Nothing in the Compact shall be deemed to require the United States to furnish administrative services or facilities for carrying out functions of the commission except to the extent that the President may direct.

(i) All laborers and mechanics employed by contractors or subcontractors in the construction, alteration or repair, including painting and decorating, of projects, buildings and works which are undertaken by the commission or are financially assisted by it, shall be paid wages at rates not less than those prevailing on similar construction in the locality so determined by the Secretary of Labor in accordance with the Davis-Bacon Act, as amended (40 U. S. C. 276a-276a-5), and every such employee shall receive compensation at a rate not less than one and one-half times his basic rate of pay for all hours worked in any workweek in excess of eight hours in any workday or forty hours in any workweek, as the case may be. A provision stating the minimum wages thus determined and the requirement that overtime be paid as above provided shall be set out in each project advertisement for bids and in each bid proposal form and shall be made a part of the contract covering the project. The Secretary of Labor shall have, with respect to the administration and enforcement of labor standards specified in this provision, the supervisory, investigatory and other authority and functions set forth in Reorganization Plan Numbered 14 of 1950 (15 F. R. 3176, 64 Stat. 1267, 5 U. S. C. 133z-15, and Section 2 of the Act of June 13, 1934, as amended (48 Stat. 948, as amended; 40 U. S. C. 276(c)).

(j) Contracts for the manufacture or furnishing of materials, supplies, articles and equipment with the commission which are in excess of $10,000 shall be subject to the provisions of the Walsh-Healey Public Contracts Act (41 U. S. C. 35 et seq.).

(k) Notwithstanding any other provision of this Act, nothing contained in this Act or in the Compact shall be construed as superseding or limiting the functions, under any other law, of the Secretary of Health, Education, and Welfare or of any other officer or agency of the United States, relating to water pollution: *Provided,* That the exercise of such functions shall not limit the authority of the commission to control, prevent, or abate water pollution.

(l) The provisions of Section 8.4 of Article 8 of the Compact shall not be construed to apply to facilities operated pursuant to any other Federal law.

(m) For purposes of the Act of June 25, 1948, 62 Stat. 982, as amended (Title 28, U. S. Code, chapter 171, and Sections 1346(b) and 240 (b)) and the Act of March 3, 1887, 24 Stat. 505, as amended (Title 28, U. S. Code, Section 1402, 1491, 1496, 1501, 1503, 2071, 2072, 2411, 2412, 2501), and the Act of June 11, 1946, 60 Stat. 237, as amended (Title 5, U. S. Code, Sections 1001 and 1011, Title 50 App. U.S. Code, Section 1900), the commission shall not be considered a Federal agency.

(n) The officers and employees of the commission (other than the United States member, alternate United States member, and advisors, and personnel employed by the United States member under direct Federal appropriation) shall not be deemed to be, for any purpose, officers or employees of the United States or to become entitled at any time by reason of employment by the commission to any compensation or benefit payable or made available by the United States solely and directly to its officers or employees.

(o) Neither the Compact nor this Act shall be deemed to enlarge the authority of any Federal agency other than the commission to participate in or to provide funds for projects or activities in the Delaware River Basin.

(p) The United States district courts shall have original jurisdiction of all cases or controversies arising under the Compact, and this Act and any case or controversy so arising initiated in a State Court shall be removable to the appropriate United States district court in the manner provided by ' 1446, Title 28 U. S. C. Nothing contained in the Compact or elsewhere in this Act shall be construed as a waiver by the United States of its immunity from suit.

(q) The right to alter, amend, or repeal this Act is hereby expressly reserved. The right is hereby reserved to the Congress or any of its standing committees to require the disclosure and furnishing of such information and data by the Delaware River Basin Compact Commission as is deemed appropriate by the Congress or any such committee.

(r) The provisions of Sections 2.4 and 2.6 of Article 2 of the Compact notwithstanding, the member and alternate member appointed by the President and advisor there referred to may be paid compensation by the United States, such compensation to be fixed by the President at the rates which he shall deem to prevail in respect to comparable officers in the executive branch.

(s) (1) Nothing contained in this Act or in the Compact shall impair or affect the constitutional authority of the United Sates or any of its powers, rights, functions, or jurisdiction under other existing or future legislation in and over the area or waters which are the subject of the Compact including projects of the commission: *Provided,* That whenever a comprehensive plan, or any part or revision thereof, has been adopted with the concurrence of the member appointed by the President, the exercise of any powers conferred by law on any officer, agency or instrumentality of the United States with regard to water and related land resources in the Delaware River Basin shall not substantially conflict with any such portion of such comprehensive plan and the provisions of Section 3.8 and Article 11 of the Compact shall be applicable to the extent necessary to avoid such substantial conflict: *Provided further,* That whenever the President shall find and determine that the national interest so requires, he may suspend, modify or delete any provision of the comprehensive plan to the extent that it affects the exercise of any powers, rights, functions, or jurisdiction conferred by law on any officer, agency or instrumentality of the United States other than the commission. Such action shall be taken by executive order in which such finding and determination shall be set forth.

(2) For the purposes of paragraph 1 hereof, concurrence by the member appointed by the President shall be presumed unless within 60 days after notice to him of adoption of the comprehensive plan, or any part or revision thereof, he shall file with the commission notice of his nonconcurrence. Each concurrence of the member appointed by the President in the adoption of the comprehensive plan or any part or revision thereof may be withdrawn by notice filed with the commission at any time between the first and sixtieth day of the sixth year after the initial adoption of the comprehensive plan and of every sixth year thereafter.

(t) In the event that any phrase, clause, sentence or provision of Section 1.4 of Article 1 of the Compact, is declared to be unconstitutional under the constitution of any of the signatory parties, or the applicability thereof to any signatory party, agency or person is held invalid by a court of last resort of competent jurisdiction, the United States shall cease to be a party to the Compact, except to the extent that the President deems remaining a party necessary and proper to protect the national interest, and shall cease to be bound by the terms thereof.

(u) All Acts or parts of Acts inconsistent with the provisions of this Act are hereby amended for the purpose of this Act to the extent necessary to carry out the provisions of this Act: *Provided, however,* that no act of the commission shall have the effect of repealing, modifying or amending any Federal law.

Section 15.2 Effectuation.

(a) The President is authorized to take such action as may be necessary and proper, in his discretion, to effectuate the Compact and the initial organization and operation of the Commission thereunder.

(b) Executive departments and other agencies of the executive branch of the Federal Government shall cooperate with and furnish appropriate assistance to the United States member. Such assistance shall include the furnishing of services and facilities and may include the detailing of personnel to the United States member. Appropriations are hereby authorized as necessary for the carrying out of the functions of the United States member, including appropriations for the employment of personnel by the United States member.

Section 15.3 Effect Date.

This Act shall take effect immediately.

DELAWARE: (from 53 Delaware Laws, Chapter 71)

Section 1011 Repealer.

All acts and parts of acts inconsistent with any provision of this act are to the extent of such inconsistency hereby repealed.

Section 1012 Effectuation by Chief Executive.

The chief executive is authorized to take such action as may be necessary and proper, in his discretion, to effectuate the Compact and the initial organization and operation of the commission thereunder.

Section 1013 Effective Date.

This act shall take effect immediately.

NEW JERSEY: (from New Jersey Laws of 1961, Chapter 13)

Section 15.1 Repealer.

All acts and parts of acts inconsistent with any provision of this act are to the extent of such inconsistency hereby repealed.

Section 15.2 Effectuation by Chief Executive.

The chief executive is authorized to take such action as may be necessary and proper, in his discretion, to effectuate the Compact and the initial organization and operation of the commission thereunder.

Section 15.3 Effective Date.

This act shall take effect immediately.

NEW YORK:[4] *(from New York Laws of 1961, Chapter 148)*; with Sections of the Conservation Law as renumbered by Laws of 1962, Chapter 73)

Section 631 Commissioner and Alternate.

1. As provided in the second subdivision of section two of article two of the Compact, the governor shall be this state's member on the commission established thereby. The governor shall appoint a member of the water resources commission as his alternate pursuant to the third subdivision of said section two of article two of the Compact. In the absence of the governor and such member of the water resources commission, the powers, duties and functions of this state's member of the Delaware River Basin Commission shall be performed by the alternate of said department head on the water resources commission.

2. Any person serving on the Delaware River Basin Commission pursuant to this section shall be reimbursed for all necessary expenses incurred as an incident of such service, and such reimbursement shall be from the funds of said person's department or office.

Section 632 Advisors.

1. The member of the Delaware River Basin Commission from this state shall have an advisor as contemplated by subdivision six of section two of article two of the Compact. Such advisor shall

[4] The Sections have been renumbered by Laws of 1962, Chapter 73 and now constitute Sections 802-812 of the Conservation Law.

be the mayor of the city of New York or his designee, but no designee of the mayor shall be recognized as an advisor or accorded any privileges as such unless the mayor shall have notified the commission member from this state and the Delaware River Basin Commission in writing of the selection of such designee and of his identity.

2. The members of the water resources commission and the state commissioner of commerce shall constitute an advisory committee with whom the member of the Delaware River Basin Commission from this state shall consult with respect to the conduct of New York participation in the Compact. Such member of the commission also shall consult from time to time with other officers of the state government or any subdivision thereof, as may be appropriate.

Section 633 Consent to Alteration of Diversions.

1. Consent of this state to the impairment, diminution or other adverse effect on diversions, compensating releases, rights, conditions, obligations, and provisions for the administration thereof as contemplated by subdivision three of section three of article three of the Compact shall not be given, except with the prior approval of the water resources commission.

2. Except with respect to diversions governed by subdivision one of this section and the provision of the Compact referred to therein, the provisions of section four hundred fifty-two of the conservation law shall not apply to any diversion or furnishing of water authorized by or made pursuant to the Compact.

Section 634 Jurisdiction of Courts.

Except as otherwise specifically provided herein, the phrase "court of competent jurisdiction" as used in the Compact shall, with reference to this state, mean the supreme court, and said court is hereby given all necessary and appropriate jurisdiction to hear and determine any action or proceeding brought before it pursuant to appropriate provisions of the Compact. As used in subdivision six of section ten of article ten of the Compact, the phrase "court of competent jurisdiction" shall mean a court in which an appropriate proceeding under article seventy-eight of the civil practice act may be brought. As used in item one of paragraph (a) of subdivision one of section fourteen of article fourteen of the Compact, the phrase "court of competent jurisdiction" shall mean any court of this state in which an action or proceeding of the class brought by the Delaware River Basin Commission may be heard and determined.

Section 635 Prior to Project Approval.

No project requiring a license, permit or other approval by any agency or officer of this state, or any subdivision thereof, shall be given any such license, permit, or approval, if such project requires approval of the Delaware River Basin Commission pursuant to the Compact and such has not been given.

Section 636 Agreements with Municipalities.

Any city, county, town or village within the "basin", as that term is defined in the Compact, shall have power to make agreements to provide technical and financial aid as contemplated by paragraph (b) of subdivision two of section six of article six of the Compact. Nothing herein contained shall be construed to relieve any such city, county, town or village from compliance with any general or special laws relating to the receipt of grants or other assistance from other governmental units and contracts in connection therewith.

Section 637 Delegations of Power.

No agency or officer of this state or any subdivision thereof shall accept or exercise any delegation of power pursuant to subdivision one of section ten of article ten of the Compact unless, in the absence of the Compact, it would have the constitutional or statutory power to exercise such power on its own account.

Section 638 Cooperative Services.

Departments, agencies and officers shall provide technical and administrative services to the Delaware River Basin Commission upon request, within the limits of available appropriations and shall cooperate generally with said commission for the purposes of the Compact.

Section 639 Budget.

The Delaware River Basin Commission shall submit annually to the director of the budget, in accordance with the rules and practice of the state, for study and consideration by such director, an estimate of moneys required to administer, manage and support the commission during the ensuring fiscal year. Such estimate shall include any request for appropriation of funds by New York and shall be accompanied by a tabulation of similar requests which the commission expects to make to each other member state and the formula or factors upon which such respective requests are based. The provisions of subdivision three of section thirteen of article thirteen of the Compact shall apply to the budgetary and other fiscal matters related to the participation of this state in the Compact.

Section 640 Audit.

Pursuant to paragraph (b) of subdivision eleven of section fourteen of article fourteen of the Compact, the state comptroller is hereby authorized and empowered from time to time to examine the accounts and books of the commission, including its receipts, disbursements and such other items referring to its financial standing as such comptroller may deem proper and to report the results of such examination to the governor.

Section 641 Inconsistent Laws.

No provision of the conservation law or of any other law, which is inconsistent with the provisions of the Compact shall be applicable to the Delaware River Basin Commission or to any matter governed by the Compact.

Section 2 Effectuation.

The Compact set forth in the conservation law as amended by section one of this act shall become binding and effective in accordance with the provisions of subdivision twenty-one of section fourteen of article fourteen thereof. The governor is hereby authorized and directed to sign and seal the Compact as provided in said subdivision twenty-one and to cause copies thereof to be filed in accordance therewith.

Section 3 Effective Date.

This act shall take effect immediately.

PENNSYLVANIA: (from Pennsylvania Acts of 1961, Act No. 268)

Section 2 Repealer.

All acts and parts of acts inconsistent with any provision of this act are to the extent of such inconsistency hereby repealed.

Section 3 Effectuation by Chief Executive.

The chief executive is authorized to take such action as may be necessary and proper in his discretion to effectuate the Compact and the initial organization and operation of the commission thereunder.

Section 4 Effective Date.

This act shall take effect immediately.

EDITOR'S NOTE

CONCERNING THE UNITED STATES MEMBER

In June of 1997, Congress enacted and President Clinton signed into law the 1997 Emergency Appropriations Act ("the Act"), which specified that beginning in fiscal year 1997 and thereafter, the United States members and alternate members appointed under the Delaware River Basin Compact "shall be officers of the U.S. Army Corps of Engineers, who hold Presidential appointments as Regular Army officers with Senate confirmation …." P.L. 105-18, Sec. 3001(a). The Act also repealed Section 15.1(d) of the Compact, which provided that the member of the Commission appointed by the President and his alternate would serve at the pleasure of the President, and amended Section 2.2 by replacing the words "during the term of office of the President" with the words "at the pleasure of the President." Previously, Sections 2.2 and 15.1(d) were inconsistent as to the term of the federal representative's appointment.

A decade later, Congress enacted and President Bush signed into law the Water Resources Development Act of 2007, which further modified the Compact in relevant part by providing that notwithstanding the 1997 amendments, "beginning in fiscal year 2002, and each fiscal year thereafter, the Division Engineer, North Atlantic Division, Corps of Engineers … shall be … the ex officio United States member of the … Delaware River Basin Compact; … shall serve without compensation; and … may designate an alternate member in accordance with the terms of those compacts."

EXHIBIT B

PENNSYLVANIA BULLETIN

Volume 51 Number 49
Saturday, December 4, 2021 • Harrisburg, PA
Pages 7395—7606

See Part II page 7485
for the Notices

Part I

Agencies in this issue

Detailed list of contents appears inside.

PROPOSED RULEMAKING

ENVIRONMENTAL QUALITY BOARD

Acceptance of Two Rulemaking Petitions for Study

On November 16, 2021, the Environmental Quality Board (Board) accepted two rulemaking petitions for study under 25 Pa. Code Chapter 23 (relating to Environmental Quality Board policy for processing petitions—statement of policy). Both petitions were submitted on behalf of the Sierra Club, Clean Air Council, Earthworks, PennFuture, Protect Penn-Trafford and Mountain Watershed Association. One petition requests the amendment of 25 Pa. Code § 78.302 (relating to requirement to file a bond) to increase bonding amounts for conventional oil and gas wells. The other petition requests the amendment of 25 Pa. Code § 78a.302 (relating to requirement to file a bond) to increase bonding amounts for unconventional gas wells.

Under the Board's acceptance of the petitions, the Department of Environmental Protection (Department) will prepare a report evaluating each petition. These reports will include recommendations on whether the Board should proceed with proposed rulemakings and, if so, the process that the Department would need to undertake to develop the proposed rulemakings.

The previously-referenced petitions are available to the public by contacting the Environmental Quality Board, P.O. Box 8477, Harrisburg, PA 17105-8477, (717) 787-4526 and accessible on the Department's web site at www.dep.pa.gov (select "Public Participation," then "Environmental Quality Board," then "2021 Meetings," then scroll to "Meeting Agendas/Minutes/Handouts: November 16, 2021: In-Person/WebEx Meeting").

PATRICK McDONNELL,
Chairperson

[Pa.B. Doc. No. 21-1996. Filed for public inspection December 3, 2021, 9:00 a.m.]

DELAWARE RIVER BASIN COMMISSION

[25 PA. CODE CHS. 901 AND 903]

Importations of Water into and Exportations of Water from the Delaware River Basin; Discharges of Wastewater from High Volume Hydraulic Fracturing and Related Activities

Summary: The Commission will hold public hearings and accept written comment on a proposal to amend its Comprehensive Plan and *Water Code* concerning importations of water into and exportations of water from the Delaware River Basin; to amend its *Special Regulations—High Volume Hydraulic Fracturing* to prohibit the discharge of wastewater from high volume hydraulic fracturing and related activities to waters or land within the Delaware River Basin; and to incorporate key elements of the latter proposed amendments into the Commission's *Water Quality Regulations*.

Dates:

Written comments: Written comments will be accepted through 5 p.m. on February 28, 2022.

Public hearings: Public hearings will be held remotely via Zoom on the following dates at the noted times. Details about accessing the hearings are available on the Commission's website, www.drbc.gov.

1. December 8, 2021, 2:30 p.m. to no later than 4:30 p.m.
2. December 8, 2021, 6:30 p.m. to no later than 8:30 p.m.
3. December 15, 2021, 1 p.m. to no later than 3 p.m.
4. December 15, 2021, 4 p.m. to no later than 6 p.m.

On October 28, 2021, a notice including these public hearing dates, times and locations was posted on the Commission's website and circulated directly to Commission notice subscribers interested in this subject matter. Members of the public may sign up through the Commission's website to receive direct notice via email of additions or changes to the information provided above.

Addresses:

To submit written comments: Written comments will be accepted until 5 p.m. on February 28, 2022 through the Commission's online public comment collection system at: https://dockets.drbc.commentinput.com/?id=x2K8A. To request an exception from use of the online system based on lack of access to the Internet, please contact: Commission Secretary, DRBC, P.O. Box 7360, West Trenton, NJ 08628.

To register to speak at public hearings: Although attendance at the hearings is not limited and requires no registration, those who wish to provide oral comment at a hearing must register in advance to do so. Registration will be through EventBrite. Links to EventBrite for each of the public hearing dates and times are posted at www.drbc.gov. Online registration will remain open until 5 p.m. on the day prior to the hearing date or until all available speaking slots have been filled, whichever is earlier. Each person who wishes to provide oral comment may do so at only one public hearing. Registrations will be monitored, and if capacity is not adequate to accommodate all who wish to speak, additional opportunities may be added.

See SUPPLEMENTARY INFORMATION for details regarding the substance of written comments.

For Further Information Contact: For information regarding the public hearings and submission of written comments, contact Kate Schmidt, Communications Specialist, at kate.schmidt@drbc.gov (preferred) or 609-883-9500, ext. 205. For information concerning the proposed amendments, contact Pamela Bush, Commission Secretary and Assistant General Counsel, at pam.bush@drbc.gov (preferred) or 609-477-7203.

Supplementary Information: The Delaware River Basin Commission ("DRBC" or "Commission") is a regional interstate and federal agency formed by compact legislation of four states and the United States in 1961[1] to manage the water resources of the Delaware River Basin (the "Basin") without regard to political boundaries. Its members are, *ex officio*, the governors of the Basin states (Delaware, New Jersey, New York, and Pennsylvania) and the commander of the U.S. Army Corps of Engineers North Atlantic Division, who represents the United States.

[1] United States Public Law 87-328, Approved Sept. 27, 1961, 75 Statutes at Large 688; 53 Delaware Laws, Ch. 71, Approved May 26, 1961; New Jersey Laws of 1961, Ch. 13, Approved May 1, 1961; New York Laws of 1961, Ch. 148, Approved March 17, 1961; Pennsylvania Acts of 1961, Act. No. 268, Approved July 7, 1961.

Background

By Resolution No. 91-9 on June 19, 1991, the Commissioners amended the Commission's Comprehensive Plan by the addition of policies and regulations relating to transfers of water into and out of the Basin. These provisions were later codified in the Delaware River Basin Water Code.[2] The Commission on November 30, 2017 proposed regulations that, in part, concerned inter-Basin transfers of water and wastewater associated with high volume hydraulic fracturing ("HVHF") ("2017 draft rule") and that addressed the treatment and discharge of wastewater generated by HVHF. Concurrently with adoption of its final rule by Resolution No. 2021-01 on February 25, 2021, the Commission withdrew from consideration those provisions of the 2017 draft rule that concerned the exportation of water to support HVHF and the importation, treatment, and discharge of "produced water" and "CWT wastewater" as defined therein.[3] By a Resolution for the Minutes on February 25, 2021, the Commissioners directed the Executive Director to prepare and publish for public comment a set of amendments to the Comprehensive Plan and implementing regulations to update the Commission's policies and provisions concerning importation and exportation of water and wastewater from and into the Basin and "to include such other proposed amendments. . .as [the Executive Director, in consultation with the Commissioners] deem necessary or appropriate."

In accordance with the Commissioners' February 25, 2021 directive, the Commission is proposing amendments to its Comprehensive Plan and regulations to better provide for the planning, conservation, utilization, development, management and control of the Basin's water resources in connection with: the importation of water, including wastewater, into the Basin; the exportation of water, including wastewater, from the Basin; and the discharge of wastewater from HVHF and HVHF-related activities. The Commission proposes to amend the Water Code by clarifying the circumstances in which exportations of water, including wastewater, from the Basin and importations of water, including wastewater, into the Basin are considered by the Commission and the factors to be used in evaluating whether such proposed imports and exports of water may be approved. The proposed amendments will not apply to importations and exportations that existed prior to the effective date of any final rules, but are proposed to apply to increases in the rate or volume of existing importations and exportations. The Commission also proposes to amend its Special Regulations regarding HVHF by the addition of a finding that the discharge of wastewater from HVHF and HVHF-related activities poses significant, immediate, and long-term risks to the development, conservation, utilization, management, and preservation of the Basin's water resources, and that controlling future pollution by prohibiting such discharge is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. The finding is accompanied by a provision prohibiting the discharge to waters of the Basin of wastewater from HVHF and HVHF-related activities.

[2] Delaware River Basin Water Code (hereinafter "Water Code") (incorporated by reference at 18 CFR part 410), section 2.30.

[3] 83 FR 1586, pp. 1589, 1591 (defining "produced water" as "any water or fluid returned to the surface through the production well as a waste product of hydraulic fracturing," and defining "CWT wastewater" as "wastewater or effluent resulting from the treatment of produced water by a centralized waste treatment facility ('CWT')").

Managing water quantity and quality through a basinwide Comprehensive Plan. The Delaware River Basin Compact directs the Commission to develop and adopt, and from time to time review and revise, a Comprehensive Plan "for the immediate and long range development and use of the water resources of the [B]asin" to which Federal, State and local agencies and private parties are bound.[4] Through the adoption of a series of polices and regulations establishing and amending its Comprehensive Plan, the Commission over the past half-century has developed and implemented in-stream water quality standards throughout the Basin, prohibited degradation of groundwater, instituted reservoir drought operating plans, established protected areas to prevent the depletion of groundwater, and provided special protection to the non-tidal portion of the Delaware River to preserve its exceptionally high scenic, recreational, ecological and water supply values. As the agency through which the five signatory parties to the Compact—the States of Delaware, New Jersey and New York, the Commonwealth of Pennsylvania, and the United States—collectively manage the Basin's water resources on a regional basis, the Commission has taken these steps to, among other things, ensure an adequate supply of suitable quality water for domestic use, recreation, power generation, industrial activity and aquatic life, and to accommodate large out-of-Basin diversions by the City of New York and the State of New Jersey that are authorized by the 1954 decree of the U.S. Supreme Court in *New Jersey v. New York*, 347 U.S. 995 (the "Decree").

Water Exportation. Since June 19, 1991, the Commission's policy as articulated in the Comprehensive Plan and Water Code (incorporated by reference at 18 CFR part 410) has been to discourage the exportation of water from the Basin on grounds that the Basin's waters "are limited in quantity and the Basin is frequently subject to drought warnings and drought declarations due to limited water supply storage and streamflow during dry periods."[5]

In allocating the waters of the Basin under Section 3.3 of the Compact, the Commission is constrained by limited reservoir storage, particularly during periods of low flow.[6] Droughts of varying intensity and length have impacted the Basin since the Commission was formed in October 1961.[7] The Commission has implemented drought operations thirteen times over six decades, including during seven droughts so severe the Commission declared them to be drought emergencies.[8]

The Commission's current Comprehensive Plan includes three major types of exportations of water from the Basin, many of which have also been the subject of DRBC project approvals:

■ Pre-Compact out-of-Basin diversions by New York City and the State of New Jersey authorized by the Decree; and with the unanimous consent of the parties to the Decree in accordance with Section 3.3 of the Compact, modifications of such diversions;

■ Out-of-Basin transfers approved on a long-term basis pursuant to Section 3.8 and Article 11 of the Compact to

[4] Compact, supra note 1, sections 3.2 and 13.1.

[5] See Water Code section 2.30.2.

[6] See e.g., Water Code section 2.30.2; U.S. Department of the Interior U.S. Geological Survey Office of the Delaware River Master, History of the Reservoir Releases Program in the Upper Delaware River Basin, available at: https://webapps.usgs.gov/odrm/about/history.

[7] Delaware River Basin Commission, An Overview of Drought in the Delaware River Basin (Feb. 2019), Sec. "DRBC's Basinwide Drought Actions," par. 1, available at: https://www.state.nj.us/drbc/library/documents/drought/DRBdrought-overview_feb2019.pdf.

[8] Id., at Table 1: Basinwide Drought Actions (two of the emergency actions were conditional and did not go into effect).

meet the needs of public water systems with service areas straddling or adjacent to a Basin boundary; and

■ Out-of-Basin transfers approved on a temporary or emergency basis pursuant to Section 3.8 of the Compact to ensure the public health and safety of communities adjacent to or straddling a Basin boundary.

The draft amendments establish the circumstances under which proposed exportations that meet the existing threshold for review established by the Commission's Rules of Practice and Procedure may be considered for approval. Under the proposed rule, the Commission may approve an exportation of water from the Basin if the export is needed to serve a straddled or adjacent public water system; if it is required on a temporary, short-term, or emergency basis to meet public health and safety needs; or if it comprises an exportation of wastewater. The proposed amendments provide that in reviewing proposed exportations, an analysis of alternatives to the proposed exportation will be considered, along with factors that include the effects of the proposal on public health and safety and effectuation of the Comprehensive Plan. The amended rules will further the Commission's objectives of conserving, utilizing, managing, and controlling the Basin's water resources by ensuring that the uses included within the Comprehensive Plan are protected, and will preserve the diversions, compensating releases, rights, conditions, and obligations of the parties to the U.S. Supreme Court Decree of 1954 in *New Jersey v. New York*, 347 U.S. 995 (1954).

Water Importation. At the time the Commission was created in 1961, the tidal Delaware River suffered from water quality impairments that included severe hypoxia (lack of dissolved oxygen) annually from May through November, preventing the passage of fish species that migrate between marine and fresh waters to reproduce. A key step in the Estuary's restoration was the establishment of water quality uses and criteria by the Commission in 1967. Because even after treatment, wastewater typically contains oxygen-depleting substances, the Commission has for decades used wasteload allocations for carbonaceous oxygen demand to protect the uses it established, including by maintaining dissolved oxygen in the Estuary at levels sufficient to support aquatic life.[9]

The presence of persistent bioaccumulative toxic contaminants in sediment, the water column and fish tissue is a legacy of the Delaware River Estuary's nearly two centuries of industrial use. Although water quality improvements over the past fifty years have substantially increased the variety and abundance of Estuary fish, multiple species are contaminated with polychlorinated biphenyls ("PCBs"), dioxins and furans, mercury, and dieldrin at levels exceeding human health risk advisory limits for their consumption.[10] By Resolution No. 2000-4 the Commission in 2000 determined that allocations of the waste assimilative capacity of the Estuary were necessary in Water Quality Zones 2 through 5 to maintain stream quality objectives for acute toxicity and chronic toxicity. The Commission and its members face new challenges in the emergence of previously unknown contaminants now understood to have adverse impacts on human health and aquatic life.

Although water quality management objectives in the Delaware River Estuary have of necessity prioritized restoration, the focus in the non-tidal Delaware River has been to prevent degradation of waters that are exceptionally clean. By resolutions in 1992, 2005 and 2008, the Commission designated the entire 197-mile reach of the non-tidal main stem Delaware River from Hancock, New York to Trenton, New Jersey as "Special Protection Waters," due to their exceptionally high scenic, recreational, ecological, and water supply values. The importance of these waters to the public is underscored by their national designation: the non-tidal main stem within and downstream of potential HVHF activity includes 147 river miles designated by Congress as parts of the National Wild and Scenic Rivers System, including 113 river miles that have also been designated as units of the National Park System.[11] New or expanded pollutant loadings to Special Protection Waters—whether from imported wastewater or wastewater generated within the Basin—are permitted only if they do not measurably change the defined, existing water quality.

For the foregoing reasons, since June 19, 1991, the Commission's policy as set forth in the Water Code and Comprehensive Plan is to discourage the importation of wastewater into the Basin on grounds that the Basin's waters "have limited assimilative capacity and limited capacity to accept conservative substances without significant impacts."[12] The Commission will continue to use its authority to preclude the discharge of wastewater that would impede the restoration of water quality and aquatic life in the tidal Delaware River or that would degrade the Basin's Special Protection Waters.

The proposed rules regarding importation clarify the factors the Commission will use in evaluating proposed importations that meet the existing thresholds for review established by the Commission's Rules of Practice and Procedure. Although importations of wastewater are "discouraged," they may be permitted after careful consideration to ensure that available alternatives have been evaluated, treatment is employed to ensure applicable water quality criteria are achieved, restoration efforts are not impeded, and uses incorporated in the Commission's Comprehensive Plan are protected. The amended rules will further the Commission's objectives of conserving, utilizing, managing, and controlling the Basin's water resources by ensuring continued protection of the uses included within the Comprehensive Plan.

Notably, to date, the Commission has not approved transfers into the Basin of wastewater associated with HVHF, and no applications for such transfers are under consideration. Additionally, in many instances, the Commission has conditioned its approvals of wastewater discharge projects on a requirement that no importation, treatment or discharge of HVHF wastewater may be undertaken by a docket holder without the Commission's prior review and approval. As discussed below, amendments to the Commission's Special Regulations at 18 CFR Part 440—High Volume Hydraulic Fracturing are being

[9] See Delaware River Basin Water Code, sections 3.30.2 D.2, 3.30.3 D.2, 3.30.4 D.2, 3.30.5 D.2, 3.30.6 D.2.

[10] See Delaware Department of Natural Resources and Environmental Control, Delaware Fish Consumption Advisories (Jan. 2018), available at: https://documents.dnrec.delaware.gov/fw/Fisheries/Documents/2018-Delaware-Fish-Consumption-Advisory-Table.pdf; New Jersey Department of Environmental Protection & New Jersey Department of Health, Fish Smart, Eat Smart: A guide to Health Advisories for Eating Fish and Crabs Caught in New Jersey Waters (Nov. 2020), available at: https://www.nj.gov/dep/dsr/fish-advisories.pdf; Pennsylvania Department of Environmental Protection, Commonwealth of Pennsylvania Public Health Advisory 2021 Fish Consumption (Feb. 2021), available at: https://pfbc.pa.gov/fishpub/summaryad/sumconsumptionotepdf.

[11] See 16 U.S.C. 1274(a)(19)-(20) (Upper Delaware Scenic and Recreational River and Delaware Water Gap National Recreation Area), 16 U.S.C. 1274(a)(165) (Lower Delaware River and Associated Tributaries). Other Basin waters included in the Wild and Scenic Rivers System and protected by state antidegradation programs include: 190 miles of the White Clay Creek and its tributaries in Delaware and Pennsylvania, 35 miles of the Maurice River and its tributaries in New Jersey, and 25 miles of the Musconetcong River, also in New Jersey. See, 16 U.S.C. 1274(a)(163) (White Clay Creek and its tributaries); 16 U.S.C. 1274(a)(146)—(149) & 1274(a)(151)—(153) (Maurice River and its tributaries); 16 U.S.C. 1274(a)(169) (Musconetcong River).

[12] See Water Code section 2.30.2 (or "limited capacity to assimilate pollutants" as reflected in the proposed amendments).

proposed that would prohibit the discharge of HVHF wastewater to water or land within the Basin.

Prohibition on Discharge of Wastewater from HVHF and HVHF-Related Activities. The Commission's Comprehensive Plan and Water Code provide in part that "[t]he quality of Basin [surface] waters, except intermittent streams, shall be maintained in a safe and satisfactory condition" for uses that include, "agricultural, industrial, and public water supplies after reasonable treatment, except where natural salinity precludes such uses; . . .wildlife, fish and other aquatic life; recreation; navigation; [and] controlled and regulated waste assimilation to the extent that such use is compatible with other uses."[13] Similarly, the Comprehensive Plan and Water Code provide that the quality of ground waters of the Basin "shall be maintained in a safe and satisfactory condition, except where such uses are precluded by natural quality, for. . .domestic, agricultural, industrial, and public water supplies; [and]. . .a source of surface water suitable for recreation, wildlife, fish and other aquatic life."[14]

In its proposed and final rules prohibiting HVHF within the Basin in November 2017 and February 2021, respectively, the Commission recognized that the treatment and disposal of HVHF wastewater, among other activities associated with HVHF, posed risks, vulnerabilities and impacts to the Basin's water resources.[15] The peer-reviewed science discussed in detail in the Comment and Response Document adopted concurrently with the Commission's final rule (hereinafter, the "CRD")[16] demonstrates that for a variety of reasons, protecting public health and preserving the Basin's water resources for uses in accordance with the Comprehensive Plan require that discharges of HVHF wastewater to Basin waters or land be prohibited.

Hydraulic fracturing wastewater may contain a complex blend of constituents, including known carcinogens, neurotoxins, or endocrine disruptors, or are characterized by reproductive or developmental toxicity or adverse immune system effects.[17] As discussed at length in the CRD, some of the chemicals used are not known because they are accorded protection as trade secrets.[18] The U.S. Environmental Protection Agency (hereinafter, "EPA"), has reported that the majority of chemicals associated with hydraulic fracturing, both known and unknown, have not undergone significant toxicological assessment.[19] The impacts from those chemicals to human health and aquatic life are thus undetermined.[20] In addition to the potential pollutants in fracturing fluid, the fluid returned from an oil or natural gas well after HVHF (typically called "produced water" and including "flowback water") is mixed with water from the target formation, which contains: salts, including chloride, bromide, sulfate sodium, magnesium, and calcium; metals, including barium, manganese, iron, and strontium; naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, and xylenes; oil and grease; and radioactive materials, including radium, found in ancient sea water trapped within the oil- and gas-bearing shale formations.[21]

A report by the U.S. Geological Survey ("USGS") observed that the salts in shale waters (which are sometimes referred to as "total dissolved solids" or "TDS") reached extreme concentrations over millions of years, and their chemical interactions with surrounding rock can mobilize radionuclides.[22] The USGS authors cite radioactivity as a key characteristic of the HVHF waste stream that potentially represents a substantial risk to water resources, aquatic ecosystems and biota, and public health, if released.[23]

Wastes associated with oil and natural gas exploration, development and production, including oil and gas drilling fluids and produced waters, are exempt from federal regulations for the management of hazardous wastes.[24] But these wastes may cause harm to public health and the environment if they are not properly managed. The CRD references multiple studies documenting adverse impacts to water resources from HVHF wastewater after treatment, whether by municipal or industrial treatment facilities.[25] Because produced water contains high TDS and dissolved inorganic constituents that most publicly owned treatment works and other municipal wastewater treatment facilities are not designed to remove, EPA in 2016 issued a final rule banning the treatment and discharge of oil and gas extraction wastewater from publicly owned treatment works ("POTWs").[26] Privately owned treatment works that treat primarily domestic and commercial wastewater remain outside the scope of EPA's "zero discharge" rule.

The Commonwealth of Pennsylvania manages the risks associated with disposal of HVHF wastewater in part through a detailed statute and regulations focused on protecting water resources and public health while preserving commercial interests. Regulations adopted in 2010 pursuant to the Pennsylvania Clean Streams Law address risks associated with HVHF wastewater treatment and discharge by limiting new discharges of TDS, chlorides, barium and strontium in treated wastewater, regardless of the type of discharge—public, private, municipal or industrial.[27]

Research has demonstrated that even with specialized treatment, however, the discharge of HVHF wastewater to surface waters can adversely impact downstream waters. The Commission's CRD contains an extensive discus-

[13] Water Code, section 3.10.2. B.
[14] Id., section 3.40.3.
[15] See, e.g., DRBC Resolution No. 2021-01, p. 4, par. 4. Available at: https://www.state.nj.us/drbc/library/documents/Res2021-01_HVHF.pdf. See generally, Delaware River Basin Commission, Comment and Response Document: Proposed Amendments to the Administrative Manual and Special Regulations Regarding High Volume Hydraulic Fracturing Activities; Additional Clarifying Amendments, Feb. 25, 2021 (hereinafter, "CRD"), at, e.g., pp. E-1, 65-66 ("Synthesis" of response to comments concerning spills); pp. 158-59 (water quality impacts from discharges of treated hydraulic fracturing wastewater). The CRD is available at: https://www.state.nj.us/drbc/library/documents/CRD_HVHFrulemaking.pdf
[16] See CRD, supra note 15.
[17] CRD, supra note 15, pp. 131, 161, and 255 (citing E.G. Elliott, et al., A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity, J. Exposure Science & Environmental Epidemiology, 27: 90—99 (2017)). See also, United States Environmental Protection Agency ("U.S. EPA"), Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States (final report) (EPA/600/R-16/236F) (2016) (hereinafter "U.S. EPA 2016 Assessment"), p. ES-20; U.S. EPA, Technical development document for the effluent limitations guidelines and standards for the oil and gas extraction point source category (EPA-820-R-16-003), 2016, pp. 43—47 (Sec. 1.2).
[18] See CRD, supra note 15, pp. 259—264.
[19] Id., p. 132 (citing U.S. EPA 2016 Assessment, supra note 17, p. ES-42-45, 9-1).
[20] U.S. EPA, Detailed study of the centralized waste treatment point source category for facilities managing oil and gas extraction wastes. (EPA-821-R-18-004) (2018), p. 9-36. Available at: https://www.epa.gov/sites/default/files/2018-05/documents/cwt-study_may-2018.pdf.

[21] CRD, supra note 15, pp. E-6, 71.
[22] CRD, supra note 15, p. 84 (citing E.L. Rowan, et al., Radium content of oil- and gas-field produced waters in the Northern Appalachian Basin (USA): Summary and discussion of data, U.S. Department of the Interior, U.S. Geological Survey: Scientific Investigations Report 2011-5135 (2011)).
[23] CRD, supra note 15, p. 86 (citing E.L. Rowan, et al., supra note 22) (also noting that chemically, radium behaves in a manner similar to calcium and is capable of bioaccumulation in plants and animals).
[24] See, e.g., U.S. Environmental Protection Agency, Office of Solid Waste, Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations, EPA530-K-01-004 (2002).
[25] See CRD, supra note 15, pp. 18-19, 128—143. See also U.S. EPA, infra note (regarding impacts associated with discharges from municipal wastewater treatment plants); U.S. EPA, supra note 20 (regarding impacts associated with discharges from the industrial wastewater treatment facilities known as "CWTs").
[26] U.S. EPA, Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category, 81 FR 41845 (Aug. 29, 2016) (preamble). See also 81 FR 88126 (Dec. 7, 2016) (extending deadline for compliance); CRD, supra note 15, pp. 18-19, 128.
[27] 25 Pa. Code section 95.10. See also CRD, supra note 15, pp. 132, 178.

sion of the potential risks associated with the treatment and discharge of HVHF wastewater to Basin waters from CWTs.[28] The Commission concluded that treatment of HVHF wastewater at CWTs with subsequent discharge of effluent to the waters of the Basin would present significant risks to the receiving waters.[29]

Growth in Marcellus shale gas production is anticipated,[30] and in the Marcellus production area immediately west of the Basin, recent data show increasing water use by the shale gas production industry, which may result in increasing volumes of wastewater.[31] Although additional factors may affect demand for HVHF wastewater treatment and discharge options, these shale gas production and water use trends create the potential for increased demand for CWT services in the region.[32] To protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan, the Commission thus proposes to prohibit the discharge of treated or untreated HVHF wastewater to waters or land within the Basin.

Water Quality Regulations. To facilitate the alignment of certain Basin state discharge permits with the Commission's proposed regulations regarding wastewater from high volume hydraulic fracturing, the Commission further proposes to amend its Water Quality Regulations, Article 4—Application of Standards. The proposed amendment would consist of a new section 4.50, captioned "Wastewater from High Volume Hydraulic Fracturing and Related Activities," expressly incorporating into the Water Quality Regulations the determination and prohibition comprising § 440.4 of title 18 of the CFR, and the purpose and definitions encompassing sections 440.1 and 440.2. Existing section 4.50 of the Water Quality Regulations and its sub-paragraphs 4.50.1 through 4.50.6 are proposed to be redesignated as section 4.60 and 4.60.1 through 4.60.6.

Public Process

Substance of comments: The Commission expressly seeks comment on the effects the proposed rules may have within the Basin on: water availability, the control and abatement of water pollution, economic development, the conservation and protection of drinking water supplies, the conservation and protection of aquatic life, the conservation and protection of water quality in Special Protection Waters, and the protection, maintenance and improvement of water quantity and quality Basinwide. The Commission welcomes and will consider any other comments that concern the potential effects of the draft rules on the conservation, utilization, development, management and control of the water and related resources of the Basin. Comments on matters not within the scope of the proposed rules may not be considered.

Non-digitized, voluminous materials such as books, journals or collected letters and petitions will not be accepted. Digital submissions of articles and websites must be accompanied by a statement containing citations to the specific findings or conclusions the commenter wishes to reference.

Submission of written comments. Written comments along with any attachments should be submitted through the Commission's web-based comment system (https://dockets.drbc.commentinput.com/?id=x2K8A) until 5 p.m. on February 28, 2022. All materials should be provided in searchable formats, preferably in .pdf searchable text. Notably, a picture scan of a document may not result in searchable text. Comments received through any method other than the designated on-line method, including via email, fax, postal/delivery services or hand delivery, will not be considered or included in the rulemaking record unless an express exception has been granted. Requests for exceptions from the web-based-submissions-only policy based on lack of access to the web-based comment system may be addressed to: Commission Secretary, DRBC, P.O. Box 7360, West Trenton, NJ 08628.

Public hearings. To provide for an orderly process and to support public and community health measures, the Commission is conducting its public hearings virtually. Attendance at the hearings is not limited and requires no registration. However, to eliminate uncertainty on the part of attendees about whether they will have an opportunity to provide oral comment, those who wish to speak at a hearing must register in advance to do so, using links on the Commission's website. Registrations will be monitored, and if capacity is not adequate to accommodate all who wish to speak, additional opportunities may be added. Key elements of the procedure are as follows:

■ Online registration to speak at a public hearing will remain open until 5 p.m. the day prior to each hearing.

■ Each person who wishes to provide oral comment may do so at only one public hearing.

■ Speaking time will be limited to approximately three minutes per speaker.

■ Elected government officials and their staff will have the opportunity to identify themselves when registering to attend a hearing.

■ Attendance at the public hearings is not limited and requires no advance registration.

■ Written and oral comment will receive equal consideration.

The Commission appreciates the public's participation and input on this important matter.

More Information. Detailed and up-to-date information about the public process, including all proposed rule text, related documents and links for online registration to speak at each of the scheduled public hearings, can be found on the DRBC website, www.drbc.gov.

For the reasons set forth in the preamble, the Delaware River Basin Commission proposes to amend its *Water Code* and *Water Quality Regulations* (incorporated by reference in the Code of Federal Regulations at 18 CFR Part 410 and in the *Pennsylvania Code* at 25 Pa. Code Ch. 901), and its *Special Regulations* (codified at 18 CFR Part 440), which are incorporated by reference at 25 Pa. Code Ch. 903, as set forth below.

DELAWARE RIVER BASIN WATER CODE

ARTICLE 2—CONSERVATION, DEVELOPMENT AND UTILIZATION OF DELAWARE RIVER BASIN WATER RESOURCES

[INCORPORATED BY REFERENCE AT 25 PA CODE § 901.2]

(*Editor's note*: Section 2.30 of the Delaware River Basin Water Code is proposed to be replaced in its entirety with the text set forth below. Existing Section 2.30 of the Water Code is available at: https://www.state.nj.us/drbc/

[28] See CRD, supra note 15, pp. 130—143, 178. See generally U.S. EPA, supra note 20.
[29] See CRD, supra note 15, p. 138.
[30] U.S. EPA, supra note 20, p. 8-6.
[31] See CRD, supra note 15, p. 16 (reporting increased length of natural gas well laterals and increased use of water per foot of well fractured in the Susquehanna River Basin, which adjoins the Basin) (citing Susquehanna River Basin Commission, Water use associated with natural gas development in the Susquehanna River Basin: An update of activities through December 2018 (Publication No. 323) (2020)).
[32] See U.S. EPA, supra note 20, pp. 8-4—8-6.

library/documents/watercode.pdf. For the text of the entire Water Code, visit: https://www.state.nj.us/drbc/library/documents/watercode.pdf.)

2.30 IMPORTATIONS AND EXPORTATIONS OF WATER, INCLUDING WASTEWATER

2.30.1 *Definitions (Resolutions Nos. 91-9 and xxx)*. For purposes of this section 2.30:

A. "Adjacent public water system" means a public water system located outside of the Delaware River Basin that either: (1) is interconnected with a public water system located entirely inside the Basin or with a "straddled public water system" (as defined herein); or that (2) has a service area directly bordering the service area of a public water system located entirely within the Basin or that straddles the Basin boundary.

B. "Basin water" (also, "waters of the Basin") means water in, on, under or above the ground within the Delaware River Basin. "Basin water" includes wastewater.

C. "Delaware River Basin" (or "Basin") has the meaning assigned to it by Section 1.2(a) of the *Delaware River Basin Compact*—the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

D. "Exportation" means the conveyance, transfer, or diversion of Basin water from a source within the Delaware River Basin to a location outside the Basin without return of such water to the Basin. Exportations from the Basin of consumer goods or foods that have been manufactured, bottled, packaged, or processed using Basin water are not considered "exportations" for purposes of this rule.

E. "Importation" means the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside the Basin, resulting in a discharge of the imported water to land or water within the Basin, with or without prior treatment.

F. "Public water system" means a system primarily for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. A "public water system" may be publicly or privately owned.

G. "Straddled public water system" means a public water system that serves an area partially within and partially outside of the Delaware River Basin.

H. "Wastewater" means water that is stored, transported or discharged after use, including, but not limited to, any water for which a National Pollutant Discharge Elimination System (NPDES) permit under the federal Clean Water Act or any state or DRBC approval is required before the water can lawfully be discharged to waters or land within the Basin.

2.30.2 *Protection and Preservation*

A. The waters of the Delaware River Basin are limited in quantity, and the Basin is frequently subject to drought warnings, drought declarations, and drought operations due to limited water supply storage and streamflow during dry periods. In addition, portions of the Basin have been delineated by the Commission as groundwater protected areas due to water shortages. Therefore, it is the policy of the Commission to promote the conservation and preservation of water and related natural resources, including aquatic ecosystems, and effectuate the Comprehensive Plan and the uses of the water resources of the Basin identified therein, by discouraging, limiting, or placing conditions on the exportation of Basin water as may be required to protect the health and safety of Basin residents, aquatic ecosystems and the uses of water identified in the Compact and Comprehensive Plan.

B. The Commission shall review a proposed new exportation of Basin water, including any proposed increase in the rate or volume of an existing exportation, and may impose conditions, obligations and release requirements related thereto, pursuant to Sections 3.3, 3.8, 5.2, 10.3, 10.4 and Article 11 of the Compact and the regulations and docket approvals implementing these provisions.

C. A proposed new exportation of Basin water that is subject to review under the Compact and implementing regulations, including any proposed increase in the rate or volume of an existing exportation, may be approved by the Commission after consideration of the factors set forth at Section 2.30.3 below, if:

1. the sponsor demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system;

2. the sponsor demonstrates that the exportation of Basin water is required on a temporary, short-term, or emergency basis to meet public health and safety needs; or

3. the sponsor is proposing an exportation of wastewater.

D. Basin waters have limited capacity to assimilate pollutants without significant impacts to the health and safety of Basin residents, the health and functioning of aquatic ecosystems in the Basin, and the effectuation of the Comprehensive Plan. Accordingly, it is the policy of the Commission to discourage, limit, or condition the importation of wastewater into the Delaware River Basin as necessary to avoid impairment of Basin waters. A proposed new importation of water or wastewater, including any proposed increase in the rate or volume of an existing importation, shall be reviewed by the Commission consistent with the factors set forth at Section 2.30.3 below.

E. This Section 2.30 shall not apply to importations and exportations of water, including wastewater, that existed prior to enactment of the Compact or that were approved by the DRBC prior to [date of adoption of these amendments].

2.30.3 *Commission Considerations (Resolutions Nos. 91-9 and xxx)*. In evaluating importations and exportations, the Commission's review will include consideration of the following factors:

A. For exportations of Basin water:

1. the effect of the exportation on the health and safety of the Basin community;

2. the effect of the exportation on existing or future water availability or shortages, including, but not limited to, sources within areas designated by the Commission as protected areas pursuant to Section 10.2 of the Compact, sources within Delaware River reaches with flows that are frequently augmented by reservoir releases due to low flows, and sources in areas subject to DRBC drought operations or state drought declarations within the past five years;

3. the effect of the exportation on aquatic ecosystems;

4. the effect of the exportation on water quality and waste assimilation;

5. the effect of the exportation on salinity concentrations;

6. the effect of the exportation on the water uses protected by the Comprehensive Plan, DRBC regulations or DRBC docket approvals, or on the ability of DRBC to effectuate the Comprehensive Plan;

7. the effect of the exportation, including its volume, rate, timing and duration, on passby or instream flow requirements contained in DRBC regulations or project approvals;

8. the sponsor's planned use for the water and any resulting public benefits;

9. the availability to the sponsor of alternatives to the exportation of Basin water and whether these alternatives have been diligently pursued, including without limitation a review of the sponsor's uses of water outside the sponsor's service area, if any; conservation measures undertaken by the sponsor or a public water system in the service area where the sponsor is located to forestall the need for a transfer of Basin water; and the results of a water audit (or audits) performed by the sponsor in accordance with Section 2.1.8 of the Delaware River Basin Water Code; and

10. whether the exportation would contravene sections 3.3 and 3.5(a) of the Compact by impeding or interfering with the rights, powers, privileges, conditions or obligations contained in the Supreme Court Decree in *New Jersey v. New York*, 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

B. For importations of water, including wastewater:

1. the effect of the importation on the health and safety of the Basin community with due consideration of the available alternatives to the importation;

2. the characterization and treatability of the wastewater;

3. the potential impacts on water resources of the Delaware River Basin of the proposed importation and of each available alternative, including alternatives that avoid an importation of water, including wastewater. The potential impacts considered will include the effects of the quality, volume, flow rate, timing and duration of the proposed importation in relation to:

a. flow objectives or passing or instream flow requirements contained in DRBC regulations or project approvals;

b. the record of hydrologic conditions in the proposed receiving region and the larger Delaware River Basin;

c. water uses as established by the Comprehensive Plan, including the DRBC Water Code;

d. the effect of the importation on aquatic ecosystems;

e. water quality and waste assimilation capacity in the affected receiving streams; and

f. prior regulations or orders of the Commission which may be identified during the course of the Commission's review.

2.30.4 *Analyses by Applicant for Section 3.8 Approval*. When an importation or exportation of water or wastewater is subject to review by the Commission, the applicant shall furnish the Commission with such analyses of the factors set forth in Sections 2.30.2 and 2.30.3 above and as the Commission may direct.

2.30.5 *Water Charges (Resolutions Nos. 91-9 and xxx)*. Exportation of Basin water constitutes consumptive water use and will be subject to the water charges in effect at the time of transfer in accordance with the Commission's Water Supply Charges regulations (18 CFR Part 420), as amended.

2.30.6 *Wastewater Treatment Requirements (Resolution No. 91-9)*. It is the policy of the Commission to give no credit toward meeting wastewater treatment requirements for importations of wastewater. An effluent loading or concentration authorized in accordance with a water-quality-based effluent limit such as a wasteload allocation may not include loadings attributable to an importation of wastewater.

2.30.7 *Existing Allocations (Resolution No. 91-9)*. It is the policy of the Commission to charge all exportations of Basin water against any special regional allocation or any depletive use allocation as may exist at the time of receipt of a completed application for exportation.

2.30.8 *1954 Supreme Court Decree*. This Section 2.30 is intended to preserve the diversions, compensating releases, rights, conditions, and obligations of the parties to the U.S. Supreme Court Decree of 1954 in *New Jersey v. New York*, 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

WATER QUALITY REGULATIONS

ARTICLE 4—APPLICATION OF STANDARDS

[INCORPORATED BY REFERENCE AT 25 PA CODE § 901.2]

(*Editor's note*: New text appears in bold face with underscore, and text to be deleted appears in bold face within brackets. Asterisks represent no change to the existing text. For the text of the entire Water Quality Regulations, visit: https://www.state.nj.us/drbc/library/documents/WQregs.pdf.)

* * * * *

Section 4.40 Ground Water Quality Requirements.

* * * * *

4.40.2 **Enforcement Procedures**. The enforcement procedure of Section **[4.50]** **4.60** with respect to effluent quality requirements for discharges shall be deemed applicable to the enforcement of this Section and Section 3.40. For the purposes thereof, the word "discharger" as used in Section **[4.50]** **4.60** includes any party affected by this Section.

Section 4.50 Wastewater from High Volume Hydraulic Fracturing and Related Activities. The provisions of 18 CFR 440.4 and the purpose and definitions applicable thereto, encompassing 18 CFR 440.1 and 18 CFR 440.2, are hereby incorporated into these Water Quality Regulations.

Section [4.50] 4.60 Enforcement Procedures.

[4.50.1] 4.60.1 Scope. * * *

[4.50.2] 4.60.2 Abatement Schedules and Permits.

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[4.50.3] 4.60.3 Waste Load Allocations. * * *

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[4.50.4] 4.60.4 Inspection and Surveillance.

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[4.50.5] 4.60.5 Noncompliance; Notice.

* * * * *

[4.50.6] 4.60.6 Order of Abatement; Sanctions. * * *

DELAWARE RIVER BASIN COMMISSION

18 C.F.R. CHAPTER III, SUBCHAPTER B—SPECIAL REGULATIONS

PART 440—HIGH VOLUME HYDRAULIC FRACTURING

[INCORPORATED BY REFERENCE AT 25 PA CODE § 903.1]

(*Editor's note*: Proposed new text appears in bold face with underscore, and text to be deleted appears in bold face within brackets.)

440.1 Purpose, authority and relationship to other requirements.

(a) *Purpose*. The purpose of this part is to protect and conserve the water resources of the Delaware River Basin. To effectuate this purpose, this section establishes standards, requirements, conditions, and restrictions to prevent or reduce depletion and degradation of surface and groundwater resources and to promote sound practices of water resource management.

(b) *Authority*. This part implements Sections 3.1, 3.2(a), 3.2 (b), 3.6(b), 3.6(h), 4.1, 5.2, 7.1, 13.1 and 14.2(a) of the Delaware River Basin Compact.

(c) *Comprehensive Plan*. The Commission has determined that the provisions of this part are required for the immediate and long range development and use of the water resources of the Basin and are therefore incorporated into the Commission's Comprehensive Plan.

(d) *Relationship to other Commission requirements*. The provisions of this part are in addition to all applicable requirements in other Commission regulations **[in this chapter]**, dockets **[and]**, permits**, and determinations**.

(e) *Severability*. The provisions of this part are severable. If any provision of this part or its application to any person or circumstances is held invalid, the invalidity will not affect other provisions or applications of this part, which can be given effect without the invalid provision or application.

(f) *Coordination and avoidance of duplication*. In accordance with and pursuant to section 1.5 of the Delaware River Basin Compact, to the fullest extent it finds feasible and advantageous the Commission may enter into an Administrative Agreement (Agreement) with any Basin state or the Federal Government to coordinate functions and eliminate unnecessary duplication of effort. Such Agreements will be designed to: Effectuate intergovernmental cooperation, minimize the efforts and duplication of state and Commission staff resources wherever possible, ensure compliance with Commission-approved requirements, enhance early notification of the general public and other interested parties regarding proposed activities in the Basin, indicate where a host state's requirements satisfy the Commission's regulatory objectives, and clarify the relationship and project review decision making processes of the states and the Commission for projects subject to review by the states under their state authorities and by the Commission under Section 3.8 and Articles 6, 7, 10 and 11 of the Compact.

440.2 Definitions.

For purposes of this part, the following terms and phrases have the meanings provided. Some definitions differ from those provided in regulations of one or more agencies of the Commission's member states and the Federal Government. **Others are consistent with terms defined by the Delaware River Basin Compact.**

Basin is the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

Commission is the Delaware River Basin Commission (DRBC) created and constituted by the Delaware River Basin Compact.

Fracturing fluid(s) is a mixture of water (whether fresh or recycled) and/or other fluids and chemicals or other additives, which are injected into the subsurface and which may include chemicals used to reduce friction, minimize biofouling of fractures, prevent corrosion of metal pipes or remove drilling mud damage within a wellbore area, and propping agents such as silica sand, which are deposited in the induced fractures.

High volume hydraulic fracturing (HVHF) is hydraulic fracturing using a combined total of 300,000 or more gallons of water during all stages in a well completion, whether the well is vertical or directional, including horizontal, and whether the water is fresh or recycled and regardless of the chemicals or other additives mixed with the water.

***HVHF-related activities* are:**

(1) Construction of an oil or natural gas production well that is to be stimulated using HVHF as defined herein;

(2) Chemical mixing or storage of proppant, chemicals and other additives to make fracturing fluid; and

(3) Management of wastewater from hydraulic fracturing, including storage, disposal, treatment, or reuse in hydraulic fracturing operations or other uses.

Hydraulic fracturing is a technique used to stimulate the production of oil and natural gas from a well by injecting fracturing fluids down the wellbore under pressure to create and maintain induced fractures in the hydrocarbon-bearing rock of the target geologic formation.

Person is any natural person, corporation, partnership, association, company, trust, Federal, state, or local governmental unit, agency, or authority, or other entity, public or private.

***Wastewater from high volume hydraulic fracturing* is:**

(1) Any wastewater, brine, sludge, chemicals, naturally occurring radioactive materials, heavy metals or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities;

(2) Leachate from solid wastes associated with HVHF-related activities, except if the solid wastes were lawfully disposed of in a landfill within the Basin prior to the effective date of this rule; and

(3) Any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of the wastewater described in paragraphs (1) and (2) of this same definition.

Water resource(s) is**, in accordance with Section 1.2(i) of the *Delaware River Basin Compact*, "**water and related natural resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership**[,]** or control**"** within the **[hydrologic boundary of the]** Delaware River Basin.

440.3 High volume hydraulic fracturing (HVHF)

(a) *Determination*. The Commission has determined that high volume hydraulic fracturing poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the water resources of the Delaware River Basin and to Special Protection Waters of the Basin, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values. Controlling future pollution by prohibiting such activity in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

(b) *Prohibition*. High volume hydraulic fracturing in hydrocarbon bearing rock formations is prohibited within the Delaware River Basin.

440.4 Wastewater from high volume hydraulic fracturing and related activities

(a) *Determination*. The Commission has determined that the discharge of wastewater from high volume hydraulic fracturing and HVHF-related activities poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the Basin's water resources. Controlling future pollution by prohibiting such discharge is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

(b) *Prohibition*. No person may discharge wastewater from high volume hydraulic fracturing or HVHF-related activities to waters or land within the Basin.

Dated: November 2, 2021.

PAMELA M. BUSH, Esq.,
Secretary

Fiscal Note: 68-61. No fiscal impact; (8) recommends adoption.

Annex A

TITLE 25. ENVIRONMENTAL PROTECTION

PART V. DELAWARE RIVER BASIN COMMISSION

CHAPTER 901. GENERAL PROVISIONS

§ 901.2. Rules of Practice and Procedure.

The Comprehensive Plan regulations as set forth in 18 CFR Part 401, Subpart A (2014) and the Water Code and Water Quality Standards as set forth in 18 CFR Part 410 **[(2014)]** **(2021)** are hereby incorporated by reference and made a part of this title.

CHAPTER 903. HYDRAULIC FRACTURING IN SHALE AND OTHER FORMATIONS

§ 903.1. Hydraulic fracturing in shale and other formations.

The hydraulic fracturing in shale and other formation regulations, as set forth in 18 CFR Part 440 **[(2018)]** **(2021)**, are hereby incorporated by reference and made part of this title.

[Pa.B. Doc. No. 21-1997. Filed for public inspection December 3, 2021, 9:00 a.m.]

EXHIBIT C

Section 2.30 of the Delaware River Basin Water Code, as amended, is shown below. Additions are shown in red with underscore and deletions are shown in ~~red with strikethrough~~ compared to the text of the proposed amendments to Section 2.30 of the Delaware River Basin Water Code, originally published on October 28, 2021.

2.30 IMPORTATIONS AND EXPORTATIONS OF WATER, INCLUDING WASTEWATER

2.30.1 **Definitions** *(Resolutions Nos. 91-9 and xxx)*. For purposes of this section 2.30:

A. "Adjacent public water system" means a public water system (as defined herein) located outside ~~of~~ the Delaware River Basin that ~~either: (1) is interconnected with a public water system located entirely inside the Basin or with a "straddled public water system" (as defined herein); or that (2)~~ has a service area directly bordering the service area of a public water system located ~~entirely~~ in whole or in part within the Basin ~~or that straddles the Basin boundary~~.

B. "Adjacent public wastewater collection system" means a public wastewater collection system (as defined herein) located outside the Delaware River Basin that has a service area directly bordering the service area of a public wastewater collection system located in whole or in part within the Basin.

C. "Basin water" (also, "waters of the Basin") means water in, on, under or above the ground within the Delaware River Basin. "Basin water" includes wastewater.

D~~C~~. "Delaware River Basin" (or "Basin") has the meaning assigned to it by Section 1.2(a) of the *Delaware River Basin Compact* – the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

E~~D~~. "Exportation" means the conveyance, transfer, or diversion of Basin water from a source within the Delaware River Basin to a location outside the Basin without return of such water to the Basin. Exportations from the Basin of consumer goods or foods that have been manufactured, bottled, packaged, or processed using Basin water are not considered "exportations" for purposes of this rule.

F~~E~~. "Importation" means the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside the Basin, resulting in a discharge of the imported water to land or water within the Basin, with or without prior treatment.

G~~F~~. "Public water system" means a system primarily for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. A "public water system" may be publicly or privately owned.

H. "Public wastewater collection system" means a system with all required state and federal approvals that serves more than 250 people or conveys more than 25,000 gallons of wastewater per day and is primarily for the collection and conveyance of domestic sewage from private, commercial, institutional, or industrial sources, to a treatment system with all necessary state and federal approvals. A "public wastewater collection system" may be publicly or privately owned.

I~~G~~. "Straddled public water system" means a public water system that serves an area partially within and partially outside of the Delaware River Basin.

J. "Straddled public wastewater collection system" means a public wastewater collection system that serves an area partially within and partially outside of the Delaware River Basin.

K~~H~~. "Wastewater" means water that is stored, transported or discharged after use, including, but not limited to, any water for which a National Pollutant Discharge Elimination System (NPDES) permit under the federal Clean Water Act or any state or DRBC approval is required before the water can lawfully be discharged to waters or land within the Basin.

2.30.2 **Protection and Preservation**

A. The waters of the Delaware River Basin are limited in quantity, and the Basin is frequently subject to drought warnings, drought declarations, and drought operations due to limited water supply storage and streamflow during dry periods. In addition, portions of the Basin have been delineated by the Commission as groundwater protected areas due to water shortages. Therefore, it is the policy of the Commission to promote the conservation and preservation of water and related natural resources, including aquatic ecosystems, and effectuate the Comprehensive Plan and the uses of the water resources of the Basin identified therein, by discouraging, limiting, or placing conditions on the exportation of Basin water as may be required to protect the health and safety of Basin residents, aquatic ecosystems and the uses of water identified in the Compact and Comprehensive Plan.

B. The Commission shall review a proposed new exportation of Basin water, including any proposed increase in the rate or volume of an existing exportation, and may impose conditions, obligations and release requirements related thereto, pursuant to Sections 3.3, 3.8, 5.2, 10.3, 10.4 and Article 11 of the Compact and the regulations and docket approvals implementing these provisions.

C. A proposed new exportation of Basin water that is subject to review under the Compact and implementing regulations, including any proposed increase in the rate or volume of an existing exportation, may be approved by the Commission after consideration of the factors set forth at Section 2.30.3 below, if:

1. the sponsor demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system;

2. the sponsor demonstrates that the exportation of Basin water is required to meet public health and safety needs on a temporary, short-term, or emergency basis~~ to meet public health and safety needs~~; or

3. the sponsor is proposing an exportation of wastewater and demonstrates either (i) that the wastewater is being conveyed to a straddled or adjacent public wastewater collection system; or (ii) that the wastewater may not lawfully be discharged to a

public wastewater collection system and is being exported for treatment, disposal or both at a waste management facility that has all required state and federal approvals to lawfully receive it.

D. Basin waters have limited capacity to assimilate pollutants without significant impacts to the health and safety of Basin residents, the health and functioning of aquatic ecosystems in the Basin, and the effectuation of the Comprehensive Plan. Accordingly, it is the policy of the Commission to discourage, limit, or condition the importation of wastewater into the Delaware River Basin as necessary to avoid impairment of Basin waters. A proposed new importation of water ~~or wastewater~~, including any proposed increase in the rate or volume of an existing importation, shall be reviewed by the Commission consistent with the factors set forth at Section 2.30.3 below.

E. This Section 2.30 shall not apply to importations and exportations of water, including wastewater, that existed prior to enactment of the Compact or that were approved by the DRBC prior to [date of adoption of these amendments].

2.30.3 **Commission Considerations** *(Resolutions Nos. 91-9 and xxx)*. In evaluating importations and exportations, the Commission's review will include consideration of the following factors:

A. For exportations of Basin water (including wastewater):

1. the effect of the exportation on the health and safety of the Basin community;
2. the effect of the exportation on existing or future water availability or shortages, including, but not limited to, sources within areas designated by the Commission as protected areas pursuant to Section 10.2 of the Compact, sources within Delaware River reaches with flows that are frequently augmented by reservoir releases due to low flows, and sources in areas subject to DRBC drought operations or state drought declarations within the past five years;
3. the effect of the exportation on aquatic ecosystems;
4. the effect of the exportation on water quality and waste assimilation;
5. the effect of the exportation on salinity concentrations;
6. the effect of the exportation on the water uses protected by the Comprehensive Plan, DRBC regulations or DRBC docket approvals, or on the ability of DRBC to effectuate the Comprehensive Plan;
7. the effect of the exportation, including its volume, rate, timing and duration, on passby or instream flow requirements contained in DRBC regulations or project approvals;
8. the sponsor's planned use for the water and any resulting public benefits;
9. the availability to the sponsor of alternatives to the exportation of Basin water and whether these alternatives have been diligently pursued, including without limitation a review of the sponsor's uses of water outside the sponsor's service area, if any; conservation measures undertaken by the sponsor or a public water system in the

service area where the sponsor is located to forestall the need for a transfer of Basin water; and the results of a water audit (or audits) performed by the sponsor in accordance with Section 2.1.8 of the Delaware River Basin Water Code; and

10. whether the exportation would contravene sections 3.3 and 3.5(a) of the Compact by impeding or interfering with the rights, powers, privileges, conditions or obligations contained in the Supreme Court Decree in *New Jersey v. New York,* 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

B. For importations of water~~, including wastewater~~ (including wastewater):

1. the effect of the importation on the health and safety of the Basin community with due consideration of the available alternatives to the importation;

2. the characterization and treatability of the water, if it consists of wastewater;

3. the potential impacts on water resources of the Delaware River Basin of the proposed importation and of each available alternative, including alternatives that avoid an importation of water, including wastewater. The potential impacts considered will include the effects of the quality, volume, flow rate, timing and duration of the proposed importation in relation to:

   a. flow objectives or passing or instream flow requirements contained in DRBC regulations or project approvals;

   b. the record of hydrologic conditions in the proposed receiving region and the larger Delaware River Basin;

   c. water uses as established by the Comprehensive Plan, including the DRBC Water Code;

   d. the effect of the importation on aquatic ecosystems;

   e. water quality and waste assimilation capacity in the affected receiving streams; and

   f. prior regulations or orders of the Commission which may be identified during the course of the Commission's review.

2.30.4 **Analyses by Applicant for Section 3.8 Approval.** When an importation or exportation of water or wastewater is subject to review by the Commission, the applicant shall furnish the Commission with such analyses of the factors set forth in Sections 2.30.2 and 2.30.3 above and as the Commission may direct.

2.30.5 **Water Charges** *(Resolutions Nos. 91-9 and xxx)*. Exportation of Basin water constitutes consumptive water use and will be subject to the water charges in effect at the time of transfer in accordance with the Commission's Water Supply Charges regulations (18 CFR Part 420), as amended.

2.30.6 **Wastewater Treatment Requirements** *(Resolution No. 91-9)*. It is the policy of the Commission to give no credit toward meeting wastewater treatment requirements for importations of wastewater. An effluent loading or concentration authorized in accordance with a water-quality-based effluent limit such as a wasteload allocation may not include loadings attributable to an importation of wastewater.

2.30.7 **Existing Allocations** *(Resolution No. 91-9)*. It is the policy of the Commission to charge all exportations of Basin water against any special regional allocation or any depletive use allocation as may exist at the time of receipt of a completed application for exportation.

2.30.8 **1954 Supreme Court Decree.** This Section 2.30 is intended to preserve the diversions, compensating releases, rights, conditions, and obligations of the parties to the U.S. Supreme Court Decree of 1954 in *New Jersey v. New York,* 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

EXHIBIT D

Part 440 of DRBC's Special Regulations at Title 18 of the Code of Federal Regulations, as amended, is shown below. Additions are shown in red with underscore and deletions are shown in ~~red with strikethrough~~ compared to the text of the proposed amendments to 18 C.F.R. Part 440, originally published on October 28, 2021.

SUBCHAPTER B – SPECIAL REGULATIONS

* * * *

PART 440 – HIGH VOLUME HYDRAULIC FRACTURING

Sec.

440.1 Purpose, authority and relationship to other requirements.

(a) *Purpose.* The purpose of this part is to protect and conserve the water resources of the Delaware River Basin. To effectuate this purpose, this section establishes standards, requirements, conditions, and restrictions to prevent or reduce depletion and degradation of surface and groundwater resources and to promote sound practices of water resource management.

(b) *Authority.* This part implements Sections 3.1, 3.2(a), 3.2 (b), 3.6(b), 3.6(h), 4.1, 5.2, 7.1, 13.1 and 14.2(a) of the Delaware River Basin Compact.

(c) *Comprehensive Plan.* The Commission has determined that the provisions of this part are required for the immediate and long range development and use of the water resources of the Basin and are therefore incorporated into the Commission's Comprehensive Plan.

(d) *Relationship to other Commission requirements.* The provisions of this part are in addition to all applicable requirements in other Commission regulations, dockets, permits, and determinations.

(e) *Severability.* The provisions of this part are severable. If any provision of this part or its application to any person or circumstances is held invalid, the invalidity will not affect other provisions or applications of this part, which can be given effect without the invalid provision or application.

(f) *Coordination and avoidance of duplication.* In accordance with and pursuant to section 1.5 of the Delaware River Basin Compact, to the fullest extent it finds feasible and advantageous the Commission may enter into an Administrative Agreement (Agreement) with any Basin state or the Federal Government to coordinate functions and eliminate unnecessary duplication of effort. Such Agreements will be designed to: Effectuate intergovernmental cooperation, minimize the efforts and duplication of state and Commission staff resources wherever possible, ensure compliance with

Commission-approved requirements, enhance early notification of the general public and other interested parties regarding proposed activities in the Basin, indicate where a host state's requirements satisfy the Commission's regulatory objectives, and clarify the relationship and project review decision making processes of the states and the Commission for projects subject to review by the states under their state authorities and by the Commission under Section 3.8 and Articles 6, 7, 10 and 11 of the Compact.

440.2 Definitions.

For purposes of this part, the following terms and phrases have the meanings provided. Some definitions differ from those provided in regulations of one or more agencies of the Commission's member states and the Federal Government. Other definitions are consistent with terms defined by the Delaware River Basin Compact.

Basin is the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

Commission is the Delaware River Basin Commission (DRBC) created and constituted by the Delaware River Basin Compact.

Discharge of wastewater from HVHF and HVHF-related activities is an intentional or unintentional action or omission resulting in the releasing, spilling, leaking, pumping, pouring, emitting, emptying, spreading, spraying, injecting, leaching, dumping, or disposing of such wastewater to waters or land within the Basin, and including the abandonment or discarding of barrels, containers, and other receptacles containing such wastewater.

Fracturing fluid(s) is a mixture of water (whether fresh or recycled) and/or other fluids and chemicals or other additives, which are injected into the subsurface and which may include chemicals used to reduce friction, minimize biofouling of fractures, prevent corrosion of metal pipes or remove drilling mud damage within a wellbore area, and propping agents such as silica sand, which are deposited in the induced fractures.

High volume hydraulic fracturing (HVHF) is hydraulic fracturing using a combined total of 300,000 or more gallons of water during all stages in a well completion, whether the well is vertical or directional, including horizontal, and whether the water is fresh or recycled and regardless of the chemicals or other additives mixed with the water.

HVHF-related activities are:

(1) Construction of an oil or natural gas production well that is to be stimulated using HVHF as defined ~~herein~~in this section;

(2) Chemical mixing or storage of proppant, chemicals and other additives to make fracturing fluid; and

(3) Management of wastewater from hydraulic fracturing, including storage, disposal, treatment, or reuse in hydraulic fracturing operations or other uses.

Hydraulic fracturing is a technique used to stimulate the production of oil and natural gas from a well by injecting fracturing fluids down the wellbore under pressure to create and maintain induced fractures in the hydrocarbon-bearing rock of the target geologic formation.

Person is any natural person, corporation, partnership, association, company, trust, Federal, state, or local governmental unit, agency, or authority, or other entity, public or private.

Wastewater from ~~high volume hydraulic fracturing~~HVHF and HVHF-related activities is:

(1) Any wastewater, brine, or sludge~~,~~ containing chemicals, naturally occurring radioactive materials, heavy metals or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities;

(2) Leachate from solid wastes associated with HVHF-related activities, except if the solid wastes were lawfully disposed of in a landfill within the Basin prior to [INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER]~~the effective date of this rule~~; and

(3) Any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of the wastewater described in paragraphs (1) and (2) of this ~~same~~ definition.

Water resource(s) is, in accordance with Section 1.2(i) of the *Delaware River Basin Compact,* ~~"~~water and related natural resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership or control~~"~~ within the Delaware River Basin.

440.3 High volume hydraulic fracturing (HVHF)

(a) **Determination.** The Commission has determined that high volume hydraulic fracturing poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the water resources of the Delaware River Basin and to Special Protection Waters of the Basin, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values. Controlling future pollution by prohibiting such activity in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

(b) **Prohibition.** High volume hydraulic fracturing in hydrocarbon bearing rock formations is prohibited within the Delaware River Basin.

440.4 Wastewater from high volume hydraulic fracturing and related activities

(a) **Determination.** The Commission has determined that the discharge of wastewater from high volume hydraulic fracturing and HVHF-related activities poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the Basin's water resources. Controlling future pollution by prohibiting such discharge is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

(b) **Prohibition.** No person may discharge wastewater from high volume hydraulic fracturing or HVHF-related activities to waters or land within the Basin.

EXHIBIT E

18 CFR Parts 410 and 440

Importations of Water into and Exportations of Water from the Delaware River Basin and Discharges of Wastewater from High Volume Hydraulic Fracturing and Related Activities

Comment and Response Document

December 7, 2022

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
API	American Petroleum Institute
BTEX	Benzene, ethylbenzene, toluene and xylene
CAS	Chemical Abstracts Service
CDC	Centers for Disease Control and Prevention
C.F.R.	Code of Federal Regulations
CO_2	Carbon Dioxide
CWT	Centralized waste treatment
DBP	Disinfection byproduct
DRB	Delaware River Basin
DCS	Damascus Citizens for Sustainability
DRBC	Delaware River Basin Commission
DRN	Delaware Riverkeeper Network
dSGEIS	Draft Supplement Generic Environmental Impact Statement (2009)
EDC	Endocrine disrupting chemical
EIA	U.S. Energy Information Administration
EPA	Environmental Protection Agency
EPT	The EPT index is the number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
GHG	Greenhouse gas
GLD	Gas leak drainage
HVHF	High volume hydraulic fracturing
IPCC	Intergovernmental Panel on Climate Change
LWV	League of Women Voters
MG	Million gallons per month
MSC	Marcellus Shale Coalition
NJDOH	New Jersey Department of Health
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NYC	New York City
NYSDEC	New York State Department of Environmental Conservation
OGW	Oil and gas wastewater
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
PADEP BOGM	PADEP Bureau of Oil and Gas Management
PCBs	Polychlorinated biphenyls
PSR	Physicians for Social Responsibility

Acronym	Definition
PubMed	Searchable Database of the US National Library of Medicine, National Institutes of Health
SRBC	Susquehanna River Basin Commission
TDS	Total dissolved solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
THMs	Trihalomethanes
U.S.C.	United States Code
UDS&RR	Upper Delaware Scenic and Recreational River
US or U.S.	United States (of America)
USGS	United States Geological Survey
VOC	Volatile organic compound

NOTE ON TERMINOLOGY

The term "HVHF wastewater" is used in this Comment and Response Document as shorthand for the term "Wastewater from HVHF and HVHF-related activities," which is defined in the final regulations, at 18 C.F.R. 440.2, as shown below:

> Wastewater from HVHF and HVHF-related activities is:
>
> (1) Any wastewater, brine, or sludge containing chemicals, naturally occurring radioactive materials, heavy metals or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities;
>
> (2) Leachate from solid wastes associated with HVHF-related activities, except if the solid wastes were lawfully disposed of in a landfill within the Basin prior to the effective date of this rule; and
>
> (3) Any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of the wastewater described in paragraphs (1) and (2) of this definition.

Section 440.2 defines "HVHF-related activities" as follows:

> HVHF-related activities are:
>
> (1) Construction of an oil or natural gas production well that is to be stimulated using HVHF as defined in this section;
>
> (2) Chemical mixing or storage of proppant, chemicals and other additives to make fracturing fluid; and
>
> (3) Management of wastewater from hydraulic fracturing, including storage, disposal, treatment, or reuse in hydraulic fracturing operations or other uses.

1. INTRODUCTION

1.1 Background

The Delaware River Basin Commission (the "Commission" or "DRBC") is a federal-interstate compact agency formed by concurrent legislation of Delaware, New Jersey, New York, Pennsylvania, and the United States in 1961[1] to manage the water resources of the Delaware River Basin ("Basin") without regard to political boundaries.[2] The Commissioners are, *ex officio*, the governors of the Basin states[3] and the Division Engineer, North Atlantic Division, United States Army Corps of Engineers, who represents the United States.[4]

By Resolution No. 91-9 on June 19, 1991, the Commissioners amended the Commission's Comprehensive Plan by the addition of policies and regulations relating to transfers of water into and out of the Basin. These provisions were later codified in the Delaware River Basin Water Code (the "Water Code").[5]

The Commission on November 30, 2017 proposed regulations (the "2017 draft rule") that in part concerned inter-Basin transfers of water and wastewater associated with high volume hydraulic fracturing ("HVHF") and that addressed the treatment and discharge of wastewater generated by HVHF. Concurrently with adoption of its final rule by Resolution No. 2021-01 on February 25, 2021, prohibiting HVHF in hydrocarbon bearing rock formations in the Basin, the Commission withdrew from consideration those provisions of the 2017 draft rule that concerned the exportation of water to support HVHF and the importation, treatment, and discharge of "produced water" and "CWT wastewater" as defined therein.[6]

By a Resolution for the Minutes on February 25, 2021, the Commissioners directed the Executive Director to prepare and publish for public comment a set of amendments to the Comprehensive Plan and DRBC regulations that would update the Commission's policies and provisions concerning importation and exportation of water and wastewater from and into the Basin. The Resolution also authorized the Executive Director "to include such other proposed amendments . . . as [the Executive Director, in consultation with the Commissioners] deem necessary or appropriate."

In accordance with the Commissioners' February 25, 2021 directive, the Commission in October 2021 published for public comment proposed amendments to its Comprehensive Plan and

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[1] Pub. L. No. 87-328, 75 Stat. 688, Approved Sept. 27, 1961; 53 Del. Laws ch. 71, Approved May 26, 1961; 1961 N.J. Laws ch. 13, Approved May 1, 1961; 1961 N.Y. Laws ch. 148, Approved Mar. 17, 1961; 1961 Pa. Laws Act 268, Approved July 7, 1961 (the "Compact").
[2] *Id*. § 1.3(e).
[3] *Id*. § 2.2.
[4] Water Resources Development Act of 2007, § 5019(a).
[5] Water Code, § 2.30 (prior to amendment by the final rules). The Water Code has been incorporated by reference into the Code of Federal Regulations at 18 C.F.R. § 410.1.
[6] 83 Fed. Reg. 1589, 1591 (defining "produced water" as "any water or fluid returned to the surface through the production well as a waste product of hydraulic fracturing," and defining "CWT wastewater" as "wastewater or effluent resulting from the treatment of produced water by a centralized waste treatment facility ('CWT')").

regulations to better provide for the planning, conservation, utilization, development, management and control of the Basin's water resources in connection with: the importation of water, including wastewater, into the Basin; the exportation of water, including wastewater, from the Basin; and the discharge of wastewater from HVHF and HVHF-related activities ("HVHF wastewater").[*] The final rules amend the Water Code by clarifying the circumstances in which exportations of water, including wastewater, from the Basin and importations of water, including wastewater, into the Basin are considered by the Commission and the factors to be used in evaluating whether such proposed imports and exports of water may be approved.[7] To effectuate the Comprehensive Plan for the immediate and long-term development and use of the water resources of the Basin, the final rules also prohibit the discharge of HVHF wastewater to waters or land within the Basin.[8] The final rule includes amendments to Article 4 of the Commission's Water Quality Regulations[9] (the "Water Quality Regulations") to facilitate the alignment of certain Basin state regulations and discharge permits with the Commission's Special Regulations by incorporating into the Water Quality Regulations the prohibition on the discharge of wastewater from HVHF and related activities.[10]

The October 2021 proposed rule amendments, Notice of Proposed Rulemaking, and a link to the comments received on the proposal can be found on the Commission's website at:
https://www.state.nj.us/drbc/meetings/proposed/notice_import-export-rules.html.

1.2 Public Input Purpose and Process

Multiple opportunities for public input on this rulemaking were provided during a 124-day comment period that ran from October 28, 2021 through February 28, 2022. Written comments were accepted throughout the comment period through an on-line comment intake system. An exception process was provided for those who lacked access to the on-line system or were otherwise unable to use it. The Commission received no requests for exceptions.

Opportunities for oral comment included five virtual public hearings at the dates and times listed below.

- Hearing #1: December 8, 2021 – 2:30 p.m.
- Hearing #2: December 8, 2021 – 6:30 p.m.
- Hearing #3: December 15, 2021 – 1:00 p.m.
- Hearing #4: December 15, 2021 – 4:00 p.m.
- Hearing #5: February 3, 2022 – 1:30 p.m.

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[*] *See also* Note on Terminology in front matter (p. iv).
[7] *See* Water Code § 2.30 (as amended by the final rules).
[8] *See* 18 C.F.R. § 440.4.
[9] *See* Water Quality Regulations § 4.50 (as amended by the final rules). The Water Quality Regulations have been incorporated by reference into the Code of Federal Regulations at 18 C.F.R. § 410.1.
[10] The Basin states have promulgated regulations incorporating the Water Quality Regulations as state requirements.

Enhanced opportunities for written comment and for oral comment in connection with the final public hearing on February 3, 2022 are described below:

- Real-time English-to-Spanish and Spanish-to-English professional translation was provided on a pilot basis. Hearing attendees could choose to participate in the virtual hearing in either English or Spanish.
- Individuals without convenient access to a computer or the internet could join the virtual hearing by phone using a new toll-free number.
- DRBC's website was improved by the addition of an interactive language translation widget capable of translating web-based formatted text on any of DRBC's web pages from English to over 100 different languages.
- The Commission's rulemaking notice and draft rules were published on the DRBC website in Spanish, and a process was established for requesting certified translations of all rulemaking documents into additional languages.

The Commission received 2,388 written "submissions" through its online comment system. These submissions are available for review and download at:

https://hearing.drbc.commentinput.com/?id=x2K8A

In many cases, a single written "submission" included two or more "comments" by different individuals or organizations. Some submissions consisted of written petitions with multiple signers. In many cases, similar or identical comments were submitted by multiple commenters using form letters or template language provided by others. Commenters were not limited to a single submission, and some commenters offered two or more submissions. The 2,388 figure represents the number of individual written submissions the Commission received during the comment period without regard to the number of comments within a submission, the number of signers to a submission or a comment, or the number of submitters making a joint submission. Within this comment and response document ("CRD"), issues raised by multiple commenters are described as such. In evaluating the comments, the staff and Commissioners evaluated and gave resulting weight to the substance and scientific support for a comment rather than the number of times it was submitted.

The Commission also received 73 oral comments during its five public hearings and evaluated these in the same manner as the evaluation of written comments. Every person who wished to speak at each of the five hearings was afforded an opportunity to do so. Transcripts of the public hearings are available for review on the DRBC web site at:

- Hearing #1: 12/08/2021 Transcript
- Hearing #2: 12/08/ 2021 Transcript
- Hearing #3: 12/15/ 2021 Transcript
- Hearing #4: 12/15/ 2021 Transcript
- Hearing #5: 02/03/2022 Transcript

The Commissioners, in consultation with the DRBC staff and staff of their respective agencies, carefully reviewed and considered all of the duly submitted public comments before voting to adopt final rules and incorporate them into the Comprehensive Plan.

1.3 Organization of Comments and Responses

This CRD is generally organized by proposed rule section. In some cases, a single comment concerned multiple rule sections. In such cases, a response may be repeated, cross-referenced to another section, or addressed in a general summary response. In many instances, similar or identical comments were submitted by multiple individuals and organizations. The Commission staff reviewed all the comments and then distilled those with similar themes into "statements of concern." Each statement of concern is a representative quoted or paraphrased version of one or more comments on a shared theme. The Commission has responded to each statement of concern. The process of screening, grouping, paraphrasing and organizing comments for response is depicted in Figure 1.

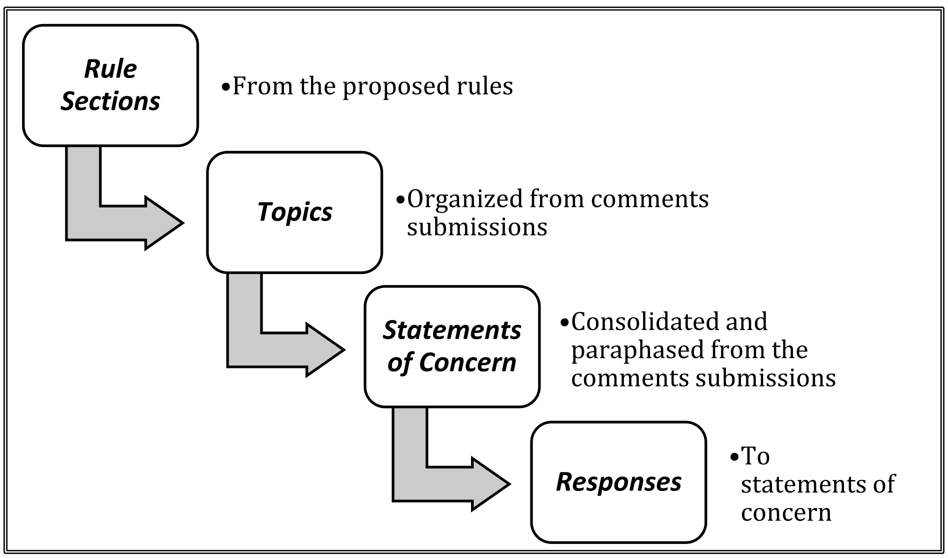

Figure 1: Process for organizing comment submissions and responses

The Commission also received comments on subjects outside the scope of the rules, and in some cases, outside the scope of the Commission's authority as defined by the Delaware River Basin Compact. To provide a complete and comprehensive view of the comments received, the staff developed statements of concern for these comments. In some cases, responses to these out-of-scope submissions are provided; however, in other cases the Commission simply notes that the comments are beyond the scope of the proposed action.

Footnotes to statements of concern (designated by "SC-" followed by a number) within this CRD are footnotes that appeared in the original comments (although the format of these notes may differ from that in the original comments). Footnotes to the Commission's responses (designated by "R-" followed by a number) are to authorities relied on by the Commission or references furnished by it for the benefit of readers. The "References" table at the end of this CRD includes only those sources cited in the Commission's responses, not those referenced solely by commenters.

2. RESPONSE TO COMMENTS – AUTHORITY

STATEMENT OF CONCERN (SC-1)

Many commenters suggested that the Commission has the authority and should exercise it to (i) expand the scope of the proposed regulations to prohibit any and all importation, transportation, storage, and treatment of wastewater from high volume hydraulic fracturing ("HVHF") and HVHF-related activities (in accordance with the "Note on Terminology," such wastewater is hereinafter referred to as "HVHF wastewater") within the Delaware River Basin, and (ii) expand the proposed regulations to prohibit any and all exportations of water or wastewater to support hydraulic fracturing outside the Basin. Some commenters averred that "the DRBC has the authority to protect our waters from the impacts of the harmful, toxic, and forever chemicals—and all the unknown chemicals—in fracking wastewater" by expanding the scope of its regulations to prohibit treatment, storage, underground injection, placement in landfills, or road spreading or other "beneficial uses" of HVHF wastewater.

Commenters suggested that "[t]he Commission has the authority to—and should revise its regulations to—specifically prohibit those projects that would consequently discharge fracking wastewater into the Basin that may not otherwise be considered a discharge."

One commenter was "shocked and appalled [th]at the Delaware River Basin Commission has the authority to vote on allowing the possible contamination and/or withdrawal of our potable water supply and the public's water supply."

RESPONSE (R-1)

This response focuses on the relationship between the final regulation and the Commission's Compact-based authority. Other sections of this document explain the Commission's view that its final rules on importations of water into the Basin, exportations of water from the Basin, and discharges of HVHF wastewater to land or waters of the Basin constitute a regulatory response proportionate to the risks to the Basin's water resources posed by the regulated activities. *See* Sections 3.2 Water and Wastewater Exportation, 3.3 Water and Wastewater Importations, 4.2.1 Potential Risks to Water Resources, and 4.2.2 Potential Impacts to Water Resources and Their Uses.

Importantly, the final rules are grounded in the authorities conferred on the Commission by the Delaware River Basin Compact (the "Compact"), a federal-interstate compact enacted in 1961 concurrently by the Commission's four member states and the United States, approved by Congress pursuant to Article 1, Section 10, Clause 3 of the United States Constitution and enacted by Congress as federal law.

The Commission's final rules are based on the authority granted to the Commission by the following sections of the Compact, either individually or in combination: Section 3.3—Allocation, Diversions and Releases; Sections 3.2(a) and 13.1—Comprehensive Plan; Section 4.1—Water Supply—Generally; Section 4.2—Water Supply—Storage and Release of Waters; Section 5.2—Pollution Control—Policy and Standards; Section 14.2—Regulations; and Enforcement; and Sections 3.6(b) and (h)—General Powers.

Authority for the Regulations

The Compact grants the Commission broad authority to "make and enforce reasonable rules and regulations for the effectuation, application and enforcement of the Compact" (§ 14.2). The Commission may also "establish standards of planning, design and operation of all projects and facilities in the Basin which affect its water resources" (§ 3.6(b)); and it may "have and exercise all powers necessary or convenient to carry out its express powers" (§ 3.6(h)). To complement these general rulemaking provisions, Section 5.2 confers authority on the Commission to adopt rules, regulations and standards to control pollution.

The Commission's authority regarding exportations of water from the Basin is rooted in part in its power to equitably apportion the waters of the Basin. In its Decree in *New Jersey v. New York*, 347 U.S. 995 (1954) (the "Decree"), the U.S. Supreme Court equitably apportioned the Basin's waters based on conditions existing in 1954. To avoid the future need for one or more of the Decree Parties to return to the Court to modify the Decree as conditions in the Basin change, the Compact grants the Commission "the power from time to time as need appears, in accordance with the doctrine of equitable apportionment, to allocate the waters of the basin to and among the states signatory to this compact and to and among their respective political subdivisions, and to impose conditions, obligations and release requirements related thereto." (§ 3.3).[11]

Consistent with the principles underlying the doctrine of equitable apportionment, *see*, *e.g.*, *Mississippi v. Tennessee*, 142 S.Ct. 31 (2021); *Florida v. Georgia*, 138 S.Ct. 2502 (2018); *New Jersey v. New York*, 347 U.S. 995 (1954), the Commission has considered the rights and needs of the states, including municipalities and other water users within their jurisdictions, to make reasonable use of the Basin's shared water resources. As stated in Section 2.30.2 of the Water Code and discussed in Section 3.2 of this CRD, the Basin's water resources are limited and subject to shortages, particularly in dry periods or when otherwise stressed. The regulations implement Section 3.3 of the Compact by allowing exportations of water from the Basin only after an evaluation of factors that address need and impacts on the Basin's water resources and community, and only when required to serve straddled and adjacent public water systems; or on a temporary, short-term, or emergency basis; or in the case of wastewater, subject to geographic limitations similar to those for exports of water generally or when exported for special treatment or disposal.

Other sections of the Compact likewise support the exportation provisions of the regulations. Section 4.1 grants the Commission power to develop, implement and effectuate plans (and projects) for the use of the waters of the Basin for domestic, municipal, agricultural and industrial water supply. The regulations implement the Commission's plans to conserve the waters of the Basin by allowing exportation of water only under certain conditions, as described above. *See also,* Compact § 3.1 (requiring the Commission to adopt and promote uniform and coordinated policies for water conservation, control, use and management in the Basin). In addition, during periods when the

[11] The Compact requires the Commission to obtain the unanimous consent of the parties to the Decree for any allocation adversely affecting the diversions, compensating releases, rights, conditions, obligations and provisions for the administration thereof as provided in the Decree. (§ 3.3(a)). Here, the Commission's regulations have no adverse effect on these terms of the Decree.

Commission is releasing water from storage to augment flow, Section 4.2(b) likewise authorizes limitations on the diversion of any water of the Basin.

The Commission's regulations also effectuate Sections 3.2(a) and 13.1 of the Compact, which instruct the Commission to develop a comprehensive plan for the immediate and long-range development and use of the water resources of the Basin. The exportation regulations limiting the use of Basin water comprise part of the Comprehensive Plan and manifest the Commission's exercise of its authority to conserve the waters of the Basin. Promoting water conservation enables the Commission to effectuate a Comprehensive Plan that satisfies other objectives of the Compact, including, among other things, maintaining the diversions and compensating releases set forth in the Decree as modified by the Commission (Compact § 3.5), meeting water supply needs (Compact § 4.1), promoting sound practices of watershed management and maintaining and improving fish and wildlife habitats (Compact §§ 7.1 and 7.3), providing for the development of water related sports and recreational facilities (Compact § 8.1) and developing hydroelectric power (Compact § 9.1).

The Commission's authority regarding pollution control provides a further basis for regulation of importations and exportations of water and discharges of wastewater. Section 5.2 of the Compact grants the Commission authority to control future pollution and abate existing pollution pursuant to the following standard of control: "pollution . . . shall not injuriously affect the waters of the basin as contemplated by the Comprehensive Plan." This article further provides in relevant part that the Commission may "classify the waters of the Basin and establish standards of treatment of sewage, industrial or other waste" and may "adopt and from time to time amend and repeal rules, regulations and standards to control such future pollution and abate existing pollution . . . as may be required to protect the public health or to preserve the waters of the Basin for uses in accordance with the comprehensive plan" (*Id*.). Exportation of water may decrease the assimilative capacity of the withdrawal source and hydraulically connected surface waters and ground waters, and increase the concentration of pollutants. Importation of wastewater may adversely affect the receiving waters in the event of a discharge. Discharges of HVHF wastewater pose particular, heightened risks associated with that waste stream because they may increase concentrations of the toxic, radioactive and conventional pollutants in the receiving waters and render them unfit for other uses identified in the Comprehensive Plan. The Commission's prohibition on the discharge of HVHF wastewater to waters or land within the Basin is narrowly tailored to accomplish the purposes articulated in Section 5.2.

The Commission's Geographic Jurisdiction

Many commenters stated that the Commission should prohibit any exportation of water or wastewater that would support hydraulic fracturing outside of the Delaware River Basin. However, the Compact provides expressly that the Commission "shall have, exercise and discharge its functions, powers and duties *within the limits of the basin*." (§ 2.7) (Emphasis added). Exceptions to this geographical restriction are narrow. The Commission may exercise its discretion to act outside the Basin in relevant part "whenever such action may be necessary or convenient *to effectuate its powers or duties within the basin* . . .." and "only upon the consent of the state in which it proposes to act." *Id*. (Emphasis added). Reinforcing the notion that the Commission's focus is water management *within* the Basin, Section 3.1, "Purpose and Policy," of Article 3 of the Compact, "Powers and Duties of the Commission," provides that the Commission "shall adopt and promote uniform and coordinated policies for water conservation, control, use and management *in the basin.*" (Emphasis added).

In accordance with the authorities conferred on the Commission by the Compact, under the final rule regarding exportation the Commission will consider various factors including, among others, the sponsor's planned use for the water and any resulting benefits, Water Code § 2.30.3 A.8, and the availability of alternatives. Water Code § 2.30.3 A.9. Once a project sponsor demonstrates need to utilize Basin water to serve a straddled or adjacent public water system, the Commission will evaluate proposals primarily on the basis of their effects on the health and safety of the *Basin community,* including on water availability; aquatic ecosystems; salinity concentrations; water uses protected by the Comprehensive Plan; DRBC regulations and docket approvals; pass-by or instream flow requirements; and the provisions of the Decree. The information reviewed by the Commission to date does not demonstrate that a categorical prohibition on any out-of-Basin exportation of Basin water for HVHF (or for hydraulic fracturing more broadly) without regard to the other considerations set forth in the regulations is necessary to achieve the purposes of the Compact.

For additional detail on the Commission's authority to adopt regulations, *see* Section 2.1.1, *Authority*, of the Commission's *Comment and Response Document* adopted concurrently with the final regulations prohibiting HVHF within the Basin (the "February 2021 CRD").

3. RESPONSE TO COMMENTS – SECTION 2.30 DRBC WATER CODE

3.1 Water Code Section 2.30 Definitions

STATEMENT OF CONCERN (SC-2)

Commenters suggested that the definition of "Exportation" in proposed Section 2.30.1 D. of the Water Code should be revised by the deletions shown in strikethrough in the following:

> "Exportation" means the conveyance, transfer or diversion of Basin water from a source within the Delaware River Basin to a location outside the Basin ~~without return~~

> ~~of such water to the Basin~~. Exportations from the Basin of consumer goods or foods that have been manufactured, bottled, packaged, or processed using Basin water are not considered "exportations" for purposes of this rule.

Commenters suggest that the removal of "without return of such water to the Basin" would close a loophole under which the oil and gas industry could otherwise take Basin water out of the Basin for use in HVHF and return the resulting HVHF wastewater to the Basin, "without any regulation or oversight by DRBC."

Response (R-2)

The definition of "Exportation" (Section 2.30.1 E. of the Water Code in the final rule) was not revised. The commenters are concerned that if water is returned to the Basin (as HVHF wastewater), then it is not "exported" under DRBC rules, and hypothetical transfers out and into the Basin by the oil and gas industry will evade review. Under the final regulations at Section 440.4, however, even if water has been exported, water that comprises HVHF wastewater cannot be discharged to waters or land within the Basin. Thus, HVHF wastewater is unlikely to be transported into the Basin after the effective date of the final rule, and the likelihood of the hypothetical events about which the commenters express concern is remote.

The Commission's prohibition on the discharge of HVHF wastewater to land or waters of the Basin also makes it unlikely that operators will be transporting HVHF wastewater into the Basin or storing it in the Basin. Please see Section 4.2.1.5, Transport, Leaks and Spills, for a discussion of oil and gas operators' HVHF wastewater transportation and disposal practices.

Statement of Concern (SC-3)

Commenters suggested that the definition of "Importation" in proposed Section 2.30.1 E. of the Water Code should be revised by the deletions shown in strikethrough in the following:

> "Importation" means the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside the Basin~~, resulting in a discharge of the imported water to land or water within the Basin, with or without prior treatment~~.

Commenters' objective in removing the discharge requirement from the definition of "importation" is to prohibit pollution that may occur "through means other than an actual discharge to water [or] land," such as air emissions, reuse and recycling, storage, and transportation.

Response (R-3)

The definition of "Importation" (Section 2.30.1 F. of the Water Code in the final rule) was not revised because the proposed change would result in an overly broad restriction that is not needed to achieve the purposes of the Compact. For discussions of the risks and impacts and the Commission's role in connection with air emissions, reuse and recycling, storage, and transportation, see Sections 4.2.1.2, Air Pollution and Air Deposition, 4.2.1.5, Transport, Leaks and Spills, and 4.2.1.7, Waste Storage and Recycling, below.

Statement of Concern (SC-4)

Commenters stated that the rules were unclear as to how nonpublic water systems or industrial water withdrawal systems are affected by the definition of "public water system."

Response (R-4)

As amended, Section 2.30.1 G. of the Water Code, concerning importations and exportations of water from the Basin, provides:

> "Public water system" means a system primarily for the provision to the public of piped water for human consumption if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. A "public water system" may be publicly or privately owned.

The term "public water system" appears in the proposed amended text of Section 2.30.1 in two other definitions— "Adjacent public water system" and "Straddled public water system"—and in two substantive provisions of the Water Code amendments—2.30.2 C. and 2.30.3 A.9. Section 2.30.2 C. states that "a proposed new exportation of Basin water that is subject to review under the Compact and implementing regulations . . . may be approved by the Commission after consideration of the factors set forth at Section 2.30.3 below, if: 1. the sponsor demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system; . . .." Section 2.30.3 A.9. provides that in evaluating exportations of water from the Basin, the Commission's review will consider, among other factors:

> the availability to the sponsor of alternatives to the exportation of Basin water and whether these alternatives have been diligently pursued, including without limitation . . . conservation measures undertaken by the sponsor or a public water system in the service area where the sponsor is located to forestall the need for a transfer of Basin water . . . [.]

The effect of the definition of "public water system" in each of these instances and in all of them collectively is to limit exportations of water to effectuate purposes of the Compact and the Comprehensive Plan. In particular, any proposed export to a water system that does not meet the definition of a "public water system" (nonpublic, industrial, or otherwise) is ineligible for the Commission's review and approval under the proposed and final rule unless it falls within one of two other eligible classifications, i.e., it is required on a temporary, short-term, or emergency basis in accordance with Section 2.30.2 C.2, or it is an eligible exportation of wastewater pursuant to Section 2.30.2 C.3.

As set forth in a discussion of the Commission's authority in R-1 of this CRD, provisions of Section 2.30 of the Water Code limiting the use of Basin water comprise part of the Comprehensive Plan and manifest the Commission's exercise of its authority to conserve the waters of the Basin. Promoting water conservation enables the Commission to effectuate a Comprehensive Plan that satisfies other objectives of the Compact, including, among other things, maintaining the diversions and compensating releases set forth in the Decree as modified by the Commission (Compact § 3.5), meeting water supply needs (Compact § 4.1), promoting sound practices of watershed management and maintaining and improving fish and wildlife habitats (Compact §§ 7.1 and 7.3), providing for the development of water related sports and recreational facilities (Compact § 8.1) and developing hydroelectric power (Compact § 9.1).

STATEMENT OF CONCERN (SC-5)

Several commenters stated that the definition of "wastewater" in Section 2.30 of the Water Code should be modified by the additions and deletions shown by underscore and strikethrough in the following:

> "Wastewater" means water that is stored, transported, or discharged after use, <u>and will not be reused in an industrial or commercial process. This definition includes</u>, ~~including,~~ but <u>is </u>not limited to, any water for which a National Pollutant Discharge Elimination System (NPDES) permit under the federal Clean Water Act or any state or DRBC approval is required before the water can lawfully be discharged to waters or land within the Basin.

RESPONSE (R-5)

The Commission has considered the effect of the proposed change on its policies and proposed rules concerning both exportations and importations of wastewater. It has concluded that the commenters' proposed change would not achieve purposes of the Compact. However, it also has concluded that its proposed language at Section 2.30.2 C.3. concerning exportations of wastewater was overly broad. As explained below, that language is modified in the final rule to better align with longstanding conservation and water quality objectives included in the Comprehensive Plan.

Exportation concerns. The Commission's proposed rule included "wastewater" as a class of Basin water that may be approved by the Commission for exportation from the Basin subject to consideration of the factors set forth at Section 2.30.3. The commenter's proposal would narrow the categories of wastewater eligible for exportation under Section 2.30.2 C. of the amended regulation.

As the Commission explained in its FAQ document published on December 7, 2021, because water and wastewater service areas often straddle basin boundaries, it is not uncommon for wastewater generated in one basin to be disposed of in another. Imports and exports of water and wastewater occur routinely around the Basin boundary in this manner. The Commission's purpose in making exportations of wastewater eligible for review and approval was to ensure that straddled and adjacent systems, including for both sewered and hauled septage, could continue to operate, and if necessary, expand, normally.

However, the Commission has concluded that the language it originally proposed at Section 2.30.2 C.3 of the Water Code was overly broad. Authorizing the Commission to evaluate and, subject to consideration of the factors at Section 2.30.3., to approve *any* exportation of wastewater risks undercutting the conservation objectives served by limiting exportations of Basin water in Sections 2.30.2. C.1. and 2.

Accordingly, under the final rule, the text of Section 2.30.2 C. is revised to read as follows (additions appear in bold face, and deletions in strikethrough):

C. A proposed new exportation of Basin water that is subject to review under the Compact and implementing regulations, including any proposed increase in the rate or volume of an existing exportation, may be approved by the Commission after consideration of the factors set forth at Section 2.30.3 below, if:

1. the sponsor demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system;

2. the sponsor demonstrates that the exportation of Basin water is required **to meet public health and safety needs** on a temporary, short-term, or emergency basis ~~to meet public health and safety needs~~; or

3. the sponsor is proposing an exportation of wastewater **and demonstrates either (i) that the wastewater is being conveyed to a straddled or adjacent public wastewater collection system; or (ii) that the wastewater may not lawfully be discharged to a public wastewater collection system and is being exported for treatment, disposal or both at a waste management facility that has all required state and federal approvals to lawfully receive it.**

In order to support these revisions to Section 2.30.2 C. of the Water Code, and to simplify the definition of "adjacent" public water systems and public wastewater collection systems, the following changes to Section 2.30.1 Definitions, were also adopted in the final rule:

A. "Adjacent public water system" means a public water system **(as defined herein)** located outside ~~of~~ the Delaware River Basin that ~~either: (1) is interconnected with a public water system located entirely inside the Basin or with a "straddled public water system" (as defined herein); or that (2)~~ has a service area directly bordering the service area of a public water system located ~~entirely~~ **in whole or in part** within the Basin ~~or that straddles the Basin boundary~~.

B. "Adjacent public wastewater collection system" means a public wastewater collection system (as defined herein) located outside the Delaware River Basin that has a service area directly bordering the service area of a public wastewater collection system located in whole or in part within the Basin.

C~~B~~. "Basin water" (also, "waters of the Basin") means water in, on, under or above the ground within the Delaware River Basin. "Basin water" includes wastewater.

D~~C~~. "Delaware River Basin" (or "Basin") has the meaning assigned to it by Section 1.2(a) of the *Delaware River Basin Compact* – the area of drainage into the Delaware River and its tributaries, including Delaware Bay.

E~~D~~. "Exportation" means the conveyance, transfer, or diversion of Basin water from a source within the Delaware River Basin to a location outside the

Basin without return of such water to the Basin. Exportations from the Basin of consumer goods or foods that have been manufactured, bottled, packaged, or processed using Basin water are not considered "exportations" for purposes of this rule.

F~~E~~. "Importation" means the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside the Basin, resulting in a discharge of the imported water to land or water within the Basin, with or without prior treatment.

G~~F~~. "Public water system" means a system primarily for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. A "public water system" may be publicly or privately owned.

H. "Public wastewater collection system" means a system with all required state and federal approvals that serves more than 250 people or conveys more than 25,000 gallons of wastewater per day and is primarily for the collection and conveyance of domestic sewage from private, commercial, institutional, or industrial sources, to a treatment system with all necessary state and federal approvals. A "public wastewater collection system" may be publicly or privately owned.

I~~G~~. "Straddled public water system" means a public water system that serves an area partially within and partially outside of the Delaware River Basin.

J. "Straddled public wastewater collection system" means a public wastewater collection system that serves an area partially within and partially outside of the Delaware River Basin.

K~~H~~. "Wastewater" means water that is stored, transported or discharged after use, including, but not limited to, any water for which a National Pollutant Discharge Elimination System (NPDES) permit under the federal Clean Water Act or any state or DRBC approval is required before the water can lawfully be discharged to waters or land within the Basin.

The final rule thus authorizes the Commission, after consideration of the factors set forth in Section 2.30.3, to consider and approve an exportation of wastewater from the Basin under circumstances that align with the Commission's polices for water conservation and pollution prevention adopted pursuant to the Compact and incorporated into the Comprehensive Plan and other implementing regulations.

Importation concerns. The Commission also considered the commenters' proposal in relation to the proposed rules regarding importation. As proposed, and as adopted in Section 2.30 of the Water Code, the rule provides:

> "Importation" means the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside

> the Basin, resulting in a discharge of the imported water to land or water within the Basin, with or without prior treatment.

By Resolution No. 91-9 in 1991, the Commission added to the Water Code and the Comprehensive Plan the following concerning importations of wastewater:

> [T]he Basin waters have limited assimilative capacity and limited capacity to accept conservative substances without significant impacts. Accordingly, it . . . shall be the policy of the Commission to discourage the importation of wastewater into the Delaware River Basin that would significantly reduce the assimilative capacity of the receiving stream on the basis that the ability of Delaware River Basin streams to accept wastewater discharges should be reserved for users within the Basin.

The proposed Water Code amendments include at Section 2.30.2 D. a refined version of this policy that preserves the purpose of the original – limiting importations of wastewater as necessary to avoid impairment of Basin waters. It provides:

> Basin waters have limited capacity to assimilate pollutants without significant impacts to the health and safety of Basin residents, the health and functioning of aquatic ecosystems in the Basin, and the effectuation of the Comprehensive Plan. Accordingly, it is the policy of the Commission to discourage, limit, or condition the importation of wastewater into the Delaware River Basin as necessary to avoid impairment of Basin waters. A proposed new importation of water or wastewater, including any proposed increase in the rate or volume of an existing importation, shall be reviewed by the Commission consistent with the factors set forth at Section 2.30.3 below.

As articulated in the final rule, the policy remains focused on potential impacts to Basin waters that may result from discharges to land or water within the basin. The Commission's evaluation of the factors set forth in Section 2.30.3 B. will result in the imposition of conditions or limits on a proposed importation of wastewater as appropriate to protect the waters of the Basin, regardless of whether the discharge is preceded by reuse in an industrial or commercial process. Accordingly, the proposed change to the definition of "wastewater" is not needed based on concerns regarding importations of wastewater.

3.2 Water and Wastewater Exportation

Statement of Concern (SC-6)

The Delaware Riverkeeper Network (DRN) and others commented that Section 2.30 of the Water Code should be amended to provide that no new exportation of Basin water will be approved where the proposed exportation will result in the permanent loss of water to the hydrologic cycle, or where the purpose of the proposed exportation is to replace water that was consumptively used by the HVHF industry. DRN offered that placing such a condition on exportations falls within the Commission's authority for the protection and preservation of the Basin's water resources.

RESPONSE (R-6)

Most water transferred from the Basin is not returned to it after use. Such transfers are exportations that have an effect similar to consumptive uses of the Basin's water. The Commission has long recognized that Basin water supply objectives and flow management operations can be significantly impacted by consumptive uses. These uses may impact downstream water availability and the management of salinity in the Delaware Estuary, where public water supply intakes for the City of Philadelphia and a large New Jersey purveyor, among others, are located, and may impact mandatory compensating releases from New York City's Delaware River Basin reservoirs. February 2021 CRD, R-31, p. 61.

For this reason, among others, the Commission in 1991 adopted Water Code Section 2.30.2—Policy of Protection and Preservation, which states:

> The waters of the Delaware River Basin are limited in quantity and the Basin is frequently subject to drought warnings and drought declarations due to limited water supply storage and streamflow during dry periods. Therefore, it shall be the policy of the Commission to discourage the exportation of water from the Delaware River Basin.

The proposed and final rule includes an expanded articulation of this longstanding policy, as follows, at new Section 2.30.2 A:

> The waters of the Delaware River Basin are limited in quantity, and the Basin is frequently subject to drought warnings, drought declarations, and drought operations due to limited water supply storage and streamflow during dry periods. In addition, portions of the Basin have been delineated by the Commission as groundwater protected areas due to water shortages. Therefore, it is the policy of the Commission to promote the conservation and preservation of water and related natural resources, including aquatic ecosystems, and effectuate the Comprehensive Plan and the uses of the water resources of the Basin identified therein, by discouraging, limiting, or placing conditions on the exportation of Basin water as may be required to protect the health and safety of Basin residents, aquatic ecosystems and the uses of water identified in the Compact and Comprehensive Plan.

Consistent with this more detailed policy statement, under the final rules, exportations may be approved by the Commission only after consideration of certain factors set forth at Section 2.30.3 of the Water Code, and only if the sponsor: 1) demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system; 2) demonstrates that the exportation of Basin water is required to meet public health and safety needs on a temporary, short-term, or emergency basis; or 3) proposes an exportation of wastewater to a straddled or adjacent public wastewater collection system.

In combination with these limitations, the Commission routinely structures withdrawals so that potential risks to water resources are minimized through, for example, restrictions such as pass-by flow requirements, interruptible service and consumptive use make up (*see* February 2021 CRD, R-29, p. 60).

The final regulations thus manifest the Commission's exercise of its authority to conserve the waters of the Basin and to preserve them for uses in accordance with the Comprehensive Plan. The information reviewed by the Commission to date does not demonstrate that a categorical prohibition on any out-of-Basin use of Basin water without regard to the other considerations set forth in the regulations is necessary to achieve these or other purposes of the Compact.

Please refer to Section 2.0 of this CRD for a more detailed discussion of the Authority of the Commission.

STATEMENT OF CONCERN (SC-7)

Several commenters, including DRN and the Pennsylvania Council of Trout Unlimited, suggested that the volume of water used for hydraulic fracturing in shale formations has grown in recent years and that water exported from the Basin for hydraulic fracturing:

- does not return to the Basin and is thus a depletive use.
- threatens or interferes with available water supplies.
- depletes aquifers and other groundwater, and in turn reduces hydrologic contributions to wetlands, springs, and waterways.
- changes natural groundwater flows and can move pollution plumes in unexpected directions.
- changes water quality and related habitat such as reduced oxygen and increased temperature.
- changes the rate and volume of flow and stream morphology impacting existing uses and Special Protection Waters.
- lowers water levels, impacting aquatic habitats and wildlife that depend upon aquatic habitats.
- lowers surface water levels, impacting streams and near-stream recreation (such as camps).

RESPONSE (R-7)

The Commission agrees that a transfer of water out of the Basin is depletive and consumptive whenever, as is often the case, the exported water is not returned to the Basin after it is used. Please see Responses R-5 and R-6 above for the Commission's response to this concern.

The Commission also acknowledges that certain exports and withdrawals have the potential to result in the other impacts enumerated by the commenters. The amendments to the Water Code at Sections 2.30.2 C. (establishing geographic and need-based limitations on exportation) and 2.30.3 A. (establishing factors to be considered in evaluating proposed exports) are designed to ensure that the Basin's waters are conserved to meet in-Basin uses established by the Comprehensive Plan. These provisions will work together with existing measures routinely used by the Commission to minimize the risk to water resources posed by withdrawals, including restrictions such as pass-by flow requirements, interruptible service, and consumptive use make up requirements (*see* February 2021 CRD, R-29, p. 60).

The potential streamflow and water quantity impacts of water use for high volume hydraulic fracturing are discussed at length in Section 2.3.2.1 of the February 2021 CRD. Among other things, that discussion compares the total volume of water used for hydraulic fracturing in the Susquehanna River Basin to total water uses and total consumptive uses in the Delaware River Basin. The Commission's conclusions from that section state in relevant part:

> On the basis of data for HVHF within the Susquehanna River Basin, the total water used for hydraulic fracturing activities is not large compared to water use by other sectors in the Delaware River Basin. However, consumptive use of such large quantities of water and permanent removal of the water from the hydrologic cycle is unique to this industry.
>
> Although the likelihood of impacts due to water use [i.e., impacts on streamflows and on ground- and surface water availability] associated with HVHF if permitted is relatively high, the severity of the impacts relative to other potential impacts described in this document [i.e., those related to water quality] is relatively low, provided that adequate regulations and best practices are employed.

As noted above, to implement its conservation policies and to preserve the Basin's waters for uses in accordance with the Comprehensive Plan, the Commission is limiting exportations of water based on geography and demonstrations of need. When withdrawals are approved—whether for purposes of exportation or for use within the Basin—best practices are employed to minimize the risk of adverse impacts on waters of the Basin. Moreover, to date, water supplies outside the Basin have been adequate to meet hydraulic fracturing needs outside the Basin. No requests or applications for water exportation to support hydraulic fracturing activities outside the Basin are currently pending before the Commission. Accordingly, the adverse impacts the commenters describe are unlikely to occur as a result of withdrawals generally, and even less likely to occur as a result of withdrawals to serve HVHF.

Statement of Concern (SC-8)

Many commenters objected to the possibility of water being exported from the Basin for use by the oil and gas industry. Concerns were raised that:

- the industry's need for more water would motivate it to "raid" and "exploit" the Delaware River Basin.
- the water should not be used for private profit and specifically profits for the oil and gas industry.
- the exportation of water will create opportunities for hydraulic fracturing outside the Basin.

- the growth in hydraulic fracturing outside the Basin will impact climate change and cause environmental harms.
- water should not be exported for natural gas to be exported to China.

Response (R-8)

The creation of opportunities for hydraulic fracturing outside the Basin is not an objective of the proposed or final rules and is not an expected outcome of these rules. As the responses in this CRD attempt to make clear, the Commission's focus is to conserve and protect the Basin's water resources. The preceding responses at R-6 and R-7 explain how the final rules accomplish these over-arching purposes.

The risks and impacts of HVHF on water resources of the Basin are comprehensively addressed in the February 2021 CRD. By prohibiting HVHF within the Basin, the Commission's rulemaking finalized in February 2021 substantially reduced those risks. The Commission's final rule prohibiting discharges of wastewater from HVHF and HVHF-related activities to waters or land within the Basin further reduces the risk to the Basin's water resources posed by waste generated by HVHF and HVHF-related activities conducted elsewhere. As to exportations of water, the final rule allows them only to straddled or adjacent public water systems that have demonstrated need (§ 2.30.2 C.2) and to straddled or adjacent public wastewater collection systems (§ 2.30.2 C.3(i)), unless the water is needed to address short-term public health and safety needs (§ 2.30.2 C.2), or (in the case of wastewater) requires special treatment, disposal or both at a state-licensed facility that may lawfully receive it (§ 2.30.2 C.3(ii)). Section 13.1 of the Compact and the Commission's Comprehensive Plan recognize that public and private projects and facilities may be required for the optimum planning, development, conservation, utilization, management and control of the water resources of the Basin. The final rule does not favor or disfavor water use "for private profit," nor is the large-scale export of Basin water for HVHF an expected outcome of the final rule.

The concern about the potential for water exported from the Basin to be used to support U.S. exportation of natural gas to China is not within the scope of the Commission's authority or its proposed or final rules. The Commission's jurisdiction is to manage the water resources of the Basin, not to determine the destination of natural gas produced outside the Basin. According to the United States Energy Information Administration, in 2021, approximately 89 percent of the natural gas produced in the U.S. was consumed domestically. As of 2021, the United States consumed 30.28 trillion cubic feet (Tcf) of natural gas while, at the same time, exported roughly 6.65 Tcf. Exports of natural gas from the U.S. exceeded imports for the first time in 2017.[12] Of the total amount of natural gas exported by the United States in 2021, less than 7 percent went to China.[13]

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[12] *See* EIA, Natural gas explained: Natural gas imports and exports (Last updated May 12, 2022), accessed at: https://www.eia.gov/energyexplained/natural-gas/imports-and-exports.php (data as of July 2022, preliminary data for 2021) (hereinafter. "EIA, 2022a").

[13] *See id.*; As of 2021, China imports more liquefied natural gas than any other country (May 2, 2022), accessed at: https://www.eia.gov/todayinenergy/detail.php?id=52258#.

STATEMENT OF CONCERN (SC-9)

Several commenters stated that wastewater could be exported under the rules and wastewater could be used for hydraulic fracturing. The same commenters stated that wastewater is also water and objected to wastewater being permitted to be exported. The DRN commented that "The allowance of the exportation of wastewater is short-sighted, lacks environmental integrity, and shows disregard for neighboring watersheds."

RESPONSE (R-9)

The Commission agrees that wastewater is a category of water. Please see Response R-5 for a discussion of changes to proposed Section 2.30.2 C.3 of the Water Code, concerning the exportation of wastewater, to better align this provision with the objectives of the Comprehensive Plan and other regulations.

DRN's statement that with respect to exportation the proposed rule shows a "disregard for neighboring watersheds" suggests that the Commission has authority to protect water resources outside the Delaware River Basin. The Commission does not have that specific authority. Nevertheless, federal, state, and local laws (and in some instances rules promulgated by another interstate commission) are applicable within jurisdictions that may receive (import), use and dispose of wastewater from the Delaware Basin or other river basins.

STATEMENT OF CONCERN (SC-10)

Several commenters objected to allowing the exportation of Basin water to adjacent or straddled public water systems because those systems could sell water for use in connection with hydraulic fracturing. Another commenter urged the Commission to "rethink the change" to its longstanding policy of discouraging the exportation of Basin water.

RESPONSE (R-10)

The amended regulations continue to discourage the exportation of Basin water to conserve the waters of the Basin for uses in accordance with the Comprehensive Plan as follows:

- The Commission's longstanding policy of discouraging the exportation of Basin water is being retained, and the amended Water Code provisions articulate this policy with greater clarity and provide with greater specificity for its implementation.
- Under Section 2.30 of the Water Code as amended, Basin water can be exported only when it is required to serve a straddled or adjacent public water system; on a temporary, short-term, or emergency basis to meet public health and safety needs; or under limited geographic or other circumstances when the exported water is wastewater (*see* R-5 for a detailed discussion of the revision to Section 2.30.2 C.3 concerning exportations of wastewater). An application for exportation of water to serve HVHF activities will not meet these thresholds.
- Before approving an exportation, the Commission must consider specific factors that include, among others: 1) the sponsor's planned use for the water and any resulting

public benefits; 2) the availability to the sponsor of alternatives to the exportation of Basin water; and 3) whether these alternatives have been diligently pursued, including consideration of the sponsor's uses of water outside the sponsor's service area.

- DRBC dockets allocating water include a condition that states, "The docket holder is permitted to provide the water approved in this docket to the areas included in Section A.3. Area Served of this docket. Any expansion beyond those included in Section A.3. Area Served is subject to DRBC review and approval in accordance with Section 3.8 of the Compact."
- As discussed in R-7, past practice indicates that sufficient water resources exist outside the Basin to serve HVHF projects where permitted.

Statement of Concern (SC-11)

Several commenters objected to a suggested potential "loophole" whereby exporting water on a "temporary, short-term, or emergency basis to meet public health and safety needs" is undefined and could allow water to be used for hydraulic fracturing.

Response (R-11)

The Commission does not agree that allowing the exportation of water on a "temporary, short-term, or emergency basis to meet public health and safety needs" is a loophole that will allow water to be used for hydraulic fracturing. The Commission does not consider water needed for high volume hydraulic fracturing to meet the criteria of a "public health and safety need" under any foreseeable circumstances. No additional definition of "public health or safety need" is required. The Commission must retain its discretion to export water to meet emergency public needs. To make clearer that the demonstration of a "public health or safety need" applies to all exports proposed in reliance on this provision, the Commission is revising the wording slightly. The final rule at Section 2.30.2 C. 2. of the Water Code reads:

> the sponsor demonstrates that the exportation of Basin water is required to meet public health and safety needs on a temporary, short-term or emergency basis; or . . ..

Statement of Concern (SC-12)

Several commentors objected to the possibility that water could be exported without any required conditions if the volume is under DRBC's threshold of a 100,000 gallons per day average withdrawal during any calendar month or under 10,000 gallons per day average withdrawal in DRBC's Southeastern Pennsylvania Ground Water Protected Area.

Response (R-12)

The Commission previously determined and has established by its Rules of Practice and Procedure (18 C.F.R. Part 401) that "[t]he diversion or transfer of water from the Delaware River Basin (exportation) whenever the design capacity is less than a daily average rate of 100,000 gallons" (18

C.F.R. 401.35(a)(16)) is "deemed not to have a substantial effect on the water resources of the Basin and is not required to be submitted under Section 3.8 of the Compact" (18 C.F.R. 401.35(a)) (intro paragraph). This determination applies to all exportations of water for any purposes. The proposed rule and final rule include no changes to Section 401.35.

3.3 Water and Wastewater Importation

Most of the substantive comments that were submitted concerning the importation of wastewater were not specifically related to proposed amendments in Water Code Section 2.30, which contain policies for all importations and exportations. Rather, most called for a blanket prohibition on the importation of HVHF wastewater (which would necessitate a modification of the Commission's definition of "importation," which requires a discharge of either treated or untreated wastewater). Such comments are addressed in Section 4.2 of this CRD, focused on the Commission's Special Regulations at 18 CFR Part 440.

3.4 Water Code Section 2.30, Generally

Statement of Concern (SC-13)

The Sierra Club objected to proposed Section 2.30.2 E. of the Water Code, which exempts from Section 2.30 of the Water Code "importations and exportations of water, including wastewater, that existed prior to enactment of the Compact or that were approved by the DRBC prior to" the date of adoption of the final regulations. The Sierra Club suggested that the Commission make the final regulations retroactive to capture any existing, ongoing transfers.

Response (R-13)

The Commission has not revised Section 2.30.2 E. of the Water Code as the commenter suggests. Applying the final Water Code Section 2.30 regulations only to new and expanded projects simultaneously conserves the waters of the Basin and supports the water uses protected by the Comprehensive Plan, while not changing rules applicable to current importers and exporters that have relied on the Commission approvals they have received. As the Commission made clear in its Notice of Proposed Rulemaking, the new regulations will apply to any proposed expansion of an existing importation or exportation.

4. RESPONSES TO COMMENTS – SPECIAL REGULATIONS AT 18 C.F.R. PART 440

4.1 Comments related to the absence of a prohibition on exportation of Basin water to support HVHF

STATEMENT OF CONCERN (SC-14)

Numerous individuals and organizations submitted comments suggesting that water and wastewater from the Delaware River Basin should not be exported for uses related to hydraulic fracturing. Many of the comments were general in nature and objected to water being used for any purposes related to hydraulic fracturing. The DRN and others suggested that any proposed new exportation of Basin water to be used for HVHF or HVHF-related activities, or to replace a water supply diminished by HVHF or HVHF-related activities, be prohibited. A representative comment opposing the exportation of water (a version of which was submitted multiple times) follows:

> The export of water for use in fracking outside of a watershed inflicts irreparable harm in multiple ways: It deprives springs, tributaries, groundwater and the Delaware River of critical flows, quantity and quality; it induces fracking in locations where it may not occur due to water shortages in overdrawn streams; it induces more fracking, which damages public health and the environment; and it increases the emissions of the powerful greenhouse gas methane, worsening the climate crisis.

The DRN specifically, and others more generally, called for the Commission to prohibit: any exportation resulting in the permanent loss of water to the hydrologic cycle; any exportation the purpose of which is to replace water that was consumptively used by HVHF outside of the Basin and any exportations that serves the HVHF industry.

RESPONSE (R-14)

As described in R-1 above, the final rules are grounded in the authorities conferred on the Commission by the Delaware River Basin Compact (the "Compact"), a federal-interstate compact enacted in 1961 concurrently by the Commission's four member states and the United States. In accordance with Sections 1.3 (Purpose and Findings) and 13. 1 (Comprehensive Plan) of the Compact, DRBC is amending its Comprehensive Plan and regulations to better provide for the planning, conservation, utilization, development, management, and control of the Basin's water resources. While many of the comments relating to exportation focused on hydraulic fracturing as an end use of water exported from the Basin, the Commission's rules are focused on impacts to water resources within the Basin, consistent with its Compact authorities, including Section 2.7 of the Compact, providing that the Commission "shall have, exercise and discharge its functions, powers and duties within the limits of the basin . . . ." as discussed above in Section 2.

Potential harm to the Basin's water resources associated with water withdrawals and consumptive uses of water for HVHF are discussed in Section 3.2, at R-7, above. The issue of "inducing" hydraulic fracturing elsewhere is addressed in the same section at R-8 and R-9 Comments related to climate change impacts associated with HVHF and related activities outside the Delaware River Basin are addressed in Section 5.3 below. The final rule does not include a prohibition on the exportation of Basin water for uses related to hydraulic fracturing because, as noted in R-1, the information reviewed by the Commission to date does not demonstrate that such a categorical prohibition without regard to the other considerations and limitations set forth in the regulations is necessary to achieve the purposes of the Compact.

4.2 Comments related to the absence of a prohibition on the importation of HVHF wastewater

Statement of Concern (SC-15)

The following comments are representative of many critical of the proposed rule for being "inconsistent" with prior DRBC rulemaking, allegedly failing to address recognized risks, and falling short of a "complete ban" on the importation of HVHF wastewater into the Basin (comments not in quotation marks are paraphrased; footnotes are from the original comments):

DRN made the following assertions:

- "In this Proposed Rulemaking, the Commission must act on its previous conclusion regarding HVHF-related activities[14] and also prohibit those activities as defined in proposed § 440.2. To do otherwise would result in an arbitrary and capricious decision falling short of the Commission's obligations under the Compact."
- "Without a prohibition on HVHF-related activities within the Basin, the Proposed Rulemaking undermines the Commission's objectives by focusing exclusively on prohibiting intentional "discharge" of HVHF wastewater accepted into the Basin.[15] The Commission was created, in large part, for the purpose of controlling pollution within the Basin, and was granted multiple powers to exercise that control beyond point source discharges.[16] This limited and narrow prohibition runs counter to the Commission's findings and determinations in Resolution No.

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[14] DRBC, Res. No. 2021-01 (Feb. 25, 2021), available at: https://www.nj.gov/drbc/library/documents/Res2021-01_HVHF.pdf ("high volume hydraulic fracturing *and related activities* pose significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the water resources of the Delaware River Basin and to Special Protection Waters of the Basin, considered by the Commission to have exceptionally high scenic, recreational, ecological, and/or water supply values.") (Emphasis by commenters.)

[15] See Proposed § 440.4. Commenters noted that, "Although 'discharge' is not defined in the regulations, based on the context of environmental regulation and pollution control, it is likely to be interpreted in the context of the federal Clean Water Act, 33 U.S.C. § 1362(12)(A) ('any addition of any pollutant . . . from any point source')."

[16] Commenters noted that the Commission's purpose may be broader than the scope of 33 U.S.C. § 1311. "(The federal Clean Water Act prohibits only 'the discharge of any pollutant by any person.')

2021-01, which were based on the extensive record created during the Commission's HVHF Rulemaking process."

- "As the Commission has acknowledged, '[t]he potential for contamination of water resources from spills [was] an important factor underlying the Commission's decision' to prohibit HVHF in the Basin.[17] This risk is completely unaddressed in proposed § 440.4, which prohibits only the *intentional* discharge of HVHF wastewater in the Basin. In February 2021, the Commission concluded that "the collection, storage, handling, transport, treatment, discharge, and disposal of wastewater from high volume hydraulic fracturing activities presents significant risks, vulnerabilities and impacts to the water resources of the Delaware River Basin."[18] Nothing in the Proposed Rulemaking addresses the threat from storage, handling, transport, treatment, or disposal."

- "Many of the risks [noted in the February 2021 CRD] are not addressed in the Proposed Rulemaking—specifically spills, leaks, and other releases, inadequate treatment, air emissions, improper storage or disposal, and reuse for roadway de-icing or dust control."[19]

- "The Commission has recognized that "regulation is not capable of preventing adverse effects or injury to water resources from HVHF-related spills and releases of chemicals and hydraulic fracking wastewater"—which is why it found the total ban of HVHF within the watershed necessary.[20] The Commission has also concluded that regulatory approaches that may be acceptable in other jurisdictions are not necessarily sufficient to protect the water resources of the Basin.[21] As a result, the Commission should not rely here on state or federal regulatory programs to prevent the hazards associated with HVHF-related activities. Instead, a complete ban on HVHF-related activities within the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan."[22]

- "By prohibiting all HVHF-related activities including the acceptance of HVHF wastewater within the Basin, the Commission would greatly reduce the risk that HVHF wastewater being

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[17] DRBC, February 2021 CRD, available at: https://www.nj.gov/drbc/library/documents/CRD_HVHFrulemaking.pdf.
[18] *Id*. at 127.
[19] *See id*. at 156, 183–84, 210. Commenters noted that, "Although the FAQ document provided along with the Proposed Rulemaking states that '[l]and application of HVHF wastewater by road spreading would constitute a prohibited discharge' under the Proposed Rulemaking, in Pennsylvania and other states, the HVHF industry is creating consumer products from HVHF wastewater and selling it to the public. *See also* Glen Hendrix, *The Fracking Industry Is Selling Radioactive Waste Brine to the Public as a Road Deicer and Pool Treatment*, medium.com (Jan. 27, 2020), available at: https://medium.com/age-of-awareness/the-fracking-industry-is-sellingradioactive-waste-brine-to-the-public-as-a-road-deicer-and-pool-ba77a0f67e1d."
[20] DRBC, February 2021 CRD at 92, 179, 206, 226, 264.
[21] See *id*. at 260 ("The Commission respects Pennsylvania's choices for the area of the Commonwealth outside the Delaware River Basin. For its part, in light of the geology of the Basin and the likelihood and severity of potential adverse water resource impacts, the Commission has determined that the risks to water resources posed by HVHF—however well regulated—are not acceptable within the Basin, a shared resource that provides the water supply for more than 13 million people in four states.").
[22] See 18 C.F.R. § 440.1(a).

stored, treated, transported, reused, or disposed of within the Basin will spill and endanger water resources."

- "The robust scientific and technical analysis undertaken by the Commission for its HVHF Rulemaking requires that HVHF-related activities must be prohibited in the Basin."

Other commenters expressed the following (paraphrased) concerns:

- Like the high volume hydraulic fracturing operations prohibited by DRBC regulations, the storage and injection of wastewater from high volume hydraulic fracturing and HVHF-related activities are fraught with problems and have a high risk of resulting in water pollution, such that they pose significant, immediate and long-term risks to the Basin's water resources.
- The importation of hazardous wastewater from high volume hydraulic fracturing and related activities places residents at higher risk of exposure to harmful substances.
- The risks to drinking water supplies from handling HVHF wastewater are severe and likely to be irremediable. Wastewater resulting from high volume hydraulic fracturing and HVHF-related activities contains salts, metals, and organic compounds from bedrock formations, along with chemical compounds that were introduced as additives. Many of these chemicals are toxic and some are carcinogenic with known adverse health impacts associated with ingestion or other exposure.
- If the DRBC allows HVHF wastewater to be imported into the Basin, it would be allowing radioactive wastewater to be imported and deposited here, posing an unacceptable threat to human health and all life within the Delaware River Watershed.
- Prohibiting the importation of HVHF wastewater is necessary because of the highly water-soluble nature of the toxics and contaminants in the wastewater and because the spills, accidents, and dumping that inevitably occur can negatively impact human health. The lack of cradle to grave tracking of oil and gas waste combined with unreliable industry self-reporting also add to public health risks.

RESPONSE (R-15)

The Commission agrees that discharges of HVHF wastewater pose particular, heightened risks associated with that waste stream because they may increase concentrations of the toxic, radioactive and conventional pollutants in the receiving waters and render them unfit for other uses identified in the Comprehensive Plan. As the above comments recognize, the risks and impacts of HVHF on water resources of the Basin are comprehensively described in the February 2021 CRD.

Although not acknowledged by the commenters, by prohibiting HVHF within the Basin, the Commission's rulemaking finalized in February 2021 substantially reduced those risks. The Commission's further prohibition on the discharge of HVHF wastewater to waters or land within the Basin is narrowly tailored to accomplish the purposes articulated in Section 5.2 of the Compact, including to ensure that "pollution . . . shall not injuriously affect the waters of the basin as contemplated by the Comprehensive Plan." Contrary to the suggestion of a commenter, this prohibition is not limited to intentional discharges.

More detailed responses to comments on risks to water resources of the Basin from the storage, transport, processing, treatment, recycling, road spreading and injection of HVHF wastewater and from spills, leaks, landfill leachate, air emissions, and chemical disclosure/ non-disclosure associated with HVHF wastewater are addressed in Section 4.2.1 Potential Risks to Water Resources, below.

More detailed responses to other comments on impacts to drinking water, aquatic life, and human health are presented in Section 4.2.2 Potential Impacts to Water Resources and Their Uses.

Statement of Concern (SC-16)

While many commenters expressed concern that the proposed rules do not go far enough and that a "full ban" on HVHF-related activities is necessary, many also expressed support for the proposed discharge prohibition. Representative examples follow:

- "Catskill Mountainkeeper submits these comments in strong support of the draft regulations banning the discharge of wastewater from high volume hydraulic fracturing (HVHF) and HVHF- related activities to waters or land within the Delaware River Basin, including the discharge or dumping on roads (road dumping) of HVHF-wastewater or products or co-products made from that wastewater."
- "The proposed ban on discharge to water or land is an absolute necessity that Delaware Riverkeeper Network fully supports."
- "Given the known risks of fracking wastewater on water quality, we [NRDC] strongly support the Commission's proposal to ban the disposal of fracking wastewater in the region."

Response (R-16)

The DRBC acknowledges and affirms those comments highlighting the Commission's responsibility to manage the water resources of the Basin. The Commission appreciates the support expressed by many commenters for the discharge prohibition as an appropriate component of regulations to meet this responsibility.

Statement of Concern (SC-17)

Comments representative of those critical of the proposed prohibition on discharges of wastewater from HVHF or HVHF-related activities to waters or land within the Basin follow:

- "We can have all the necessary controls in place to make sure the use of natural resources is environmentally acceptable. Indeed, the resource companies have improved very substantially over the last decade, and the number of serious infractions is way down. We need the natural gas for heating, cooking, and electricity. So let's work together to produce the gas in an environmentally friendly way, rather than simply say 'no way, no how.'"
- "We were disappointed to see both the 2017 proposal and then a final rulemaking, released on February 25, 2021, formally prohibiting HVHF in the Basin. We continue to believe that the prohibition is unnecessary and, in many ways, duplicative and/or conflicting with Pennsylvania Department of Environmental Protection ("DEP") oil and natural gas

regulations and is not responsive to a legislative mandate or based on clearly demonstrated need. API has similar concerns of duplication, conflict, and need regarding this most recent proposal."

RESPONSE (R-17)

The regulation published for public notice and comment did not propose to modify the prohibition on HVHF in the Basin adopted by the Commissioners on February 25, 2021. Although the DRBC recognizes and appreciates industry's efforts to develop unconventional gas resources safely, for the reasons described in this CRD and in the Commission's February 25, 2021 Comment Response Document, we disagree that the prohibition on HVHF in the Basin or the regulations adopted in the current rulemaking are unnecessary. The regulations adopted in 2021 prohibiting HVHF in hydrocarbon-bearing formations in the Basin and those proposed in 2021 and now finalized concerning discharges of wastewater from HVHF and HVHF-related activities are grounded in current and accurate information about the potential risks to the Basin's water resources posed by HVHF and discharges of HVHF wastewater. For details, please see Section 4.2.1 Potential Risks to Water Resources and Section 4.2.2 Potential Impacts to Water Resources and Their Uses, below, and the February 2021 CRD.

4.2.1 Potential Risks to Water Resources

4.2.1.1 Withdrawals and Diversions

STATEMENT OF CONCERN (SC-18)

Commenters suggested that exports of water from the Basin for HVHF would impact the Basin water resources as paraphrased in the following sample comments:

- The withdrawal and export of water from groundwater robs aquifers that feed water supply wells, reduces and disrupts natural groundwater flows, and potentially destroys essential hydrologic connections with wetlands and other water dependent systems. This harms water quality, degrades and diminishes aquifers, streams, aquatic life and flora and fauna, and threatens the safety of drinking water supplies.
- Water withdrawals from water bodies have a cascade of degrading effects on stream life and quality that can be exacerbated by complete water loss or depletive use.
- The life in a stream or river is adapted to its habitat based on its seasonal fluctuation, oxygen and nutrients in the water, its rate of flow and resulting rippling effects, the temperature and depth of the water, the benthic creatures that provide the base of the food web and define the biodiversity of a stream, and many other elements that are sensitive to water withdrawals and depletion.
- DRBC has an obligation to prohibit exportation of water that will result in a loss to the Basin (consumptive uses).

RESPONSE (R-18)

Responses to this set of concerns are provided in Section 3.2. above, at R-7 and R-8.

4.2.1.2 Air Pollution and Air Deposition

STATEMENT OF CONCERN (SC-19)

Representative paraphrased comments expressing concern about air pollution from HVHF activities and related impacts to human health are paraphrased below (footnotes are from the original comments):

- Commenters pointed to a 2014 report by the Natural Resources Defense Council (NRDC) finding that air pollution accompanies gas well development, including in the Marcellus Shale. The NRDC investigators determined that air pollutants are released during at least 15 different parts of the oil and gas development process.[23] Others, citing a 2021 report by the NRDC, asserted that hydraulic fracturing has resulted in dangerous levels of toxic air pollution, and that hydraulic fracturing sites "release a toxic stew of air pollution that includes chemicals that can cause severe headaches, asthma symptoms, childhood leukemia, cardiac problems, and birth defects."[24]
- Commenters said that hydraulic fracturing emits particulate matter and ground-level ozone, two of six "criteria air pollutants" regulated by the EPA because of their harmful effects on health and the environment.[25] They pointed to a 2014 report published by the NRDC that presented evidence of the harmful effects of hydraulic fracturing on air quality and public health.[26] NRDC's investigators found that the hydraulic fracturing process emits airborne pollutants that are known to cause cancer and harm the nervous, respiratory, and immune systems.
- Commenters referred to a 2014 study, also cited in the 2014 NRDC report noted above, which found that mothers who lived near many oil and gas wells were 30 percent more likely to have babies with heart defects.[27] The commenters said that preliminary results from a study in Pennsylvania also showed impacts among newborns, including an increased incidence of low birth weights, that could be linked to air pollution from hydraulic fracturing.[28] The

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[23] Tanja Srebrotnjak and Miriam Rotkin-Ellman, NRDC, Fracking Fumes: Air Pollution from Hydraulic Fracturing Threatens Public Health and Communities, December 2014. Available at: https://www.nrdc.org/sites/default/files/fracking-air-pollution-IB.pdf.
[24] NRDC, Reduce Fracking Health Hazards, accessed at: https://www.nrdc.org/issues/reduce-fracking-health-hazards.
[25] *See,* e.g., EPA, Criteria Air Pollutants, accessed at: https://www.epa.gov/criteria-air-pollutants.
[26] Tanja Srebotnjak and Miriam Rotkin-Ellman, NRDC, Fracking Fumes: Air Pollution from Hydraulic Fracturing Threatens Public Health and Communities (2014), accessed at: https://www.nrdc.org/sites/default/files/fracking-air-pollution-IB.pdf.
[27] L.M. McKenzie et al., Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado, Envtl. Health Perspectives, 122:4, 412–17 (Apr. 2014), accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3984231/pdf/ehp.1306722.pdf.
[28] J.L. Adgate et al., Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development, Envtl. Sci. & Tech., 48:15, 8307–20 (Feb. 24, 2014).

commenters noted that researchers who looked at air pollution levels near hydraulic fracturing sites in Colorado also found an increased risk of chronic and sub-chronic effects mainly stemming from oil and gas related pollutants, which can harm the respiratory and neurological systems and lead to such symptoms as shortness of breath, nosebleeds, headaches, dizziness, and chest tightness.[29]

- Some commenters were concerned that DRBC does not review air emissions, creating "a blind spot" in its reviews and oversight. They reasoned that pollutants released to the air fall back to earth, depositing on surface water, vegetation, and soils, and contaminating the water, even if they are not directly "discharged" to water or land. The commenters state that air deposition is as threatening as direct discharges to the health of water resources.

Response (R-19)

The U.S. Environmental Protection Agency and the states regulate air quality and air emissions under the federal Clean Air Act and respective state air quality statutes and implementing regulations. When fulfilling its water resources mandate, the DRBC has not done so, and it is not now proposing to replicate or supplement those programs.

The Commission's 2021 final rule prohibiting HVHF in the Delaware River Basin has the effect of precluding the development of HVHF wells within the Basin, and thus preventing their associated air emissions and any resulting deposition to water resources. By this separate rulemaking, the Commission is prohibiting the discharge of treated or untreated wastewater from HVHF and HVHF-related activities to the Basin's land and waters. These measures together substantially reduce the risk to water resources of the Basin posed by HVHF wastewater generated elsewhere, without replicating federal and state programs or reaching beyond the Commission's geographic jurisdiction under the Delaware River Basin Compact.

As explained further in Section 4.2.1.5 Transport, Leaks and Spills, below, because the volume of HVHF wastewater imported into the Basin is anticipated to be low, the air emissions associated with such wastewater, and the impacts to water resources that may result, are likewise anticipated to be low.

For Commission responses to concerns about air pollution resulting from HVHF activities, submitted as comments on our 2017 proposed rule, please see Section 2.7.1 Air Emissions of the February 2021 CRD.

Statement of Concern (SC-20)

Representative paraphrased comments critical of the proposed rule because it would allow HVHF-wastewater to be imported, stored and treated in the Basin by means that do not involve a discharge to Basin waters, follow:

[29] Wyo. Dep't of Health, Associations of Short-Term Exposure to Ozone and Respiratory Outpatient Clinic Visits — Sublette County, Wyoming, 2008–2011 (Mar. 1, 2013), accessed at: https://fossil.energy.gov/app/DocketIndex/docket/DownloadFile/162.

- Commenters expressed concern that if allowed into the Basin, "toxic and radioactive" hydraulic fracturing wastewater could pollute the Basin environment if processed by incineration, thermal oxidation, air-drying systems, or other waste processing or storage systems that do not generate immediate discharges to water and land but nevertheless allow emissions to air or to ultimately to water via air deposition.

- Commenters asserted that pollution emitted into the air by burning, thermal oxidation, evaporation or air-drying of HVHF wastewater is as much a source of water contamination[30] as discharges of such wastewater, and that these airborne contaminants themselves constitute an importation of hydraulic fracturing pollution that endangers human health and the environment.

- Citing the February 2021 CRD, commenters pointed out that, "although the Commission does not directly regulate air emissions, the Commission has considered air deposition in its development of total maximum daily loads (TMDLs) pursuant to Article 4 of its Water Code and Water Quality Regulations, and in the development of strategies for implementing these TMDLS as appropriate."[31]

- Commenters, including Damascus Citizens for Sustainability (DCS) and the Sierra Club, among others, observed that Elcon Recycling Services ("Elcon") tried to get approvals for a hazardous waste processing plant that would use thermal oxidation to treat the waste and that the plant could have included hydraulic fracturing wastewater in the waste stream because no permit would have disallowed it. The commenters' further observations included: that Elcon decided not to discharge wastewater to the river and to instead rely on a system that only discharged to air; technical analysis revealed that approximately 39 tons of air pollution would be emitted, affecting the air quality within a 30-mile radius; that the Philadelphia Water Department opposed the project due to potential pollution; that the air pollution would have direct environmental and public health impacts but without a water discharge, the permitting was left to the PA Department of Environmental Protection which has not been a good guardian of the environment allowing extensive contamination of air and water in PA; and that if this project had not been stopped by the public, hydraulic fracturing wastewater could have entered the Basin and contaminated the watershed's air, water, soils, vegetation and communities.

- Commenters asserted that "no-discharge" thermal oxidation hazardous waste treatment can form more toxic by-products than does incineration of hazardous waste due to low or moderate temperature processing; that toxic byproducts are formed during various phases of the treatment process and released.[32]

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[30] Falabella, J.B., Air – Water Partitioning of Volatile Organic Compounds and Greenhouse Gases in the Presence of Salts; a Thesis Presented to the Academic Faculty of Georgia Institute of Technology, (Aug. 2007), accessed at: https://smartech.gatech.edu/bitstream/handle/1853/16221/Falabella_James_Benjamin_200708_PhD.pdf.
[31] DRBC, February 2021 CRD, p. 319.
[32] Stephania A. Cormier, Slawo Lomnicki, Wayne Backes, and Barry Dellinger, "Origin and Health Impacts of Emissions of Toxic By-Products and Fine Particles from Combustion and Thermal Treatment of Hazardous Wastes and Materials," Envt'l Health Perspectives, 114:6, 810–17 (June 2006), accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1480527/.

- Commenters were also concerned that radioactive materials are taken up by micro-organisms in the riverbed and, sometimes, directly from the water into the gills of species such as catfish, and that even with low concentrations of radioactive materials in surface water, they can bioaccumulate and create serious problems, impacting fish and aquatic organisms throughout the food web and human health.

- Some commenters said that selenium in the emissions from thermal oxidation creates a serious toxicity problem, and that selenious acid is formed when selenium oxides are dissolved in water, and that the acid is extremely toxic to all types of aquatic creatures. There was expressed concern that selenium is a known constituent in wastewater produced by hydraulic fracturing, and that human health effects of air pollution that can be caused by thermal oxidation of hazardous waste include decreased lung function, inflammatory responses, diminished lung function and lung function growth in children, increased cardiovascular events, genotoxicity, and reproductive effects.

- Commenters were concerned that despite the known impacts of thermal oxidation and combustion described above, very little study has been done about the health effects of thermal oxidation and combustion of hazardous wastes.

- Commenters expressed concern that although much attention is paid to contribution to priority air pollutants (i.e., ozone, volatile organic compounds (VOCs), and nitrogen oxides (NOx)), combustion and thermal processes also produce chronically toxic products of incomplete combustion (PICs). They stressed that the greenhouse gas carbon dioxide is a product of complete combustion of carbon, and the ozone promoter NOx is a product of complete combustion of nitrogen; that chronically toxic organic pollutants, such as benzene, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), acrylonitrile, and methyl bromide, are products of incomplete combustion of carbon, carbon and chlorine, carbon and nitrogen, and carbon and bromine compounds, respectively; and that another concern is the formation of large, complex molecules known as polyaromatic hydrocarbons (PAHs), which are carcinogenic.[33] They note that the presence of PFAS in at least some wastes complicates the situation because incineration of PFAS has generally not been successful, so these materials need to be separated out before incineration.

- Commenters made numerous statements about radium and selenium, which are constituents commonly found in wastewater produced by hydraulic fracturing.[34] The commenters stated that exposure to high levels of radium-226 and radium-228 can cause cancer and that low-level exposures are also highly dangerous to humans.

- A commenter was concerned that air permits issued by the states will result in polluting air emissions that deposit on surface water, vegetation, and soils, contaminating the watershed and its water, even if they aren't directly "discharged to water or land" and that his pollution threatens public health as people breathe in dangerous pollutants and that by reducing the

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[33] H. Sabbah et al, *Exploring the Role of PAHs in the Formation of Soot: Pyrene Dimerization*, Physical Chemistry Letters. 1:19, 2962–67 (Sept. 20, 2010).
[34] EPA, Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (June 2016), accessed at: https://www.epa.gov/sites/default/files/2016-06/documents/uog_oil-and-gas-extraction_tdd_2016.pdf.

quality of water and other environmental media, it also endangers our watershed's health, including ecosystems, habitats, species and important recreational and economic values.[35]

- A commenter requested that the Commission "Please consider whether evaporation of hydraulic fracturing wastewater could damage the air quality of the Basin."

RESPONSE (R-20)

As stated in R-19 above, the U.S. Environmental Protection Agency and the states regulate air quality and air emissions under the federal Clean Air Act and respective state air quality statutes and implementing regulations. The DRBC has not done so, and it is not now proposing to replicate those programs.

The Commission's 2021 final rule prohibiting HVHF in the Delaware River Basin has the effect of precluding the development of HVHF wells within the Basin, and thus preventing their associated air emissions and any ensuing deposition to water resources. By this separate rulemaking, the Commission is prohibiting the discharge of treated or untreated wastewater from HVHF and HVHF-related activities to the Basin's land and waters. These measures together substantially reduce the cumulative risk to water resources of the Basin from all sources, including any HVHF wastewater imported into the Basin, without replicating federal and state air pollution programs or reaching beyond the Commission's geographic jurisdiction under the Delaware River Basin Compact.

The commenter correctly notes that the Commission measured air deposition in the context of its development of total maximum daily loads (TMDLs) for polychlorinated biphenyls (PCBs) in the Delaware River Estuary. Air sources of PCBs within the Basin were also identified by Estuary dischargers in the course of the trackdown work they performed as part of their DRBC-mandated pollutant minimization plans (PMPs) to implement the TMDLs. Once air sources of PCBs were identified, however, state regulators and the DRBC worked cooperatively with dischargers to eliminate those sources under state and federal laws. The Compact authorizes the Commission to utilize or employ the agencies of the signatory parties where feasible and advantageous. Compact, §§ 1.5, 3.9(b).

The risks posed by particular pollutants present in HVHF wastewater are addressed in Section 4.2.1.3 R-21 of this CRD, below. The comments about storage of HVHF wastewater are addressed in Section 4.2.1.7 of this CRD.

4.2.1.3 Waste characterization / toxicity / radioactivity

STATEMENT OF CONCERN (SC-21)

Many commenters expressed concern about the characteristics of HVHF wastewater, its toxicity and radioactivity, and the risk of pollution that could result from allowing its importation into the

[35] Government of Canada, "*Air pollution: effects on soil and water*," (July 17, 2013), accessed at: https://www.canada.ca/en/environment-climate-change/services/air-pollution/quality-environment-economy/ecosystem/effects-soil-water.html.

Delaware River Basin. (Representative comments are paraphrased, and citations within original comments have been omitted.)

- Commenters averred that HVHF wastewater consists of hydraulic fracturing fluid (a mixture of water, sand, and chemical additives) and naturally occurring constituents (such as radioactive elements) that are picked up from the target formation and returned to the surface. They expressed concern that even when the wastewater undergoes treatment, certain chemical additives may either persist in treated effluent or react with the chlorine used to treat wastewater and form potentially dangerous chemical byproducts.

- Commenters were concerned that the hazardous properties of the wastewater are not recognized by regulators, which allow the waste to be handled, transported, and disposed of through less restrictive processes than would be required for contaminants classified as hazardous waste.

- Citing authorities not included here, commenters averred that oil and gas liquid waste contains carcinogens, endocrine disrupting chemicals, heavy metals, poisonous hydrocarbons, radioactivity, and toxic "BTEX" materials (benzene, toluene, ethylbenzene, and xylenes), and has an extremely high salt content. They stated that it was recently revealed that highly toxic per- and polyfluoroalkyl substances ("PFAS") have been used in the fluids used in hydraulic fracturing in Pennsylvania and elsewhere, and that in its national study of hydraulic fracturing and drinking water, EPA identified 1,606 chemicals in hydraulic fracturing fluid or drilling wastewater, including 1,084 identified in hydraulic fracturing fluid and 599 identified in wastewater, yet only 173 had toxicity values from sources that met EPA's standards for conducting risk assessments.

- Other commenters stated that HVHF wastewater contains toxic contaminants like selenium, thallium, radium, and ammonium, all of which are dangerous to human health and the environment.

- Another concern voiced by commenters is that HVHF wastewater contains variable and unpredictable amounts of TENORM (Technologically Enhanced Naturally Occurring Radioactive Material) and that the wastewater should therefore not be disposed of in the environment.

- Some commenters pointed out that conventional and unconventional oil and gas wastewaters have organic and inorganic constituents that are similar, but that wastewaters from unconventional oil and gas development may also include chemicals from the HVHF process that could be potentially more toxic than the formation-specific constituents.

- Commenters were concerned that no testing is required for the presence of dangerous constituents in HVHF wastewater. They stated that New York's 2009 DSGEIS identified 154 of these dangerous parameters in Marcellus shale wastewater, that many are hazardous, some have known harmful health impacts, and that some are carcinogenic.

- Commenters were also concerned that Marcellus Shale is known to have extremely high levels of radioactivity, with samples of produced waters showing combined concentrations of radium 226 and 228 as high as 28,500 picocuries per liter, compared to an EPA drinking water standard of maximum 5 picocuries per liter. They noted that average levels of radioactivity in drilling waste are lower, but that, given the vast volumes involved, the cumulative effect can be significant.

- Commenters expressed concerns were that exposure to high levels of radium-226 and radium-228 can cause cancer and studies show low levels are also highly dangerous.
- One commenter stated that HVHF wastewater has been found to contain the pesticide atrazine; 1,4-dioxane, an organic compound that is irritating to the eyes and respiratory tract; toluene, which at low exposure has health effects like confusion, weakness, and loss of vision and hearing; and polycyclic aromatic hydrocarbons, which have been linked to skin, lung, bladder, liver and stomach cancers.
- Commenters cited studies showing that disinfection by-products (DBPs) can form when hydraulic fracturing wastewater effluent mixes with halides during drinking water treatment, and that brominated and iodinated DBPs are known to increase the risk of bladder cancer. They noted that DBPs are a drinking water hazard because of the propensity for the brominated DBPs to form trihalomethanes and haloacetic acid, which can cause cancer.
- A commenter cited to a publication by Concerned Health Professionals of New York for an extensive list of human health impacts linked to the industrial processes and wastes from hydraulic fracturing.

RESPONSE (R-21)

The Commission recognizes that wastewater from high volume hydraulic fracturing or HVHF-related activities contains substances that are toxic and substances that are radioactive, that the toxicity of many of the substances is unknown, that the identity of some HVHF chemicals is not disclosed, and that many of the substances are not monitored in the environment.

The Commission also recognizes that research published only recently provides additional evidence of the breadth of HVHF wastewater toxicity. An example is a 2020 paper prepared by several U.S. universities[36] that synthesizes a body of work examining toxic effects of exposure to 23 chemicals found in HVHF wastewater. The paper highlights the substantial effects on mammals and amphibians resulting from developmental exposure to HVHF wastewater and the need to examine human and animal health in regions of unconventional oil and gas development. Other recent examples of this important research include papers by: O'Dell et al., (2021)[37] suggesting that exposure results in alteration of the adult immune system; Aghababaei, et al. (2021)[38] finding acute mammalian toxicity

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[36] Nagel, S.C., et al., Developmental exposure to a mixture of unconventional oil and gas chemicals: A review of experimental effects on adult health, behavior, and disease, Molecular Cell Endocrinology, 513 (Aug. 1, 2020), accessed at:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7539678/pdf/nihms-1631826.pdf .

[37] O'Dell, C.T., et al., Exposure to a mixture of 23 chemicals associated with unconventional oil and gas operations alters immune response to challenge in adult mice, Journal of Immunotoxicology 18:1, 105–17 (Dec. 2021), accessed at:
https://www.tandfonline.com/doi/full/10.1080/1547691X.2021.1965677.

[38] Aghababaei, M., et al., Toxicity of hydraulic fracturing wastewater from black shale natural-gas wells influenced by well maturity and chemical additives, Envt'l Sci.: Processes & Impacts., 4 (Apr. 8, 2021).

and thiol reactivity; and Lu et al. (2021),[39] showing toxicity of suspended sediment in HVHF wastewater to larval zebrafish.

The Commission also acknowledges the limits of the federal and state regulations being implemented to manage oil and gas wastes, the risks of accidents, spills, leaks, and illegal discharges involving HVHF wastewater, and the history of such discharges resulting in documented impacts to water resources that include sources of drinking water, as well as to aquatic life and human health in regions of shale gas production. The Commission took into consideration these and other factors, including the characteristics of HVHF wastewater, in its decision to prohibit HVHF in the Basin in 2021 and in its decision by the current rulemaking to prohibit discharges of HVHF wastewater to waters and land within the Basin.

The Commission has no pending requests to import HVHF wastewater. Because the Commission is prohibiting HVHF in hydrocarbon bearing formations in the Basin and discharges of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin and that the amount and severity of any spills, leaks, or other releases and resulting impacts to the Basin's water resources from such activities will likely be sufficiently low so as not to injuriously affect the waters of the Basin as contemplated by the Comprehensive Plan.

The Commission's responses to comments regarding chemical disclosure are provided in Section 4.2.1.4 below. Its responses to comments on impacts to water resources and human health are presented in Section 4.2.2.3 below. For additional detail about the Commission's review and evaluation of HVHF wastewater characteristics, please also see the February 2021 CRD, Section 2.3.2.2 Pollution from Spills.

Statement of Concern (SC-22)

Many commenters expressed concerns about per- and polyfluoroalkyl substances (PFAS) that may be present in HVHF wastewater and the potential for PFAS releases in the Delaware River Basin and impacts to drinking water quality and human health.

Representative paraphrased comments regarding PFAS include the following (all footnotes are from the original comments unless otherwise noted):

- Commenters noted that in 2021 the public discovered that the EPA had approved the use of Per- and polyfluoroalkyl substances (PFAS) in hydraulic fracturing.[40] They stated that it was

[39] Lu, Y., et al., Suspended solids-associated toxicity of hydraulic fracturing flowback and produced water on early life stages of zebrafish (Danio rerio), Envt'l Pollution, 287 (Oct. 15, 2021).
[40] Horwitt, D., J.D., Fracking with "Forever Chemicals," PSR (July 2021), accessed at: https://www.psr.org/wp-content/uploads/2021/07/fracking-with-forever-chemicals.pdf.

recently revealed that PFAS have been used in fluids used in hydraulic fracturing in Pennsylvania and elsewhere.[41]

- Commenters observed that PFAS are known as "forever chemicals" because they do not break down in the environment and they accumulate over time to become highly toxic. The commenters were concerned that PFAS could be present in HVHF wastewater that may be transported and stored within the Basin under DRBC's proposed rule.

- Commenters said that the EPA has published research showing PFAS are linked to cancer, liver, endocrine, and immune problems, and impact on fetuses and breastfeeding babies [U.S. EPA, 2016],[42] and that the EPA has issued a drinking water health advisory for PFOA, PFOS, and other PFAS substances based on the same concerns.

- One commenter stated: "Maybe you folks know of a new treatment protocol for the removal of all chemicals, including the forever family of PFAS, PFOA, which we now know can be found in frack liquids. If so, you might want to share it with the long-suffering residents of Bucks and Montgomery counties who have been burdened with living with poisoned water for too many years."

- Another commenter stated: "If nothing that has been discovered before about the magnitude of harms caused by fracking activities, including wastewater disposal, has convinced the Commission to ban all fracking related activity within the Basin, the revelation of the use of toxic forever chemical PFAS in fracking alone should lead to an immediate moratorium on all fracking-related activities, including the importing of fracking wastewater."

Response (R-22)

The Commission acknowledges that PFAS may be present in HVHF wastewater, that these chemicals are toxic, and that they present treatability challenges. Many PFAS do not break down in the environment (CDC, 2022). They remain in the human body for many years after exposure ends, cause multiple types of toxicity, and may cause adverse human health effects at low exposures. Exposures to even low levels of PFAS in drinking water can be greater than exposures through food and consumer products (NJDOH, 2022).[43] Thus, the human health risk from PFAS is distinct from that associated with other persistent, bioaccumulative and toxic ("PBT") contaminants, such as PCBs and dioxins, which have low water solubility (Post et al., 2017). PFAS are a concern to the Commission.

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[41] Philadelphia Inquirer Editorial Board, Fracking's use of EPA-approved toxic chemicals shows again that regulators prioritize industry over health, Philadelphia Inquirer Editorial Opinion (July 15, 2021), accessed at: https://www.inquirer.com/opinion/editorials/fracking-epa-pfas-forever-chemicals-water-pennsylvania-20210716.html.

[42] EPA, Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States (Dec. 2016) at ES-45–ES-46, 9-1. (The Commission notes that the cited EPA report does not mention PFOA or PFAS, but acknowledges the accuracy of the commenter's information as reflected on the EPA's "Drinking Water Health Advisories for PFOA and PFOS" website, accessed at: https://www.epa.gov/sdwa/drinking-water-health-advisories-pfoa-and-pfos.)

[43] *See also* N.J. Dep't of Envtl. Prot., Frequently Asked Questions (FAQ): PFAS in Drinking Water, available at: https://www.nj.gov/dep/pfas/docs/faq-pfas-in-drinking-water.pdf.

The Commission has no pending requests to import HVHF wastewater. The Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin and that the amount and severity of any spills, leaks, or other releases and resulting impacts to the Basin's water resources from such activities will likely be sufficiently low so as not to injuriously affect the waters of the Basin as contemplated by the Comprehensive Plan.

Statement of Concern (SC-23)

The American Petroleum Institute (API) claims that PFAS in HVHF wastewater are exaggerated stating:

- that PFAS is not widely used in fracturing fluids, and that API members will continue to review available data and analyses to better understand and mitigate the use of these chemicals across the upstream segment.
- that the recent report by Physicians for Social Responsibility (PSR) entitled "Fracking with Forever Chemicals" was "greatly flawed". API cited key findings of a report by its consultant, allegedly disproving the findings of the PSR report.

Response (R-23)

PADEP has advised the Commission that very few unconventional gas wells in Pennsylvania were completed using HVHF fluids containing PFAS. However, as described in the previous response, the potential presence of PFAS in HVHF wastewater remains a concern to the Commission and contributes to the totality of the risks to water resources of the Basin posed by potential discharges of HVHF wastewater. The Commission took these risks into consideration in deciding to prohibit the discharge of HVHF wastewater to waters and land within the Basin.

However, as noted in the previous response and in other sections of this CRD, the likelihood of impacts to the Basin's water resources resulting from spills, leaks, or other releases of HVHF wastewater from are in the Commission's view effectively reduced by the rules prohibiting HVHF and the discharge wastewater from HVHF and HVHF-related activities to land or waters within the Basin.

4.2.1.4 Chemical Disclosures

Statement of Concern (SC-24)

Paraphrased comments asserting that concerns about chemical disclosure are unwarranted follow:

- The American Petroleum Institute (API) asserted that the controversy over disclosure is focused on the approximately 0.5% of hydraulic fracturing fluid that consists of additives that are formulated to improve the performance of the hydraulic fracturing operation. API contended that substances that are most commonly found in this 0.5% of hydraulic fracturing fluid systems are also commonly found in food, cosmetics, detergents, and other household products.
- The API maintained that while there are narrow instances where companies use existing laws and regulations to protect as proprietary certain constituents in their hydraulic fracturing

fluid systems, they are generally protecting specific ingredients within additives that commonly represent less than a thousandth of a percent (0.001%) of the total hydraulic fracturing fluid volume.

- The API further contended that even in narrow circumstances where precise chemical identification is not publicly released, the industry typically provides chemical category information that allows the public to identify the class and function of the chemical, and states require that the precise identity of these ingredients be disclosed to regulators (and, if necessary, to physicians and emergency responders) when the information is needed. Moreover, API asserted, materials safety data sheets, which contain safety, health, and environmental information for all ingredients (including those denoted as proprietary), are always available onsite for the substances used in the hydraulic fracturing process.

- The API also noted that companies in a variety of industries avail themselves of the benefits of trade secret protection for exactly the same reasons as oil and gas service companies.

Comments representative of those expressing concern about chemical disclosure follow:

- A commenter stated that there are no uniform requirements for the disclosure of chemicals used in hydraulic fracturing operations, resulting in the largely unknown nature of the chemicals' potential impact on health and the environment.

- A commenter asserted that the June 2020 report of the PA Grand Jury investigation into the unconventional oil and gas industry found among other things that while the industry must disclose trade secret chemicals to the DEP, the public and first responders lack access to this information. The commenter expressed concern that keeping these proprietary chemicals secret leaves firefighters and Hazmat teams incapable of effectively or safely responding to emergencies at unconventional gas well or spill sites.

- One commenter was concerned that if there is a wastewater spill, the fire department responders could be exposed to unknown carcinogens or other dangerous chemicals.

- Many commenters were concerned that quantities of undisclosed chemicals used during hydraulic fracturing operations on private or public lands can volatilize into the air from tanks and wastewater impoundments and contribute to air pollution.[44]

- DRN commented, "What makes information even more hidden, if the trade secret claims are asserted by the chemical manufacturers themselves, is that Pennsylvania law appears to allow complete secrecy. An exemption for chemical manufacturers that relieves them of reporting to drillers or other entities the complete ingredients in their formulas leaves a huge knowledge gap that keeps the public, regulators such as DEP, emergency personnel and first responders, health professionals, and even the drillers themselves in the dark."

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[44] NRDC, Fracking Fumes: Air Pollution from Hydraulic Fracturing Threatens Public Health and Communities (Dec. 2014), accessed at:
https://www.nrdc.org/resources/fracking-fumes-air-pollutionfracking-threatens-public-health-and-communities.

- DRN also provided this quote from the "Keystone Secrets" report by The Partnership for Policy Integrity: "When companies drill unconventional gas wells and designate a chemical as a trade secret, Pennsylvania requires that they must provide the public with a rough idea of what chemical was used by disclosing the chemical's "chemical family or similar description associated with the chemical." The federal Toxic Substances Control Act has a similar provision. However, these disclosures are inadequate because even chemicals within the same family can have very different toxicities and health effects."
- DRN provided this quote from an EPA report: "…non-disclosure of fracking chemical identities may leave people unknowingly exposed to harmful substances. Between 2003 and 2014, the EPA identified health concerns about 109 of 126 new chemicals proposed for use in oil and gas drilling and fracking. The chemicals' manufacturers submitted information about the chemicals for review under a program that requires EPA to screen and regulate new chemicals for health and environmental impacts before they are used commercially. Despite concerns by EPA scientists about the chemicals' health effects, EPA approved most of the 109 chemicals for use, and 62 were later used in or likely used in oil and gas wells. Manufacturers took advantage of trade secret protections that are permitted by federal law to conceal 41 of the 62 chemicals' identities."[45]
- DRN stated that the amount of secret chemical use in oil and gas wells is likely much greater than publicly disclosed because of regulatory exemptions that don't require reports or readily accessible records of all chemicals used in drilling and hydraulic fracturing.
- The League of Women Voters (LWV) asserted that no protocol for completely removing and destroying all the substances found in hydraulic fracturing wastewater has yet been published and that while such an operation is theoretically possible, it would first require reversal of laws that currently shield the oil and chemical industries from disclosing all chemicals used in hydraulic fracturing operations, so that they can be identified. They further claimed that this, coupled with the time-consuming and potentially prohibitively expensive breakthroughs required to neutralize the adverse effects of such toxic chemical, suggests that a complete protocol for handling these wastes will not become available in the near future.
- Many commenters were concerned that we don't know what is in this "toxic mix" of wastewater because many of the constituents are either hidden from the public as "secrets" or they are not properly tested or assessed by agencies for toxic properties. They said "How can the waste be stored in a manner that is safe for public health and the environment when we don't even know what is in it and its hazardous properties are ignored? Commissioners, you must ban the import of fracking wastewater to prevent the harm that would be done if it were allowed to be imported and stored here."

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[45] Horwitt, D., J.D., Partnership for Policy Integrity, Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals Is a Looming Risk for Delaware River Basin, Pennsylvania Communities,4–5 (Sept. 11, 2018), accessed at: https://www.pfpi.net/wp-content/uploads/2018/09/PASecretFrackingChemicalsReportPFPI9.10.2018.pdf.

RESPONSE (R-24)

As stated in the February 2021 CRD and in this document, the Commission acknowledges the risks to water resources posed by HVHF and HVHF-related processes. The Commonwealth of Pennsylvania manages these risks in part through a detailed statute and regulations focused on protecting water resources and public health while preserving commercial interests that include the interest of chemical manufacturers in protecting trade secrets. In some instances, the responses to these risks may be influenced by the timing of access to protected proprietary chemical identity information. In February 2021, the Commission determined that no set of regulations, however extensive, can adequately control the totality of the risks, vulnerabilities, impacts, and uncertainties, including those surrounding chemical disclosure or nondisclosure, which would accompany HVHF and related activities in the Basin. A similar determination with regard to discharges of HVHF wastewater underlies the rule that is the subject of this CRD. The Commission has no pending requests to import HVHF wastewater. Because the Commission is prohibiting HVHF in hydrocarbon bearing formations in the Basin and discharges of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin and that the amount and severity of any spills, leaks, or other releases and resulting impacts to the Basin's water resources from such activities will likely be sufficiently low so as not to injuriously affect the waters of the Basin as contemplated by the DRBC Comprehensive Plan.

Please see the Commission's February 2021 CRD, Section 2.6.2 Chemical Disclosure, for additional responses to concerns about HVHF chemical disclosure.

4.2.1.5 Transport, Leaks and Spills

STATEMENT OF CONCERN (SC-25)

Many commenters expressed concern that the proposed rules would allow HVHF wastewater to be transported into and within the Basin, resulting in impacts to water resources from leaks, spills, accidents, and illegal dumping. Representative comments are paraphrased or quoted below:

- Commenters expressed concern that the transport of hydraulic fracturing wastewater into or through the Basin for processing, storage, reuse or other purposes would threaten the release of dangerous pollution from tankers, containers, rail cars or other modes of mobile transport.
- Commenters maintained that transportation of hazardous waste within the Basin exposes Basin communities and the environment to the risk of contamination should there be a spill to water or land as a result of an accident, sabotage or intentional unpermitted release.
- Citing one or more government reports, commenters said that hydraulic fracturing fluid can spill into surface water bodies at every stage before, during, and after the hydraulic fracturing process—during transportation of the hydraulic fracturing fluid to the well site, during storage and handling of the fluid at drill sites, and afterwards, when hydraulic fracturing

wastewater is being trucked from well pads for treatment and disposal.[46] They noted that spills or releases can result from tank ruptures, piping failures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, drilling and production equipment defects, or improper operations and that spilled, leaked, or released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers.[47]

- A commenter cited EPA (without naming the specific publication) for the proposition that spills have occurred wherever transport of hydraulic fracturing wastewater has occurred. Specifically, commenters attributed to EPA the finding that between May 2009 and April 2013, eight spills of hydraulic fracturing wastewater ranging from more than 4,000 gallons to more than 57,000 gallons reached surface water resources in Pennsylvania and that these spills were reported to have resulted in local impacts to environmental receptors, requiring remediation and monitoring. The commenter asserted that the number of reported spills is likely to be only a subset of actual spills. The commenter cited a news report to the effect that legal action in Pennsylvania alleging long-term illegal dumping raised questions about the difficulty of detecting this behavior and quantifying it on a regional basis.[48]

- Environment New Jersey cited a 2015 letter from the Philadelphia Water Department (PWD) to the PADEP, objecting to the application by Elcon Recycling Services, LLC to construct and operate a zero-discharge hazardous waste processing facility in Falls Township, Bucks County, PA on the Delaware River, in part on grounds that there would be a substantial risk of drinking water contamination from release of hazardous waste during transport to or from the facility.[49]

- Another commenter cited a Canadian journal article reporting that in the province of Alberta, Canada, an estimated 2,500 hydraulic fracturing wastewater spills occurred from 2005 to 2012, with more than 113 of those spills entering directly into freshwater lakes and streams.[50]

- Commenters relying on diverse published sources pointed to mounting evidence of the adverse impact of hydraulic fracturing operations and waste transport on water quality. Acknowledging that analytical data on water impacts is often unavailable or incomplete, they

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[46] NYSDEC, Final Supplemental Generic Environmental Impact Statement of Regulatory Program for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs (May 2015), accessed at: https://www.dec.ny.gov/energy/75370.html.
[47] *Id*.
[48] Jonathan D. Silver, Pittsburgh Post-Gazette, State Charges Local Company for Dumping Wastewater and Sludge (Mar. 18, 2011), accessed at: http://www.post-gazette.com/pg/11077/1132812-454.stm. Kaitlynn Riely, Pittsburgh Post-Gazette, Greene County Man Pleads Guilty to Illegally Dumping Liquid Waste, Pittsburgh Post-Gazette (Feb. 11, 2012), accessed at: https://www.post-gazette.com/news/environment/2012/02/11/Greene-County-man-pleads-guilty-to-illegally-dumping-liquid-waste/stories/201202110485.
[49] Philadelphia Water Dep't, Comment to PADEP on Elcon Recycling Services, LLC Phase I Criteria Siting Permit application (Oct. 14, 2015), accessed at: https://water.phila.gov/pool/files/elcon-falls-twp-permit-comments.pdf.
[50] D. S. Alessi et al., Comparative Analysis of Hydraulic Fracturing Wastewater Practices in Unconventional Shale Development, Water Sourcing, Treatment, and Disposal Practices. 42 Can. Wat. Resour. J. 105 (2016).

asserted that adequate information exists to conclude that hydraulic fracturing activities and waste transport can adversely affect groundwater, surface water, and drinking water supplies.[51, 52, 53]

Response (R-25)

The Commission acknowledges the risks posed by the transport of HVHF wastewater, including the possibility of spills, leaks, and other releases, and the impacts to water resources that can result from such releases. These risks and impacts are described in detail in the Commission's February 2021 CRD, Section 2.3.2.2 Pollution from Spills and Section 2.3.3 Significant Impacts to Water Resources and their Uses. The Commission based its decision in 2021 to approve a final rule prohibiting HVHF within the Basin in part on evidence of spills associated with HVHF production activity outside the Delaware River Basin in northeastern Pennsylvania.

The Commission also recognizes that the risks of impacts to water resources in a region from the release of HVHF wastewater are strongly related to the volume of HVHF wastewater present in the region. If the volume of wastewater being transported through a region is high, then the probability of spills is correspondingly high. If the volume is low, then the probability of spills is correspondingly low. The volume of HVHF wastewater in active shale-gas production areas is high, because large volumes of wastewater are generated from many gas wells and must be stored, transported and disposed of. In areas outside active production areas, the volume of wastewater present is lower. EPA has reported, in reference to oil and gas wastewater transport, that "generally, operators will not be inclined to transport waste more than 50 to 75 miles unless no other alternatives are available."[54] In Pennsylvania, the average distance of transport from the location of HVHF wastewater generation to the location of its destination declined steadily from 95 miles in 2012 to 23 miles in 2017.[55]

A comparison of the volume of oil and gas wastewater generated in Pennsylvania with the volume imported to New York, where HVHF is prohibited, is instructive. A comprehensive 2019 study of Pennsylvania's oil and gas waste management conducted by SPE Healthy Energy, Stanford University, UC Berkeley, and Lawrence Berkeley National Laboratory, provides the basis for this comparison.[56] During the years 2010-2017, the volumes of oil and gas wastewater imported from Pennsylvania to

[51] PSR, Concerned Health Professionals of NY, Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction), Fifth Edition (Mar. 2018).
[52] Hays, J. and Shonkoff, S., Toward an Understanding of the Environmental and Public Health Impacts of Unconventional Natural Gas Development: A Categorical Assessment of the Peer-Reviewed Scientific Literature, 2009-2015, PLOS ONE 11:4 (Apr. 20, 2016), accessed at: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0154164&type=printable.
[53] Myers, T., Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers,. Groundwater, National Ground Water Association (Apr. 17, 2012).
[54] EPA, Management of Exploration, Development and Production Wastes: Factors Informing a Decision on the Need for Regulatory Action, (Apr. 2019), accessed at: https://www.epa.gov/sites/default/files/2019-04/documents/management_of_exploration_development_and_production_wastes_4-23-19.pdf.
[55] Hill et al., Temporal and spatial trends of conventional and unconventional oil and gas waste management in Pennsylvania, 1991–2017. Sci. of the Total Env't, 674, 623–36, 631, Table 5, 634 (Apr. 2, 2019), accessed at: https://doi.org/10.1016/j.scitotenv.2019.03.475.
[56] *Id*.

the State of New York averaged about 7.3 thousand barrels per year. In comparison, during the same period, 7.8 *millions* of barrels per year of oil and gas wastewater were generated in northeastern Pennsylvania's Tioga, Bradford, and Susquehanna counties where shale-gas is intensively produced along the New York-Pennsylvania border.[57] In other words, New York State imported the equivalent of less than 0.1% of the oil and gas wastewater volume generated in these three adjacent Pennsylvania counties during the 2010-2017 study period. The probability of spills of imported oil and gas wastewater was thus far lower in New York during this period than the probability of spills of oil and gas wastewater in the bordering shale-gas production counties in northeastern Pennsylvania.

Data on spills of oil and gas wastewater during truck transport demonstrate that spill events were more frequent in the northeastern Pennsylvania counties with active shale gas production than in adjacent counties in New York, where shale gas production was (and continues to be) prohibited. The number of spills occurring in two adjacent regions of similar area were compared: Tioga, Bradford, and Susquehanna Counties in Pennsylvania and Steuben, Chemung, Tioga, and Broome Counties, New York. Both regions occupy about 3,100 square miles. According to the spills databases maintained by Pennsylvania Departments that track spill events, between 2008 and 2020 there were eight spills of oil and gas brine, flowback or HVHF fluid being transported on roads in Pennsylvania's Tioga, Bradford, and Susquehanna Counties.[58] In contrast, according to a comparable database maintained by the New York State Department of Environmental Conservation,[59] during the same period, only one such spill occurred in the adjacent New York counties of Steuben, Chemung, Tioga, and Broome. (Under New York law, solid and liquid HVHF wastes from Pennsylvania were allowed to be imported for disposal at New York landfills or by other means until August, 3, 2020, when New York classified oil and gas waste, including but not limited to drilling fluids and produced waters, as hazardous wastes subject to all pertinent hazardous waste regulations.) This data provides further evidence that the probability of roadway spills of HVHF wastewater in areas where HVHF is prohibited is lower than in nearby areas where HVHF is permitted.

The comparatively higher probability of HVHF wastewater transport spills in active shale-gas production areas relative to the low probability of such spills outside shale-gas production areas is also evidenced by data on spills from oil and gas fluid transport in different areas within Pennsylvania. According to the spills databases maintained by Pennsylvania departments that track spill events, between 2008 and 2021, 50 spills of oil and gas brine, flowback or HVHF fluid occurred during transport of these materials in Pennsylvania. Twenty-eight (28) of these occurred during highway transport and 22 during pipeline transport. All 50 of these spills occurred in Pennsylvania counties where shale gas is produced. None of the spills occurred within the portion of Pennsylvania counties located within the Delaware River Basin, where shale gas is not produced, or in any other Pennsylvania counties where shale gas is not produced.[60] The data on oil and gas wastewater volumes and spills demonstrate that the probability of impacts from transport-related spills has

[57] Id.
[58] PADEP, 2022. Spills databases provided to DRBC on April 28, 2022.
[59] NYSDEC, 2022. Spills database provided to DRBC on June 8, 2022.
[60] PADEP, 2022, *supra* note 58.

been, and will remain, lower in the Delaware River Basin than in HVHF production areas of Pennsylvania.

Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater to land or waters within the Basin, it anticipates that only low volumes of HVHF wastewater will be transported to or through the Basin. The number of probable spills of HVHF wastewater during transport within the Basin and the related potential for adverse impacts on the Basin's water resources resulting from such spills are in the Commission's view reduced by these measures sufficiently to protect the water resources of the Basin.

STATEMENT OF CONCERN (SC-26)

Citing to its own report, the NRDC asserted that the transport of produced water to and from the hydraulic fracturing site hundreds of times per well has significant potential to pollute water bodies.[61] They further alleged that the greatest risk pathway for water contamination occurs not at the hydraulic fracturing site, but where produced water is transported, including in areas where hydraulic fracturing itself is prohibited.[62]

RESPONSE (R-26)

The Commission disagrees with the proposition that the risk of impacts to water resources from the transportation of HVHF wastewater is as high in regions where HVHF is prohibited as in areas where natural gas production using HVHF is permitted. As described in the previous response, the presence of HVHF wastewater, and thus the risk of impacts from HVHF wastewater releases in a region, is strongly related to the volume of HVHF wastewater generated in the region. Because the Commission prohibited the use of HVHF in hydrocarbon bearing formations in the Basin in 2021 and is now prohibiting the discharge of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported to or across the Basin. In the view of the Commission, the number of spills and releases of HVHF wastewater within the Basin and the risk to water resources from such events are thus effectively reduced.

STATEMENT OF CONCERN (SC-27)

Some commenters said that the transportation of hydraulic fracturing wastewater also emits pollutants to the air that are subsequently deposited on land, soil, vegetation, or surface water and/or are breathed in by people and animals; and that this occurs from mobile emissions of carbon and air pollutants from engines as well as off-gassing from container tanks being used for transport.

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[61] *See, e.g.,* NRDC, In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater (May 2012), accessed at:
https://www.nrdc.org/sites/default/files/Fracking-Wastewater-FullReport.pdf.
[62] *Id*.

RESPONSE (R-27)

As explained at R-19 and R-25 of this CRD, above, because the Commission in 2021 prohibited HVHF in the Delaware River Basin and with the present rulemaking is prohibiting the discharge of HVHF wastewater within the Basin, the volume of HVHF wastewater imported into the Basin is anticipated to be low. The air emissions within the Basin associated with transport of such wastewater are likewise expected to be low, as are the impacts to water resources that could potentially ensue. As the Commission also states in R-19 above, the U.S. Environmental Protection Agency (EPA) and the states regulate air quality and air emissions under the federal Clean Air Act and respective state air quality acts and implementing regulations. The DRBC has not done so, and it is not now proposing to replicate or supplement those programs.

Please also see the Commission's February 2021 CRD, at R-112.

STATEMENT OF CONCERN (SC-28)

Comments representative of those expressing other concerns about truck transport of HVHF wastewater into and within the Delaware River Basin follow:

- Commenters said that transport of HVHF wastewater will most likely be by trucks and that studies have shown that the presence of these trucks creates safety issues and increased fatalities. The commenters alleged that increased truck traffic increases the number of accidents in which trucks are involved[63] (even if trucks carrying HVHF wastewater are not always involved in these accidents), and likewise, increases the chances of major spills. They noted that leaks from trucks transporting HVHF wastewater can occur, whether or not in connection with accidents. Allegedly, drivers transporting HVHF wastewater may open their tank spigots slightly as they drive down back roads or may pull up to streams and drain their tanks into them. While such acts would be illegal, the commenters aver that DRBC lacks enforcement power and that the Pennsylvania Department of Environmental Protection (PA DEP) lacks the personnel to control such practices.
- Commenters expressed a concern that illegal and intentional dumping of hazardous hydraulic fracturing wastewater by trucking contractors could increase in the DRB if the importation of HVHF wastewater into the Basin is not prohibited. They recalled that a 2009 fish kill in Dunkard Creek in southwestern Pennsylvania was linked to illegal dumping of hydraulic fracturing wastewater. A trucking contractor in the region was charged by Pennsylvania's Office of Attorney General in 2011 with disposing of hydraulic fracturing wastewater and other liquid wastes during 2003-2009, by dumping them into a disused mine shaft connected to the Creek, where a resulting bloom of golden algae produced a toxin that

[63] Muehlenbachs, L., et al., The Accident Externality from Trucking, Resources for the Future (Sept. 2017 (rev. Jan. 2021)), accessed at: https://media.rff.org/documents/RFF-Report-Accident-Externality-Trucking_uhY6Lvg.pdf.

killed 160 species of fish and other aquatic life forms.[64] The commenter averred that Dunkard Creek became a saline, toxic, sterile stream for 38 miles and that such outcomes in the DRB must be prevented.

- Commenters averred that in addition to increasing traffic accidents, transportation of HVHF wastewater by truck adds air pollution, wear and tear on roadways, traffic congestion, and climate impacts, and that additional impacts occur related to transfer stations and stream obstructions.

- Some commenters stated that vehicles transporting toxic and radioactive hydraulic fracturing waste byproducts increase the risk of human and animal exposure to toxicants by contributing to contamination of water, air, soil and farmland when accidents, leaks, and spills occur. Commenters averred that not only could surface waters, residential areas, school properties and cropland be contaminated by spills but also that radioactive particles and other contaminants may become airborne as trucks and passenger vehicles travel along roads and can be tracked on tires; and that rain and snowmelt carrying radioactive materials and other pollutants can run off of road surfaces and migrate onto nearby properties, including farms, and into streams, ponds and irrigation systems, or leach into soil and seep into groundwater. The commenters said these numerous pathways of exposure pose increased risk for human and livestock inhalation and ingestion of highly radioactive materials and carcinogenic and endocrine disrupting chemicals.

- A commenter recounted that in 2010, a truck carrying oil and gas wastewater overturned in the small Ohio town of Barnesville and spilled 5,000 gallons of its wastewater load into a stream only a few hundred yards from where the stream runs into a drinking water reservoir.[65]

- Citing a New York City DEP report, a commenter noted that, based on its review of the risk of spills generated from truck trips alone, New York City concluded in its 2009 report that “acute spill scenarios are realistic and should be expected.”[66]

- Citing an EPA report, a commenter asserted that the chances of an accident during transportation of hydraulic fracturing waste have been assessed by EPA, using available

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[64] *See, e.g.,* San Deigo Tribune, Pa. man, company accused of dumping gas wastewater (Mar. 17, 2011), accessed at: https://www.sandiegouniontribune.com/sdut-pa-man-company-accused-of-dumping-gas-wastewater-2011mar17-story.html;
Federmn, A., What Killed Dunkard Creek?, Earth Island Journal, accessed at:
https://www.earthisland.org/journal/index.php/magazine/entry/what_killed_dunkard_creek/;
Barrett, S., Tentative settlement reached in Dunkard Creek fish kill, Greene County Messenger (Aug. 6, 2015 (updated Jan. 6, 2016)), accessed at:
https://www.heraldstandard.com/gcm/news/local_news/tentative-settlement-reached-in-dunkard-creek-fish-kill/article_83f5c33f-535d-527f-9475-8b5526142da0.html.

[65] Mall, A., Drinking Water Reservoir Contaminated by Oil and Gas Wastewater in Ohio, NRDC Expert Blog (Mar. 11, 2016), accessed at: https://www.nrdc.org/experts/amy-mall/drinking-water-reservoir-contaminated-oil-and-gaswastewater-ohio.

[66] NYCDEP, Final Impact Assessment Report: Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed (Dec. 22, 2009), 37, accessed at:
https://www.nj.gov/drbc/library/documents/dockets/stone-energy/NYCDEP-FinalImpactAssessmentReportTOC.pdf.

information on estimated volumes, disposal distances, truck sizes, and accident rates. EPA found that the total travel distance by trucks ranges from about 9,600 miles to 22,000 miles per well and that each truck is assumed to carry 5,440 gallons of waste.[67] It assumed 3.4 percent of accidents involving these vehicles were truck crashes and that 28 crashes occurred per 100 million miles travelled. Although the results predict a relatively low number of expected releases, if any one of them involves a spill that reaches groundwater, surface water or drinking water resources, the commenter maintained, it can seriously impact the chemical composition of the receiving water.

- Commenters including Environment New Jersey noted that EPA has also concluded that studies show the likelihood of spills increases as the volume of wastewater and number of trips increase,[68] and that EPA also found that the likelihood of accidents is increased because the federal government has created a special loophole for the industry: Federal Motor Carrier Safety Administration (FMCSA) regulations require oil/gas industry drivers to take only 24 hours off for every 60 hours of driving, compared to 34 hours off for other drivers. The commenters contend that at least some transported oil and gas wastewater will leak, spill, or migrate into water supplies during transport and handling at a processing, storage or re-use facility.
- Commenters expressed concern that waste from the oil and gas industry is exempt from being classified as hazardous, and therefore is not subject to regulations imposing special safety and handling requirements, including appropriate labeling of trucks and tracking of the waste.

Response (R-28)

The Commission acknowledges the risks described by commenters regarding truck transport of HVHF wastewater. Research has shown the reality of these risks: in three regions of active natural gas production in Texas, for example, the number of roadway crashes of commercial vehicles in rural areas from 2006 through 2013 was shown to be strongly correlated with the number of horizontal wells drilled in the region.[69] The Commission has concluded based on this and other information that in regions of active shale gas production, where large volumes of HVHF wastewater are present and routinely transported by truck, the risk of crashes resulting in spills is substantial and constitutes one of the reasons why the Commission has prohibited HVHF in the Delaware River Basin.

[67] EPA, Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States, (Dec. 2016), accessed at: https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

[68] EPA, Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes (May 2018), accessed at: https://www.epa.gov/sites/default/files/2018-05/documents/cwt-study_may-2018.pdf.

[69] Quiroga, C., and Tsapakis, I., Oil and Gas Energy Developments and Changes in Crash Trends in Texas, Final Report, Texas A&M Transportation Institute (Oct. 2015), accessed at: https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-15-35-F.pdf.https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-15-35-F.pdf.

However, the Commission also recognizes that the probability of spills resulting from HVHF wastewater transport in active shale-gas production areas is higher than in areas where shale-gas is not produced, as evidenced in the data on spills discussed at R-26 above.

Because the Commission has prohibited the use of HVHF in hydrocarbon-bearing rock formations within the Basin and is prohibiting the discharge of HVHF wastewater (broadly defined to include products, co-products, byproducts or waste products from the treatment, processing or modification of HVHF wastewater) to waters or land within the Basin, the volumes of HVHF wastewater trucked into or through the Basin are expected to be low, and the likelihood of inadvertent or intentional releases with impacts to water resources, commensurately low.

Please also see Section 2.7.8 Miscellaneous, R-123, of the February 2021 CRD for related content.

Statement of Concern (SC-29)

Comments representative of those expressing concern about conveyance of HVHF wastewater into and within the Delaware River Basin by means other than truck transport follow:

- Commenters expressed concern about the potential use of pipelines to carry the HVHF wastewater into and/or out of the watershed and the adverse impacts they believe would result. Some objected that "DRBC has not taken full jurisdiction of pipeline projects" under current regulations, "despite the public's insistence that they must."
- Citing news and journal coverage, commenters said that in 2015, a four-inch pipeline operated by Summit Midstream Partners LP burst north of Williston, North Dakota, leaking almost 3 million gallons of saltwater brine, a byproduct of hydraulic fracturing.[70] The hydraulic fracturing brine spilled into Blacktail Creek, which flows into the Missouri River, the drinking water source for Williston.[71] Later that month, officials found chloride concentrations in the creek to be as high as 92,000 mg/L, much higher than normal concentrations of about 10 to 20 mg/L.[72] In samples taken a year later, soil and sediment downstream of the spill site had radium concentrations up to 100 times greater than in samples taken upstream.[73]

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[70] R. Jacobson, Fracking Brine Leak In North Dakota Reaches Missouri River, Prompts State Democrats to Call For More Regulation, PBS News Hour (Jan. 26, 2015), accessed at: https://www.pbs.org/newshour/nation/fracking-brine-leak-north-dakota-reaches-missouri-river-prompts-state-democrats-call-regulation.
[71] *Id*.
[72] K. Valentine, Nearly 3 Million Gallons Of Drilling Waste Spill From North Dakota Pipeline, Think Progress, (Jan. 22, 2015), accessed at: https://archive.thinkprogress.org/nearly-3-million-gallons-of-drilling-waste-spill-from-north-dakota-pipeline-3690ea16c937/.
[73] D. Lockwood, Toxic Chemicals From Fracking Wastewater Spills Can Persist For Years, Chemical & Engineering News, (May 20, 2016), accessed at: https://cen.acs.org/articles/94/web/2016/05/Toxic-chemicals-fracking-wastewater-spills.html.

- Another commenter noted that efforts are currently underway to begin transporting hydraulic fracturing waste by barge, which would pose additional risks to waterways.[74]

RESPONSE (R-29)

The Commission acknowledges the potential impacts to water resources that could result from spills associated with pipeline and barge transport of HVHF wastewater. The Commission is not aware of any current or proposed barge transport of HVHF wastewater within the Basin. Any storage container used to transfer HVHF wastewater to and from a barge within the Pennsylvania portion of the Basin would need to comply with the storage requirements provided in 25 Pa. Code Chapter 299 – Storage and Transportation of Waste.

The Commission also recognizes that the probability of spills from HVHF wastewater pipelines is substantially higher in active shale-gas production areas than in areas where shale-gas is not produced. The data on spills from oil and gas fluid transport in Pennsylvania discussed at R-25, above, supports the Commission's view. As discussed in that response, Pennsylvania databases that track spill events show that between 2008 and 2021, 22 spills occurred from pipelines transporting oil and gas brine, flowback or HVHF fluid in the Commonwealth.[75] All 22 of these pipeline spills occurred in Pennsylvania counties where shale gas is produced from unconventional wells, and none occurred within the Pennsylvania counties of the Delaware River Basin where shale-gas is not produced from unconventional wells, or in any other Pennsylvania counties where shale-gas is not produced from unconventional wells.

Because the Commission has prohibited the use of HVHF in hydrocarbon-bearing rock formations within the Basin and is prohibiting the discharge of HVHF wastewater (broadly defined to include products, co-products, byproducts or waste products from the treatment, processing or modification of HVHF wastewater) to waters or land within the Basin, little if any use of pipelines to convey HVHF wastewater within the Basin is anticipated, and the likelihood of spills from such pipelines is significantly reduced.

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[74] K. Marusic, Should oil and gas companies be exempt from Pennsylvania's hazardous waste laws?, Envtl. Health News (Oct. 6, 2021), accessed at:
https://www.ehn.org/radioactive-waste-oil-and-gas-2655217995.html

[75] PADEP, 2022, *supra* note 58. In developing this CRD, PADEP noted that pipelines on a permitted waste facility are required to be doubled-walled with leak detection procedures in place. However, once the pipeline is offsite, including between two permitted waste facilities, construction is typically reduced to single-walled pipelines.

4.2.1.6 Stormwater Runoff

STATEMENT OF CONCERN (SC-30)

Paraphrased comment representative of those expressing concern about stormwater runoff from sites where HVHF wastewater is processed, treated, stored, or transported follow:

- Commenters expressed concern that stormwater runoff from the storage, use and reuse, and related transport of HVHF wastewater poses a contamination risk to the Basin's water resources.
- Commenters averred that the use and reuse of hydraulic fracturing wastewater increases the opportunity for releases of pollutants to the land, air and water. They noted in particular that stormwater runoff from facilities that process, store, transfer, or handle wastewater generated by hydraulic fracturing can carry pollution into the surface water and ground water, resulting in immediate impacts and impacts arising in the future, which may persist in the long term.
- Other commenters said that if DRBC allows HVHF wastewater to be imported to the Basin for storage, processing, or reuse, including in non-HVHF activities, hydraulic fracturing wastewater and the pollutants it contains will be released to the environment through indirect discharges that do not trigger the requirement for a NPDES permit or fall under a General Permit, escaping close regulatory scrutiny. The commenters said that stormwater runoff can transport to surface water pollutants that are deposited to the land and vegetation by air, or that are inadvertently discharged to land directly by spills and leaks.
- Commenters stressed that contamination of a surface water source may occur not only due to activity at a natural gas wellhead but also due to activity related to fluid storage and transportation or industrial reuses that are not in proximity to a wellhead.[76]
- Some commenters said that allowing the storage, transport and possible reuse of HVHF wastewater within the Basin will result in releases of HVHF contaminants to the Basin's waters through spills and the erosion of soils contaminated by spills that occur at facilities where HVHF water is transferred, stored or used, and from pipelines or other conveyances of HVHF wastewater.
- Many commenters opined that, "The construction, operation, and maintenance of a fracking wastewater storage project or processing facility that has no direct discharge to water or land, can still expose surface and groundwater, air, fish and wildlife, and people to fracking-related pollution. However, without DRBC permitting that involves a direct discharge, the project may not be reviewed or monitored by DRBC. It is important to realize that if a project is not under DRBC jurisdiction, the regulations of the state where the project is located will apply."

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[76] DRN, Unsafe & Unsustainable: Experts Review the Center for Sustainable Shale Development's Performance Standards for Shale Gas Development, (2014) 14, accessed at: https://www.delawareriverkeeper.org/sites/default/files/resources/Reports/DRN_Report_Unsafe%2BUnsustainable_fr.pdf.

- Commenters maintained that "A major flaw in current DRBC policy and regulations is that the states each have their own stormwater regulations, implementing the NPDES-2 nonpoint source pollution prevention program based on their own interpretations of the federal Clean Water Act. There is no unified stormwater best management practice manual or regulatory regime at the DRBC level that would ensure strict adherence to, for instance, the Special Protection Waters program mandate of 'no measurable change' in the outstanding water quality of the anti-degradation waters of the Delaware River Basin."
- Commenters stated, "Stormwater runoff can transfer pollution from fracking wastewater from a closed loop system, a storage site, or other handling facility that was supposed to be a no-discharge project. This cannot be tolerated. [DRBC] banned fracking within the watershed. You must now ban the pollution produced by fracking by prohibiting its toxic and radioactive wastewater from entering the watershed where it can be used, reused, processed, stored, or disposed of."

RESPONSE (R-30)

The Commission acknowledges that stormwater runoff is a pathway by which contaminants from spills or leaks at facilities that store, process, treat, reuse, or transport HVHF wastewater may reach and impact water resources.

Because the Commission is prohibiting HVHF in hydrocarbon bearing formations in the Basin and discharges of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin and that the amount and severity of any spills, leaks, or other releases and resulting impacts to the Basin's water resources from such activities will likely be sufficiently low so as not to injuriously affect the waters of the Basin as contemplated by the DRBC Comprehensive Plan.

Please also see related responses at Section 4.2.1.5 Transport, Leaks and Spills and Section 4.2.1.7 Wastewater Storage and Recycling.

4.2.1.7 Waste Storage and Recycling

STATEMENT OF CONCERN (SC- 31)

Comments representative of those expressing concern about storage of HVHF wastewater within the Delaware River Basin follow:

- Many commenters pointed out that the draft regulations would allow for the storage of HVHF wastewater in the Delaware River Basin and maintained that as large quantities of toxic and radioactive wastewater come into the Basin to be stored, the likelihood increases that spills and leaks of toxic materials from the containers will occur, while transloading of wastewater into and out of containers further increases that likelihood.
- Commenters also asserted, without citing authorities, that existing storage capacity is insufficient for the volume of hydraulic fracturing wastewater generated, and that the industry is in desperate need of more.

- Commenters expressed concern that regardless of how this material is stored, whether in holding tanks, landfills, lagoons, lined pits, pipelines, or by other means, the containers will corrode, break down and eventually leak into the environment, which will impact the air, water, soil, our food, public health, and the health of all life forms in the Basin.
- Some commenters expressed concern that as radioactive elements in HVHF wastewater are stored, radioactive properties can build up in tanks, liners, piping, and residual material in the storage vessel. The commenters maintained that there is no requirement for sampling of such tanks, units, or other infrastructure over time, and that the sampling of the fluids may not accurately represent the level of radioactivity embodied in the units, impoundment liners, or other related components of the storage system.
- Citing the Commission's February 2021 CRD, some commenters claimed that, given the "highly mobile and decentralized nature of unconventional oil and gas operations," prohibiting all HVHF-related activities within the Basin will prevent the widespread "storage and use of hazardous substances throughout the landscape" and multiple vehicular trips carrying HVHF fluids in and out of the Basin.[77] The commenters asserted that without a total prohibition, these sorts of cross-basin operations would pose the same threats the Commission sought to prevent with its 2021 prohibition on HVHF.

RESPONSE (R-31)

The Commission acknowledges the risks posed by the storage of HVHF wastewater, including the potential for spills, leaks, and other releases and ensuing impacts to water resources that can result from such releases. These risks and impacts are described in detail in the Commission's February 2021 CRD, at Section 2.3.2.2 Pollution from Spills and Section 2.3.3 Significant Impacts to Water Resources and their Uses, respectively. The storage of HVHF waste is regulated under detailed state and federal programs that support effectuation of the Commission's Comprehensive Plan (*see, e.g.,* 25 Pa. Code Chapter 78a – Oil and Gas Wells or 25 Pa. Code Chapter 299 – Storage and Transportation of Waste). Duplication of these programs is not practicable or necessary.

Because the Commission has prohibited HVHF within the Basin and by this rulemaking is prohibiting the discharge of HVHF wastewater to waters and land within the Basin, the Commission expects demand for HVHF wastewater storage facilities within the Basin to be low and the probability of releases or spills related to storage of HVHF wastewater to be commensurately low. As noted in Section 4.2.1.5 Transport, Leaks and Spills, operators are disinclined to transport HVHF wastewater over long distances. Although in Pennsylvania the average distance of HVHF wastewater transport declined steadily from 95 miles in 2012 to 23 miles in 2017, the Commission expects operators will be unlikely to transport HVHF wastewater into the Basin (including its Pennsylvania portions) and store the wastewater in the Basin because the discharge of HVHF wastewater in the Basin is prohibited. Please see Response R-25, in Section 4.2.1.5 Transport, Leaks and Spills, above, for further discussion of Pennsylvania spill data highlighting the comparatively high probability of HVHF wastewater transport spills in active shale-gas production areas relative to the low probability of such spills outside shale-gas production areas in the Commonwealth.

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[77] *See* DRBC, February 2021 CRD, at 67. (Citations to other portions of comment omitted.)

STATEMENT OF CONCERN (SC-32)

Comments representative of those expressing concern about the adequacy of existing regulations applicable to the storage of HVHF wastes follow:

- Commenters expressed concern that Pennsylvania general permit WMGR123, issued in 2021 with an expiration date of 2031, allows "temporary" storage that can extend for years and even for the length of the permit. The commenters maintained that unless storage of the HVHF waste is eliminated by prohibiting its import into the Delaware River Basin, the tanks containing waste will corrode and leak; the surface impoundments lined with plastic will leak; the trucks or pipes bringing in the waste will leak; and wastes will be deliberately dumped, all causing lasting contamination.

- Commenters stated that there is no requirement limiting the size or capacity of storage units, which are being built in enormous sizes today.

- Commenters claimed that under PA General Permit WMGR123, testing of waste fluids from HVHF is less frequent, and fewer parameters are tested for, increasing the likelihood that pollutants will go unidentified and undetected, compounding containment and cleanup problems should there be a release to the environment, and making air emissions unknowable. One or more commenters added, "You can't test to see what is polluting your water supply without that information."

- Commenters said that in the other Basin states, New York, New Jersey and Delaware, the handling of waste (including open pits, and other storage aspects) differs, but regulatory rules are often not clear, and enforcement is unreliable.

- Citing information on the Delaware River Frack Ban Coalition website,[78] DCS and Environment New Jersey, among others, stated that industry exemptions from disclosing the identity of components of their produced waters makes attempts to regulate the adequacy of wastewater storage containers (e.g., materials, construction, and maintenance standards for corrosion and leak prevention) effectively impossible.

- Commenters expressed concern that caverns, which may be used for storage of liquids under state regulations, are not adequately regulated. Some asserted that there is no requirement that vapors and emissions from storage vessels be treated or filtered to remove contaminants, including methane, noting that PADEP air regulations address only certain types of fugitive emissions and only when volume thresholds are met.

- Citing a peer-reviewed journal article, a commenter pointed out that a research team at the University of Missouri traced a spike in endocrine-disrupting activity in a West Virginia stream to an upstream facility that stores hydraulic fracturing wastewater. The commenter related that the study found that levels detected downstream of the waste facility were above levels known to create adverse health effects and alter the development of fish, amphibians,

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[78] *See* Delaware River Frack Ban Coalition, Watershed Wednesdays #5 & #7 (Jan. 12, 2022, & Jan. 26, 2022, respectively), accessed at: https://sites.google.com/view/delawareriverfrackban/.

and other aquatic organisms, and that endocrine-disrupting compounds were not found to be elevated in upstream sections of the creek.[79]

RESPONSE (R-32)

The Commission acknowledges spills from HVHF wastewater storage facilities have occurred, and some spills have resulted in impacts to water resources and aquatic life. A decade of experience has shown that in regions where shale-gas is produced, while state regulation includes measures to prevent spills or leaks from containers that store HVHF wastewater,[80] regulation alone is not capable of preventing all adverse effects or injury to water resources from HVHF-related spills and releases of chemicals and hydraulic fracturing wastewater. In regions of active shale-gas production where large volumes of HVHF wastewater are present and stored, the risks are substantial and constitute one of the reasons why the Commission prohibited HVHF in the Delaware River Basin by a final rule adopted in February 2021.

However, the Commission also recognizes, as described in detail at Response R-25 above, that the probability of such spills is higher in areas of active shale-gas production and comparatively lower in areas where shale-gas is not produced. Because the Commission has prohibited the use of HVHF in hydrocarbon-bearing rock formations within the Basin and is prohibiting the discharge of HVHF wastewater (broadly defined to include products, co-products, byproducts or waste products from the treatment, processing or modification of HVHF wastewater) to waters or land within the Basin, the volumes of HVHF wastewater stored within the Basin are expected to be low, and the likelihood of spills and resultant impacts to water resources, to be commensurately low. The Commission's regulatory response is in the Commission's view proportional to the risk and potential impact on water resources of the Basin from spill events, given the reduced likelihood that such events will occur in the absence of HVHF wells and permitted HVHF wastewater discharges.

With respect to vapors emitted from storage vessels, as required by the EPA, PADEP is in the process of finalizing air quality regulations to control harmful volatile organic compound ("VOC") emissions, while simultaneously controlling methane as a co-benefit, from five specific categories of air emission sources used by the oil and gas industry. These source categories include storage vessels. These air quality regulations would require storage vessels with an annual potential to emit of 2.7 tons per year of VOC emissions to control VOC emissions by at least 95 percent.

Although the Commission has received comments criticizing the sufficiency of state regulations regarding storage of HVHF wastewater, the prohibitions on both use of HVHF and discharge of HVHF wastewater in the Basin eliminate any need for more stringent regulation of HVHF wastewater storage in the Basin than existing state-wide regulations already provide. It is thus reasonable to rely

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[79] Testimony of Sandra Steingraber, Co-founder, Concerned Health Professionals of New York, Senior Scientist, Science and Environmental Health Network (Dec. 8, 2021) (citing Kassotis, C.D., et al., Endocrine disrupting activities of surface water associated with West Virginia oil and gas industry wastewater disposal site, Sci. of the Total Env't (July 2016), 557–58, accessed at: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/3317634.

[80] For example, in the Pennsylvania portion of the Basin, PA General Permit WMGR123 requires storage tanks to be constructed with secondary containment units and other safeguards to prevent leaks from the storage structure from entering the environment.

on statewide programs administered by experienced state environmental agencies to control the remaining risks to water resources. Please see Section 5.2 Coordination with Other Regulators, below, for responses to other comments regarding the adequacy of existing regulations.

STATEMENT OF CONCERN (SC-33)

Representative paraphrased comments asserting that regulatory oversight of HVHF wastewaster recycling is inadequate follow:

- Many commenters asserted that the Commission must prohibit uses of hydraulic fracturing wastewater, including any "beneficial reuse," that could impair the quality of Basin waters. Some averred that there is no such thing as "beneficial reuse" of hydraulic fracturing wastewater.
- Commenters opined that the regulation of beneficial use or reuse in Pennsylvania is inadequate.
- A statement submitted by multiple commenters read, "Without prohibiting HVHF-related activities and acceptance of wastewater produced by HVHF in the Basin, the use and reuse of this wastewater will be allowed and DRBC may not review or docket these projects if they do not involve a discharge or a withdrawal, leaving these projects outside of the DRBC's jurisdiction. Without review for compliance with the DRBC's Comprehensive Plan, there is no means to assure that projects meet the anti-degradation policies, water quality standards, and improvement programs that DRBC implements in its management of the water resources of the basin."
- Commenters asserted that reuses of wastewater produced by HVHF that could occur without DRBC review and oversight include: for cooling in manufacturing and by utilities; in construction such as cement making; as boiler feed water; in processing aggregate; in industrial processing; in treating acidic hazardous wastes such as water from mines; and as an ingredient in other products, such as road salts and pool salts, deemed "beneficial uses" under state regulations.
- Citing an NRDC report, some commenters stated that cyclic reuse of HVHF wastewater in the hydraulic fracturing of new HVHF wells eventually produces a highly concentrated residual waste that can be toxic and radioactive.[81] This waste could be imported into the Delaware River Basin for processing, disposal, storage or reuse under the proposed rules.
- Some commenters stated that HVHF wastewater is minimally controlled, analyzed or monitored, and they pointed out that under the proposed rule, absent a planned discharge to water or land within the Basin, each state's regulatory system will apply once this material enters the watershed.

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[81] Hammer, R. & VanBriesen, J., Ph.D., PE, In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater, NRDC (May 2012), 79, accessed at: https://www.nrdc.org/sites/default/files/Fracking-Wastewater-FullReport.pdf (citations to other portions of comment omitted).

RESPONSE (R-33)

The Commission has prohibited the use of HVHF in hydrocarbon-bearing rock formations within the Basin and is prohibiting the discharge of HVHF wastewater (broadly defined to include products, co-products, byproducts or waste products from the treatment, processing or modification of HVHF wastewater) to waters or land within the Basin. Accordingly, any recycling or reuse of HVHF wastewater within the Basin may occur only if no discharge of the reused wastewater is involved.

Examples of recycling or reuse of HVHF wastewater offered by commenters included: for cooling in manufacturing and by utilities; in construction such as cement making; as boiler feed water; in processing aggregate; in industrial processing; in treating acidic hazardous wastes such as water from mines; and as an ingredient in other products, such as road salts and pool salts, deemed "beneficial uses" under state regulations. Notably, road spreading of HVHF wastewater for dust suppression or deicing is prohibited under the final regulations. *See* Response R-38 in Section 4.2.1.9, Road Spreading, and Response R-49 in Section 4.3, Section 440.2—Definitions, for a more detailed discussion of this topic. The use of acid mine drainage as a source of water for hydraulic fracturing has been discussed in the academic literature as a means of removing radioactive elements from HVHF wastewater.[82] This use in theory remains available for hydraulic fracturing within the Basin that does not constitute "high volume hydraulic fracturing" as defined at 18 C.F.R. § 440.2, and thus is not prohibited by DRBC's regulations at 18 C.F.R. 440.3(b). But the use of HVHF wastewater to "treat" acid mine drainage in the Basin would likely entail discharges that are prohibited under the proposed and final rule.

Commenters are correct that the final regulations do not categorically prohibit in-Basin recycling or reuse of HVHF wastewater where no discharge to Basin land or water occurs. In the absence of local sources of HVHF wastewater and some means of legally discharging this material, the described re-uses of HVHF wastewater within the Basin are expected to be few and the associated risks and impacts to water resources minimal. For additional discussion of leaks and spills, *see* Section 4.2.1.5, *Transport, Leaks and Spills*, within this CRD. Air emission and deposition appear to be the other pollution pathway of concern to commenters in connection with reused or recycled HVHF wastewater. For a discussion of this topic, please *see* Section 4.2.1.2, *Air Pollution and Air Deposition.*

As noted in Response R-38 in Section 4.2.1.9 of this CRD, the Commission will continue to coordinate with the Commonwealth to review the scientific evidence regarding harm to water resources caused by road spreading of oil and gas production brines and may in the future consider whether additional regulation of the practice of applying conventional drilling brines to roadways is needed in the Basin. The Commission may likewise in the future review and consider additional evidence of adverse impacts on water resources associated with reuses of HVHF solid and liquid wastes in commercial products, but it has not seen evidence to date warranting DRBC regulation in this area. Please see Section 5.2 Coordination with Other Co-regulators, below, for related discussion.

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[82] *See* State Impact Pennsylvania, Study finds acid mine drainage reduces radioactivity in fracking wastewater (Jan. 13, 2014) (citing Kondash, A.J., et al., Radium and Barium Removal through Blending Hydraulic Fracturing Fluids with Acid Mine Drainage, Envt'l Sci. & Tech. (Dec. 24, 2013)), accessed at: https://stateimpact.npr.org/pennsylvania/2014/01/13/study-finds-acid-mine-drainage-reduces-radioactivity-in-fracking-wastewater/.

STATEMENT OF CONCERN (SC-34)

Paraphrased comments representative of those expressing concern about pollution resulting from HVHF wastewater recycling follow:

- Commenters expressed concern that beneficial reuses of wastewater release pollution to the air, soil or water, and degradation of products that contain the reused waste will also result in pollution.
- Commenters also expressed concern that the demand for reused HVHF wastewater has plummeted with the lack of new oil and gas well starts, creating a glut of wastewater that is more expensive to dispose of when it must be transported to injection wells or industrial treatment plants. They are concerned that the need for new HVHF wastewater storage and disposal locations will cause operators to look to the Delaware Basin for storage and reuse opportunities.
- Citing an EPA website, some commenters, including the group Citizens for Pennsylvania's Future (PennFuture), stated that additional "beneficial uses" of HVHF wastewater may include fire control, equipment washing, and land spreading for irrigation. Additionally, wastewater facilities can produce sludge, which can in turn be used as "fertilizer" and spread on land. This sludge could include varying levels of radium and barium if produced water passes through the treatment facility.[83] The commenters asserted that all these activities run the risk of causing HVHF wastewater to be released into waters of the Basin.

RESPONSE (R-34)

Few instances of HVHF wastewater recycling within the Basin are expected. Under the proposed and final rule, and as noted in R-33, R-32, R-29 above and elsewhere in this CRD, recycling or reuse of HVHF wastewater within the Basin may occur only if no discharge of the wastewater to land or waters of the Basin is involved. In the absence of local sources of HVHF wastewater under the prohibition on HVHF adopted by the Commission in 2021, and in the absence of a means to lawfully inject or otherwise dispose of HVHF wastewater in the Basin under the new rule, such instances are expected to be few. The final rule significantly reduces the potential for pollution of the Basin's water resources resulting from the discharge to water or land of stored, transported, recycled, or modified HVHF wastewater.

Responses to comments regarding the storage of HVHF wastewater are set forth at R-31 and R-32 above.

STATEMENT OF CONCERN (SC-35)

The Marcellus Shale Coalition asserted that: ". . . The Commission has trampled on constitutionally protected private property rights and ignored sound science and our industry's leadership in water recycling and reuse technology. Pioneered in Pennsylvania, 93 percent of water used by the

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[83] EPA, Radiation Protection, TENORM: Oil and Gas Production Wastes, accessed at: https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes.

Commonwealth's unconventional natural gas industry is recycled dramatically reducing the need for freshwater withdrawals."

Response (R-35)

The February 2021 CRD at Section 2.6.10. contains the Commission's refutation of the commenter's assertions with respect to property rights. Because companies performing HVHF activities outside the Basin have alternative sources of water and disposal locations, any economic impact on these companies from the importation and exportation regulations is minimal. The assertion that the Commission has ignored sound science is false. Rather, the Commission conducted an extensive scientific and technical investigation, and based its decisions on the results of that investigation.

The Commission acknowledges that recycling HVHF wastewater for reuse in HVHF reduces the demand for freshwater withdrawals that might otherwise be needed to support HVHF activities. Nevertheless, consumptive uses and exportation of water from the Basin may impair the uses protected by the Comprehensive Plan and impair the Commission's conservation responsibilities unless managed in accordance with the Commission's regulations.

4.2.1.8 Landfill Leachate

Statement of Concern (SC-36)

Some commenters expressed concerns about the potential for impacts to water resources and their uses from the disposal of HVHF wastes in landfills and the subsequent release of landfill leachate containing HVHF contaminants.

Representative paraphrased comments on this topic follow:

- Commenters stated that drill cuttings from HVHF well boreholes contain bromine; toxic metals and metalloids, including cadmium, chromium, copper, manganese and arsenic; and radioactive materials, including radium, thorium and uranium. They said that landfills accepting drill cuttings could produce leachate (rainwater that has percolated through the landfill) that is heavily contaminated with radioactive materials that cannot be effectively treated by the sewage treatment plants to which they are taken. Citing a published report, they asserted that radioactivity can build up to high levels in a landfill after the radioactive material is covered, because radon generated by radioactive decay is trapped beneath the cover of soil and other waste.[84]
- Citing a news report by the Allegheny Front, a commenter stated that loopholes in federal and state laws have resulted in oil and gas waste going to landfills that cannot properly contain the radioactivity, salts, and other dangerous toxins that are in the waste, and these

[84] Nelson, A.W., et al., Understanding the radioactive ingrowth and decay of naturally occurring radioactive materials in the environment: an analysis of produced fluids from the Marcellus Shale, Envtl. Health Perspectives (July 2015), accessed at:
https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1408855.

constituents end up in highly polluted landfill leachate.[85] Citing other news reports and a published report,[86] the commenters averred that the waste has polluted waterways, contaminated drinking water, harmed fish and wildlife, and impaired the public's access to fishable and swimmable waters.

- PSR commented that an investigative team at the Public Herald (PH) found that the Pennsylvania Department of Environmental Protection (DEP) is limiting the amount of TENORM disposed of in Pennsylvania landfills only by limiting the amount of waste a landfill can receive. According to the PH team, the DEP is not tracking the amount of TENORM leaving the landfill, including by conveyance to water treatment facilities in the form of leachate; DEP is instead treating the transaction between landfill and treatment plant as private.

- The LWV, citing a published report, stated EPA and PADEP allowed leachate from landfills accepting radioactive hydraulic fracturing waste to be conveyed to fourteen (14) Pennsylvania sewage plants for treatment and discharge to waters of the Commonwealth.[87]

- DRN asserted that the proposed regulations do not prohibit disposal of HVHF wastes in landfills, and that the Commission has stated that it will "review discharges of treated [landfill] leachate when such discharges meet the thresholds set forth in DRBC's Rule of Practice and Procedure ("RPP")."[88] The commenter further asserted that, given the obstacles posed by the hydraulic fracturing industry's use of unidentified chemicals, there is a chance that leachate may contaminate water resources despite the Commission's oversight.

- Citing a published report, a commenter noted that if landfill leachate leaks directly into waterbodies near the landfills or is released into streams after undergoing ineffective treatment at sewage plants, the radium present will be found in the downstream sediments where it persists for years.[89] They expressed concern that micro-organisms in the sediment

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[85] Frazier, R., DEP Fines Landfill Near Pittsburgh for Problems Tied to Fracking Waste, Allegheny Front (Feb. 21, 2020), accessed at: http://go.pardot.com/e/176172/oblems-tied-to-fracking-waste-/x4sqw/278450588?h=q1kB50DEowt7PG886EezI9xud2IZUEC3tPpotM_fGU4.

[86] Marusic, K., Should oil and gas companies be exempt from Pennsylvania's hazardous waste laws? Envtl. Health News (Oct. 6, 2021), accessed at: http://go.pardot.com/e/176172/te-oil-and-gas-2655217995-html/x4sqy/278450588?h=q1kB50DEowt7PG886EezI9xud2IZUEC3tPpotM_fGU4;
Marusic, K., Fracking chemicals dumped in the Allegheny River a decade ago are still showing up in mussels: Study, Envtl. Health News (Sept. 5, 2018), accessed at: http://go.pardot.com/e/176172/hwater-mussels-2602333500-html/x4sr1/278450588?h=q1kB50DEowt7PG886EezI9xud2IZUEC3tPpotM_fGU4;
Geeza, T.J., et al., Accumulation of Marcellus Formation Oil and Gas Wastewater Metals in Freshwater Mussel Shells, Envtl. Sci. & Tech. (Sept. 1, 2018).

[87] Nelson, A.W., et al., Understanding the radioactive ingrowth and decay of naturally occurring radioactive materials in the environment: an analysis of produced fluids from the Marcellus Shale, Envtl. Health Perspectives (July 2015), accessed at: https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1408855.

[88] *See* DRBC, February 2021 CRD at 327 (citing 18 C.F.R. §§ 401.35(a)(5), 401.35(b)(8)).

[89] Lauer, N., et al., Sources of Radium Accumulation in Stream Sediments Near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater, Envtl. Sci. & Tech., (Jan. 4, 2018) accessed at: https://nicholas.duke.edu/news/radioactivity-oil-and-gas-wastewater-persists-pennsylvania-stream-sediments.

will ingest the radium, along with the organic matter in the sediment, allowing radium to enter the food chain, and that this will impact the largest and most iconic birds, fish and mammals found in the Delaware River, Estuary and Bay, as well as the fish and marine mammals in the nearby waters of the Atlantic Ocean.

- A commenter expressed concern that although the state requires landfills to obtain permits before accepting solid waste containing radioactive material, there is no required sampling or standard applicable to the amount of radioactive material found in landfill leachate.[90] The commenter opined that the Commission cannot rely on federal or state regulators to protect Basin communities from exposure to radioactive materials via hydraulic fracturing wastewater; rather, the Commission must take the initiative to put such protections in place.

RESPONSE (R-36)

The Commission acknowledges that toxins and radioactive materials have been detected in leachate from landfills that accepted HVHF wastes and that such leachates can present treatment and disposal challenges. Under the proposed and final rule, discharges of HVHF wastewater to waters and land within the Basin are prohibited. Thus, to the extent a landfill in the past accepted HVHF waste containing "wastewater from HVHF and HVHF-related activities" as defined in the rule, it may no longer do so under the rule. The rule also expressly defines HVHF wastewater to include leachate from solid wastes associated with HVHF-related activities, except those wastes lawfully disposed of in a landfill within the Basin prior to the effective date of the rule. Accordingly, leachate from a landfill that accepts solid waste from HVHF activities after the effective date of the rule *cannot be discharged to Basin waters, even after treatment.* The risks to the Basin's water resources, aquatic life, and human health from the discharge of landfill leachate that has been contaminated by HVHF waste are in the Commission's view effectively reduced by the new regulation.

The Commission notes that the U.S. Environmental Protection Agency and the states regulate the construction and operation of landfills under the federal Resource Conservation and Recovery Act (RCRA) and in Pennsylvania, the Solid Waste Management Act (Act 97 of 1980) and implementing regulations. Chapter 78a – Unconventional Oil and Gas Wells of Title 25 of the Pennsylvania regulatory code includes detailed regulations applicable to the storage and disposal of HVHF wastes. For example, in Pennsylvania, a TENORM disposal protocol uses readings from monitors located at the gate of every landfill in Pennsylvania to calculate the radioactive content attributable to TENORM of each waste load that enters the landfill. The protocol is designed to ensure that a landfill's operations do not expose the public or workers to levels of radioactivity above thresholds set by the U.S. Nuclear Regulatory Commission and the federal Occupational Safety and Health

[90] 25 Pa. Code § 288.201(h)(2) (denoting TENORM as a material that cannot be disposed of at a landfill without approval from the Pennsylvania Department of Environmental Protection); 25 Pa. Code § 288.456(a)(2) (providing leachate treatment requirements for Class I landfills); 25 Pa. Code § 288.556(a)(2) (providing leachate treatment requirements for Class II landfills).

Administration.[91] The DRBC has not, and is not now, proposing to replicate or supplement these programs.

The Commission's discussion in its February 2021 CRD of concerns related to the discharge of treated leachate from landfills that accept HVHF wastes is superseded by the current rulemaking.

Statement of Concern (SC-37)

Paraphrased comments representative of those recommending more far-reaching Commission action to eliminate impacts of landfill leachate containing HVHF contaminants follow:

- Penn Future commented that while the Commission has specifically included "leachate from solid wastes associated with HVHF-related activities" in the proposed definition of wastewater, it specifically excepts situations where those solid wastes were "lawfully disposed of in a landfill within the Basin prior to the effective date of this rule." Penn Future averred that this does not go far enough to protect the Basin's water resources from the toxic, harmful, radioactive, and forever chemicals that will enter and contaminate the leachate from solid wastes placed in landfills after the promulgation of these rules, and that the Commission has a duty to protect the Basin's water resources from threats such as this,[92] and therefore must prohibit the placement of solid wastes from hydraulic fracturing to and in landfills within the Basin.
- A commenter asserted that the Commission should prohibit any importation of radioactive drill cuttings and leachate taken from landfills into the Basin. The commenter was concerned that if the radioactive drill cuttings and leachate are transferred to municipal waste disposal facilities in the Basin, more contamination of these areas will occur. The commenter asserted that the radioactive drill cuttings and leachate should not be discharged into waterways from "treatment" facilities with downstream drinking water intakes, resulting in devastating impacts on human health, wildlife, all life forms, the environment, and agriculture. The commenter further asserted that New York State currently imports both drill cuttings and liquid waste from oil and gas wells in Pennsylvania—with all the air, water, and soil impacts.

Response (R-37)

Please see the Commission's response at R-36 above. By prohibiting the discharge to Basin waters of any leachate from a landfill that accepts solid waste from HVHF activities *after the effective date of the rule,* the Commission is in its view effectively reducing the risk of harm to the Basin's water resources, aquatic life, and human health associated with the discharge of landfill leachate that may have been in contact with HVHF waste. The Commission expects that landfills that discharge treated

[91] *See, e.g.*, PADEP, Bureau of Radiation Protection and Bureau of Waste Management, 250-3100-001, Guidance Document on Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities (June 11, 2022), accessed at: https://www.depgreenport.state.pa.us/elibrary/GetFolder?FolderID=365834.
[92] Water Code § 3.1.1, incorporated by reference into the Code of Federal Regulations at 18 CFR § 410.1 ("The commission may assume jurisdiction to control future pollution and abate existing pollution in the waters of the basin, whenever it determines after investigation and public hearing upon due notice that the effectuation of the comprehensive plan so requires.").

leachate within the Basin or that send leachate to wastewater treatment plants within the Basin for treatment and discharge will end the practice of accepting HVHF wastes or will refrain from ever accepting such wastes upon adoption of the new rule. The Commission cannot reasonably prohibit the discharge to Basin waters of leachate from landfills that may have lawfully accepted HVHF drilling wastes prior to the effective date of the rule.

The Commission notes that PADEP has commenced a study that evaluates the radium concentration of the leachate from all landfills in the Commonwealth regardless of whether a landfill has historically received oil- and gas-derived wastes. This study is currently ongoing.

The Commission further notes that on August 3, 2020, the State of New York adopted a law that makes oil and gas waste, including but not limited to drilling fluids and produced waters, subject to the same reporting requirements and special treatment as hazardous wastes under New York law, ensuring that disposal of these wastes takes place only at facilities that can safely manage it. *See* N.Y. Envtl. Conservation Law § 27-0903. Please see R-25 of this CRD, above, regarding the importation of HVHF wastes by the State of New York prior to enactment of the 2020 statute.

4.2.1.9 Road Spreading

Statement of Concern (SC-38)

Some commenters expressed concerns about the potential for impacts to water resources from the spreading of HVHF wastewater on roadways for ice control and dust suppression. Representative comments (paraphrased except where direct quotations are indicated) follow:

- Commenters expressed concern that polluted HVHF wastewater has already made its way into the Pennsylvania environment, including by means of spreading on roadways, due to regulatory loopholes.
- Commenters averred that Pennsylvania permits road spreading, land application, and the disposal of hydraulic fracturing wastewater to surface waters without regard to its TENORM (radioactivity) content.[93]
- One commenter described spreading of hydraulic fracturing wastewater on roads as "a[n] environmental travesty" that "continues to put residents like myself . . . at grave risk."
- Another stated that hydraulic fracturing wastewater was allowed by Pennsylvania, New York and possibly other states "to be placed on our roads and highways . . . as a means of "getting rid of it."
- Others were concerned that HVHF waste is used in products sold at hardware stores and spread on local roads as a deicer.

[93] *See* 25 Pa. Code §§ 78a.70–70a (governing road spreading); 25 Pa. Code § 78a.63 & ch. 291 (governing land spreading of residual waste from hydraulic fracturing operations); 25 Pa. Code § 78a.60 (providing discharge requirements for hydraulic fracturing wastewater); 25 Pa. Code § 93.7 (providing list of water quality criteria applicable to Pennsylvania surface waters that does not include a criterion for radioactivity or radioactive material).

- Referencing a May 2021 blog post by the PA Environment Digest, and citing a section of the post on "Relevant Studies," the League of Women Voters alleged the practice of spreading oil and gas wastewater on roadways in Pennsylvania continued even after the state made it illegal in 2018. The commenter charged that even if DRBC were to disallow the practice within the Delaware Basin, it has proposed no way to enforce such a rule.

- A commenter on behalf of Berks Gas Truth recognized that road spreading of conventional oil and gas wastewater is not relevant to the proposed regulations, but nevertheless, submitted a report by the Better Path Coalition[94] "in hopes that you will review it to see how incompetently our DEP is dealing with drilling wastewater."

- The Better Path Coalition's report dated December 2021 contains the following assertions, among others, about the spreading of conventional oil and gas wastewater on roads in Pennsylvania:

    - that in 2018, the PADEP "halted . . . the practice of spreading [oil and gas drilling] wastewater as a dust suppressant and deicer on Pennsylvania roadways, in response to a 2017 Environmental Hearing Board appeal."

    - that "conventional gas drillers spread 54,327 barrels or 2,281,747 gallons of . . . drilling wastewater on Pennsylvania roads between 2018, when the Department of Environmental Protection (DEP) declared the moratorium, and the end of 2020 [and that] [a]nother arm of the agency, the Bureau of Waste Management, provides drillers the loophole that has allowed them to keep spreading the waste."

    - that the so-called "Coproduct Determination Loophole" allows owners of a waste product to determine whether or not it can be beneficially used in place of a commercially available product.

    - that "[a]ccording to Oil and Gas Waste Reports from 2018 through 2020, at least 29 owners presumably determined for themselves that the wastewater was on par with commercial dust suppressants and deicers and used that as justification for continued road spreading."

    - that a Pennsylvania State University (Penn State) study that looked at the efficacy of road spreading with drilling wastewater found it to be far less effective than commercial products and, in some cases, worse than using no treatment.[95]

    - that a growing body of research has found oil and gas wastewater to pose a threat to aquatic life and human health due to its toxic, radioactive contents.

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[94] Better Path Coalition, The moratorium morass: How the halt to road spreading toxic oil & gas wastewater made Pennsylvania less safe, (Dec. 2021), accessed at: https://breatheproject.org/reports_and_studies/the-moratorium-morass-how-the-halt-to-road-spreading-toxic-oil-gas-wastewater-made-pa-less-safe/.

[95] Stallworth, A.M., et al, 2021, Efficacy of oil and gas produced water as a dust suppressant. Science of The Total Environment, 799 (10), (December 10, 2021). https://www.sciencedirect.com/science/article/abs/pii/S004896972104420X

- that drillers' self-determinations under the coproduct determination program are "an inconsistent mess of reliance on old data, irrelevant supporting documentation, and a lack of evidence of any thorough analysis."
- that decades-old problems with the management and tracking of oil and gas wastewater spread on Pennsylvania's roads have made it impossible to know where it has been spread and in what quantities, and reliance by drillers on the coproduct determination program has worsened these problems.
- in conclusion, that "DEP is not willing or able to clean up the messes you'll create if you approve the regulations" and that the Commission must "reject the proposed regs and give us the full fracking ban everyone now and future generations deserves."

- Catskill Mountainkeeper submitted a 2018 report by hydrogeologist Paul Rubin of HydroQuest, which includes as an addendum a November 2011 letter from Mr. Rubin to the PADEP Bureau of Waste Management on behalf of HydroQuest, DRN, and DCS, opposing the renewal of WMGR064, a waste management general permit authorizing oil and gas brine spreading on Pennsylvania roadways for dust suppression and de-icing.[96]
  - The primary HydroQuest submission (2018 report) includes data demonstrating that concentrations of contaminants in brines from non-shale formations may equal or exceed those in brines from the Marcellus and other shale formations. For example, "The high percentage of oil saturation present in Bradford Group produced waters may make its contaminant potential greater than those from the Marcellus Shale." (pp. 11, 15).
  - HydroQuest also asserts that the hazard to surface and ground water resources posed by road spreading of production brines has been described in the literature for some time: "This waste disposal technique jeopardizes the water quality of surface and groundwater resources and ignores treatment considerations (e.g., Baudendistel et al., 2015; Geza et al., 2013; Hum et al., 2005; Hussain et al., 2014; Lawrence et al., 1993 & 1995; Sookdeo, 2003; Balch et al., 2014; Silva et al., 2017; Oetjen et al., 2017).
  - HydroQuest's 2011 letter states in part, "Whether brine contaminants are applied on dry days, wet days, 50 or 200 feet from streams or houses, or in one concentration or another is largely irrelevant. The hydrology is simple and straight forward. Under wet hydrologic conditions, and with repeated applications, whether today, tomorrow, or in two months – the contaminants **will move** into our waterways, reservoirs, and aquifers (i.e., toward our drinking water supplies). Once significant precipitation occurs, brines will then be mobilized and transported away from source areas." (emphasis in original) (Addendum 2, p. 4).

[96] According to PADEP staff, WMGR064 was issued in 2000 (prior to the surge in Marcellus shale drilling activity that began in 2008). WMGR064 expired in September 2010. The HydroQuest comment was submitted as PADEP considered renewing or reissuing WMGR064. In response to substantial public comment opposing renewal, the permit remained expired.

RESPONSE (R-38)

Most of the comments received, including the Better Path and HydroQuest reports submitted by commenters, were directed at road-spreading of brines from conventional natural gas wells, an activity that is not addressed by the draft DRBC rule but which has been suspended in the Commonwealth by the Pennsylvania Department of Environmental Protection. By regulation, Pennsylvania banned the practice of road spreading of HVHF ("unconventional" in Pennsylvania terms) wastewater in 2016.[97]

The Commission acknowledges that road spreading of wastewater from conventional HVHF activities in Pennsylvania has occurred in the past and that such practices present risks to water resources.

The risks and resulting impacts of spreading oil and gas wastewater on roadways are described in detail at Section 2.3.2 Significant Risks to Water Resources and Section 2.3.3 Significant Impacts to Water Resources and their Uses, respectively, of the February 2021 CRD.

Research on the impacts of road spreading continues. Findings of a new study released by Penn State University on May 26, 2022 further demonstrate the potential adverse impacts on water resources that may result from road spreading of oil and gas wastewaters.[98] The researchers conducted a series of laboratory-scale experiments to evaluate the environmental impacts of several substances used as dust suppressants on roadways, including *conventional* oil and gas produced waters. Results showed that after application of oil and gas wastewater to the laboratory-scale roadways, runoff from simulated rainfall events contained concentrations of barium, strontium, lithium, iron, and manganese that exceed human-health based criteria and levels of radioactive radium that exceed industrial discharge standards.[99]

The Commission's final regulations at 18 C.F.R. Part 440 (the "Discharge Prohibition") prohibit the discharge of HVHF wastewater to waters or land within the Basin. The rule thus prohibits road spreading of HVHF wastewater within the Basin. Such wastewater is broadly defined to include any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of HVHF wastewater. However, prohibiting the discharge of brines from *conventional* drilling on land or waters of the Basin is beyond the scope of the Commission's proposed rule, published in November 2021, and thus could not be considered for inclusion in the final rule. The Commission has reviewed the reports of The Better Path and HydroQuest and is aware that the PADEP is currently investigating the issues they highlight and considering the latest findings of the Penn State research team.

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[97] *See* 25 Pa. Code §§ 78a.70("Production brines from unconventional wells may not be used for dust suppression and road stabilization.") and 78.70.a ("Production brines from unconventional wells may not be used for pre-wetting, anti-icing and de-icing.").
[98] Burgos, W., Ph.D., et al., Evaluation of Environmental Impacts from Dust Suppressants Used on Gravel Roads (May 26, 2022), accessed at:
https://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/PADEP_Final_Brine_Report.pdf.
[99] Id.

The Commission will continue to coordinate with the Commonwealth to review the scientific evidence regarding harm to water resources caused by road spreading of oil and gas production brines. The Commission may in the future consider whether additional regulation of the practice of applying conventional drilling brines to roadways is needed in the Basin.

4.2.1.10 Well Injection

STATEMENT OF CONCERN (SC-39)

Representative paraphrased examples from commenters concerned about HVHF waste injection and contamination of groundwater resources:

- Some commenters were concerned that if the Proposed Rulemaking were to be finalized, hydraulic fracturing wastewater would likely be permitted to be accepted into the Basin and not "discharged" to land or water but rather "disposed" of in a landfill, cavern or underground injection well. Citing the February 2021 CRD, they claimed that the proposed regulations do not clearly prohibit storage or disposal of HVHF wastewater via underground injection wells, as disposal could be characterized as a method of "containing" the contamination rather than an intentional "discharge."[100]

- Some commenters asserted that injection wells are possible, depending on how "disposal to water or land" is defined, which is unclear. Citing a 2016 study of an injection facility in West Virginia, they noted that injection of wastewater risks the migration of untreated wastewater to aquifers and surface water through leaks from the injection well and spills and accidental releases while being handled and that injection wells are causing earthquakes in Ohio and Oklahoma and in other locations and are not leak-proof, exposing groundwater and aquifers to contamination.[101]

- Commenters cited the findings of the study that included sampling in June 2014 of water in a tributary of Wolf Creek in West Virginia downstream from an injection disposal facility. They noted that results showed elevated conductivity (416 μS/cm) compared to background waters upstream (74 μS/cm). There were also elevated TDS, Ba, Br, Sr, Cl, Li and Na concentrations, while sediments downstream from the facility were enriched in Ra and had high bioavailable Fe (III) concentrations relative to upstream sediments.[102]

- "Here on the Ohio side of the Ohio River Basin we have witnessed excessive brine (fracking) waste being shipped from fracking wells in our state as well as from WV and PA, both of which have stricter regulations on fracking waste than OH. Our county (Washington) has the highest

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[100] DRBC, February 2021 CRD, p. 67.
[101] Akob, D.M., et al., Wastewater Disposal from Unconventional Oil and Gas Development Degrades Stream Quality at a West Virginia Injection Facility, Envtl. Sci. & Tech. 50 (May 9, 2016), 5517–5525, accessed at: https://pubs.acs.org/doi/pdf/10.1021/acs.est.6b00428.
[102] Partnership for Policy Integrity, Toxic Secrets: Companies Exploit Weak US Chemical Rules to Hide Fracking Risks (Apr. 7, 2016), accessed at: http://www.pfpi.net/toxic-secrets-companies-exploit-weak-us-chemical-rules-to-hide-fracking-risks. (The Commission notes that the cited article is unrelated to the substance of the comment, but suspects the correct citation would be to Akob, D.M., et al., *supra* note 100.)

amount (per barrel) of fracking waste and is among the top two in number of injection wells in the state. Not only have there been spills and leaks in our county, which have threatened drinking-water aquifers, but these injection wells, where brine waste is put in the ground under high pressure, have damaged oil and gas production wells."

RESPONSE (R-39)

The Commission acknowledges that the discharge of HVHF wastewater to the land via deep well injection presents risks to water resources. These risks were part of the justification for the Commission's decision in 2021 to prohibit HVHF in the Delaware River Basin and for its current rulemaking, which provides that "[n]o person may discharge wastewater from high volume hydraulic fracturing or HVHF-related activities to waters or land within the Basin." The Commission intends by this provision to prohibit the injection of HVHF wastewater into deep wells within the Basin.

If, as a commenter avers, the language used in the Commission's February 2021 CRD can be read to mean that the Commission deems underground injection of HVHF wastewater to be a method of "containing" HVHF wastewater and not as a "discharge" of such wastewater, this response is intended to eliminate any ambiguity on that point.

Please see the Commission's February 2021 CRD, Section 2.7.6 Underground Injection Wells for Disposal of HVHF Wastewater, for related content, including references to peer-reviewed science showing impacts to surface and groundwater resources linked to deep well injection of HVHF wastewater.

STATEMENT OF CONCERN (SC-40)

Paraphrased comments representative of those expressing concerns about depletion of groundwater as a result of deep well injection follow:

- Citing a 2018 publication, a commenter asserted that groundwater in the U.S. is being depleted not only by excessive withdrawals, but due to injection, and potentially contamination, from the oil and gas industry in areas of deep fresh and brackish groundwater.[103]
- Many commenters noted that disposal by deep well injection results in water being permanently removed from the hydrologic cycle.

RESPONSE (R-40)

The Commission agrees that the discharge of HVHF wastewater through deep well injection is depletive and permanently removes water from the hydrologic cycle. By prohibiting the discharge to land or waters of the Basin of wastewater from high volume hydraulic fracturing and HVHF related activities, the Commission is prohibiting the disposal of HVHF wastewater by deep will injection

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[103] Ferguson, G. et al., Competition for shrinking window of low salinity Groundwater, Envtl. Research Letters (Nov. 14, 2018), accessed at: https://iopscience.iop.org/article/10.1088/1748-9326/aae6d8.

within the Basin. In addition, because the Commission prohibited HVHF in hydrocarbon-bearing rock formations in the Basin, the discharge prohibition in practice affects only HVHF wastewater produced during HVHF activities outside the Basin.

4.2.2 Potential Impacts to Water Resources and Their Uses

4.2.2.1 Impacts to Drinking Water

Statement of Concern (SC-41)

The following paraphrased comments are representative of many expressing concern that allowing the importation of HVHF wastewater into the Delaware River Basin could impact sources of drinking water in the Basin:

- Many commenters expressed concern that the proposed regulations would allow HVHF wastewater to be imported into the Delaware River Basin and would threaten sources of drinking water for millions in the region.
- PSR commented that HVHF wastewater is highly toxic, noting that in addition to its high salinity and levels of radium 226 and 228, it may contain any of more than 100 known carcinogenic or endocrine disrupting substances used or generated by the hydraulic fracturing process, including the "forever chemicals" and known carcinogens PFAS and PFOA. Because the majority of the chemicals used in HVHF fluid have not been studied for human toxicity, PSR averred, they must be presumed to be dangerous.
- DRN expressed concern that the proposed regulations prohibit the importation of wastewater produced by HVHF only when an associated discharge to land or water is proposed. They said pathways for HVHF pollution would nevertheless exist through wastewater processing systems that don't strictly "discharge to water or land" and that other pathways could include leaks and spills resulting from storage, handling, transport, and "beneficial use," including road spreading, of this material. DRN averred that stormwater runoff could convey inadvertently released HVHF wastewater into sources of drinking water.
- DRN also said that exemptions for the oil and gas industry from federal and state environmental laws and regulations could apply to facilities within the Basin that undertake to treat, store, transfer, or otherwise handle HVHF wastewater, and called the potential risks to drinking water "untenable."
- A commenter stated that the municipal water purification systems for drinking water withdrawn from the river are designed to remove harmful microorganisms (pathogens) and particulate matter but cannot remove the compounds used in hydraulic fracturing fluids, and further, that the hydraulic fracturing industry has a history of not disclosing all the components in their hydraulic fracturing fluids, making it impracticable to detect their presence in drinking water.
- Citing a 2015 report, PSR asserted that analysis of discharged effluents from three brine treatment sites in Pennsylvania and a spill site in West Virginia show elevated levels of halides (iodide up to 28 mg/L) and ammonium (12 to 106 mg/L) that mimic the composition

of oil and gas wastewater (OGW) and mix conservatively in downstream surface waters. They were concerned that bromide, iodide, and ammonium in surface waters can promote the formation of toxic brominated-, iodinated-, and nitrogen disinfection byproducts during chlorination at downstream drinking water treatment plants. They pointed to findings of the study indicating that discharge and accidental spills of OGW to waterways pose risks to human health.[104]

Response (R-41)

The Commission's February 2021 CRD, at Section 2.3.3 Significant Impacts to Water Resources and their Uses, describes in detail the risks that HVHF and related activities pose to groundwater and surface water sources used for public and private drinking water. These water supply sources are vulnerable to releases of chemicals and highly contaminated fluids from spills and accidents; migration of fluids including gases; inadequate wastewater treatment; improper wastewater storage or disposal; wastewater reuse on roadways; and other related activities and events. The Commission also acknowledges that the potential presence of PFAS in HVHF wastewater and the potential formation of disinfection byproducts downstream from centralized waste treatment facilities (CWTs) treating HVHF wastewater are legitimate concerns when the likelihood of HVHF wastewater releases to the environment (treated or untreated) is high. The risks associated with human exposure to PFAS in drinking water are described at R-22 and R-23 above.

However, the Commission also recognizes, based on data and information described at length in Response R-25 of this CRD and throughout Section 4.2.1 Potential Risks to Water Resources, above, that the risks of these impacts are lower in areas where HVHF is prohibited than in areas of active HVHF shale-gas development. Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater within the Basin, it anticipates that only low volumes of HVHF wastewater will be transported to or through the Basin, or stored, processed, or recycled within the Basin. The likelihood of HVHF wastewater HVHF releases within the Basin and the corresponding risk of impacts to the Basin's drinking water resources resulting from such releases are in the Commission's view effectively reduced by these measures.

4.2.2.2 Impacts to Aquatic Life

Statement of Concern (SC-42)

Comments representative of those expressing concern that importing HVHF wastewater into the Delaware River Basin may impact water quality and aquatic life follow:

- Commenters expressed concern that HVHF wastewater is highly saline, contains toxic chemicals and substances, and is radioactive. They asserted that if it is brought into the Basin, it will be released to the environment and will negatively impact habitats, diversity, and

[104] Harkness, J.S., et al., Iodide, Bromide, and Ammonium in Hydraulic Fracturing and Oil and Gas Wastewaters: Environmental Implications Envtl. Sci. & Tech., 3 (Jan. 14, 2015), 49.

trophic levels of the aquatic ecosystems, impairing water quality and harming aquatic life, from microorganisms up through predatory fish and bird species. They averred that sport and commercial oyster, clam, and mussel fisheries that make up part of the region's human food chain would be contaminated.

- Commenters said that proof that controls on the toxic pollution from HVHF wastewater are ineffective can be found in the many studies and reports examining the impacts of hydraulic fracturing-related spills and leaks on water resources, the longevity of the contaminants in sediments, soil, and streams, and the adverse health effects in humans, fish and aquatic life.
- Commenters cited examples of such impacts, including a relatively small spill into Acorn Creek in Kentucky that "killed virtually all aquatic wildlife" in a significant portion of the creek, and a spike in endocrine-disrupting activity in a West Virginia stream that was traced by a University of Missouri research team to an upstream facility that stores hydraulic fracturing wastewater. In the latter case, the commenters noted, levels detected downstream of the wastewater storage facility were above levels known to create adverse health effects and alter the development of fish, amphibians, and other aquatic organisms.[105]

RESPONSE (R-42)

The Commission's February 2021 CRD at Section 2.3.3 Significant Impacts to Water Resources and their Uses describes in detail the risks that HVHF and related activities pose to surface water quality and aquatic life. Surface waters are vulnerable to releases of chemicals and highly contaminated fluids from spills and accidents; migration of fluids including gases; inadequate wastewater treatment; improper wastewater storage or disposal; wastewater reuse on roadways; and other related activities. The Commission also acknowledges that peer-reviewed research published in 2021 shows further evidence of HVHF wastewater toxicity, exposure risks, and persistent environmental impacts, and documents changes to water quality across some regions where shale gas is developed in the U.S.[106]

However, the Commission also recognizes, based on data and information described at length in Response R-25 of this CRD and throughout Section 4.2.1 Potential Risks to Water Resources, above, that the risks of these impacts are lower in areas where HVHF is prohibited than in areas of active HVHF shale-gas development. Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater within the Basin, it anticipates that only low volumes of HVHF wastewater will be transported to or through

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[105] Kassotis, C. D., et al., Endocrine disrupting activities of surface water associated with West Virginia oil and gas industry wastewater disposal site, Sci. of the Total Env't, 557-558 (July 1, 2016), 901–10.

[106] Aghababaei et al., *supra* note 38. 2021; Bain et al., Oil and gas wastewater as road treatment: radioactive material exposure implications at the residential lot and block scale, Envtl. Research Communications, 3 (Nov. 18, 2021), accessed at: https://iopscience.iop.org/article/10.1088/2515-7620/ac35be/pdf; Bonetti et al., Large-sample evidence on the impact of unconventional oil and gas development on surface waters, Sci. 373:6557 (Aug. 20, 2021), 896–902; Cozzarelli et al., Sci. of the Total Env't, 755:1 (Feb. 10, 2021), accessed at: https://www.sciencedirect.com/science/article/pii/S0048969720364391; Lu, et al., 2021, *supra* note 39; O'Dell et al., 2021, *supra* note 37; Vandenburg, et al., Endocrine disrupting chemicals: strategies to protect present and future generations, Expert Review of Endocrinology & Metabolism, 16:3 (May 11, 2021).

the Basin, or stored, processed, or recycled within the Basin. The likelihood of HVHF wastewater releases within the Basin and the corresponding risk of impacts to the Basin's water resources and aquatic life resulting from such releases are in the Commission's view effectively reduced by these measures.

STATEMENT OF CONCERN (SC-43)

Paraphrased comments representative of those expressing concern that the exportation of water from the Delaware River Basin for HVHF activities may impact water quality and aquatic life follow:

- Citing a 2004 report by the Instream Flow Council, many commenters asserted that the export of water from the DRB is a depletive use that can have far-reaching adverse environmental impacts on the water resources of the Basin, and that the impacts of water withdrawals from streams are not adequately regulated by most agencies.[107]
- DNR expressed concern that these impacts include diminishment of groundwater, aquifers, wetlands, seeps, springs, streams, and the main stem river, and sedimentation from truck traffic, all of which may have cascading ecologic and hydrologic impacts, including harm to water quality, benthic and aquatic life, and other wildlife.
- DNR also commented that exportations of water for HVHF would result in the degradation of aquatic habitat qualities, including reduced oxygen, temperature changes, changes in rate and volume of flow, and changes to stream morphology, that may reduce or eliminate existing uses and produce measurable change to waters classified by the Commission as Special Protection Waters.
- Citing reports by the Instream Flow Council and the NYSDEC, many commenters claimed that the loss of flow in waterways results in a cascade of degrading impacts that can harm in-stream habitats, disrupt species' life cycles, reduce biodiversity, and destroy ecological flow regimes.[108]

RESPONSE (R-43)

The Commission does not agree that the final regulations will result in an increased rate of depletive water uses or water loss generally in the Basin. The Commission in R-6 and R-7 above explains to the contrary, how the final rules at Section 2.30 of the Water Code will support conservation and preservation of the Basin's water resources by limiting exportations of water from the Basin

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[107] Annear, T., et al., Instream Flows for Riverine Resource Stewardship, Revised Edition, Instream Flow Council (2004), 178.

[108] "Potential impacts that should be evaluated due to decreased flow include loss of habitat, direct impacts on sensitive life stages, loss of mobility for aquatic organisms, thermal impacts, decreased dissolved oxygen, impacts on wetland hydrology, impacts on recreation and fishing, and decreased quantity of water available for public water supply. Any new flow-related permit conditions should give priority to the best usage of domestic and municipal water supply." Extracted from: NYSDEC, Division of Water Technical and Operational Guidance Series, Incorporation of Flow-Related Conditions in Water Withdrawal Permits, (Apr. 12, 2017), accessed at: https://www.dec.ny.gov/docs/water_pdf/flowtogsfinal.pdf.

generally. Under the final rule, proposed exportations are eligible for consideration by the Commission only if the sponsor demonstrates the exportation is required to serve a straddled or adjacent public water system, that the exportation is required to meet public health and safety needs on a short-term or emergency basis, or that the water consists of wastewater that may not lawfully be discharged to a public wastewater collection system and is being exported for treatment, disposal or both at a waste management facility that has all required state and federal approvals to lawfully receive it. Potential exportations must satisfy additional criteria, including those designed to protect aquatic species. The Commission's final rule is designed to ensure that exportations of water from the Basin do not result in the impacts to surface water and aquatic life described in the comments, and that the waters of the Basin are conserved and preserved for current and future uses in accordance with the Comprehensive Plan.

STATEMENT OF CONCERN (SC-44)

Commenters said that by providing Delaware Basin water to the natural gas industry, the draft regulations will encourage more hydraulic fracturing, which will result in the release of more methane to the atmosphere and contribute to climate change, which in turn will affect river flows, temperature, seasonal variability, reservoir levels, the concentration of pollutants in both ground and surface water, the habitats, health and diversity of flora and fauna, recreation, economic values, and human health.

RESPONSE (R-44)

While the Commission and Commission staff share significant concerns about climate change and its impact upon the water cycle, for the reasons set forth in R-6 and R-7 above, and as noted in R-8, the Commission does not agree that the proposed rule supports additional high volume hydraulic fracturing or thereby contributes to climate change and its attendant impacts. Please also see Responses R-57 and R-58 in Section 5.3 Climate Change below, for additional discussion of this topic.

4.2.2.3 Impacts to Human Health

STATEMENT OF CONCERN (SC-45)

Many commenters expressed concerns about the impacts on human health of exposure to HVHF and related activities.[109] One commenter asked, “Has DRBC identified human health and environmental toxicities associated with this wastewater?”

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[109] While some comments cited scientific studies of human health impacts specifically related to exposure to wastewater from high volume hydraulic fracturing and HVHF-related activities, other commenters cited scientific studies of human health impacts that are related to exposure to HVHF activity generally, without identifying the specific HVHF activity that is or may be the source of the exposure. The rules amending Section 2.30 of the Water Code relate only to the importation of water, including wastewater, into the Basin, and the exportation of water, including wastewater, from the Basin. The rules amending the Commission’s Special Regulations at Part 440 prohibit the discharge of HVHF wastewater. In considering and addressing these

RESPONSE (R-45)

The Commission's February 2021 CRD at Section 2.3.2 Significant Risks to Water Resources, Section 2.3.3 Significant Impacts to Water Resources and Their Uses, and Section 2.6.1 Public Health, recognizes the human health impacts associated with HVHF wastewater that have been documented in the scientific and public health literature. The potential human health impacts in the Basin from exposure to HVHF wastewater are substantially reduced by the prohibition adopted by the Commission in February 2021 prohibiting HVHF in hydrocarbon-bearing rock formations in the Basin and the prohibition on the discharge of wastewater from HVHF and HVHF related activities to the land and waters of the Basin adopted in this rulemaking.

STATEMENT OF CONCERN (SC-46)

Many commenters expressed concerns about the toxicity and radioactivity of HVHF wastewater and specific effects of exposure to HVHF wastewater on human health. Paraphrased comments representative of these follow:

- Commenters noted that in Resolution No. 2021-01, adopting the Commission's final rule prohibiting HVHF in hydrocarbon-bearing formations in the Basin (in language repeated in the final rule), the Commission determined that "[c]ontrolling future pollution by prohibiting high volume hydraulic fracturing in the Basin is required to effectuate the Commission's Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health . . . ."
- Many commenters expressed concern that the proposed regulations would allow toxic hydraulic fracturing wastewater to be imported into the Basin, threatening human health in the region.
- Commenters asserted that, according to the EPA, there are more than 1,000 known chemicals used in hydraulic fracturing, of which many have serious and well-documented public health impacts, and many more are considered "proprietary" and have not been disclosed.
- PSR commented that HVHF wastewater is highly toxic, noting that in addition to its high salinity and levels of radium 226 and 228, it may contain any of more than 100 known carcinogenic or endocrine disrupting substances used or generated by the hydraulic fracturing process, including the "forever chemicals" and known carcinogens PFAS and PFOA. Because the majority of the chemicals used in HVHF fluid have not been studied for human toxicity, PSR averred, they must be presumed to be dangerous.
- DRN stated that PFAS are called "forever chemicals" because they never biodegrade and they persist indefinitely in the environment; and they are highly water soluble and bioaccumulative. Citing state websites, DRN noted that PFAS accumulate in the natural world (including in fish and wildlife, hence the "Do Not Eat" fish consumption advisory issued by

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comments, the Commission notes the respective scopes of the activity or activities under investigation within the studies cited with regard to the HVHF activity or activities under investigation.

PADEP due to PFAS in the Neshaminy Creek[110] and New Jersey's recent fish consumption advisories covering PFAS statewide[111]) and in the human body, are highly toxic even in very tiny doses, and are linked to several diseases and adverse health conditions, including cancers. The commenter further stated that the fetus, infants, children, women of childbearing age, and immune compromised individuals are the most vulnerable to PFAS health damages.

- Commenters expressed concern that hydraulic fracturing wastewater contains or can cause the formation of chemicals such as disinfection byproducts, including brominated trihalomethanes (THMs), which are harmful to the environment and human health, and that: the presence of such chemicals has been correlated with increased diseases and infirmities such as birth defects, bladder and other cancers; that certain chemicals found in wastewater are also known to disrupt the endocrine system with potential health consequences such as spontaneous abortions, fetal death and irregular fertility cycles; and that these chemicals can interfere with both human and animal reproduction and may have long-term consequences for agriculture and food production, especially when such chemicals begin to enter the food chain at or near the affected areas of discharge.

- Commenters were concerned that HVHF wastewater contains toxic heavy metals, hydrocarbons/volatile organic compounds (VOCs), radioactive elements and high levels of salt (which adds to corrosiveness). They noted that VOCs, including ethylbenzene, toluene and xylene, cause liver, kidney and brain toxicity; disrupt endocrine systems, and are carcinogenic and teratogenic. They expressed concern that these chemicals not only can cause cancer and disrupt the endocrine system, but also may affect the nervous, immune and cardiovascular systems, defense sensory organisms and the respiratory system.

- A commenter stated that HVHF wastewater has been found to contain the pesticide atrazine; 1,4-dioxane, an organic compound that is irritating to the eyes and respiratory tract; toluene, which at low exposure has health effects like confusion, weakness, and loss of vision and hearing; polycyclic aromatic hydrocarbons, which have been linked to skin, lung, bladder, liver and stomach cancers; and that over 1,000 toxic chemicals have been found in HVHF wastewater.

- Citing a 2018 report by the Partnership for Policy Integrity, many commenters stated that wastewater is one of the top three materials spilled in hydraulic fracturing activities, including during transportation of wastewater, and that health effects associated with chronic oral exposure to these chemicals include carcinogenicity, neurotoxicity, immune system effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity.[112]

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[110] PADEP, Neshaminy Creek Fish Advisory, accessed at: https://www.dep.pa.gov/About/Regional/SoutheastRegion/Community%20Information/Pages/Neshaminy-Creek-Fish-Advisory.aspx.

[111] NJDEP, Fish Smart Eat Smart NJ (Aug. 26, 2021), accessed at: https://www.nj.gov/dep/dsr/njmainfish.htm.

[112] Horwitt, D., J.D., Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals Is a Looming Risk for Delaware River Basin, Pennsylvania Communities, Partnership for Policy Integrity (Sept. 11, 2018), 4, accessed at: https://www.pfpi.net/wp-content/uploads/2018/09/PASecretFrackingChemicalsReportPFPI9.10.2018.pdf.

- Commenters quoted a peer-reviewed journal article published in 2011 that examined chemicals in hydraulic fracturing waste, for the statement: "The technology to recover natural gas depends on undisclosed types and amounts of toxic chemicals. A list of 944 products containing 632 chemicals used during natural gas operations was compiled. Literature searches were conducted to determine potential health effects of the 353 chemicals identified by Chemical Abstract Service (CAS) numbers. More than 75% of the chemicals could affect the skin, eyes, and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40-50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations. These results indicate that many chemicals used during the fracturing and drilling stages of gas operations may have long-term health effects that are not immediately expressed."[113]

- A commenter cited findings of a group called The Endocrine Disruption Exchange (TEDX), referenced in the report "Hydraulic Fracturing and Your Health: Water Contamination" by PSR.[114] TEDX "examined the toxicity of 353 chemicals used in fracking and found that 25 percent can cause cancer and mutations; 37 percent affect the endocrine system; 40 to 50 percent affect the brain, kidneys, and nervous, immune, and cardiovascular systems; and more than 75 percent affect other organs and organ systems."

- The commenter opined that the additional substances entrained in HVHF wastewater are the kinds that "everyone would rather leave undisturbed deep underground where they come from." They were concerned that these substances include radioactive and highly carcinogenic substances like: radon and radium (radioactive elements for which long-term exposure via ingestion or inhalation increases the risk of developing lymphoma, leukemia and aplastic anemia, and which can increase the risk of cancer in all tissues and organs.); arsenic (which can cause partial paralysis, blindness, and cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate); strontium (linked to bone cancer, cancer of the soft tissue near the bone, and leukemia); and methane, ethane, and propane (which may cause rapid breathing, rapid heart rate, clumsiness, emotional upset and fatigue, and at greater exposure, may cause vomiting, collapse, convulsions, coma and death).

- Commenters concerned that the contaminants found in hydraulic fracturing fluid and hydraulic fracturing wastewater pose significant health and environmental risks noted that the EPA found in its 2016 report on hydraulic fracturing and drinking water that 1,606 chemicals were associated with hydraulic fracturing, including 599 chemicals that had been detected in wastewater.[115] The commenters noted that the agency found high-quality information on health effects for only 173 of these chemicals, and the available information was troubling. They further noted that EPA found that health effects associated with chronic oral exposure to these chemicals include carcinogenicity, neurotoxicity, immune system

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[113] Colborn, T. et al., Natural Gas Operations from a Public Health Perspective, Int'l Journal of Human and Ecological Risk Assessment, 17 (Jun. 8, 2010), 1039–56.
[114] PSR, Hydraulic Fracturing and Your Health: Water Contamination, accessed at: https://www.psr.org/wp-content/uploads/2018/09/fracking-and-water-contamination.pdf (citing T. Colborn et al., *supra* note 112).
[115] EPA, Hydraulic fracturing for oil and gas: impacts from the hydraulic fracturing water cycle on drinking water resources in the United States (Dec. 2016), 9-1, accessed at: https://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=332990.

effects, changes in body weight, changes in blood chemistry, liver and kidney toxicity, and reproductive and developmental toxicity[116] and that some of the chemicals with these toxic effects, such as benzene, were found in both hydraulic fracturing chemicals and wastewater,[117] while others such as radium, were found only in wastewater.[118]

- DCS stated that "The Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking,"[119] developed and periodically updated by the Concerned Health Professionals of New York contains a massive list of human health impacts of hydraulic fracturing, including both from the various industrial processes involved and the resulting waste.[120]

Response (R-46)

The Commission acknowledges that HVHF wastewater contains substances that are toxic or radioactive, that the toxicity of many of the substances is unknown, and that the identities of some substances are not disclosed. The Commission is aware of the wide range of impacts to human health that can result from exposure to chemicals and radiation present in HVHF wastewater. These are among the concerns weighed by the Commission in reaching its decision to prohibit HVHF in the Basin in 2021, and to prohibit the discharge of HVHF wastewater by this rulemaking.

As described in more detail in Response R-25, the Commission also recognizes that the risks of impacts to human health from exposure to contaminants present in HVHF wastewater are lower in areas where HVHF is prohibited than in areas of active HVHF shale-gas development. Because the Commission has prohibited HVHF in hydrocarbon bearing formations in the Basin and is now prohibiting discharges of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin, and that the likelihood of impacts to the Basin's water resources resulting from spills, leaks, or other releases from such activities will be low.

Please see the Commission's February 2021 CRD at Section 2.3.3 Significant Impacts to Water Resources and Their Uses and Section 2.6.1 Public Health for additional discussion of these concerns, including in particular, regarding the formation of disinfection byproducts (DBPs) in drinking water as a result of HVHF wastewater discharges, and the impacts of DBPs on human health.

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116 *Id*.
117 *Id*. at Table G-1e. Available qualitative cancer classifications for chemicals reported to be used in hydraulic fracturing fluids (noting that chemicals in italics including benzene were found in both hydraulic fracturing fluids and wastewater).
118 *Id*. at Table G-2a. Chemicals reported to be detected in produced water, with available chronic oral RfVs, OSFs, and qualitative cancer classifications from United States federal sources.
119 Concerned Health Professionals of NY, Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure, Seventh Edition (Dec. 2020), accessed at: https://www.psr.org/wp-content/uploads/2020/12/fracking-science-compendium-7.pdf (the Commission notes the Eighth Edition of this Compendium (Apr. 2022) is accessible at: https://concernedhealthny.org/wp-content/uploads/2022/04/CHPNY-Compendium-8-FINAL.pdf).
120 *Id*.

Also see above, Sections 4.2.1.3 Waste characterization/ toxicity/ radioactivity; and 4.2.1.4 Chemical Disclosure for additional content regarding chemical disclosure and concerns about toxicity, radioactivity, and PFAS in HVHF wastewater.

STATEMENT OF CONCERN (SC-47)

Many commenters expressed concerns about the potential for human health impacts on people living near HVHF-related activities, and many cited published studies or anecdotal evidence showing an association between proximity to HVHF activity and human health impacts.

Paraphrased and quoted comments representative of those expressing concern about the potential for human health impacts on people living near HVHF-related activities follow:

- Citing an article published in Rolling Stone magazine, a commenter was concerned that no requirement currently exists for properly testing HVHF wastewater, or the people or machinery that come into contact with it at any stage of the hydraulic fracturing process, for radioactivity, or for any of the other highly toxic substances it may contain, and that people living near hydraulic fracturing wells or disposal sites, or near the waters into which these wastewaters are discharged, are getting sick and even dying.[121]
- A commenter cautioned that, "Unintended consequence of injection in East Texas were many reports of birth defects from people down the roads from those injection wells, and I witnessed that firsthand. It was absolutely sad and terrifying, but nonetheless allowed to happen."
- A commenter stated, "As an obstetrician and maternal fetal medicine physician I am very concerned about fracking activities. Studies have shown an association between fracking activities and pregnancy harms, including decreased birthweight and preterm birth. Additionally, a number of chemicals used in fracking and found in fracking wastewater are "endocrine disrupting compounds" (EDCs), which can impact the development of fetal boys' genitalia and cause other health harms."[122]
- A commenter stated: "I have personally seen the damage caused by fracking in Demick [sic], PA where literally hundreds of wells have been drilled. There were unusually high cases of asthma, unexplained nosebleeds, and cancer."

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[121] *See* Nobel, J., America's Radioactive Secret, Rolling Stone Magazine (Jan. 21, 2020), accessed at: https://www.rollingstone.com/politics/politics-features/oil-gas-fracking-radioactive-investigation-937389/.
[122] Casey, J.A., et al., Unconventional natural gas development and birth outcomes in Pennsylvania, USA, Epidemiology, 27:2 (Mar. 2016), 163–72, accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4738074/pdf/nihms-728721.pdf;
Stacy, S.L., et al., Perinatal outcomes and unconventional natural gas operations in Southwest Pennsylvania, PLOS One, 10:6 (Jun. 3, 2015), accessed at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4454655/pdf/pone.0126425.pdf.

RESPONSE (R-47)

Under the Commission's regulation finalized in 2021 prohibiting HVHF in hydrocarbon-bearing formations in the Basin and the current rulemaking prohibiting the discharge of HVHF wastewater to land or waters within the Basin, Basin residents will not reside in proximity to HVHF wells or HVHF wastewater discharge sites, including injection wells. In the Commission's view, the risk to Basin residents of exposure to HVHF wastewater is sufficiently reduced by these measures to minimize human health impacts.

STATEMENT OF CONCERN (SC-48)

A comment representative of many expressing concern about the impacts on human health of exposure to air pollution from thermal oxidation, a potential treatment for HVHF wastewater, follows:

- "Human health effects of air pollution that can be caused by thermal oxidation of hazardous waste include decreased lung function, inflammatory responses, diminished lung function and lung function growth in children, increased cardiovascular events, genotoxicity, and reproductive effects. Despite these known impacts, very little study has been done about the health effects of thermal oxidation and combustion of hazardous wastes. It is wrong to use people as guinea pigs by blindly exposing them to toxins."

RESPONSE (R-48)

Because the Commission has prohibited HVHF in hydrocarbon bearing formations in the Basin and is now prohibiting discharges of HVHF wastewater within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin, and that the likelihood of impacts on human health from exposure to HVHF wastewater associated with these activities is thus effectively reduced. Comments regarding thermal oxidation of HVHF waste are also discussed above, in Section 4.2.1.2 Air Pollution and Air Deposition of this CRD.

4.3 Section 440.2 – Definitions

STATEMENT OF CONCERN (SC-49)

Paraphrased comments representative of those concerning the meaning of "discharge" in proposed new Section 440.4 of the Commission's Special Regulations at 18 C.F.R Part 440 follow:

- Commenters opined that the word "discharge" should be defined for purposes of Section 440.4 and that the definition should expressly include discharges to disposal wells, caverns, and landfills.
- NRDC asked the Commission to define the term "discharge" to encompass "spilling, leaking, pumping, pouring, spreading, spraying, emitting, emptying, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of

barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant)," which would make it similar in scope to the definition of "release" in the federal Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA").

- Commenters also suggested that the rule should, but as drafted does not, prohibit air emissions of pollutants at processing facilities and the reuse of HVHF wastewater in manufacturing, as cooling water for power plants, and in refineries or other systems lacking a permitted "discharge".
- Commenters objected that the rule would allow the storage and transfer of wastewater within the watershed and that it does not prohibit "beneficial uses" of HVHF wastewater, including the integration of such wastewater into construction materials and other commercial products.

RESPONSE (R-49)

In the Commission's view, the meaning of Section 440.4 was clear in the rule as proposed. However, the inclusion of a definition of "discharge" in combination with the definitions of "Wastewater from HVHF and HVHF-related activities" and "HVHF-related activities" undoubtedly makes the meaning and intent of the rules more explicit. The Commission has included in the final rule the following new definition:

> *Discharge of wastewater from HVHF and HVHF-related activities* is an intentional or unintentional action or omission resulting in the releasing, spilling, leaking, pumping, pouring, emitting, emptying, spreading, spraying, injecting, leaching, dumping, or disposing of such wastewater to waters or land within the Basin, and including the abandonment or discarding of barrels, containers, and other receptacles containing such wastewater.

The new definition makes clearer that activities about which many commenters expressed concern are prohibited by the final rule. These include, among other things:

- discharge of HVHF wastewater to waters or land within the Basin;
- road spreading of HVHF wastewater (*see* Section 4.2.1.9, Response R-38 of this CRD for a discussion of road spreading);
- injection of HVHF wastewater into deep wells within the Basin (*see* discussion in Section 4.2.1.10 of this CRD);
- disposal of HVHF wastewater in Basin landfills;
- discharge of leachate from any landfill in the Basin that accepts HVHF waste after the effective date of the final regulations, including after treatment at an onsite or off-site leachate or wastewater treatment plant (*see* discussion in Section 4.2.1.8 of this CRD); and
- spills and leaks during transport, transfer, or storage of HVHF wastewater within the Basin if not fully captured by a containment system in place throughout the duration of

the spill or leak and thereafter promptly removed or remediated (*see* Section 4.2.1.5 above concerning transport, leaks and spills, and Section 4.2.1.7 concerning waste storage and recycling).

The final rule does not:

- regulate air emissions from HVHF activities (see Section 4.2.1.2 for a discussion of air emissions and air deposition);
- categorically prohibit the transfer of HVHF wastewater into the Basin when no resulting discharge is proposed; or
- regulate the transportation and storage of HVHF materials, which are regulated under detailed state and federal programs focused on these activities.

Notably, PADEP has confirmed that with one exception,[123] no beneficial use permits are currently in effect or pending that include the use of HVHF wastewater as a construction material or commercial product, or as an ingredient in the manufacturing of a construction material or commercial product. The Commission has not proposed and is not at this time considering rules of this kind.

Statement of Concern (SC-50)

Commenters suggested that the definition of "high volume hydraulic fracturing" should be deleted and replaced with a definition that includes all "hydraulic fracturing."

Response (R-50)

The Commission has evaluated and made a determination only about the risks and impacts to water resources of the Basin associated with high volume hydraulic fracturing (HVHF) and HVHF wastewater. Based on findings set forth at length in the Commission's February 2021 CRD, the Commission has prohibited HVHF within the Basin and is now prohibiting the discharge of wastewater from HVHF and HVHF-related activities. Activities that do not meet the definitions in Section 440.2 of the Commission's Special Regulations at 25 C.F.R. Part 440 are not covered by these prohibitions. The Commission's Notice of Proposed Rulemaking and draft rule addressed HVHF, not other hydraulic fracturing. The definition of high volume hydraulic fracturing has not been replaced or revised.

Statement of Concern (SC-51)

A commenter stated that waste from hydraulic fracturing is not defined as hazardous waste in some jurisdictions.

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[123] The sole exception is General Permit WMGR123, which authorizes the treatment, storage and transfer of oil and gas liquid waste for beneficial use in the hydraulic fracturing of additional oil and gas wells. Because HVHF in hydrocarbon-bearing rock formations is not permitted in the Delaware River Basin (*see* 18 C.F.R. 440.3(b)), these uses are expected to be rare within the Basin.

RESPONSE (R-51)

The Commission has not proposed and is not now adopting any system for classifying solid wastes as "hazardous" or "non-hazardous." The prohibition on discharges to land or waters of the Basin of wastewater from high volume hydraulic fracturing and HVHF-related activities will nevertheless avoid injury to waters of the Basin from HVHF wastewater, protect the public health, and preserve the waters of the Basin for uses in accordance with the Commission's Comprehensive Plan.

STATEMENT OF CONCERN (SC-52)

PennFuture suggested that the Commission should clarify the definition of "Fracking Wastewater" to specifically include produced water and flowback water.

RESPONSE (R-52)

The term "fracking wastewater" did not appear in the proposed rule and is not used in the final rule. The term "wastewater from HVHF and HVHF-related activities," as adopted, is defined at Section 440.2 as:

> (1) Any wastewater, brine, or sludge containing chemicals, naturally occurring radioactive materials, heavy metals or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities; (2) Leachate from solid wastes associated with HVHF-related activities, except if the solid wastes were lawfully disposed of in a landfill within the Basin prior to the effective date of this rule; and (3) Any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of the wastewater described in paragraphs (1) and (2) of this definition."

Part (1) of the definition was revised slightly from the proposed version for clarity. This definition, both as proposed and as now adopted, clearly encompasses "produced water" and "flowback water," both of which constitute "any wastewater, brine . . . or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities."

STATEMENT OF CONCERN (SC-53)

Commenters acknowledged that the Commission has specifically included in the proposed definition of wastewater, "leachate from solid wastes associated with HVHF-related activities," but they objected to the express exclusion of solid wastes "lawfully disposed of in a landfill within the Basin prior to the effective date of this rule." The commenters averred this falls short of protecting the Basin's water resources from "the toxic, harmful, radioactive, and forever chemicals" that will continue to contaminate leachate from landfills that accepted solid wastes from HVHF prior to the effective date of the rules.

Response (R-53)

Landfill operators who lawfully accepted HVHF wastes prior to the effective date of the rule have reasonably relied on federal and state laws pertaining to disposal of these wastes and the management of landfill leachate. By prohibiting discharges to Basin waters or land of leachate from landfills that accept HVHF solid waste *after* the rule becomes effective, the Commission is substantially reducing the risk of adverse impacts on the Basin's water resources from this practice without unnecessarily burdening owners and operators of solid waste facilities who reasonably relied on government approvals.

Statement of Concern (SC-54)

The NRDC proposed:

- that the term "waters" in the phrase "waters or land within the Basin" in new Section 440.4 of the Commission's Special Regulations at 18 C.F.R. Part 440 be replaced with the term "Basin water," as defined in the proposed version of Section 2.30.1 of the Water Code.
- that the term "waters . . . in the basin" should be expanded to include "both surface and groundwater bodies, part or all of which are located in the basin."
- that the prohibition in new Section 440.4 be expanded to encompass discharging *and storing* wastewater from hydraulic fracturing and related activities.

Response (R-54)

The commenter seeks to broaden the prohibition effected by Section 440.4(b). It is unclear how the commenter's first suggestion would accomplish this purpose. The suggestion has not been accepted.

The commenter's second suggestion would expand the meaning of "waters . . . in the Basin" (a phrase that does not appear in the proposed or final regulations) to expressly include groundwater that may migrate beyond the Basin's boundary, a boundary that is defined by surface water drainage divides. The Commission acknowledges that groundwater may migrate beyond the boundaries of surface drainages. If the receiving body of a prohibited discharge is groundwater within the Basin, the discharge is prohibited by the regulation. The DRBC has authority to regulate activity in the Susquehanna River Basin or in other regions outside the Delaware River Basin only when "such action may be necessary or convenient to effectuate its powers or duties within the Basin . . . and only upon the consent of the state in which it proposes to act." Compact, § 2.7. The commenter has not suggested, and the Commission has not found, that these conditions for exercising the Commission's power outside the Basin are satisfied.

The storage of HVHF wastewater is not prohibited for reasons discussed in Section 4.2.1.7 of this CRD.

5. RESPONSES TO COMMENTS – OTHER

5.1 Section 4.5 of the Water Quality Regulations

There were no specific comments on the proposed revisions to Section 4.5 of the Water Quality Regulations.

5.2 Coordination with other Regulators

STATEMENT OF CONCERN (SC-55)

Quoted and paraphrased comments representative of those critical of the proposed rule on grounds that the DRBC—either alone or in cooperation with PADEP or other co-regulators—lacks the ability to effectively implement the proposed rule follow:

- "The Commission will have no control over [PA]DEP's awarding [10-year general permits for the processing and beneficial use of oil and gas liquid waste]. I urge the Commission to have a conversation with the Pennsylvania DEP to understand these permits and what is at risk for the Basin should waste be imported to the Basin under these permits."
- "If hydraulic fracking were permitted in the Pennsylvania area of the Basin, the staffing, management, inspection resources for the activity would be in PaDEP-Office of Oil and Gas Management (OGM.) This Department, and particularly OGM, are insufficiently staffed for the task. This Department is not sufficiently funded by Pennsylvania (there is no natural gas severance tax as is done in other major natural gas producing states) and Pennsylvania taxpayers are not going to pay for this overhead expense. Therefore, if fracking activity were allowed, DRBC would not have a viable collaborator to oversight of fracking activity in PA."
- "Pennsylvania does not require an individual NPDES permit for gas well sites. While the DRBC's draft regulations do not apply to gas extraction wells, which are banned in the watershed, the lax regulatory approach to stormwater runoff from oil and gas sites speaks volumes about the Commonwealth's approach to fracking-related activities. This lax regulatory approach is what will rule should fracking wastewater and its stormwater runoff pollution potential be allowed by the import and handling of this waste here."
- "DRBC has not taken full jurisdiction of pipeline projects in its review of such projects under current regulations, despite the public's insistence that they must."
- A commenter said the DRBC should coordinate with PADEP to minimize any harmful impacts of wastewater from high volume hydraulic fracturing and HVHF-related activities imported into the Basin.
- A commenter recommended that a nationwide "cradle-to-grave waste tracking program" be instituted by PADEP and other federal and state oil and gas regulatory agencies to provide detailed information on where waste ends up. One commenter recommended an alternative tracking program that would identify trucks, barges, and possibly other vehicles with

placards, indicating that they are transporting wastewater from high volume hydraulic fracturing and HVHF-related activities.

- A commenter averred that under the proposed regulations, Basin state policies governing reuse of wastewater from high volume hydraulic fracturing and HVHF-related activities would govern how reuse occurs because many beneficial reuses do not involve discharge to water or land.
- A commenter opined that the DRBC cannot rely on PADEP to protect the Basin from exposure to radioactive materials in wastewater from high volume hydraulic fracturing and HVHF-related activities because PADEP permits road spreading, land application, and the disposal of hydraulic fracturing wastewater to surface waters; and in addition, Pennsylvania does not require sampling and does not impose limitations on the amount of radioactive material in landfill leachate discharged by landfills that accept HVHF wastewater.
- A commenter said that if hydraulic fracturing were permitted in the Pennsylvania portion of the Basin, the DRBC would find it difficult to coordinate with PADEP's Office of Oil and Gas Management due to PADEP staffing and funding issues.

RESPONSE (R-55)

The proposed and final rules are grounded in the authority conferred on DRBC by its organic statute, the Delaware River Basin Compact. The Commission recognizes the concurrent authorities and oversight of its member states and the United States, and appreciates the protection to water resources and the environment afforded by such authorities and each member's continued commitment to coordinated management of the Basin's water resources with and through the DRBC. The Commission will continue to coordinate with its members to address risks and impacts to the water resources of the Basin. Any comments regarding specific member state and federal authorities and regulations not specifically related to the present rulemaking should be directed to the appropriate member agencies as well.

Comments relating to risks from transportation of HVHF wastewater discharge of HVHF wastewater, and to importation of HVHF wastewater, are addressed elsewhere in this Comment and Response Document. Comments regarding the hypothetical coordination with PADEP if HVHF or the discharge of HVHF wastewater were allowed in the Basin are rendered moot by the prohibition on HVHF activities in hydrocarbon-bearing rock formations adopted by the Commission in February, 2021 and the prohibition of the discharge of HVHF wastewater to waters or land within the Basin adopted in this rulemaking.

STATEMENT OF CONCERN (SC-56)

The American Petroleum Institute stated that the proposed regulations are "unnecessary and, in many ways, duplicative and/or conflicting with Pennsylvania Department of Environmental Protection[ ] oil and natural gas regulations."

Response (R-56)

The American Petroleum Institute's comment echoes a comment it made on the Commission's proposed rule prohibiting high volume hydraulic fracturing within the Basin, which was finalized in February 2021. About that earlier proposal, API said the regulations were "unnecessary and, in many ways, duplicative and/or conflicting with Pennsylvania Department of Environmental Protection[ ] oil and natural gas regulations." Based on an extensive scientific and technical analysis, the Commission, at the time, concluded that in light of the Basin's specific setting and circumstances, applicable regulations of the PADEP would not be adequate to protect the water resources of the Basin from the impacts of HVHF and related activities. DRBC Resolution No. 2021-01 and the February 2021 CRD lay out in detail the scientific and policy bases for the Commission's decision to prohibit HVHF in the Basin. The Commission's Response R-2, in Section 2.1.2 (page 30) of the February 2021 CRD, discusses the relationship between the Commission's final rule and the rules of its member state and federal agencies.

Response R-2 of the February 2021 CRD is equally applicable here. Based upon its technical and scientific evaluation, the Commission has similarly determined that controlling future pollution by prohibiting discharges of wastewater from hydraulic fracturing and HVHF-related activities is necessary to avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin, which are limited in quantity and capacity to assimilate pollutants, for uses in accordance with the Comprehensive Plan.

5.3 Climate Change

Statement of Concern (SC-57)

Several organizations raised concern about the potential for additional fossil fuel development using hydraulic fracturing, and the impact of the proposed rules on continued fossil fuel use and climate change. Their comments included both short statements and detailed reference-driven information. Representative comments are paraphrased as follows:

- Providing a dumping ground for the hydraulic fracturing industry for their toxic waste and giving them water from the Delaware River Basin will induce more hydraulic fracturing and more of the greenhouse gas emissions that drive the climate catastrophe.
- DRBC is exacerbating climate change with the proposed regulations because they give the industry the two things it needs—more water for hydraulic fracturing and more places to dump its waste.
- LNG (methane gas) has 86 times more greenhouse gas potency than CO_2. The planet is going to continue to warm unless we substantially cut methane emissions.
- Climate change will have impacts on the water cycle, including from sea level rise, water shortages, water quality impairment, reductions in snowpack, and increased flooding, that will impact people and communities throughout the Delaware River Basin.
- The only method of mitigating the grave threats to public health and the climate is a complete and comprehensive prohibition on hydraulic fracturing.

Response (R-57)

The Commission appreciates the comments related to climate change generally and acknowledges the potential for impacts to the water resources of the Delaware River Basin in particular. Most comments on this issue highlighted natural gas as a regional and national energy source, and the role of natural gas, a principal component of which is methane, in contributing to global warming. While the Commissioners and DRBC staff share the commenters' concerns about climate change and its impacts on the water cycle, as discussed in this CRD, the Commission does not agree that the proposed rule supports the development of additional high volume hydraulic fracturing, or that it is the Commission's goal to discourage HVHF activities outside the Basin absent a showing that limiting such activities is required for the effectuation of the Comprehensive Plan or otherwise authorized by the Compact.

The DRBC is actively evaluating the impacts of climate change on the Basin's water resources and the resource management strategies that must be considered in response. Temporal, spatial and quantitative changes in precipitation, evapotranspiration and snowpack, and corollary effects on drought, flooding, and streamflow Basin-wide, as well as saltwater excursion in the Delaware River Estuary are among the observed and anticipated shifts as the result of a warming climate. DRBC is also examining sea level rise and its related effects. To assess impacts on the Basin's water resources and the management approaches available to address these effects, Commission staff are using regional climate projections and models based upon the representative concentration pathways for the cumulative measurement of human emissions of greenhouse gases ("GHG") from all sources, adopted by the 2013 Intergovernmental Panel on Climate Change ("IPCC").

In 2019 the Commission established an Advisory Committee on Climate Change ("ACCC"). The Commission along with DRBC staff and with input from the ACCC and the public, will continue to examine policy, regulation, science, and planning directions as needed to adapt to water resource related climate impacts. In accordance with the authority conferred on the Commission by the Compact, the February 2021 regulations that prohibited HVHF in the Delaware River Basin and these rules prohibiting the discharge of HVHF wastewater into the Basin will be incorporated in and will effectuate the Comprehensive Plan for the planning, development, conservation, utilization, management, and control of the water resources of the Basin to meet present and future needs.

Statement of Concern (SC-58)

Comments submitted by the American Petroleum Institute (API) concerning climate are paraphrased below:

- The oil and natural gas industry is focused on achieving economy-wide emissions reductions, while maintaining America's global energy leadership and providing affordable, reliable energy to the American people.
- API's climate action framework represents industry's commitment to produce cleaner energy and lower greenhouse gas emissions consistent with the goals of the Paris Agreement by: accelerating technology and innovation to reduce emissions; mitigating emissions from operations (including direct regulation of methane) to accelerate environmental progress; endorsing a Carbon Price Policy at the federal level, to drive market-based solutions;

advancing cleaner fuels to provide lower-carbon choices; and driving climate reporting to provide consistency and transparency.

- Environmental justice is supported by balancing economic benefits that have helped fuel growth and prosperity, and common-sense regulations to manage potential environmental and health related risks.

RESPONSE (R-58)

The Commission agrees with the consensus among scientists that climate change is influenced by anthropogenic forces[124] through the combustion of fossil fuels and the emission of greenhouse gases that are associated with the energy sector and other sources. Although the Commission recognizes the importance of energy policy, including industry contributions to mitigate climate impacts, the Commission does not set energy policy for the nation, the region, or our member states. In accordance with the authority conferred on the Commission by the Compact, any proposed rules related to high volume hydraulic fracturing and related activities are limited to addressing the planning, development, conservation, utilization, management, and control of the water resources of the Basin to meet present and future needs.

5.4 Fossil Fuels

STATEMENT OF CONCERN (SC-59)

Several comments were provided about renewable energy and fossil fuels that can be paraphrased as follows:

- Fossil fuels should be left in the ground.
- Fossil fuels should be eliminated.
- Investment in and support for renewable energy sources (wind, solar, others) should be accelerated.
- Clean energy should be the goal to keep air and water clean, to create jobs in the energy sector and to create energy independence.

Some of the commenters suggested that the proposed rules support additional hydraulic fracturing and fossil fuel development.

RESPONSE (R-59)

As discussed in this CRD, the Commission does not agree that the proposed rule supports additional high volume hydraulic fracturing. Although the Commission recognizes the importance of energy

[124] Hegerl, G.C., et al., Climate Change 2007: The Physical Science Basis, Chapter 9: Understanding and Attributing Climate Change (Jun. 2007), accessed at: https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter9-1.pdf.

conservation and renewable energy sources to any long-term national, regional, or state energy policy, the Commission does not set energy policy for the nation, the region, or our member states. In accordance with the authority conferred on the Commission by the Compact, any proposed rules related to high volume hydraulic fracturing and related activities are limited to addressing the planning, development, conservation, utilization, management, and control of the water resources of the Basin to meet present and future needs.

5.5 Oil and Gas Industry

Statement of Concern (SC-60)

Several individuals and organizations submitted negative comments and accusations about the oil and gas industry and stated or implied that the rules would favor the industry's hydraulic fracturing needs.

Response (R-60)

As stated in this CRD, the Commission does not agree that these rules favor industry or its needs for hydraulic fracturing. The risks and potential impacts of HVHF on the water resources of the Delaware River Basin have been comprehensively addressed in the February 2021 CRD and this document. The commenters' statements about the oil and gas industry do not address the Commission's proposed rules, and the Commission has no response to them.

Statement of Concern (SC-61)

The American Petroleum Institute (API) commented that many statements about the oil and natural gas industry's behavior and operations made by participants in the Commission's public hearings on the rulemaking were "either grossly exaggerated or flat-out incorrect." API wished to "correct the record." The API's comment included a brief history of the Resource Conservation and Recovery Act ("RCRA"), its amendment process, and recent decisions of the U.S. Environmental Protection Agency on the current state of exploration and production ("E&P") waste management. The information provided on RCRA did not reference the DRBC rulemaking.

Response (R-61)

The Commission acknowledges the responsible regulatory oversight by its member states and the federal government and appreciates each member's continued commitment to coordinated oversight of the Basin's water resources. Responses to other comments regarding the federal government and Basin member states' regulatory oversight are presented in Section 5.2. Coordination with Other Regulators. This rulemaking is based on the scientific and technical review and evaluation performed by Commission staff and not on statements by members of the public disputed by industry where the accuracy of the statements could not be verified.

5.6 Economic Impacts

Statement of Concern (SC-62)

Several individuals and organizations suggested that the rules will promote additional hydraulic fracturing activities and thereby cause significant economic harm to the region because of fossil fuel induced climate change.

Response (R-62)

The creation of opportunities for hydraulic fracturing outside the Basin is not an objective of the proposed or final rules and is not an expected outcome of these rules. As the responses in this CRD emphasize, the Commission's focus is to conserve and protect the Basin's water resources. To advance these purposes, the proposed and final rule limits the importation into and exportation from the Basin of water, including wastewater. As discussed in Section 5.3 above, the Commissioners and Commission staff share concerns expressed by many commenters about climate change and its impact upon the hydrologic cycle and the region's economy. For a discussion of the ways in which the Commission is addressing those concerns, please see Response R-57 above.

Statement of Concern (SC-63)

Referencing a 2011 study by the University of Delaware,[125] several commenters suggested that the impact of the proposed rules would result in harm to the economic value of the water resources of the Basin.

Response (R-63)

In the view of the Commission, the economy of the region and the quality of life available to its residents depends upon the availability of abundant water of suitable quality to support human activities and a diverse ecosystem. By adopting regulations in February, 2021 prohibiting HVHF in the Basin and by prohibiting the discharge of HVHF wastewater by the current rulemaking, the Commission has provided substantial protection for the water resources of the Basin from injury related to high volume hydraulic fracturing.

Please see Sections 2, 3 and 4 above for discussion of how the final rule addresses particular risks and impacts to water resources posed by or resulting from HVHF. Based on data and information described in Section 4.2.1.5 Transport, Leaks, and Spills, Response R-25, the Commission has concluded that the risks of impacts to water resources are significantly lower in areas where HVHF is prohibited than in areas of active HVHF shale-gas development. As such, the proposed and final rule will do much to prevent adverse impacts to the economic value of the Basin's water resources and to the region's economy.

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[125] Kauffman, G.J., Socioeconomic Value of the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania, University of Delaware (Oct. 11, 2011), 26, accessed at: https://www.nj.gov/drbc/library/documents/SocioeconomicValueDRB-UDEL-FinalRpt.pdf.

A more detailed review of the University of Delaware study assumptions is provided in the February 2021 CRD at Section 2.6.6 (beginning on page 294).

STATEMENT OF CONCERN (SC-64)

The API stated that DRBC has a responsibility to consider economics in its decision making and that the hydraulic fracturing industry drives employment, opportunity, and economic growth. It provided a link to its July 2021 analysis of the impact of the oil and natural gas industry on the U.S. economy. One commenter asserted that the fossil fuel industry has provided billions of people with a higher standard of living around the world.

RESPONSE (R-64)

The Commissioners received numerous comments concerning economic impacts and have considered those comments. In addition to the responses noted in this section, Section 2.6.6 of the February 2021 CRD fully considers and addresses the economic issues raised by API and others. API's July 2021 analysis, which does not take into consideration the costs attributable to the industry's impacts on water resources, other water-dependent industries, or human health, does not alter the Commission's 2021 analysis. Because HVHF has proceeded outside the Basin without any significant discharge of HVHF wastewater to the land or waters of the Basin, DRBC does not anticipate that the prohibition on discharge of HVHF wastewater that is the subject of this rulemaking will have a major economic impact.

5.7 Susquehanna River Basin

STATEMENT OF CONCERN (SC-65)

One commenter suggested that the Susquehanna River Basin and the Susquehanna River have been destroyed by the hydraulic fracturing industry and that no additional water withdrawals should be allowed.

RESPONSE (R-65)

The DRBC has no authority to regulate activity in the Susquehanna River Basin or in other regions outside the Delaware River Basin except where "such action may be necessary or convenient to effectuate its powers or duties within the Basin. . .. and only upon the consent of the state in which it proposes to act." Compact, § 2.7. The Commenter has not suggested, and the Commission has not found, that these conditions for exercising the Commission's power outside the Basin are satisfied.

STATEMENT OF CONCERN (SC-66)

Commenters suggested that the industry is "pushing" DRBC to accept hydraulic fracturing waste because, the commenters aver, the industry has run out of space for storage and disposal in the

Susquehanna River Basin, and the Delaware River Basin is a proximate and "especially attractive" location.

Response (R-66)

As suggested in the comments and as noted in in the February 2021 CRD (page 129), the average volume of fluid used per hydraulic fracturing event has increased significantly to accommodate the expanding depth and length of directional drilling. Over time, industry has extended the horizontal lateral portion of unconventional natural gas wells further through the targeted shale formation and has deepened wells to reach the Utica Shale formation. As a result, the quantity of flowback and produced water returned to the surface overall (not simply per well) is expected to increase in Pennsylvania. However, as also noted in the February 2021 CRD, about 87-90 percent of produced water from HVHF was recycled and reused. Yoxtheimer (2014) reported an 87 percent recycle rate and a 10 percent disposal rate at regulated underground injection wells. While HVHF wastewater volumes may increase in the Susquehanna River Basin, part of the increase is expected to be mitigated by continued use of industry recycling efforts.

Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater within the Basin, the Basin is not an "especially attractive" location for storage and disposal of hydraulic fracturing waste. As described in R-25 above, the frequency of transportation of HVHF wastewater is lower in areas where HVHF is not conducted. The Commission anticipates that only low volumes of HVHF wastewater will be transported to or through the Basin, or stored, processed, or recycled within the Basin.

The assertion that the industry has "pushed" the DRBC to accept wastewater from HVHF in the Basin is unsupported by any evidence. Industry's comments on this rulemaking and the Commission's rulemaking completed in February 2021 indicate no such purpose. Nor has the Commission received any communications from industry representatives that suggest it. The Commission is unaware of HVHF wastewater storage in the Basin to date, notwithstanding that there has never been a moratorium on the importation of HVHF wastewater into the Basin. The Commissioners' May 5, 2010 Resolution for the Minutes (sometimes referred to as a "*de facto* moratorium" on in-Basin HVHF activity) was silent concerning importations of HVHF wastewater. With the exception of some early inquiries by industry or by Basin wastewater treatment facility operators regarding the possibility of treating and discharging HVHF wastewater at the outset of the HVHF boom (none of which resulted in a DRBC approval), the Commission has received no further inquiries about the importation of HVHF wastewater for use, treatment or discharge, activities that under the current DRBC regulations at Section 2.30.1 of the Water Code and Section 2.3.5(a)(18) (18 C.F.R. 401.35(a)(18)) of the Rules of Practice and Procedure require Commission approval.

Statement of Concern (SC-67)

The Marcellus Shale Coalition (MSC) commented that "while the DRBC Commissioners advance priorities of environmental extremists, a decade of evidence from the Susquehanna River Basin demonstrates that safe, responsible natural gas development has no detrimental effect on water quality or quantity."

RESPONSE (R-67)

The Commission disagrees. Commission Resolution No. 2021-01, adopting the Commission's prohibition on HVHF within the Basin, sets forth the Commission's findings, based on "more than a decade of experience with high volume hydraulic fracturing outside the Delaware River Basin," that "despite the dissemination of industry best practices and government regulation, high volume hydraulic fracturing and related activities have adversely impacted surface water and groundwater resources, including sources of drinking water, and have harmed aquatic life in some regions where these activities have been performed." The scientific and technical data and information on which the Commission relied are described at length in the February 2021 CRD. Those data and information document impacts on water resources in the Susquehanna River Basin and in other regions in which HVHF is performed.

The Marcellus Shale Coalition and others often point to studies published by the SRBC to claim that natural gas development has had no impact on water quality. The February 2021 CRD (starting at page 268) contains an extensive analysis that refutes this claim. The conclusions of that analysis include that:

- The SRBC data do not include adequate indicator parameters related to the impacts from high volume hydraulic fracturing.
- The SRBC data do not comprehensively, conclusively, or definitively address the question of long-term impacts to water resources.
- The SRBC has recognized its study limitations and the need for more work. One of the SRBC reports most cited by the MSC and others, states, "Water quality trends will be re-examined when there are 10 years of continuous data at each station. The extended timeframe will allow for more robust analysis of the data, and also allow additional supplemental data, such as discrete water chemistry samples, to be collected in each watershed."
- A 2016 report by the USGS and the Northeast Midwest Institute (USGS/NEMWI), entitled "Water data to answer urgent water policy questions: monitoring design, available data and filling data gaps for determining whether shale gas development activities contaminate surface water or groundwater in the Susquehanna River Basin," examined the SRBC's and other monitoring programs. Significant findings by the study team included that: "The existing surface water quality data in the Susquehanna River Basin are insufficient to detect water-quality change related to shale gas development. . . ." and "The publicly available groundwater quality data in the Susquehanna River Basin are not sufficient to detect whether shale gas development is contaminating groundwater, and the available data are not adequate to serve as the foundation of a new monitoring program."

5.8 Wild and Scenic Rivers

Statement of Concern (SC-68)

Concerns representative of those referencing the Wild and Scenic Rivers Act are paraphrased below:

- Congressionally designated wild and scenic rivers in the Delaware River Basin have ecological resources and water quality as key attributes of the river that must be "protected and enhanced."
- The importation of toxic wastes conflicts with the DRBC's role in the administration of the national Wild and Scenic Rivers Act by not eliminating or diminishing pollution risks to the river.
- The exportation of water from the Delaware River Basin conflicts with the national Wild and Scenic Rivers Act.
- Please protect the designated wild and scenic lands and rivers from hydraulic fracturing waste and hydraulic fracturing risk.
- The consumptive loss of exported water has economic impacts on the source watershed. Impacts can be on the community, habitat, ecosystem and to the Delaware Wild and Scenic River (including its aesthetic and recreational values). Impacts can be permanent or long-lived, impacting us today and future generations.
- Unlike most U.S. rivers, the Delaware, a Wild and Scenic River and a National Estuary recognized by Congress, is clean enough to support many of the most vulnerable shellfish and insect species, ones that require clean water, along with the fish, bird, and mammal species that depend on them.

Response (R-68)

In 1968, Congress passed the Wild and Scenic Rivers Act, which declared it:

> to be the policy of the United States that certain selected rivers of the Nation, which with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free- flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations.

Between 1978 and 2006, portions of the Delaware River and some of its tributaries have been designated by the federal government as parts of the National Wild and Scenic Rivers System. During this time, between 1992 and 2008, the Commission designated most of the main stem river from the Upper Delaware River region to Trenton, New Jersey as "Outstanding Basin Waters" or "Significant Resource Waters" under its Special Protection Wates program. For additional information regarding the Delaware River Basin's Wild and Scenic River designations and its relationship to the

Commission's regulations and Special Protection Waters program, *see* Section 2.3.4.2, *National Wild and Scenic Rivers Program* (R-73), of the February 2021 CRD.[126]

Although the federal government administers the Wild and Scenic program, when Congress created the program in 1968, it envisioned a cooperative system that would rely on the combined efforts of state, local, and federal governments, along with individual citizens and non-governmental organizations. The system was intended to be flexible enough to provide a means for communities to protect their rivers in a way that is sensitive to the needs and concerns of the people who live, work, and recreate along the rivers.

DRBC is a federal-interstate compact agency, not a federal agency. The Commission's water quality programs—in particular, its Special Protection Waters program—protects the Delaware River's Wild and Scenic designations by protecting water quality, one of the natural resource values that served as a basis for these congressional Wild and Scenic designations.

Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater within the Basin, it anticipates that only low volumes of HVHF wastewater will be transported to or through, or stored, processed, or recycled within the Basin. The data and information on which the Commission bases this understanding are set forth in Response R-26 in Section 4.2.1.5, above. The risk of HVHF wastewater releases within the Basin and the likelihood of impacts to the Basin's Wild and Scenic rivers resulting from such releases are in the Commission's view effectively reduced by the Commission's HVHF prohibitions.

The Commission's final rules on exportation of Basin waters limit exportations from the Basin to instances where the sponsor: 1) demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system; 2) demonstrates that the exportation of Basin water is required to meet public health and safety needs on a temporary, short-term, or emergency basis; or 3) is proposing an exportation of wastewater to a straddled or adjacent public wastewater collection system. If the required demonstration is made, the Commission may approve an exportation only after it has evaluated a suite of factors designed to ensure no harm to the Basin's water resources or the health and safety of the Basin community. Additional discussion in Responses R-5, R-6, R-7, R-8 and R-10 in Section 3.2 above, of how the final rules protect Basin waters from the potential adverse impacts of withdrawals and exportations, is also relevant to protection of the Basin's Special Protection Waters.

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[126] *See* February 2021 CRD at235–37.

5.9 Enforcement

Statement of Concern (SC-69)

Many commenters expressed concerns about whether the proposed regulations could be enforced and, even if so, whether enforcement would adequately protect the Basin's water resources from contamination by HVHF wastewater.

Representative paraphrased comments follow:

- The Commission does not have any enforcement capabilities and Pennsylvania has a bad record of enforcement on matters like oil and gas spills and leaks.
- Because storage of wastewater from high volume hydraulic fracturing and HVHF-related activities would not be prohibited by the proposed regulations and would be overseen by the Basin states, the DRBC would not be able to enforce its regulation if there were truck and pipe spills or leaks from storage containers.
- The lack of DRBC being able to enforce its regulations coupled with the chemicals in hydraulic fracturing waste known to cause persistent harm over long periods of time is particularly concerning.
- It is not clear from the proposed prohibition on the discharge of wastewater from high volume hydraulic fracturing and HVHF-related activities how that prohibition will be enforced.
- Allowing wastewater from high volume hydraulic fracturing and HVHF-related activities into the Basin increases the risks of leaks, spills, or other possible incidental or illicit discharges, for which there is no preventative enforcement.
- There is no clear mechanism to enforce the discharge prohibition. For example, a truck carrying wastewater from high volume hydraulic fracturing or HVHF-related activities could "drive onto a little-traveled road at night, pull over to a stream and drain the wastewater into it."
- Basin state enforcement of regulations regarding waste handling is unreliable.
- The federal and state agencies responsible for enforcement of environmental laws are underfunded and understaffed. Under these conditions, permissive regulations are ineffective due to inadequate enforcement, so a full prohibition on all hydraulic fracturing-related activities is necessary.

Response (R-69)

The final regulations at 18 C.F.R. 440.4 prohibit the discharge of HVHF wastewater to waters or land within the Basin. Given this full prohibition on discharges of HVHF wastewater, the need for compliance and enforcement measures to enforce the prohibition at wastewater treatment facilities should be minimal.

Because the Commission has prohibited HVHF within the Delaware River Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater within the Basin, it anticipates that only low volumes of HVHF wastewater will be transported to or through, or stored, processed, or recycled within the Basin. The risks and impacts from spills to Basin waters from these activities are expected to be commensurately low. (The data and information on which the Commission bases this understanding are set forth in R-25 in Section 4.2.1.5, above.) If not contained, spills and leaks during transport, transfer, or storage of HVHF wastewater within the Basin would constitute prohibited discharges under the Commission's final rule.

Illegal discharges of HVHF wastewater, like illegal discharges of other waste, may from time to time occur. Section 14.17 of the Compact and the Commission's Rules of Practice and Procedure codified at 18 C.F.R. Part 401, Subpart G, provide the Commission with the ability to assess penalties for non-compliance. The Commission will work within its authority and in coordination with its member states, which have active and comprehensive compliance and enforcement programs, to ensure compliance and address any violations of its new rules.

For related discussion, also see Section 4.2.1.5 above concerning transport, leaks and spills, and Section 4.2.1.7 concerning waste storage and recycling.

5.10 Public Input Process

STATEMENT OF CONCERN (SC-70)

Berks Gas Truth, Catskill Mountainkeeper, Clean Air Council, Clean Water Action, DCS, DRN, Food & Water Watch, NRDC, and others submitted comments and requests seeking additional and more inclusive opportunities for public input and to provide a "a fair, equitable, and easy-to-access public input process." These included requests for DRBC to:

- extend the public comment period from 90 days to 180 days.
- provide 4 to 6 days of hearings in addition to the original four hearings scheduled in 2021, in part to accommodate people too busy in December 2021 due to holidays, travel, family commitments, college finals, and COVID stress, to attend the four December 2021 virtual hearings.
- make the hearings hybrid (both virtual and in-person) and conduct them throughout the watershed.
- provide opportunities for verbal testimony that would not require a computer.
- provide more avenues for submitting written comments, beyond the web form, including: e-mail, fax, U.S. mail, and hand delivery.
- provide the rules and supporting information to the public in Spanish.

RESPONSE (R-70)

Originally, four hearings were scheduled on the proposed rule, and all four were conducted virtually in December 2021. In response to public feedback, in January 2022, the Commission invited individuals and organizations throughout the Basin to attend an additional public hearing on February 3, 2022. The following additional measures were implemented to expand opportunities for public participation in the Commission's rulemaking process:

- The public hearing on February 3, 2022, included enhanced language access, consisting of real-time English-to-Spanish and Spanish-to-English professional translation, on a pilot basis. Attendees could choose to participate in the virtual hearing in either English or Spanish.
- The February 3, 2022, public hearing was also held virtually; however, individuals who may not have had access to a computer or the internet could join the virtual hearing by phone using a new toll-free number.
- The DRBC upgraded its website to provide an interactive language translation widget that can translate web-based formatted text on any of DRBC's web pages from English to over 100 different languages.
- The DRBC posted certified translated copies of the draft rules and rulemaking notice in Spanish on its website and established a process for requesting certified translation of documents related to the rulemaking into additional languages.

On November 16, 2021, the DRBC announced an extension through February 28, 2022 of the original January 28, 2022 deadline for the submission of written public comment. As a result, the comment period on the proposed regulations ran for a total of 124 days.

While the commenters suggested that the demand for hearings was significant and that 4 to 6 more hearings should be added, actual demand did not appear to support this request. Only 73 speakers provided comments over the 5 scheduled hearings—about 15 speakers per hearing on average. Sixty-three (63) individuals who registered to speak at the hearings did not show up. There was ample opportunity to speak at each hearing and no apparent demand for 4 to 6 more hearings on this matter. In addition, the request that the additional hearing be in-person or both in-person and virtual, was not advisable during the pandemic, and the virtual hearing format (which included a toll-free phone-in option) provided significantly more inclusive opportunity for comment than an in-person hearing requiring attendees to travel.

The Commission did not change the requested on-line intake system to allow e-mail, fax, U.S. mail, and hand delivery. Internet access is near-universal and the on-line intake system was convenient, easy to use, and allowed commenters to easily submit supporting attachments as needed. The on-line system has been used successfully by the Commission for several years for comment intake on rulemakings and project reviews. It is recognized that not everyone has access to the internet, and as discussed in R-73 below, the Commission established a simple process for individuals to request and receive an exception to use of the online system. No exceptions were requested during the process.

Statement of Concern (SC-71)

The commenters identified in SC-70 also objected to the DRBC requiring prior approval to receive an exception from use of the web-based comment collection system. These commenters suggested that the process was unduly cumbersome and posed an unfair roadblock to the submission of written comments.

Response (R-71)

The DRBC clarified during the comment period that requests for exceptions from use of the web-based comment system could be submitted simultaneously with comments—eliminating the apparent need for two steps. The request explaining why the commenter was unable to use the web-based system, together with the accompanying comment, were to be sent to the Commission Secretary, DRBC, P.O. Box 7360, West Trenton, NJ 08628. The DRBC also committed to accommodating all reasonable exception requests. The Commission received no requests for exceptions.

Statement of Concern (SC-72)

The commenters identified in SC-70 also stated that DRBC did not perform enough outreach to inform hard-to-reach communities of the proposed regulations and that "the job of notifying people is typically left to advocacy groups who are currently challenged to do the kind of in-person organizing they have not been able to do during the pandemic."

Response (R-72)

While the DRBC and interested parties routinely use social media and other on-line communications to share notices about rulemakings and public hearings, for the February 3, 2022 hearing the DRBC conducted additional community outreach. Through contacts with NGOs, social service groups, local media, and local, state and federal legislative offices, DRBC staff researched, identified and informed harder-to-reach communities with significant Spanish-language speakers in each Basin state, as well as rural communities in the upper Basin.

Statement of Concern (SC-73)

After attending the hearings in December 2021, some commenters complained that:

- They and others found the instructions for registering to speak at the virtual hearings confusing and had a difficult time registering, and that "some frustrated registrants were not able to testify due to these insufficient instructions." One stated, "It is unfair to assume that everyone joining the hearing is familiar with zoom, evite, or other internet platforms or that people have unfettered access to a computer, smart phone, or other device needed to join the hearing session."
- The public should have been notified prior to the last two sessions that they might have an opportunity to speak at these hearings if time permitted, even if they had not registered.

- The time clock was too controlling.
- The atmosphere was "closed" and "controlled."
- There was no camera access and no view of who else was attending the hearings.
- There was no chat feature.
- There was only one "call-out" for speakers and if they were not ready, they missed their turn.

RESPONSE (R-73)

In any public comment process, some participants may become confused by the instructions for the hearings. However, the DRBC's instructions were reasonably clear, and interested parties from diverse communities were able to navigate them to a successful result. In addition, commenters had alternatives to participating in the public hearings via the Zoom platform. First, speakers could have dialed in to the public hearings by phone, avoiding the need to use the Zoom platform if they were unfamiliar or uncomfortable with it or did not have access to the internet. Second, the Commission provided a 124-day period for written comment and made clear that written comments and oral comments receive equal consideration. To increase participation opportunities, the Commission provided a toll-free number for the February 2022 hearing.

In an effort to expand opportunities for input, the hearing officer made certain day-of decisions to allow unregistered individuals to provide comment at a hearing based upon the number of preregistered commenters for the hearing, the remaining time available, and the availability of additional hearings. The expanded opportunity was not provided on the first day of hearings because ample capacity to speak on the second day of hearings remained available. The hearing officer explained the procedure for the expanded opportunity to hearing attendees on the occasions when the opportunity was offered. The Commission did not rescind any commenter's opportunity to comment. DRBC disputes that preregistered commenters were called only once, causing them to miss their turn. The hearing transcripts show that the hearing officer routinely called preregistered speakers at least one additional time if they did not respond when first called. As noted previously, in many instances, individuals who registered to provide comment did not attend the hearing. The record shows that the Commission provided reasonable notice of the hearing opportunities and that its efforts to communicate its procedures both in advance of and during each hearing went well beyond the required written notices.

In response to complaints about the "controlling nature of the hearing" and "no access to chat," the Commission reminds commenters that the purpose of holding public hearings on actions under consideration by the Commission is to obtain public input that will inform the Commissioners' decision. The Commission recognizes that virtual formats do not afford the same opportunities for interest-based groups to organize or demonstrate as in-person proceedings do. However, ample opportunity for such activities is available in forums the participants create. As the Commission has experienced, the use of chat features and camera access during virtual proceedings creates opportunities for disruption, including "Zoom-bombing." For this rulemaking, the participants were asked to follow reasonable rules to ensure orderly provision of comment on the proposed regulations, the hearings' intended purpose.

STATEMENT OF CONCERN (SC-74)

One commenter stated: "I would like to thank you for the opportunity to speak and for the efforts you made to provide Spanish language interpretation for this [February 2022] hearing. Might I suggest that as you refine this process, it would make sense to offer instructions on how to access Spanish translation in Spanish rather than English."

RESPONSE (R-74)

The Commission thanks the commenter for this feedback. We note that the translation widget added to the Commission's website made possible the translation of the posted instructions into any one of over 100 languages, including Spanish. However, we are working continually to improve our communications and outreach, especially as we employ new technologies. We will be mindful of this issue in the future.

5.11 Pennsylvania Constitution

STATEMENT OF CONCERN (SC-75)

Several commenters expressed concerns about the consistency of the proposed regulations with the Environmental Rights Amendment to the Pennsylvania Constitution. A number asserted that the the Commission's proposed regulation would violate the rights guaranteed by the Environmental Rights Amendment. A statement submitted by multiple commenters reads:

> In Pennsylvania, residents are guaranteed the right to clean air and pure water by Article 1, Section 27 [of the Pennsylvania Constitution (the Environmental Rights Amendment)]. The DRBC, as a trustee of these resources, has an obligation to uphold these rights and protections.

RESPONSE (R-75)

Article I, § 27 of the Pennsylvania Constitution (the "Environmental Rights Amendment") recognizes and protects Pennsylvania citizens' "right to clean air, pure water and to the preservation of the natural, scenic, historical and esthetic values of the environment." The Pennsylvania Supreme Court has affirmed this right. *See, e.g., Pennsylvania Envt'l Def. Fund v. Commonwealth,* 161 A. 3d 911 (Pa. 2017); *Robinson Twp. v. Commonwealth,* 83 A. 3d 901 (Pa. 2013); *Yaw et al. v. Del. River Basin Comm'n,* Case No. 21-2315 (3d Cir. 2022).

Although the Environmental Rights Amendment and the Compact have overlapping goals, as a federal-interstate compact agency, the Commission is not bound by, nor is it empowered to carry out, state constitutional provisions. While the Commission believes its regulations are consistent with the Environmental Rights Amendment, the Commission has acted pursuant to the authority granted by the Compact, not pursuant to the Pennsylvania Constitution. The Pennsylvania Commissioner has concluded that the Commission's regulations, together with applicable Pennsylvania and federal laws, are consistent with and ensure the protections provided in the Pennsylvania Constitution. The

Pennsylvania Commissioner votes in a manner consistent with the Commissioner's obligations under Article 1, Section 27.

5.12 Other Miscellaneous Comments

STATEMENT OF CONCERN (SC-76)

One commenter was critical of the proposed rule for being too lax regarding allowable importations of water, even when the imported water is not derived from HVHF or HVHF-related activities, suggesting that only natural precipitation runoff should be allowed to enter the Basin due to the potential adverse impacts of contaminated wastewater.

RESPONSE (R-76)

The Commission's Comprehensive Plan and Water Code have long recognized that, "the Basin waters have limited assimilative capacity and limited capacity to accept conservative substances without significant impacts."

Since 1991, the Comprehensive Plan and the Water Code have provided that "it . . . shall be the policy of the Commission to discourage the importation of wastewater into the Delaware River Basin that would significantly reduce the assimilative capacity of the receiving stream on the basis that the ability of Delaware River Basin streams to accept wastewater discharges should be reserved for users within the Basin." Water Code § 2.30.2 (prior to amendment by the final rule).

The final rule, at Section 2.30.2 D, expands on this provision. It includes in part a requirement that any "proposed new importation of water or wastewater, including any proposed increase in the rate or volume of an existing importation, shall be reviewed by the Commission consistent with the factors set forth at Section 2.30.3 below." Those factors include, among others, the effects of the proposed importation on aquatic ecosystems, water quality and waste assimilative capacity in the receiving streams (§§ 2.30.3 B.3.d. and B.3.e.), and the effect of the importation on the health and safety of the Basin community (§ 2.30.3 B.1). They further require the Commission to consider "alternatives that avoid an importation of water." § 2.30.3 B.3. (intro par.). Accordingly, the final rule ensures that proposed importations will be carefully evaluated to ensure they do not adversely affect the Basin's water resources or the health and safety of Basin water users.

The proposed restriction on importations would be impracticable. Because water and wastewater service areas often straddle basin boundaries, it is not uncommon for wastewater generated in one basin to be disposed of in another, and imports and exports of wastewater occur routinely around the Basin boundary. The final rule protects these existing transfers. It allows for new and expanded transfers only after careful evaluation and the imposition of protective conditions, if and as needed.

STATEMENT OF CONCERN (SC-77)

A commenter stated that the proposed regulations "would gut the earlier ban and make it completely ineffective."

RESPONSE (R-77)

The Commission rejects this assertion. The final regulations will not render the Commission's 2021 prohibition on high volume hydraulic fracturing within the Basin ineffective. Rather, the amendments to DRBC's regulations on importation and exportation and the prohibition on discharges of HVHF wastewater provide additional protection from potential injury to the waters of the Basin that might otherwise result from high volume hydraulic fracturing and HVHF-related activities, complementing the HVHF prohibition.

STATEMENT OF CONCERN (SC-78)

A commenter stated that the damage to human health caused by the burning of fossil fuels incommensurately impacts those living in poverty, who are disproportionately people of color. The Environmental Justice Center of Chestnut Hill United Church commented that "health costs" related to fossil fuels "are incommensurately borne by those living in poverty." The Environmental Justice Center urged the Commission to expand its regulations to not enable "fracking or any actions that support fracking, such as discharge or importation of wastewater in or beyond the Basin."

RESPONSE (R-78)

As described in the February 2021 CRD, the Commission recognizes the environmental injustices that can be caused by high volume hydraulic fracturing.[127] The Commission believes its prohibition on HVHF within the Basin, finalized in 2021, and the final regulations prohibiting discharges of HVHF wastewater to waters or land within the Basin will assist in reducing pollution and contamination that could otherwise disproportionately affect disadvantaged communities. As discussed in Section 2 above, and in R-65 above, the Commission does not have authority to regulate activities beyond the Basin boundary. *See* Compact, § 2.7. With respect to the development of fossil fuels generally, please see R-59 above. Also see R-62 above concerning climate change.

STATEMENT OF CONCERN (SC-79)

Many commenters requested that the Commission keep the Basin free from pollutants, high volume hydraulic fracturing-related or otherwise, without expressing whether they support or are critical of the proposed regulations.

The Commission received numerous comments that did not explicitly support, oppose, or suggest changes to the proposed regulations, but generally asked the Commission to protect the Basin. For example, commenters offered the following, among other similar submissions:

- "We need your support to protect the Delaware River from the effects of fracking discharges."
- Please keep the Delaware Water Basin pure. Keep it free from any and all pollutants. Take responsibility for the health of this planet."

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[127] DRBC, February 2021 CRD, R-94, pp. 296–97.

- "Please keep the water pure and wild."
- "Water is too important to life to mess up—let's keep the water pollution-free!"
- "Our waters are important we must protect our water and river now."
- "Protect water from fracking. Water is life."

Response (R-79)

- The Commission received numerous comments including those listed in SC-79 that did not explicitly state whether the commenter was supportive of, or opposed to, the proposed regulations, but generally asked the Commission to protect the Basin.

The Commission appreciates the passion exhibited by the commenters regarding this rulemaking and the Commission's work.

Statement of Concern (SC-80)

Several individuals provided general comments that suggested that hydraulic fracturing be prohibited in the Delaware River Basin. Others suggested that hydraulic fracturing be prohibited everywhere and stopped in places where it is currently permitted. A representative sample of these comments is provided below.

- "Please ban any fracking in NY/NJ/PA."
- "Fracking must end."
- "Categorically ban fracking in the Delaware River Watershed."
- "Banning all fracking would be the safe and prudent thing to do."
- "Please do not allow High Volume Hydraulic Fracturing anywhere near the Delaware River Basin."
- "Stop fracking our area."
- "I urge you without reservation to ban fracking in the Delaware river watershed."
- "No fracking should ever be allowed in the Delaware River Basin or anywhere."
- "Fracking must be banned everywhere."

Response (R-80)

High volume hydraulic fracturing is already prohibited in the Delaware River Basin and is not a subject of this rulemaking. After an extensive rulemaking process, on February 25, 2021, the Commission found and determined that:

- HVHF poses significant, immediate and long-term risks to the development, conservation, utilization, management and preservation of the water resources of the Delaware River

Basin and to Special Protection Waters of the Basin, considered by the Commission to have exceptionally high scenic, recreational, ecological and/or water supply values.

- Controlling future pollution by prohibiting such activity in the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

The Commission has no authority to prohibit HVHF activity outside the Delaware River Basin.

Statement of Concern (SC-81)

One commenter made the following statement: "Quit funding Russia by buying natural gas from them when we have all the resources hear [sic] on our on [sic] soil. I support exploration of our own resources so we can put this country back in control on a global platform."

Response (R-81)

While the comment is not pertinent to this rulemaking, the Commission notes that according to the EIA, the last time the U.S. imported any hydrocarbon gas liquids into the United States from Russia was in October 2019 (about 7 thousand barrels). Prior to that the U.S. imported 247 and 246 thousand barrels from Russia in March 2014 and June 2015, respectively.[128] In 2021, the United States exported natural gas to 41 countries.[129] Beginning in March 2022, the U.S. banned the importation of Russian oil, liquefied natural gas, and coal to the United States.[130]

Statement of Concern (SC-82)

DRBC received comments from several individuals on topics not related to the proposed rules, including statements concerning:

- a former U.S. President;
- the project to expand the Port of Wilmington;
- bills being considered by the Pennsylvania General Assembly;
- public school water inspection;
- the "Bentsen Amendment;"

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[128] EIA, Petroleum & Other Liquids: U.S. Imports by County of Origin – Russia (July 5, 2022), accessed at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=M_EPL0_IM0_NUS-NRS_1&f=M.
[129] EIA, 2022a, *supra* note 12.
[130] United States White House Statements and Releases, Fact Sheet: United States Bans Imports of Russian Oil, Liquefied Natural Gas, and Coal (Mar. 8, 2022), accessed at: https://www.whitehouse.gov/briefing-room/statements-releases/2022/03/08/fact-sheet-united-states-bans-imports-of-russian-oil-liquefied-natural-gas-and-coal/.

- the Americans with Disabilities Act; and
- water bottlers.

RESPONSE (R-82)

As the Commission explained in its Notice of Proposed Rulemaking: "Comments on matters not within the scope of the proposed rules may not be considered." The Commission will not respond to submissions on the above topics, which are beyond the scope of the present rulemaking or unrelated to it.

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APPENDIX-1 RESOLUTION NO. 2022 – 04

EXHIBIT F

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

DEP OFFICE OF OIL AND GAS MANAGEMENT
WASTE FACILITIES

1/5/2023 8:24:51 PM

Waste Facility: All
Disposition Method: ROAD SPREADING
Owner: All
Waste Facility State: PA

WASTE FACILITY	OWNER	WASTE FACILITY PERMIT	DISPOSITION METHOD	FACILITY ADDRESS1	FACILITY ADDRESS2	FACLIITY CITY	FACILITY STATE	FACILITY ZIP	FACILITY LATITUDE	FACILITY LONGITUDE	WELL PAD ADDRESS1	WELL PAD ADDRESS2	WELL PAD CITY	WELL PAD STATE	WELL PAD ZIP	WELL PAD LATITUDE	WELL PAD LONGITUDE
BERKS COUNTY ROADSPREADING - ROCKLAND TOWNSHIP			ROAD SPREADING				PA										
BUTLER COUNTY ROADSPREADING-DONEGAL TOWNSHIP			ROAD SPREADING				PA										
BUTLER COUNTY ROADSPREADING-FAIRVIEW TOWNSHIP			ROAD SPREADING				PA										
CAMBRIA COUNTY ROADSPREADING - ELDER TOWNSHIP			ROAD SPREADING				PA	16646									
CAMBRIA COUNTY ROADSPREADING - JACKSON TOWNSHIP			ROAD SPREADING				PA		40.445118	-78.86158							
CLARION COUNTY ROADSPREADING - ASHLAND TOWNSHIP			ROAD SPREADING				PA										
CLARION COUNTY ROADSPREADING - BEAVER TWP			ROAD SPREADING				PA		41.198161	-79.532003							
CLARION COUNTY ROADSPREADING - LICKING TWP			ROAD SPREADING				PA		41.139041	-79.553804							
CLARION COUNTY ROADSPREADING - REDBANK TOWSHIP			ROAD SPREADING				PA		41.072881	-79.279404							
CRAWFORD COUNTY ROADSPREADING - ATHENS TOWNSHIP			ROAD SPREADING				PA		41.742115	-79.839706							

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

DEP OFFICE OF OIL AND GAS MANAGEMENT WASTE FACILITIES

1/5/2023 8:24:51 PM

WASTE FACILITY	OWNER	WASTE FACILITY PERMIT	DISPOSITION METHOD	FACILITY ADDRESS1	FACILITY ADDRESS2	FACLIITY CITY	FACILITY STATE	FACILITY ZIP	FACILITY LATITUDE	FACILITY LONGITUDE	WELL PAD ADDRESS1	WELL PAD ADDRESS2	WELL PAD CITY	WELL PAD STATE	WELL PAD ZIP	WELL PAD LATITUDE	WELL PAD LONGITUDE
CRAWFORD COUNTY ROADSPREADING - BEAVER TOWNSHIP			ROAD SPREADING				PA		41.742115	-79.839706							
CRAWFORD COUNTY ROADSPREADING - BLOOMFIELD TOWNSHI			ROAD SPREADING				PA		41.811755	-79.852753							
CRAWFORD COUNTY ROADSPREADING - CONNEAUT TOWNSHIP			ROAD SPREADING				PA	16412									
CRAWFORD COUNTY ROADSPREADING - CONNEAUTVILLE BORO			ROAD SPREADING	1317 EAST MAIN STREET		CONNEAUTVILLE	PA	16406-7205	41.765678	-80.36911							
CRAWFORD COUNTY ROADSPREADING - CUSSEWAGO TOWNSHIP			ROAD SPREADING				PA		41.802031	-80.209465							
CRAWFORD COUNTY ROADSPREADING - EAST FALLOWFIELD			ROAD SPREADING				PA		41.526058	-80.332375							
CRAWFORD COUNTY ROADSPREADING - EAST MEAD TOWNSHIP			ROAD SPREADING				PA		41.621602	-80.065269							
CRAWFORD COUNTY ROADSPREADING - FAIRFIELD TOWNSHIP			ROAD SPREADING				PA		41.623912	-80.063896							
CRAWFORD COUNTY ROADSPREADING - GREENWOOD TOWNSHIP			ROAD SPREADING				PA		41.527343	-80.208092							
CRAWFORD COUNTY ROADSPREADING - HAYFIELD TOWNSHIP			ROAD SPREADING				PA		41.724693	-80.210495							
CRAWFORD COUNTY ROADSPREADING - NORTH SHENANGO TWP			ROAD SPREADING				PA		41.616982	-80.46524							
CRAWFORD COUNTY ROADSPREADING - RANDOLPH TOWNSHIP			ROAD SPREADING				PA		41.621089	-79.941673							

WASTE FACILITY	OWNER	WASTE FACILITY PERMIT	DISPOSITION METHOD	FACILITY ADDRESS1	FACILITY ADDRESS2	FACLIITY CITY	FACILITY STATE	FACILITY ZIP	FACILITY LATITUDE	FACILITY LONGITUDE	WELL PAD ADDRESS1	WELL PAD ADDRESS2	WELL PAD CITY	WELL PAD STATE	WELL PAD ZIP	WELL PAD LATITUDE	WELL PAD LONGITUDE
CRAWFORD COUNTY ROADSPREADING - RICHMOND TOWNSHIP			ROAD SPREADING				PA		41.740834	-79.942703							
CRAWFORD COUNTY ROADSPREADING - ROCKDALE TOWNSHIP	ROCKDALE TWP CRAWFORD CNTY	EIN# 69-0235168	ROAD SPREADING	29393 MILLERSTATION ROAD		CAMBRIDGE SPRINGS	PA	16403-4959	41.824293	-79.987335							
CRAWFORD COUNTY ROADSPREADING - ROME TOWNSHIP			ROAD SPREADING				PA		41.755178	-79.672852							
CRAWFORD COUNTY ROADSPREADING - SADSBURY TOWNSHIP			ROAD SPREADING				PA		41.615956	-80.344048							
CRAWFORD COUNTY ROADSPREADING - SPRING TOWNSHIP			ROAD SPREADING				PA		41.813291	-80.299759							
CRAWFORD COUNTY ROADSPREADING - SUMMERHILL TWP			ROAD SPREADING				PA		41.730842	-80.298729							
CRAWFORD COUNTY ROADSPREADING - SUMMIT TOWNSHIP			ROAD SPREADING				PA		41.665218	-80.332375							
CRAWFORD COUNTY ROADSPREADING - TROY TOWNSHIP			ROAD SPREADING				PA		41.649058	-79.808121							
CRAWFORD COUNTY ROADSPREADING - UNION TOWNSHIP			ROAD SPREADING				PA		41.571022	-80.154533							
CRAWFORD COUNTY ROADSPREADING - VENANGO TWP			ROAD SPREADING				PA		41.827363	-80.108528							
CRAWFORD COUNTY ROADSPREADING - VERNON TWP			ROAD SPREADING				PA		41.622116	-80.207062							
CRAWFORD COUNTY ROADSPREADING - WAYNE TWP			ROAD SPREADING				PA		41.544561	-79.986305							

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CRAWFORD COUNTY ROADSPREADING - WOODCOCK TWP			ROAD SPREADING				PA		41.711111	-80.076942							
ELK COUNTY ROADSPREADING - HIGHLAND TOWNSHIP			ROAD SPREADING				PA		41.583735	-78.832998							
ERIE COUNTY ROADSPREADING - AMITY TOWNSHIP			ROAD SPREADING				PA		41.96383	-79.806747							
ERIE COUNTY ROADSPREADING - FAIRVIEW TOWNSHIP			ROAD SPREADING				PA		42.031444	-80.243111							
ERIE COUNTY ROADSPREADING - FRANKLIN TOWNSHIP			ROAD SPREADING				PA		42.028639	-80.243454							
ERIE COUNTY ROADSPREADING - GREENFIELD TOWNSHIP			ROAD SPREADING				PA		42.121909	-79.851379							
ERIE COUNTY ROADSPREADING - HELEN NELSON TRUCKING		NW3314	ROAD SPREADING				PA										
ERIE COUNTY ROADSPREADING - LE BOEUF TOWNSHIP			ROAD SPREADING				PA		41.998284	-80.143204							
ERIE COUNTY ROADSPREADING - MCKEAN TOWNSHIP			ROAD SPREADING				PA		41.995222	-80.14286							
ERIE COUNTY ROADSPREADING - NORTH EAST TOWNSHIP			ROAD SPREADING				PA		42.189355	-79.81842							
ERIE COUNTY ROADSPREADING - UNION CITY BORO			ROAD SPREADING				PA		41.899211	-79.852753							
ERIE COUNTY ROADSPREADING - UNION TOWNSHIP			ROAD SPREADING			UNION	PA		41.913264	-79.818764							

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ERIE COUNTY ROADSPREADING - VENANGO TOWNSHIP			ROAD SPREADING				PA		42.02035	-79.831381							
ERIE COUNTY ROADSPREADING - WASHINGTON TOWNSHIP			ROAD SPREADING				PA		41.899211	-80.085526							
ERIE COUNTY ROADSPREADING - WATERFORD TOWNSHIP			ROAD SPREADING				PA		41.980421	-79.985962							
ERIE COUNTY ROADSPREADING - WAYNE TOWNSHIP			ROAD SPREADING				PA		41.954384	-79.717827							
FOREST COUNTY ROADSPREADING - GREEN TOWNSHIP			ROAD SPREADING				PA		41.534925	-79.366436							
FOREST COUNTY ROADSPREADING - HARMONY TOWNSHIP			ROAD SPREADING				PA		41.584377	-79.458961							
FOREST COUNTY ROADSPREADING - KINGSLEY TOWNSHIP			ROAD SPREADING				PA		41.492057	-79.457932							
FOREST COUNTY ROADSPREADING - TIONESTA TOWNSHIP			ROAD SPREADING				PA		41.516997	-79.483166							
GREENE COUNTY ROADSPREADING - SPRINGHILL TOWNSHIP			ROAD SPREADING				PA		39.763686	-80.46627							
INDIANA COUNTY ROADSPREADING - GREEN TOWNSHIP			ROAD SPREADING				PA		40.709011	-79.016676							
JEFFERSON COUNTY ROADSPREADING - BEAVER TOWNSHIP			ROAD SPREADING				PA										
JEFFERSON COUNTY ROADSPREADING - ELDRED TOWNSHIP			ROAD SPREADING				PA		41.26684	-79.08251							

WASTE FACILITY	OWNER	WASTE FACILITY PERMIT	DISPOSITION METHOD	FACILITY ADDRESS1	FACILITY ADDRESS2	FACLIITY CITY	FACILITY STATE	FACILITY ZIP	FACILITY LATITUDE	FACILITY LONGITUDE	WELL PAD ADDRESS1	WELL PAD ADDRESS2	WELL PAD CITY	WELL PAD STATE	WELL PAD ZIP	WELL PAD LATITUDE	WELL PAD LONGITUDE
JEFFERSON COUNTY ROADSPREADING - PERRY TOWNSHIP			ROAD SPREADING				PA		40.921814	-79.043884							
JEFFERSON COUNTY ROADSPREADING - WARSAW TOWNSHIP			ROAD SPREADING				PA		41.020029	-78.949728							
MCKEAN COUNTY ROADSPREADING - ANNIN TOWNSHIP			ROAD SPREADING				PA		41.884132	-78.241324							
MCKEAN COUNTY ROADSPREADING - PRIVATE ROADS / LOTS			ROAD SPREADING				PA		41.835805	-78.479462							
MCKEAN COUNTY ROADSPREADING - WETMORE TOWNSHIP			ROAD SPREADING				PA		41.667494	-78.733134							
MERCER COUNTY ROADSPREADING - DEER CREEK TOWNSHIP			ROAD SPREADING				PA										
MERCER COUNTY ROADSPREADING - FAIRVIEW TOWNSHIP			ROAD SPREADING				PA										
MERCER COUNTY ROADSPREADING - FRENCH CREEK TWP			ROAD SPREADING				PA		41.461125	-80.041752							
MERCER COUNTY ROADSPREADING - GREENE TOWNSHIP			ROAD SPREADING				PA		41.46444	-80.451849							
MERCER COUNTY ROADSPREADING - JEFFERSON TOWNSHIP			ROAD SPREADING				PA		41.26555	-80.310745							
MERCER COUNTY ROADSPREADING - LAKE TOWNSHIP			ROAD SPREADING				PA										
MERCER COUNTY ROADSPREADING - NEW VERNON TOWNSHIP			ROAD SPREADING				PA		41.409647	-80.131874							

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MERCER COUNTY ROADSPREADING - PERRY TOWNSHIP			ROAD SPREADING				PA										
MERCER COUNTY ROADSPREADING - SALEM TOWNSHIP			ROAD SPREADING				PA		41.453406	-80.299416							
MILLER BRINE & SEPTIC SVC - WARREN CNTY RDSPRD		365216	ROAD SPREADING				PA		41.824549	-79.289703							
POTTER COUNTY ROADSPREADING - GENESEE TOWNSHIP			ROAD SPREADING				PA		41.950682	-77.866201							
VENANGO COUNTY ROADSPREADING - ALLEGHENY TOWNSHIP			ROAD SPREADING				PA		41.584153	-79.53299							
VENANGO COUNTY ROADSPREADING - CANAL TOWMSHIP			ROAD SPREADING				PA		41.484148	-79.949741							
VENANGO COUNTY ROADSPREADING - CORNPLANTER TWP			ROAD SPREADING				PA		41.517543	-79.599681							
VENANGO COUNTY ROADSPREADING - MINERAL TOWNSHIP			ROAD SPREADING				PA										
VENANGO COUNTY ROADSPREADING - OIL CREEK TOWNSHIP			ROAD SPREADING				PA		41.585276	-79.611182							
VENANGO COUNTY ROADSPREADING - PINEGROVE TOWNSHIP			ROAD SPREADING				PA	16301									
VENANGO COUNTY ROADSPREADING - RICHLAND TOWNSHIP			ROAD SPREADING				PA		41.230444	-79.682808							
WARREN COUNTY ROADSPREADING - COLUMBUS TOWNSHIP			ROAD SPREADING				PA		41.938807	-79.538269							
WARREN COUNTY ROADSPREADING - ELDRED TOWNSHIP			ROAD SPREADING				PA		41.742499	-79.537926							

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WARREN COUNTY ROADSPREADING - FARMINGTON TOWNSHIP			ROAD SPREADING				PA		41.938807	-79.538269							
WARREN COUNTY ROADSPREADING - SOUTHWEST TOWNSHIP			ROAD SPREADING				PA										
WARREN COUNTY ROADSPREADING - SPRING CREEK TWP			ROAD SPREADING				PA		41.863425	-79.537926							
WARREN COUNTY ROADSPREADING - SUGAR GROVE TOWNSHIP			ROAD SPREADING				PA		41.950043	-79.347038							
WARREN COUNTY ROADSPREADING - TRIUMPH TOWNSHIP			ROAD SPREADING			TRIUMPH	PA		41.653162	-79.447632							

EXHIBIT G

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Oil and Gas Well Brines for Dust Control on Unpaved Roads – Part 1: Ineffectiveness

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Abstract

Natural gas and oil drilling have expanded rapidly in the U.S in recent years. The volume of various associated waste products has been increasing. One such waste product is the typically saline water produced from the wells along with the hydrocarbons. A variety of methods are currently being employed to dispose of this oil and gas well brine (OGB). One such practice is spreading OGB on unpaved roads for dust control and road stabilization. This investigation focused on the likely effectiveness and anticipatable risks of spreading OGB on unpaved roads. Despite decades of regulated use of OGB for dust control, there appears to be a complete lack of data indicating the practice is effective. Analysis of regulations, related literature, and original data indicated spreading OGB on unpaved roads is ineffective and likely counterproductive for dust control and road stabilization as reported here in Part 1, and presents numerous potential and immediate environmental, health and economic risks as reported in Part 2 (publication pending).

Keywords: Oilfield brine, produced water, dust suppression, dust control, road stabilization, unpaved roads, oil and gas wastewater disposal

Introduction

1. Oil and gas well brine and its disposal

It is not common knowledge that oil and gas wells typically produce substantially more water than oil or gas, usually less water earlier, and increasingly more later in the production life of a well (Conselman, 1967; Veil et al., 2004; Morris, 2004). That water must be separated from the hydrocarbon product stream before the product is transported.

Produced water typically has a high salt content, mostly sodium chloride, and is consequently also referred to as oil and gas well brine (OGB).

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Once separated, the OGB is a waste. Conventional gas wells produce somewhat less wastewater than conventional oil wells. Horizontal wells typically produce more wastewater per unit of production than vertical wells, and wells stimulated with hydraulic fracturing typically produce more than their conventional counterparts. It has been reported that before 2000, nearly no U.S. oil wells were hydraulically fractured, but 51% of oil produced in the U.S. in 2015 came from hydraulically fractured wells (USEIA, 2016). Consequently, oil and gas well wastewater production will likely increase along with the management challenge it presents.

Numerous practices have been used to manage oil and gas well wastewater (Veil et al., 2004). Among such practices are deep-well injection, evaporation, and various treatment methods followed by recycling for use in oil and gas wells and other industrial processes. One of these, due to the typically elevated salt content, is to apply OGB to paved roads as a winter deicer and to unpaved roads as a summertime dust-control and stabilization agent. Though less important than some other methods of disposal with respect to total amount of wastewater involved, application on roadways is common and locally important in some areas, including at least the states of Michigan, New York, Ohio and Pennsylvania.

2. Studies on the application of OGB to roads

Michigan appears to have the oldest developed documentation of the history and regulation of the spreading of OGB on roads. A thorough report prepared in 1984 by J.E. Herrold of the Michigan Department of Natural Resources (DNR) is among the most informative single documents available on the history, theory, and the limited data on the use of OGB on roads, though it does not address brine impacts on road stability.

Herrold (1984) concluded application of OGB to unpaved roads seems to date back to early development of the oil and gas industry in Michigan. Similarly, the Pennsylvania Department of Environmental Protection (PaDEP) Environmental Quality Board (2016) stated, “Throughout the history of conventional oil and gas development, brine has been beneficially used in dust suppression and road stabilization activities on dirt roads….” Historical data from Michigan show that there was an industrial market for OGB until the early 1950s. When that industrial demand ended, road spreading of OGB increased substantially in Michigan. Due to its high salinity, OGB was applied as a deicer on paved roads and for dust control on unpaved roads, substituted for commercial brine or related dry products.

2.1. Risk to water quality recognized

Despite those practical uses, realistically, road application of OGB was primarily an oil-well waste-disposal practice. In the 1970s, concerns arose in Michigan that widespread abusive spreading of OGB on land, including roads,

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was occurring and could impact water quality. The Michigan DNR developed rules, issued in 1981, to regulate use of OGB on roads. Herrold (1984) discussed those rules, similar to rules adopted in other states, and how their effectiveness depends on compliance and enforcement, neither of which had been achieved by 1984. Non-compliance and a lack of enforcement, usually due to lack of resources to support enforcement, are still common problems that can result in exploitation of roadways as OGB disposal grounds.

The PaDEP (1996) investigated the potential for water contamination from OGB applications for dust control at seven locations from 1992 to 1995. Based on the findings and recommendations of that investigation, PaDEP lowered its maximum allowable application rate. That PaDEP report contained a brief literature review, which included most of the literature reviewed by the present author. However, the PaDEP review of the literature was neither critical nor thorough, and the report recommended application rates based solely on the subjective opinions of OGB users.

2.2. Limited evidence supporting effectiveness

Herrold (1984) found very limited data on the effectiveness of OGB as a dust-control agent for unpaved roads. Now, over 30 years later, there is still surprisingly little. Herrold (1984) cited a report by Moore and Welch (1977) at the College of Engineering at the University of Arkansas on their brief investigation. Moore and Welch (1977) applied an industrial-waste brine with a composition similar to OGB and concluded the brine did provide dust control for a period of about 30 days when applied at a rate of 0.3 gallons per square yard.

Interestingly, neither the Moore and Welch (1977) application rate of 0.3 gallons per square yard (gal/sq yd) nor schedule (monthly) appeared as part of the Michigan rules for OGB applications to roads for dust control, but are the OGB road-spreading application rate and schedule adopted in several states, including as recently as 2013 by the North Dakota Department of Environmental Quality. It appears that many current guidelines for road spreading of OGB for dust control are based on the single Moore and Welch (1977) study done 40 years ago, which suggests an ongoing need to critically examine that study.

2.3. Moore and Welch: Experimental design and data analysis

The Arkansas State Highway and Transportation Department commissioned the Moore and Welch (1977) study. The report was not found as a peer-reviewed article, raising the possibility that the methods and conclusions were not subjected to external scientific or engineering scrutiny. A closer examination of Moore and Welch (1977) reveals a series of shortcomings, especially with regard to the conclusions drawn.

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The field investigation of dust control involved 5 sequential sections of unpaved road, each about 1,000 feet long. For experimental design purposes, each road section may be regarded as the equivalent of an experimental field plot. There were 4 treated plots and one untreated control plot. Plots 1 and 2 ran north-south, 4 and 5 ran more northwest-southeast, and 3 was curved and sloped between the 1-2 and 4-5 sections. The brine application rates (treatments) were not randomized among the plots, running effectively sequentially from low in plots 1 and 2, somewhat higher in 3, highest in 4 and none in 5, the control plot (see table below).

Plot (road section)	Brine application rate (gal/sq yard)
1	0.19
2	0.19
3	0.21
4	0.31
5	0

Over approximately 5,000 running feet of test road, variations could have occurred, and in some cases definitely did occur, in local soil type, slope, distribution of rainfall and direction of wind, aspect and insolation, and potentially other factors that could affect dust release. The experimental design provided no means of accounting for such variations. That such variations did have an effect is suggested by the authors' report of lack of significant difference (t-test 95% confidence level) between the mean dust data for plot 3 (0.21 gal/sq yd) and the no-brine control plot (5), while finding significant differences between the control plot (5) and both the low (plots 1, 2) and high (plot 4) brine levels. The authors speculated that the slope of plot 3 might have caused more rapid washing of brine from plot 3, resulting in earlier loss of dust control, but closer examination of the dust data shows that plot 3 always had the highest dust level among the brined plots. That is, the data indicate there were inherent differences in potential dustiness among the plots.

Given that it is reasonable to expect variations in potential for dust release over 5,000 feet of roadway, and that the data suggest such differences did occur, it follows that responses to wind, weather and solar exposure would differ among the plots on a daily basis. Further, it would be reasonable to expect the variability of the data (e.g., standard deviation) would increase as dust levels increase, i.e., dustier plots would have higher variability, with or without brine treatment. It would, therefore, be more appropriate to compare treatment effects on each sample date instead of mean behavior over the 15 sample dates.

The present author performed such an analysis by examining whether the 95% (t-test) confidence intervals for each of the 4 brined plots (1-4) and the no-brine control plot (5) overlapped on each of the 15 reported sample dates, a

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total of 60 treatment-vs.-control by-date comparisons. That analysis showed that the confidence intervals overlapped, i.e., there was no significant difference between the treated and untreated road sections for 35 of the 60 by-date differences. Of the 25 by-date differences suggesting a significant effect due to brining, 13 occurred following a rain event, when dust levels for all plots were, or would have been expected to be, low.

Further, of the 25 by-day differences suggesting a significant dust-reducing effect due to brine, 7 occurred for plot 2 (the lowest brine application rate) but only 6 for plot 4 (the highest brine application rate). The only sampling date away from rain events on which all 4 treated plots had significantly lower dust levels than the control plot was the first sampling date, 2 days after the brine application.

It is the present author's opinion that the dust palliation data collected in the Moore and Welch (1977) study, in fact, showed that application of an industrial waste brine similar to OGBs provided little or no dust control, and that the contrary conclusion by Moore and Welch was due to a failure to adequately consider the complexity of factors inherent in their experimental design. This suggests that 40 years of OGB use for dust control has been based on a study the data from which actually indicated the practice provided measurable dust control for not more than three days.

2.4. Moses: more questions than answers

Herrold (1984) also cited a comparative investigation of dust control reported by P.J. Moses (1982) of the Dow Chemical Company. Referring to the Moses study, Herrold (1984) stated that the "…study…found that LIQUIDOW may provide three times better dust suppression than will a typical oil field brine." LIQUIDOW is a liquid calcium chloride product sold by Dow Chemical Company as a dust-control product. In his report, Herrold (1984) pointed out that the maximum calcium content of Michigan oilfield brine (75 g/L) is about 3 times lower than that of LIQUIDOW (195 g/L). The average calcium content of Michigan oilfield brine (28 g/L) is about 7 times lower than that of LIQUIDOW, but also contains 50 g/L sodium.

The present author has been unable to locate a copy of the Moses (1982) study. Consequently, a detailed examination of its methods, data and conclusions could not be developed for this review. The following are among questions of concern for any such studies, which for now must remain unanswered for the Moses (1982) study:

- Where were the test roads, and what were the road characteristics?
- What was the composition (mineralogy, particle size distribution, etc.) of the road material?
- What were weather conditions during the investigation?
- How were dust levels measured?

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- What were the application methods and rates?
- Was there one application, or multiple?
- Did application of the brine reduce dust emissions by 1/3 compared to LIQUIDOW at the next dust event, or did it provide similar dust reduction, but for only 1/3 the time that LIQUIDOW reduced dust?

2.5. Russell and Caruso data: Even high-volume applications exceeding most state guidelines show rapid decline in effectiveness

After consideration of Moore and Welch (1977) and what we know of Moses (1982), one is left with a practice that is without verified effectiveness. There was apparently another related investigation. In Cowherd and Kinsey (1986) their "Figure 5-5. TSP [Total suspended particulates] control efficiency decay for light-duty traffic on unpaved roads" plotted data generated by a test of oil-well brine for dust control reported by Russell and Caruso (1982). As of the time of submission of this report, the present author has been unable to locate a copy of the original Russell and Caruso (1982) study. Consequently, Cowherd and Kinsey's Figure 5-5 appears to be the only, albeit secondarily, documented data from an actual test of the use of oil well brine for dust control.

Cowherd and Kinsey (1986) gave a "C" quality rating to the Russell and Caruso (1982) results as data from "Tests that are based on an untested or new methodology or that lack a significant amount of background data." The Cowherd and Kinsey (1986) report focused on methods of designing and estimating effectiveness and costs of particulate emissions control efforts and offered no further interpretation of the Russell and Caruso (1982) oil-well brine dust control data. Nevertheless, it appears that the Russell and Caruso (1982) data as presented by Cowherd and Kinsey (1986) is the only actual measurement data on an actual use of oil well brine for dust control on an unpaved road (see also 2.6 below). Consequently, it is necessary to consider that data more thoroughly.

The dust measurement method, experimental design, weather conditions, and characteristics of the road (or roads) and the oil well brine used by Russell and Caruso (1982) were not documented beyond Cowherd and Kinsey (1986) data quality rating of "C." Cowherd and Kinsey (1986) report that Russell and Caruso (1982) used an upwind/downwind approach to determine the dust levels for each experimental plot (treatment). Presumably, all treatments were run in a single experimental effort that lasted only 32 days. The average vehicle characteristics for traffic on the road were a total of 4 wheels and gross weight of 6000 pounds. Oil-well brine was initially applied at a very heavy rate of 3.8 gallons per square yard, with a heavy follow-up application of 0.6 gallons per square yard 22 days later.

It is notable that an application rate of 3.8 gal/sq yd is equivalent to a standing layer of brine 0.68 inches deep on the road surface. Assuming a void

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space volume of 10% in the presumably compacted road material, such an application rate would saturate the road surface soil to a depth of 6.8 inches—an unworkably high moisture content. Alternatively, since a graded and compacted road surface would result in runoff of most of such a heavy brine application, the test road may have been loosened and prepared for a single 3.8 gal/sq yd application and compacted subsequently. However, even if the road material were loosened to an effective pore space of 30%, 3.8 gal/sq yd would still result in saturated conditions to a depth of over 2 inches, which would drain to an unworkably high moisture content to a considerably greater depth. Hence, application to a prepared, graded but un-compacted road surface would likely require the road to be out of service for at least a few days. Consequently, it appears reasonable to assume that the initial brine application was accomplished as a series of lighter applications until the target application rate was reached. Since the follow-up application was 0.6 gal/square yard, it also would appear reasonable to assume that was an application rate that did not result in excessive runoff.

In light of the preceding, the present consideration of the results of Russell and Caruso (1982) assumes an initial application applied in 5 increments of about 0.6 gal/sq yd, because if that were not the case, then the Russell and Caruso (1982) data cannot be considered representative of any reasonable practice. Presumably the entire application could have been completed in 3-5 days. This assumption leaves unclear whether days after initial application were counted from the day of the first or the last incremental application.

Apparently, day 8 after the heavy brine application was the first dust-control sample date. The 3.8 gal/sq yd oil-well brine application resulted in a 91% reduction in dust emissions on days 8 and 18. However, on day 19, the dust control effectiveness dropped slightly to 90%. While this minor decline could have been within measurement method variability, it appears likely that it was associated with an actual decline in effectiveness for three reasons:

1. The other two dust control products being tested also began to decline in effectiveness on or soon after day 18.
2. Use of a relatively heavy (0.6 gal/sq yd) follow-up application of brine on day 22 would appear unreasonable if a decline in effectiveness had not become observationally apparent between days 18 and 21.
3. The follow-up application increased dust control to 94% on day 26; however, effectiveness dropped to 83% by the final sample date only six days later (sample day 32).

So, apparently the only available data on an actual use of oil-well brine for dust control (see 2.6 below) indicated that an application of 3.8 gallons of brine per square yard had a dust-control effectiveness that began to decline after

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18 days, and that an additional application of 0.6 gal/square yard extended the time to decline of dust control by only a few days, with a steep decline in effectiveness apparent by day 32, despite an exceptionally heavy total brine-application rate of effectively 4.4 gallons per square yard per month. Such rates exceed by far the state guideline once-per-month, 0.3 to 0.5 gal/sq yd rate that purportedly poses an acceptable environmental risk.

2.6. Data on OGB for dust control: a 45-year hiatus

A reasonable literature search by the author found no publications or mentions of studies involving actual measurements of dust control effectiveness of OGB after 1982, with a single exception by Graber et al. (2017), too recent to have influenced state guidelines. Citations in documents of relevant authorities from various states suggest that the only documented basis for the acceptance of the use of OGB for dust control was, and remains, the Moore and Welch (1977) study, the conclusions of which on further examination appear to be unsupported by their data (see 2.3 above). The 1982 findings of Russell and Caruso (1982) indicating that effective dust control using OGB requires high-risk application rates do not appear to have been cited, except by Cowherd and Kinsey (1986).

It appears the only scientific or engineering work on the dust control effectiveness of OGB since the 1980s is that of Graber et al. (2017), who concluded that the OGB was not effective as a dust control agent. So, within the relevant historical context, the consistency of the maximum brine application guidelines across states and time would seem to require that the findings of Russell and Caruso (1982) have been ignored; imply that current OGB application guidelines are based on a single, one-month study done 40 years ago on bromide plant waste brine, not OGB; and indicate that when applied as directed by state guidelines, OGB is not effective for dust control.

3. Studies on commercial dust-control products: requirements for effectiveness

Given the foregoing, one must either conclude that OGB applied at anywhere near the state-advocated maximum rates will not provide effective dust control, or seek additional information to further consider the potential dust control effectiveness of OGB. Additional useful information on the likely effectiveness of OGB for dust control can be extracted from investigations of the effectiveness of commercial dust-control chloride products.

E.N Johnson and R.C. Olson (2009) reported on a 2006-2008 study of the effectiveness of commercial magnesium and calcium chlorides and organic-polymer-plus-binder products, and concluded that the chlorides were effective for dust control and road stabilization. The data suggested the chlorides caused increased moisture retention in road material, which improved mechanical stability and reduced dust release and need for maintenance (re-grading of road

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surface). The authors pointed out the importance of fine road-soil particles (passing 0.075 mm sieve). Among the particle-size fractions unpaved road materials contain, the small-particle-size fraction interacts most strongly with moisture, increasing in strength as moisture levels increase (up to a limiting moisture level beyond which strength of the soil-fines fraction, or "binder," decreases).

Johnson and Olson (2009) reported findings with respect to application methods, rates, and schedules. Though their findings were for commercial products that are much more concentrated (typically 32-38% calcium chloride) than OGB (average 11-12% sodium chloride and 4-5% calcium chloride), the results provide a useful reference for consideration of reasonable expectations of OGB in similar use. Johnson and Olson (2009) found application rates of 0.18 to 0.55 gallons per square yard were effective for up to 200 days. Numerous others reported or cited similar results from their own or others' investigations (Sanders and Addo, 1993; Bolander and Yamada, 1999; Gebhart, 1999; Scott et al., 2004; Monlux and Mitchell, 2006; Jones et al., 2013; McHattie, 2015; Vermont Local Roads Program).

3.1. Incorporation improves performance

All those authors and agencies recommended or applied calcium and/or magnesium chlorides for dust control by mixing with the road materials during or following road-surface preparation. Recommended road-surface preparation included scarifying to loosen and break up surface materials to a minimum depth of 2 inches and to reduce maximum individual aggregates to <2 inches in diameter, application of dust control product and thorough mixing to assure a consistent blend of particle sizes over the entire road surface, and subsequent crowning and compaction of the road surface. Establishment of effective roadway drainage was regarded as essential to an effective road-preparation effort. Effective drainage requires construction of ditches and ancillary drainage ways along the roadside to assure water drains freely and uniformly from the road surface and road base.

None of the authors or agencies recommended surface application of chlorides for dust control and stabilization without incorporation into road material. Only one agency, the Wisconsin Transportation Information Center (1997)(WTIC), recommended road-surface preparation and surface application of dust control product if followed by sufficient watering to dissolve and infiltrate the chloride into the road material, but cautioned that incorporating the product during preparation would be necessary on roads where difficulties are encountered getting uniform dissolution and infiltration of the chloride.

There were varying degrees of admonition against surface spreading without incorporation. Two concerns were most commonly cited. First, all three chlorides (Na, Ca, Mg) used for dust control, whether in commercial products or OGB, are readily soluble salts. Consequently, when on the surface

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of a roadway, the next occurrence of rain in sufficient amount will dissolve these chlorides and carry them off the road, reducing their stabilizing effects. Second, such runoff water and its dissolved salts will move into the associated ditches and other drainage pathways, where they can impact ground or surface waters, soils and plants.

The more permeable a road surface, the more efficiently water runoff will deplete surface-applied chlorides, and the greater the potential for contamination of soils and surface waters. Among the objectives of compaction during road construction is establishing a surface that is minimally permeable.

On roads where chlorides are applied and incorporated into the surface material, compaction reduces permeability, reducing water infiltration, which reduces leaching of incorporated chlorides. It follows that application of brines to a finished, well-constructed road surface will not be as effective as incorporation before compaction.

In contrast, spreading OGBs on poorly maintained or unstable road surfaces has destructive implications. On unstable roads, traffic can increase degradation of the surface, especially during periods of high moisture. Moisture interacts with and occurs predominantly in the pockets of fines and void spaces among coarser particles within the road soil. When moisture levels rise too high, the bulk strength of bound (aggregated) fines in the road soil decreases. The road can become noticeably softer, even muddy. Even when such obviously "soft" conditions are not readily observable, minor softening of aggregates of fine particles can result in traffic-load-induced movement of coarser particles "pumping" soil fines toward the surface.

As fines are pumped from below they accumulate nearer, or on, the road surface. Due to the cumulatively increasing fines content of the developing surface layer, water-retention capacity increases and permeability decreases. Without sufficient coarser material, the fines-enriched surface layer cannot resist mechanical forces of traffic loads, increasing dust during dry weather, and softening and muddiness during wet weather. Fines on the road surface are then more subject to loss by wind erosion (dust), water erosion, and removal due to throw by, or attachment to, passing vehicles. When dust is released, the texture (particle-size distribution) of the surface road soil becomes coarser. As those fines are lost, the more permeable, coarser underlying layer becomes more exposed. Loose surface material, a.k.a. "float," accumulates on the road surface. Such float material is now texturally distinct from, and no longer hydraulically contiguous with the underlying more stable road surface, and even within itself is texturally heterogeneous. Water infiltration into the still-intact road surface increases, more fines are pumped to the surface, and the degradation of the road becomes a self-promoting process.

Any solution applied to a road surface will be preferentially absorbed by finer compared to coarser materials. Consequently, any fine road-float material will absorb and retain applied brine, becoming obviously wet, often muddy, in

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the process. If any of the chloride solution does get through to the underlying intact road surface, that more stable material is now both texturally and hydraulically distinct from the loose surface material. At such textural hydraulic boundaries, bonding between texturally distinct soil volumes is weak. When the wetted soil materials dry out, the body of float material will undergo dimensional changes at a rate different from the underlying intact road soil. The float body will peel away from the more stable intact road surface, a phenomenon known as "biscuiting." The float "biscuit" will destabilize to dust more quickly than and separately from the underlying, more stable material.

Loss of fines has still another destructive impact. As fines are lost as dust or sediment, loose, coarser particles will accumulate in the float material on the surface. Traffic action on those coarse particles will increase breakdown of coarse particles into fines, as well as abrasion of the underlying stable road surface. That is, once stability of the road surface has diminished to the point dust release is substantial, the constituents of any chloride solution applied to a worn, impermeable road surface will become part of the road dust, and will likely increase the amount of dust emitted and will consequently destabilize the road.

Consequently, spray application of chlorides to the surface of roads in poor condition is not only a wasted effort, but can be expected to exacerbate the already poor condition (Jones et al., 2013). Further, Na-rich brines can be expected to have more negative effects than calcium or magnesium (see section 7. below). Because application of brines is not reasonable or practical on poor-condition roads that are wet, most such applications occur when dust emissions are occurring or imminent, i.e., when conditions are, or soon will be, dry enough to promote dust release, and assure the brine application will enhance rather than reduce dust emissions.

3.2. Dust control vs. road stabilization

Some authors and agencies recommend incorporation of chlorides into road material as a road-stabilization practice, others as a dust control practice. Other authors and agencies also point out that dust control and the related road construction and maintenance objective of stabilization are functionally inseparable (e.g., Gesford and Anderson, 2007). A road that is producing dust is necessarily losing road material. A road that is losing material is unstable.

It is interesting to note that instead of regarding road stabilization as an objective, Gesford and Anderson (2007) define road stabilization as a practice that includes application of chlorides during road construction at rates already discussed, a practice they more accurately named "full depth reclamation." This distinction is important in that it eliminates the confusion implicit in recurring statements by various state authorities regarding use of OGB for "dust control and road stabilization," as though road stabilization were a passive side-

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effect of dust control. This suggests an important, and erroneous, misunderstanding of the dependency of the two objectives.

Dust control is a necessary consequence of road stabilization, but road stabilization is not necessarily a consequence of dust control. For example, a surface application of water will provide short-term dust control, but will not stabilize the road. Ambiguous usages undoubtedly are in part the source of the apparently widespread misconception that “road stabilization” is a concomitant effect of “dust control”.

4. State guidelines lack supporting data

As an example, consider the following from the North Dakota “Guidelines for the Use of Oilfield Salt Brines for Dust and Ice Control” (2013):

> When used in the manner outlined in this guidance, the North Dakota Department of Health (NDDoH) considers oilfield-produced saltwater (brine) to be an effective substitute for commercial dust and ice control products.
>
> …
>
> 4. <u>Brine spreading guidelines</u>
>
> …
>
> d) Recommended rates for dust control: The initial application of brine shall be spread at a rate of approximately one-half… gallon per square yard, after the road or parking lot has been freshly graded. …Subsequent applications shall not exceed an application rate of one-third (1/3) gallon per square yard per month, unless weather or traffic conditions require more frequent applications to suppress the dust or stabilize the road bed. Application rates for race tracks and mining haul roads shall not exceed one (1) gallon per square yard.

In the three-page North Dakota Depart of Health Guidelines (2013) the word “dust” appears 18 times, 16 of which in the term “dust control.” In contrast, there is only one occurrence of the word “stabilize” in “[brine] applications to…stabilize the road bed,” (quoted above). Functionally, it appears that the NDDoH distinguishes dust control from road stabilization, but it is not clear from the ND Guidelines (2013), or any similar, related or predecessor document, why occasional applications of small amounts of mixed chlorides, mostly sodium, in OGBs to the road surface can be reasonably expected to have any stabilizing effect on the underlying road bed.

In fact, sodium loading of the cation exchange sites on many soil clays, which comprise much of the fines in many unpaved road surface materials, including the road bed, will result in dispersion of the clay particles (see section 7. below). Under conditions that occur frequently on many unpaved roads, sodium dispersion of the clays will have a number of destructive effects. When

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the road is dry, dispersion of the clays will destabilize the road surface, leading to increased dust, and, when wet, will increase softening, muddiness and slipperiness. If the sodium reaches and disperses the clays in the road bed, the resulting destabilization will increase potholing and other structural problems in the affected road.

Further, section 4.b) of the ND guidelines requires that brine be applied "in a way that minimizes impact to the environment" only in amounts "necessary to control dust…" and "controlled to minimize the impact of brine infiltrating to ground water or running off the road surface into" surface waters. Then, as in other states, the ND Guidelines (2013) specify that amount of brine is 1/3 gallon per square yard per month, but then relinquishes the need to control brine application to minimize impact by stating, "unless weather or traffic conditions require more frequent applications," and adds a final exception regarding racetracks and mine haul roads. Those who would apply brine in compliance with the ND Guidelines (2013) need to be able to evaluate several conditions, which can be considered as sets of questions implied by the guidelines [implications of some of which will be addressed in Part 2, publication pending].

1. When is a dust problem sufficient to warrant an OGB application? How does one evaluate the severity of a dust problem? When is another OGB application for dust control appropriate under the guidelines?
2. When is a "road bed" in need of stabilization? How can one know if OGB will work to stabilize a particular "road bed"? How can one determine if OGB has improved road stability?
3. How can one assess when impacts to the environment are no longer being minimized? Which impacts? How much impact to waters is acceptable or unacceptable?
4. What about other environmental impacts besides water quality? What about dust impacts on plant, animal, and human health? Nuisance impacts? Are those impacts reduced or increased by use of OGB for dust control or road stabilization?

The ND Guidelines (2013) provide no guidance as to how one should operate to assure compliance. One could interpret Sections 4.b) and d) as license to apply amounts considerably beyond the prescribed rates if weather or traffic or dust conditions or road stability are judged to be beyond some never-specified range implied by the guidelines. The vagueness of the ND Guidelines (2013) leaves the impression that the effectiveness of OGB for dust control or road stabilization, and its environmental impacts, were more likely presumed than determined. The guidelines used by several other states are functionally identical to those of ND.

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In 1998, the Pennsylvania Department of Environmental Protection, Bureau of Oil and Gas Management issued guidance titled, "Approval of Brine Roadspreading Plans." The ND guidelines (2013) are effectively identical to the PA guidelines (1998). In Ohio, OGB spreading has been controlled by regulations since the 1980s. Ohio did provide a more thorough guidance document (Kell et al., 2004), but its application rate, 3000 gallons per 12-foot-wide road mile, guidance is applicable to control of both ice and dust. Ohio imposed no minimum time intervals other than sufficiently separated in time to prevent environmental impacts. New York guidelines are similar to those of Ohio. Prior to 1998, Pennsylvania allowed a 1 gal/sq yd application rate, but based on a PaDEP (1996) study, concluded there was potential for degradation of surface and ground waters, and lowered the recommended rates for dust control/road stabilization to the currently common rate of ½ gal/sq yd initial application plus supplemental applications of 1/3 gal/sq yd per month (recall Moore and Welch, 1977). Notably, no state authorities have spoken to air quality impacts of application of OGB for dust control.

The lack of cited supporting data sources, facile citation of equivocal or contraindicating data sources, lack of specific enforceable rules and monitoring or enforcement standards among the reviewed guidelines of various states suggest an overall lack of supporting evidence for the practice. Instead, the guidelines provide a vague endorsement of OGB spreading for "dust control and road stabilization." Although the guidelines stipulate or recommend application rates, all provide the same escape clause, which functionally makes the local responsible party the sole authority over how much brine can be applied.

The guidelines suggest application of brine for dust control and road stabilization is a legacy waste-disposal practice of convenience, instead of a road maintenance practice of verified efficacy. There has been no functional revision or documented additional data supporting the effectiveness of brine use on roads since the early 1980s, and the only recent investigation concluded the practice is not effective (Graber et al., 2017). Flannery and Lannan (1988) in an industry response to U.S. Environmental Protection Agency (EPA) findings of environmental impacts, cited Moody and Associates (1984) who concluded, "since oil and gas well fluids are not substantially different in composition from commercial salt, similar concerns are apparent. However, with proper management techniques… to minimize environmental impact, these fluids can be used effectively for dust and ice control." The Moody "conclusion" appears to be more of a proposition based on a facile assembly of presumptions rather than a conscientious analysis of facts.

Contrary to the Moody and Associates (1984) conclusion, OGBs have substantially lower (salts) concentrations than commercial dust-control salt products, so much so the presumption of effectiveness must be regarded as baseless (see section 8 below). Further, though OGBs do give rise to the same

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concerns as commercial chloride products, OGBs give rise to numerous other concerns as well. The Moody conclusion supporting OGB as functionally equivalent to commercial salt/brine products for dust control or road stabilization must be regarded as either deceptive or misguided reasoning.

The Pennsylvania Environmental Quality Board (2013)(EQB) published a proposed new regulation titled "Environmental Protection Performance Standards at Oil and Gas Well Sites." The proposed regulation contained sections on disposal of OGB, including use on roads. In accord with state law, the Pennsylvania Independent Regulatory Review Commission (2014)(IRRC) reviewed and commented on the proposed regulations. The IRRC stated, "… we remain concerned that the final-form regulation fulfill EQB's obligation to protect the quality and sustainability of the Commonwealth's natural resources." Later in their report the IRRC wrote:

> "EQB has indicated that data is not the basis for this regulation. If data is not the basis for this regulation, how did EQB determine that the many standards being imposed are adequate? … Since the regulation is not based on data, we ask EQB to explain how it determined that the numerous standards being proposed are appropriate… ."

Further indication of the lack of data supporting the use of OGB for dust control and road stabilization is the wording of a 2014 letter from the PaDEP approving a brine spreading plan submitted by Farmington Township, Warren County, Pennsylvania. The brine application rates and other presumed environmental protection measures are as described in the foregoing discussion of guidelines of various states. Near the end of the letter the following text occurs:

> "The approval of these pollution prevention measures is not an approval of the activity itself. The Department of Environmental Protection neither approves nor denies the activity of spreading brine fluids for dust control, but reviews the activity due to its potential for water pollution."

This PaDEP disclaimer of the effectiveness of spreading of OGB for dust control seems to confirm the validity of the comments of the Pennsylvania IRRC, as well as the broader impression that there is no data that supports the effectiveness of OGB for dust control. This seems to have been further supported by a recent conclusion by PADEP that its previous approvals of applications of OGB to roads did not comply with state waste management law and that it must cease granting approvals for the practice (Pennsylvania Environmental Hearing Board, 2018).

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There appears to be no literature that directly addresses effectiveness of use of OGB for dust except the data of Russell and Caruso (1982) and Graber et al. (2013). The conclusion from the Russell and Caruso (1982) data is that an OGB application of at least 7 times higher than permitted by various state guidelines can reduce dust, but effectiveness begins to decline in 20 days, and such a heavy application rate effectively guarantees environmental impacts. Graber et al. (2013) concluded an exceptionally high-calcium OGB applied at the state guideline rate was not effective. There appears to be no data from any source that comes close to suggesting OGB, or any similar brine, could have the effectiveness several state agencies presume in their use guidelines, which, given that the risk of pollution increases as the amount of applied OGB increases, raises several questions. Why are plan submitters effectively granted functional discretionary authority for how much OGB should be applied? Why is water pollution the only pollution of concern? Can dust from OGB-treated roads carry contaminants from the brine to surfaces, including skin and lungs, leaves, clothing, etc.? Could such OGB-treated-road dust impose additional health risks to those who are exposed? Some of these questions can be preliminarily answered with reasonable confidence by consulting relevant science and engineering literature. [Some of these questions are considered in Part 2, publication pending.]

5. Data on actual use of commercial products and OGB for dust control

As previously discussed, there is considerable literature on the effectiveness of calcium, magnesium and sodium chlorides for road stabilization and dust control. In 2013 the U.S. Department of Transportation Federal Highway Administration released two related reports, “Unpaved Roads Chemical Treatments-State of the Practice Survey” (Kociolek, 2013) and “Unpaved Road Dust Management-A Successful Practitioner’s Handbook” (Jones et al., 2013). These two reports summarize current actual and best practices.

Neither OGB nor sodium chloride was mentioned in the Handbook (Jones et al., 2013); however, sodium chloride was included in “Appendix E. Basics about Road Dust Suppressant Categories.” The Survey (Kociolek, 2013) did not mention OGB, but 15 respondents indicated they used “other brine” and all “other brine” was applied by spraying directly onto the road surface. Out of 198 respondents, 3 explicitly commented that they used OGB. When asked, “If your agency/organization manages unpaved roads but does not use any form of chemical treatment, please state why,” one of the 3 responded that his organization used gas-well brine for dust control. Presumably the respondent did not perceive gas-well brine as a “chemical treatment” or “other brine”. When asked for positive comments to the survey question, “For your agency/organization’s most commonly used treatment, how would you rate your satisfaction with performance?” another respondent commented, “Lower

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chloride content in oil field brine," apparently regarding lower chloride content desirable even though chloride content is the basis for any dust-control or road-stabilizing effects of OGBs, if there were any. To the same question, the third OGB-using respondent commented, "Oil-well brine controls the dust and doesn't cost us anything."

Among the general results of the Survey (Kociolek, 2013), 80% of respondents stated they had been using chemical treatments for their unpaved roads for at least 6 years, while 25% reported not using any chemical treatments. Of those that used treatments, >50% used $MgCl_2$ or $CaCl_2$ or both; 98% of those who used chemical treatments did so primarily for dust control, regulatory compliance, health or public opinion concerns; and 52% to reduce road-maintenance (surface-grading) needs. Among respondents using treatments, >90% applied treatments by spraying directly on the road surface, ~40% also mixed treatments into the wearing course, ~10% into deeper portions of the road structure. While 95% reported satisfaction, only ≤25% used objective methods to evaluate effectiveness of treatments. With regard to best management practices, 80% considered chemical treatments an unpaved road best management practice, while 60% believed their own program represented a best management practice. More than 80% agreed more research and comprehensive guideline documentation are needed. According to the general responses to the Survey (Kociolek, 2013), cost is a primary concern, effectiveness is evaluated subjectively, and application is often by spraying directly on road surface.

The three comments from three OGB-using respondents and the general results of the full Survey (Kociolek, 2013) provide some insight into who uses OGB and how. OGB users obtain brine at no or minimal cost and apply only by spraying directly onto the road surface. Most state approved OGB application rates are similar, but state OGB spreading plans typically have numerous exceptions that allow application at unspecified higher rates. Given that actual application rates are unknown, this report presumes that OGB users follow state guidelines, typically an initial application at 1/2 gal/sq yd with follow-up applications of 1/3 gal/sq yd at monthly intervals.

OGBs are lower in chlorides than commercial chemical treatments. The most commonly used commercial chemical treatment products are (typically 30%) $MgCl_2$ and (typically 38%) $CaCl_2$ solutions. OGBs from western Pennsylvania average 0.8%$MgCl_2$, 5.0% $CaCl_2$ and 11.4% NaCl (Dresel and Rose, 2010). Concentrations of chlorides in OGBs vary with source, but western Pennsylvania brines are reasonably representative of OGBs generally.

The Handbook (Jones et al., 2013) and other reports state that water is the oldest, fastest, and most readily available dust suppressant. In Appendix E of the Handbook (Jones et al., 2013), which is the source of the following information, water is the first listed dust suppressant. The surface tension of water between moistened road particles holds them together, preventing

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separation and suspension as dust particles. Water is typically readily available. Use of water as a dust suppressant is, however, expensive because the effect lasts only until the water evaporates, usually <1 to 12 hours. The longer-lived effectiveness of any brine is due to the deliquescent quality of chloride salts the brine contains. Deliquescent salts attract and retain moisture from the atmosphere, resulting in moisture-binding of fines in the road surface.

The Handbook (Jones et al., 2013) Appendix E allows comparison of water with other dust suppressants, including NaCl, the most relevant to consideration of OGBs. Magnesium chloride ($MgCl_2$) is deliquescent when relative humidity (RH) is above 29%. It generally requires an initial application at 1/2 gal/sq yd and a follow-up at 1/4 gal/sq yd about 2 months later. The characteristics of calcium chloride ($CaCl_2$) are very similar, though $CaCl_2$ becomes effective at a lower RH, 20%-29%, depending on temperature. NaCl is hygroscopic, but not deliquescent until RH≥79%. NaCl also does not increase surface tension as much as $MgCl_2$ or $CaCl_2$, that is, does not strengthen the road surface as much even at RH>79%. However, because it is only deliquescent at higher humidities, under sufficiently dry conditions NaCl can dry to form crystals that may function to bind road soil particles together. NaCl must be applied at higher rates, which, according to the Pennsylvania Department of Transportation (2009), are 1 to 2 lb/sq yd per inch of compacted soil depth, compared to ½ lb/sq yd per inch for $CaCl_2$. Notably, the Handbook (Jones et al., 2013) Appendix E states that when used at concentrations below 20%, $CaCl_2$ and $MgCl_2$ solutions suppress dust about as well as water, and that NaCl tends "not to hold up as well" when applied directly to the road surface.

6. Commercial products and OGBs: expectable effectiveness

6.1. Concentration deficiencies

The information in the Handbook (Jones et al., 2013) Appendix E enables comparisons of expectable dust suppression effectiveness of OGBs and commercial chloride products. OGBs are mixtures of Mg, Ca, and Na chlorides. Mg and Ca chlorides have similar dust-suppressant properties, hence, the sum of their concentrations should approximate their effective dust suppressing concentration. Two to four times as much NaCl is needed to provide the same stabilization as $MgCl_2$ or $CaCl_2$ (Pennsylvania Department of Transportation, 2009).

The average total concentration of Mg and Ca chlorides in western Pennsylvania oil well brine is 5.8%, for convenience herein rounded to 6% (Dresel and Rose, 2010). NaCl is 11.4%, for convenience herein, rounded to 12%. The Handbook (Jones et al., 2013) Appendix E indicates $CaCl_2$ brines with concentrations <20% will be no more effective than water. It follows that there would be no reason to expect an average OGB with a $MgCl_2$+$CaCl_2$ concentration < 6% to be more effective than water. There is, however, more dust suppression potential in the NaCl in OGB. Assuming a generous 2:1

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equivalence, 12% NaCl in OGB would be equivalent to another 6% $CaCl_2$ and raise the total $CaCl_2$ equivalent concentration in an average OGB to 12%, still just over half the minimum concentration necessary to be more effective than water. That is, the chlorides concentrations in OGB do not justify an expectation that OGB will provide more effective dust suppression than an equal volume of water. This result is compatible with the no-effect data of Moore and Welch (1977), the results of Russell and Caruso (1982), which showed dust suppression but only at several times the state maximum application rates, and Graber et al. (2013), who concluded that even exceptionally high-Ca OGB is not effective at state-recommended application rates.

6.2. OGB not incorporated

The Handbook (Jones et al., 2013) states, "Spraying dust control treatments onto unprepared roads is a waste of time and money." The Survey (Kociolek, 2013) indicated 90% of all users spray them on the road surface, but did not indicate how many prepare the road surface before spraying. Anecdotal reports and the author's observations are that OGB is typically sprayed directly onto the road surface without prior grading or preparation. The Handbook (Jones et al., 2013) Appendix E indicates that surface-applied NaCl tends not to hold up as well as, presumably, mixed-in applications. Consequently, in actual use, the previous assumption of a 2:1 dust suppression equivalence of NaCl to $CaCl_2$ in OGB is likely to be overly optimistic. Hence, it is even less likely OGB will be an effective dust suppressant.

6.3. OGB use in road stabilization likely precluded by required application rates

As mentioned in the Handbook (Jones et al., 2013) Appendix E, typical treatment application rates assume adequate road preparation and incorporation into the wearing course. OGB tends to be applied to unprepared road surfaces with no effort to incorporate into the wearing course. This raises a question about whether OGB could be a practical substitute for commercial chloride products if it were applied during or following appropriate road preparation.

Using the recommended chlorides application rates (Pennsylvania Department of Transportation, 2009) and the average chlorides concentration of western PA OGB (Dresel and Rose, 2010), one can calculate that 1.65 gallons of OGB would be needed to provide a total of sodium, calcium and magnesium chlorides (assuming 2 lb NaCl has the dust suppression equivalence of 1 lb $CaCl_2$) equivalent to the recommended initial 38% $CaCl_2$ brine application rate of 0.5 gal per sq yd of treated road. A working compacted soil depth of 2 inches over an area of 1 sq yd contains 2592 cubic inches of soil. 1.65 gallons of brine contains 381 cubic inches of water. So, the application of 1.65 gal/sq yd OGB would increase the moisture content by 15%. For many soils, 15%

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moisture is too wet for compaction. Many road soils under field conditions will contain moisture before the application of 1.65 gal/sq yd OGB, further increasing the moisture content following, and reducing the practical usability of, OGB in many common road situations. If the road were prepared, including compaction, before the OGB application, then substantial runoff or puddling would be expected if 1.65 gal/sq yd OGB were applied. Therefore, it appears substitution of OGB for commercial $CaCl_2$ or $MgCl_2$ solutions during recommended road preparation work would be impractical in many, perhaps most, cases.

6.4. OGB use as refresher brine not cost effective

Given substitution of OGB for commercial brine during an initial road stabilization/dust-suppression treatment appears impractical, could OGB potentially be used for follow-up applications to maintain an already effectively chloride treated road? It is not clear that replacing dissipated Ca or Mg chlorides in an already treated road using high-NaCl follow-up treatments would be as effective as Ca or Mg chloride follow-up. Further, a 2:1 NaCl: $CaCl_2$ dust suppression equivalence is likely be overly optimistic. Nevertheless, one can disregard these concerns to explore whether use of OGB might be reasonable in terms of foreseeable costs.

To begin, one might, despite no supporting data, accept that state guideline OGB follow-up applications of 1/3 gal/sq yd per month will be effective. For commercial calcium and magnesium chloride products the Handbook (Jones et al., 2013) Appendix E indicates only one follow-up application per season is typically needed. Assuming the dust suppression season is 6 months long, and no follow-up applications will be needed until 2 months after the initial commercial dust suppression treatment, then 3 or 4 months will remain in the season for monthly OGB applications. Repeating the previous calculation of OGB application rate equivalence for these conditions (see sections 5 and 6.3), one finds that 3 successive monthly applications of average OGB at 0.3 gal/sq yd would be total-chlorides equivalent to a single application of 38% $CaCl_2$ at 0.25 gal/sq yd.

At this point the cost effectiveness of three machine operations with presumably no-cost brine must be compared to a single machine operation with 38% $CaCl_2$. Prorating from the data in the Handbook (Jones et al., 2013) "Appendix C—County Road Budget Proposal," operations for a single application of brine or $CaCl_2$ solution per mile of 24-foot-wide road costs $685. Over the same road mile, 0.25 gal/sq yd $CaCl_2$ product cost would be $1,230 and OGB cost is assumed to be $0. One application of $CaCl_2$ then would cost $685+$1,230=$1,915 while 3 applications of brine would cost 3x$685=$2,055. So, costs do not favor use of brine for follow up treatments in lieu of commercial $CaCl_2$, even without considering likely additional maintenance

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(grading) cost savings from use of $CaCl_2$ or that the actual functional mass equivalence of $NaCl:CaCl_2$ may actually be >2:1.

7. Clay-cation interactions and effectiveness of OGB vs. commercial brine – implications for dust control and road stabilization

Certain useful properties of many soils depend on the type and amount of clay minerals present. Briefly, in many soils, the predominant clay minerals belong to a class known as layer alumino-silicates. A set of images with introductory information on the structure, properties and uses of clays has been assembled and posted by H.Z. Hassan (2016).

The three most common layer alumino-silicate clay minerals in soils are kaolins (a form that would be known to some as Fuller's earth), illites (more recognizable forms of which are mica and vermiculite), and smectites (or montmorillonites, a more well-known form of which is called bentonite). Most soil clays occur as colloidal-size particles. In soils kaolin and montmorillonite particles typically are a few micrometers in their longest dimension. Illites in soils can and do occur as larger particles, though usually <100 μm in their longest dimension. All exist as layered crystalline particles, the thickness of which is typically 100 times smaller than the length or width. Because clay particles are sheets, they have high surface areas per unit weight.

All of these layer alumino-silicate clay minerals carry some net negative point charges in their crystalline structure, many of which occur on their outside surfaces. Kaolins, which have the least such negative charges, are relatively inert minerals with low cation exchange capacity (CEC). In contrast, smectites have many surface charge sites and consequently high CEC. Illites are intermediate in charge density and CEC. These clay minerals retain cations in proportions determined by the particular mineral and the relative concentrations of the cations in the water that the clay mineral contacts.

The cations held by a clay mineral affect the properties of that mineral, including its physical behavior at the scale of individual particles and bulk properties (Hassan, 2016; Sullivan and Graham, 1940; Warrence et al., 2018; Bell, 1992; Trask and Close, 1957). Clay minerals are considered desirable in unpaved road materials because they can function as binder, filling voids and providing flexible bonding at contact points among larger particles and aggregate, thereby reducing porosity and increasing strength of the road surface. The most favorable road soils contain 4-15% fines, most of which will often be clay minerals (US Department of Transportation, 2015).

Sodium is a particularly important cation with respect to clay-mineral behavior (Hassan, 2016; Sullivan and Graham, 1940; Warrence et al., 2018; Bell, 1992; Trask and Close, 1957). When sodium ions are held by a clay mineral two conditions develop. First, when a sodium ion is attached to a clay-surface charge site, both charges are neutralized and the capacity of the clay to form charge-based connections to other particles or ions at that charge site ends.

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Second, when a sodium ion attaches to one of the charge sites, it brings much of its hydration shell of water molecules with it.[a] Consequently, clay particles bearing excessive sodium cannot approach each other due, in part, to the hydration water molecules retained in the remaining hydration shell of the sodium ions. This retention of inter-particulate water reduces the bulk strength of the clay, which can lead to liquefaction of clay soils, as in landslides, or, on a smaller scale, a consistency some refer to as "slickness" or "sliminess" of soils, including road soils.

Ca and Mg occur as divalent cations and interact with clay particles very differently than sodium. When a Ca ion attaches to a point-negative charge site on a clay crystal surface, one calcium positive charge is neutralized, but one remains and is exposed to the surroundings of the crystal. In many situations, or over time, the nearest charged entity in the clay particle surroundings is another clay particle. When the clay particles are in proximity, the remaining positive charge on the calcium ion can attach to a point-negative charge site on a nearby clay crystal. That is, calcium (and magnesium, or other multivalent cation) ions can effectively bond clay particles together, a structural condition called "cation bridging", resulting in an associated increase in bulk strength.

This effect is exploited when working with colloidal suspensions of soil clay minerals in the laboratory, sometimes referred to as "chocolate milkshakes" due to their appearance. If there is need to collect the clays from that suspension, a small amount of $CaCl_2$ can be added, causing the dispersed clay particles to flocculate, settling out of suspension for collection. Flocculation is important in soil structure and strength, including in unpaved roads. Flocculation is reversible, the reverse process, known as dispersion, can be induced by addition of NaCl to a flocculated clay suspension.

It is also important at this point to consider the phenomenon known as "salting out." In the previous example of a "chocolate milkshake" laboratory clay suspension, the clay in suspension was settled out by adding a small amount of $CaCl_2$. A similar effect will result from addition of a large amount of NaCl. When a large amount of NaCl, or other ionic salt, compared to the amount of clay, is added, the suspended clay particles are in effect pushed toward each other as the sodium ions attract water away from the clay particles. As the clay particles coalesce, or gel, within the high-salt suspension, the density of the coalescences of clay particles will eventually become high

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[a]All soluble cations carry a hydration shell. [http://www1.lsbu.ac.uk/water/ion_hydration.html] In solution, divalent calcium and magnesium ions have larger hydration shells than monovalent sodium ions, but when held by a clay particle as an exchangeable cation the hydration shell of monovalent sodium ions is particularly important with respect to clay behavior.

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enough that they will settle out of suspension. This response of clay particles to high levels of soluble salts is, in fact, one of the objectives of chloride treatments of roads to control dust or stabilize structure. High concentrations of deliquescent salts attract water into the road material matrix while also causing clay particles to "salt out." That is, under high-salt conditions, the fine-particle aggregates in the road matrix are strengthened by the presence of a stabilizing amount of water due to the deliquescence of the salt and the "salting out" coalescence of clay particles.

In the case of treatment with $CaCl_2$, the clay-particle charge sites are saturated with calcium, causing the clay particles to be attracted and bonded to each other, resulting in flocculation. This flocculation can then be further enhanced by the addition of more $CaCl_2$, adding repulsive forces of salting-out to the attractive forces of flocculation. In the case of treatment with NaCl the clay particle charge sites are saturated with sodium, electrostatically neutralized, resulting in no attraction or bonding between clay particles, which then coalesce only when there is a sufficiently high concentration of sodium in the surrounding solution.

One importance of salting out of clays by NaCl compared to flocculation plus salting out by $CaCl_2$ lies in what happens in a typical seasonal sequence of dust control on unpaved roads. Assume that at the beginning of the season one of these salts is applied in an effective amount and appropriately incorporated into the road surface layer. Either salt can provide effective dust control until enough rain and associated leaching of the chloride agent have occurred.

If the chloride used was NaCl, the concentration of NaCl drops, "salting out" ceases, and sodium saturation of the clay particles takes effect and disperses the clay particles, weakening the road structure. If the chloride used was $CaCl_2$, then the effect of calcium saturation of the clay charge sites takes effect, the clay particles bond to each other, providing strength to the road material matrix. With respect to dust control on unpaved roads, the work of Graber et al. (2017) provides clear indication of the importance of the type of clay and flocculation/dispersion vs. salting out, which they assessed through sodium-adsorption ratio and electrical conductivity, respectively.

The stabilizing effects of "salting out" clays with high salt concentrations are greater than the stabilizing effects of calcium (or magnesium) flocculation of the clays. Nevertheless, it should also be recognized that the flocculating effects of calcium are effective along with "salting out" at high concentrations of $CaCl_2$, and continue after those high concentrations have been depleted. In contrast, "salting out" with NaCl must overcome the dispersing effect of sodium saturation of the clay charge sites, and that dispersing effect will remain after the high concentration of NaCl has been depleted. Hence, the better performance of $CaCl_2$ (and $MgCl_2$), compared to NaCl, as a dust control agent on unpaved roads, is due not only to its stronger

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deliquescence but also the effects of calcium on clay-aggregate formation and stability, which is, again, supported by the findings of Graber et al. (2017).

All cations in solution around a clay particle compete for the negative charge sites on the clay surface. Consequently, whether a clay is loaded with calcium or sodium depends primarily on which one is present in greater effective concentration in the surrounding solution. Soil scientists have long been concerned with this property because dispersed clay soils have poor soil structure, low porosity, low strength, and tend to be soft and sticky when wet, and hard and dusty when dry (Warrence et al., 2018). An index has been developed to assess whether a water is likely to cause soils to acquire too much sodium. That index is the sodium adsorption ratio, or SAR, which may be calculated as

$$SAR=\sqrt{2}\, C_{Na}/\sqrt{(C_{Ca}+C_{Mg})}$$

where C_{Na}, C_{Ca}, and C_{Mg} are the concentrations of Na^+, Ca^{2+} and Mg^{2+} in meq/L, respectively.[b]

Water with SAR values above 3 will result in eventual sodium displacement of calcium and magnesium; at values above 9, sodium will displace calcium and magnesium quickly. The high-Ca OGB used by Graber et al. (2017) had an unusually low OGB SAR of 7.5. The average western Pennsylvania OGB (Dresel and Rose, 2010) had a SAR of 85. The sodium in a single application of such high-SAR brines applied to a road surface will cause sodium to dominate the behavior of the clays in the road soil. Repeated applications will cause sodium to displace calcium and magnesium from the clays to continuously increasing depth, eventually reaching below the wearing course down into the road base (Occidental Chemical Corporation, 2006).

The effects that make NaCl effective as a dust control and stabilizing agent in the wearing course are not desirable in the subgrade, which needs to be mechanically stable, but permeable. Over time, water percolating through a NaCl-treated wearing course into the subgrade will cause sodium loading of the charge sites on the clays in the subgrade. If the dissolved sodium concentration is not high enough to "salt out" the clay particles, they will disperse, clay aggregates will fail, dispersed clays will migrate out of the road base in percolating water (Winston et al., 2016), and the road subgrade will be de-stabilized. When the dissolved sodium levels fall too low in the overlying wearing course of the road, clay dispersion will occur with increased dust under dry conditions and increased mud and slipperiness when wet. If the Na-dominated (sodic) condition continues, the road will eventually be destabilized throughout its depth.

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[b] Or, in a more traditional form, $SAR = (Na^+ meq/L) / \sqrt{(1/2\,(Ca^{2+} + Mg^{2+} meq/L))}$.

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Use of multiple applications of OGB can be expected to generate such sodic conditions any time of year, because brine applications do not provide the spring-to-fall stabilization that a properly executed initial granular NaCl application could provide. That is, for reasons previously discussed, applications of OGB in accord with the recommendations of various states will provide little or no dust suppression, but, instead, because of the very high SAR of OGBs, load the road clays with sodium and destabilize the road.

Use of OGB can be reasonably expected to exacerbate dust problems for another reason. As previously mentioned, magnesium and calcium chlorides, the most used commercial chloride dust-suppression agents, work because they are strongly deliquescent. NaCl, in contrast, is much more weakly deliquescent. Sodium chloride, though it does absorb some moisture at RH≥79%, cannot absorb nearly as much water, or at as low RH, as calcium or magnesium chloride. Consequently, though it has some moisture-related dust-suppressing ability when humidity levels are high, its dust-control mechanism is distinctly different at more typical daytime humidity below 79%.

Sodium chloride controls dust at normal daytime humidity levels by salting out clay particles, as previously discussed, and by forming crystals that bind the road surface particles together. When granular sodium chloride is incorporated into the working course of a road, i.e., pressed into place during compaction of road surface materials with an appropriate moisture level for incorporation and compaction, it will remain present as crystals, or somewhat moistened crystals, at night or when humidity is higher, binding adjacent road particles together until it is eventually dissolved and leached or washed out. An effective application of sodium chloride during construction of a well-designed unpaved road can strengthen the roadway for several months (Pennsylvania Department of Transportation, 2009).

The same benefits, however, cannot be expected from most surface applications of sodium chloride that are not appropriately designed and incorporated into the road itself, i.e., a surface application of NaCl-rich OGB to an inadequately prepared road. Dust control applications to roads can be assumed to occur in the summer, during the day, when temperatures are higher and humidity is lower, and dust release is occurring or imminent. When a NaCl-rich solution is applied under these conditions, the water in the brine solution will be absorbed predominantly by surface fines and then evaporate relatively quickly. Any sodium chloride present, unlike calcium and magnesium chlorides, will crystallize. If crystallization occurs among inadequately compacted road surface fines, the growth of the crystals will exclude any surrounding particles, pushing those fines apart while forming small mechanically separate crystalline salt particles among them. That is, the very property that makes sodium chloride effective when incorporated into a compacted road working course also makes it damaging and dust-increasing when applied to an inadequately prepared road surface.

So, when applied to the road surface without effective incorporation, sodium chloride solutions will either soften road structure and contaminate surrounding waters in wet weather; or will exacerbate dustiness of the road, while becoming part of the actual dust leaving the roadway under dry conditions. Such entrainment of chlorides in dust from brine-treated roads was confirmed by field investigations of impacts on roadside trees as early as 1936 (Strong, 1944).

8. No supporting evidence for use of OGB for dust control

At this time there appears to be no actual measurement data that support the use of OGB as an effective dust-control agent. The very limited available data indicates that OGB cannot be effective unless applied at rates several times the maximum rates state authorities consider acceptable environmental risks. Further, examination of the more thorough literature on commercial chloride dust-control agents clearly indicates there is no reason to expect OGB to be an effective dust control agent. Due to the effects of sodium ions on behavior of soil clays, typical applications of sodium-rich OGB to unpaved roads can be reasonably expected to increase dustiness and weaken soil structure. Finally, a conservative cost comparison for dust control, based on OGB compared to a commercial $CaCl_2$ product, showed the use of brine is actually more expensive, without considering potential need for more road maintenance work if sodium-rich brine is used instead of calcium chloride, and without considering increased health and environmental risks.

A subsequent paper, Part 2, anticipated publication in October 2018, will address known or anticipatable environmental and health impacts of the practice of applying OGB for dust control on unpaved roads.

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EXHIBIT H

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Oil and Gas Well Brines for Dust Control on Unpaved Roads - Part 2: Environmental and Health Impacts

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Abstract

Natural gas and oil drilling have expanded rapidly in the U.S in recent years. The volume of various associated waste products has been increasing. One such waste product is the typically saline water produced from the wells along with the hydrocarbons. A variety of methods are currently being employed to dispose of this oil and gas well brine (OGB). One such practice is spreading OGB on unpaved roads for dust control and road stabilization. This investigation focused on the likely effectiveness and anticipatable risks of spreading OGB on unpaved roads. Despite decades of regulated use of OGB for dust control, there appears to be a complete lack of data indicating the practice is effective. Analysis of regulations, related literature, and original data indicated, as previously presented in Part 1 (Payne, 2018), that spreading OGB on unpaved roads is ineffective and likely counterproductive for dust control and road stabilization, and presents numerous potential and immediate environmental and health risks as discussed in this Part 2.

Keywords: Oilfield brine, produced water, dust suppression, dust control, unpaved roads, oil and gas wastewater disposal, environmental impacts, health impacts

Introduction

Oil and gas well brine and its disposal

It is not common knowledge that oil and gas wells typically produce substantially more water than oil or gas, usually less water earlier, and increasingly more later in the production life of a well (Conselman, 1967: Moritis, 2004; Veil et al., 2004). That water must be separated from the hydrocarbon product stream before the product is transported.

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Produced water typically has a high salt content, mostly sodium chloride, and is consequently also referred to as oil and gas well brine (OGB). Once separated, the OGB is a waste. Conventional gas wells produce somewhat less wastewater than conventional oil wells. Horizontal wells typically produce more wastewater per unit of production than vertical wells, and wells stimulated with hydraulic fracturing typically produce more than their conventional counterparts. It has been reported that before 2000, nearly no U.S. oil wells were hydraulically fractured, but 51% of oil produced in the U.S. in 2015 came from hydraulically fractured wells (USEIA, 2016). Consequently, oil and gas well wastewater production will likely increase along with the management challenge it presents.

Numerous practices have been used to manage oil and gas well wastewater (Veil et al., 2004). Among such practices are deep-well injection, evaporation, and various treatment methods followed by recycling for use in oil and gas wells and other industrial processes. One of these, due to the typically elevated salt content, is to apply OGB to paved roads as a winter de-icer and to unpaved roads as a summertime dust-control and stabilization agent. Though less important than some other methods of disposal with respect to total amount of wastewater involved, application on roadways is common and locally important in some areas, including at least the states of Michigan, New York, Ohio and Pennsylvania.

Studies on the application of OGB to unpaved roads for dust control

Herrold (1984) concluded application of OGB to unpaved roads seems to date back to early development of the oil and gas industry in Michigan. Similarly, the Pennsylvania Department of Environmental Protection (PaDEP) Environmental Quality Board (2016) stated, "Throughout the history of conventional oil and gas development, brine has been beneficially used in dust suppression and road stabilization activities on dirt roads…." Despite that OGB has reportedly been applied to unpaved roads for dust control since the early days of the oil industry, the literature on such of OGB is sparse. A search for discoverable literature on science or engineering measurements of the actual effectiveness of OGB for dust control found only four such reports, two of which could only be accessed indirectly, and only one of which was published less than 36 years ago (Moore and Welch, 1977; Moses, 1981; Russell and Caruso, 1982; Graber et al., 2017). Realistically, road application of OGB was primarily an oil-well waste-disposal practice (Herrold, 1984).

In the 1970s, concerns arose that abusive spreading of OGB on land, including roads, was occurring and could impact water quality. Michigan and other states developed rules to regulate use of OGB on roads. Non-compliance and a lack of enforcement, usually due to lack of resources to support

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enforcement, are still common problems that can result in exploitation of roadways as OGB disposal grounds.

As reported in Part 1 (Payne, 2018) at this time there appears to be no actual measurement data that support the use of OGB as an effective dust-control agent. There are direct observations of its ineffectiveness (Figure 1.).

Figure 1. September 2017 dust from unpaved road in northwest Pennsylvania treated multiple times with OGB over the summer, with most recent treatment no more than 6 days and perhaps as recently as several hours before this image was taken (photo courtesy Siri Lawson).

The very limited available data indicates that OGB cannot be effective unless applied at rates several times the maximum rates state authorities consider acceptable in terms of environmental risks. Further, examination of the more thorough literature on commercial chloride dust-control agents clearly indicates there is no reason to expect OGB to be an effective dust control agent. Finally, a conservative cost comparison for dust control, based on OGB compared to a commercial $CaCl_2$ product, showed the use of brine is actually more expensive, without considering the potential need for more road maintenance work if sodium-rich brine is used instead of calcium chloride, and without considering the increased health and environmental risks. This, Part 2, considers some of those health and environmental risks.

Considerations of Some Environmental Risks

Environmental and health impacts are notoriously difficult to evaluate even when direct evidence is available. Reported or, lacking direct empirical evidence, potential environmental and health impacts can be considered in terms of contaminants, exposure pathways, and likelihood of occurrence. For example, consider a simple comparison of basic requirements of OGB compared to commercial chloride dust control product applications. A typical

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dust season would require at least 4 OGB applications per state guidelines while use of commercial product on the same road would typically require 2. Weather events, vehicle collisions, mechanical malfunction, inadvertent or intentional over- or misapplication and more could cause leakage or uncontrolled delivery to unintended areas. Further, NaCl and $CaCl_2$ are both close to 60% chloride by weight, but effective dust control/road stabilization requires twice as much NaCl as $CaCl_2$ (PaDOT, 2009) and, therefore, use of NaCl poses a greater risk of chloride contamination. Consequently, considerations as simple as composition and total number of required applications can change risk.

In addition, when direct or reliable, reasonably relevant data are available, there is risk associated with the failure of investigators to adequately explore such data. The PaDEP (1996) investigated the potential for water contamination from OGB applications for dust control at seven locations from 1992 to 1995. Based on the findings and recommendations of that investigation, PaDEP lowered its maximum allowable application rate, clearly indicating that the previous allowable rate had been based on inadequate supporting data. The 1996 PaDEP report contained a brief literature review, which included most of the literature reviewed by the present author. However, the PaDEP review of the literature was neither critical nor thorough, and the report recommended application rates based solely on the subjective opinions of OGB users. Again, risks from OGB applications were underestimated due to a failure to adequately consider available data, and deference to the subjective opinions of OGB users.

Environmental risks of chloride salts

Chloride is a monovalent anion. Chloride is strongly conserved in environmental waters; once in an environmental water it tends to remain there. Some organisms are particularly sensitive to chlorides. For example, chloride concentrations as low as 400 mg/L can be harmful to trout and other cold-water fish. The chlorides applied in concentrated form to roads as dust suppressants are readily soluble in water. Consequently, road application of chlorides as a dust suppressant carries a real risk of contamination of waters even at considerable distances from the treated roads (Ramakrishna and Viraraghavan, 2005; Eckstein, 2010).

Calcium and magnesium are essential nutrients for animal and plant life. Nevertheless, excessive levels of these two elements can cause harm, especially to plants, soils, and aquatic ecosystems. Sodium and chloride are so ubiquitous they might not be considered nutrients, but they are essential ions for most forms of life and have fundamentally important interactions with the physical components of the environment, especially soil and water.

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Sodium occurs in nature as a highly water-soluble monovalent cation, which, though not directly toxic in most situations, competes with other cations in environmental and biological processes. If present in excessive amounts relative to other soluble cations, sodium can displace those cations from their functional sites and alter the function of the biological or physical system. Of particular interest with respect to road applications of chlorides, sodium has a particularly troublesome property when present in excess in many soils.

Clay-cation interactions and effectiveness of OGB vs. commercial brine

[The following discussion is presented in more detail in Section 7 of Part 1 (Payne, 2018).] Certain useful properties of many soils depend on the type and amount of clay minerals present. Briefly, in many soils, the predominant clay minerals belong to a class known as layer alumino-silicates. The three most common layer alumino-silicate clay minerals in soils are kaolins (a form that would be known to some as Fuller's earth), illites (more recognizable forms of which are mica and vermiculite), and smectites (or montmorillonites, a more well-known form of which is called bentonite). Most soil clays occur as colloidal-size particles. All exist as layered crystalline particles, the thickness of which is typically 100 times smaller than the length or width.

All of these layer alumino-silicate clay minerals carry some net negative point charges in their crystalline structure, many of which occur on their outside surface and give rise to cation exchange capacity. These clay minerals retain exchangeable cations in proportions determined by the particular mineral and the relative concentrations of the cations in the water that the clay mineral contacts. The cations held by a clay mineral affect the properties of that mineral, including its physical behavior at the scale of individual particles, bulk properties, and properties critical to structure and performance of unpaved roads (Sullivan and Graham, 1940; Trask and Close, 1957; Bell, 1992; Warrence, Bauder, and Pearson, 2018).

Sodium is a particularly important cation with respect to clay-mineral behavior (Sullivan and Graham, 1940; Trask and Close, 1957; Bell, 1992; Warrence, Bauder, and Pearson, 2018). Clay particles bearing excessive sodium retain more inter-particulate water reducing the bulk strength of the clay, which can lead to liquefaction of clay soils, as in landslides, or, on a smaller scale, a consistency some refer to as "slickness" or "sliminess" of soils, including road soils.

Ca and Mg occur as divalent cations and interact with clay particles very differently than sodium. Multivalent cations, like Ca and Mg, can effectively bond individual clay particles together by linking between cation

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exchange sites on separate clay particles, a structural condition called "cation bridging", which results in an increase in bulk strength.

The effects of monovalent Na compared to multivalent cations, predominantly Ca and Mg in many soils, on the bulk properties in clays give rise to two types of behavior in response to the amounts of such cations dissolved in the water that the clay particles contact. Flocculation/dispersion is important at lower cation concentrations. "Salting out" is important at higher cation concentrations.

The stabilizing effects of "salting out" clays with high salt concentrations are greater than the stabilizing effects of calcium (or magnesium) flocculation of the clays. Nevertheless, it should also be recognized that the flocculating effects of calcium are effective along with "salting out" at high concentrations of $CaCl_2$, and continue after those high concentrations have been depleted. In contrast, "salting out" with NaCl must overcome the dispersing effect of sodium saturation of the clay charge sites, and that dispersing effect will remain after the high concentration of NaCl has been depleted. Hence, the better performance of $CaCl_2$ (and $MgCl_2$) compared to NaCl as a dust control agent on unpaved roads is due not only to its stronger deliquescence (see 3.3, below, and Payne, 2018) but also the effects of calcium on clay-aggregate formation and stability, which is supported by the findings of Graber et al. (2017).

Because of the differences in flocculation/dispersion and "salting out" effectiveness of Na compared to Ca or Mg, along with related differences in intensity of adsorption of water from ambient air and related crystallization behaviors, and the dominance of NaCl in OGB, application of OGB for dust control can be reasonably expected to exacerbate dust problems. When applied to the road surface without effective incorporation, as typically done with OGB, sodium chloride solutions will either soften road structure and contaminate surrounding waters in wet weather; or will exacerbate dustiness of the road, while becoming part of the actual dust leaving the roadway under dry conditions. Such entrainment of chlorides in dust from brine-treated roads was confirmed by field investigations of impacts on roadside trees as early as 1936 (Strong, 1944).

Runoff and contaminant distribution: commercial vs. OGBs

The sodium that moves off or through and out of the road must eventually end up somewhere else. That which leaves the road dissolved in water will move through ditches and drainage-ways to end up in nearby soils, sediments and waterways. As soil and sediment sodium levels increase, vegetation and local water-flow patterns will be impacted. As sodium and chloride levels in waters rise, aquatic life will be impacted. When salt accumulates sufficiently in the soil, animals will use the soil as a salt lick. If

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the salt is associated with toxic contaminants, those animals will be impacted, which raises the issue of toxic contaminants in brine.

Commercial $CaCl_2$ and $MgCl_2$ products typically are evaporites from natural water bodies in closed drainage basins or are industrial products.

Consequently, the commercial products are relatively free of toxic components, or relatively well understood in terms of their toxic components. OGBs, in contrast, are from geological formations where they developed along with petroleum and a related range of toxic components. State authorities that authorize use of OGBs have testing requirements that provide little information on potential toxic impacts. In most cases the only requirement is that a single OGB sample from the source geological formation be analyzed every year to few years. Hence, the actual amounts of toxic compounds delivered by OGBs applied to roads is unknown. The toxic components in OGBs range from dissolved inorganic elements such as lead and arsenic, to toxic petroleum compounds such as benzene, to toxic radioactive species such as radium and uranium. Which and how much of these occur in OGBs depends primarily on the source geological formation.

Poje (1986) developed a toxicological review of composition data for Ohio and Michigan OGBs and concluded that sodium and chloride were the inorganic contaminants of most concern and benzene, due to its toxicity, the organic contaminant of most concern. Poje (1986) pointed out that polycentric (or polycyclic) aromatic hydrocarbons (PAHs) and phenolics are almost certainly present in OGBs and should also be considered with respect to potential environmental and health impacts. The conclusions of Poje (1986) agree with more recent conclusions by others (Irwin et al., 1997; Skalak et al., 2014).

There have been reports on the environmental impacts of applications of chlorides on roads for ice control, fewer about the impacts of commercial brine-spreading for dust control, and far fewer with respect to spreading of OGBs (Farmer, 1993; Norrstrom and Bergstedt, 2001; Goodrich et al., 2009; Nelson et al., 2009; Fayun et al., 2015; Hiki and Nakajima, 2015; Ramakrishna and Viraraghavan, 2015). Most of those reports have focused on impacts on water resources, along with soils and vegetation. Perhaps most telling with regard to implications of the reported impacts is the conclusion of the PaDEP (1996) that the OGB applications rate then being approved (1 gal/sq yd) was unsafe. The PaDEP lowered its maximum application rates to the current 1/2 and 1/3 gal/sq yd per month. As a means of evaluating some of the likely environmental impacts of dust emissions from roads treated with OGB, it is helpful to consider from a soil perspective the implications of Poje's (1986) conclusions in terms of foreseeable situations on actual road surfaces receiving typical OGB applications.

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The guidelines of several states set a maximum OGB-spreading rate for dust control on unpaved roads at a single application of OGB at 1/2 (initial application) or 1/3 (follow-up applications) gal/sq yd, applied once per month[1] during the dust-control season, in most areas late spring through fall. Assume brine will have a sodium chloride concentration around 10%, calcium chloride around 5%, magnesium chloride around 1% (Dresel and Rose, 2010; Payne, 2018). For convenience in this discussion, the density of OGB is assumed to be the same as water.

To perform such an evaluation, assumptions are necessary with regard to road conditions at the time of OGB application. Within typical ranges, the practical consequences will be similar regardless of assumed compared to actual road conditions. For well-constructed and maintained roads, the surface material will contain around 4% to 15% fines (US Dept. of Transportation, 2015) and will be compacted to a porosity of around 10% (or less). Assuming 15% fines, a brine application of 1/3 gal/sq yd will first saturate the road surface material to a depth of about 0.6 in (1.5 cm), then drain further to wet perhaps the top 1 in (2.5 cm). After drainage, about 90% of the water will be associated with the aggregated soil fines in that wetted surface layer.

What happens to the dissolved salts when the water in the brine evaporates under the summer sun? If evaporation is rapid, some of the salts will be deposited as efflorescence on the road surface. Such salt efflorescences are mechanically fragile and readily soluble in water. The salts in such efflorescences will most likely leave the road as dust or, if they are not blown away as dust, they will be dissolved and washed away in the next rain. Such salt efflorescences will continue to form as long as there is capillary continuity between the actual road surface and the deeper portions of the wetted road surface material. Because most road surfaces are quite warm, even hot, in summer weather conditions, evaporation of the water from the OGB will usually be rapid. The more rapid the evaporation, the less time for deep infiltration, the more rapid the capillary rise and the more salt will end up as efflorescence on the surface, increasing dust from even a well-constructed and maintained road surface.

If the same OGB application were spread during relatively cool and moderately humid weather, brine-water evaporation will be slower, the brine will have time to infiltrate more thoroughly, and less salt-laden water will be drawn by capillary rise back to the surface. Under such circumstances, as previously discussed, which salts are in the brine will contribute to, or weigh against, effectiveness of the OGB as a dust control agent.

[1] Bear in mind that almost all state guidelines allow application rates higher than the specified "maximum" rate if dust, weather, traffic or other conditions require higher rates as judged by the local authority or its approved agent.

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$CaCl_2$ is a strongly deliquescent salt, which even in solution can draw moisture from the air into the road surface material, thereby preventing airborne release of fine particles (dust). Though it is generally considered that the deliquescence of $CaCl_2$ becomes effective at a RH of 29%, that deliquescence is actually related to both temperature and humidity, and the deliquescence becomes effective at lower RH as temperature increases (Kirchner and Gall, 1991). The resulting retention of moisture strengthens aggregates of soil fines, thereby preventing mechanical separation and air suspension of particles as dust under most conditions.

$MgCl_2$ is also deliquescent, but its deliquescence is related only to RH, being effective at RH above 31% over the full temperature range of concern for road surfaces. However, the ability of air to hold moisture increases as temperature increases. So, assuming no weather change is occurring, on a typical summer day, the RH will be high in the morning and drop until the daily high temperature is reached. Further, road surfaces are hotter than the air on most summer days. Consequently, the deliquescence of $MgCl_2$ can become less effective as a road-wetting mechanism during some hotter, drier summer days.

NaCl does accumulate deliquescent moisture from the air, but not until RH is above 79%. Deliquescence is reversible, that is, a salt wetted by deliquescent water can dry back into a solid. Typically, however, a phenomenon known as hysteresis occurs in the deliquescence wet-dry cycle. That is, the path of accumulation of deliquescent water as humidity increases is not the same as the path of the loss of water (drying out) as humidity decreases. For most deliquescent salts hysteresis is apparent in that drying begins at a humidity lower than the humidity at which wetting begins. In the case of NaCl, loss of accumulated deliquescent water does not begin until the RH drops below 45% (Wise et al., 2007). On many summer nights, RH rises well above 79%. Roads treated with NaCl may appear moist in the morning, because the NaCl in the road accumulated deliquescent water overnight. As the summer sun warms the road surface and air, RH falls relatively rapidly, often below 45%. Consequently, roads on which NaCl is used as a dust suppressant will be without an effective moisture retention agent during the dustiest hours of many warm days.

Deliquescence and a sodium chloride potential for road destabilization

Within a matrix of road material, solid salt occurs as individual particles. This is true even for sodium chloride applied as a solution, like OGB, because a single afternoon under typical summer road surface conditions will dry a road sufficiently to crystallize all the sodium chloride in a light application, such as 1/3 gallon per square yard. So, it is helpful to

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consider what likely happens to a typical crystal of a deliquescent salt in a road materials matrix.

As deliquescent water accumulates the salt particle will dissolve. If enough water accumulates, the particle may dissolve nearly completely, becoming a volume of salt water within the soil matrix. If two or more particles are in proximity to each other, the wetted volumes of those particles may contact and become a single wetted volume. When drying begins, a salt crystal will begin to form. If the wetted volumes of previously separate salt particles have merged, the new, larger wetted volume may or may not form salt crystals at the same locations as the originals. If a salt crystal grows at a new location, or crystals grow at new locations, the crystal growth process can force other particles to move as the forces generated during crystal growth can be extreme; recrystallization of some salts is capable of spalling concrete and fracturing rock.[52,53] Cumulatively over an extensive area, such microscopically small movements within the road material matrix will reduce the mechanical strength of the road.

Calcium, magnesium and sodium chlorides are the three salts of most concern as dust-control agents, and as the major components in OGB. Each of them has its own crystalline properties and conditions for crystallization. Calcium chloride has several different hydration state crystalline forms. However, only calcium chloride hexahydrate ($CaCl_2.6H_2O$) is stable under the conditions found on most roads. Further, at typical summer temperature and humidity conditions, each calcium chloride (hexahydrate) crystal exists within a surrounding volume of deliquescent water. Consequently, roads with enough incorporated $CaCl_2$ will rarely “dry out” under summer environmental conditions. In fact, one of the disadvantages of $CaCl_2$ as a dust-control agent is that roads can actually become too wet if humidity is too high for prolonged periods. $MgCl_2$ wetted by deliquescence can begin to dry out when temperatures get high enough, but it remains an effective wetting agent on unpaved roads under the environmental conditions that occur in many locales, with less tendency to become too wet under prolonged high humidity conditions.

As discussed in the previous section (3.3), under most common environmental conditions, the drying behavior of NaCl is different. Because of hysteresis in the wet-dry cycle of NaCl, while accumulation of deliquescent water does not begin until RH goes above 79%, loss of the deliquescent water accumulated by a NaCl crystal does not begin until RH drops below about 45%. Nevertheless, once the drying begins, it can progress rapidly, along with regrowth of the NaCl crystal. If the newly formed NaCl crystals are of a different size, shape or location than the original sodium chloride particles, resultant physical movements within the road matrix and road weakening can be expected. Such shifting of particles, even on a microscopic scale, weakens

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the road surface, which makes mechanical fragmentation by traffic more likely. Mechanical fragmentation generates dust, emission of which results in loss of fines, which results in further mechanical weakening of the road. That is, surface application of any amount of dissolved or solid NaCl, even to well-constructed and maintained roads, can contribute to initiating a set of mutually reinforcing processes that can initiate and propagate road destabilization and dust emissions (see 3. in Part 1, Payne 2018).

Application to poorly maintained roads exacerbates problems

Now, the situation is more complicated and the effects of all these salts are destructive when surface applied to a poorly maintained road. As an illustration, consider a road otherwise in apparently fair condition, but which has already accumulated a surface layer of float, i.e., loose road material, including fines. Let us assume for this discussion that the fines content of the float is the same as the road surface soil. This is not likely, in that if the float is present due to pumping of fines to the surface under wet conditions, then the float will be heavier in fines, but, if fines have been blown out of the float under dusty dry conditions, then the float will be lower in fines than the intact road surface soil. Nevertheless, for present purposes, this assumption provides a reasonable approximation of the average, or at least the starting conditions when material is first loosened on the road surface.

Since the float material necessarily resides on the surface of the road, any surface-applied brine will first encounter the float layer. Applying the same conditions used in the preceding discussion of salts in well-constructed and maintained roads, the road soil contains 15% fines that have a water holding capacity of 30% (by volume). Again, as previously, since most of the water holding capacity of road soil is in the fines, once the float has been drained by gravity, 90% of the applied brine in the float will be retained in the fines. When the road surface dries to the point of releasing dust, that dust will be nearly entirely composed of fines that separate from the road surface and suspend in the air. Given the foregoing, and using a brine composition based on an average western Pennsylvania oil brine[29], i.e., 12% NaCl, 5% $CaCl_2$, and 1% $MgCl_2$, one can perform a relatively simple calculation to obtain a rough estimate of the salts content of the dust coming off the brine treated road:

$$W_{Na} = \frac{V_{Na} \times V_B}{\rho_d}$$

where W_{Na} is NaCl %(wt) in dust, V_{Na} is NaCl %(wt/vol) in brine, V_B%(wt/vol) brine in fines, and ρ_d is the dry density of dust in g/ml. Using V_{Na}=(12 g NaCl)/(100 ml brine)=12%, V_B=(30 ml brine)/(100ml) dust)=30%, and ρ_d=(1.3 g dust)/(1 ml dust), we find W_{Na}=2.8% NaCl/dust.

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Making the same calculation for calcium and magnesium chlorides yields concentrations in the dust of around 1% $CaCl_2$ and 0.2% $MgCl_2$, and therefore a total salts concentration of around 4% by weight. The bulk density of dust was assumed to be 1.3, but might range from 1 to around 2 g/ml. Use of the more extreme densities would increase or decrease the concentration of salts in the dust, thus the concentrations would range from 2.5% to 5% by weight; a range for which any value would be an environmentally appreciable amount of salts, consistent with the previously mentioned tree impacts reported by Strong (1944).

It is worthwhile to consider that there are factors that would increase the estimated salt concentrations. In particular, upon saturation with applied brine, the bulk geometry of the fines may lose hydraulic contact with the underlying intact road surface. When this occurs, the fines will be wetter, i.e., have a higher OGB content when they begin to dry to dust, which would increase the salt concentration in the dust into the range of 4% to 8% by weight.

The fines may also accumulate on and seal the road surface, resulting in ponding of the brine on the surface. Drying of ponded brine over saturated fines would result in formation of efflorescence salt crystals along with salt crystals associated with the dust particles, further increasing the salts concentration in the dust.

So, for the likely range of conditions on a poorly constructed and maintained road with float materials on the surface, and to which OGB is applied for dust control, the dust released from that road can be expected to have a soluble salts concentration of something in the range of 2% to over 8%. Further, since the assumption was that the fines concentration in the float was the same as in the intact road soil, the same calculation applies for dust derived from release of the fines from the intact road soil as well. Hence, until there is a weather event (rain, wind) that removes soluble salts, the dust from brine-treated roads, whether well maintained or not, will contain soluble chloride salts concentrations in the range of 2.5% to potentially over 8%.

Dust bearing such soluble salt concentrations can be expected to have environmental and health impacts. For example, if airborne dust with such salt concentrations settled upon vegetation, it would result in substantial osmotic stress on leaf tissue, recalling again the observations of Strong,[40] who also reported that runoff from roads receiving brine killed vegetation. So, even as early as 1936, the potential for environmental impacts on both air (dust) and water due to the use of OGB for dust control had been recognized.

Environmental risks of dust

As previously mentioned, water, soil and vegetation impacts from road spreading of brines, especially for ice control, have received some attention

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(Farmer, 1993; Sanders and Addo, 1993; Norrstrom and Bergstedt, 2001; Goodrich et al., 2009; Nelson et al., 2009; Eckstein, 2010; Fayun et al., 2015; Hiki and Nakajima, 2015; Ramakrishna and Viraraghavan, 2015; among others), but not so for the dust impacts of OGB spreading. The general health and environmental risks posed by dust pollution from unpaved roads that do not receive dust control treatments are now becoming more widely recognized (Greening, 2011). It follows that elevated levels of contaminants, like soluble salts in dusts from OGB-treated roads, can be reasonably expected to increase those risks.

The lack of attention to the anticipatable additional risks posed by exposure to dust from OGB treated roads may have a plausible explanation. If one accepts the premise that applying OGB will control dust, then it follows that dust is controlled and, therefore, air pollution by released dust may be disregarded. As previously discussed, however, there is, in fact, no reason beyond a traditional belief to accept the premise that spreading OGB for dust control is, or under practical conditions is ever likely to be, effective.

Concentrations of other contaminants in dust from OGB-treated roads

The chloride salts that OGB shares with commercial dust-control products are its predominant, but not its only constituents. OGBs contain a wide range of constituents, but there is a currently limited list of troubling constituents present at levels of potential concern. That short list includes petroleum hydrocarbons, typically DRO (diesel range organics), which include PAHs (polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethyl benzene, and xylenes), along with bromide, iron, manganese and radioactive isotopes of some elements, typically radium. Except to a limited degree for BTEX, these contaminants of concern are functionally nonvolatile under the conditions that would exist following a surface application of OGB containing them. Consequently, the same approach used to estimate salt concentrations in dust from brine-treated roads in 3.5 above can be adapted to estimate likely concentrations of these additional contaminants in the dust.

The following are typical concentrations of OGB components of toxic concern reported by Poje (1986), Dresel and Rose (2010) or determined on samples collected by the present author.

DRO (PA) …………………..…....1000 mg/L
Benzene (MI, OH, PA) …..…. 7, 9, >1 mg/L
Bromide (PA) ……………..…….. 1000 mg/L
Strontium (PA) ……………..….. 2120 mg/L
Radium 226 (PA) …..…….…….. 2150 pCi/L

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Applying these concentrations in the previous calculation to estimate salt concentrations in OGB-treated-road dust leads to the following likely concentrations of these other contaminants:

DRO (PA) ……….……….…. >200 ppm
Benzene (MI, OH, PA) ……. 0.2 to 2ppm
Bromide (PA) ……..…………… 200ppm
Strontium (PA) ………….……….. 500 ppm
Radium 226 (PA) …..……..…… 500 pCi/kg

It should be pointed out these concentrations can be expected to become part of the dust on brine-treated roads due to a single application of brine. If, as permitted by the brine-spreading guidelines of various states, the local responsible party concludes that more brine is needed to control dust, then each additional application will increase the concentrations of the contaminants in the brine that will reside in the dust. This contaminant accumulation effect will be countered by two factors, traffic and weather, which interact.

Impact of contaminants on adjacent soil, water, structures, vehicles

Rain events of sufficient intensity or duration wash some or all these contaminants, or the dust bearing these contaminants, from the road surface, delivering them to adjacent soils and waters. Upon wetting by rain, the dust on the surface of an OGB-treated road will become mud, which will be thrown by passing vehicles onto adjacent vegetation, structures, and the vehicles themselves. Portions of the mud will adhere to the contacted surfaces, the adhesiveness of the mud increasing with the sodium saturation of the clays present. Once attached to a surface, the previously described wetting/drying process that occurs on the road surface will occur in the now attached OGB-treated road dust mud. The NaCl will dry and form crystals that will bond the mud together, while the $CaCl_2$ and $MgCl_2$ will cause the bonded mud to retain moisture. Such circumstances can be expected to lead to corrosion of affected metal surfaces and osmotic and mechanical stress as well as light, and potentially air, deprivation of contacted plant tissue. Further, the deleterious effects (already discussed) of spreading of Na-rich brine on structural integrity of most unpaved roads will exacerbate the amount of mud released by the road, compared to the same road without OGB treatment.

The counterpart to rain is dry weather. Every summer rain will, sooner or later, be followed by hot, dry conditions giving rise to, or anticipation of, renewed dust emissions. The response will be more OGB spreading. The cycle will repeat, increasing contaminants in the road surface fines, and affected waters and soils.

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There is no reason to expect OGB spreading to provide any better dust control than spreading plain water under any road conditions (see Jones et al., 2013, Graber et al., 2017, and previous discussion). There is reason to believe most OGB is spread on roads that are not properly prepared for chloride-based dust control. Due to the impacts of sodium on most soils, including most road soils, spreading OGB will actually increase the total cumulative dust emitted and eventually weaken the road base. In addition, OGB spreading necessarily loads the road surface and the dust that comes from it with contaminants, which will have environmental impacts. Despite this situation, the potential impacts of dust from brine-treated roads seems to have received nearly no interest or serious consideration, especially potential health impacts.

Human health impacts of dust from OGB-treated roads: expectations

Although health impacts exposure to road dust are cited in many road-dust control documents (Gesford and Anderson, 2007; Jones et al., 2013; Barnes and Connor, 2014; McHattie, 2015; Aleadelat and Ksaibati, 2017), quantitative information is rare or weakly developed. Some of the available quantitative information has been reviewed and summarized by Greening (2011). Inspirable particles with aerodynamic diameters of 5 m -10 m that enter the upper airways are filtered out by the upper airways tissues. Particles less than 5 m can pass through the upper airways and travel into the lungs coming to rest in the bronchioles and alveoli. It is reasonable to assume that all insoluble inorganic particles that contact respiratory tissues have some irritating or injurious effect. The severity of the irritation can vary by the type of particle inhaled, with the well-known severe long-term injury and disease due to inhalation of asbestos particles and the minimal impacts of other mineral particles, such as zeolites, which have been proposed as carriers in formulations of inhaled medications. Soluble inorganic particles, e.g., sodium, calcium or magnesium chloride crystals, can be expected to cause localized osmotic tension on the contacted tissue. Toxic contaminants may be present in the dust as chemically and physically distinct particles, or attached to the more typical dust particles derived from local road soil material. Particles <1 m in size can pass through the walls of the alveoli directly into the circulatory system where they can travel to impact other organ systems (Barnes and Connor, 2014).

Given the small size of the OGB-treated-road dust particles that will contact respiratory tissues, any irritation or injury will be localized near the point of attachment. None of the contaminants at the concentrations present in brine road dust would be expected to result in disease if a sufficiently limited number of such particles contacted respiratory tissues. It may be the case, however, that due to the intimacy of contact with the tissue and the potential for multiple simultaneous stresses, i.e., toxic, osmotic, and

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mechanical, at the contact point, the likelihood of injury may be greater than expected for similar dust particle exposure without the additional coincident stressors associated with dust particles from OGB-treated roads.

For any dust the occurrence and severity of respiratory disease can be expected to increase as exposure increases (ATSDR; University of Nebraska Environmental Health and Safety, 2003; Wyatt et al., 2008; Ghio et al., 2014; Dehghani et al., 2017; Di et al., 2017;). It also seems reasonable to presume that as the concentrations of high-risk contaminants increase, or the number and concentrations of contaminants generally increase, as in dust from OGB-treated compared to untreated roads, the amount of dust exposure needed to cause disease will decrease. Unfortunately, there is not sufficient information to directly estimate additional risk from the contamination of road dust due to application of OGB.

Given the lack of numerical risk information, an alternate approach is needed to evaluate potential health risks of OGB-treated-road dust. One such approach is to consider how the likely contaminant levels in OGB-treated-road dust compare to currently accepted limits for soil contaminants. Acceptable soil contaminant levels are often referred to as cleanup or action levels because they are often applied on sites where environmental contamination has occurred and cleanup is required. Typically, action or cleanup levels are derived from modeling of potential pathways for toxic exposure, including inhalation. There are differences among authorities with regard to soil cleanup levels, but as a matter of convenience this discussion will start with the PaDEP1993 cleanup levels for diesel-contaminated soils (PaDEP, 1993).

The 1993 PaDEP diesel cleanup standards were based on the determination of total petroleum hydrocarbons as diesel-range organics (DRO) in soil, and required cleanup to ≤10 ppm DRO. DRO is an appropriate comparison for OGB-treated road dust because most of the petroleum hydrocarbons remaining in OGB are DRO due to losses of more volatile petroleum hydrocarbons during storage and handling of OGB. In 1993, the PaDEP had concluded that cleanup to 10 ppm DRO would render a contaminated soil safe. The likely DRO concentration in dust from a road after a single application of an average OGB is ≥200 ppm (see 9.1 above), which is ≥20 times higher than the level the PA DEP considered safe in 1993. Under hot, dry, low-wind summer conditions, multiple OGB applications could occur on the same road. Some OGBs have higher than average DRO concentrations. If used under such summer conditions, the OGB-treated-road dust would likely have DRO levels a hundred or more times greater than the 1993 PA DEP cleanup level.

More recently, cleanup levels have been based on specific contaminants of toxic concern, such as benzene. Prior to soil contact, benzene is a relatively volatile hydrocarbon. Consequently, the benzene contents of

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OGB are relatively low, ranging from 1 to 9 mg/L in the Michigan, Pennsylvania, and Ohio OGBs previously cited. Nevertheless, due to the toxicity of benzene, especially with regard to cancer, these levels cannot be regarded as trivial. Further, dust from an unpaved road that has received a single application of OGB can be expected to have benzene concentrations in the range of 0.2 to 2 ppm. The PaDEP cleanup level for benzene in soils to be reused on-site at underground storage tank (UST) sites is 0.5 ppm (PaDEP, 2012), and the limit for clean fill is 0.13 ppm (PaDEP, 2010). Hence, it is reasonable to expect that dust from a road after a single summertime OGB application can exceed the current PaDEP UST soil cleanup standard, and all will exceed the PaDEP limits for clean fill.

Another group of related toxic compounds are the polycyclic aromatic hydrocarbons (PAHs), which include compounds like naphthalene, pyrene, and anthracene. In diesel fuel, typical total PAHs appear to be in the range of 1 to several percent by weight, i.e. 10,000 to perhaps 70,000 ppm (Irwin et al., 1997; Stogiannidis and Laane, 2015). Naphthalenes (including methylated forms) are the most common PAHs in diesel fuel, and by extension presumably in DRO. It is reasonable to assume a low-end typical level of only non-methylated naphthalene is around 1000 ppm. Applying the previous calculation for estimating the concentration of contaminant to be expected in dust from a road following a single application of OGB (see 3.5 and 4.1 above), one finds the estimated concentration of naphthalene to be around 20 ppm. Referring again to the PaDEP UST site closure requirements (PaDEP, 2010), one finds the action (cleanup) level for naphthalene to be 25 ppm. It then follows that if there are 2 or more applications of OGB, a definitively toxic contaminant can be expected to be present in the dust at levels above those considered acceptable (for reuse of soil on UST closure sites). In addition, there are numerous other PAHs in DRO that are regarded as somewhat less toxic than naphthalene, but the presence of which can be regarded as further increasing the health risk of exposure to PAHs in dust from roads treated with OGB for dust control.

It is generally accepted that some OGBs contain radioactive contaminants, especially radium. It has also been, in effect, contended that the safety of road spreading of OGB has been established by a lack of historical recognition of impacts. This rationale ignores that, in the data of Dresel and Rose (2010), 5 of 6 western PA OGBs tested contained substantial amounts of Ra, with an average concentration of 2,150 pCi/L (picoCuries per liter, about 80,000 Bq/m^3); similar levels having been reported by others (Rowan et al., 2007). Again applying the dust contamination estimate calculation, one application of OGB would increase the Ra concentration by 0.5 pCi/g in the road dust. Naturally occurring soil Ra levels in PA have been reported in the range of 0.5 to 2 pCi/g (Greeman et al., 1999). In a laboratory simulation of

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multiple PA OGB applications with intervening rain events, Tasker et al. (2018) recently found that Ra increased effectively in accord with the preceding estimate up to around 2 pCi/g, with no further increase from additional applications. This finding suggests three implications. (1) Soils in western PA would seem to have an inherent Ra retention limit of 2 pCi/g, provided there are adequate rain events following each OGB application. (2) Ra applied in brine but not retained in soil is lost to runoff/leaching to contaminate local water and soil, as suggested by findings of Lauer et al. (2018). (3) Repeated OGB applications with insufficient intervening rain events, as in the dry summer weather most likely to cause dust and increased applications of OGB, will likely result in Ra concentrations in dust exceeding 2pCi/g, perhaps substantially. Because of its carcinogenic hazard, every incremental increase in radiation exposure is regarded as an increase in risk. Consequently, an additional 0.5 pCi/g in road dust for a single application of OGB is a substantial increase in radiation exposure risk. Tasker et al. (2018) also explored available data and concluded that by far the largest release of radium into the environment by the oil and gas industry in PA is from the road spreading of OGB for dust control.

The U.S. Environmental Protection Agency (EPA) has established a Ra cleanup level of 5 pCi/g for Superfund sites (Luttig and Weinstock, 1998). This is substantially higher than occurs in PA soils or found by Tasker et al. (2018) in lab-simulated OGB applications, though higher levels likely occur in dust from roads repeatedly treated with OGB. Nevertheless, with regard to risk, it is important to recognize the Ra cleanup level was based on the assumption that exposure would be due to remote release of gamma rays from radium in a surface soil, not inhalation of Ra-bearing dust (Luttig and Weinstock, 1998). It seems likely such Ra levels would present greater risk when present as dust retained in the airways than as soil underfoot.

Anticipatable levels of toxic contaminants added to road dust by a single application of OGB are at, or well above, relevant cleanup levels. It is reasonable, therefore, to conclude health risks are appreciably increased by exposure to dust from OGB-treated roads. Further, there are other biologically offensive or toxic organic and inorganic contaminants in OGB that have not been addressed in this report, but will also accumulate in the dust on OGB-treated roads. So, the toxic risks of the contaminants discussed above will be acting in a matrix of other contaminants all of which will be simultaneously active. For those individuals exposed to appreciable amounts of such dust, due either to brief intense or prolonged lower level exposures, one might expect health impacts beyond those of dust from uncontaminated local soils.

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Conclusion on effectiveness and risks of use of OGB for dust control on unpaved roads

The very limited available data and more thorough related literature clearly indicate OGB is not an effective dust-control agent (Payne 2018) and has verified environmental and foreseeable health risks when applied at rates currently considered acceptable by state regulators, even without considering that enforcement of state OGB application rate limits is rare. Rudimentary analysis indicates the practice is not cost effective, and in many cases will be counterproductive with regard to road stabilization. It is, therefore, difficult to view the use of OGB on unpaved roads for dust control and road stabilization as anything more than a legacy oil- and gas-well waste-water disposal practice with substantial environmental and foreseeable health risks, especially health risks of exposure to dust from OGB-treated roads. Further, it is important to recognize the use of OGB for dust control is an insidious practice in that it is presumed to reduce dust when in most cases it will increase dust, which will lead to the conclusion more OGB is needed. Due to the Na saturation of road soil after prolonged periods of OGB treatment, it can be anticipated that cessation of the practice will likely result in increased dust and calls for resumption of OGB spreading when that is exactly the wrong course.

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EXHIBIT I

Environmental Science & Technology

Policy Analysis

Sources of Radium Accumulation in Stream Sediments near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater

Nancy E. Lauer, Nathaniel R. Warner, and Avner Vengosh

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Sources of Radium Accumulation in Stream Sediments near Disposal Sites in Pennsylvania: Implications for Disposal of Conventional Oil and Gas Wastewater

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KEY WORDS

Radium, Produced Water, Appalachian Basin, Marcellus Shale, Hydraulic Fracturing

ABSTRACT

In Pennsylvania, Appalachian oil and gas wastewaters (OGW) are permitted for release to surface waters after some treatment by centralized waste treatment (CWT) facilities. While this practice was largely discontinued in 2011 for unconventional Marcellus OGW, it continues for conventional OGW. This study aimed to evaluate the environmental implications of the policy allowing the disposal of conventional OGW. We collected stream sediments from three discharge sites receiving treated OGW between 2014-2017 and measured ^{228}Ra, ^{226}Ra, and their decay products, ^{228}Th and ^{210}Pb, respectively. We consistently found elevated activities of ^{228}Ra and ^{226}Ra in stream sediments in the vicinity of the outfall (total Ra = 90-25,000 Bq/kg) compared to upstream sediments (20-80 Bq/kg). In 2015 and 2017, ^{228}Th/^{228}Ra activity ratios in sediments from two disposal sites were relatively low (0.2-0.7), indicating that a portion of the Ra has accumulated in the sediments in recent (<3) years, when no unconventional Marcellus OGW was reportedly discharged. ^{228}Ra/^{226}Ra activity ratios were also higher than what would be expected solely from disposal of low ^{228}Ra/^{226}Ra Marcellus OGW. Based on these variations, we concluded that recent disposal of treated conventional OGW is the source of high Ra in stream sediments at CWT facility disposal sites. Consequently, policies pertaining to the disposal of only unconventional fluids are not adequate in preventing radioactive contamination in sediments at disposal sites, and the permission to release of treated Ra-rich conventional OGW through CWT facilities should be reconsidered.

INTRODUCTION

The large-scale development of unconventional shale gas in the Appalachian Basin has been associated with different types and mechanisms of water contamination, including the management and disposal of the oil and gas wastewater (OGW) that is comprised of flowback fluids and produced waters.[1-3] Flowback and produced waters from the Appalachian Basin are highly saline and enriched in naturally occurring radioactive materials (NORM).[4-7] Previous studies have demonstrated that NORM in formation waters mainly consists of radium-226 ($t_{1/2}$=1600 years) and radium-228 ($t_{1/2}$=5.8 years) from the uranium and thorium decay series.[7-9] Total Ra ($^{228}Ra+^{226}Ra$) activities have been measured in Appalachian Basin formation waters up to hundreds of Becquerels per liter (Bq/L; up to 660 Bq/L and 250 Bq/L for Marcellus and conventional produced waters, respectively)[7] that exceed by several orders of magnitude the activities typically measured in fresh surface waters (0.5- 20 mBq/L for ^{226}Ra) by several orders of magnitude.[10] Elevated ^{228}Ra and ^{226}Ra may pose environmental and human health risks if released to the environment, as they are carcinogenic,[11] bioaccumulate (concentration factors between sediment and aquatic plants and fish of 0.014 and 2.3-700, respectively),[12-17] persist in the environment due to their relatively long half lives, and decay into a suite of other radioactive elements including gaseous ^{222}Rn, ^{210}Pb, and ^{210}Po.

Due to their high salinity, unique chemistry, and immense volume, OGW pose significant management challenges when brought to the surface with hydrocarbons. In Pennsylvania, 43 million bbl of unconventional and 6.6 million bbl of conventional OGW were produced in 2014. A large fraction of this OGW (64% of unconventional OGW and 5% of conventional OGW; >50% of the combined total) was reused for hydraulic fracturing operations.[18] A major option for disposal is injection underground via EPA Class II deep-well injection wells, but since there are a relatively limited number of these disposal wells in Pennsylvania, the OGW is often transported to neighboring states for disposal. Therefore, alternative disposal options in Pennsylvania consist of spreading on roads as a deicing agent or dust suppressant and treatment by wastewater treatment plants, including centralized waste treatment (CWT) facilities.[18] Treatment of OGW at these facilities has been described previously[19-21] and often includes the addition of Na_2SO_4 to promote the precipitation of metals, as well as Ra, before the treated OGW is discharged to local surface waters.

Due to concerns of contamination, in the spring of 2011 the Pennsylvania Department of Environmental Protection (PADEP) requested unconventional well operators to cease sending Marcellus OGW to wastewater treatment facilities. Although participation was voluntary, treatment of Marcellus waste at many wastewater treatment plants in Pennsylvania nearly ended by the fall of 2011.[22] However, these facilities continued to receive, treat, and dispose conventional OGW to the local streams.[18]

Several studies addressing this issue were published in 2013, relatively soon after Marcellus OGW treatment and discharge was discontinued. These studies showed that the releases of highly saline effluent causes direct contamination of the stream water at disposal sites, [19, 20, 23, 24] and also increases the risk of the formation of disinfection byproducts in downstream communities.[25] In addition to degrading water quality, Warner et al.[20] found that the release of treated OGW to Blacklick Creek, a tributary of the Allegheny River in Josephine, PA, resulted in the accumulation of Ra (^{226}Ra activities of 544- 8,759 Bq/kg) in stream sediments in close vicinity (<200 m) to the outfall. Skalak et al.[26] found no increase in ^{226}Ra in stream sediments downstream of effluent sites from five wastewater treatment facilities. In two facilities, Skalak et al.[26] also collected sediments at the disposal sites, one of which was found to have ^{226}Ra activities slightly elevated (73 Bq/kg) above background (40 Bq/kg). These investigations, however, were conducted during the time period that Marcellus OGW were treated and discharged (2008-2011), or relatively soon after this practice was discontinued, and consequently the Ra accumulation in sediments has been attributed to contamination from the time period of high volumes of Marcellus OGW discharge.[20]

While much attention has been paid to understanding and mitigating contamination from unconventional OGW, the environmental impact from disposal of conventional OGW from CWT facilities has not been thoroughly investigated. Previous research has shown that conventional OGW from the Appalachian basin is also enriched in both ^{226}Ra and ^{228}Ra, with total Ra activities reaching 250 Bq/L (median 27 Bq/L).[7] Accordingly, we hypothesized that in spite of Marcellus OGW no longer being sent to wastewater treatment facilities, long-term release of conventional OGW by CWT facilities would still result in Ra accumulation in stream sediments at disposal sites.

In this study, we collected stream sediments from three disposal sites in PA receiving treated OGW. These include sediments from Blacklick Creek in Josephine, the Allegheny River in Franklin, and McKee Run in Creekside (Figure 1). Stream sediments were collected between 2014 and 2017 while the CWT facilities were not receiving Marcellus OGW but did report receipt of conventional OGW.[18] The objectives of this study were to (1) assess Ra accumulation and the ingrowth of Ra decay products in sediments of streams receiving treated conventional OGW; (2) use the U-Th series disequilibrium to constrain the timing of Ra accumulation and determine whether the Ra in stream sediments reflects ongoing conventional OGW disposal or legacy disposal of Marcellus OGW; and (3) use the data to evaluate the environmental implications of current policies that solely regulate and restrict unconventional fluids and allow continued disposal of treated conventional OGW to the environment.

MATERIALS AND METHODS

Site Selection. We investigated three sites where OGW effluents were released to surface waters from CWT facilities (Figure 1). The CWT facilities that were chosen are defined by Standard Industrial Classification (SIC) codes that only relate to oil and gas wastes. Although the possibility that these facilities received other undocumented wastes during the study period is unknown, we are not aware of any other NORM-rich wastewater sources in the study area. These facilities include (1) the Pennsylvania Brine Treatment Josephine Facility ("Josephine Facility") in Josephine, PA which discharges treated OGW to Blacklick Creek; (2) the Pennsylvania Brine Treatment Franklin Facility ("Franklin Facility") in Franklin, PA, which discharges to the Allegheny River; and (3) Hart Resource Technologies Creekside Facility ("Hart Facility") in Creekside, PA, which discharges to McKee Run (Figure 1).

In 2010, the PADEP issued regulations that required effluents from wastewater treatment plants have total dissolved solid (TDS) levels below 500 mg/L. However, the Josephine, Franklin, and Creekside facilities were 3 of initially 27 facilities grandfathered in to previous regulations that do not strictly limit the TDS of effluents.[27] These three investigated facilities also reported that they stopped receiving unconventional OGW by the end of 2011, following PADEP asking that well operators voluntarily stop sending unconventional OGW to wastewater treatment facilities grandfathered in to the less stringent TDS standards.[22, 27] Total conventional and unconventional waste sent to CWT facilities investigated in this study was compiled from the PADEP oil and gas reporting website for the years 2010-2016.[18] These data confirm that treatment of unconventional wastes at these three facilities diminished by 2012, while treatment of conventional waste and discharge of high salinity waters continued at consistent rates (Figure S1). Average annual discharge rates from 2012 to 2017 were of $236 \pm 61 \times 10^6$ L per year at the Franklin Facility and $174 \pm 29 \times 10^6$ L per year at the Josephine Facility.[28]

In each of the sites, effluents from the CWT facilities discharge to the local streams. The stream sediments in these areas are common to northern Appalachian watersheds. Grain size distribution analyses indicate that the stream sediments consistently range from 5-15% silt and clay across all streams. The remainder of the size fraction is fine to very coarse sand. Results in this study refer to the bulk sediments without analysis of selective grain-size fractions.

Sample Collection. Grab stream sediments were collected in May 2014 (Franklin n= 2, Josephine n=7, Hart n=2), June and August 2015 (Franklin n= 4, Josephine n=2, Hart n=2), and June 2017 (Franklin n= 4, Josephine n=3) from the three effluent sites. Approximately 100 grams of the top 2-4 cm of sediment were scooped with a shovel and stored in a polypropylene jar. Multiple sediment samples were similarly collected from various points upstream of the disposal site over the course of the sampling campaigns (Franklin n=5, Josephine n=7, Hart n=6). Upstream sediments are assumed to be unaffected by effluents and therefore are used as reference sites. However, other upstream sources such as coal mine discharges and other CWT facilities could potentially influence the "background".

One effluent sample was also collected from the Franklin Facility in 2015. The sample was collected unfiltered, prior to coming in contact with stream water. The effluent was diluted with freshwater to a specific conductivity less than seawater (<50 mS/cm) and passed through two sequential plastic columns each containing 10 grams of MnO_2 coated acrylic fiber that efficiently adsorbs Ra.[29-36] The flow rate through the columns was monitored periodically and kept at less than 1 L/min. Fibers were rinsed with DI water, hand squeezed to remove particulates and excess moisture, and stored in separate plastic bags prior to laboratory processing.

Radionuclide Analyses. Approximately 40-60 grams of sediment were oven dried at 105 degrees C and, if necessary, ground with a mortal and pestle to a diameter less than 5 mm. Samples were packed and weighed in plastic snap close Petri style dishes (6.5 cm in diameter and 2 cm in height) that were then sealed with electrical tape and coated in wax to prevent the escape of gaseous ^{222}Rn ($t_{1/2}$ =3.8 days) and ^{220}Rn ($t_{1/2}$=55 seconds). The MnO_2 coated fibers from the Franklin Facility were compressed and then packaged and incubated similarly to the sediment samples. The two fibers were packaged and analyzed separately to monitor for potential Ra bleed through that would result in underestimation of Ra activities.[34]

Sealed samples incubated for a minimum of 21 days to allow ^{226}Ra to reach radioactive secular equilibrium (i.e. the activity of the parent nuclide is equal to the activity of decay product) with ^{222}Rn along with other decay products, ^{214}Bi ($t_{1/2}$ = 19.9 minutes) and ^{214}Pb ($t_{1/2}$ = 27 minutes). This holding time also allows ^{228}Th to reach radioactive secular equilibrium with ^{224}Ra ($t_{1/2}$=3.6 days) and the succeeding short-lived radionuclides including ^{212}Pb ($t_{1/2}$=10.6 hours) and for ^{228}Ra to reach radioactive secular equilibrium with its immediate decay product ^{228}Ac ($t_{1/2}$=6.1 hours). If radioactive secular equilibrium is assumed in these sections of the U and Th decay series, ^{228}Ra, ^{226}Ra, and ^{228}Th can be measured through their decay products [36-39] when direct measurement is not feasible (e.g. the significant interference of ^{235}U (54% yield) on the 186 KeV peak).

Following incubation, samples were counted on a Canberra Broad Energy 5030 Germanium Gamma detector surrounded by 10 cm of lead shielding. Samples typically counted for 6- 48 hours so that counting errors (2σ) were less than 10%. ^{226}Ra activities were measured through the 351 KeV energy peak of ^{214}Pb. ^{228}Ra activities were measured through the 911 KeV energy peak of ^{228}Ac. ^{228}Th activities were measured through the 239 KeV energy peak of ^{212}Pb. Finally, ^{210}Pb ($t_{1/2}$ = 22 years) activities were measured directly through the 47 KeV energy peak. The detector efficiencies were determined using a U-Th reference ore material (DL-1a) prepared by the Canadian Certified Reference Materials Project (CCRMP) that was packaged and incubated in a container identical to the samples. Background and efficiency checks were performed routinely prior to and during the time frame of sample analyses.

We accounted for attenuation of gamma photons by the sample itself at each energy investigated in this study using U and Th point sources according to methods described in Cutshall et al.[40] At low energies (<200 KeV; ^{210}Pb), differences in sample density and composition between the standard and samples of interest resulted in significant attenuation differences. However, we found at higher energies (>200 KeV), these differences were generally minor (i.e. within statistical counting error) for our sample set.

RESULTS AND DISCUSSION

Accumulation of Ra and decay products in sediments at OGW disposal sites. At all three investigated sites, we consistently find elevated Ra activities in stream sediments collected near effluent pipes at the outfall sites (^{226}Ra = 57-14,949 Bq/kg; n= 26) compared to upstream sediments (^{226}Ra = 9-41 Bq/kg; n=18) (Figure 2). Sediments from the Franklin effluent site had ^{226}Ra activities ranging from 269-14,949 Bq/kg (n=10), sediments the Josephine effluent site had ^{226}Ra activities ranging from 119- 10,747 Bq/kg (n=12), and sediments from the Hart effluent site had ^{226}Ra activities ranging from 57-351 Bq/kg (n=4). We did not observe any apparent trends in activities increasing or decreasing with time.

Because Ra is significantly higher in sediments from disposal sites compared to sediments from upstream sites (up to ~650 times compared to the average ^{226}Ra background activity at the Franklin Facility), combined with direct evidence for water contamination from OGW effluents in the stream water,[20, 41] we suggest that the CWT facility discharges are the source for the elevated Ra in the impacted stream sediments. While total Ra activities in conventional OGW can be found up to 250 Bq/L, low ^{226}Ra activities in the discharged effluents from Josephine site were reported by Warner et al[20] (0.13-0.19 Bq/L), which indicate substantial Ra removal as part of the CWT treatment. Similarly, we found relatively low activities of ^{226}Ra and ^{228}Ra (0.4 Bq/L and 0.6 Bq/L, respectively) in effluents collected from the Franklin Site in 2015. In spite of the large removal of Ra from the treated effluents, Ra in sediments collected from the disposal sites was still elevated. These data suggest that the release of low Ra effluents can potentially results in high Ra accumulation in sediments at the disposal sites. However, we cannot exclude the possibility of infrequent pulses of high Ra effluents to the streams as a major contributor to the Ra activities measured in sediments from the disposal sites.

We conducted mass-balance calculations to evaluate the possibility that the ongoing release of low-Ra effluents is responsible for the elevated Ra observed in the sediments near the effluents discharge sites. Our model (see SI for details) takes into account the Ra loading to the stream (based on the Ra activities and volume of the discharge effluents), variable salinity ranges that control the Ra adsorption coefficient (K_d)[42], and the volume of impacted sediments. We find that the Ra activities in impacted stream sediments modeled from these mass-balance calculations are similar to the measured Ra activities in the sediments, supporting the notion that Ra accumulation at the levels observed in this study is possible from long-term discharge of treated OGW effluents even with low Ra activities. Our model does not account for any sediment losses from the system due to continuous downstream transport. A previous study estimated sedimentation rates at 5 to 8 cm per year in a location downstream of the discharge site of Blacklick Creek[43], suggesting that there is likely some transport of sediments to and from the discharge sites, which could effectively be "diluting" the Ra activities at the discharge sites.

The retention of Ra in stream sediments following OGW disposal can be obtained by (1) Ra adsorption to clays and/or manganese and iron oxides;[42, 44, 45] (2) incorporation of Ra into secondary minerals such as barite ((Ba,Ra)SO_4) that could be generated upon the blending of Ba-rich OGW with high-sulfate river water; [46] and/or (3) episodic or ongoing addition of extremely fine-grained barite particles that were generated during the treatment process, suspended in the liquid effluents, and then transported to the stream sediments. While determining the mechanism of Ra accumulation to sediments is outside the scope of this study, future research should investigate whether Ra is incorporated into sediments in these streams through adsorption, authigenic barite formation, or effluent-transported solid barite particles. Such a distinction could have important implications for mitigating future contamination.

In addition to ^{226}Ra and ^{228}Ra, elevated activities of Ra decay products, ^{210}Pb and ^{228}Th, were detected in the sediments collected from two CWT disposal sites at substantially elevated activities compared to the upstream sediments (Figure 2). Sediments from the Franklin site had ^{228}Th activities ranging from 91-4591 Bq/kg and ^{210}Pb activities ranging from 117-1593 Bq/kg, and sediments the Josephine effluent site had ^{228}Th activities ranging from 32- 2614 Bq/kg and ^{210}Pb activities ranging from 33-82 Bq/kg. Upstream ^{228}Th and ^{210}Pb activities ranged from 9-38 Bq/kg and 14-81 Bq/kg, respectively, at both sites. Given the low solubility of Th and Pb and their negligible levels in OGW[8], we assume that the accumulation of ^{228}Th and ^{210}Pb in the stream sediments is likely due to Ra decay and subsequent ingrowth in situ, rather than the transport and addition of these nuclides via retention from discharged effluents.

Source and Age Constraints of Radionuclide Accumulation. Determination of the timing of Ra accumulation has important implications for assessing the source of Ra contamination in the investigated streams. If elevated Ra activities are found to be solely due to legacy contamination from Marcellus OGW treatment and disposal, then the end of this practice in 2011 should have prevented any additional contamination from OGW disposal after 2011. However, if the age of the contamination is relatively recent, then the elevated Ra activities in stream sediments at the disposal sites can be attributed to continued disposal of treated conventional OGW.

The $^{228}Th/^{228}Ra$ activity ratios have been previously used to determine the age and source of OGW spills and radioactive barite associated with oil and gas development.[38, 47, 48] Unsupported ^{228}Ra decays into ^{228}Th, and the $^{228}Th/^{228}Ra$ activity ratio can serve as a chronometer of contamination events[8, 38, 47, 49] due to the insolubility and suitable 1.9 year half-life of ^{228}Th.[45, 50-52] With time, ^{228}Th approaches transient equilibrium with ^{228}Ra, and the $^{228}Th/^{228}Ra$ activity ratio will approach ~1.5 after about 15 years. Changes in the $^{228}Th/^{228}Ra$ activity ratio with time can be modeled according the Equation 1.

$$\frac{228Th}{228Ra} = \frac{\lambda_{Th228}}{\lambda_{Th228} - \lambda_{Ra228}} \left[1 - e^{(\lambda_{228Ra} - \lambda_{Th228})t}\right] \qquad \text{(Eq. 1)}$$

Previous studies have typically employed this $^{228}Th/^{228}Ra$ dating technique on relatively specific events,[38, 47, 48] while its application to dating contamination events derived from OGW effluents that have been released over multiple years is less established. Here we develop the use of the ^{228}Th-^{228}Ra disequilibrium to constrain the age of ongoing contamination from discharging effluents. If all the excess Ra measured in the sediments from the disposal sites was solely accumulated between 2008 and 2011, when the Marcellus OGW was discharged, then observed $^{228}Th/^{228}Ra$ activity ratios would fall within the range of 0.8-1.2 in 2015 and 1.1-1.3 in 2017 (Figure 3). However, the relatively low $^{228}Th/^{228}Ra$ activity ratios (0.3-0.7 in 2015 and 0.2-0.4 in 2017) found in impacted sediments at the Franklin and Josephine sites indicate that at least a portion of the measured Ra has accumulated during the ~0.5 to 3 years prior to sample collection. These relatively low $^{228}Th/^{228}Ra$ activity ratios observed in the stream sediments rule out the possibility that the elevated Ra activities in the sediments is entirely derived from legacy contamination from documented Marcellus OGW, and rather suggests that at least a portion of the excess radioactivity in sediments from the disposal sites is derived from recent disposal of conventional OGW.

$^{228}Th/^{228}Ra$ age dating assumes a closed system with no losses of ^{228}Ra or external source of ^{228}Th in the impacted sediments. Adsorption/desorption is heavily controlled by the ionic strength of the fluid, among other parameters such as pH and the cation exchange capacity (CEC) of the sediment.[42, 44, 45, 53] For example, in groundwater systems, the sediment partition coefficient (K_d; the ratio of the adsorbed nuclide to the nuclide in the dissolved phase) for Ra exponentially increased from 1.4 at TDS~200,000 mg/L to >500 at TDS<1000 mg/L.[42] We posit that the dilution of highly saline OGW with stream water following discharge permits Ra adsorption to stream sediment. Subsequent desorption of Ra or ingrown ^{228}Th is possible following fluctuations in salinity or pH. However, Th is far less mobile than Ra,[52, 54] and losses to the system from desorption would more heavily affect Ra rather than Th. In such a case, the $^{228}Th/^{228}Ra$ activity ratios measured in this study would be artificially high and derived age constraints would be artificially old (i.e., indicating even younger ages than our evaluation assuming no Ra lost). Additionally, $^{228}Th/^{228}Ra$ age dating in this system assumes a fixed sediment substrate despite potential transport of sediments downstream. Regardless, the results from this study indicate that contamination has occurred on a recent time scale and cannot solely be attributed to discharges of Marcellus OGW from 2008-2011.

Age constraints determined from the ^{228}Th/^{228}Ra activity ratios can be corroborated with ^{228}Ra/^{226}Ra activity ratios, which also suggest that Ra is being continually introduced to the stream sediments from the disposal of conventional OGW. While distinctly low ^{228}Ra/^{226}Ra activity ratios (typically less than 0.3) characterize OGW from the Marcellus Shale, higher ^{228}Ra/^{226}Ra (~1) activity ratios have been reported for OGW from conventional formations.[6, 7, 55] The ^{228}Ra/^{226}Ra activity ratios in the impacted sediments are expected to mimic the ratios of the OGW, combined with the decay of ^{228}Ra over time. Following the retention of Ra to the stream sediments, unsupported ^{228}Ra decays with a half-life of 5.8 years, while ^{226}Ra is relatively unchanged over this time scale. Therefore, the ^{228}Ra/^{226}Ra activity ratio in contaminated sediment is expected to decrease with time according the Equation 2, where lambda is the ^{228}Ra decay constant (0.12 yr^{-1}) and t is time.

$$\frac{228Ra}{226Ra} = \left(\frac{228Ra}{226Ra}\right)_o e^{-\lambda_{Ra228} t} \qquad \text{(Eq.2)}$$

Therefore, if all excess Ra was accumulated in the sediments during the period of Marcellus OGW disposal (2008 to 2011), we would expect ^{228}Ra/^{226}Ra activity ratios to be well below 0.3 as ^{228}Ra decays with time. Instead, we observed ^{228}Ra/^{226}Ra activity ratios ranging from 0.4-0.9 in sediments collected in 2015 and 2017, which are higher than typical Marcellus ^{228}Ra/^{226}Ra ratios (< 0.3), suggesting that Ra in the sediments was derived from relatively recent conventional OGW with a relatively high ^{228}Ra/^{226}Ra activity ratio of ~1 (Figure 4).

Policy Implications for Disposal of Conventional OGW from CWT Facilities. Previous[20] and new data presented in this study indicate that the disposal of OGW to the environment results in the accumulation of Ra and Ra-decay products in the upper section of impacted stream sediments. Our data indicate that in spite of the removal of a large fraction of Ra from treated OGW, the discharge of effluents results in accumulation of Ra (^{226}Ra up to 15,000 Bq/kg) in impacted sediments. This observation is supported by a Ra mass-balance model (See SI for details) that shows that the modeled Ra accumulation in the stream sediments is similar to the observed Ra activities in the impacted sediments. While there is no federal regulation, several states have developed limits for solids containing NORM, which typically range from 185-1850 Bq/kg (5 pCi/g to 50 pCi/g).[56] Our data indicate that the disposal of treated OGW results in elevated NORM activities in impacted stream sediments above the 1850 Bq/kg threshold. Waste materials with ^{226}Ra above 1850 Bq/kg should be transferred to a licensed radioactive waste disposal facility that has strict requirements related to site location and the following features: (1) lined walls, back up lining, and a cover, (2) a leachate collection system, and (3) leak detector systems.[57]

Relatively low ^{228}Th/^{228}Ra and high ^{228}Ra/^{226}Ra activity ratios measured in sediments collected from two CWT discharge sites in PA indicate that at least a portion of the Ra measured in sediments has accumulated in recent (0.5-3) years when no Marcellus OGW was reportedly discharged, suggesting that conventional OGW discharges are a noteworthy source of radium accumulation. Accordingly, data from this study indicate that restricting treatment to only conventional OGW at CWT facilities does not prevent the large accumulation of Ra in stream sediments from disposal sites. Our data and previous data[20] also suggest that the large Ra removal from the disposed effluents potentially does not mitigate the high NORM accumulation in sediments at the disposal sites, although we cannot rule out the possibility of infrequent pulses of high-Ra effluents as a major contributor of Ra to the sediments rather than long-term discharge and accumulation from low-Ra effluent.

In addition to treatment at wastewater treatment plants, unconventional OGW is also prohibited from being used as a deicing agent or dust suppressant on roads, while untreated conventional OGW is permitted for application to roads.[26] While the fate of NORM following the use of OGW as deicing agents and dust suppressants remains a major question, data from this study suggests that permission of conventional OGW will not protect the environment from radioactive contamination. In an initial assessment, Skalak et al. [26] found elevated Ra (1.2x), Sr, Ca, and Na in roadside sediments in Vernon County, PA, where OGW was applied to roads for dust suppression when compared to background sites. Future research addressing the application of OGW to roads as a deicing agent and dust suppressant is important to fully understand the impact of OGW related NORM on soils and sediments and the human and environmental health implications of this practice.

Overall, this study shows consistently elevated activities of Ra and their decay products in stream sediments at three disposal sites of CWT facilities in PA receiving conventional OGW, up to five years after unconventional Marcellus OGW were no longer discharged. The $^{228}Th/^{228}Ra$ and $^{228}Ra/^{226}Ra$ activity ratios in the sediments suggest that at least a portion of the Ra has accumulated in recent years when no Marcellus OGW were reportedly discharged, indicating that permitting CWT facilities to treat and release only conventional OGW does not prevent radioactive contamination and accumulation in the upper portion of sediments at disposal sites. In order to prevent radionuclide accumulation in the environment, we suggest that disposal restrictions should apply to any type of Ra-rich water, regardless of source, and that current policies differentiating the treatment and disposal of conventional OGW from unconventional OGW should be reconsidered.

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SUPPORTING INFORMATION AVAILABLE

Expanded information on the Ra mass balance calculations, 1 figure, and 1 table are available.

Figures

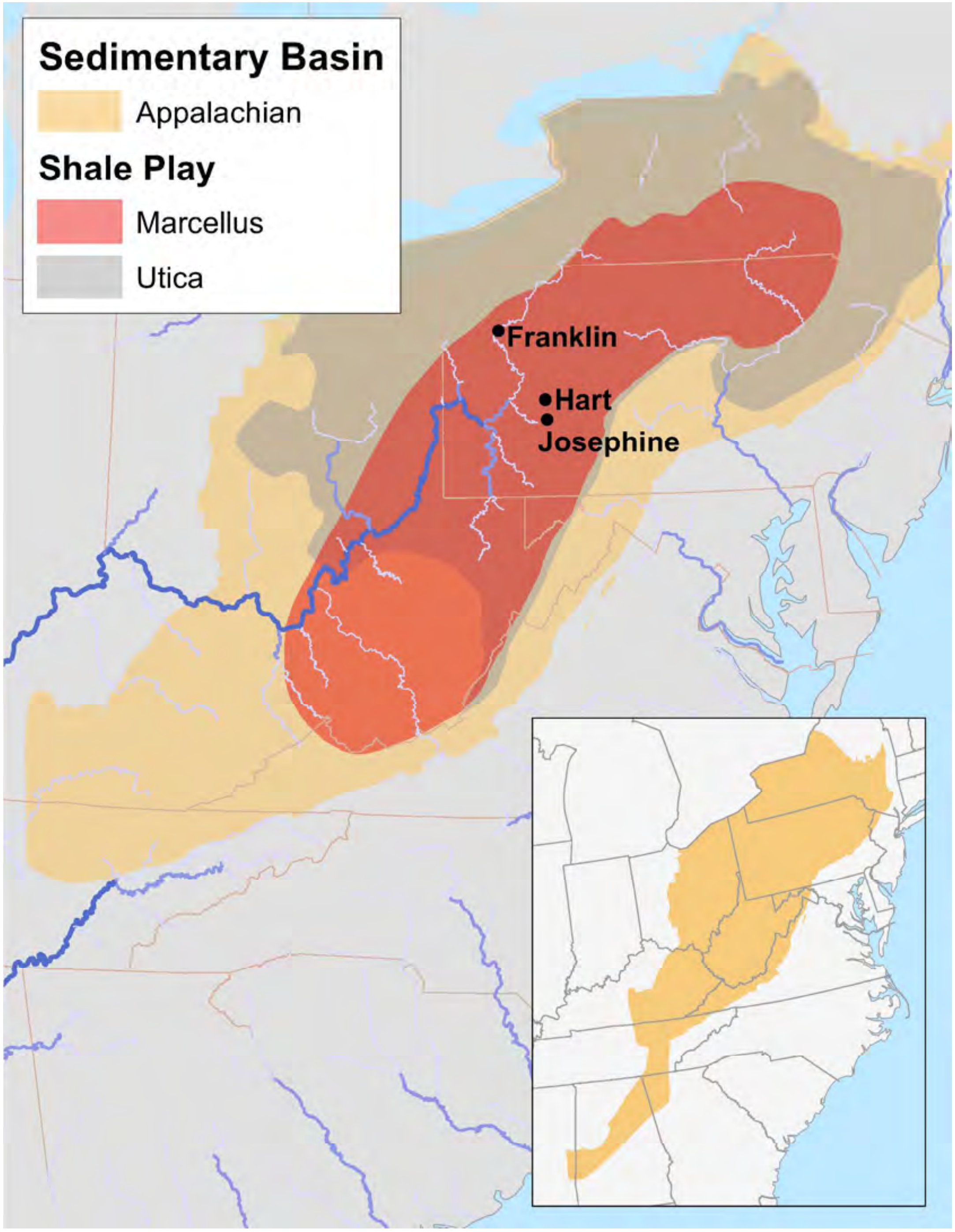

Figure 1. A map of the northern Appalachian Basin and major shale plays in the eastern United States. Inset map shows the entirety of the Appalachian Basin, that extends from New York southward through Pennsylvania, Maryland, Ohio, West Virginia, Virginia, Kentucky, and Tennessee before terminating in Alabama. The location of the three CWT facilities investigated in this study are also shown.

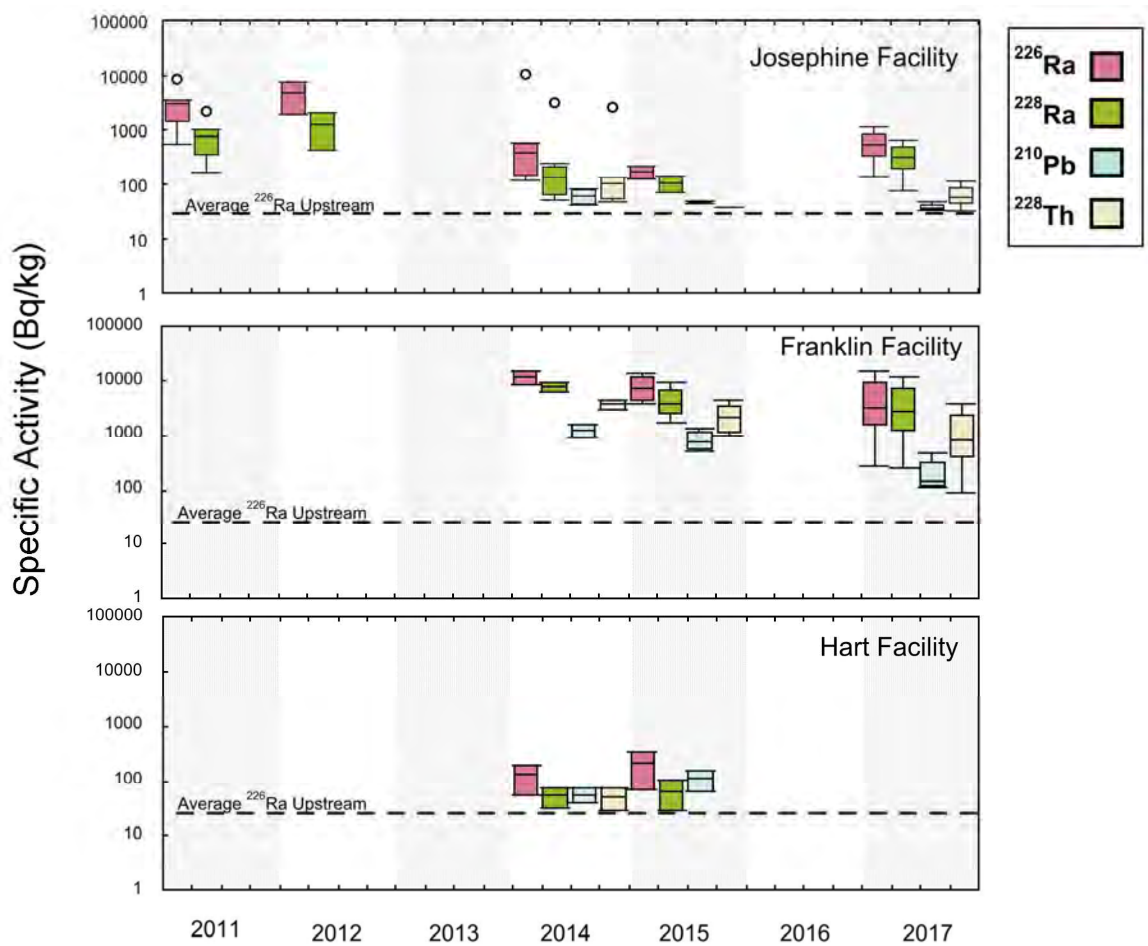

Figure 2. ^{226}Ra, ^{228}Ra, ^{210}Pb, and ^{228}Th in sediments collected from three streams receiving OGW discharged by CWTs in 2014, 2015, and 2017. Josephine data from 2011 and 2012 were compiled from the literature.[18] The boxplots indicate the middle 50% and the median of the data. Boxplot whiskers indicate the minimum and maximum values, excluding outliers which are indicated by open circles. Dashed lines show the average ^{226}Ra activity of upstream samples, assumed to be unaffected by treated OGW effluents. Elevated activities were measured at all three effluent sites compared to upstream sites.

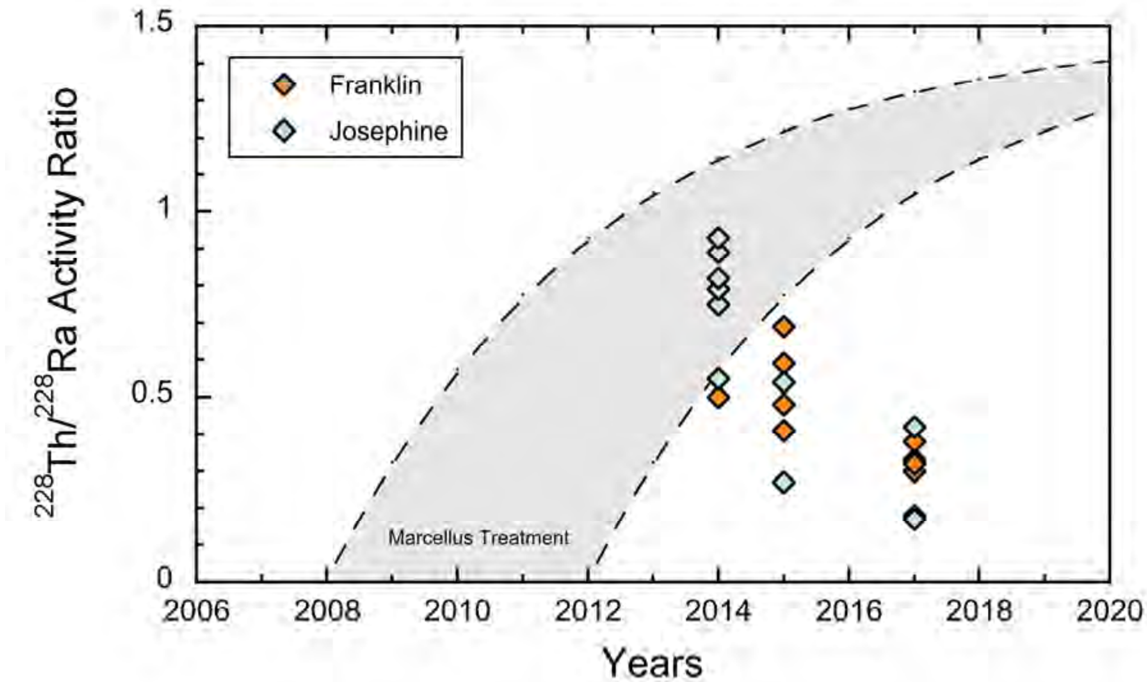

Figure 3. ^{228}Th/^{228}Ra activity ratios in sediments collected from the Franklin and Josephine CWT facilities in 2014, 2015, and 2017. Ratios that fall within the gray band reflect contamination that can be dated to the time period of high discharges of treated unconventional Marcellus OGW (2008-2011). Sediments collected in 2015 and 2017 had ^{228}Th/^{228}Ra activity ratios that fall below the expected range if contamination was solely from Marcellus OGW contamination. These relatively low ratios suggest that at least a portion of the Ra that has accumulated in the sediments is from relatively recent releases of conventional OGW.

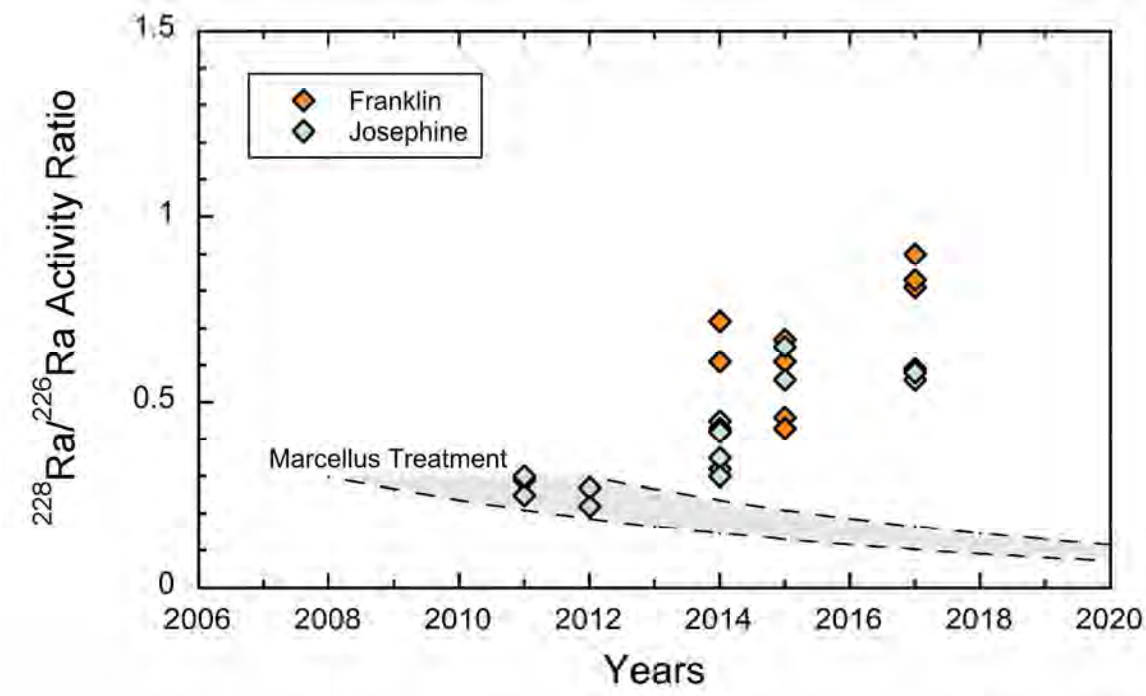

Figure 4. $^{228}Ra/^{226}Ra$ activity ratios in sediments collected from the Franklin and Josephine CWT facilities in from 2011-2017. 2011 and 2012 data are compiled from Warner et al. (2013).[20] Ratios that fall within the gray band reflect the ratios that would be expected from Marcellus OGW contamination from 2008-2011. Sediments from this study collected in 2014, 2015 and 2017 had $^{228}Ra/^{226}Ra$ activity ratios above the Marcellus range, suggesting that at least some of the contamination is sourced from conventional OGW with a relatively higher $^{228}Ra/^{226}Ra$ activity ratio (~1).

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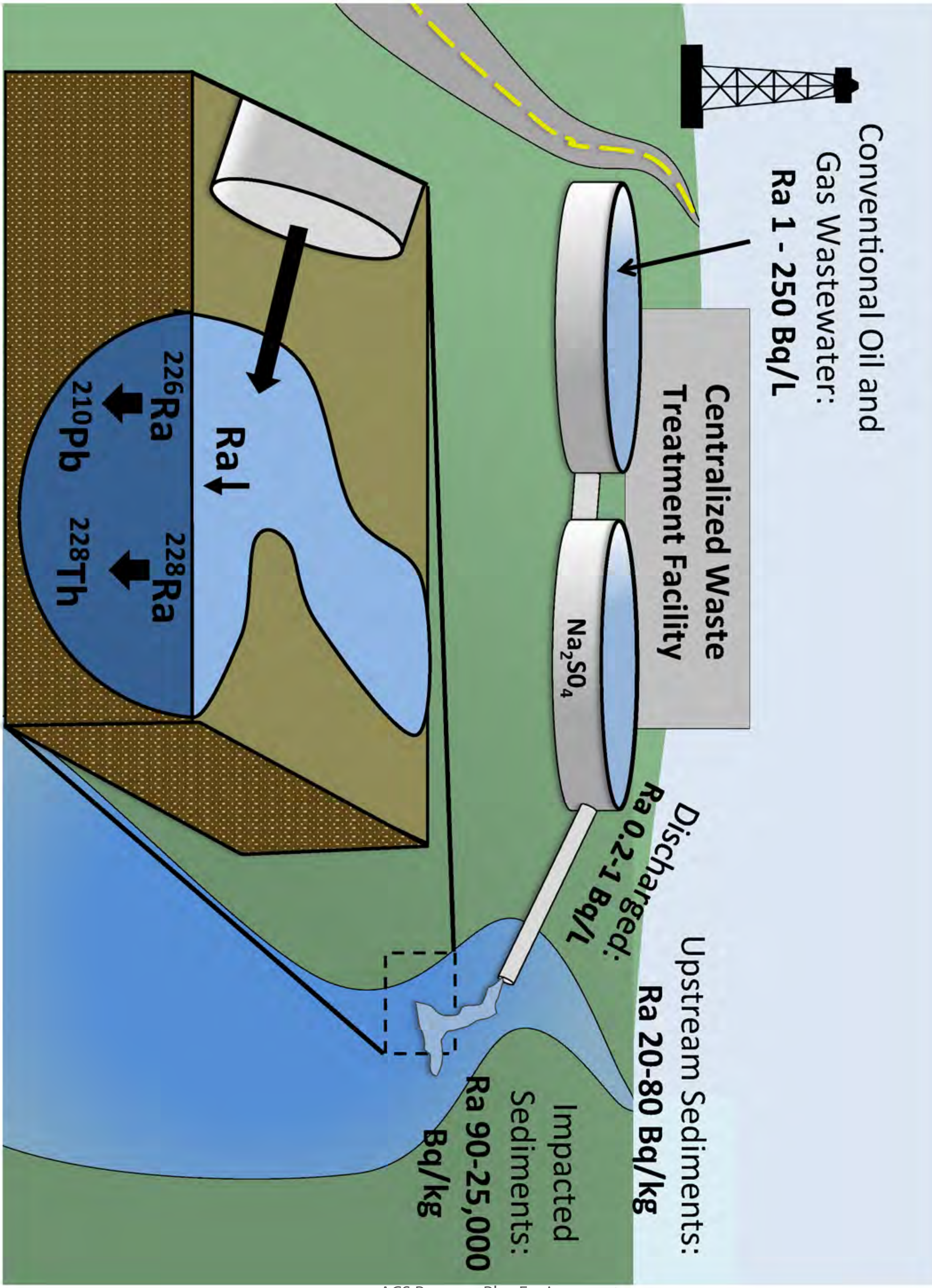
Conventional Oil and Gas Wastewater:
Ra 1 - 250 Bq/L
Centralized Waste Treatment Facility
Na_2SO_4
Discharged:
Ra 0.2-1 Bq/L
Upstream Sediments:
Ra 20-80 Bq/kg
Impacted Sediments:
Ra 90-25,000 Bq/kg
Ra↓
^{226}Ra
^{210}Pb
^{228}Ra
^{228}Th

EXHIBIT J

RESOLUTION FOR THE MINUTES

A RESOLUTION directing the Executive Director to publish for comment proposed amendments to the Comprehensive Plan and implementing regulations with respect to transfers of water and wastewater from and to the Delaware River Basin.

WHEREAS, by Resolution No. 1991-9 on June 19, 1991, the Commission amended the Comprehensive Plan by the addition of policies and regulations codified at Section 2.30 of the Commission's Water Code, relating to transfers of water and wastewater from and to the Delaware River Basin; and

WHEREAS, on November 30, 2017 the Commission proposed new rules, including new Part 440 of Title 18, Chapter III, Subchapter B of the Code of Federal Regulations, which in part concerned inter-basin transfers of water and wastewater, to protect the water resources of the Basin from adverse impacts associated with water withdrawals and wastewater treatment and disposal to support hydraulic fracturing; and

WHEREAS, after carefully considering the public comments received on the November 2017 draft rules, the Commission by Resolution No. 2021 - 01 on February 25, 2021 withdrew from consideration the provisions of such draft rules relating to the exportation of water and the importation, treatment, and discharge of "produced water" as defined therein; and

WHEREAS, the Commission's current policies on the transfer of water and wastewater from and into the Delaware River Basin as set forth at Section 2.30.2 of the Water Code, provide:

> The waters of the Delaware River Basin are limited in quantity and the Basin is frequently subject to drought warnings and drought declarations due to limited water supply storage and streamflow during dry periods. Therefore, it shall be the policy of the Commission to discourage the exportation of water from the Delaware River Basin.
>
> …[T]he Basin waters have limited assimilative capacity and limited capacity to accept conservative substances without significant impacts. Accordingly, it also shall be the policy of the Commission to discourage the importation of wastewater into the Delaware River Basin….

and

WHEREAS, the Commission's Comprehensive Plan currently includes the following classes of transfers of water from the Basin:

- Out-of-basin diversions by New York City and the State of New Jersey authorized by the 1954 United States Supreme Court Decree in *New Jersey v. New York,* 347 U.S. 995 ("Decree"), as subsequently modified by the Commission with the unanimous consent of the parties to the Decree, in accordance with Section 3.3 of the Delaware River Basin Compact;

- Out-of-Basin transfers approved on a long-term basis pursuant to Section 3.8 of the Compact to meet the needs of public water systems with service areas straddling or adjacent to a Delaware River Basin boundary;

- Out-of-Basin transfers approved on a temporary and/or emergency basis pursuant to Section 3.8 of the Compact to ensure the public health and safety of communities adjacent to or straddling a Delaware River Basin boundary;

and

WHEREAS, to date the Commission has approved no transfers of water and/or wastewater from or into the Delaware River Basin to support hydraulic fracturing for the extraction of oil or natural gas, and no applications for such transfers are currently under consideration; and

WHEREAS, since 2009, the Commission has in many instances conditioned its approvals of wastewater discharge projects on a requirement that no importation, treatment and/or discharge of hydraulic fracturing wastewater may be undertaken by the docket holder without the Commission's prior review and approval; now therefore,

BE IT RESOLVED by the Delaware River Basin Commission:

1. No later than September 30, 2021 the Executive Director shall prepare and publish for public comment a set of amendments to the Comprehensive Plan and implementing regulations to update its policies and provisions concerning inter-basin transfers of water and wastewater from and to the Delaware River Basin.

2. The proposed rule amendments directed by this Resolution shall include and the public notice shall solicit comment on:

    a. Conditions under which an exportation of water from the Basin may be approved or prohibited;

    b. Conditions under which an importation of wastewater into the Basin may be prohibited;

    c. Any other provisions concerning inter-basin transfers of water and wastewater that commenters believe are necessary and appropriate to protect the public health or to preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

3. The Executive Director, in consultation with the Commissioners, may include in the draft regulations such other proposed amendments of DRBC's rules and regulations as they deem necessary or appropriate.

4. To ensure that all public comments on the proposed amendments are captured and included in the Commission's official rulemaking record, public comments on the proposed amendments will be included in such record only when submitted in accordance with the procedures set forth in the notice of proposed rulemaking to be issued by the DRBC.

APPROVED: February 25, 2021

EXHIBIT K

Final Rule: Water Imports, Exports & Prohibition of HVHF Wastewater Discharges

Final Rule: Key Information

Title:

Regulatory Amendments concerning importations of water into and exportations of water from the Delaware River Basin and prohibiting the discharge of wastewater from high volume hydraulic fracturing (HVHF) and HVHF-related activities.

Action:

Final Rule, adopted December 7, 2022 (effective thirty days after publication in the *Federal Register*)

Summary:

By Resolution No. 2022-04 on December 7, 2022, the DRBC approved amendments to its:

- Comprehensive Plan and the Delaware River Basin Water Code concerning any importation of water and wastewater into and any exportation of water and wastewater from the Delaware River Basin;
- Special Regulations – High Volume Hydraulic Fracturing prohibiting discharges to waters or land within the Basin of wastewater from HVHF and HVHF-related activities; and
- Water Quality Regulations facilitating the implementation in state-issued permits of the prohibition on such discharges.

Key Information:

- Resolution No. 2022-04 approved December 7, 2022 (pdf)
  - Resolution No. 2022-04 as html (for translation using Google Translate widget)
- Comment and Response Document (pdf)
- News Release (issued December 7, 2022)
- Frequently Asked Questions (FAQ) (pdf)
  - FAQ as html (for translation using Google Translate widget)
- View final amended DRBC regulations

Please Note:

- The text on this page and all html webpages on the DRBC website can be translated into multiple languages using the Google Translate widget found at the top right of each webpage.
- Requests for translation of additional documents related to this rulemaking can be made by contacting translate@drbc.gov.

Final Rule: Findings & Determinations, Summary & Rule Text

After an extensive public rulemaking process, the Commission found and determined that:

- The waters of the Delaware River Basin are limited in quantity, and the Basin is frequently subject to drought warnings, drought declarations and drought operations due to limited water supply storage and streamflow during dry periods. In addition, portions of the Basin have been delineated by the Commission as groundwater protected areas due to water shortages. Therefore, it is the policy of the Commission to promote the conservation and preservation of water and related natural resources, including aquatic ecosystems, and effectuate the Comprehensive Plan and the uses of the water resources of the Basin identified therein, by discouraging, limiting or placing conditions on the exportation of Basin water as may be required to protect the health and safety of Basin residents, aquatic ecosystems and the uses of water identified in the Compact and Comprehensive Plan.
- Basin waters have limited capacity to assimilate pollutants without significant impacts to the health and safety of Basin residents, the health and functioning of aquatic ecosystems in the Basin, and the effectuation of the Comprehensive Plan. Accordingly, it is the policy of the Commission to discourage, limit, or condition the importation of wastewater into the Delaware River Basin as necessary to avoid impairment of Basin waters.
- The discharge of wastewater from HVHF and HVHF-related activities poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the Basin's water resources.
- The Commission further finds and determines that controlling future pollution by prohibiting discharges of wastewater from HVHF and HVHF-related activities to waters or land within the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan.

Based on the above, the following DRBC Regulations are amended by the Final Rule:

Delaware River Basin Water Code:

- Amended Section 2.30 by clarifying the circumstances in which exportations of water, including wastewater, from the Basin and importations of water, including wastewater, into the Basin are considered by the Commission and the factors to be used in evaluating whether such proposed imports and exports of water may be approved.
  - Final Water Code Section 2.30 (pdf)
  - Redline comparison of proposed Water Code Section 2.30 to Final Water Code Section 2.30 (pdf)
  - Former Water Code Section 2.30 (pdf)

Special Regulations: Part 440—High Volume Hydraulic Fracturing:

- Amended 18 CFR Part 440 by prohibiting the discharge of wastewater from HVHF and HVHF-related activities to waters or land within the Basin.
  - Final Part 440 (pdf)
  - Redline comparison of Final Part 440 to former Part 440 (pdf)
  - Redline comparison of proposed Part 440 to Final Part 440 (pdf)

Water Quality Regulations:

- Amended Article 4 facilitates the alignment of certain Basin state discharge permits with the Commission's Special Regulations by incorporating into the Water Quality Regulations the prohibition on the discharge of wastewater from HVHF and HVHF-related activities.
  - Final Article 4 (pdf)
  - Redline comparison of Final Article 4 to former Article 4 (pdf)

Note: The final rule incorporates by reference into the Code of Federal Regulations at 18 CFR part 410 the Commission's Water Quality Regulations and the Delaware River Basin Water Code as amended by the Commission on December 7, 2022.

Final Rule: Changes from Proposed Rule

Delaware River Basin Water Code:

- The final language of Section 2.30.2 C.3 of the Water Code narrows the circumstances in which the Commission may approve an exportation of wastewater to instances in which the project sponsor demonstrates either:
  - that the wastewater is to be conveyed to a straddled or adjacent public wastewater collection system; or

- that the wastewater may not lawfully be discharged to a public wastewater collection system and is being exported to a waste management facility that has all state and federal approvals required to lawfully receive it.

- To clarify the changes to Section 2.30.2 C.3 of the Water Code, Section 2.30.1 of the final rule includes definitions of "Public wastewater collection system," "Adjacent public wastewater collection system" and "Straddled public wastewater collection system" that were not included in the proposed rule. The definitions are designed to parallel those previously proposed for "Public water system," "Adjacent public water system" and "Straddled public water system," respectively.

- The final rule includes additional non-substantive changes in two sections.
    - Language in Section 2.30.1 A., defining "Adjacent public water system," was revised for greater stylistic consistency and clarity.
    - The wording of Section 2.30.2 C.2. was changed slightly to make clear that any exportation under that provision must be for the purpose of meeting public health and safety needs of the receiving system regardless of whether the exportation is intended to be temporary, short-term or in response to an emergency.

Special Regulations: Part 440—High Volume Hydraulic Fracturing:

- The final rule includes a new defined term, "Discharge of wastewater from HVHF and HVHF-related activities," to make the meaning of the rules more explicit.

- The final rule also includes the addition of two words to section (1) of the definition of "Wastewater from HVHF and HVHF-related activities" in § 440.2 of the Special Regulations. The words "or" and "containing" are added to clarify that the definition refers to wastewater, brine, or sludge *containing* (as opposed to constituting) the various listed contaminants.

- Additional non-substantive changes were made to conform proposed rule text in § 440.2 to Code of Federal Regulations standards.

Water Quality Regulations:

- The final rule includes no changes from the amendments proposed to the Water Quality Regulations.

Final Rule: Activities Prohibited & Activities Not Regulated by the Final Rule

One of the main components of the final rule prohibits the discharge of wastewater from HVHF and HVHF-related activities to waters or land within the Delaware River Basin.

Examples of activities that <u>are prohibited</u> by the final rule:

- Discharge of HVHF wastewater to waters or land within the Basin;

- Road spreading of HVHF wastewater;

- Injection of HVHF wastewater into deep wells within the Basin;

- Disposal of HVHF wastewater in Basin landfills;

- Discharge of leachate from any landfill in the Basin that accepts HVHF waste after the effective date of the final regulations, including after treatment at an onsite or off-site leachate or wastewater treatment plant; and

- Spills and leaks during transport, transfer or storage of HVHF wastewater within the Basin if not fully captured by a containment system in place throughout the duration of the spill or leak and thereafter promptly removed or remediated.

Examples of activities that are beyond the scope of the proposed and final rule follow. The final rule <u>does not</u>:

- Regulate air emissions from HVHF activities;

- Categorically prohibit the transfer of HVHF wastewater into the Basin when no resulting discharge is proposed;

- Regulate the transportation and storage of HVHF materials, which are regulated under detailed state and federal programs focused on these activities;

- Categorically prohibit the transfer of water from the Basin if it would be used to support HVHF (or any other specified activity). However, the rule does limit the circumstances under which transfers of water from the Basin will be considered and provides for an evaluation of such proposals based on factors designed to ensure no harm to the Basin's water resources or the health and safety of the Basin community; or

- Prohibit road spreading of wastewater from *conventional* drilling activities, an activity not within the scope of DRBC's proposed rulemaking. The Commission will continue to coordinate with the Basin states to review the scientific evidence regarding harm to water resources caused by road spreading of conventional oil and gas production wastewater and may in the future consider whether additional regulation of the practice is needed in the Basin.

Proposed Rule: Key Info & Link to Full Archives

Background:

At its Special Public Business Meeting on February 25, 2021, a deadline of September 30, 2021, was set for the publication of draft proposed regulatory amendments regarding DRB water imports and exports.

- Resolution for the Minutes directing the Executive Director to publish for comment proposed amendments to the Comprehensive Plan and implementing regulations with respect to transfers of water and wastewater from and to the Delaware River Basin (pdf; February 25, 2021)

At the DRBC's 3Q Business Meeting on September 9, 2021, the date by which DRBC will publish these proposed amendments was extended through November 30, 2021.

- Resolution for the Minutes extending through November 30, 2021 the date by which the DRBC will publish proposed amendments to the Comprehensive Plan and implementing regulations with respect to transfers of water and wastewater from and to the Delaware River Basin (pdf; September 9, 2021)

Publication of Proposed Rule:

The proposed amendments and implementing regulations were published on October 28, 2021.

- Notice of Proposed Rulemaking and Public Hearing (pdf; note this version includes the originally posted comment deadline of January 28, 2022, which the Commission on November 16, 2021, extended to February 28, 2022.)

Extensive opportunity for public input on this proposed rule was provided during the 124-day public comment period that took place from October 28, 2021, to February 28, 2022, and included five public hearings.

View complete information on the proposed rulemaking

Public Submissions on the Proposal:

During the comment period the Commission received a total of 2,461 comment submissions.

- Online: The DRBC received 2,388 written submissions on-line through its online comment system: https://hearing.drbc.commentinput.com/?id=x2K8A
- Public Hearing Transcripts (all pdfs): The Commission received 73 oral comments during five public hearings:
  - Hearing #1: December 8, 2021 - 2:30 p.m.
  - Hearing #2: December 8, 2021 - 6:30 p.m.
  - Hearing #3: December 15, 2021 - 1 p.m.
  - Hearing #4: December 15, 2021 - 4 p.m.
  - Hearing #5: February 3, 2022 - 1:30 p.m.

Enhanced Public Access:

- The Notice of Proposed Rulemaking and proposed rule documents were officially translated into Spanish and posted online.
- HTML pages of key proposed rulemaking information were created to allow for translation into multiple languages using the Google Translate widget.
- Public hearing #5 included enhanced language access to include real-time English-to-Spanish and Spanish-to-English professional translation (on a pilot basis). Attendees could choose to participate in the virtual hearing in either English or Spanish.
- Public hearing #5 also included toll-free phone numbers for individuals to use to participate in the public hearing via phone (on a pilot basis). This enhanced access was for those who do not have a computer or those who live in regions with limited internet access.

Related Resources

Contacts:

- Elizabeth Koniers Brown, Director of External Affairs and Communications
- Kate Schmidt, Communications Specialist

Learn More:

- Final Rule Prohibiting HVHF in the DRB (February 25, 2021)
- DRBC Regulations Info
- DRBC Natural Gas Webpage

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Notice Final Rule Adopted & Posted: December 7, 2022

P.O. Box 7360, West Trenton, NJ 08628-0360
Phone (609)883-9500; Fax (609)883-9522

Last Modified: 12/07/2022

EXHIBIT L

Final Regulations Addressing Importation and Exportation of Water and the Discharge of Wastewater from High Volume Hydraulic Fracturing and HVHF-Related Activities

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Frequently Asked Questions (FAQs)

1. ***Why has the Delaware River Basin Commission (DRBC or Commission) adopted these new rules?***

   The Delaware River Basin Commission is a federal/interstate government agency that manages the water resources of the Delaware River Basin (the Basin). The five Commission members are the governors of the Basin states (Delaware, New Jersey, New York, and Pennsylvania) and the commander of the U.S. Army Corps of Engineers, North Atlantic Division, who represents the federal government.

   On November 30, 2017, the DRBC published draft rules regulating high volume hydraulic fracturing (HVHF) in the Basin. On February 25, 2021, the Commissioners approved a final rule prohibiting HVHF in the Basin and, separately, adopted a Resolution for the Minutes directing DRBC's executive director to propose amendments to update the Commission's rules concerning importation into the Basin of water and wastewater from outside the Basin and exportation of Basin water and wastewater. The proposed and final rules also address the discharge of wastewater from HVHF and HVHF-related activities (HVHF wastewater) to waters or land within the Basin.

2. ***Do the adopted rules prohibit the discharge of wastewater from high volume hydraulic fracturing (HVHF)?***

   Yes. The Commission determined that controlling future pollution by prohibiting discharges of wastewater from HVHF and HVHF-related activities to waters or land within the Basin is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. To protect the water resources of the Basin, the Commission adopted amendments to Part 440 of Title 18, Chapter III of the Code of Federal Regulations (18 CFR Part 440) and to Article 4 (Application of Standards) of the Commission's Water Quality Regulations (incorporated by reference at 18 CFR Part 410). Specifically:

   - **Amended Part 440 of Title 18 of the Code of Federal Regulations** prohibits the discharge of wastewater from HVHF and HVHF-related activities to waters or land within the Basin.

   - **Amended Article 4 of the Water Quality Regulations** facilitates the alignment of certain Basin state discharge permits with the Commission's amendments to 18 CFR Part 440 by incorporating into the Water Quality Regulations the prohibition on the discharge of wastewater from HVHF and HVHF-related activities.

3. What discharges of HVHF wastewater are specifically prohibited?

As defined in the regulations, "wastewater from HVHF and HVHF-related activities" means:

> (1) Any wastewater, brine, or sludge containing chemicals, naturally occurring radioactive materials, heavy metals or other contaminants that have been used for or generated by high volume hydraulic fracturing or HVHF-related activities;
>
> (2) Leachate from solid wastes associated with HVHF-related activities, except if the solid wastes were lawfully disposed of in a landfill within the Basin prior to [the effective date of the rule]; and
>
> (3) Any products, co-products, byproducts or waste products resulting from the treatment, processing or modification of the wastewater described in paragraphs (1) and (2) of this definition.

Activities about which multiple commenters expressed concern and that are prohibited by the final rule include (but are not necessarily limited to) the following:

- discharge of HVHF wastewater to waters or land within the Basin;
- road spreading of HVHF wastewater;
- injection of HVHF wastewater into deep wells within the Basin;
- disposal of HVHF wastewater in Basin landfills;
- discharge of leachate from any landfill in the Basin that accepts HVHF waste after the effective date of the final regulations, including after treatment at an onsite or off-site leachate or wastewater treatment plant; and
- spills and leaks during transport, transfer, or storage of HVHF wastewater within the Basin if not fully captured by a containment system in place throughout the duration of the spill or leak and thereafter promptly removed or remediated.

4. Do the final rules prohibit the importation of HVHF wastewater into the Delaware River Basin?

Yes, if the proposed importation of wastewater from HVHF and HVHF-related activities would result in a discharge of the imported wastewater to land or water within the Basin, with or without prior treatment. Otherwise, no. The final amendments expressly prohibit the *discharge* of treated and untreated wastewater from HVHF and HVHF-related activities to waters or land within the Basin.

Because the Commission has prohibited HVHF within the Basin and is also prohibiting the discharge of treated or untreated HVHF wastewater to land or waters within the Basin, DRBC anticipates that only low volumes of HVHF wastewater will be transported to or through the Basin. (For data that supports this view, see Response R-25 of the Comment and Response Document (CRD) adopted by the Commission concurrently with the final rule.) The number of probable spills of HVHF wastewater during transport within the Basin and the related potential for adverse impacts on the Basin's water resources resulting from such spills are in the Commission's view reduced by these measures sufficiently to protect the Basin's water resources. Notably, storage and transportation of HVHF wastewater are activities subject to detailed state and federal regulatory programs that the Commission does not seek to replicate.

Under the adopted rule, the Commission will evaluate proposed importations of water or wastewater using the factors set forth at section 2.30.3 B. of the Water Code. Those factors include, among others, the effects of the proposed importation on aquatic ecosystems, water quality and waste assimilative capacity in the receiving streams (§§ 2.30.3 B.3.d. and B.3.e.), and the effect of the importation on the health and safety of the Basin community (§ 2.30.3 B.1). They further require the Commission to consider "alternatives that avoid an importation of water." (§ 2.30.3 B.3. intro par.). Accordingly, under the final rule, any proposed importation will be carefully evaluated to ensure it does not adversely affect the Basin's water resources or the health and safety of Basin water users.

Please see FAQs 6 and 7 below, and Responses R-25, R-31 and R-32 of the Comment and Response Document (CRD) for additional discussion related to concerns about the transportation and storage of HVHF wastewater.

5. What changes have been made to the rules since they were proposed in October 2021?

Changes made in response to comments on the proposed rule include the following:

- The final rule amending the Water Code narrows the circumstances in which the Commission may approve an exportation of water that consists of wastewater. Under the final rule, the Commission may approve an exportation of wastewater when the project sponsor demonstrates either that the wastewater is to be conveyed to a straddled or adjacent public wastewater collection system or that the wastewater may not lawfully be discharged to a public wastewater collection system in the Basin and is being exported for treatment outside the Basin at specialized waste management facilities that have all appropriate state and federal approvals.

- The final rule modified the "public health and safety needs" category of allowable exportations to make clear that any exportation under this provision must be made for the purpose of meeting public health and safety needs of the receiving system regardless of whether the exportation is intended to be temporary, short-term, or in response to an emergency.

- The final rule includes additional definitions in the Water Code for "Public wastewater collection system," "Adjacent public wastewater collection system," and "Straddled public wastewater collection system." The definition of "Adjacent public water system" has been simplified.

- In the final rule amending the Commission's Special Regulations, 18 C.F.R. Part 440 – High Volume Hydraulic Fracturing, to make explicit the scope of the prohibition on discharges of wastewater from HVHF and HVHF-related activities, the Commission added a definition of the term "Discharge of wastewater from HVHF and HVHF-related activities," which is defined as "an intentional or unintentional action or omission resulting in the releasing, spilling, leaking, pumping, pouring, emitting, emptying, spreading, spraying, injecting, leaching, dumping, or disposing of such wastewater to waters or land within the Basin, and including the abandonment or discarding of barrels, containers, and other receptacles containing such wastewater."

- Also in 18 C.F.R. Part 440, the definition of "Wastewater from HVHF and HVHF-related activities" is modified to make clear that this term encompasses wastewater, brine, or sludge *containing* (as opposed to constituting) the various listed contaminants.

6. ***Many commenters called for a prohibition on all importation of HVHF wastewater, including transportation across the Basin and storage within it, as well as disposal of HVHF wastewater within the Basin (in their words, a "full ban"). Some have suggested that the Delaware River Basin will be an especially attractive location for the importation and storage of HVHF wastewater under the adopted rules. Why did the Commission not enact a "full ban" on HVHF wastewater importation?***

The Commission does not agree that the Delaware River Basin is an attractive location for importation or storage of HVHF wastewater. In the Commission's view, which is supported by data and set forth in detail at Response R-25 of the CRD adopted by the Commission concurrently with the final rule:

- Wastewater storage and treatment infrastructure is typically located proximate to HVHF activities.
- Data on spills of oil and gas wastewater during truck transport demonstrate that spill events are more frequent in regions with active shale gas production than in adjacent regions where shale gas has been prohibited.
- HVHF has been prohibited within the Basin since February 2021.
- There is a "high bar" for approval of any importation of wastewater into the Delaware River Basin consistent with the policy and evaluation factors included in final sections 2.30.2 and 2.30.3 of the Water Code. The latter include "consideration of the available alternatives to the [proposed] importation" (§ 2.30.3 B.1.).

Because the Commission in 2021 prohibited HVHF in hydrocarbon bearing rock formations in the Basin and has now prohibited discharges of wastewater from HVHF and HVHF-related activities within the Basin, the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin.

The Commission has never approved a proposal to import HVHF wastewater into the Basin and has no pending applications of this kind.

7. ***Do these rules consider the risks of HVHF wastewater leaks or spills from trucks, pipelines, or storage facilities?***

Yes. Such spills, leaks or releases to land or waters of the Basin are explicitly prohibited by the final rule. However, because the Commission has prohibited the use of HVHF within the Basin and is prohibiting the discharge to waters or land within the Basin of HVHF wastewater (broadly defined to include products, co-products, byproducts or waste products from the treatment, processing or modification of HVHF wastewater), the Commission anticipates that only low volumes of HVHF wastewater will be transported, stored, treated, processed, or reused within the Basin and that the amount and severity of any spills, leaks, or other releases and resulting impacts to the Basin's water resources from such activities will likely be sufficiently low so as not to injuriously affect the waters of the Basin as contemplated by the Comprehensive Plan.

The Commission also has determined based on spill data that the probability of spills from HVHF wastewater pipelines (as well as other conveyances) is substantially higher in active shale gas production areas than in areas where shale gas is not produced. The likelihood of spills from such pipelines is expected to remain quite low within the Basin.

Finally, DRBC's authority is limited to water resources of the Delaware River Basin. It has responsibility for protecting these resources and has determined that controlling future pollution by prohibiting discharges of HVHF wastewater to the land or waters of the Basin is required to fulfill that responsibility. The adopted rules do not regulate the transportation and storage of wastewater originating outside of or within the Basin. These activities are regulated by other administrative agencies of the Commission's member states and the United States.

8. ***Do the adopted rules prohibit the exportation of water to support HVHF outside the Delaware River Basin?***

While the adopted rules do not include this specific prohibition, the Commission's final rules on exportation of Basin waters limit exportations from the Basin to instances where the sponsor: 1) demonstrates that the exportation of Basin water is required to serve a straddled or adjacent public water system; 2) demonstrates that the exportation of Basin water is required to meet public health and safety needs on a temporary, short-term, or emergency basis; or 3) is proposing an exportation of wastewater to a straddled or adjacent public wastewater collection system or is proposing to export wastewater for treatment, disposal or both at a waste management facility that has all required state and federal approvals to lawfully receive it. Other classes of exportations are ineligible for Commission review and approval. As the Commission makes explicit in Response R-10 of the CRD, an application for exportation of water to serve HVHF activities will not meet these thresholds.

If the required demonstration is made, the Commission may approve an exportation only after it has evaluated a suite of factors designed to ensure no harm to the Basin's water resources or the health and safety of the Basin community. These factors include: 1) the sponsor's planned use for the water and any resulting public benefits; 2) the availability to the sponsor of alternatives to the exportation of Basin water; and 3) whether these alternatives have been diligently pursued, including consideration of the sponsor's uses of water outside its service area. As discussed in Response R-7 in the CRD, past practice indicates that sufficient water resources exist outside the Basin to serve HVHF projects where permitted.

9. For projects involving the exportation of Basin water that are subject to review by the Commission, what are all the factors considered in the Commission's review?

As outlined in section 2.30.3 A. of the adopted Water Code amendments, once eligibility for consideration is established under section 2.30.2 C., the Commission will consider 10 factors in evaluating a project that involves an exportation. These are:

1. the effect of the exportation on the health and safety of the Basin community;
2. the effect of the exportation on existing or future water availability or shortages, including, but not limited to, sources within areas designated by the Commission as protected areas pursuant to section 10.2 of the Compact, sources within Delaware River reaches with flows that are frequently augmented by reservoir releases due to low flows, and sources in areas subject to DRBC drought operations or state drought declarations within the past five years;
3. the effect of the exportation on aquatic ecosystems;
4. the effect of the exportation on water quality and waste assimilation;
5. the effect of the exportation on salinity concentrations;
6. the effect of the exportation on the water uses protected by the Comprehensive Plan, DRBC regulations or DRBC docket approvals, or on the ability of DRBC to effectuate the Comprehensive Plan;
7. the effect of the exportation, including its volume, rate, timing and duration, on passby or instream flow requirements contained in DRBC regulations or project approvals;
8. the sponsor's planned use for the water and any resulting public benefits;
9. the availability to the sponsor of alternatives to the exportation of Basin water and whether these alternatives have been diligently pursued, including without limitation a review of the sponsor's uses of water outside the sponsor's service area, if any; conservation measures undertaken by the sponsor or a public water system in the service area where the sponsor is located to forestall the need for a transfer of Basin water; and the results of a water audit (or audits) performed by the sponsor in accordance with section 2.1.8 of the Delaware River Basin Water Code; and
10. whether the exportation would contravene sections 3.3 and 3.5(a) of the Compact by impeding or interfering with the rights, powers, privileges, conditions or obligations

contained in the Supreme Court Decree in *New Jersey v. New York*, 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

10. Can "straddled" or "adjacent" public systems sell water for HVHF or HVHF-related activities?

DRBC's authority is limited to the protection of the water resources of the Delaware River Basin. Under the final amendments, proposed new or expanding exports that meet the review threshold and are eligible for Commission consideration pursuant to section 2.30.2 C. will be evaluated using the ten factors set forth at section 2.30.3 A. The factors include, among others, the effects of the proposed export on the health and safety of the Basin community and on aquatic ecosystems within the Basin, and the availability of alternatives to the exportation.

11. Why are certain exportations of wastewater allowable under the adopted regulations?

Because water and wastewater service areas often straddle basin boundaries, it is not uncommon for wastewater generated in one basin to be disposed of in another. Imports and exports of wastewater occur routinely around the Basin boundary in this manner. Under the adopted rules, exportations that the Commission has previously approved will be permitted to continue. To be eligible for review and approval under the amended regulations, new and expanding exportations that meet the threshold for review set forth in the Commission's Rules of Practice and Procedure must also satisfy at least one of the threshold eligibility criteria at Water Code section 2.30.2 C.

The purpose of making certain exportations of wastewater eligible for review and approval is to ensure that straddled and adjacent public wastewater collection systems can continue to operate, and if necessary, expand, normally. The provision is not intended to support exportations of wastewater for HVHF. As noted elsewhere in this document, in addition to the eligibility criteria at section 2.30.2 C., the amendments include ten evaluation factors at section 2.30.3 A. that the Commission will apply in evaluating proposed exportations of Basin water, including wastewater, that are eligible for consideration. The factors include, among others, the availability of alternatives to the exportation.

12. Does the final rule regulate air emissions from HVHF activities?

No. This activity is beyond the scope of the proposed or final rule. Refer to the Commission's CRD (Response R-20) for a more detailed explanation.

13. Does the final rule prohibit road spreading of wastewater from conventional drilling activities?

No. The rule prohibits road spreading of HVHF wastewater. The Commission will continue to coordinate with the Basin states to review the scientific evidence regarding harm to water resources caused by road spreading of conventional oil and gas production wastewater and may in the future consider whether additional regulation of the practice is needed in the basin. Refer to the Commission's CRD (Response R-38) for a more detailed explanation.

14. ***Many commenters suggested that the proposed rules would encourage hydraulic fracturing outside of the Delaware River Basin which in turn would adversely impact climate change and prevent the transition to renewable energy. Did the Commission consider these factors?***

The Delaware River Basin Compact expressly provides that the Commission "shall have, exercise and discharge its functions, powers and duties ***within the limits of the basin***." However, the Commission does not agree that the rule supports the development of additional high volume hydraulic fracturing outside of the Delaware River Basin.

The Commissioners and DRBC staff share the commenters' concerns about climate change and its impacts on the water cycle, as described in the CRD. The Commission also recognizes the importance of renewable energy sources to any long-term national, regional, or state energy policy; however, the Commission does not set energy policy for the nation, the region, or its member states. In accordance with the authority conferred on the Commission by the Compact, any rules related to high volume hydraulic fracturing and HVHF-related activities are limited to addressing the planning, development, conservation, utilization, management, and control of the water resources of the Basin to meet present and future needs.

15. ***Was there a moratorium on the exportation of water for hydraulic fracturing or the importation of wastewater from hydraulic fracturing? Aren't these rules taking a step backwards?***

No. The Commission's May 5, 2010, Resolution for the Minutes (sometimes referred to as the "*de facto* moratorium") was silent concerning exports of water to support hydraulic fracturing (HF) or importations of HF wastewater, leaving the then-existing importation and exportation regulations in the Water Code and Rules of Practice and Procedure unchanged.

With respect to exportation, at the request of New York State, the Commission for a time deferred the consideration of any proposed exportations of Basin waters from within New York State to support HVHF until the State Environmental Quality Review (SEQR) process was complete. New York's SEQR process on HVHF was completed in 2015. The Commission has never approved an exportation of water to support HVHF, and no such proposals are currently under review.

Since 2008, many of the Commission's dockets issued for wastewater treatment plant discharges have included a condition prohibiting the docketed facility from accepting HF wastewater for treatment and discharge without the Commission's prior review and approval. To date, no docket holder has applied for or obtained the Commission's approval to treat and discharge HF wastewater. With the adoption of these final rules, the docket restrictions relating to HF wastewater continue and are reinforced by the new prohibition.

16. Are these rules consistent with the Pennsylvania Constitution's Environmental Rights Amendment?

Although the Environmental Rights Amendment to the Pennsylvania Constitution and the Compact have overlapping goals, as a federal-interstate compact agency, the Commission is not bound by, nor is it empowered to carry out, state constitutional provisions. While the Commission believes its regulations are consistent with the Environmental Rights Amendment, the Commission has acted pursuant to the authority granted by the Compact, not pursuant to the Pennsylvania Constitution. The Pennsylvania Supreme Court has affirmed the rights enshrined in the Amendment in cases such as *Pennsylvania Environmental Defense Fund v. Commonwealth,* 161 A. 3d 911 (Pa. 2017); *Robinson Township v. Commonwealth,* 83 A. 3d 901 (Pa. 2013); and *Yaw v. Delaware River Basin Commission,* No. 21-2315 (3d Cir. 2022). For a more complete response, refer to the Commission's CRD (Response R-75).

17. Can DRBC enforce these rules?

Yes. Section 14.17 of the Compact and Article 7 of the Commission's Rules of Practice and Procedure (18 C.F.R. Part 401, Subpart G) provide the Commission with the ability to seek penalties for non-compliance. The Commission will work within its authority and in coordination with the host states in the event of a violation of the rules.

EXHIBIT M

Proposed Regulations Addressing Importation and Exportation of Water and the Discharge of Wastewater from High Volume Hydraulic Fracturing

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Frequently Asked Questions (FAQs)

1. ***Why has the Delaware River Basin Commission (DRBC or Commission) released new proposed rules?***

The Delaware River Basin Commission is a federal/interstate government agency that manages the water resources of the Delaware River Basin. The five Commission members are the governors of the Basin states (Delaware, New Jersey, New York, and Pennsylvania) and the commander of the U.S. Army Corps of Engineers' North Atlantic Division, who represents the federal government.

On November 30, 2017, the DRBC published draft rules regulating high volume hydraulic fracturing (HVHF) in the Delaware River Basin. On February 25, 2021, the Commissioners approved a final rule prohibiting HVHF in the Delaware River Basin and, separately adopted a Resolution for the Minutes directing DRBC's executive director to propose amendments to update the Commission's rules concerning importation of wastewater from outside the Basin and exportation of Basin waters.

The proposed rules, which were published on the Commission's web site on October 28, 2021, among other things prohibit the discharge of wastewater from HVHF and HVHF-related activities to waters or land within the Basin. They also clarify and establish as a Commission policy that in order to protect and preserve the water resources of the Basin the DRBC will discourage, limit, or place conditions on the importation into and exportation from the Basin of water and wastewater.

2. ***What proposed rules has the Delaware River Basin Commission released for public comment regarding discharges of wastewater from high volume hydraulic fracturing (HVHF)?***

To protect the water resources of the Basin, the Commission is proposing amendments to Part 440 of title 18, chapter III of the Code of Federal Regulations and to the Commission's Water Quality Regulations, Article 4—Application of Standards. Specifically:

- **Amended Part 440 would:** Prohibit the discharge of wastewater from high volume hydraulic fracturing or HVHF-related activities to waters or land within the Basin.
- **Amended Article 4 of the Water Quality Regulations would:** Facilitate the alignment of certain Basin state discharge permits with the Commission's proposed amendments to 18 CFR Part 440, by incorporating into the Water Quality Regulations the prohibition on the discharge of wastewater from HVHF and related activities.

3. ***What proposed rules has the Commission released for public comment regarding importations and exportations of water from the Delaware River Basin?***

The Commission is proposing amendments to Section 2.30 of its Water Code by clarifying the circumstances under which exportations of water, including wastewater, from the Basin and importations of water, including wastewater, into the Basin may be considered by the Commission and the factors to be used in evaluating whether such proposed imports and exports of water may be approved.

The proposed Water Code amendments clarify that proposed new or increased *exportations* of water may be approved by the Commission only if the project sponsor demonstrates as a threshold matter that the exportation: is needed to serve a straddled or adjacent public water system; is required on a temporary, short-term, or emergency basis to meet public health and safety needs; or is an exportation of wastewater. If one or more of these eligibility criteria is satisfied, then under the revised rule, the Commission will evaluate the proposed exportation using the ten factors set forth at section 2.30.3 A. The factors include, among others, effects of the export on the health and safety of the Basin community and on aquatic ecosystems within the Basin, and the availability of alternatives to the exportation.

Under the revised rule, the Commission will evaluate proposed *importations* of water, including wastewater, using the factors set forth at section 2.30.3 B. These include, among others, the effects of the importation on the health and safety of the Basin community and the findings of a requisite characterization of the wastewater and an analysis of its treatability.

Importantly, “importation” under the proposed amendments means “the conveyance, transfer, or diversion of water, including wastewater, into the Delaware River Basin from a source outside the Basin, *resulting in a discharge of the imported water to land or water within the Basin,* with or without prior treatment” (emphasis added). Although a proposed importation of wastewater resulting in a discharge to land or water within the Basin would be subject to review using the factors set forth at section 2.30.3 B. of the Water Code, discharges of treated or untreated wastewater from HVHF and related activities are prohibited under proposed 18 CFR 440.4(b) and thus not eligible for review under the proposed amendments.

No changes to the Commission’s thresholds for review, set forth at 18 CFR 401.35(a) and (b) (in DRBC’s *Rules of Practice and Procedure*) are proposed.

4. Do the proposed rules prohibit the importation of high volume hydraulic fracturing wastewater into the Delaware River Basin?

Yes, if the proposed importation of wastewater from HVHF and related activities would be accompanied by a discharge to land or waters of the Basin. Otherwise, no. The proposed amendments expressly prohibit the *discharge* of treated and untreated wastewater from HVHF and related activities to waters or land within the Basin.

The draft regulations include a specific determination that the discharge of treated or untreated wastewater from high volume hydraulic fracturing and HVHF-related activities poses significant, immediate and long-term risks to the development, conservation, utilization, management, and preservation of the Basin's water resources, and that controlling future pollution by prohibiting such discharge is required to effectuate the Comprehensive Plan, avoid injury to the waters of the Basin as contemplated by the Comprehensive Plan, and protect the public health and preserve the waters of the Basin for uses in accordance with the Comprehensive Plan. The Commission has made no such determination regarding the transport of HVHF wastewater into or across the Basin (by rail, truck, or other means) or the storage of HVHF wastewater in the Basin.

5. Do the proposed rules prohibit the transport of high volume hydraulic fracturing wastewater into the Delaware River Basin?

No. DRBC's authority is limited to water resources of the Delaware River Basin. It has responsibility for protecting these resources and proposes to do so by prohibiting *discharges* of HVHF wastewater to the land or waters of the Basin. The Commission is not proposing to regulate the transport or storage of wastewater originating outside of or within the Basin. These activities are regulated by other administrative agencies of our member states and the United States.

6. Do the proposed rules prohibit the treatment of high volume hydraulic fracturing wastewater within the Delaware River Basin?

No, the proposed rules do not prohibit the treatment of HVHF wastewater. To protect the water resources of the Basin, the proposed rules prohibit the *discharge* of treated or untreated wastewater from HVHF and related activities to land or water within the Basin.

7. Why do the proposed draft regulations not include a provision for ensuring safe and protective storage and treatment as contemplated by the resolution dated September 13, 2017?

In November of 2017 the Commission proposed regulations that included provisions for the treatment and discharge within the Basin of wastewater from HVHF and related activities. Upon adoption of a final rule prohibiting HVHF in the Basin on February 25, 2021, the Commission withdrew from further consideration these portions of its 2017 proposal. It did so based upon comments received on the draft rules and on new data and information released by the U.S. EPA and other investigators. The draft regulations published by the Commission on October 28, 2021 were developed under a new directive from the Commission—a Resolution for the Minutes approved on February 25, 2021—that did not include the same charge as the 2017 directive. The draft rules currently under consideration protect the Basin's water resources by prohibiting discharges of HVHF wastewater to water or land within the Basin, eliminating the need for provisions relating to treatment and disposal of this waste stream. The storage of waste is regulated under detailed state and federal programs that support effectuation of the DRBC's Comprehensive Plan and that the Commission has no reason to duplicate.

8. Do the proposed rules prohibit the exportation of water to support HVHF outside the Delaware River Basin?

The proposed rules provide for the Commission to review proposed exportations that meet existing review thresholds if the proposed export:

1. is to serve a straddled or adjacent public water system;
2. would provide water on a temporary, short-term, or emergency basis to meet public health and safety needs; or
3. when the proposal is for an exportation of wastewater.

Other classes of exportations are ineligible for Commission review and approval.

The Commission is proposing these eligibility criteria because the Basin's waters are limited in quantity and the Basin is frequently subject to drought warnings and drought declarations due to limited water supply storage and streamflow during dry periods.

9. For projects involving the exportation of Basin water that are subject to review by the Commission, what factors are considered in the Commission's review?

As outlined in Section 2.30.3 A. of the proposed Water Code amendments, once eligibility for consideration is established under Section 2.30.2 C., the Commission will consider 10 factors in evaluating a project that involves an exportation. These are:

1. the effect of the exportation on the health and safety of the Basin community;
2. the effect of the exportation on existing or future water availability or shortages, including, but not limited to, sources within areas designated by the Commission as protected areas pursuant to Section 10.2 of the Compact, sources within Delaware River reaches with flows that are frequently augmented by reservoir releases due to low flows, and sources in areas subject to DRBC drought operations or state drought declarations within the past five years;

3. the effect of the exportation on aquatic ecosystems;
4. the effect of the exportation on water quality and waste assimilation;
5. the effect of the exportation on salinity concentrations;
6. the effect of the exportation on the water uses protected by the Comprehensive Plan, DRBC regulations or DRBC docket approvals, or on the ability of DRBC to effectuate the Comprehensive Plan;
7. the effect of the exportation, including its volume, rate, timing and duration, on passby or instream flow requirements contained in DRBC regulations or project approvals;
8. the sponsor's planned use for the water and any resulting public benefits;
9. the availability to the sponsor of alternatives to the exportation of Basin water and whether these alternatives have been diligently pursued, including without limitation a review of the sponsor's uses of water outside the sponsor's service area, if any; conservation measures undertaken by the sponsor or a public water system in the service area where the sponsor is located to forestall the need for a transfer of Basin water; and the results of a water audit (or audits) performed by the sponsor in accordance with Section 2.1.8 of the Delaware River Basin Water Code; and
10. whether the exportation would contravene sections 3.3 and 3.5(a) of the Compact by impeding or interfering with the rights, powers, privileges, conditions or obligations contained in the Supreme Court Decree in New Jersey v. New York, 347 U.S. 995 (1954), as modified by the Commission with the unanimous consent of the parties to the Decree.

10. Can "straddled" or "adjacent" public systems sell water for HVHF or related activities?

DRBC's authority is limited to the protection of the water resources of the Delaware River Basin. The Commission's evaluation of proposed exportations that meet the applicable DRBC threshold for review and satisfy the proposed eligibility criteria (at proposed Water Code section 2.30.2 C.) will remain within this scope. Under the draft amendments, proposed new or expanding exports that meet the review threshold and are eligible for Commission consideration pursuant to section 2.30.2 C. will be evaluated using the ten factors set forth at proposed section 2.30.3 A. The factors include, among others, the effects of the proposed export on the health and safety of the Basin community and on aquatic ecosystems within the Basin, and the availability of alternatives to the exportation.

11. Why are exportations of wastewater allowable under the proposed regulations?

Because water and wastewater service areas often straddle basin boundaries, it is not uncommon for wastewater generated in one basin to be disposed of in another. Imports and exports of wastewater occur routinely around the Basin boundary in this manner. Under the proposed rules, exportations that the Commission has previously approved will be permitted to continue. To be eligible for review and approval under the proposed amended regulations, new and expanding exportations that meet the threshold set forth in the Commission's Rules of Practice and Procedure must also satisfy at least one of the criteria at proposed Water Code section 2.30.2 C. The purpose of making exportations of wastewater eligible for review and approval is to ensure that straddled and adjacent systems can continue to operate, and if necessary, expand, normally; the provision is not intended to support exportations of wastewater for HVHF or other uses. As noted elsewhere in this document, in addition to the eligibility criteria at section 2.30.2 C., the draft amendments include ten evaluation factors at section 2.30.3 A. that the Commission will apply in evaluating proposed exportations of Basin water, including wastewater, that are eligible for approval. The factors include, among others, the availability of alternatives to the exportation.

12. Was there a moratorium on the exportation of water for hydraulic fracturing or the importation of wastewater from hydraulic fracturing? Aren't these rules taking a step backwards?

No. The Commissioners' May 5, 2010 Resolution for the Minutes (sometimes referred to as the "*de facto* moratorium") was silent concerning exports of water to support hydraulic fracturing (HF) or importations of HF wastewater, leaving the existing importation and exportation regulations in the Water Code and Rules of Practice and Procedure unchanged.

With respect to exportation, at the request of New York State, the Commission for a time deferred the consideration of any proposed exportations of Basin waters from within New York State to support HVHF until the State Environmental Quality Review (SEQR) process was complete. New York's SEQR process on HVHF was completed in 2015. The Commission has never approved an exportation of water to support HVHF, and no such proposals are currently under review.

Since 2008, many of the Commission's dockets issued for wastewater treatment plant discharges have included a condition prohibiting the docketed facility from accepting HF wastewater for treatment and discharge without the Commission's prior review and approval. To date, no docket holder has applied for or obtained the Commission's approval to treat and discharge HF wastewater. Upon adoption of a final rule prohibiting the discharge of treated or untreated wastewater from HVHF and related activities, the docket restrictions relating to HF wastewater will continue and will be reinforced by the new prohibition.

13. Would the spreading of HVHF wastewater or by-products on roads be permitted if the proposed rule amendments are adopted?

Land application of HVHF wastewater by road spreading would constitute a prohibited discharge under 18 CFR 440.4(b) of the proposed amendments, which provides that "no person may discharge wastewater from high volume hydraulic fracturing or HVHF-related activities to waters or land within the Basin."

14. Can DRBC enforce these proposed rules?

Once final rules are adopted, Section 14.17 of the Compact and Article 7 of the Commission's Rules of Practice and Procedure (18 C.F.R. Part 401, Subpart G) provide the Commission with the ability to seek penalties for non-compliance. The Commission will work within its authority and in coordination with the host states in the unlikely event of a violation of the proposed rules.

15. Has the Commission made a final decision to adopt the proposed rules?

No. The Commission will not adopt final rules until it has gathered and considered public comment on the revised draft regulations. After the close of the public comment period, the Commission will review the public's comments and consider any changes to the draft rules that may be appropriate based on the comments.

16. Why are the public hearings not in person?

Remote meeting technology allows the Commission to conduct these hearings in a manner that provides access to all while supporting public and community health measures. Even those without access to the Internet may attend by phoning in.

17. Will the Commission add more hearings if needed?

DRBC staff will monitor the hearing capacity and registrations and consider adding additional hearing sessions if needed.

18. Do I need to register to attend a hearing or to provide oral comments?

You do not need to register simply to attend one or more of the hearings virtually. If you wish to <u>provide oral comments at one of the hearing sessions, you must register in advance.</u> Information on how to attend the virtual hearings and register to speak at one of the hearings can be found at: https://www.nj.gov/drbc/meetings/proposed/notice_import-export-rules.html.

19. Can I register to speak at more than one hearing?

No. Each individual may provide oral comments at only one hearing.

20. Do I need to register to provide written comments?

No. Anyone can provide written comments through DRBC's online comments system at any time through February 28, 2022. Access to the online comments system is provided at:

https://dockets.drbc.commentinput.com/?id=x2K8A. Comments via e-mail, mail, delivery service, personal delivery or any method other than the on-line system will not be included on the record unless an exception has been obtained from the Commission Secretary, based on lack of Internet access. To request an exception from use of the online system, please contact: Commission Secretary, DRBC, P.O. Box 7360, West Trenton, NJ 08628.

Last updated: December 7, 2021

EXHIBIT N

EVALUATION OF ENVIRONMENTAL IMPACTS FROM DUST SUPPRESSANTS USED ON GRAVEL ROADS

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EXECUTIVE SUMMARY

This report was prepared by a group of faculty, staff, and graduate students at The Pennsylvania State University (Penn State) for the Pennsylvania Department of Environmental Protection's (PADEP) Office of Oil and Gas Management to assess environmental impacts associated with dust suppressants used on dirt and gravel roads. Test systems were developed to conduct rainfall-runoff experiments to evaluate water quality impacts from gravel roads treated with dust suppressants, and dust generation experiments to evaluate efficacy of dust suppressants. Funding for the rainfall-runoff experiments was provided by PADEP. Penn State personnel independently conducted the dust generation experiments. Six dust suppressants were tested in rainfall-runoff and dust generation experiments: synthetic rainwater, calcium chloride ($CaCl_2$) brine, soybean oil, and three oil and gas produced waters (OGPWs). Two additional commercially available calcium chloride dust suppressants were tested in dust generation experiments.

When applied as a dust suppressant, oil and gas produced waters were essentially no more effective than rainwater. Oil and gas produced waters are likely ineffective dust suppressants because of their relatively high concentrations of sodium. Sodium is a monovalent cation that does not effectively bridge clay particles (the size-fraction most likely to be mobilized as road dust) to promote dust suppression. Instead, sodium can destabilize gravel roads and increase long-term road maintenance costs. Based on dust generation experiments, only the $CaCl_2$-based brines and the organic-based soybean oil were effective dust suppressants. Based on rainfall-runoff experiments, the $CaCl_2$-based brines led to the lowest concentrations of total suspended solids (TSS) washed off the roadbeds. There was no difference in the amounts of TSS washed off the roadbeds treated with OGPWs as compared to synthetic rainwater.

Maximum constituent concentrations in the runoff were related and essentially proportional to constituent concentrations in the dust suppressants. Contaminants of interest related to salinization of freshwater resources include electrical conductivity, total dissolved solids (TDS), chloride, and bromide. Contaminants of interest related to human health include combined radium (^{226}Ra + ^{228}Ra), barium, strontium, lithium, iron, and manganese. Contaminants of interest related to irrigation water include sodium, magnesium, and calcium. Contaminants of interest related to organic-based dust suppressants include chemical oxygen demand and dissolved organic carbon. Contaminants of lesser concern include aluminum, arsenic, lead, nitrate, and sulfate. Through mass balance analysis of material applied to, washed from, and retained by the roadbed, most contaminants of interest were washed from the roadbed. An important exception occurred with roadbeds treated with oil and gas produced waters. For oil and gas produced waters, the roadbeds retained radium, sodium, iron, and manganese.

Runoff from $CaCl_2$ brine-treated roadbeds contained the highest concentrations of most contaminants of interest – including total dissolved solids, electrical conductivity, chloride, bromide, barium, strontium, lithium, iron, manganese, sodium, magnesium, and chloride. Roadbeds treated with calcium chloride brine produced runoff with high TDS (up to 57,000 mg/L) and chloride concentrations (up to 34,000 mg/L Cl) and elevated activities of combined radium (up to 48 pCi/L). Aside from calcium and chloride, most of the contaminants of interest were likely sourced from impurities in the brine.

OGPWs-treated roadbeds led to the highest concentrations of combined radium in the runoff. Combined radium activities in the three OGPWs when applied to the roadbeds ranged from 84 to 2,500 pCi/L, within the anticipated range for OGPWs from western Pennsylvania. Combined radium activities in runoff from the OGPW-treated roadbeds exceeded 60 pCi/L, the effluent standard for industrial wastewater discharges, during both the 'first flush' and the 'maximum flush' parts of the rain event. Roadbeds treated with OGPWs also produced runoff with high TDS (up to 19,000 mg/L), chloride (up to 12,000 mg/L Cl), and bromide (up to 300 mg/L Br) concentrations.

1. INTRODUCTION

This project was conducted for the Pennsylvania Department of Environmental Protection's (PADEP) Office of Oil and Gas Management by faculty and staff of The Pennsylvania State University (Penn State) to address potential environmental issues associated with the practice of spreading oil and gas produced water (OGPW) on unpaved dirt and gravel roads for dust suppression. The objectives of this project were to investigate water quality issues associated with runoff from OGPW-treated gravel roads and evaluate the efficacy of OGPWs as dust suppressants. These objectives were addressed by completing the following tasks: (1) design and fabricate a lab-scale test bed to conduct rainfall-runoff experiments from gravel roadbeds, (2) conduct a series of controlled rainfall-runoff experiments using a gravel roadbed treated with different dust suppressants to measure surface water quality parameters, (3) conduct a series of lab-scale experiments to measure dust generation, and (4) integrate and analyze all test results into a final report with recommendations on the suitability of OGPW and other products for dust suppression and their potential environmental impacts. Funding for the rainfall-runoff experiments was provided by PADEP. Penn State personnel independently conducted the dust generation experiments. The project began on June 1, 2020 and all testing was completed by May 31, 2021. A draft of this report was provided to PADEP on December 30, 2021.

2. SCOPE OF WORK

The number of experimental variables was minimized to constrain the overall amount of time and effort of this project. The only variable in the rainfall-runoff experiments was the dust suppressant. Six dust suppressants were tested: synthetic rainwater, calcium chloride brine, soybean oil, and three OGPWs. Synthetic rainwater served as the experimental control. Calcium chloride ($CaCl_2$) represented a common commercially available inorganic product used for dust suppression. Soybean oil represented a brine-free, common commercially available organic product used for dust suppression. The three OGPW represented fluids that could have been historically spread on dirt and gravel roads in northwestern Pennsylvania. These six dust suppressants and two commercially available $CaCl_2$ dust suppressants were tested in lab-scale dust generation experiments.

The constants in the rainfall-runoff experiments included: the road aggregate (PennDOT 2RC, a well-graded pit run gravel obtained from a sand and gravel plant in northwestern Pennsylvania), the size of the lab-scale gravel roadbed (9-foot long by 3 foot-wide), the side slope of the roadbed (5%), the depth of the roadbed (loose depth of 9-inch compacted to 6-inch), the initial moisture content of the treated roadbed before road compaction (6.5% mass/mass), the extent of compaction (≥95%), the application rate of the dust suppressants after compaction (0.5-gallons per square yard of road surface, except for 0.25-gallons per square yard of road surface with soybean oil), the storm event (2-year, 24-hour rainfall, 2.44-inch total rain), the rain distribution system (grid of controlled nozzles), the synthetic rainwater chemistry (distilled water + H_2SO_4/HNO_3, pH = 4.2, EC = 31 µS/cm), the water runoff sampling frequency (sampled after every 1/24th of the storm volume using an automated sampler, and sampled every 10-seconds using a multimeter probe), and the water chemistry analytes (cations, anions, radium, and organics).

All rainfall-runoff experiments were conducted in at least triplicate starting with newly constructed roadbeds for each test. One of the OGPWs was tested four times, the calcium chloride brine was tested four times, the synthetic rainwater was tested five times, and all other dust suppressants were tested three times for a total of 22 tests. At the conclusion of select tests, shallow (1 to 2 inch-depth) roadbed samples were collected to measure radium and petroleum hydrocarbons retained in the road.

The constants in the dust generation experiments included: the road aggregate (PennDOT 2RC, a well-graded pit run gravel obtained from a sand and gravel plant in northwestern Pennsylvania), the size and rotational speed of the mechanical tumbler, the mass and dimensions of the road aggregate discs, the moisture content of the treated discs before application of dust suppressant, the extent of compaction (modified Proctor test), the application rate of the dust suppressants after compaction, the air sampling rate of the DustTrak dust measurement device, the sampling frequency of dust concentration (sampled every second for 3 minutes), and the elapsed time of the test (between 2:00-3:00 minutes) to calculate the average dust concentration. A previous study confirmed that the lab measurements were in direct agreement with DustTrak measurements collected in the field from the back of a moving vehicle (Stallworth et al., 2020).

3. BACKGROUND

Produced waters from oil and gas wells are allowed to be spread on roads for dust suppression and/or deicing in at least 12 states in the United States (Tasker et al., 2018). On May 17, 2018, the use of OGPWs for dust suppression was put on hold by PADEP in response to a decision by the Pennsylvania Environmental Hearing Board.

OGPWs are commonly referred to as brines whose chemical compositions are somewhat like commercial inorganic products commonly used for dust suppression (e.g., saturated solutions of calcium chloride or magnesium chloride). However, OGPW is not a pure solution of calcium chloride, magnesium chloride ($MgCl_2$) or sodium chloride (NaCl). Instead, OGPW from formations in the Appalachian Basin, including western Pennsylvania, are typically classified as Na-Ca-Cl waters containing a blend of alkali metals (Na, K, Li) and alkaline earth metals (Mg, Ca, Sr, Ba) charge-balanced primarily by chloride. OGPWs also contain a variety of contaminants of interest raising questions about the practice of spreading them on roads. Based on analysis of 14 OGPW samples used for road spreading in northwestern Pennsylvania, Tasker et al. (2018) reported median concentrations of chloride, barium, strontium, arsenic, lead, and combined radium (^{226}Ra + ^{228}Ra) above corresponding drinking water maximum contaminant limit (MCL) standards. The median concentration of combined radium (^{226}Ra + ^{228}Ra) was 1,230 pCi/L as compared to the US Nuclear Regulatory Commission's (NRC) industrial wastewater discharge standard of 60 pCi/L and the US Environmental Protection Agency's (EPA) drinking water maximum contaminant limit (MCL) standard of 5 pCi/L. Graber et al. (2017) also reported that application of OGPW may lead to higher concentrations of contaminants of interest in both the dust and the runoff water. The ratio between alkali metals to alkaline earth metals in brines and OGPW is expected to be one of the key factors with respect to dust suppressant efficacy (Graber et al., 2019). One measure of the ratio of alkali to alkaline earth metals based on dissolved metal concentrations, expressed as the sodium adsorption ratio (SAR), is defined as (Equation (1)):

$$SAR = \frac{Na^{+}\left(\frac{meq}{L}\right)}{\sqrt{0.5*\left(Ca^{2+}\left(\frac{meq}{L}\right)+Mg^{2+}\left(\frac{meq}{L}\right)\right)}} \qquad (1)$$

Increasing SAR tends to decrease dust suppressant efficacy (Stallworth et al., 2020a; Graber et al., 2019). Magnesium chloride and calcium chloride commercial products have very low SAR values and demonstrated effectiveness at reducing dust generation. While there are few previous studies on OGPW use as dust suppressants, one field study indicated that OGPW applied to dirt and gravel roads in North Dakota was not effective at reducing dust compared to an untreated road (Graber et al., 2017). This contrasts with field studies that tested dust suppression products such as magnesium chloride, cellulose, or synthetic fluids that all reduced dust relative to untreated roads (Kunz et al., 2015). A literature review conducted by Payne (2018a) concluded that evidence for the use of OGPW for dust suppression was questionable because of previous study designs and the use of OGPW on dirt and gravel roads may destabilize the road surface leading to more dust and road maintenance. However, a laboratory study that measured clay dispersion in salt solutions indicated that, if electrical conductivity was high enough, then the OGPW was effective at reducing dispersion regardless of elevated SAR (Graber, et al., 2019).

This project sought to simulate conditions most relevant to northwestern Pennsylvania. Specifically, 2RC gravel was sourced from a local quarry (Glenn O Hawbaker's Brokenstraw Sand and Gravel Plant in Pittsfield PA, Warren County), the design storm hyetograph was programmed to match a 2-year 24-hour rain event for Warren County, PA (Section 7.7 in PennDOT Drainage Manual 2015; United States Department of Agriculture 1986), a synthetic rainwater was designed to match chemistry of northwestern Pennsylvania (EPA publication SW-846), and OGPWs were sourced from northwestern Pennsylvania (under confidentiality agreements). The 2RC used in this study was a well-graded aggregate that consisted of a mix of coarse crushed stone (48.3% m/m) and fine materials including sand (42.2%), silt (6.6%), and clay (2.9%) with a maximum wet density of 144.3 pound/cubic foot.

4. RESEARCH METHODS

4.1 Dust suppressants

Six fluids were applied to laboratory-scale gravel roadbeds to measure water quality characteristics in rainfall-runoff experiments over a 24-hour test. Three of the six fluids tested were conventional OGPWs from western Pennsylvania provided by oilfield service companies under nondisclosure agreements to maintain confidentiality of all project participants. These OGPWs were selected by PADEP, Penn State, and project participants. These three OGPWs and all their associated runoff and roadbed samples are identified as O&G PW1, O&G PW2, and O&G PW3 in this report. Two of the six fluids tested, a calcium chloride brine and a soybean oil, were included as materials representative of commercially available dust suppressants. Calcium chloride anhydrous was purchased from Fisher Science Education (>95% mass/vol assay range). Calcium chloride brine was created by adding solid calcium chloride to distilled water more than its calculated solubility limit. Because of kinetic limitations, fully 'saturated' conditions (commonly 35% m/m) were not achieved. Saturation extents ranged from 17.2 – 25.4% m/m for the four replicate tests with calcium chloride brine. The calcium chloride brine and all their associated runoff and roadbed samples are identified as $CaCl_2$ Brine in this report. Soybean oil was provided by a soybean crushing company and is a mechanically extracted, degummed, all-natural soybean oil (>95% fatty acid). This soybean oil is currently used for dust suppression by a township in northwestern Pennsylvania. The soybean oil and all its associated runoff and roadbed samples are identified as Soybean Oil in this report. Synthetic rainwater was included as a control to represent natural wetting of the road. The synthetic rainwater recipe was designed to match rainfall chemistry of northwestern Pennsylvania. The synthetic rainwater and all its associated runoff and roadbed samples are identified as Synthetic Rainwater in this report. These six dust suppressants and two commercially available calcium chloride dust suppressants were tested in lab-scale dust generation experiments.

Commercial Brine 1 was a liquid solution that ranged from 28-42% $CaCl_2$ (m/m). This brine is marketed primarily for dust suppression and road deicing and is approved by the West Virginia Department of Environmental Protection for use on unpaved roads. Commercial Brine 1 used in this study was 28% $CaCl_2$ (m/m). Commercial Brine 2 was a blended brine comprised of Ca, Mg, K, and Na chlorides, with $CaCl_2$ being the most concentrated at 21-24% (all other salts reported <5%). This product is commonly used as a deicer in the Mid-Atlantic and Northeast United States but is also sold as a dust suppressant for underground and open cut mining operations. Commercial Brine 2 used in this study was 25% $CaCl_2$ (m/m).

4.2 Test bed for rainfall-runoff experiments

A laboratory-scale roadbed system was constructed for rainfall-runoff experiments (Figure 4.1). A rectangular steel frame (9-foot long, 3-foot wide, 1-foot tall) was fabricated with a reinforced floor strong enough to hold the weight of the gravel roadbed and withstand loads delivered from roadbed compaction equipment (Figure 4.2). Stainless-steel panels were fixed to the bottom and three sides of the frame. The roadbeds were constructed by placing a 9-inch-deep loose lift of 2RC gravel into the frame and then using a motorized vibrating plate compactor to tamp the gravel to 6-inch deep, equivalent to 95% or greater compaction. At the start of the project, road compaction was verified for two roadbeds in accordance with ASTM D6938 – Density and Moisture Content of In-Place Soil and Soil Aggregates Using Nuclear Methods (Shallow Depth) by CMT Labs (State College, PA). The number of vibratory plate tamper passes to achieve a minimum of 95% compaction was recorded for the right, middle, and left portions of each of the two constructed roadbeds. For the rest of the tests, the operationally defined number of tamper passes (one pass up and back per section of roadbed) was used to compact each roadbed. During compaction, a solid plastic insert was placed at the 'downstream' end of the frame to retain the gravel. After compaction, the plastic insert was removed, and the gravel was retained by a heavy gage stainless-steel screen with ¼-inch openings. A stainless-steel discharge chute was bolted onto the downstream end of frame to funnel runoff to a flow-through sampling bucket.

A moisture-density curve for the roadbed material was developed by Aggregates & Soils Testing Co (Enola, PA). From these data it was determined that a moisture content of 6.5 wt% (m/m) was optimal for compaction. Before each roadbed was compacted, the moisture content of the gravel was measured by drying in a microwave oven until constant weight. A 22.2-ton load of crushed gravel was delivered to the CITEL Building in State College on June 19, 2020. The gravel was stored outside on pavement until the pile began to freeze in January 2021. At that point, a portion of the remaining gravel pile was stored inside the building. Distilled water was added and manually mixed into the roadbed such that roadbeds reached 6.5 wt% at the start of each test before compaction. The exact volume of added distilled water was calculated based on the measured moisture content before the test and the target value of 6.5 wt%. After the roadbed material was compacted within the test frame, the whole frame was lifted onto a steel I-beam. A steel bar was first positioned on top of the upstream end of the I-beam such that the slope of the bed was 5% towards the sampling bucket. The slope was used to simulate the sideslope of a gravel road from the crown to the edge of the road.

A rainfall simulator was designed to meet PADEP's request to use a 2-year, 24-hour Type II storm event, the specified rainfall distribution type for Warren County, Pennsylvania based on Figure B-2 in US Department of Agriculture (USDA) TR-55 (Figure 4.3; 2.44-inch total rain) to generate runoff from the roadbed. The pumping and plumbing systems were designed to spray water uniformly over the roadbed and minimize evaporation (Figure 4.4). The rainfall simulator included a supply tank, submersible pump, constant head feed tank with supply tank, diaphragm pump, flow meter, pressure manifold and gauges, solenoid valves, and spray nozzles. The supply tank was a 55-gallon plastic drum positioned on the floor of the lab. A submersible pump was placed inside at the bottom of the drum. The drum was fitted with a plastic lid and tubing from the submersible pump to the constant head feed tank was routed through the bung hole of the lid. A scaffold was positioned next to the roadbed frame to hold all other components of the rainfall simulator. The scaffold deck was positioned at approximately the height of the roadbed and an elevated frame system was constructed such that the whole roadbed could be contained by plastic shower curtains to capture any overspray from the nozzles and minimize evaporation loss from the road during the test. The constant head feed tank was a 2-gallon plastic storage container equipped with an outlet pipe to the diaphragm pump. A bypass valve after the diaphragm pump and before the flow meter was used to recirculate water back to the supply tank to regulate the discharge to the spray nozzles. An overflow orifice and tube were connected to the constant head tank to ensure the water elevation in the head tank remained constant. This ensured the pump's performance was consistent during testing. The diaphragm pump conveyed water through the flow meter and into the pressure manifold system. Solenoid valves were used to control flow to the spray nozzles over the 24-hour test. The rainfall intensity was discretized into 5-minute bursts and rainfall volumes were computed for each 5-mintue burst. The solenoids were open for a fraction of time in each 5-minute burst, then closed for the remainder. The pre-specified open/close times were computed beforehand to ensure the volume sprayed by the nozzles equaled that shown in Figure 4.3. The solenoid valves were actuated with a microcontroller. The microcontroller was programmed to open the solenoid valves for the pre-determined open/close times. Near the beginning and end of the 24-hour rain event, the microcontroller would open the valves for only a few seconds in each 5-minute burst. At peak rainfall, the microcontroller would open the valves for approximately 95% of the 5-minute burst. Three square-pattern spray nozzles each covered a 9-ft^2 area and were positioned 12-inches above the roadbed to minimize overspray.

Runoff samples and continuous meter readings were collected from a 2-gallon plastic bucket that was hung off the end of the discharge chute (Figure 4.4). Overflowing water was collected in a large tub below the chute and disposed of after the experiment. A Hanna HI98195 Multiparameter pH/ORP/EC/Pressure/Temperature Waterproof Meter was placed within the bucket and programmed to continuously read pH, oxidation-reduction potential (ORP), electrical conductivity (EC), pressure, and temperature every 10 seconds over the 24-hour test for a total of approximately 8,640 sample points per test. A Model 6712 Portable ISCO sampler was used to automatically collect 500-mL grab samples of the runoff each time that 1/24th of the total storm volume (ca. 6.3-liter) had been applied to the roadbed. A sample collection tube was secured to the sampling bucket and connected to a suction pump in the ISCO unit. The time stamps for this sampling scheme were programmed into the sampler and are presented in Table 4.1. At each time stamp, the ISCO sampler initiated a sampling sequence where the suction pump purged the suction line, filled the sample bottle, and re-purged the suction line. This process took about 45-seconds to complete, including 15-seconds for the pump to fill the bottle. Sample bottles were arranged in a circular carousel that was stored in the bottom portion of the ISCO unit. The Hanna multimeter, the ISCO sampler, and the program controlling the solenoid valves were all started at approximately the same time to keep the rain event and sampling procedure on the same experimental timeline (rainfall simulator started ~5-seconds before sampling equipment).

4.3 Rainfall-runoff experiments on gravel roadbeds treated with dust suppressants

A single rainfall-runoff experiment with an individual roadbed treated with one dust suppressant required three days to complete followed by an extended period to complete all chemical analyses on the runoff samples. The roadbed was constructed and treated with the dust suppressant on Day 1. The treated road was allowed to rest under ambient conditions until Day 2 when the rainfall simulator started to deliver the 24-hour storm to the roadbed. The test was completed on Day 3 with removal of the sample bottles from the ISCO sampler, retrieval of the data from the Hannah multimeter, collection of post-storm roadbed samples, deconstruction of the roadbed, and cleanup of the test frame. Detailed descriptions of each step are provided below.

Synthetic rainwater

Synthetic rainwater used for all experiments was prepared to simulate the chemistry of rainfall in northwestern Pennsylvania. Synthetic rainwater was made by adding a 3:2 m/m solution of 15 N sulfuric and 15 N nitric acid to distilled water until a pH of ~4.2 was reached. The electrical conductivity

(EC) of the synthetic rainwater averaged 31 µS/cm. Synthetic rainwater was prepared in ca. 50-gallon batches stored in 55-gallon drums. Prior to use, drums were either cleaned with hot, soapy water and thoroughly rinsed or lined with plastic drum liners. All drums remained covered during storage.

Roadbed construction

Before the roadbed was constructed, samples were collected from the gravel pile to measure the initial moisture content. An initial mass of ca. 2,000-grams of gravel was placed in a Pyrex container and dried in a microwave oven until constant mass was achieved. The moisture content (m/m %) was calculated as the difference between the initial and final masses divided by the final mass.

Before the gravel was loaded into the test frame, the gravel was mixed with distilled water to reach a moisture content of 6.5%. The total mass of gravel added to the roadbed was calculated to be approximately 1,850-pounds based on the laboratory-measured maximum wet density and the compacted bed volume. The volume of distilled water added to the gravel was calculated based on the total gravel mass and its initial moisture content. This volume was slowly added to the gravel while it was in a skidloader scoop and thoroughly mixed with shovels and pickaxes. The gravel was then poured into the test frame while the frame rested on the ground. A ca. 9-inch-deep bed of loose gravel was spread evenly inside the test frame before compaction.

The gravel bed was compacted with a hand tamper and a vibratory plate compactor to a final depth of 6-inches. These same pieces of equipment were used to compact the bed when its extent of compaction was measured by ASTM D6938 – Density and Moisture Content of In-Place Soil and Soil Aggregates Using Nuclear Methods (Shallow Depth) by CMT Labs (State College, PA). A hand tamper was first used to create a solid gravel surface. A 16-inch x 22-inch vibratory plate compactor was used for three passes up and down the roadbed (up and back on the left, center, and right of the bed with some overlap due to the size of the compactor). The hand tamper was used again to compact gravel on the edges of the frame and to flatten any ridges created by the plate compactor. The roadbed was compacted with the plastic insert placed at the downstream end of the frame. The plastic insert was removed before the rainfall simulator was started. A heavy gage stainless-steel screen with ¼” openings secured the bed after the plastic insert was removed.

The compacted gravel bed was treated with six different dust suppressants: synthetic rainwater, calcium chloride brine, soybean oil, and three OGPWs. The same procedures were used for the application of synthetic rainwater, calcium chloride brine, and the OGPWs. A different procedure was used to apply the soybean oil. For the synthetic rainwater, calcium chloride brine, and OGPWs, 1.5-gallons of liquid was poured into a plastic watering can and then sprinkled evenly onto the roadbed (equal to application rate of 0.5-gallons per square yard). For the soybean oil, the oil was first heated to 120 °F (common in-field practice) and, because of the low viscosity of the oil, a paintbrush was used to evenly apply 0.75-gallons onto the roadbed. After application of any dust suppressant, a large fan was used to dry the road for 20-30 minutes to allow for infiltration and minimize runoff before the test frame was lifted onto the I-beam.

A boom crane was used to lift the test frame onto the I-beam using crisscrossed metal cables attached to the eyebolts on the frame. The test frame was positioned onto the I-beam such that the downstream end aligned with two bolts drilled into a hinge secured to the I-beam. A metal block was positioned at the upstream end of the I-beam under the test frame to create a 5-degree slope. The stainless-steel chute was attached to the end of the frame and plumber's putty was used to seal the gap between the chute and the frame to prevent any runoff loss. The sampling bucket was hung off the end of the chute. With the test frame in place, shower curtains were positioned such that the entire roadbed was surrounded with no gaps in between curtains. The bottoms of the curtains rested inside the test frame, not touching the gravel (Figure 4.5). In some areas, zip ties were used to secure the shower curtains onto the frame and ensure the curtains did not block the nozzles of the rainfall simulator.

24-hour storm event

Synthetic rainwater was pumped through the nozzles of the rainfall simulator to deliver rain to match the time-dependent quantities of the 2-year, 24-hour storm for Warren County, Pennsylvania (Figure 4.3; 2.44-inch total rain). The pH and EC of the rainwater were measured at the start of each test. The Hannah multimeter and the ISCO suction line were secured into the sampling bucket hung off the end of the chute. The Hanna multimeter, the ISCO sampler, and the program controlling the solenoid valves were all started at approximately the same time to synchronize the sampling time stamps with the 24-hour rain event.

The rainfall-runoff experiment was concluded after the final, 24th runoff sample was collected by the ISCO sampler 24-hours after the experiment was started. All ISCO sample bottles were removed from the sampler's carousel and capped. All data from the Hannah multimeter was downloaded to a desktop computer. Three gravel samples were collected from the top 1-2 inches of the roadbed. The roadbed was then manually disassembled using shovels and pickaxes. Used gravel was disposed of into a dedicated road aggregate dumpster. All tools and sampling equipment were carefully cleaned before the next experiment.

4.4 Analysis of dust suppressants, runoff samples, and roadbed samples

A comprehensive set of chemical analyses were used to characterize the dust suppressants, runoff samples, and synthetic rainwater (Table 4.2). Solid samples from the gravel pile or the roadbeds (at the conclusion of the rainfall-runoff experiments) were also analyzed for many of these same analytes (Table 4.3). Samples were divided, handled (e.g., filtration, digestion), and preserved (e.g., acidification, refrigeration) before being measured using a variety of analytical instruments.

Measurement of inorganic constituents

Samples collected for dissolved analysis were filtered through a 0.45-µm filter and acid preserved to pH < 2 with high purity nitric acid. If necessary, samples were gravimetrically diluted with 2% high purity nitric acid. Samples collected for total metals were unfiltered and only acid preserved until they were digested following a modified EPA method 3010A. 1.5 mL of concentrated ultra-pure nitric acid was added to 50-mL of sample, which was then covered with a plastic-ribbed watch glass, and gently evaporated to < 5-mL. Additional 1.5-mL aliquots of nitric acid were added as necessary until the sample turned a pale yellow, after which the sample was evaporated to 3-mL. 5-mL of trace metal grade hydrochloric acid was added to the sample and refluxed for 15-minutes. Once the digestion was complete, the evaporated sample was reconstituted to 50-mL with deionized water.

Major cation (Ca, K, Mg, Na and Sr) concentrations were measured with a ThermoFisher iCAP 7400 inductively coupled plasma optical emission spectrometer (ICP-OES) housed in the Penn State Laboratory for Metals in the Environment (LIME). Calibration standards were prepared from a 100 mg/L multi-element standard, SCP28AES, with calibration levels ranging from 0.01 to 100 mg/L. Analyte emission frequencies were optimized to avoid interferences using Qtegra ISDS software. Some analytes were measured in both radial and axial modes to improve quantification across wider concentration ranges. A 5 mg/L Lu solution was used as an internal standard to monitor instrument drift. Continuing calibration verification standards (CCVs) and a USGS M-220 CRM was analyzed with each sample batch. The acceptance criteria were 10% agreement with expected values for CCVs and 20% agreement with established values for the certified reference material (CRM).

Trace metal (Al, As, B, Ba, Co, Cr, Fe, I, Li, Mn, Ni, Pb, V, and Zn) concentrations were measured with a ThermoFisher iCAP RQ inductively coupled plasma mass spectrometer (ICP-MS) in the Penn State

LIME. Calibration standards were prepared from high purity stock solutions at calibration levels ranging from 0.01-1,000 ng/mL. A 100 ng/mL Sc solution was used as an internal standard to correct for differences in detector responses. A NIST 1640A CRM for trace elements in water was used to validate calibration curves. Quantification was taken as valid if measured concentrations agreed to within 20% of established values.

Anion (Cl^-, Br^-, SO_4^{2-}, NO_3^-) concentrations were measured by ion chromatography (IC) following a modified EPA Method 300.1. Filtered (0.45-µm) samples were injected into a Dionex 1100 IC system with a 25-µL sample loop and a 1 mL/min flowrate. 35 mM potassium hydroxide was used as the eluent solution. An AG18 guard column and a 4-mm AS18 analytical column held at 30°C were used to carry out the separation. A 4-mm AERS 500 suppressor poised at 87 mA and a Carbonate Removal Device 200 were used to reduce background conductivity and remove carbonate interferences, respectively. A 1000 mg/L calibration stock solution was made from pure salts that had been oven dried at 105°C for four hours. Calibration standards were made gravimetrically from this stock, and calibration levels ranged from 0.1 to 500 mg/L. CCVs, a laboratory fortified matrix sample (LFM), a duplicate sample, and a USGS M-220 CRM were run with every sample batch. The analysis quality control criteria were as follows: agreement within 10% for CCVs, agreement within 25% for the LFM, agreement within 20% for the duplicate sample, and agreement within 20% for the CRM.

Total dissolved solids (TDS) were calculated from the sum of the concentrations of Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba and reported as mg/L TDS. Standard Method 2540 C (evaporation at 180°C) was not used to measure TDS because the required amount of sample volume was not available from the ISCO sample bottles.

Total suspended solids (TSS) were measured with a HACH DR2800 spectrophotometer following the suspended solids 8006 photometric method.

Measurement of organic constituents

COD was measured using the USEPA Reactor Digestion Method 8000 and HACH COD digestion vials. Samples with chloride concentrations >1,000 mg/L Cl could not be measured because of reagent interferences. HACH COD2 digestion vials were used for all runoff samples associated with O&G PW1, O&G PW2, O&GPW 3, and calcium chloride brine. Dissolved organic carbon (DOC) was measured using a TOC-V CSN analyzer. Dissolved inorganic carbon (DIC) was calculated by difference between total carbon (measured on TOC-V CSN analyzer) and DOC.

Sample extraction

Selected runoff samples, dust suppressants, and roadbed samples were analyzed for diesel range organics (DRO) (aliphatic carbon chain lengths of C10-C28) and targeted organic compounds. 125 mL of each runoff sample was first acidified to pH < 2 with 1:1 (v/v) sulfuric acid and spiked with acid, base, and neutral surrogate compounds (final extract concentration: 1000 pg/µL) to evaluate extraction recoveries. The sample was extracted three times in a 1-L separatory funnel with 20-mL aliquots of dichloromethane (DCM). The pH of the sample was then increased to >11 with 10 N sodium hydroxide and extracted three times with 25-mL aliquots of DCM. Kuderna-Danish evaporative concentration was used to reduce the combined extract volume to <10-mL. The extracts were further concentrated to a final volume of 1000 µL under a steady stream of nitrogen. Duplicate 200 mL volumes of each dust suppressant (except for soybean oil) was extracted in the same manner except 25-mL aliquots of DCM were used for the serial extractions and surrogate compounds were spiked in at 2000-5000 pg/µL depending on anticipated dilution.

Soybean oil is miscible with DCM and, therefore, was extracted according to Wu and Yu (2012). Briefly, 1-g of oil was weighed into a glass centrifuge tube and dissolved into 4-mL of *n*-hexane. 8-mL of *N,N*-dimethyl formamide (DMF) was added, and the mixture was vortexed for 15-seconds, sonicated for 5-minutes, then centrifuged for 5-minutes at 2000 rpm. The DMF phase was transferred to a 125-mL separatory funnel and the extraction was repeated. The combined DMF was back-extracted three times with 8-mL aliquots of *n*-hexane. The n-hexane extract was then washed with a 4% sodium chloride solution, concentrated to 1-mL under a gentle stream of nitrogen, and cleaned up with 6-mL, 1000 mg florisil SPE cartridges. Final extract volume was reduced to 1000 µL under a steady stream of nitrogen.

Roadbed material was extracted following EPA method 3540C for Soxhlet extractions. 20-g of roadbed material was weighed into a cellulose extraction thimble and spiked with acid, base, and neutral surrogate compounds for a final extract concentration of 5000 pg/µL. 250-mL of 1:1 DCM:Acetone was added to a flat bottom flask, which was then heated in a water bath such that the Soxhlet extractor cycled six times every hour. After 24-hours, a Kuderna-Danish concentration was used to reduce the solvent volume to <10-mL. A gentle stream of nitrogen was used to further concentrate the sample volumes to 200 µL, which were then reconstituted to 1000 µL with DCM.

Gasoline range organics (GRO) were analyzed only for the dust suppressants by headspace solid phase microextraction (HS-SPME). 5-mL of each dust suppressant stock was transferred into a 10-mL headspace vial. Samples were initially incubated in the thermal agitator of a Gerstel Multipurpose Autosampler held at 50°C and shaken at 250 rpm for 10 minutes. A 50/30 µm DVB/CAR/PDMS SPME fiber assembly was then exposed to the headspace at 50°C and shaken for 250 rpm for 30 minutes.

Sample analysis

All sample extracts were analyzed on a Pegasus 4D GCxGC-TOFMS system equipped with an Agilent 7890A GC and a Gerstel Multipurpose Autosampler. DRO analyses were carried out in one dimension using a 30-m x 0.25-mm ID x 0.25-µm df Rxi-5MS column. 1 µL of extract was injected into a 300°C split/splitless inlet operating in splitless mode with a straight 4mm liner packed with deactivated wool. The carrier gas was helium at a constant flow rate of 4.00 mL/min. The oven was initially held at 40°C for 1 min, increased to 300°C at 20°C/min, then increased to 340°C at 5°C/min and held for 3 min. The TOFMS ionization energy was 70 eV, with a scanning rate of 10 Hz from 35 to 550 amu.

Targeted organic analysis was performed with a two-dimensional separation to maximize peak capacity. The chosen column ensemble for all samples was a 60-m x 0.25-mm ID x 0.25-µm df Rxi-5SilMS in the first dimension and a 0.85-m x 0.25-mm ID x 0.25-µm df Rxi-17SilMS in the second dimension with a 0.6-m x 0.18-mm ID transfer line leading to the detector. For all extracts, 1 µL was injected into a 250°C split/splitless inlet operating in splitless mode with a Topaz 4-mm single taper inlet liner packed with deactivated wool. The carrier gas was helium at a constant flow rate of 1.4 mL/min. For dust suppressant stocks, the oven was initially held at 35°C for 1.5-min, then increased to 315°C at 3°C/min and held for 8-min. The secondary oven was offset +5°C from the primary oven. The modulator was offset +15°C from the secondary oven and programmed with a 3-second modulation period (0.90 s-hot pulse and 0.6 s-cooling period). The TOFMS ionization energy was 70 eV, with a scanning rate of 200 Hz from 50 to 550 amu. For runoff and roadbed samples, the instrument conditions were kept the same expect the oven temperature ramp was increased to 5°C/min and the detector scan rate was decreased to 150 Hz.

GRO characterization of the dust suppressants was carried out by desorbing the exposed SPME fiber assembly in a 260°C split/splitless inlet outfitted with a 0.75-mm ID SPME inlet liner for 10-minutes. The splitless purge valve opened after 120-sec, and the purge flow was set to 100 mL/min. A 30-m x 0.25-mm ID x 1.4-µm Rxi-624SilMS column. The He carrier gas flow rate was set to 1.5 mL/min. The oven was initially held at 35°C for 3-minutes followed by an 8°C/min ramp to 60°C then a 30°C/min ramp to 225°C and a 6-minute final hold.

Measurement of radioactivity

Samples of roadbed aggregate were collected prior to treatment with OGPW, following application of the dust suppressant, and following the 24-hour rain event. Roadbed solid samples were sieved to remove material larger than coarse sand (1.18-mm) then placed in a 24-mL incubation tube for bulk radium analysis. Roadbed material was also sieved into sand smaller size fractions for analysis of sand (45 to 90-µm) as well as silt and clay (<45-µm). Liquid samples of the dust suppressants were all collected immediately prior to application on the roadbed. Liquid samples were acidified and placed in 24-mL incubation tubes for a minimum of 21-days. Runoff samples were collected at the same time as the inorganic samples listed above, acidified, and placed in 50-mL centrifuge tubes. Samples were then transferred to 24-mL incubation tubes prior to analysis.

Radioactivity was measured in all samples on a small anode germanium detector (Canberra Instruments) at geometries consistent with both liquid and solid internal standards. After a minimum of 21-day equilibration, ^{226}Ra was measured using Bi-214 (609 keV) and Pb-214 (295 and 351 keV) decay products. ^{226}Ra was calculated using the average of the activities in the three daughter decay products. Direct measurement of ^{228}Ra was performed using the average of its ^{228}Ac daughter at 911 keV and ^{212}Pb at 239 keV. Measurements were collected until counting errors were typically below 5% for all energies. For solid samples this was typically less than 24-hours but for many liquid samples this led to count times between 2-4 days. Method detection limits vary based on counting times of samples, but generally the detection limit for liquid samples counted for 4-days was 20 pCi/L. Values reported below this detection limit should be qualified as estimated values.

Calculation of element mass retained in roadbed

A mass balance approach was used to calculate the mass of select elements retained in the roadbed at the conclusion of the rainfall-runoff test according to Equation (2):

$$M_{j,retained} = C_{j,DS}*V_{DS} - \Sigma C_{j,i}*V_i \quad (2)$$

where, $M_{j,retained}$ is the mass of element j retained in the bed (g), $C_{j,DS}$ is the concentration of j in the dust suppressant applied to the roadbed (g/L), V_{DS} is the volume of dust suppressant applied to the roadbed (L), $C_{j,i}$ is the concentration of j in each i-th runoff sample (g/L), and V_i is the volume of rainfall during each sampling interval (= 1/24th of storm total; L). If Equation (2) resulted in a negative number (i.e., more mass of an element was present in the runoff than was added by the dust suppressant), that amount was determined to be 'leached' from the roadbed material.

4.5 Dust generation experiments

A detailed description of the laboratory methods to measure dust suppressant efficacy are provided in Stallworth et al. (2020) and Stallworth et al. (2021). A summary of relevant details is provided here. Discs of road aggregate material (6-cm diameter by 1.5-cm depth) were compacted using a modified Proctor test to create a uniform material representative of a dirt and gravel road. The discs were dried and then treated with dust suppressant material at the same application rate as the surface runoff tests. Discs were then dried overnight. The discs were then tumbled in a mechanical drum that was connected to an aerosol monitor (DustTrak II Aerosol Monitor 8530; TSI). This aerosol monitor is the same type as used in field studies. The aerosol monitor measured particulate material smaller than 10 microns (PM10) in size and reported concentrations in units of mg/m^3. Measurements were collected every second for 3 minutes and the average value between 2 and 3 minutes of tumbling was defined as the "Average Maximum Particulate Matter concentration <10-µm", or AM PM10. Replicate measurements for each treatment were collected and the mean and standard deviation of the results are reported. One important modification from the Stallworth method was that the tests in this study were all conducted in an environmental chamber with constant relative humidity of either 20% or 50%.

A relative humidity of 50% is representative of the median humidity above a shaded roadbed in northwest Pennsylvania during the months of May – August. A relative humidity of 20% is representative of the mean humidity above an unshaded roadbed in northwest Pennsylvania during the months of May – August between 11 AM to 5 PM. These relative humidity values were calculated using hourly air temperature and dew point observations from the Warren Venango Regional Airport (KFKL) in Warren County and the Bradford Regional Airport (KBFD) in Bradford County from May 1, 2021 to August 31, 2021 using the Clausius–Clapeyron relation with the August–Roche–Magnus formula to calculate saturation vapor pressure. Unshaded dirt and gravel roadbed surface temperatures commonly reach 125 – 140°F (51.7 – 60°C) in the sun and were conservatively assumed to be 20°C warmer than the observed air temperature in this model (maximum surface temperature used in model was 52.7°C).

Table 4.1 Rainfall totals as a function of time and correlations to time stamps of sampling equipment. ISCO sampler programmed to collect samples from flow-through bucket after every 1/24th of total storm volume. Hannah multimeter programmed to record data every 10-seconds from meter immersed in flow-through bucket.

Time stamp (hr)	Cumulative rainfall (in)	ISCO Sample number	Hannah multimeter Sample number
0.0	0.0	n.a.	0
3.6	0.10	1	1,290
6.2	0.20	2	2,220
8.2	0.31	3	2,940
9.6	0.41	4	3,440
10.5	0.51	5	3,770
11.0	0.61	6	3,970
11.1	0.71	7	4,000
11.2	0.81	8	4,040
11.3	0.92	9	4,080
11.4	1.02	10	4,110
11.5	1.12	11	4,150
11.6	1.22	12	4,180
11.7	1.32	13	4,220
11.8	1.42	14	4,260
11.9	1.53	15	4,290
12.1	1.63	16	4,340
12.4	1.73	17	4,480
12.8	1.83	18	4,620
13.4	1.93	19	4,840
14.4	2.03	20	5,200
15.8	2.14	21	5,700
17.8	2.24	22	6,420
20.8	2.34	23	7,500
24.0	2.44	24	8,640

Table 4.2 Summary of sample handling and analysis of runoff samples.

Analyte(s)	Sample handling	Sample preservation	Analytical instrument	Standard method
Electrical conductivity	none	none	HI98195 Multimeter	
pH	none	none	HI98195 Multimeter	
Anions	Filtered through 0.45-µm syringe filter	Acidified with Nitric Acid, pH<2	Dionex 1100 ICS	EPA 300.1
Dissolved metals	Filtered through 0.45-µm syringe filter	Acidified with Nitric Acid, pH<2	ThermoFisher iCAP 7400 ICP-OES; ThermoFisher iCAP RQ ICP-MS	EPA 6010D; EPA 6020B
Total metals	Unfiltered; Digested with Nitric and Hydrochloric Acids	Acidified with Nitric Acid, pH<2	ThermoFisher iCAP 7400 ICP-OES	EPA 3010A; EPA 6010D
Radioactivity in liquid runoff	Unfiltered	Acidified with Nitric Acid, pH<2	Canberra SAGE gamma spectrometer	
Petroleum hydrocarbons in liquid runoff	Stored in glass bottles	Refrigerated	Pegasus 4D GCxGC-ToFMS	EPA 3510C; EPA 8015C
Chemical oxygen demand	Unfiltered	Acidified with Nitric Acid, pH<2	HACH DRB 200 reactor and HACH DR2800 spectrophotometer	Hach Method 8000
Dissolved organic carbon	Filtered through 0.45-µm syringe filter	Refrigerated	TOC-V CSN	EPA 9060A
Dissolved inorganic carbon	Filtered through 0.45-µm syringe filter	Refrigerated	TOC-V CSN	EPA 9060A
Total Suspended Solids	Unfiltered		HACH DR2800 spectrophotometer	Hach Method 8006

Table 4.3 Summary of sample handling and analysis of roadbed samples.

Analyte(s)	Sample handling	Sample preservation	Analytical instrument	Standard method
Radioactivity in solid roadbed	Sorted to grain size <1.18-mm	Dried, sealed	Canberra SAGE gamma spectrometer	
Petroleum hydrocarbons in solid roadbed	Frozen in plastic until extraction	Frozen	Pegasus 4D GCxGC-ToFMS	EPA 3540C; EPA 8015C

Figure 4.1 Roadbed test frame. 3-feet wide, 9-feet long, stainless-steel lined. Crossed cables used to assist with lifting frame onto steel I-beams. Plastic endpiece removed after roadbed was compacted into test frame. Stainless-steel discharge chute conveyed runoff into flow-through sample bucket.

Figure 4.2 Compaction of gravel aggregate into roadbed test frame. Vibratory plate tamper used to achieve desired % compaction. Nuclear meter used by CMT Labs (State College, PA) to confirm % compaction in relation to number of tamper passes.

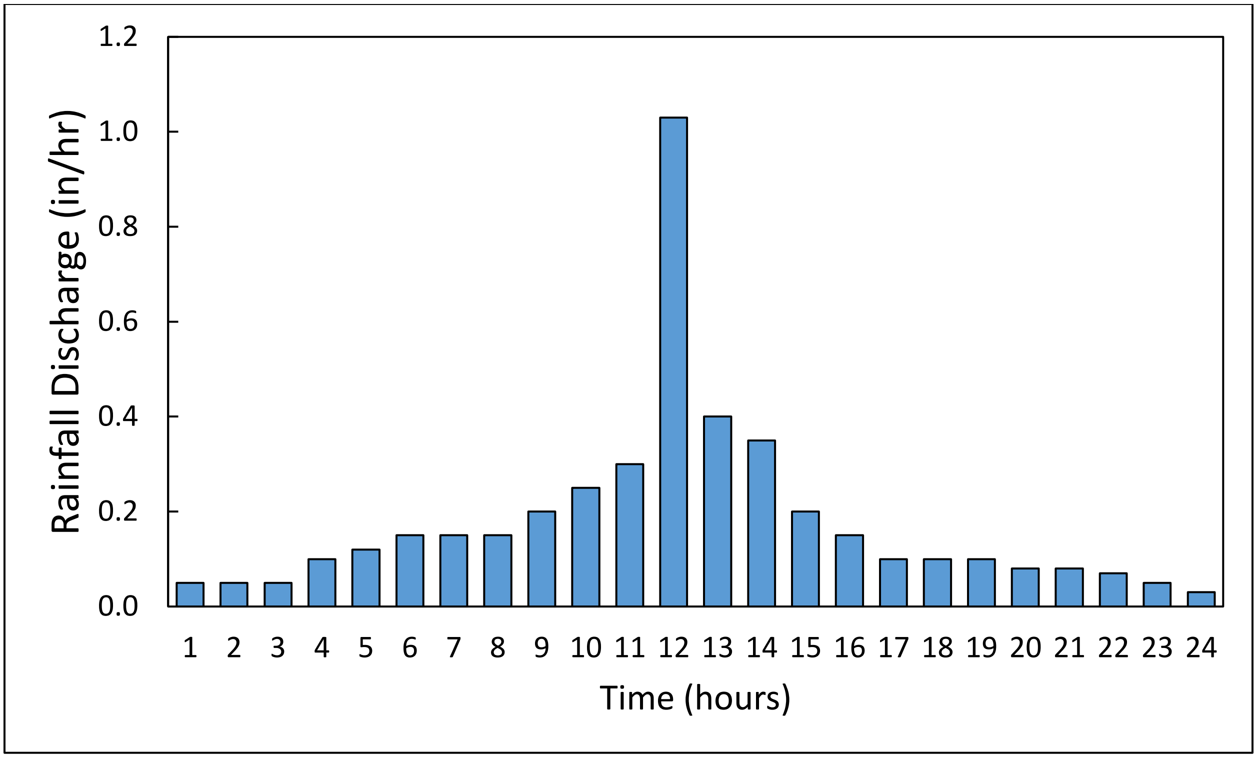

Figure 4.3 Rainfall hyetograph for the storm used for all rainfall-runoff tests in this study. Rainfall pattern matches a 2-year 24-hour rain event for Warren County, PA.

Figure 4.4 Sampling equipment positioned at downstream end of roadbed test frame. 2-gallon plastic bucket was hung onto end of discharge chute. Overflow from bucket was captured in large black plastic tank on floor. Hannah multimeter and ISCO sampling tube were fastened into sampling bucket. Rainfall nozzles positioned inside shower curtain enclosure. Rainfall pumping equipment mounted on scaffold next to test frame.

Figure 4.5 View of rainfall nozzles positioned inside of shower curtain enclosure. Each nozzle delivered synthetic rainwater evenly across a 3-foot by 3-foot square section of the roadbed. Shower curtains contained any over overspray and retained humidity.

5. RESEARCH RESULTS

5.1 Comparisons of dust suppressants

All the dust suppressants were analyzed for a variety of constituents (Table 5.1). All these data are included in a database associated with this report – i.e., every replicate measurement for every analyte for every sample. Some of these analytes were not measured in the soybean oil because it is a nonaqueous phase liquid. Rows in Table 5.1 are organized to present analytes related to salinity (electrical conductivity and total dissolved solids), radioactivity (Ra isotopes), halogens (chloride – iodide), anions (nitrate – sulfate), alkaline earth metals (calcium – barium), alkali metals (sodium – lithium), transition metals (aluminum – lead), metalloids (boron – arsenic), petroleum hydrocarbons (DRO – GRO), organic matter (COD – DOC), inorganic carbon (DIC), and pH. Water quality criteria are included in Table 5.1 for those analytes with a Federal or State standard, limit, or threshold. This report focused on analytes where the concentrations in any one of the dust suppressants divided by the regulatory criteria were much greater than one.

The calcium chloride brine had the highest concentrations of most measured constituents (Table 5.1). The electrical conductivity (EC) of the calcium chloride brine averaged 197 mS/cm, a value approximately four-times higher than seawater (seawater EC = 50 mS/cm), and 65-times higher than the regulatory guideline for irrigation water (USDA, 1997). The total dissolved solids (TDS) of the calcium chloride brine used in the rainfall-runoff experiments averaged 272,000 mg/L TDS. In comparison, seawater commonly contains 35,000 mg/L TDS and the USEPA and PADEP secondary drinking water standard is 500 mg/L TDS. The calcium chloride brine had the highest concentrations of chloride, bromide, nitrate, sulfate, calcium, strontium, potassium, lithium, lead, and boron.

To establish if the Fisher Science Education $CaCl_2$ product used in the rainfall-runoff experiments was compositionally like commercially available $CaCl_2$ dust suppressants, two other products were tested (Commercial Brine 1 and Commercial Brine 2, Table 5.1). Chemical characterizations of these products were consistent with the Fisher Science Education product, especially when normalized to chloride content. These results demonstrate that calcium chloride dust suppressants contain contaminants of interest including chloride, bromide, boron, and radium. One of the commercial products (brine 1) also contained enough sodium to decrease its efficacy as a dust suppressant (section 5.4).

Electrical conductivity (EC) is a measure of water's ability to conduct an electrical current. This ability is related to the concentration of ions in water. High quality distilled-deionized water has a conductivity of about 0.5 µS/cm at 25 °C, typical drinking water is in the range of 200 – 800 µS/cm, while sea water is about 50 mS/cm. The USDA recommends that water with EC greater than 3 mS/cm (= 3,000 µS/cm) not be used for irrigation, or only be used for salt-tolerant crops (USDA, 1997). All the OGPWs included in this study had EC values (118 – 127 mS/cm) 39 to 42-times the criterion for irrigation water. The calcium chloride brine used in this study was the most saline with an average EC value (194 – 200 mS/cm) 65 to 67-times the criterion for irrigation water. The calcium chloride brine used in the rainfall-runoff experiments ranged from 17 – 25% saturation, while the commercially available products used in the dust generation experiments were even more saline. Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid. In this study, TDS was calculated as the sum of the dissolved concentrations of Ca, Mg, Na, Sr, Ba, Cl, Br, and SO_4. The USEPA and PADEP have established a secondary drinking water standard of 500 mg/L TDS to primarily address aesthetic affects and public acceptance of drinking water. Seawater commonly contains 35,000 mg/L TDS. TDS concentrations in the OGPWs ranged from 81,000 to 84,000 mg/L, while the average TDS for the calcium chloride brine used in the rainfall-runoff experiments averaged 272,000 mg/L, and the TDS of the commercially available $CaCl_2$ dust suppressants used only in the dust generation experiments ranged from 381,000 to 387,000 mg/L. Application of saline dust suppressants to gravel roadbeds led to increased salinity in stormwater runoff (Section 5.2).

Radium is a radioactive alkaline earth metal that occurs naturally in soils and rocks. Radium is a known carcinogen. The USEPA and PADEP established a primary MCL for combined radium (sum of ^{226}Ra plus ^{228}Ra) in public drinking water supplies of 5 picoCuries per liter (pCi/L). The US NRC industrial wastewater discharge limit for combined Ra is 60 pCi/L (Rowan et al., 2011). Combined radium activities in the three OGPWs were 360 (O&G PW1), 84.4 (O&G PW2), and 2,500 pCi/L (O&G PW3; Table 5.1). The higher combined radium activities measured in O&G PW1 and O&G PW3 were consistent with the regional average of 226-radium from conventional oil and gas formations in Pennsylvania. For example, through an analysis of 20 – 25 samples from the USGS Produced Waters Database, the median 226-radium (n = 25), 228-radium (n = 20), and combined radium activities (n = 20) were, respectively, 811, 1,194, and 2,034 pCi/L (Tasker et al., 2020).

The combined radium activities for the calcium chloride brines were elevated and possibly sourced from impurities in the materials. Combined radium activity measured in the calcium chloride used for the rainfall-runoff experiments was 230 pCi/L. This calcium chloride was purchased from Fisher Science Education to prepare large volumes of brine required for the rainfall-runoff experiments. Fisher Science Education reported the purity of its calcium chloride as >95% mass/volume. The abundance of Sr, Na, K, Li, Ba, Fe, Zn, Pb and B in the Fisher Science Education $CaCl_2$ brine (Table 5.1) used in this study suggests that the salt was minimally purified. The elemental composition of this brine was like the commercially available $CaCl_2$ dust suppressants (especially when normalized to chloride concentrations) used in the dust generation experiments. Combined radium activities measured in the commercially available calcium chloride dust suppressants used in the dust generation experiments were 410 and 730 pCi/L. The analysis of these three calcium chloride brines suggest that impurities include contaminants of interest such as radium and boron (Table 5.1).

Combined radium activity in the synthetic rainwater and in the soybean oil were below the instrument's reportable quantification limit (BQL) of 20 pCi/L.

Halogens such as chloride, bromide, and iodide can increase the corrosivity of water and promote the formation of harmful disinfection byproducts in drinking water treatment plants. Bromide in OGPWs is of concern because brominated disinfection byproducts are more toxic than chlorinated disinfection byproducts (Wang et al, 2017). Chloride is the predominant anion in OGPWs. The USEPA and PADEP have established a secondary drinking water standard of 250 mg/L Cl related to taste. Chloride concentrations in the three OGPWs were 192 to 199-times above this limit. Chloride concentrations in the three calcium chloride brines were 706 to 1,070-times above this limit.

Elevated concentrations of metals such as sodium, magnesium, and calcium can affect soil fertility. The USDA established guidelines for irrigation water to protect both crop type and soil health. Sodium concentrations in the three OGPWs were 26-times above the USDA guideline of 920 mg/L Na. Magnesium concentrations in the three OGPWs were 21 to 22-times above the USDA guideline of 61 mg/L Mg. Calcium concentrations in the three OGPWs were 17 to 18-times above the USDA guideline of 401 mg/L Ca. Calcium concentrations in the three calcium chloride brines were 190 to 260-times above the Ca guideline.

The relative concentrations of sodium to calcium plus magnesium (calculated as SAR using Equation (1)) can predict the efficacy of a brine as a dust suppressant (Stallworth et al., 2020). Specifically, a low SAR value (e.g., < 3) would predict that a brine may be an effective dust suppressant (Graber et al., 2019, Stallworth, 2020). SAR values for the three OGPWs ranged from 68 to 69 suggesting that these fluids would not likely be effective dust suppressants (as confirmed by subsequent experiments). In contrast, the SAR value for the calcium chloride brine used in the rainfall-runoff experiments was 1.4. One commercial calcium chloride brine (Commercial Brine 1) used in the dust generation experiments had a SAR value of 17.4 and was the least effective calcium chloride-based product.

OGPWs and brines often contain elevated concentrations of transition metals and metalloids. Based on ratios of concentrations measured in the dust suppressants divided by regulatory standards, strontium, barium, aluminum, manganese, iron, and lead were identified as contaminants of interest.

Organic matter in the dust suppressants was measured in multiple ways. Chemical oxygen demand (COD) measures the amount of oxygen that would be depleted from a body of receiving water (in units of mg/L O_2). COD could not be measured in the OGPWs and calcium chloride brine because chloride concentrations >1,000 mg/L Cl introduce interferences in the analytical method. Dissolved organic carbon (DOC) measures only organic carbon in a sample. Diesel Range Organics (DRO) and Gas Range Organics (GRO) measure hydrocarbons in a sample. The OGPWs had relatively elevated concentrations of DOC and measurable concentrations of both DRO and GRO. O&G PW3 had the highest concentration of DRO (1,650 mg/L C) in all the dust suppressants. As noted on the product label, the soybean oil was 100% oil (>95% total fatty acid) but as a nonaqueous phase liquid, DOC could not be measured.

Table 5.1 Chemical characterization summary of dust suppressants used in the current study.

Analyte	O&G PW1	O&G PW2	O&G PW3	Synthetic Rainwater	$CaCl_2$ Brine	Commercial Brine 1	Commercial Brine 2	Soybean Oil	Regulatory Criteria
EC (mS/cm)	120	120	125	0.023	197	216	180	NA	3.0[g]
TDS* (mg/L)	84,100	82,000	85,300	2.39	272,000	381,000	387,000	0.14	500[b]
Ra-226 (pCi/L)	212	51.5	1,800	BQL	159	641	238	BQL	60[e]
Ra-228 (pCi/L)	148	32.9	696	BQL	71.6	88.9	170	BQL	60[e]
Combined Ra (pCi/L)	360	84.4	2,500	BQL	230	729	408	BQL	5[b]
Chloride (mg/L)	49,700	47,900	49,000	BQL	176,000	251,000	267,000	NA	250[b,i], 230[c]
Bromide (mg/L)	922	753	592	BQL	3,770	3,740	3,430	NA	6[d]
Iodide (mg/L)	13.8	11.2	14.5	0	0.22	47.5	2.58	NA	
Nitrate (mg/L)	324	BQL	BQL	0.7	735	BQL	BQL	NA	10[a,i]
Sulfate (mg/L)	1,480	1,350	2,000	2.14	7,210	BQL	BQL	NA	250[b,i]
Calcium (mg/L)	6,760	6,860	7,150	BQL	78,200	76,200	105,000	0.41	401[g]
Magnesium (mg/L)	1,360	1,310	1,310	BQL	BQL	14,500	896	0.10	61[g]
Strontium (mg/L)	112	112	453	0	1,480	3,070	2,610	BQL	4[f,h,i]
Barium (mg/L)	1.58	4.38	417	0	1.57	--	3.93	BQL	2[a,i]
Sodium (mg/L)	23,600	23,500	24,300	0.14	1,460	20,000	2,500	BQL	20[h], 920[g]
Potassium (mg/L)	117	125	132	0.1	3,120	12,300	5,900	BQL	
Lithium (mg/L)	2.48	2.92	13.3	BQL	57.9	91.4	111	BQL	0.01[f], 0.069[i]
SAR^ $(meq/L)^{1/2}$	68.6	68.1	69.3	BQL	1.4	17.4	2.1	NA	9[g]
Aluminum (mg/L)	BQL	BQL	BQL	BQL	BQL	5.15	5.48	BQL	0.05 to 0.2[b,i]
Manganese (mg/L)	4.06	4.82	4.91	BQL	0.07	1.63	BQL	BQL	0.05[b], 0.3[i]
Iron (mg/L)	15.0,	1.44	43.7	0.02	3.39	4.13	6.52	BQL	0.3[b,i], 1[c]
Nickel (mg/L)	0.09	0.09	0.05	BQL	0.04	BQL	BQL	BQL	0.052[c], 0.1[h,i]
Zinc (mg/L)	1.83	1.93	2.21	0.44	1.84	2.19	3.88	BQL	5[b], 0.12[c], 2[h]
Lead (mg/L)	0.11	0.13	0.11	BQL	0.4	0.1	0.3	BQL	0.015[a], 0.0025[c]
Boron (mg/L)	0.77	0.99	1.26	BQL	22	520	42	BQL	2.4[d], 6[h,i]
Arsenic (mg/L)	0.06	0.05	0.05	BQL	0.02	BQL	BQL	BQL	0.01[a,i], 0.15[c]
DRO (mg/L)	14.7	10.8	1,650	1.1	0.5	NA	NA	6.5	
GRO (mg/L)	1.3	2.6	1.1	BQL	0.6	NA	NA	22.8	
TOC (mg/L)	88.3	81.1	76.6	1.75	8.27	NA	NA	NA	
TIC (mg/L)	1.1	1.5	13.1	0.6	0.6	NA	NA	NA	
pH (std units)	6.42	6.15	6.50	4.29	9.95	4.28	6.32	NA	6.5-8.5[b]

*Calculated as sum of Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations; BQL – below quantification limit; NA – not analyzed; ^Calculated using Equation (1); [a]EPA and DEP Primary Drinking Water Standard; [b]EPA and DEP Secondary Drinking Water Standard; [c]EPA Aquatic Life Criteria; [d]WHO Drinking Water Quality Guideline; [e]Appendix B to 10 CFR Part 20; [f]USGS Human-Based Screening Level; [g]USDA Irrigation Water Quality Guidelines; [h]EPA Drinking Water Health Advisories for lifetime exposures; [i]Medium-Specific Concentrations for Inorganic Regulated Substances in Groundwater 25 PA Code Chapter 250 Appendix A Table 2.

Analyte	O&G PW1	O&G PW2	O&G PW3	Synthetic Rainwater	$CaCl_2$ Brine	Commercial Brine 1	Commercial Brine 2	Soybean Oil	Regulatory Criteria
EC (mS/cm)	120	120	125	0.023	197	216	180	NA	3.0[g]
TDS* (mg/L)	84,100	82,000	85,300	2.39	272,000	381,000	387,000	0.14	500[b]
Ra-226 (pCi/L)	212	51.5	1,800	BQL	159	641	238	BQL	60[e]
Ra-228 (pCi/L)	148	32.9	696	BQL	71.6	88.9	170	BQL	60[e]
Combined Ra (pCi/L)	360	84.4	2,500	BQL	230	729	408	BQL	5[b]
Chloride (mg/L)	49,700	47,900	49,000	BQL	176,000	251,000	267,000	NA	250[b,i], 230[c]
Bromide (mg/L)	922	753	592	BQL	3,770	3,740	3,430	NA	6[d]
Calcium (mg/L)	6,760	6,860	7,150	BQL	78,200	76,200	105,000	0.41	401[g]
Magnesium (mg/L)	1,360	1,310	1,310	BQL	BQL	14,500	896	0.10	61[g]
Strontium (mg/L)	112	112	453	0	1,480	3,070	2,610	BQL	4[f,h,i]
Barium (mg/L)	1.58	4.38	417	0	1.57	--	3.93	BQL	2[a,i]
Sodium (mg/L)	23,600	23,500	24,300	0.14	1,460	20,000	2,500	BQL	20[h], 920[g]
Potassium (mg/L)	117	125	132	0.1	3,120	12,300	5,900	BQL	
Lithium (mg/L)	2.48	2.92	13.3	BQL	57.9	91.4	111	BQL	0.01[f], 0.069[i]
SAR^ $(meq/L)^{1/2}$	68.6	68.1	69.3	BQL	1.4	17.4	2.1	NA	9[g]
Aluminum (mg/L)	BQL	BQL	BQL	BQL	BQL	5.15	5.48	BQL	0.05 to 0.2[b,i]
Manganese (mg/L)	4.06	4.82	4.91	BQL	0.07	1.63	BQL	BQL	0.05[b], 0.3[i]
Iron (mg/L)	15.0,	1.44	43.7	0.02	3.39	4.13	6.52	BQL	0.3[b,i], 1[c]
Nickel (mg/L)	0.09	0.09	0.05	BQL	0.04	BQL	BQL	BQL	0.052[c], 0.1[h,i]
Zinc (mg/L)	1.83	1.93	2.21	0.44	1.84	2.19	3.88	BQL	5[b], 0.12[c], 2[h]
Lead (mg/L)	0.11	0.13	0.11	BQL	0.4	0.1	0.3	BQL	0.015[a], 0.0025[c]
Boron (mg/L)	0.77	0.99	1.26	BQL	22	520	42	BQL	2.4[d], 6[h,i]
Arsenic (mg/L)	0.06	0.05	0.05	BQL	0.02	BQL	BQL	BQL	0.01[a,i], 0.15[c]
DRO (mg/L)	14.7	10.8	1,650	1.1	0.5	NA	NA	6.5	
GRO (mg/L)	1.3	2.6	1.1	BQL	0.6	NA	NA	22.8	
TOC (mg/L)	88.3	81.1	76.6	1.75	8.27	NA	NA	NA	
TIC (mg/L)	1.1	1.5	13.1	0.6	0.6	NA	NA	NA	
pH (std units)	6.42	6.15	6.50	4.29	9.95	4.28	6.32	NA	6.5-8.5[b]

Analyte	O&G PW1	O&G PW2	O&G PW3	Synthetic Rainwater	$CaCl_2$ Brine	Commercial Brine 1	Commercial Brine 2	Soybean Oil	Regulatory Criteria
EC (mS/cm)	120	120	125	0.023	197	216	180	NA	3.0[g]
TDS* (mg/L)	84,100	82,000	85,300	2.39	272,000	381,000	387,000	0.14	500[b]
Ra-226 (pCi/L)	212	51.5	1,800	BQL	159	641	238	BQL	60[e]
Ra-228 (pCi/L)	148	32.9	696	BQL	71.6	88.9	170	BQL	60[e]
Combined Ra (pCi/L)	360	84.4	2,500	BQL	230	729	408	BQL	5[b]
Chloride (mg/L)	49,700	47,900	49,000	BQL	176,000	251,000	267,000	NA	250[b,i], 230[c]
Bromide (mg/L)	922	753	592	BQL	3,770	3,740	3,430	NA	6[d]
Calcium (mg/L)	6,760	6,860	7,150	BQL	78,200	76,200	105,000	0.41	401[g]
Magnesium (mg/L)	1,360	1,310	1,310	BQL	BQL	14,500	896	0.10	61[g]
Strontium (mg/L)	112	112	453	0	1,480	3,070	2,610	BQL	4[f,h,i]
Barium (mg/L)	1.58	4.38	417	0	1.57	--	3.93	BQL	2[a,i]
Sodium (mg/L)	23,600	23,500	24,300	0.14	1,460	20,000	2,500	BQL	20[h], 920[g]
Lithium (mg/L)	2.48	2.92	13.3	BQL	57.9	91.4	111	BQL	0.01[f], 0.069[i]
SAR^ $(meq/L)^{1/2}$	68.6	68.1	69.3	BQL	1.4	17.4	2.1	NA	9[g]
Lead (mg/L)	0.11	0.13	0.11	BQL	0.4	0.1	0.3	BQL	0.015[a], 0.0025[c]
Boron (mg/L)	0.77	0.99	1.26	BQL	22	520	42	BQL	2.4[d], 6[h,i]
pH (std units)	6.42	6.15	6.50	4.29	9.95	4.28	6.32	NA	6.5-8.5[b]

*Calculated as sum of Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations; BQL – below quantification limit; NA – not analyzed; ^Calculated using Equation (1); [a]EPA and DEP Primary Drinking Water Standard; [b]EPA and DEP Secondary Drinking Water Standard; [c]EPA Aquatic Life Criteria; [d]WHO Drinking Water Quality Guideline; [e]Appendix B to 10 CFR Part 20; [f]USGS Human-Based Screening Level; [g]USDA Irrigation Water Quality Guidelines; [h]EPA Drinking Water Health Advisories for lifetime exposures; [i]Medium-Specific Concentrations for Inorganic Regulated Substances in Groundwater 25 PA Code Chapter 250 Appendix A Table 2.

Contaminants of interest related to human health include combined radium (^{226}Ra + ^{228}Ra), barium, strontium, lithium, iron, and manganese. Contaminants of interest related to irrigation water include sodium, magnesium, and calcium. Contaminants of interest related to organic-based dust suppressants include chemical oxygen demand and dissolved organic carbon. Contaminants of lesser concern include aluminum, arsenic, lead, nitrate, and sulfate.

5.2 Comparisons of rainfall-runoff concentrations

Runoff samples were collected over the 24-hour storm event to characterize runoff chemistry. A multimeter probe located in the flow-through sampling bucket at the downhill end of the roadbed recorded measurements every 10-seconds yielding 8,640 sampling events per test. A programmable autosampler collected 500-mL samples after every 1/24th of the storm volume. Because of the temporal pattern of the 2-year, 24-hour storm (Figure 4.3), more samples were collected during the peak of the storm as compared to the start or end of the storm. The differences between plotting results as a function of sample number versus as a function of time are illustrated in Figure 5.1. For demonstrative purposes, these comparisons are only shown for one dust suppressant (O&G PW1) but include electrical conductivity (EC; measured by multimeter) and dissolved chloride (measured after collection from automated ISCO sampler bottles). Because EC was measured every 10-seconds, graphs of EC versus multimeter sample number and EC versus time (Figures 5.1A,C) appear similar. These data reflect important stages of the rainfall-runoff test. First, a lag before any rainfall ran off the roadbed into the sampling bucket was observed, then a 'first flush' of runoff with the highest measured EC values occurred, then a 'maximum flush' period occurred during the heaviest rainfall with the lowest measured EC values (due to rainfall dilution), and then EC values rebounded during the lower-intensity end of the storm.

Because dissolved chloride was measured after every 1/24th of the storm volume, graphs of Cl concentration versus ISCO sample number (Figure 5.1B) and Cl versus time (Figure 5.1D) appear rather different. When plotted versus time (Figure 5.1D), results from the storm peak are compressed and somewhat difficult to resolve. Therefore, for the remainder of this report, results were plotted versus ISCO sample number (hereafter referred to as sample number) for enhanced visual clarity (Figure 5.1B). Time stamps for sample numbers are included in Table 4.1. Sample numbers 1 and 2 correspond to the 'first flush' portion of the test while sample numbers 7 and 8 correspond to the 'maximum flush' portion of the test. The terms first flush and maximum flush are used in this report to specifically indicate these sample numbers.

Runoff samples were either filtered (0.45-µm) to measure dissolved metals or acid-digested (unfiltered) to measure total metals. A pair-wise analysis of total metal concentrations (y-axis) versus dissolved metal concentrations (x-axis) can resolve whether metals were associated with solids in the runoff or dissolved in solution. Metal concentrations above a 1-to-1 line on such a graph reflect those metals that are associated with particles >0.45-µm in size. Metal concentrations that lie on the 1-to-1 line are completely dissolved in solution. Metal concentrations below the 1-to-1 line could indicate analytical interferences with the digestion solution and/or inaccuracies in sample dilutions because, conceptually, the total concentration cannot be less than the dissolved concentration. Pair-wise analyses for all the dust suppressants are presented in Figure 5.2. Most of the metals measured in the runoff from roadbeds treated with OGPWs and calcium chloride brine were dissolved in solution (Figure 5.2A-D). Because of the elevated metal concentrations in the OGPWs and calcium chloride brine (Table 5.1), most of the metals measured in the runoff from roadbeds treated with OGPWs and calcium chloride brine were sourced from the dust suppressant with a minor contribution from pore fluids in the roadbed.

With synthetic rainwater or soybean oil, magnesium (Mg) and strontium (Sr) in the runoff were associated with particles >0.45-µm in size while the remainder of the metals were dissolved in solution (Figure 5.2E,F). Erosion of a Mg mineral such as magnesium carbonate ($MgCO_3$) coupled with strontium substitution in the $MgCO_3$ could explain these results. Because the synthetic rainwater and soybean oil had low metal concentrations (Table 5.1), the application of these dust suppressants to the roadbed added very little metal mass to the roadbed. Therefore, dissolved metals measured in the runoff in tests with synthetic rainwater and soybean oil were likely sourced from pore fluids in the roadbed and then mobilized by the runoff.

As a dust suppressant, the synthetic rainwater added very little mass of analyzed constituents to the roadbed. Therefore, constituent concentrations measured in the runoff from roadbeds treated with synthetic rainwater effectively represent materials washed from the roadbed and/or from pore fluids in the roadbed. Thus, results from the synthetic rainwater tests represent baseline conditions, except for nitrate and sulfate added to acidify the rainwater.

Salinity and Halogens

The use of brines as road palliatives, either as a deicer or a dust suppressant, raises concerns with respect to episodic salinization of receiving streams. Electrical conductivity (EC) is a reasonable proxy for salinity. (Specific conductivity (SC) is EC temperature-corrected to 25°C.) EC was measured every 10-seconds with the multimeter (Figure 5.3). Except for soybean oil, the shape of the EC versus time curves were similar for all the dust suppressants. The maximum EC values were reached in the ‘first flush’ of runoff while the minimum EC values were reached in the maximum flush period of heaviest rain. The key difference in the EC versus time curves was the magnitude of the maximum EC. For the

OGPWs, the maximum EC ranged approximately from 17 to 26 mS/cm. For the chloride brine, the maximum EC ranged approximately from 31 to 86 mS/cm. For the synthetic rainwater, the maximum EC ranged approximately from 0.11 to 0.41 mS/cm. The recommended USDA threshold for EC in irrigation water is 3 mS/cm. The chronic aquatic life benchmark value for EC derived from all-year data from West Virginia streams is 0.30 mS/cm (EPA, 2011). Thus, the maximum EC in runoff from roadbeds treated with the OGPWs were 5.7 to 8.7-times above the USDA threshold and 57 to 87-times above the surface water threshold. The maximum EC in runoff from roadbeds treated with calcium chloride brine were 10 to 30-times above the USDA threshold and 100 to 300-times above the surface water threshold.

The maximum values for constituent concentrations measured in the runoff (section 5.2) from the dust suppressant-treated roadbeds are summarized in Table 5.2. Maximum constituent concentrations in the runoff were related and essentially proportional to constituent concentrations in the dust suppressants (Table 5.1). Single entries in Table 5.2 refer to the highest concentration measured in any of the samples from any of the replicate tests. These values represent maximum concentrations coming from the roadbed into an adjacent drainage ditch and do not account for further dilution e.g., from stormwater runoff into the drainage ditch from adjacent un-treated areas.

Maximum constituent concentrations in the runoff were most measured in the first flush samples (e.g., Figures 5.3 – 5.20). For example, the maximum TDS concentration in runoff from the calcium chloride-treated roadbed was 43,000 mg/L TDS (Figure 5.4; Table 5.2) corresponded to an TDS concentration of 272,000 mg/L TDS in the calcium chloride brine (Table 5.1). The maximum TDS concentration in runoff from the OGPW-treated roadbeds ranged from 11,000 to 13,000 mg/L TDS (Figure 5.4; Table 5.2) corresponded to TDS concentrations of 82,000 to 85,000 mg/L TDS in the OGPWs (Table 5.1).

The OGPWs had chloride concentrations of 48,000 – 50,000 mg/L Cl (Table 5.1) while maximum chloride concentrations in the runoff ranged from 5,900 – 12,000 mg/L Cl (Figure 5.5; Table 5.2), amounting to dilution factors of approximately 4 to 8 in the first flush of runoff. The secondary drinking water standard for chloride is 250 mg/L Cl and the surface water chronic exposure standard is 230 mg/L Cl to be protective of aquatic life. Thus, the maximum chloride concentrations in runoff from roadbeds treated with the OGPWs were up to 52-times above the surface water standard. The maximum chloride concentrations in runoff from roadbeds treated with calcium chloride brine exceeded 34,000 mg/L Cl, 148-times above the surface water standard.

Bromide concentrations in the runoff (Figure 5.6) displayed patterns like chloride. The maximum bromide concentrations in the runoff corresponded to the bromide concentrations in the dust suppressants. For example, the calcium chloride brine had an average bromide concentration of 3,770 mg/L Br with a maximum bromide concentration of 760 mg/L in the runoff. The elevated bromide concentration in the calcium chloride brine was surprising because Br generally stays in solution during precipitation of chloride-salts such as NaCl and $CaCl_2$. However, if the $CaCl_2$ was mined from a salt lake deposit, it may have contained additional impurities such as NaBr, KCl, $BaSO_4$ and $SrSO_4$. Indeed, the higher concentrations of Na, Br, K, Ba and Sr indicate the $CaCl_2$ was likely mined from a source with additional impurities. To confirm this, a molar balance was conducted between the elements using their respective atomic mass units (amu) Ca (40 amu), Cl (35 amu) (x2), Na (23 amu), Br (89 amu) and K (39 amu). These calculations revealed that there was enough Na to balance with Br on a mole-to-mole basis in the runoff solutions and the source brine. The OGPWs had bromide concentrations of 590 – 920 mg/L Br while maximum bromide concentrations in the runoff ranged from 65 – 300 mg/L Br.

Radium Isotopes

Due to long count times and relatively low activity, radium in runoff samples were measured only for a subset of dust suppressants (O&G PW3, Calcium Chloride Brine, and Synthetic Rainwater) from select samples (Figure 5.7). Runoff from O&G PW3 contained the two highest activities of all runoff samples measured in runoff samples 1 and 7, which represent the first flush and the maximum flush events, respectively. These are the only reported values above the NRC industrial discharge limit of 60 pCi/L. All other runoff samples from O&G PW3 contained lower radium activities between 10 – 40 pCi/L. Runoff samples collected during the calcium chloride-treated roadbed contained radium activities below 50 pCi/L with the highest values recorded during the first flush event. Runoff samples collected from the synthetic rainwater test also contained radium activities between 30 – 55 pCi/L. The highest values were from samples collected during the maximum flush event. In this case, the low-pH synthetic rainwater likely leached naturally occurring radium from the road aggregate and then mobilized the radium during the maximum flush.

Human Health Concerns

First-flush concentrations of barium, strontium, lithium, iron, and manganese in the runoff exceeded corresponding human-health based criteria (Table 5.1). The EPA and DEP Primary Drinking Water Standard for barium is 2 mg/L Ba. Maximum barium concentrations in the runoff from OGPW-treated roads ranged from 5 – 18 mg/L Ba (Table 5.2; Figure 5.8). Maximum barium concentrations in the runoff from calcium chloride brine-treated roads ranged from 16 – 46 mg/L Ba (up to 23-times above drinking water standard) even though the average barium concentration in the calcium chloride brine was only 1.6 mg/L Ba (Table 5.1). The elevated salinity of the calcium chloride brine likely increased the solubility of barium from the roadbed (Bahadori et al., 2012; Schäfer et al., 2009). Barium may be of concern in the first flush of runoff from roadbeds treated with calcium chloride brine but of lesser concern with OGPWs. Low concentrations of barium (0.04 – 0.1 mg/L Ba) were detected in the runoff from roadbeds treated with soybean oil or synthetic rainwater.

The USGS Human-Based Screening Level for strontium is 4 mg/L Sr (Table 5.1). HBSLs are benchmarks to provide perspective on potential risks to human health for measured contaminants in natural waters. Strontium concentrations in the runoff were highest from roadbeds treated with calcium chloride brine (Table 5.2) corresponding to higher concentrations in the calcium chloride brine (Table 5.1). Maximum strontium concentrations in the runoff from calcium chloride brine-treated roads ranged from 150 – 310 mg/L Sr (Figure 5.9). Maximum strontium concentrations in the runoff from OGPW-treated roads ranged from 10 – 32 mg/L Sr. As noted above, strontium was an impurity in the calcium chloride brine. The calcium chloride brine used in the rainfall-runoff experiments was compositionally like the two other commercially available calcium chloride dust suppressants used in the dust generation experiments (when normalized to chloride concentration). Thus, impurities in calcium chloride brines may be common.

The USGS Human-Based Screening Level for lithium is 0.01 mg/L Li (Table 5.1). Lithium concentrations in the runoff were highest from roadbeds treated with calcium chloride brine (Table 5.2). Maximum lithium concentrations in the runoff from calcium chloride brine-treated roads ranged from 4.6 – 11 mg/L Li (up to 1,100-times above the standard; Figure 5.10). Maximum lithium concentrations in the runoff from OGPW-treated roads ranged from 0.18 – 1.3 mg/L Li (up to 130-times the standard). Low concentrations of lithium (0.0017 – 0.0045 mg/L Li) were detected in the runoff from roadbeds treated with soybean oil or synthetic rainwater.

The EPA and DEP Primary Drinking Water Standard for iron is 0.3 mg/L Fe (Table 5.1). Iron concentrations in the runoff were highest from roadbeds treated with calcium chloride brine (Table 5.2). Maximum iron concentrations in the runoff from calcium chloride brine-treated roads ranged from 0.30 – 0.80 mg/L Fe (only up to 2.7-times above the standard). Iron may be of minor concern in the first flush of runoff from roadbeds treated with calcium chloride brine but of little concern with OGPWs (Figure 5.11).

The DEP Regulated Substances in Groundwater Standard for manganese is 0.3 mg/L Mn and the EPA and DEP Secondary Drinking Water Standard is 0.05 mg/L Mn (Table 5.1). Maximum manganese concentrations in the runoff from calcium chloride brine-treated roads ranged from 0.46 – 1.1 mg/L Mn. Maximum manganese concentrations in the runoff from OGPW-treated roads ranged from 0.23 – 0.82 mg/L Mn. Manganese may be of some concern in the runoff from roadbeds treated with calcium chloride brine or with OGPWs (Figure 5.12). Low concentrations of manganese (0.018 – 0.047 mg/L Mn) were detected in the runoff from roadbeds treated with soybean oil or synthetic rainwater.

Irrigation Water Concerns

Concentrations of sodium, magnesium, and calcium in the runoff exceeded corresponding USDA Irrigation Water Quality Guidelines (Table 5.1). The USDA Guideline for sodium is 920 mg/L Na and the EPA Drinking Water Health Advisory for lifetime exposures is 20 mg/L Na (for individuals on a low-sodium diet). Maximum sodium concentrations in the runoff from OGPW-treated roads ranged from 1,400 – 4,500 mg/L Na (up to 4.9-times the USDA Guideline; Figure 5.13) reflecting the higher Na concentrations in the dust suppressants (Table 5.1). Maximum sodium concentrations in the runoff from calcium chloride brine-treated roads ranged from 130 – 310 mg/L Na. Maximum sodium concentrations in the runoff from roadbeds treated with soybean oil were 4.9 – 17 mg/L Na and 3.7 – 25 mg/L Na with synthetic rainwater (Table 5.2). Sodium concentrations in the runoff from all tests dropped to low concentrations shortly after the 'maximum flush' period of the rain event.

The USDA Irrigation Water Quality Guideline for magnesium is 61 mg/L Mg (Table 5.1). Maximum magnesium concentrations in the runoff from OGPW-treated roads ranged from 120 – 400 mg/L Mg (up to 6.6-times the USDA Guideline; Figure 5.14). Maximum magnesium concentrations in the runoff from calcium chloride brine-treated roads ranged from 120 – 310 mg/L Mg. Maximum magnesium concentrations in the runoff from roadbeds treated with soybean oil were 6.1 – 6.2 mg/L Mg and 2.7 – 9.7 mg/L Mg from roadbeds treated with synthetic rainwater.

The USDA Irrigation Water Quality Guideline for calcium is 401 mg/L Ca (Table 5.1). Maximum calcium concentrations in the runoff from calcium chloride brine-treated roads ranged from 9,200 – 21,000 mg/L Ca (up to 52-times the USDA Guideline; Figure 5.15). Maximum calcium concentrations in the runoff from OGPW-treated roads ranged from 750 – 2,200 mg/L Ca (up to 5.5-times the USDA

Guideline). Maximum calcium concentrations in the runoff from roadbeds treated with soybean oil or synthetic rainwater were 21 – 52 mg/L Ca and sourced from the road or in the roadbed pore fluids.

Constituents of Lesser Concern

Concentrations of aluminum, lead, arsenic, nitrate, sulfate, and pH in the runoff from roadbeds treated with any of the dust suppressants rarely were above any corresponding regulatory criteria. The EPA and DEP Primary Drinking Water Standards range from 50 to 200 µg/L Al and runoff concentrations never exceeded the upper range (Figure 5.16). The EPA and DEP Primary Drinking Water Standards for lead is 15 µg/L Pb and runoff concentrations never exceeded this standard (Figure 5.17). The EPA and DEP Primary Drinking Water Standards for arsenic is 10 µg/L As and runoff concentrations never exceeded this standard (Figure 5.18). The EPA and DEP Primary Drinking Water Standards for nitrate is 10 mg/L NO_3-N and only the 'first flush' from $CaCl_2$-treated roadbeds exceed this standard (Figure 5.19). The EPA and DEP Secondary Drinking Water Standards for sulfate is 250 mg/L SO_4 and only the 'first flush' from $CaCl_2$-treated roadbeds exceed this standard (Figure 5.20). The EPA and DEP Secondary Drinking Water Standards for pH is within 6.5 to 8.5 and most exceedances occurred with the synthetic rainwater tests and during the 'maximum flush' portion of the rain event (Figure 5.21).

Organic Compounds

Dissolved organic compounds were measured as COD (Figure 5.22) and DOC and DRO (Figure 5.23). Taken together, these results demonstrated that organic compounds from OGPWs and calcium chloride brine likely pose minor environmental impacts to receiving streams. In contrast, dissolved organic compounds from organics-based dust suppressants like soybean oil may impact receiving streams. Biodegradable portions of the COD or DOC may create an oxygen demand in the receiving stream that leads to decreased dissolved oxygen concentrations. DRO may exert toxicity on aquatic species in the receiving stream. However, while DRO is operationally-defined as 'diesel', organics derived from soybean oil would not be classified as petroleum hydrocarbons. Organics from soybean oil may be less toxic than organics from petroleum-based products.

COD concentrations in the runoff (Figure 5.22) varied for the different dust suppressants. For soybean oil, COD concentrations were highest in the first flush of runoff (sample number 1) but then peaked again during the maximum flush of runoff (sample numbers 7 and 8). Maximum COD concentrations in the runoff from soybean oil-treated roadbeds ranged from 1,500 – 2,200 mg/L O_2. For soybean oil-treated roadbeds the COD concentrations in the runoff suggest that a portion of the oil was miscible in the first flush and another portion of the oil was mobilized in the maximum flush.

Table 5.2 Maximum concentrations of water quality analytes in collected runoff samples.

Analyte	Max Runoff Concentration					
	O&G PW1	**O&G PW2**	**O&G PW3**	**$CaCl_2$ Brine**	**Soybean Oil**	**Synthetic Rainwater**
EC (mS/cm)	31.3	23.8	30.5	86.1	0.186	0.482
TDS* (mg/L)	19,300	12,100	12,700	57,500	102	68
Ra-226 (pCi/L)	NA	NA	59.6	27.9	NA	28.9
Ra-228 (pCi/L)	NA	NA	42.7	39.2	NA	24.3
Combined Ra (pCi/L)	NA	NA	82.3	47.8	NA	51.5
Chloride (mg/L)	11,80	7,550	10,000	34,300	14	3
Bromide (mg/L)	296	82	134	757	BQL	BQL
Iodide (mg/L)	1.31	1.70	1.92	0.10	0.01	0.06
Nitrate (mg/L)	159	16	42	74	8	11
Sulfate (mg/L)	449	122	301	447	31	33
Calcium (mg/L)	2,200	1,360	1,590	20,700	36	32
Magnesium (mg/L)	402	224	257	310	6	4
Strontium (mg/L)	17	10	32	305	BQL	BQL
Barium (mg/L)	5.09	4.84	18.1	45.9	BQL	0.05
Sodium (mg/L)	4,540	2,730	2,650	310	17	4
Potassium (mg/L)	36	16	32	296	2	2
Lithium (mg/L)	0.24	0.18	1.29	11.2	0.00	0.00
Aluminum (mg/L)	0.08	0.18	0.03	0.14	0.17	0.23
Manganese (mg/L)	0.82	0.41	0.43	1.13	0.05	0.01
Iron (mg/L)	0.11	0.05	0.11	0.80	0.21	0.18
Zinc (mg/L)	0.04	0.03	0.03	0.10	0.02	0.04
Boron (mg/L)	0.08	0.08	0.10	2.37	0.02	0.02
DRO (mg/L)	NA	2.0	35.7	NA	NA	2.4
COD (mg/L)	276	244	182	270	2236	193
DOC (mg/L)	NA	18.7	NA	NA	57.8	10.0
DIC (mg/L)	14.6	14.3	16.7	7.7	31.1	17.7

NA – not analyzed
BQL – below quantification limit

Analyte	O&G PW1	O&G PW2	O&G PW3	$CaCl_2$ Brine	Soybean Oil	Synthetic Rainwater
EC (mS/cm)	31.3	23.8	30.5	86.1	0.186	0.482
TDS* (mg/L)	19,300	12,100	12,700	57,500	102	68
Ra-226 (pCi/L)	NA	NA	59.6	27.9	NA	28.9
Ra-228 (pCi/L)	NA	NA	42.7	39.2	NA	24.3
Combined Ra (pCi/L)	NA	NA	82.3	47.8	NA	51.5
Chloride (mg/L)	11,80	7,550	10,000	34,300	14	3
Bromide (mg/L)	296	82	134	757	BQL	BQL
Calcium (mg/L)	2,200	1,360	1,590	20,700	36	32
Magnesium (mg/L)	402	224	257	310	6	4
Strontium (mg/L)	17	10	32	305	BQL	BQL
Barium (mg/L)	5.09	4.84	18.1	45.9	BQL	0.05
Sodium (mg/L)	4,540	2,730	2,650	310	17	4
Potassium (mg/L)	36	16	32	296	2	2
Lithium (mg/L)	0.24	0.18	1.29	11.2	0.00	0.00

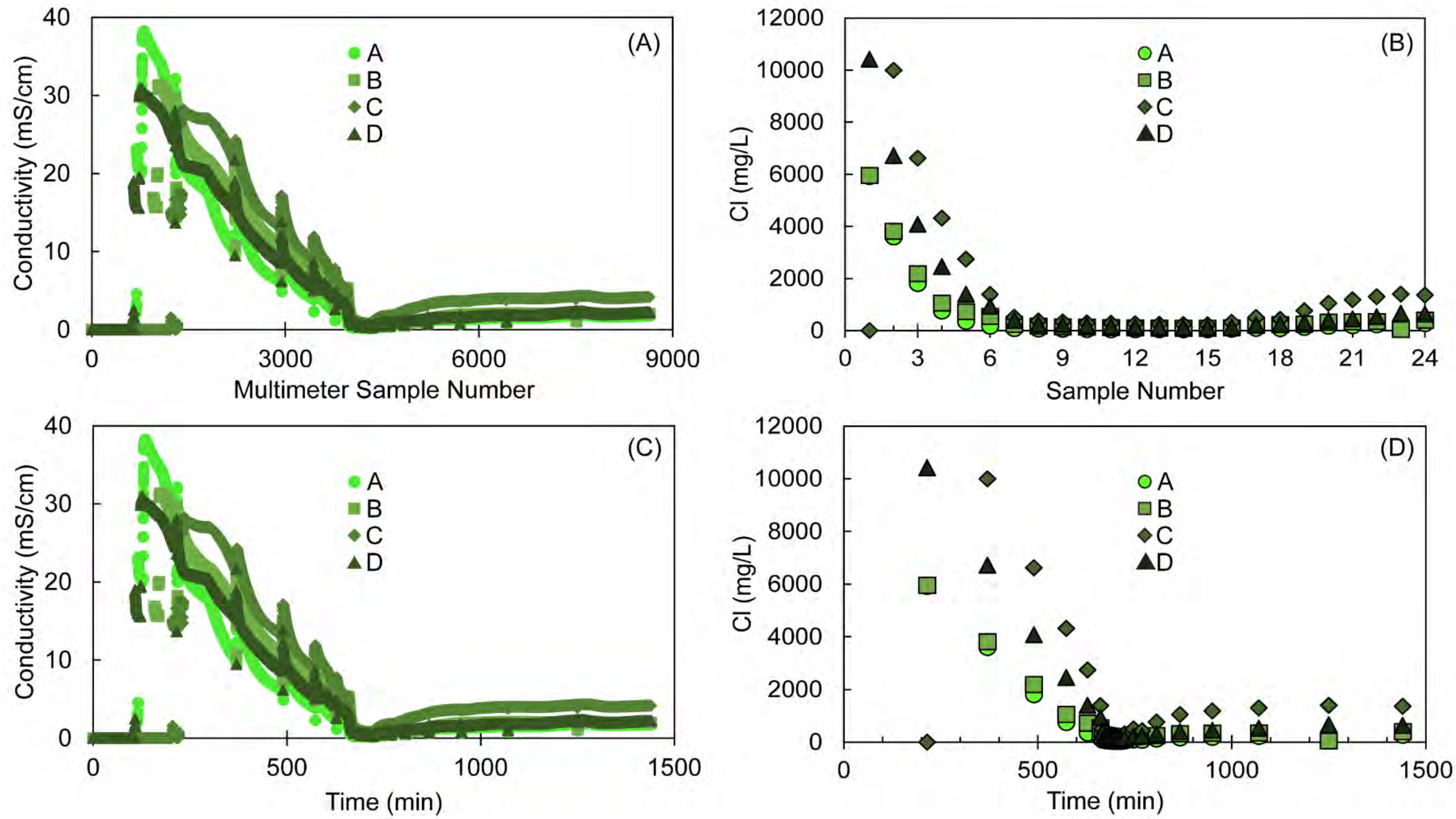

Figure 5.1 Electrical conductivity (A and C) and dissolved chloride concentrations (B and D) measured in runoff from gravel roadbeds treated with Oil & Gas Produced Water 1. Different letters refer to replicate tests. Panels A and C are used to show comparisons between plotting data as a function of sample number versus experimental run time for an analyte recorded every 10-seconds with the Hanna multimeter. Panels B and D are used to show comparisons between plotting data as a function of sample number versus experimental run time for an analyte collected with the ISCO sampler after every 1/24th of the storm volume.

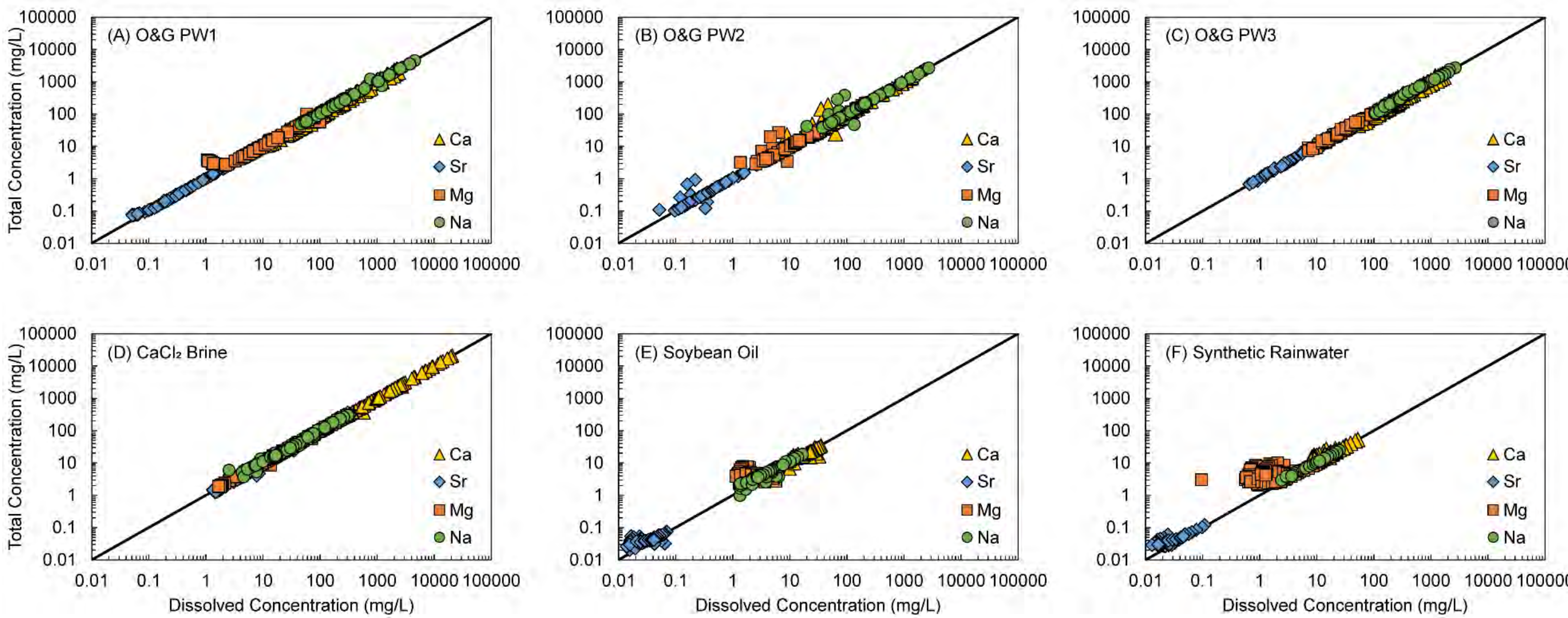

Figure 5.2 Comparisons of dissolved (0.45-µm filtered) and total (unfiltered and digested in nitric + hydrochloric acids) metal concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Solid line in each panel shows 1-to-1 correspondence. For each dust suppressant all results from all replicate tests are combined and different symbols refer to individual base cations.

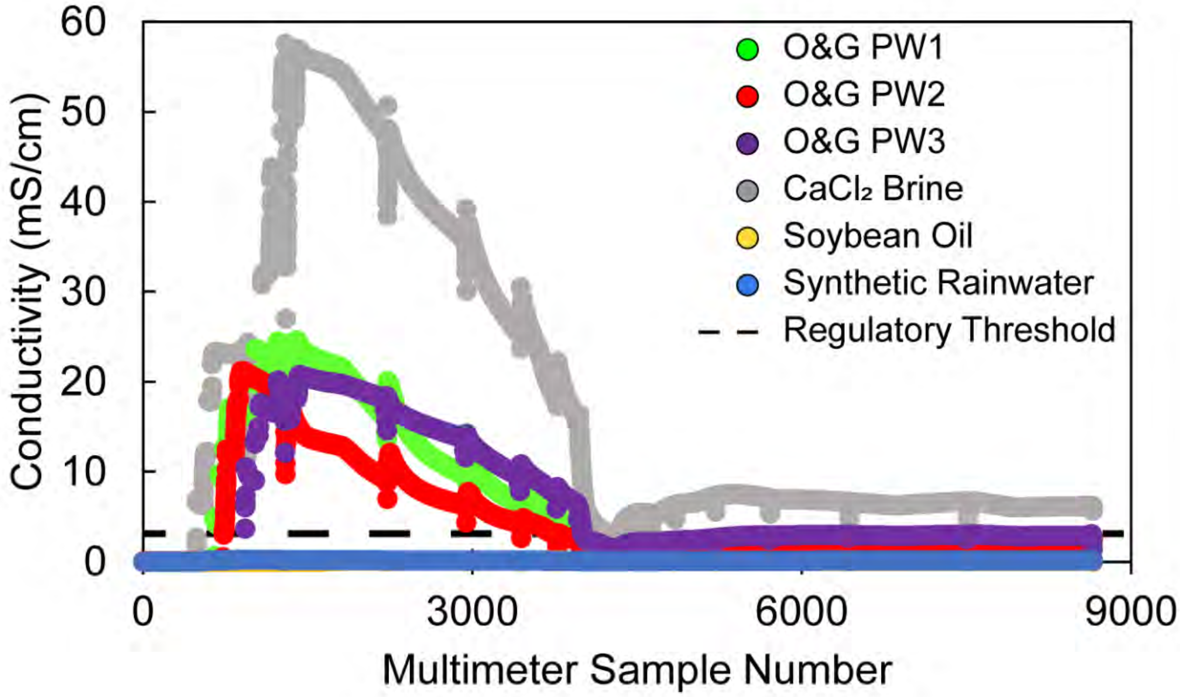

Figure 5.3 Comparisons of electrical conductivity measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Measurements were recorded every 10-seconds of the 24-hour storm. The Regulatory Threshold shown is 3.0 mS/cm from USDA Irrigation Water Quality Guidelines. The chronic aquatic life benchmark value for conductivity in central Appalachian streams is 0.30 mS/cm.

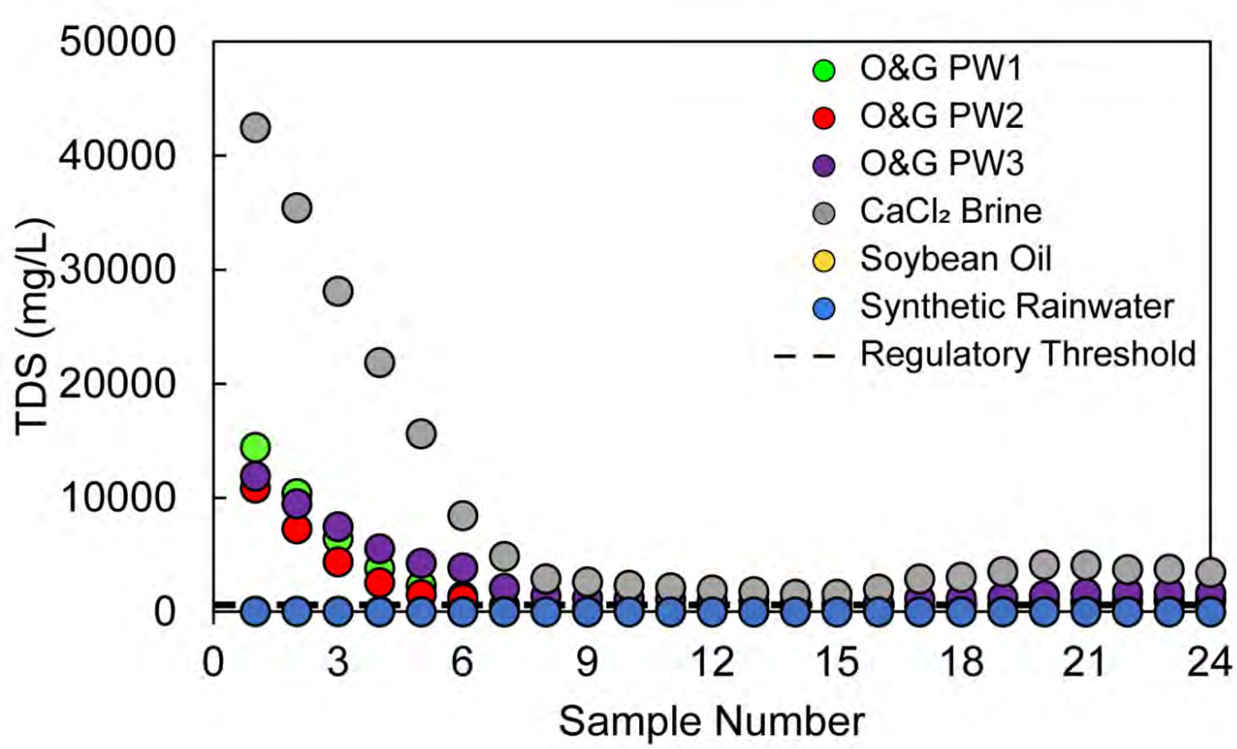

Figure 5.4 Comparisons of total dissolved solids (TDS) concentrations calculated in runoff from gravel roadbeds treated with the six dust suppressants used in this study. TDS was calculated as the sum of measured Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 500 mg/L TDS from EPA and DEP Secondary Drinking Water Standards.

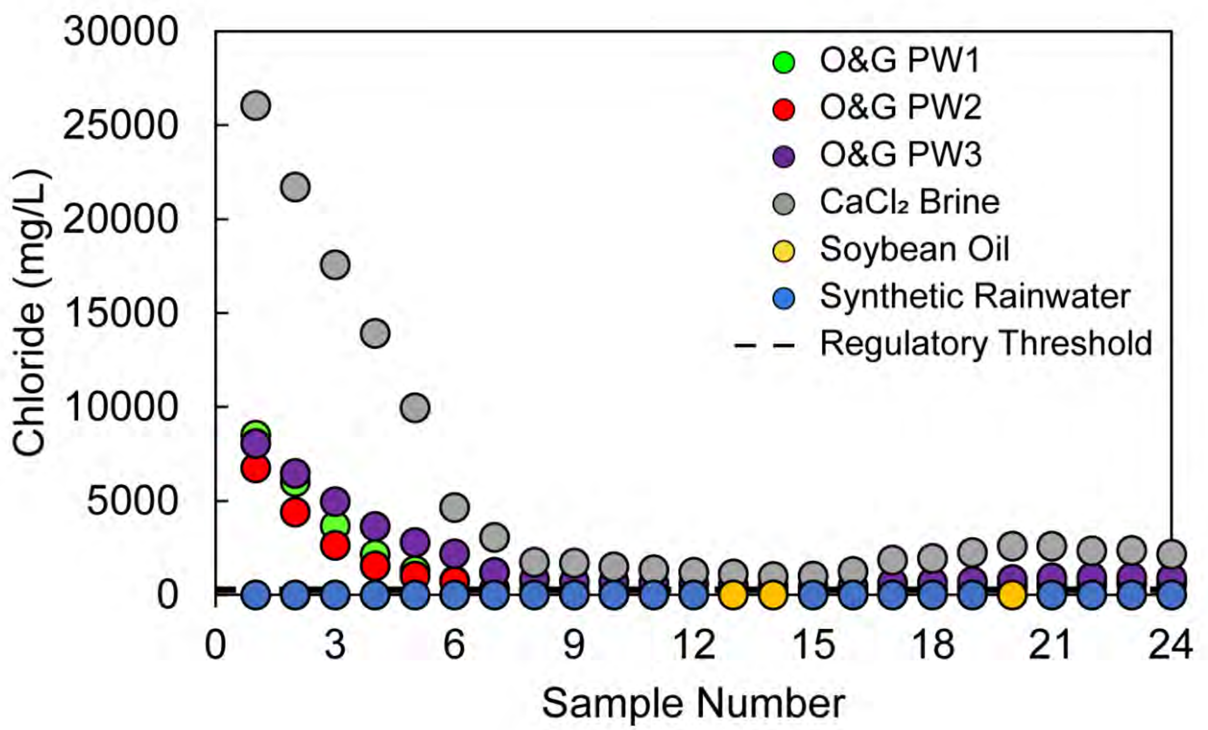

Figure 5.5 Comparisons of dissolved chloride (Cl) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 250 mg/L Cl from EPA and DEP Secondary Drinking Water Standards. The EPA chronic aquatic life benchmark value for chloride is 230 mg/L Cl.

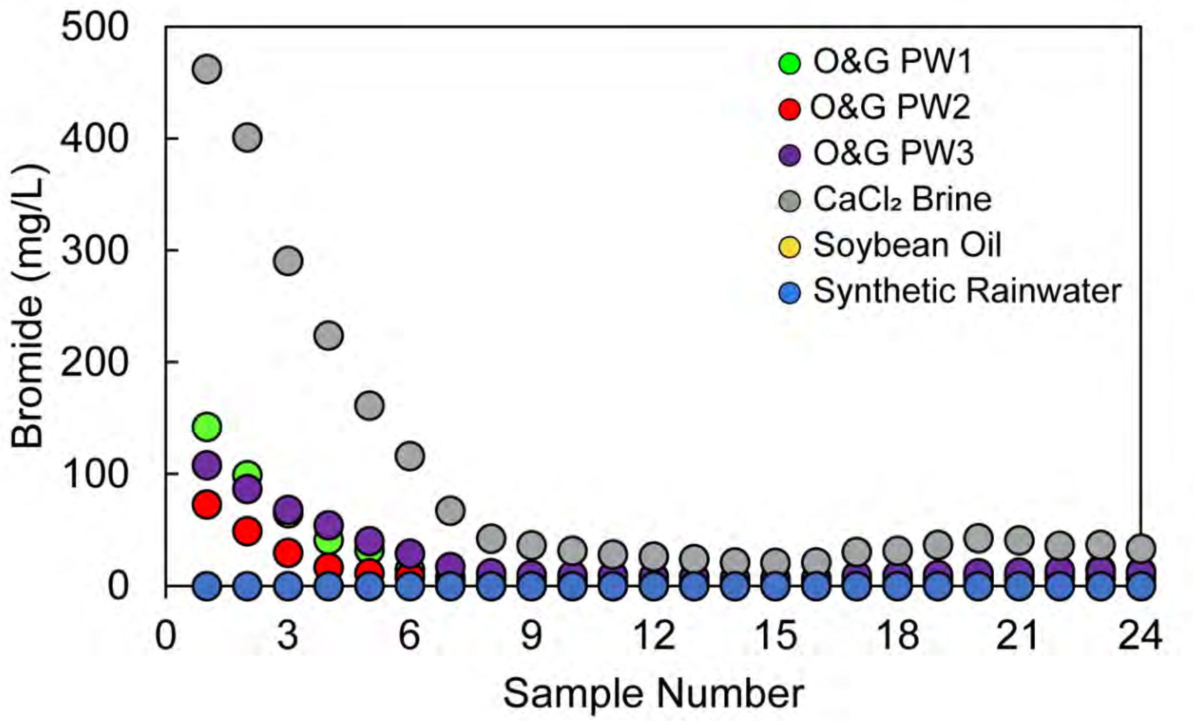

Figure 5.6 Comparisons of dissolved bromide (Br) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples collected after every 1/24th of the storm volume. There are no US regulatory thresholds for bromide, however, bromide leads to formation of disinfection byproducts (DBPs) in drinking water treatment plants. Influent bromide concentrations of 0.050 mg/L Br have shown to lead to increased formation of DBPs (Landis et al., 2016) while concentrations <0.080 mg/L Br may be protective for human health (Wang et al., 2017).

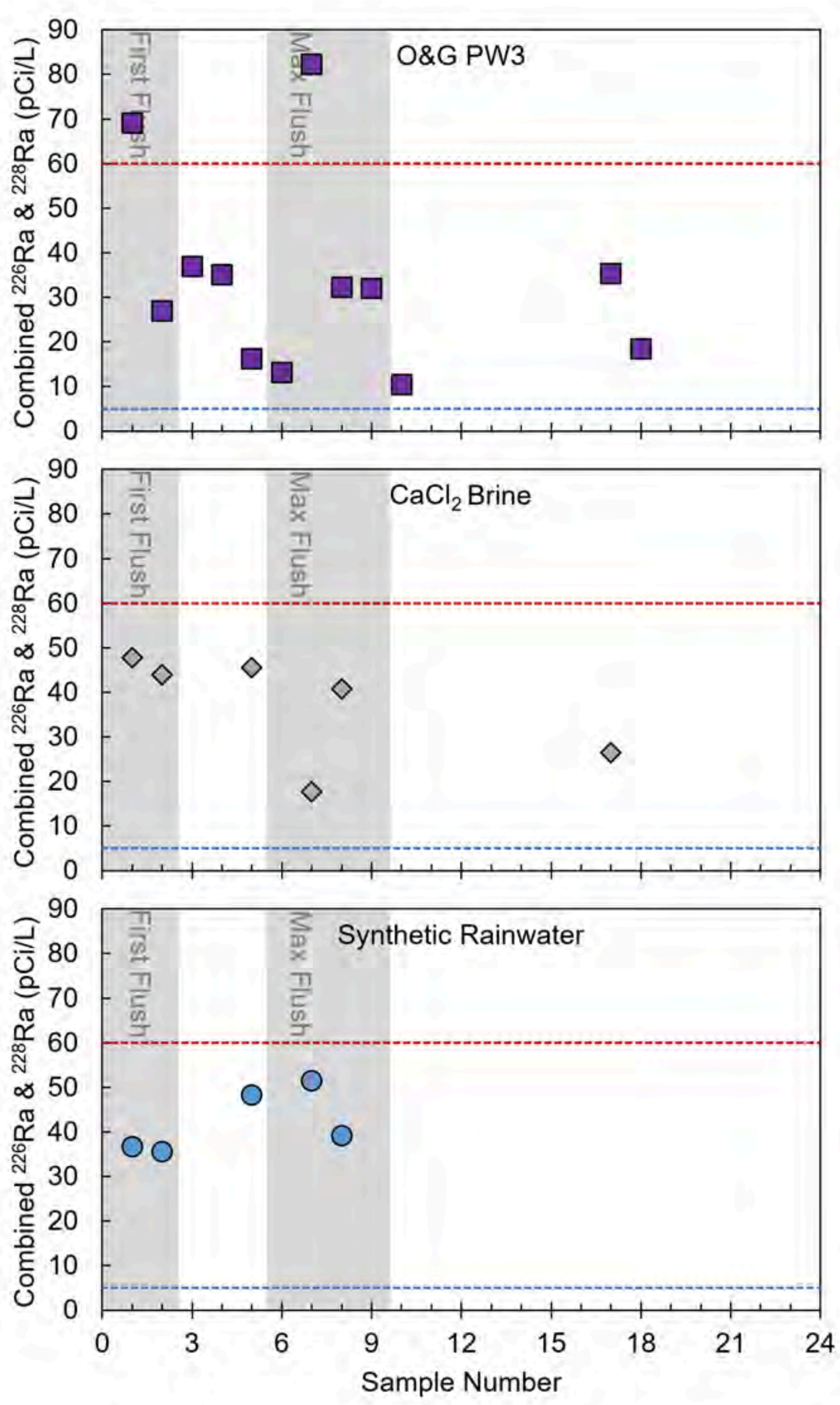

Figure 5.7 Comparisons of combined radium activities (^{226}Ra + ^{228}Ra) measured in runoff from gravel roadbeds treated with three of the dust suppressants used in this study. Results shown are from single tests. (top) Oil & Gas Produced Water 3, (middle) Calcium Chloride Brine, and (bottom) Synthetic Rainwater. Sample numbers 1 and 2 correspond to the first flush of runoff while sample numbers 7 and 8 correspond to the maximum flush of runoff. The NRC industrial wastewater discharge standard for combined radium activity is 60 pCi/L (red dashed line). The EPA and DEP Primary Drinking Water Standard for combined radium activity is 5.0 pCi/L (blue dashed line).

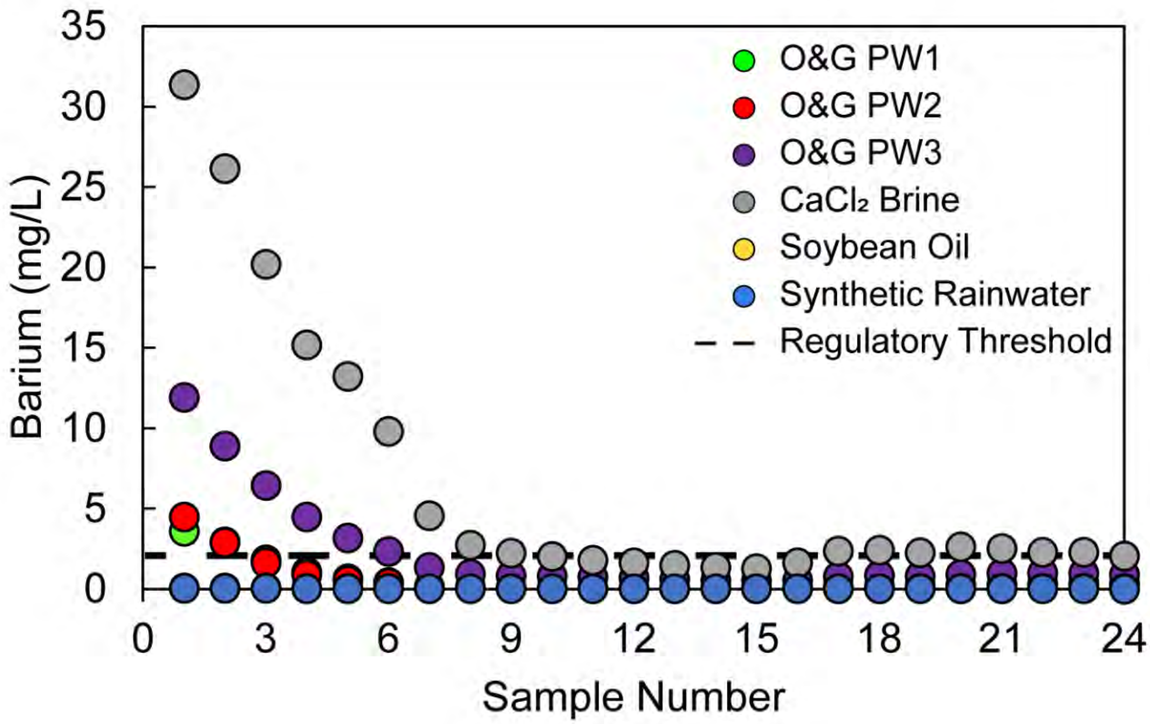

Figure 5.8 Comparisons of dissolved barium (Ba) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 2 mg/L Ba from EPA and DEP Primary Drinking Water Standards.

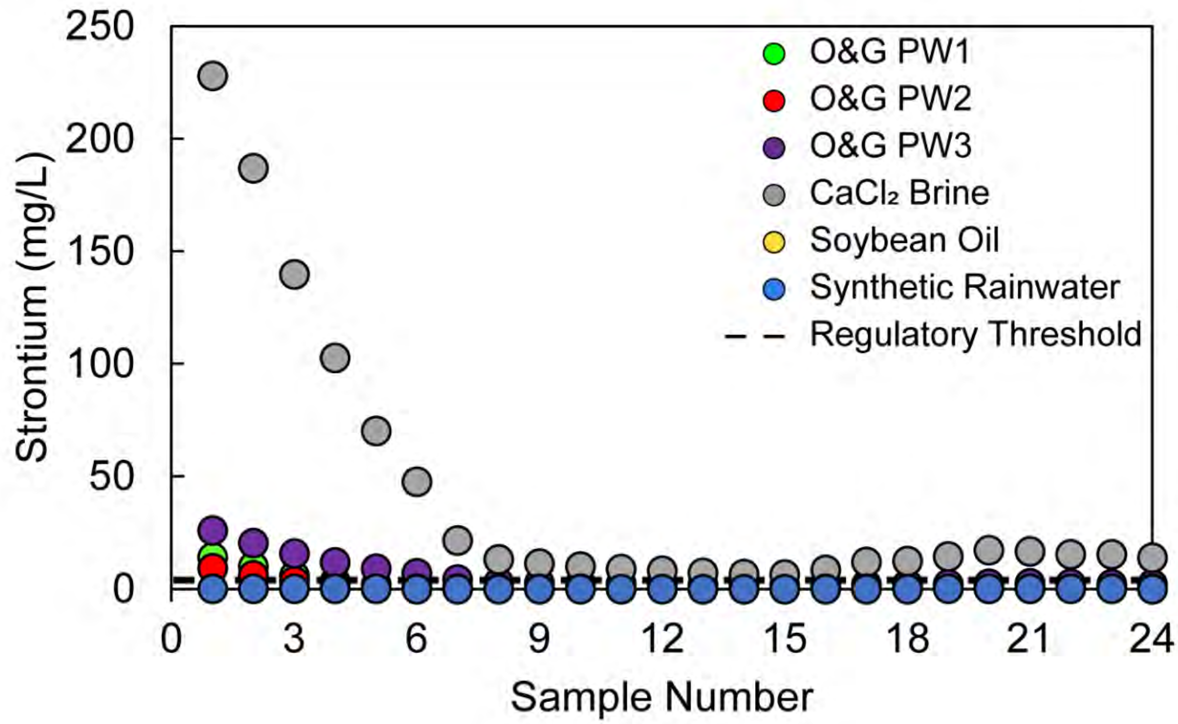

Figure 5.9 Comparisons of dissolved strontium (Sr) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 4 mg/L Sr from USGS Human-Based Screening Levels.

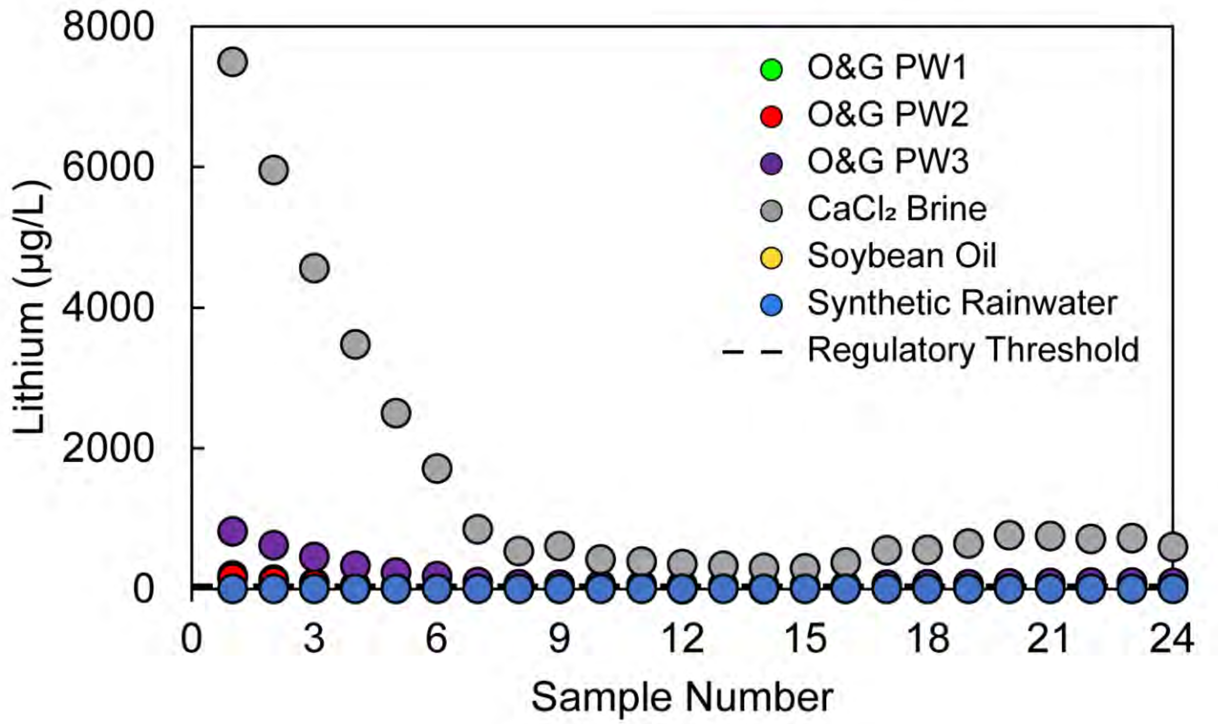

Figure 5.10 Comparisons of dissolved lithium (Li) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 0.01 mg/L Li (= 10 µg/L) from USGS Human-Based Screening Levels.

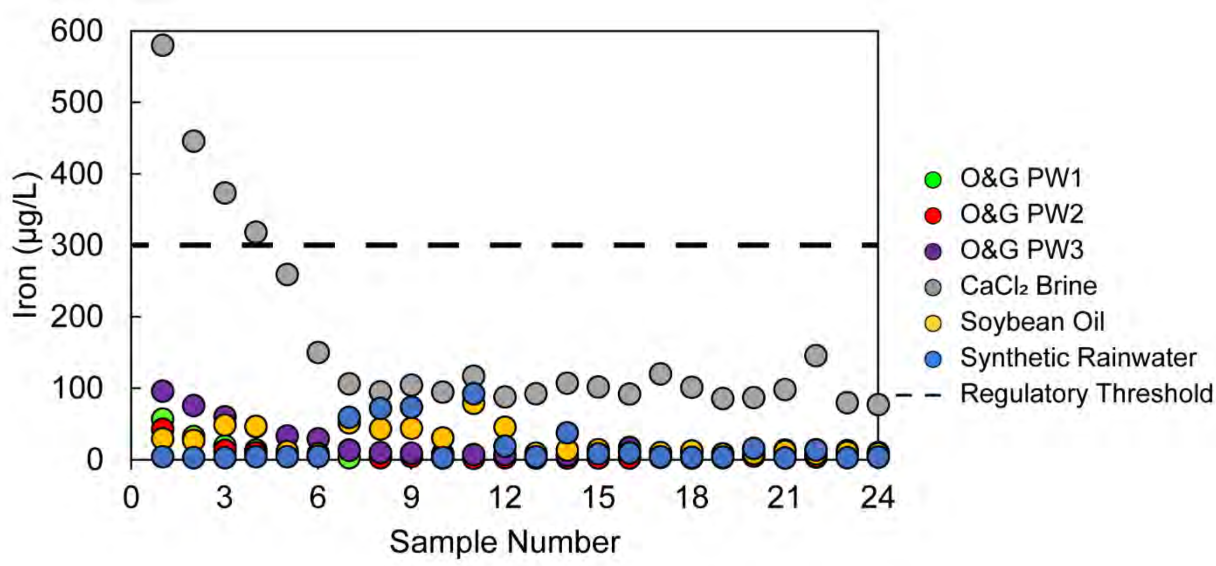

Figure 5.11 Comparisons of dissolved iron (Fe) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 0.3 mg/L Fe (= 300 µg/L) from EPA and DEP Primary Drinking Water Standards.

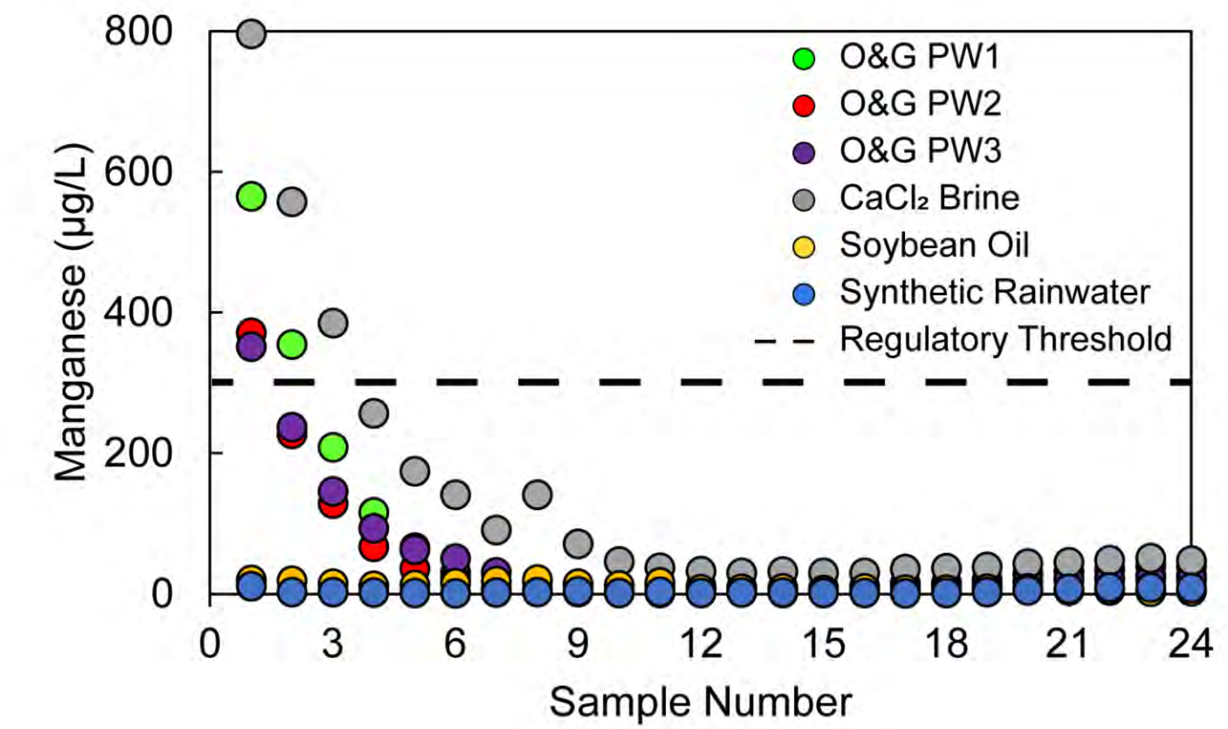

Figure 5.12 Comparisons of dissolved manganese (Mn) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 0.3 mg/L Mn (= 300 µg/L) from DEP Regulated Substances in Groundwater Standards. The EPA and DEP Secondary Drinking Water Standards is 50 µg/L Mn.

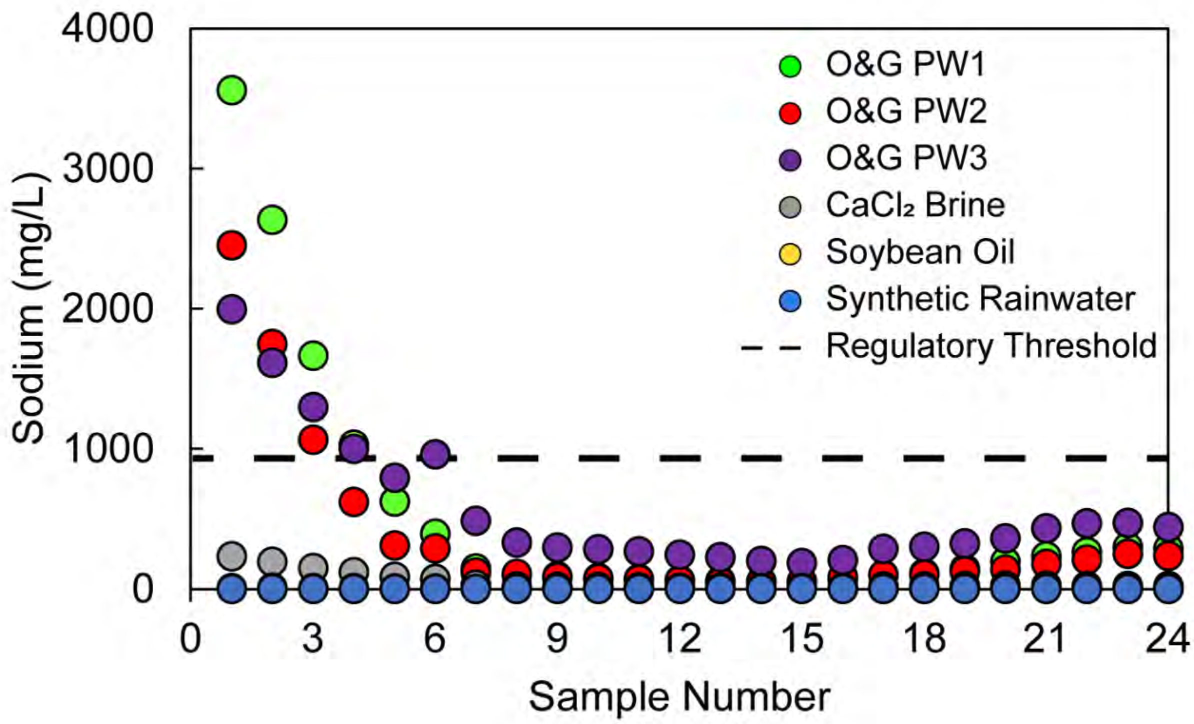

Figure 5.13 Comparisons of dissolved sodium (Na) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 920 mg/L Na from USDA Irrigation Water Quality Guidelines. The EPA Drinking Water Health Advisories for lifetime exposures is 20 mg/L Na.

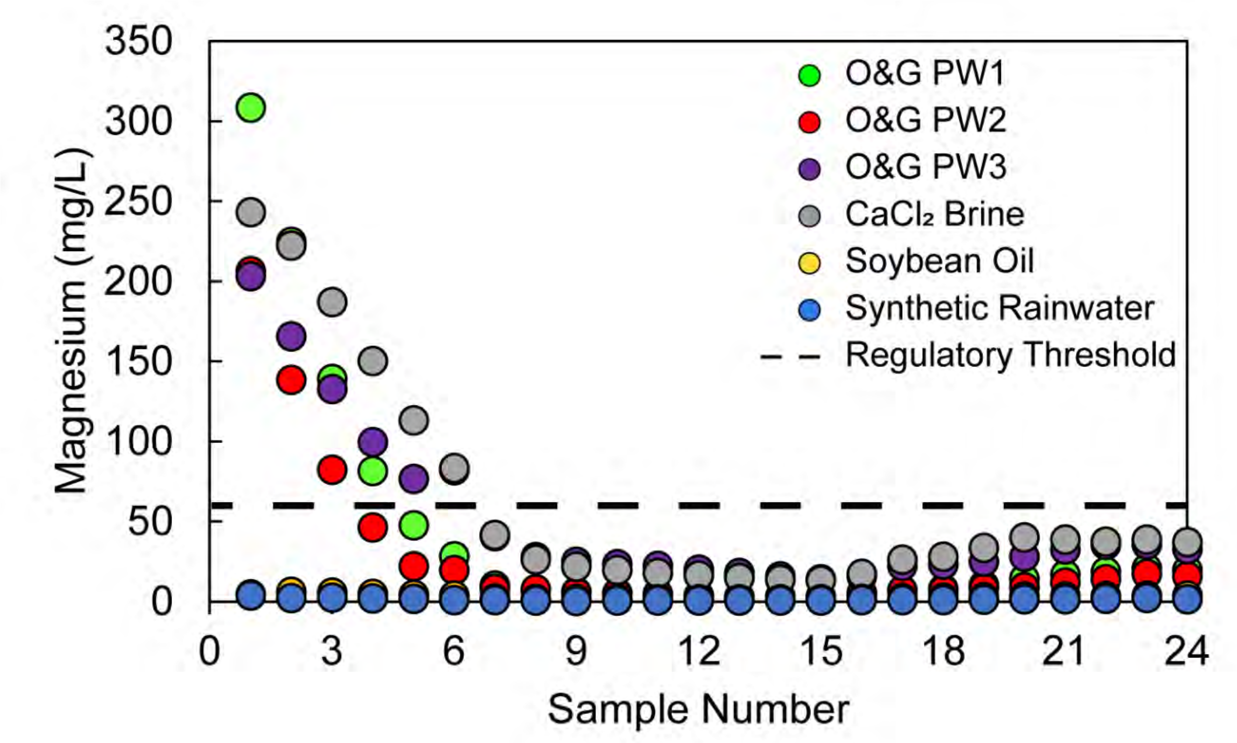

Figure 5.14 Comparisons of dissolved magnesium (Mg) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 61 mg/L Mg from USDA Irrigation Water Quality Guidelines.

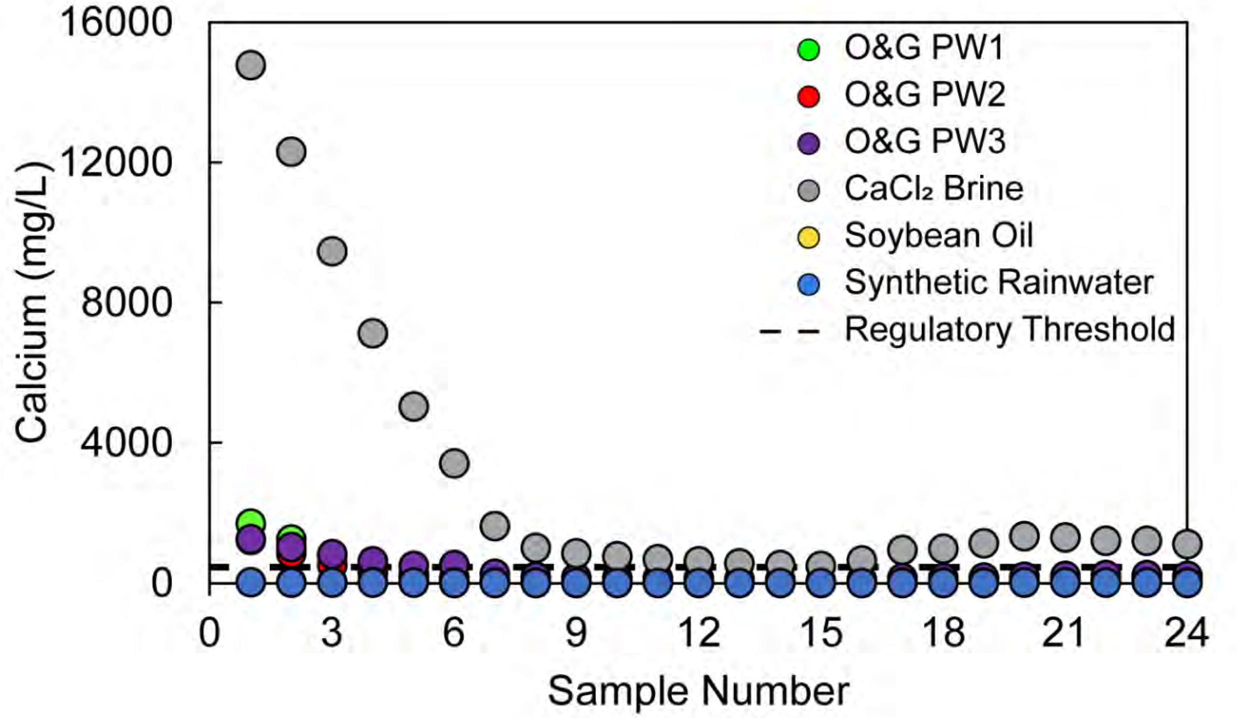

Figure 5.15 Comparisons of dissolved calcium (Ca) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 401 mg/L Ca from USDA Irrigation Water Quality Guidelines.

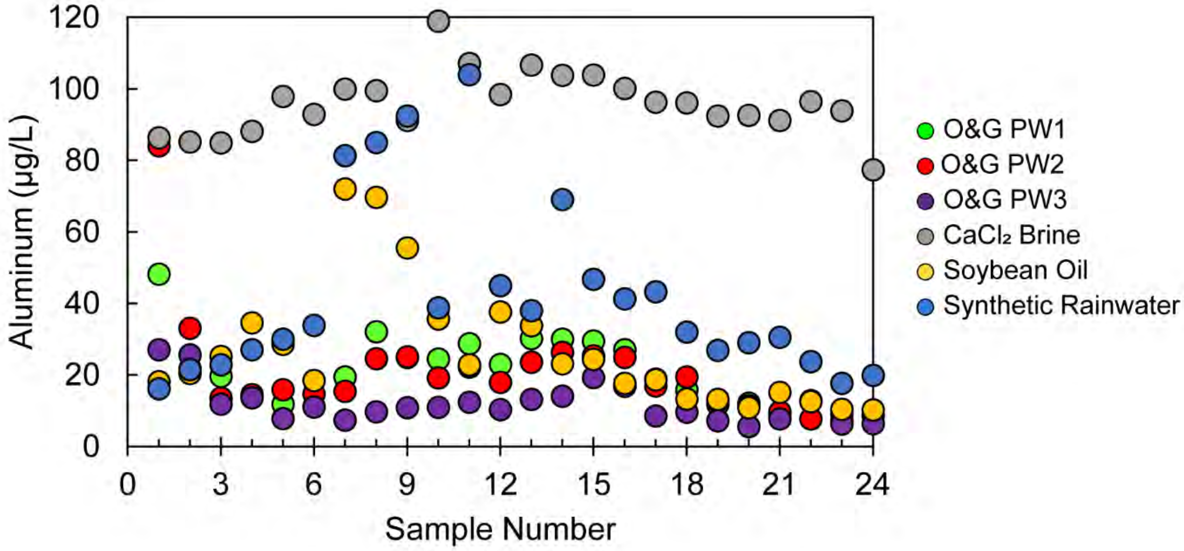

Figure 5.16 Comparisons of dissolved aluminum (Al) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The EPA and DEP Primary Drinking Water Standards range from 50 to 200 μg/L Al.

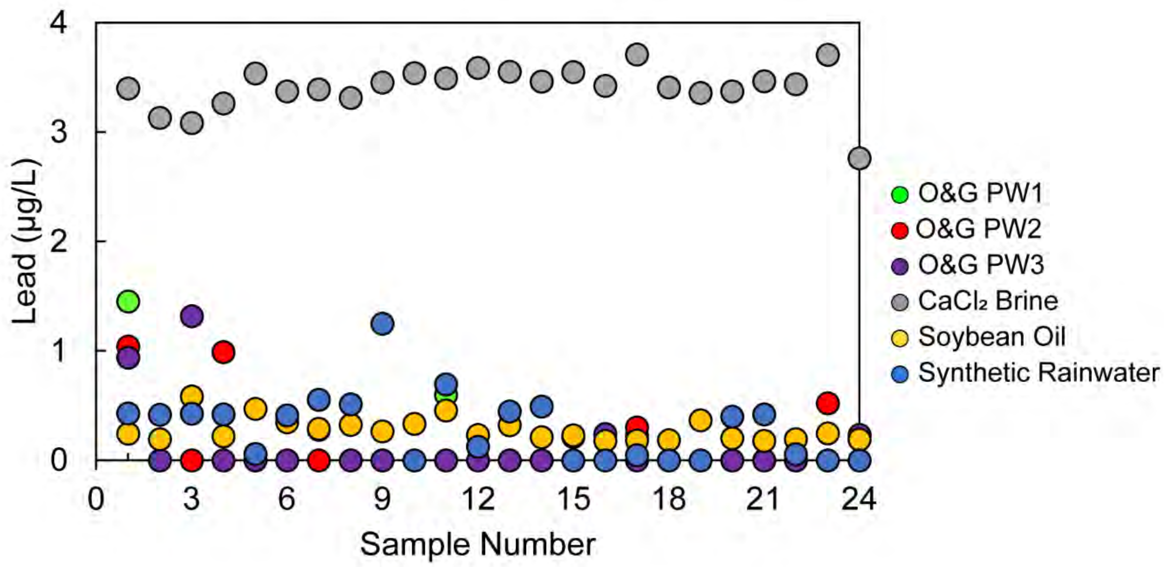

Figure 5.17 Comparisons of dissolved lead (Pb) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The EPA and DEP Primary Drinking Water Standards for lead is 0.015 mg/L Pb (= 15 µg/L).

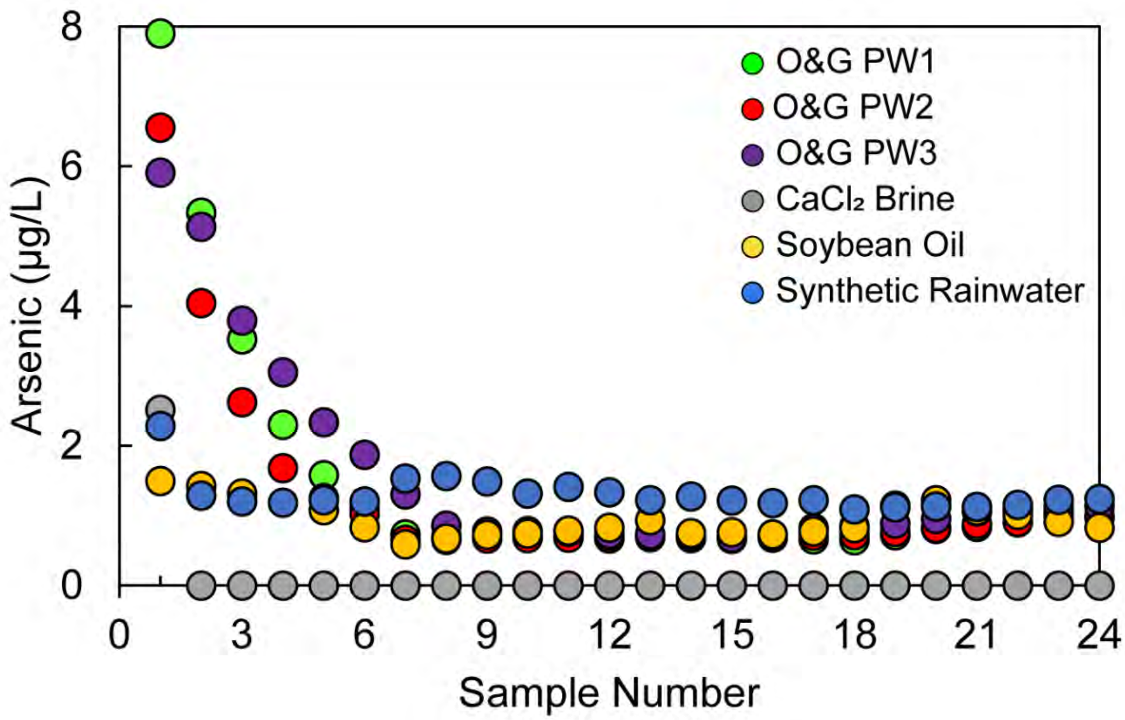

Figure 5.18 Comparisons of dissolved arsenic (As) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The EPA and DEP Primary Drinking Water Standards for arsenic is 0.01 mg/L As (= 10 µg/L).

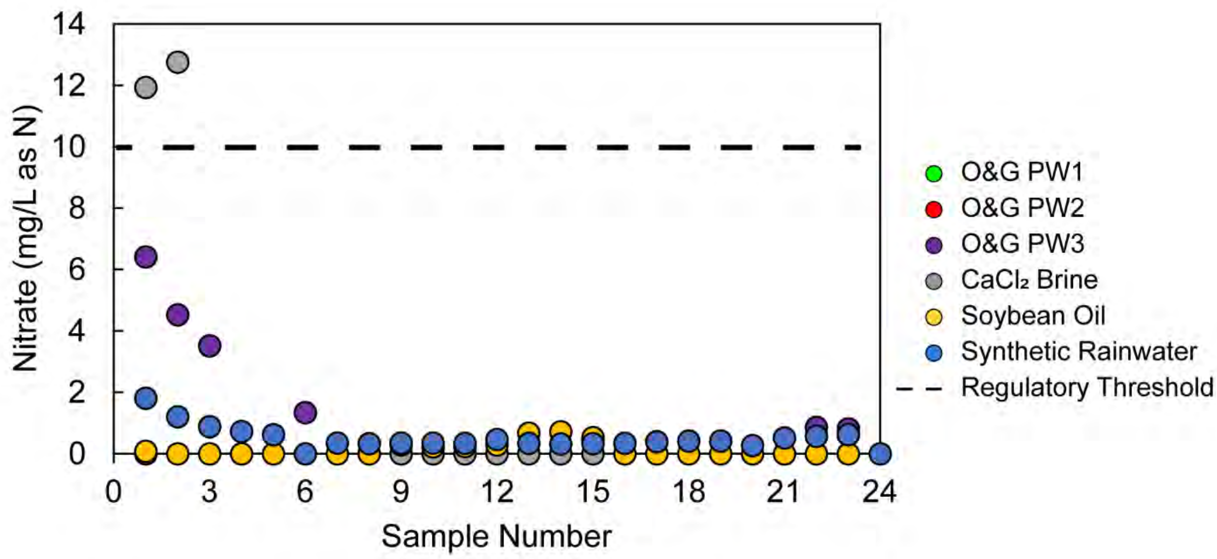

Figure 5.19 Comparisons of dissolved nitrate (NO_3^-) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 10 mg/L NO_3-N from EPA and DEP Primary Drinking Water Standards.

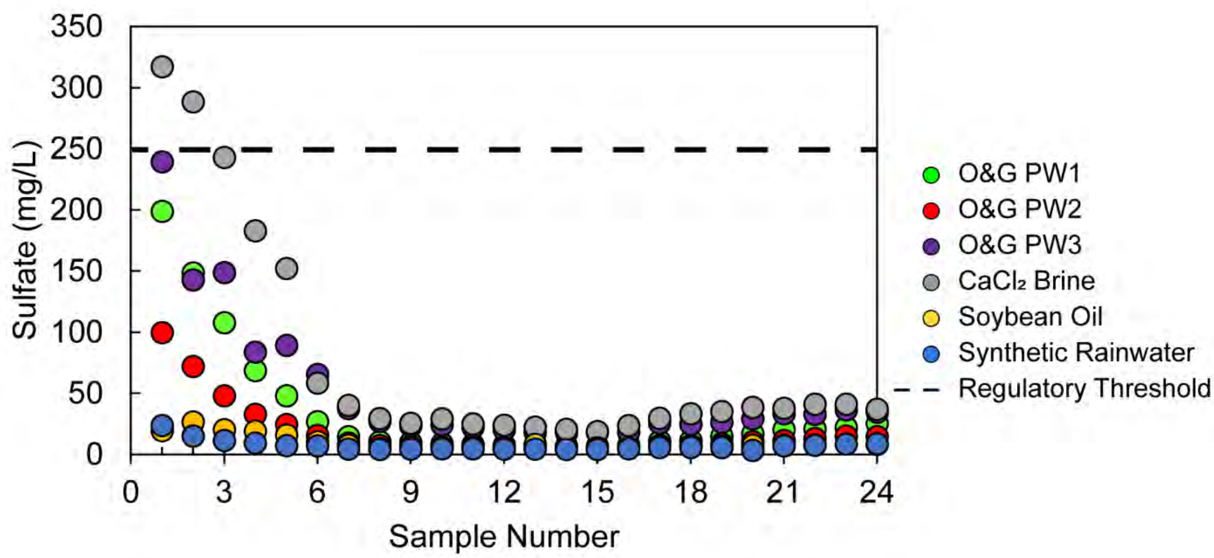

Figure 5.20 Comparisons of dissolved sulfate (SO_4^{2-}) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume. The Regulatory Threshold shown is 250 mg/L SO_4 from EPA and DEP Secondary Drinking Water Standards.

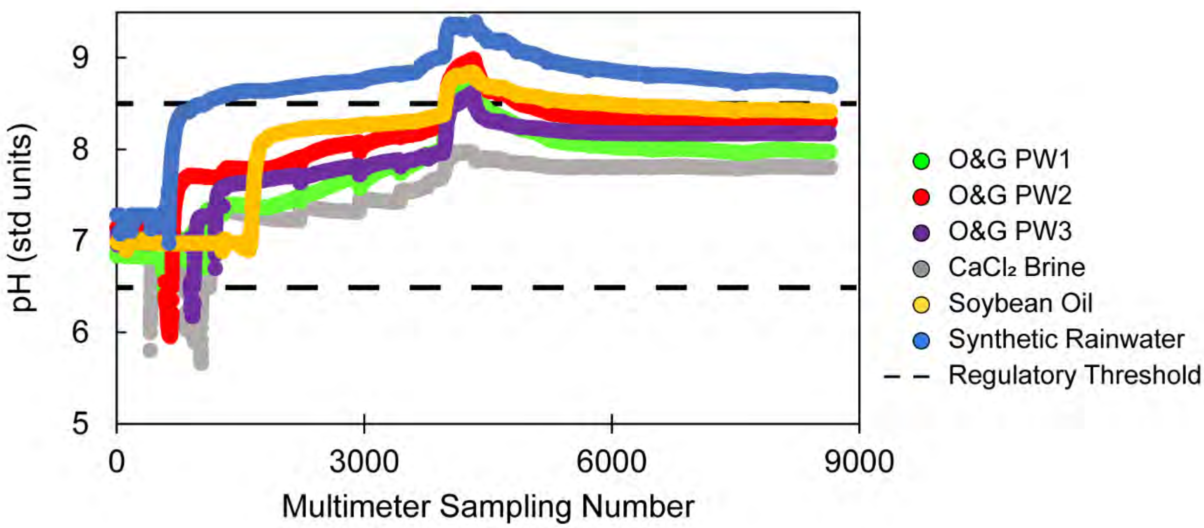

Figure 5.21 Comparisons of pH measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Measurements were recorded every 10-seconds of the 24-hour storm. The Regulatory Thresholds shown are pH 6.5 to pH 8.5 from EPA and DEP Secondary Drinking Water Standards.

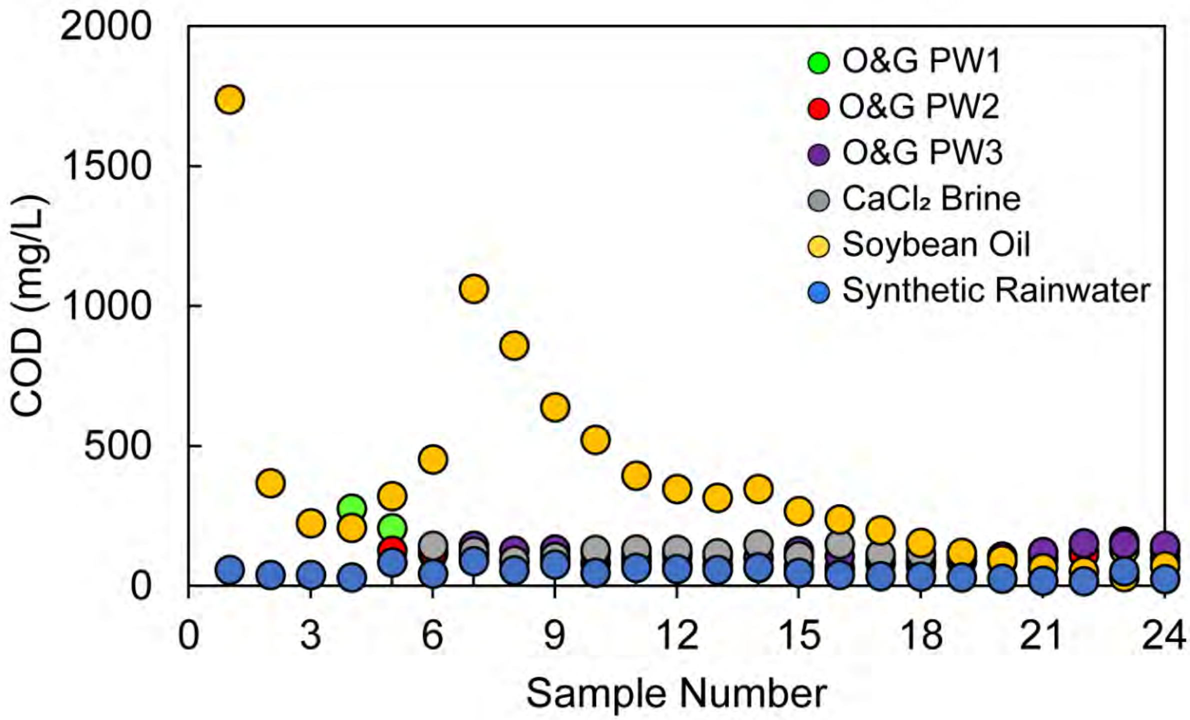

Figure 5.22 Comparisons of chemical oxygen demand (COD) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples were collected after every 1/24th of the storm volume.

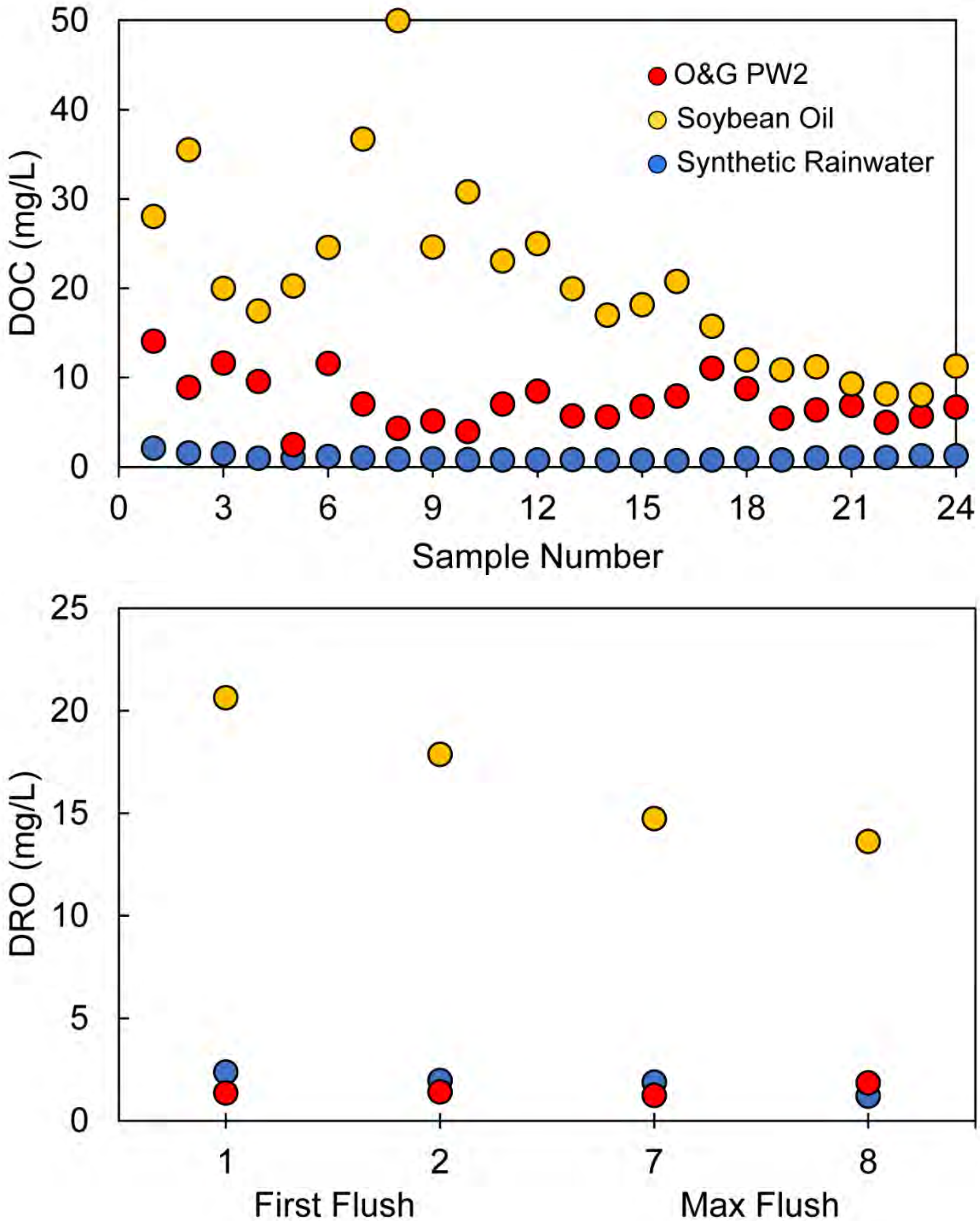

Figure 5.23 Comparisons of dissolved organic carbon (DOC) and diesel range organics (DRO) concentrations measured in runoff from gravel roadbeds treated with three of the six dust suppressants used in this study. Results shown are averaged from replicate tests for each dust suppressant except for single measurements for synthetic rainwater.

5.3 Comparisons of final roadbed concentrations

Constituent concentrations retained in the roadbeds were calculated based on mass balances or directly measured (radium and DRO) at the conclusion of the rainfall-runoff experiments. Elemental mass applied to the roadbed was calculated based on the measured concentration in the dust suppressants (Table 5.1) multiplied by the total volume of dust suppressant applied to the road. Elemental mass flushed off the road was calculated based on the measured concentrations in the runoff samples multiplied by the incremental volume of each sampling interval (equal to $1/24^{th}$ of the total storm volume using Equation (2). Elemental mass retained in the roadbed was calculated by difference according to (Equation (3)):

$$\text{Retained mass} = \text{Applied mass} - \text{Flushed mass} \tag{3}$$

Elemental mass leached out of the roadbed was defined for elements measured in runoff samples that were not measured in the applied suppressant. In this case, leached mass was calculated based on the measured concentrations in the runoff samples multiplied by the incremental volume of each sampling interval.

Based on relatively low activities of combined radium measured in the roadbeds at the conclusion of the rainfall-runoff experiments (Figure 5.24), especially compared to the control conditions measured with synthetic rainwater, most of the radium applied to the roadbeds with the dust suppressants was flushed off in the runoff. The highest radium activity measured in roadbed samples was collected from a roadbed treated with O&G PW3. This measured activity was slightly above the solid-phase combined radium activity limit of 5 pCi/g for handling the material as a radioactive waste.

Diesel range organics (DRO) were measured in roadbed samples collected from the gravel pile and from roadbeds treated with synthetic rainwater, O&G PW2, and soybean oil (Figure 5.25). Elevated concentrations of DRO were only detected in the roadbeds treated with soybean oil.

While chloride concentrations were elevated in runoff samples from roadbeds treated with calcium chloride and OGPWs (Figure 5.5), masses of chloride were retained in the roadbeds at the conclusion of the rainfall-runoff experiments (Figure 5.26). Similar results were obtained with bromide suggesting that the continued flushing of both chloride and bromide could occur with subsequent rainfalls. Sulfate and nitrate were retained to even greater extents than chloride and bromide. Sulfate (Figure 5.20) and nitrate (Figure 5.19) concentrations measured in the runoff were not elevated relative to regulatory standards. It is expected that subsequent rain events would produce even lower runoff concentrations of these constituents.

Sodium was retained in the roadbeds treated with OGPWs (Figure 5.27). As noted above, sodium tends to destabilize dirt and gravel roads. Retention of sodium from OGPWs may increase the duration of destabilization. Calcium tended to be better flushed from roadbeds treated with OGPWs or calcium chloride. Leached concentrations of magnesium and barium were only measured with calcium chloride-treated roadbeds. This leaching may be promoted by elevated TDS runoff that increases mineral solubility.

Lead and iron in OGPWs were completely retained in the roadbeds (Figure 5.28). consistent with Tasker et al. (2018). calcium chloride, SB and SRW promoted the leaching of arsenic and manganese. Elevated TDS in calcium chloride would enhance solubility of these elements. Organic-metal complexes formed by SB could enhance solubility of these elements. A potentially lower pH during the 'resting' of the roadbed could have enhanced solubility of these elements.

Roadbed aggregate was collected prior to application of dust suppressants, following application of dust suppressants, and following the 24-hour rainfall event. The road aggregate samples were sieved to isolate the silt and clay size fraction (<45 um) that could be mobilized as dust or TSS. Combined radium activity of road aggregate samples prior to the start of all tests was ca. 4 pCi/gram. Following application of O&G PW 1 and O&G PW3 the <45-µm size fractions contained higher activities, reflecting the added radium from the dust suppressants. However, following the rain event, the small size fractions of the road aggregate were again 4 pCi/g. This suggests that following a 24-hour 2-year rain event, the radium activity that was added with a dust suppressant will be flushed off the gravel road. This is consistent with the results of the runoff that showed elevated activity in the runoff samples of O&G PW3. Road aggregate treated with both synthetic rainwater and calcium chloride brine showed reduced radium activity relative to untreated road aggregate. Following the rain event, the activity of the road aggregate in the synthetic rainwater experiment decreased relative to the initial pre-treatment concentration. This result is consistent with the rainfall runoff experiment that showed that radium was mobilized to the runoff from leaching of the road aggregate.

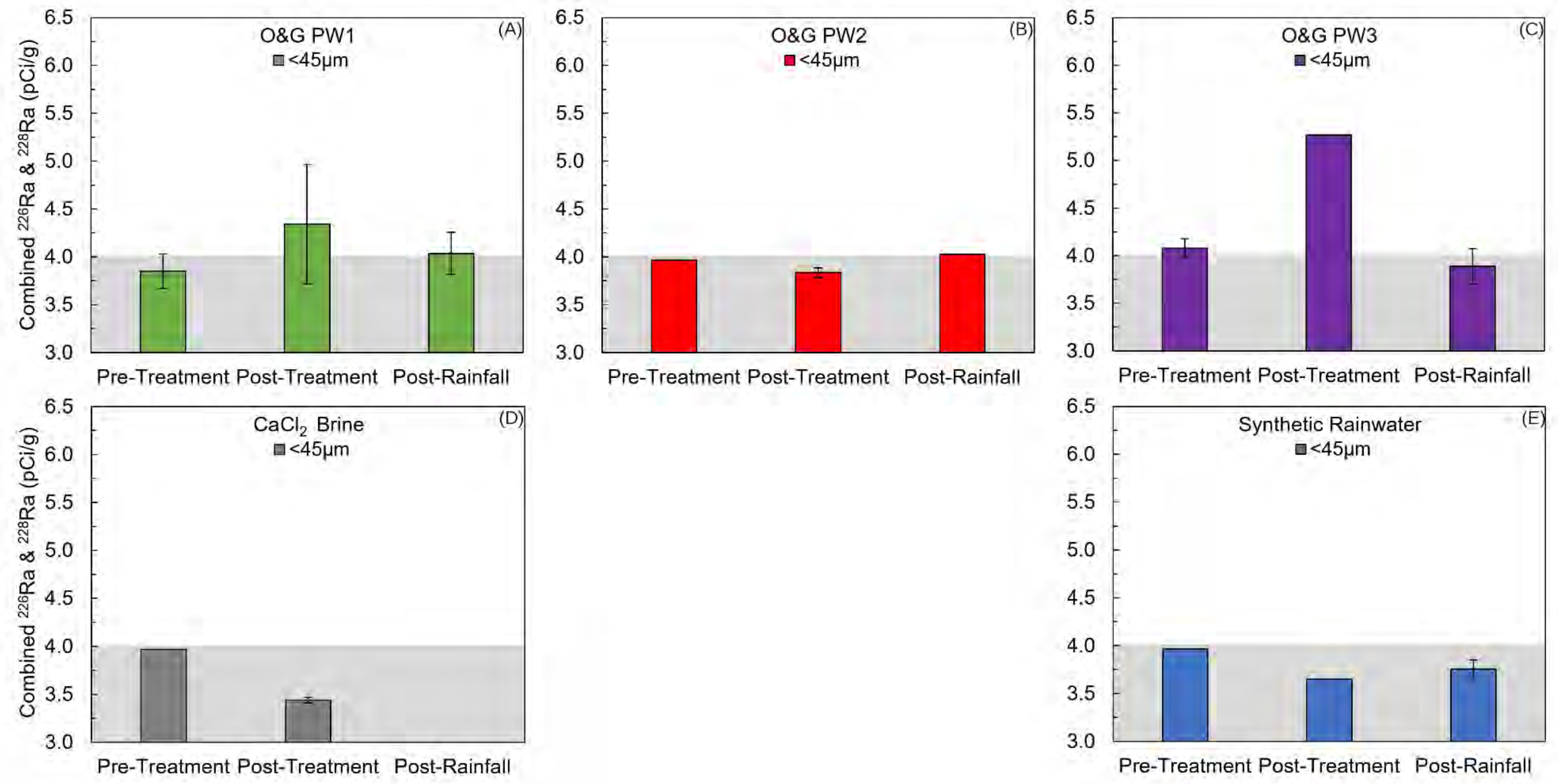

Figure 5.24 Comparisons of activities of combined radium measured in gravel roadbed samples collected after the rainfall-runoff tests for roadbeds treated with five of the dust suppressants used in this study – A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, and E) Synthetic Rainwater. Results are shown for triplicate samples collected from the roadbed of one replicate test. Samples were sieved to smaller than 45 microns before activity measurements. Note the results in relation to the grey shaded background which represents the average activity of untreated roadbed material, 3.997 pCi/g. No post-rainfall samples were collected for the Calcium Chloride Brine tests.

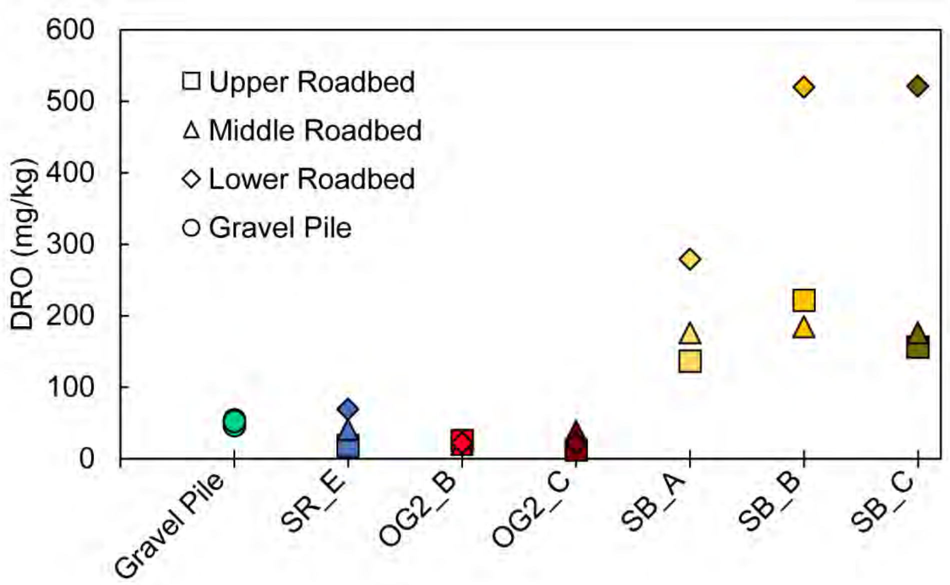

Figure 5.25 Comparisons of concentrations of diesel range organics (DRO) measured in gravel roadbed samples collected after the rainfall-runoff tests. The Gravel Pile was located outside the CITEL facility. SR_E refers to Synthetic Rainwater replicate E. OG2_B and OG2_C refer to Oil & Gas Produced Water 2 replicates B and C. SB_A, SB_B, and SB_C refer to Soybean Oil replicates A, B and C. Results are shown for triplicate samples collected from the roadbed of one replicate test.

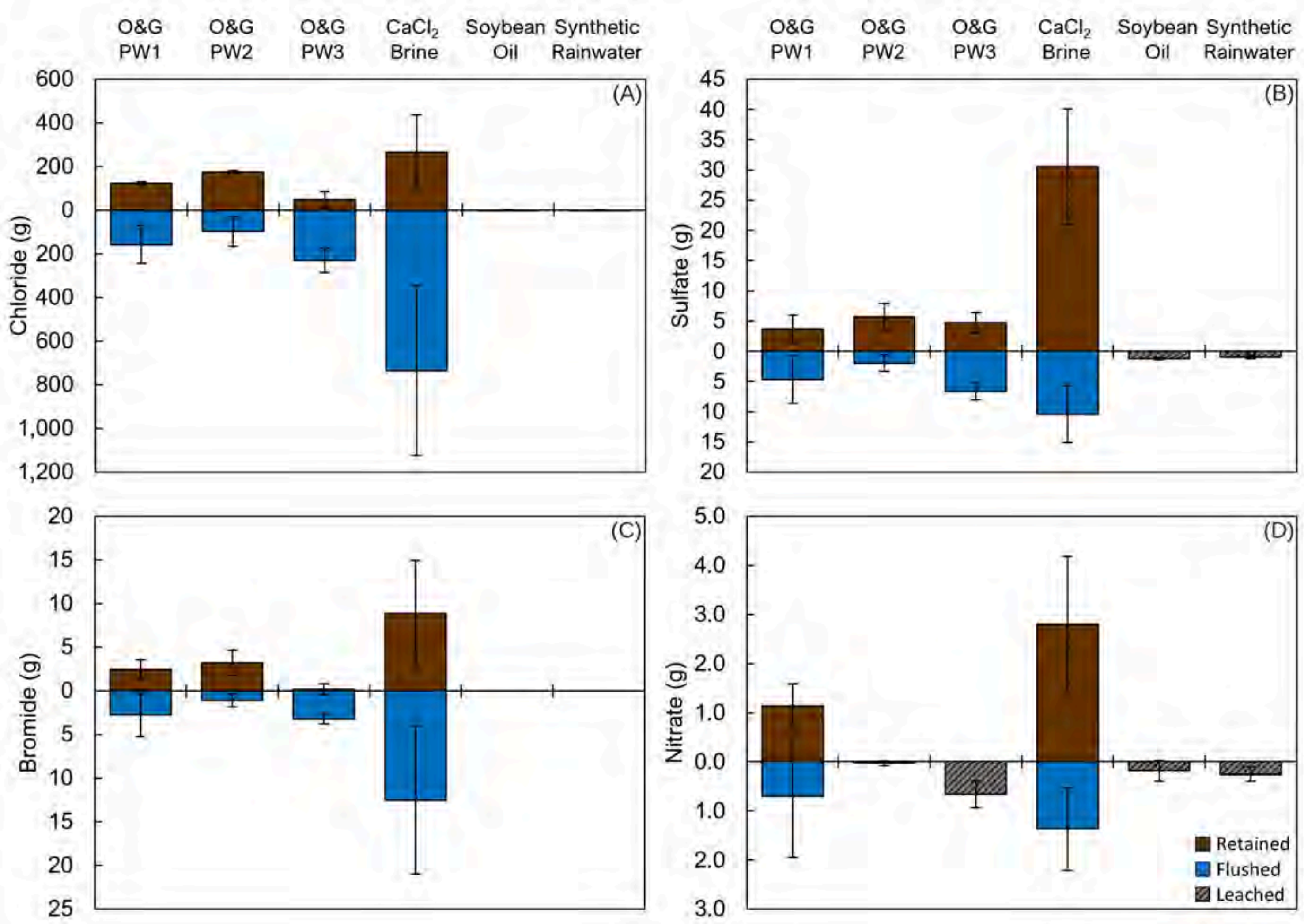

Figure 5.26 Mass balance analyses for anions retained, flushed, or leached from gravel roadbeds treated with six different dust suppressants. A) Chloride, B) Sulfate, C) Bromide, and D) Nitrate. Flushed masses were calculated from runoff concentrations. Retained masses were calculated according to Equation 3. Leached masses were mobilized from the roadbeds.

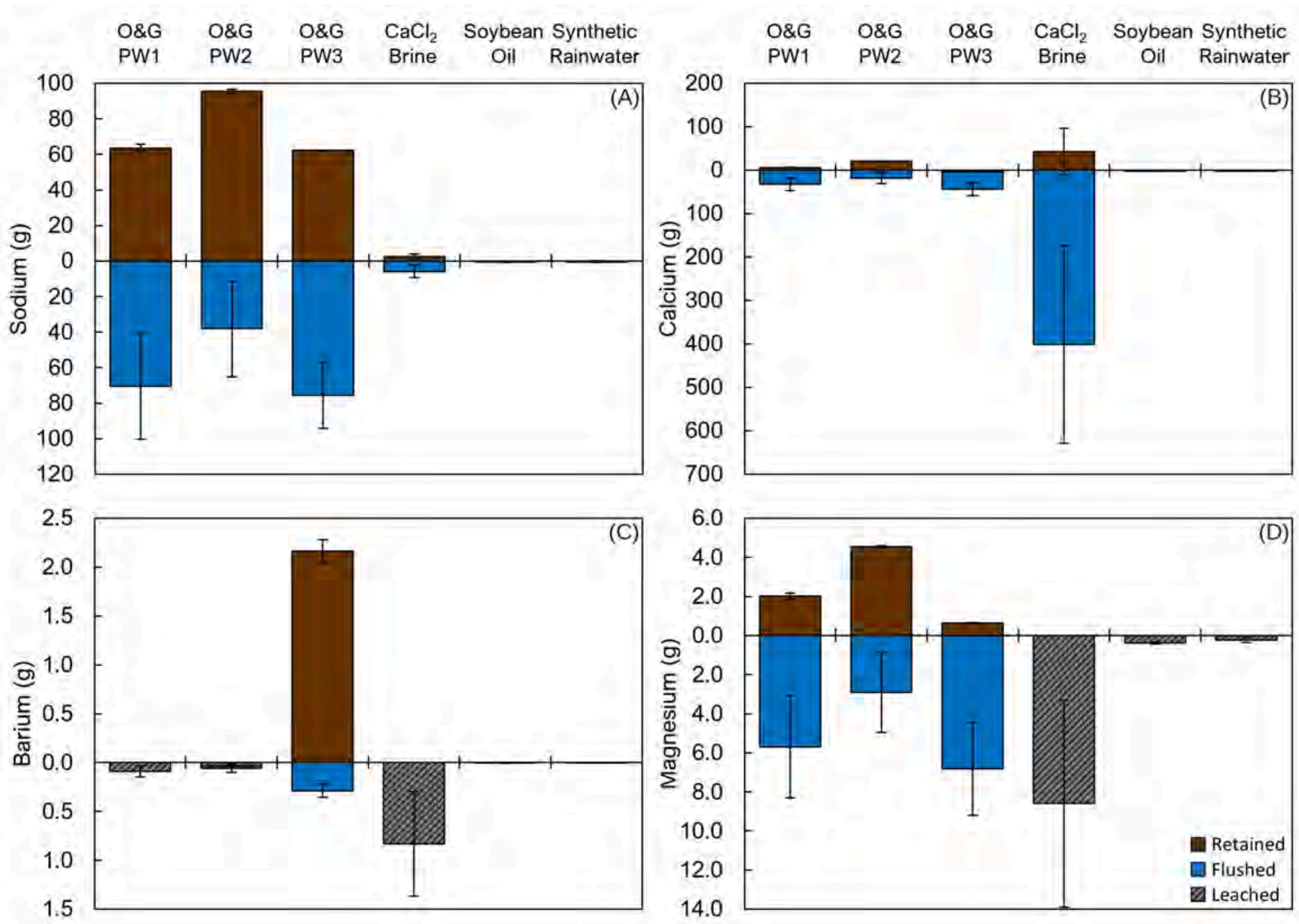

Figure 5.27 Mass balance analyses for cations retained, flushed, or leached from gravel roadbeds treated with six different dust suppressants. A) Sodium, B) Calcium, C) Barium, and D) Magnesium. Flushed masses were calculated from runoff concentrations. Retained masses were calculated according to Equation 3. Leached masses were mobilized from the roadbeds.

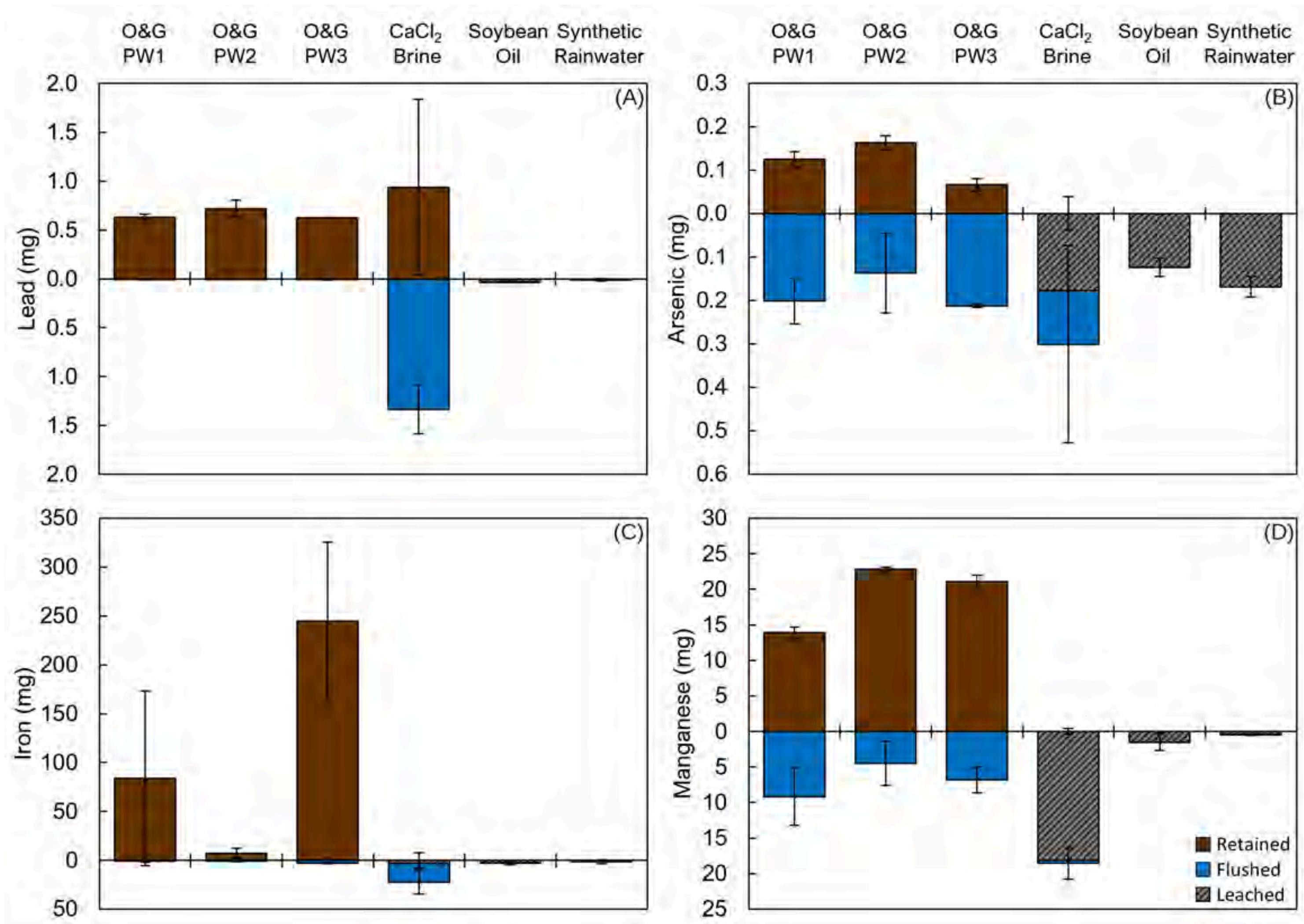

Figure 5.28 Mass balance analyses for trace elements retained, flushed, or leached from gravel roadbeds treated with six different dust suppressants. A) Lead, B) Arsenic, C) Iron, and D) Manganese. Flushed masses were calculated from runoff concentrations. Retained masses were calculated according to Equation 3. Leached masses were mobilized from the roadbeds.

5.4 Comparisons of dust suppression efficacy

Results from dust generation tests are summarized in Table 5.3. Eight dust suppressants (including synthetic rainwater) were tested under two conditions that mimic summer relative humidity (RH) conditions expected in northwestern Pennsylvania in dry sunny conditions (20% RH) or dry shaded conditions (50% RH). Dust concentrations were measured and recorded every second over a three-minute period. The average maximum PM_{10} (AM PM_{10}) dust concentrations were averaged from the last minute of the tests.

Under dry sunny conditions (20% RH), dust generated from road aggregate treated with the OGPWs saturated the dust sampler's detector (Figure 5.29A). Under these conditions the AM PM_{10} was reported as >400 mg/m^3 (Table 5.3), equivalent to the upper detection limit of the test. Under these conditions, OGPWs were no more effective than synthetic rainwater with respect to controlling dust generation. Dust generated from road aggregate treated with calcium chloride brines ranged from 4.9 to 13 mg/m^3. Dust generated from road aggregate treated with soybean oil was 0.20 mg/m^3. Low AM PM10 concentrations demonstrate that calcium chloride brines and soybean oil can suppress dust. Elevated AM PM10 concentrations demonstrate that OGPWs and synthetic rainwater cannot suppress dust under these dry sunny conditions.

Under dry shaded conditions (50% RH), dust generated from road aggregate treated with the OGPWs did not saturate the dust sampler's detector (Figure 5.29B). Dust generated from road aggregate treated with the three OGPWs was 340, 385, and 313 mg/m^3 as compared to >400 mg/m^3 for road aggregate treated with synthetic rainwater. Dust generated from road aggregate treated with calcium chloride brines ranged from 0.11 to 0.75 mg/m^3. Dust generated from road aggregate treated with soybean oil was 0.60 mg/m^3. The OGPWs and calcium chloride brines controlled dust better under higher relative humidity. However, even under higher relative humidity, two of the three OGPWs were little more effective than synthetic rainwater with respect to controlling dust generation and all the OGPWs were substantially less effective than calcium chloride brines and soybean oil.

Total suspended solids (TSS) in runoff samples may reflect efficacy of the dust suppressants to stabilize the roadbed (Figure 5.30). Unlike EC (Figures 5.3) and dissolved chloride (Figures 5.5), TSS peaked during the maximum flush period. The maximum rainfall intensity and maximum water velocities discharging off the roadbed at this time likely led to the maximum scour of the roadbed. Higher concentrations of TSS in runoff samples may reflect lesser efficacy for roadbed stabilization.

Calcium chloride brine was shown to be the most effective dust suppressant for roadbed stabilization based maximum TSS concentrations in the runoff. Calcium chloride brine was the only dust suppressant that significantly reduced TSS in runoff samples compared to the synthetic rainwater control ($p < 0.1$, Table 5.3, Figure 5.30). This result is consistent with widespread marketing and use of calcium chloride as a soil stabilizer and additive for dirt and gravel road full-depth reclamation projects. All the other dust suppressants produced maximum TSS concentrations not significantly different than synthetic rainwater. None of the OGPWs greatly improved road stabilization or decreased dust generation as compared to synthetic rainwater.

From previous lab-scale testing, the sodium adsorption ratio (SAR; Equation 1) used in combination with the TDS has proven useful in predicting a brine's efficacy for suppressing dust on dirt and gravel roads (Stallworth et al., 2020). SAR represents the equivalent ratio of monovalent sodium cations to divalent calcium and magnesium cations. This ratio is important because divalent cations are capable of bridging negatively-charged clay particles together and physically stabilizing gravel roads. In contrast, sodium cations tend to disperse clays and destabilize gravel roads. Calcium chloride, magnesium chloride, and sodium chloride salts are also hygroscopic, meaning they adsorb water from the humidity in the air. Moist roads tend to produce less dust. Based on the TDS concentrations of the OGPWs used in this study (ca. 82,000 mg/L TDS), brines with SAR values greater than about 3 are predicted to be relatively ineffective as dust suppressants. Therefore, based only on SAR values (Table 5.3) and compared to synthetic rainwater, one would predict that only the calcium chloride brine would be effective and that the OGPWs would be ineffective. SAR is not applicable to soybean oil because it is a nonaqueous phase liquid that suppresses dust by other mechanisms.

Table 5.3 Summary of efficacy metrics for roadbed stabilization and dust suppression for dust suppressants used in the current study and other commercial brines.

Dust Suppressant	**Max [TSS] (mg/L) Mean**	**±std**	**n**	**AM PM10 (mg/m^3)# 20% RH**	**AM PM10 (mg/m^3)# 50% RH**	**SAR**
O&G PW1	4580 A*	703	4	>400	341	68.6
O&G PW2	5327 A	107	3	>400	386	68.1
O&G PW3	4543 A	1083	3	>400	313	69.3
$CaCl_2$ Brine (Fisher)	2915 B	586	4	5.8	0.11	1.4
Commercial Brine 1	n.t		-	3.4	0.53	17.4
Commercial Brine 2	n.t.		-	9.1	0.82	2.1
Soybean Oil	4457 A	633	3	0.2	0.60	--
Synthetic Rainwater	4350 A	1521	3	>400	>400	--

* Different letters denote statistically significant values based on unpaired, one-tailed Student T-tests at $p \leq 0.1$.

AM PM10 = average maximum 10-µm particulate matter measured according to Stallworth et al. (2021). Maximum measurable dust concentration was 400 mg dust/m^3 air.

n.t. = not tested in rainfall-runoff experiment

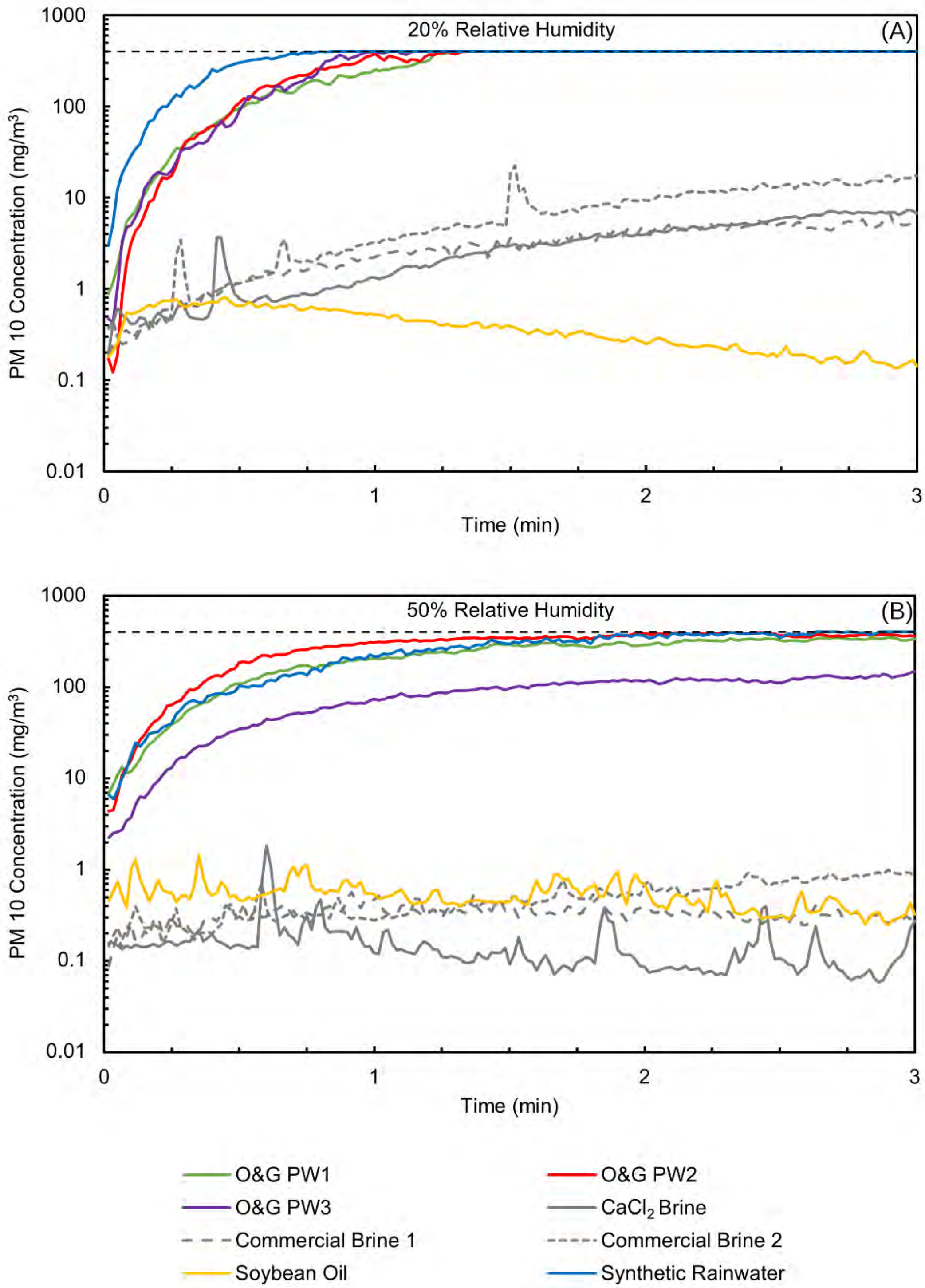

Figure 5.29 Comparison of average dust generated (PM 10 in mg/m^3) over time for dust suppressants used in this study. A) Tests conducted at 20% relative humidity. B) Tests conducted at 50% relative humidity. Results are presented for replicate dust tests. Note the instrument detection limit of 400 mg/m^3 represented by the horizontal dashed black line.

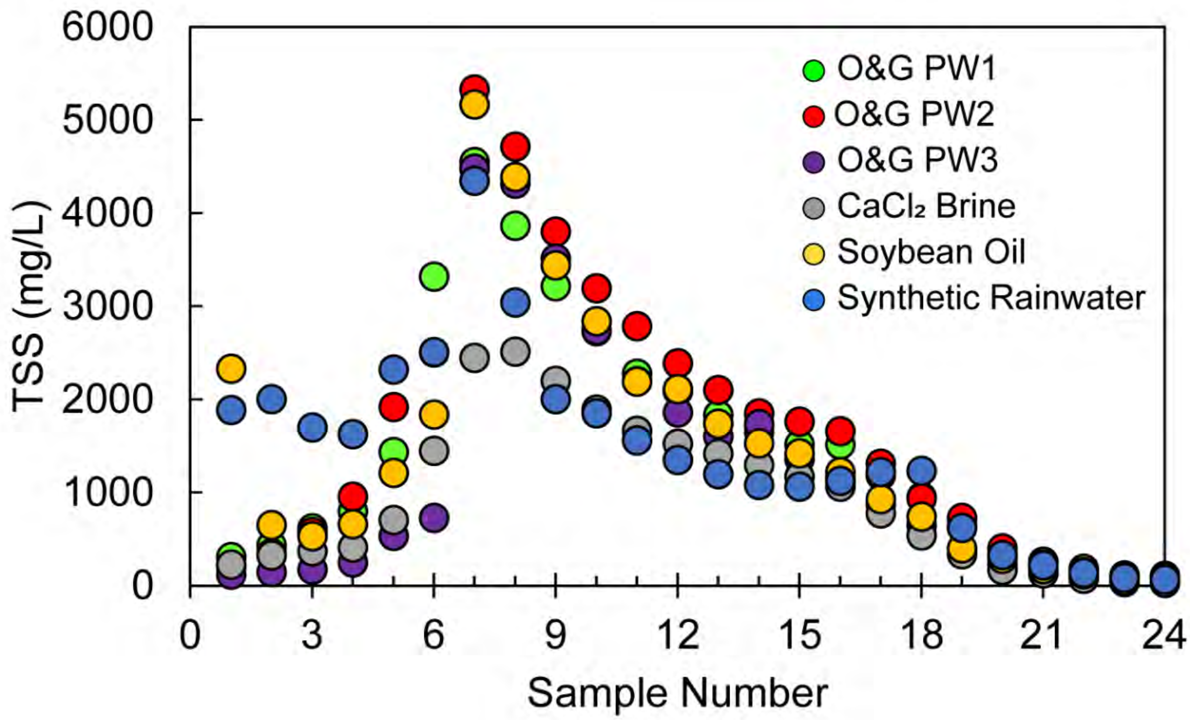

Figure 5.30 Comparisons of total suspended solids (TSS) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. Results shown are averaged from all replicate tests for each dust suppressant. Samples collected after every 1/24th of the storm volume.

6. CONCLUSIONS

A series of laboratory-scale experiments were conducted to evaluate the environmental impacts of several dust suppressants, including oil and gas produced waters. Two types of experiments were conducted, rainfall-runoff and dust efficacy. Rainfall-runoff experiments were conducted using a 3-foot wide by 9-foot long gravel roadbed treated with each dust suppressant and then subject to a controlled rain event. Runoff water samples were collected over the course of the rain event and an extensive suite of analytes were measured. Dust generation experiments were conducted with compacted 'pucks' of gravel road material treated with each dust suppressant and subjected to controlled abrasion to simulate tire wear on roadbed material. Air-borne concentrations of particulate matter were measured during abrasion. All experimental materials were selected to match conditions representative of northwestern Pennsylvania.

When applied as a dust suppressant, oil and gas produced waters were little to no more effective than rainwater. This result is consistent with previous studies conducted both in the laboratory (Stallworth et al., 2020) and in the field (Graber et al., 2019). Oil and gas produced waters are likely ineffective dust suppressants because of their elevated concentrations of sodium relative to calcium and magnesium. Sodium is a monovalent cation that does not effectively bridge clay particles (the size-fraction most likely to be mobilized as road dust) to promote dust suppression. Instead, sodium can destabilize gravel roads and increase long-term road maintenance costs. Calcium and magnesium are divalent cations that can bridge clay particles together. Calcium chloride brines and magnesium chloride brines are commonly marketed as commercial dust suppressants. Calcium chloride brines used in this study were shown to be highly effective dust suppressants.

Based on dust generation experiments, only the $CaCl_2$-based brines and the organic-based soybean oil were effective dust suppressants. The oil and gas produced waters were little to no more effective than synthetic rainwater with respect to controlling dust generation. Based on rainfall-runoff experiments, the $CaCl_2$-based brines led to the lowest concentrations of total suspended solids (TSS) washed off the roadbeds indicating enhanced roadbed stability. There was no difference in the amounts of TSS washed off the roadbeds treated with OGPWs as compared to synthetic rainwater.

Chemical analyses of brine-based dust suppressants can be used to predict their efficacy. The sodium adsorption ratio (SAR) is a measure of sodium to calcium plus magnesium (Equation 1). In the current study, brines with a SAR value of < 3 were shown to be effective dust suppressants, consistent with previous studies (Graber et al., 2019, Stallworth, 2020). SAR values for the three OGPWs ranged from 68 to 69 suggesting that these fluids would not be effective dust suppressants as confirmed by subsequent experiments. DEP should consider setting a low SAR value for any brines proposed for dust suppression.

Maximum concentrations in the runoff were related and essentially proportional to concentrations in the dust suppressants. Contaminants of interest related to salinization of freshwater resources include electrical conductivity, TDS, chloride, and bromide. Contaminants of interest related to human health include combined radium (^{226}Ra + ^{228}Ra), barium, strontium, lithium, iron, and manganese. Contaminants of interest related to irrigation water include sodium, magnesium, and calcium. Contaminants of interest related to organic-based dust suppressants include chemical oxygen demand and dissolved organic carbon. Contaminants of lesser concern include aluminum, arsenic, lead, nitrate, and sulfate. Contaminants of lesser concern in this study were so designated only because they were not elevated in the dust suppressants themselves. DEP should consider requiring measurements for contaminants of interest and contaminants of lesser concern when evaluating a proposed dust suppressant.

Through mass balance analysis of material applied to, washed from, and retained by the roadbed, most contaminants of interest were washed from the roadbed. An important exception occurred with roadbeds treated with oil and gas produced waters. For these OGPWs, the roadbeds retained radium, sodium, iron, and manganese. Sodium is of concern because it likely leads to the destabilization of dirt and gravel roads. Radium retained in the roadbed was associated with fine materials and could be subject to remobilization in dust.

Runoff from $CaCl_2$ brine-treated roadbeds contained the highest concentrations of most contaminants of interest – including TDS, electrical conductivity, chloride, bromide, barium, strontium, lithium, iron, manganese, sodium, magnesium, and chloride. Roadbeds treated with calcium chloride brine produced runoff with elevated TDS (up to 57,000 mg/L) and chloride concentrations (up to 34,000 mg/L Cl) and elevated activities of combined radium (up to 48 pCi/L). Aside from calcium and chloride, most of the contaminants of interest were likely sourced from impurities in the brine. Therefore, DEP may want to request measurements for these contaminants of interest for currently-approved calcium chloride-based and magnesium chloride-based dust suppressants.

OGPWs-treated roadbeds led to the highest concentrations of combined radium in the runoff. Combined radium activities in the three OGPWs when applied to the roadbeds ranged from 84 to 2,500 pCi/L, within the anticipated range for OGPWs from western Pennsylvania. Combined radium activities in runoff from the OGPW-treated roadbeds exceeded 60 pCi/L, the effluent standard for industrial wastewater discharges, during both the 'first flush' and the 'maximum flush' parts of the rain event. Roadbeds treated with OGPWs also produced runoff with elevated TDS (up to 19,000 mg/L), chloride (up to 12,000 mg/L Cl), and bromide (up to 300 mg/L Br) concentrations. DEP should consider setting a low standard for combined radium activity for any brines proposed for dust suppression.

7. DATA REPOSITORY

Data generated for this project is packaged as a Microsoft Access Database (.accdb) with tables for most test analytes (e.g., table CL_A_TOC includes all the TOC data for Calcium Chloride Brine Test A). Summary tables for each test are also included (e.g., SR_E includes all data collected in the database for Synthetic Rainwater Test E).

Dust testing results and radium testing results are summarized in comma separated value files (.csv).

The database, dust testing results, and radium testing results are available at:

https://pennstateoffice365-my.sharepoint.com/:f:/g/personal/wdb3_psu_edu/EptcFMGBeeROtvuqMEDPTFIBKQ60cM8qlDeOqGB92JnHMg?e=DPoC2F

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9. Appendix:

EVALUATION OF ENVIRONMENTAL IMPACTS FROM DUST SUPPRESSANTS USED ON GRAVEL ROADS

PRESENTED TO	PRESENTED BY
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Table A.1 Chemical characterization summary of dust suppressants used in the current study.

Dust Suppressant	O&G PW1		O&G PW2		O&G PW3		Synthetic Rainwater		Regulatory Criteria
Analyte	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	
EC (mS/cm)	120	1.39	120	1.13	125	1.5	0.023	0.009	3.0[g]
TDS* (mg/L)	84073	988	81967	1090	85307	6606	2.39	0.05	500[b]
Ra-226 (pCi/L)	212.0	117.9	51.5	1.9	1797.6	929.0	--	--	60[e]
Ra-228 (pCi/L)	148.4	88.0	32.9	6.0	695.6	455.3	--	--	60[e]
Combined Ra (pCi/L)	360.4	147.1	84.4	6.3	2514.4	1034.6	--	--	5[b]
Chloride (mg/L)	49683	1246	47941	1327	48951	6629	--	--	250[b], 230[c]
Bromide (mg/L)	922	188	753	253	592	110	--	--	6[d]
Iodide (mg/L)	13.8	0.37	11.2	1.3	14.5	0.72	0	0	
Nitrate (mg/L)	324	78.7	--	--	--	--	0.7	0.02	10[a]
Sulfate (mg/L)	1478	407	1348	389	2004	291	2.14	0.06	250[b]
Calcium (mg/L)	6757	116	6861	47.9	7153	65.9	--	--	401[g]
Magnesium (mg/L)	1359	25.5	1313	7.69	1311	4.6	--	--	61[g]
Strontium (mg/L)	112	1.85	112	2.09	453	3.59	0	0	4[f,h]
Barium (mg/L)	1.58	0.14	4.38	0.1	417	19.2	0	0	2[a]
Sodium (mg/L)	23643	405	23511	233	24278	30.6	0.14	0.01	20[h], 920[g]
Potassium (mg/L)	117	1.62	125	2.33	132	8.82	0.1	0.01	
Lithium (mg/L)	2.48	0.12	2.92	0.08	13.3	0.13	--	--	0.01[f]
SAR^ $(meq/L)^{1/2}$	68.6	0.58	68.1	0.46	69.3	0.17	--	--	9[g]
Aluminum (mg/L)	--	--	--	--	--	--	--	--	0.05 to 0.2[b]
Manganese (mg/L)	4.06	0.14	4.82	0.05	4.91	0.51	0	0	0.05[b]
Iron (mg/L)	15	15.7	1.44	0.89	43.7	42.5	0.02	0	0.3[b], 1[c]
Nickel (mg/L)	0.09	0.04	0.09	0.01	0.05	0.01	0	0	0.052[c], 0.1[h]
Zinc (mg/L)	1.83	0.09	1.93	0.19	2.21	0.15	0.44	0.02	5[b], 0.12[c], 2[h]
Lead (mg/L)	0.11	0	0.13	0.02	0.11	0	0	0	0.015[a], 0.0025[c]
Boron (mg/L)	0.77	0.11	0.99	0.15	1.26	0.01	0	0	2.4[d], 6[h]
Arsenic (mg/L)	0.06	0	0.05	0	0.05	0	--	--	0.01[a], 0.15[c]
DRO (mg/L)	14.7	3.2	10.8	0.2	1654.1	322.2	1.1	0.9	
GRO (mg/L)	1.3	0.04	2.6	0.08	1.1	0.27	0	0	
TOC (mg/L)	88.3	8.33	81.1	11.7	76.6	14.5	1.75	.50	
TIC (mg/L)	1.1	0.5	1.5	0.9	13.1	8.3	0.6	0.7	
pH (std units)	6.42	0.16	6.15	0.14	6.50	0.04	4.29	0.10	6.5-8.5[b]

*Calculated from Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations; ^Calculated using equation (1)
[a]EPA and DEP Primary Drinking Water Standard
[b]EPA and DEP Secondary Drinking Water Standard
[c]EPA Aquatic Life Criteria
[d]WHO Drinking Water Quality Guideline
[e]Appendix B to 10 CFR Part 20
[f]US EPA Human-Based Screening Level
[g]USDA Irrigation Water Quality Guidelines
[h]EPA Drinking Water Health Advisories for lifetime exposures

Table A.1 (cont.) Chemical characterization summary of dust suppressants used in the current study.

Dust Suppressant	$CaCl_2$ Brine		Commercial Brine 1		Commercial Brine 2		Soybean Oil		Regulatory Criteria
Analyte	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	**Avg.**	**St.Dev.**	
EC (mS/cm)	197	4	216	--	180	--	--	--	3.0^g
TDS* (mg/L)	271668	41742	381032	--	386848	--	0.14	0.02	500^b
Ra-226 (pCi/L)	158.5	41.9	640.5	--	238.2	--	--	--	60^e
Ra-228 (pCi/L)	71.6	41.7	88.9	--	170.1	--	--	--	60^e
Combined Ra (pCi/L)	230.0	59.1	729.4	--	408.3	--	--	--	5^b
Chloride (mg/L)	176402	30148	251127	--	266714	--	--	--	250^b, 230^c
Bromide (mg/L)	3769	1071	3741	--	3429	--	--	--	6^d
Iodide (mg/L)	0.22	0.04	47.50	--	2.58	--	--	--	
Nitrate (mg/L)	735	242	--	--	--	--	--	--	10^a
Sulfate (mg/L)	7211	1681	--	--	--	--	--	--	250^b
Calcium (mg/L)	78229	9441	76245	--	104788	--	0.41	--	401^g
Magnesium (mg/L)	--	--	14535	--	896	--	0.10	0.004	61^g
Strontium (mg/L)	1475	113	3070	--	2613	--	--	--	$4^{f,h}$
Barium (mg/L)	1.57	0.87	--	--	3.93	--	--	--	2^a
Sodium (mg/L)	1458	265	20014	--	2499	--	--	--	20^h, 920^g
Potassium (mg/L)	3123	547	12301	--	5904	--	--	--	
Lithium (mg/L)	57.9	9.3	91.4	--	111.4	--	--	--	0.01^f
SAR^ $(meq/L)^{1/2}$	1.4	0.18	17.4	--	2.1	--	--	--	9^g
Aluminum (mg/L)	--	--	5.15	--	5.48	--	--	--	0.05 to 0.2^b
Manganese (mg/L)	0.07	0.07	1.63	--	--	--	--	--	0.05^b
Iron (mg/L)	3.39	1.41	4.13	--	6.52	--	--	--	0.3^b, 1^c
Nickel (mg/L)	0.04	0.01	--	--	--	--	--	--	0.052^c, 0.1^h
Zinc (mg/L)	1.84	0.75	2.19	--	3.88	--	--	--	5^b, 0.12^c, 2^h
Lead (mg/L)	0.4	0.63	0.1	--	0.3	--	--	--	0.015^a, 0.0025^c
Boron (mg/L)	22	3.65	520	--	42	--	--	--	2.4^d, 6^h
Arsenic (mg/L)	0.02	0.01	--	--	--	--	--	--	0.01^a, 0.15^c
DRO (mg/L)	0.5	0	--	--	--	--	6.5	0.7	
GRO (mg/L)	0.6	0.06	--	--	--	--	22.8	6.98	
TOC (mg/L)	8.27	1.29	--	--	--	--	--	--	
TIC (mg/L)	0.6	0.02	--	--	--	--	--	--	
pH (std units)	9.95	0.19	4.28	--	6.32	--	--	--	$6.5\text{-}8.5^b$

*Calculated from Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations; ^Calculated using equation (1)
[a]EPA Primary Drinking Water Standard
[b]EPA Secondary Drinking Water Standard
[c]EPA Aquatic Life Criteria
[d]WHO Drinking Water Quality Guideline
[e]Appendix B to 10 CFR Part 20
[f]US EPA Human-Based Screening Level
[g]USDA Irrigation Water Quality Guidelines
[h]EPA Drinking Water Health Advisories for lifetime exposures

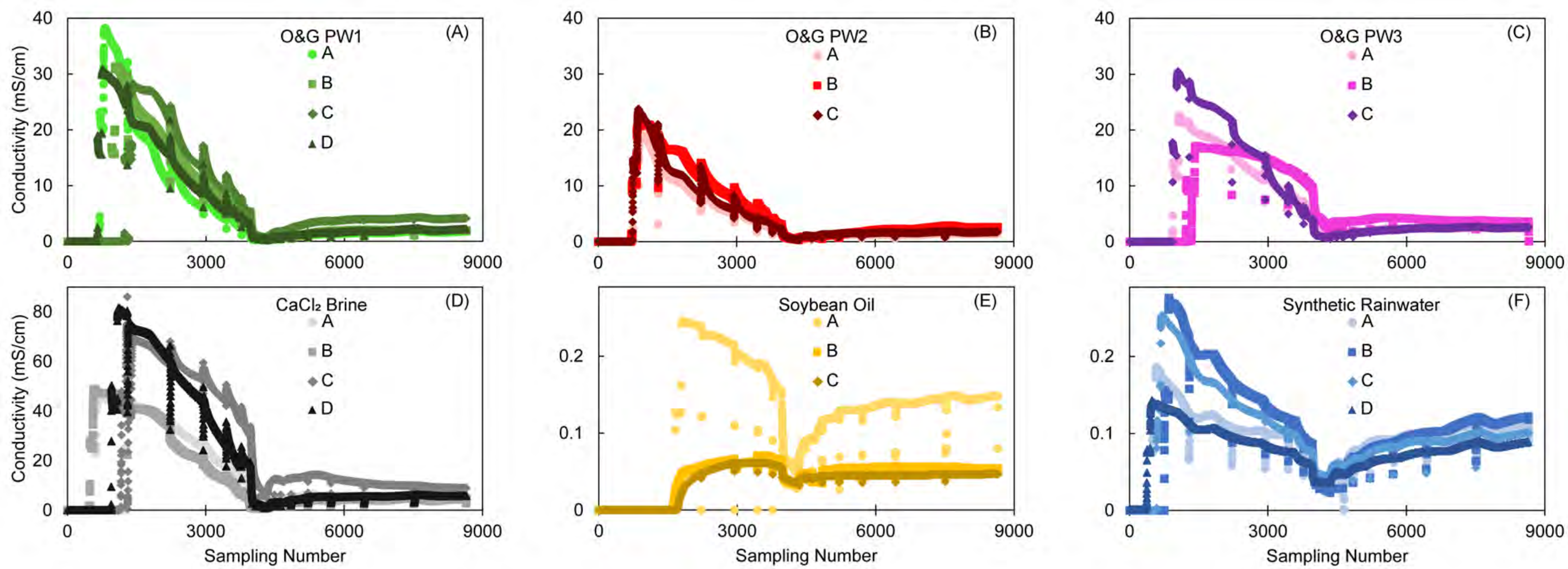

Figure A.1 Comparisons of electrical conductivity measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected every 10-seconds of the 24-hour storm. Note different y-axis scales used in each panel. A Regulatory Threshold for conductivity is 3.0 mS/cm from USDA Irrigation Water Quality Guidelines. The chronic aquatic life benchmark value for conductivity in central Appalachian streams is 0.30 mS/cm (EPA, 2011).

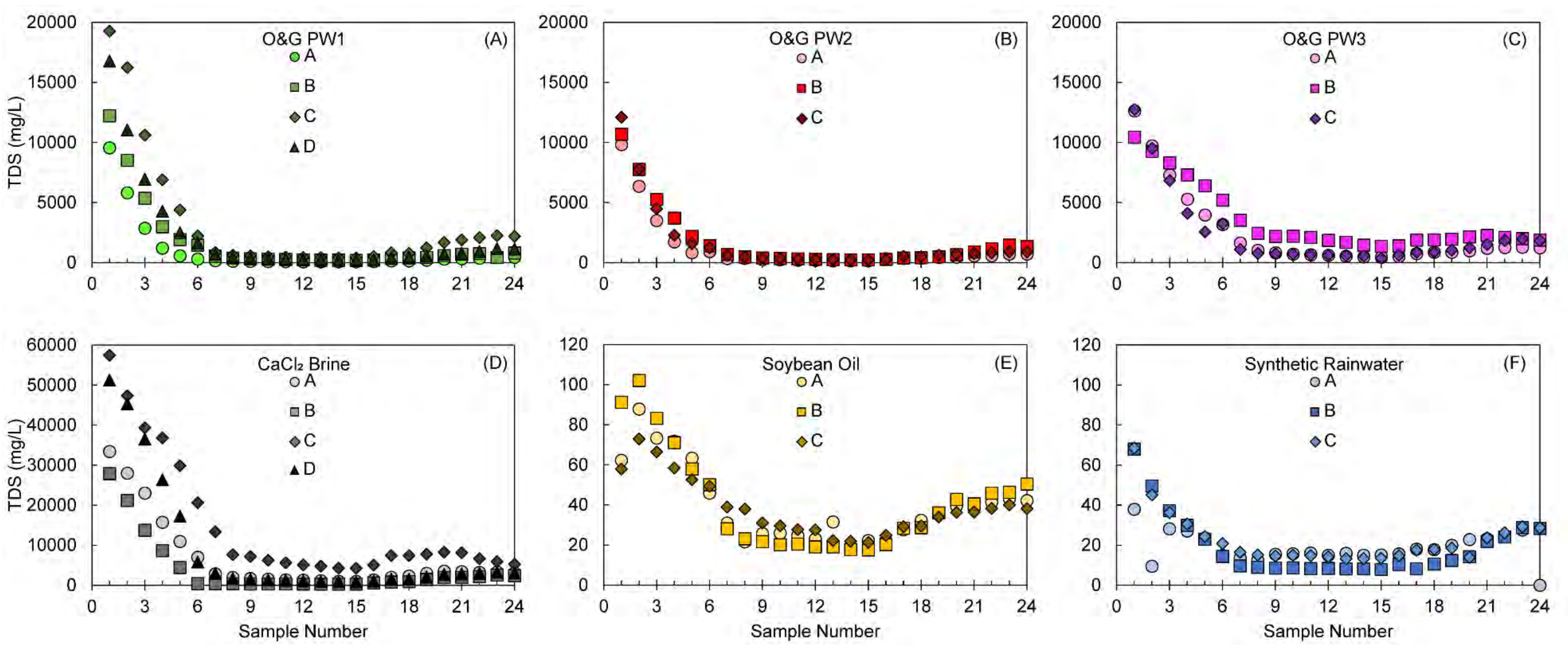

Figure A.2 Comparisons of total dissolved solids (TDS) concentrations calculated in runoff from gravel roadbeds treated with the six dust suppressants used in this study. TDS was calculated as the sum of measured Cl, SO_4, Br, Ca, Mg, Na, K, Sr, Ba concentrations. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every $1/24^{th}$ of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold for TDS is 500 mg/L from EPA and DEP Primary Drinking Water Standards.

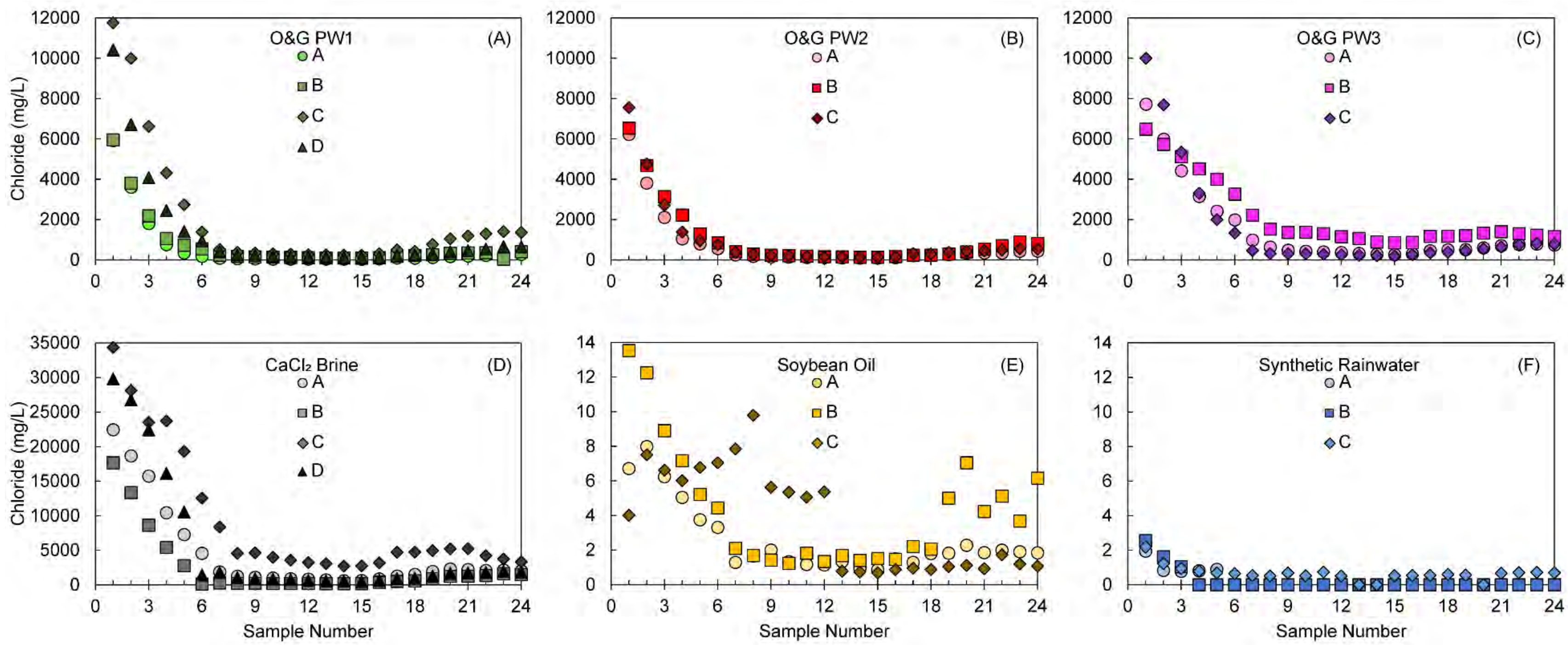

Figure A.3 Comparisons of dissolved chloride (Cl) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold is 250 mg/L Cl from EPA and DEP Secondary Drinking Water Standards.

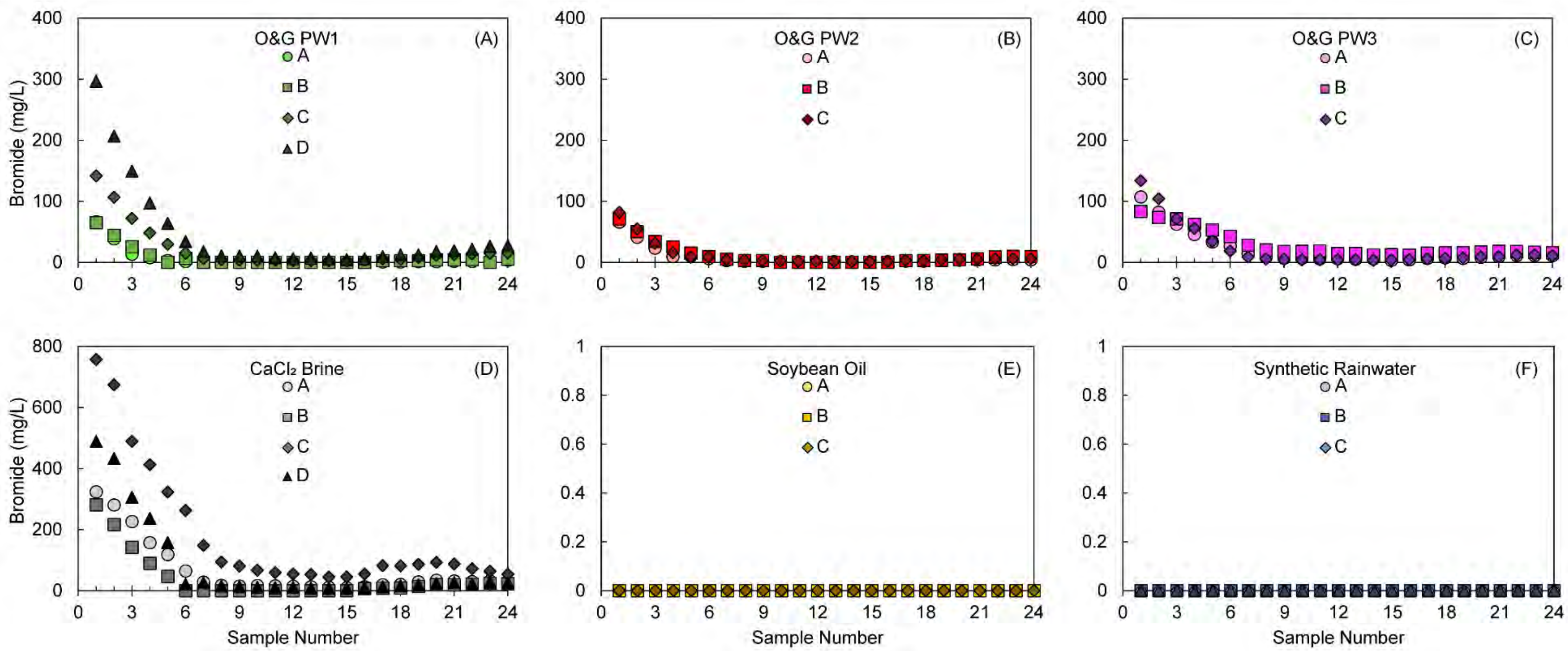

Figure A.4 Comparisons of dissolved bromide (Br) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. There are no regulatory thresholds for bromide, however, bromide leads to formation of disinfection byproducts (DBPs) in drinking water treatment plants. Influent bromide concentrations of 0.050 mg/L Br have shown to lead to increased formation of DBPs (Landis et al., 2016) while concentrations <0.080 mg/L Br may be protective for human health (Wang et al., 2017).

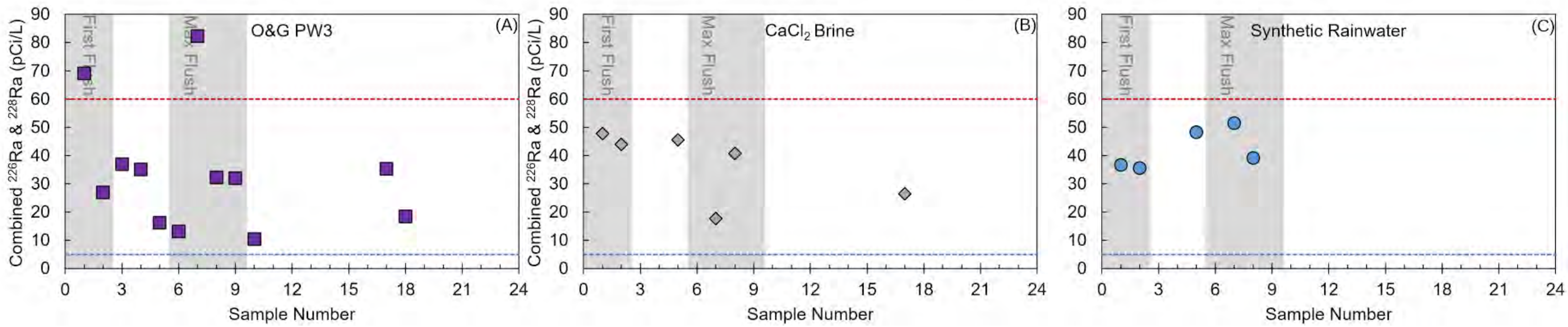

Figure A.5 Comparisons of combined radium activities (^{226}Ra + ^{228}Ra) measured in runoff from gravel roadbeds treated with three of the dust suppressants used in this study. Results shown are from single tests. (A) Oil & Gas Produced Water 3, (B) Calcium Chloride Brine, and (C) Synthetic Rainwater. Sample numbers 1 and 2 correspond to the first flush of runoff while sample numbers 7 and 8 correspond to the maximum flush of runoff. The NRC industrial wastewater discharge standard for combined radium activity is 60 pCi/L (red dashed line). The EPA and DEP primary drinking water standard for combined radium activity is 5.0 pCi/L (blue dashed line).

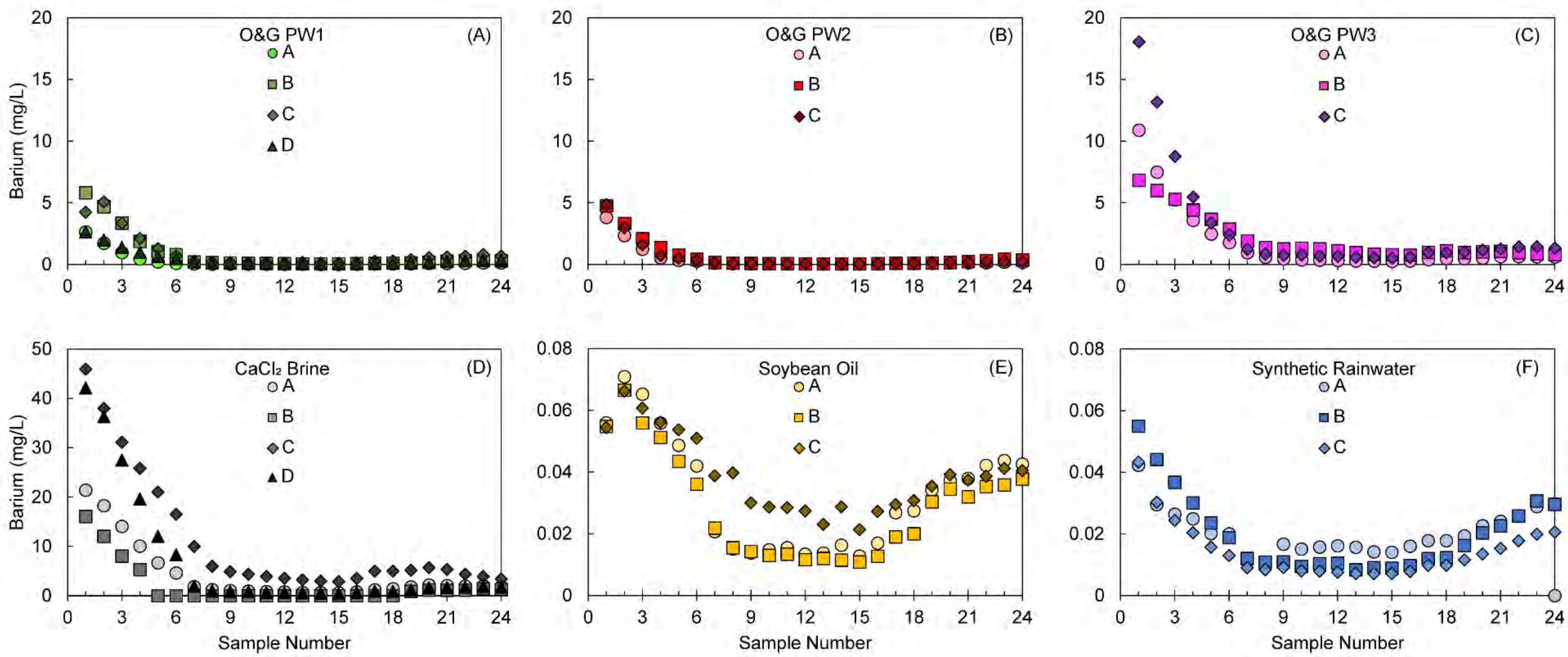

Figure A.6 Comparisons of dissolved barium (Ba) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The EPA and DEP primary drinking water standard for barium is 2 mg/L Ba.

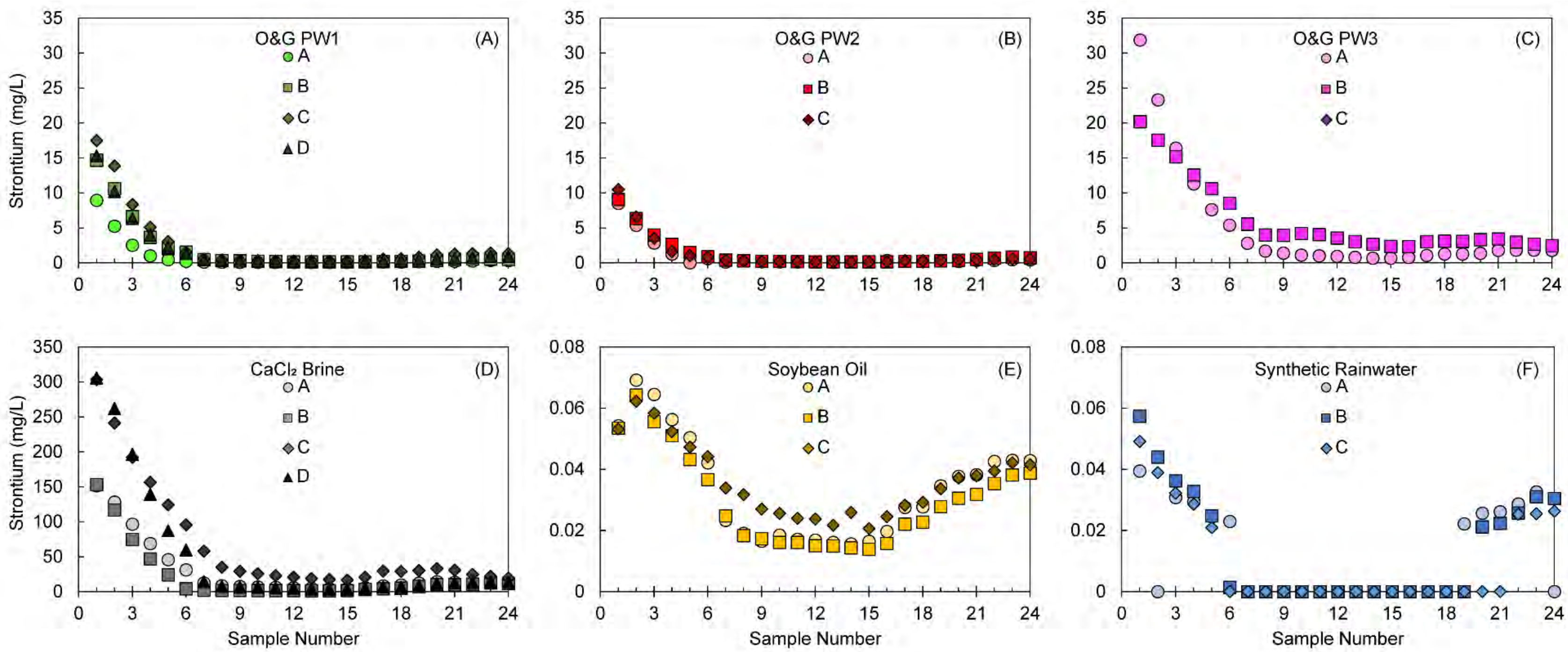

Figure A.7 Comparisons of dissolved strontium (Sr) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold is 4 mg/L Sr from EPA Human-Based Screening Levels.

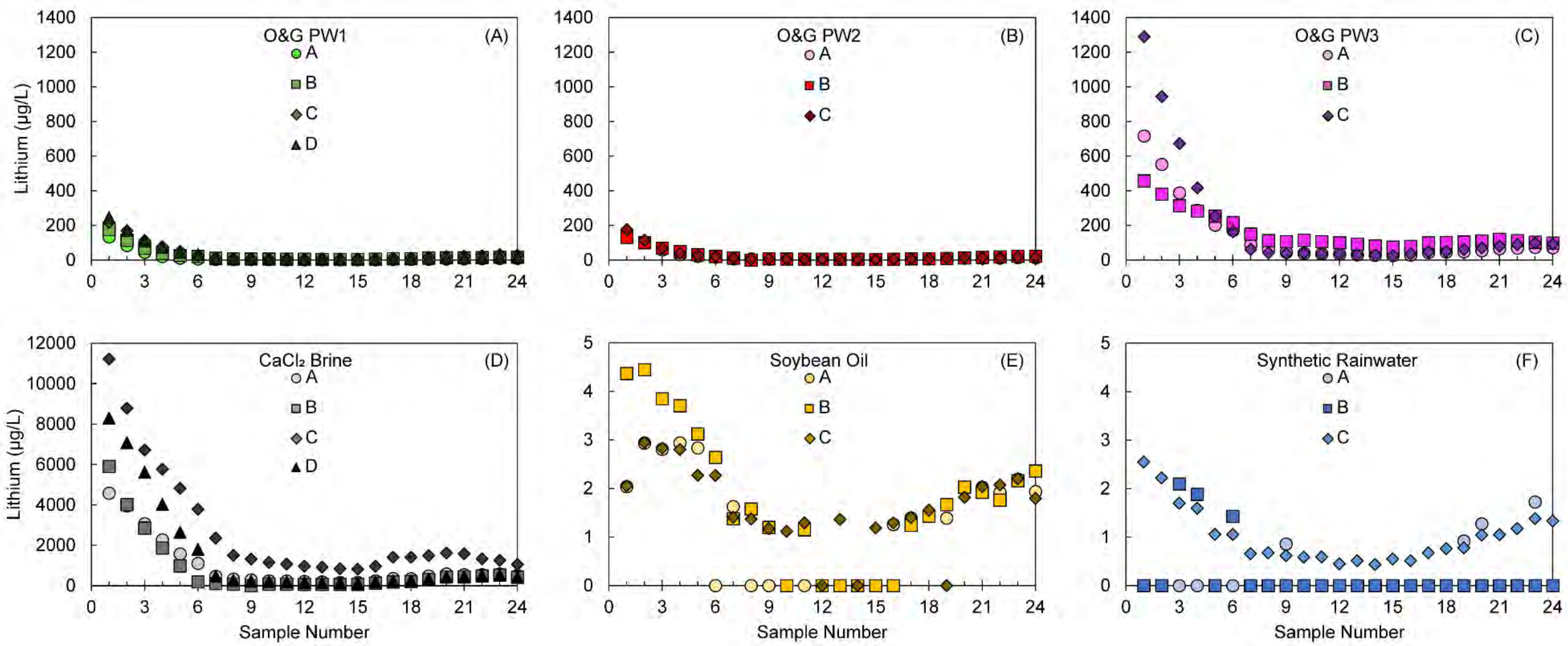

Figure A.8 Comparisons of dissolved lithium (Li) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The EPA Human-Based Screening Level for lithium is 0.01 mg/L (= 10 µg/L).

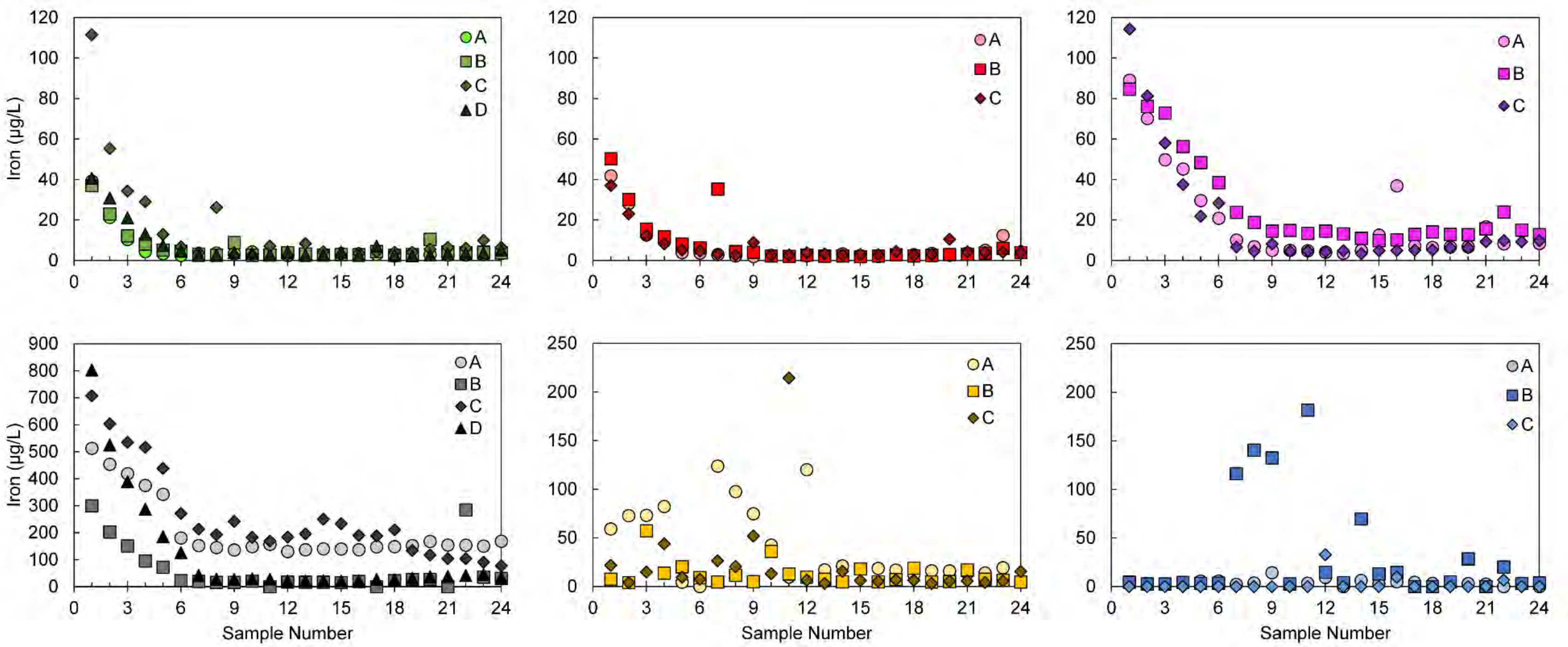

Figure A.9 Comparisons of dissolved iron (Fe) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The Pennsylvania water quality criteria for iron is 0.3 mg/L dissolved Fe and 1.5 mg/L total Fe.

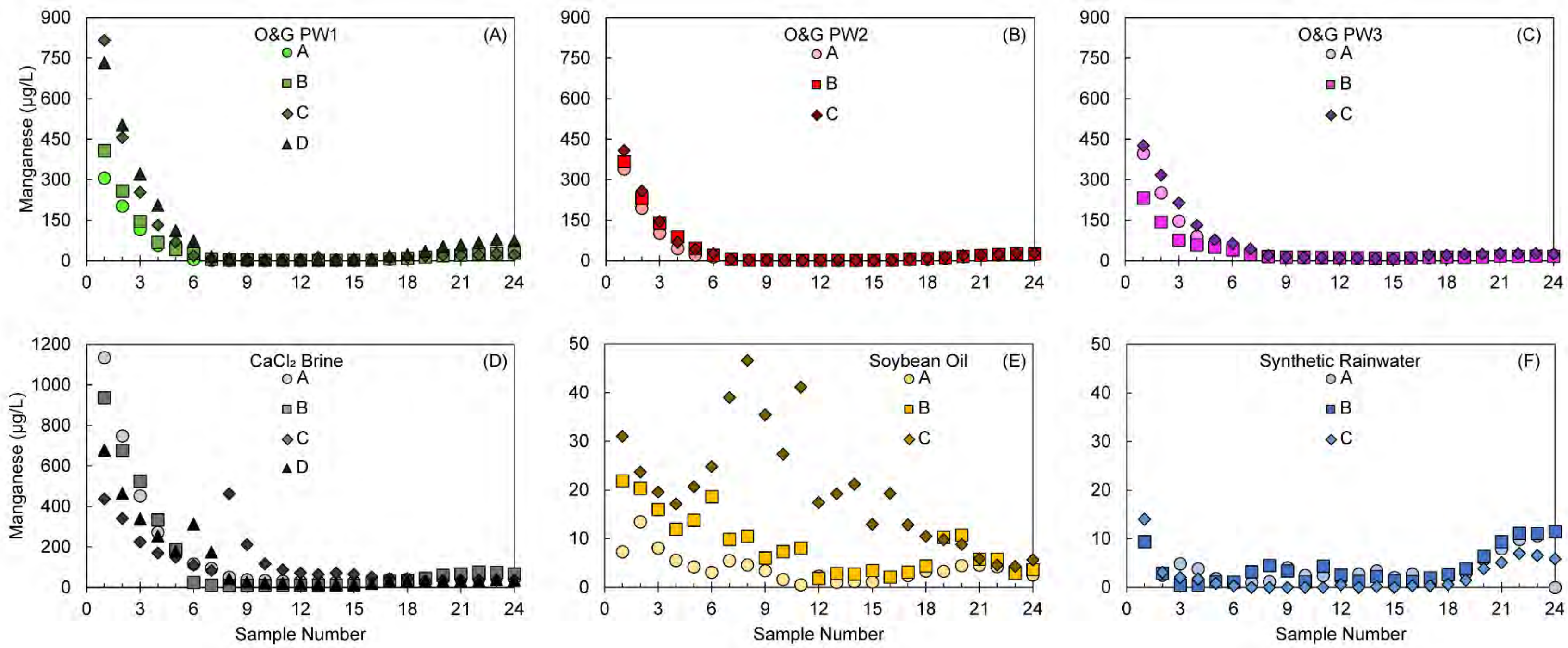

Figure A.10 Comparisons of dissolved manganese (Mn) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The EPA secondary drinking water standard for manganese is 0.05 mg/L total Mn and the Pennsylvania water quality criteria for manganese is proposed to be lowered to 0.3 mg/L total Mn.

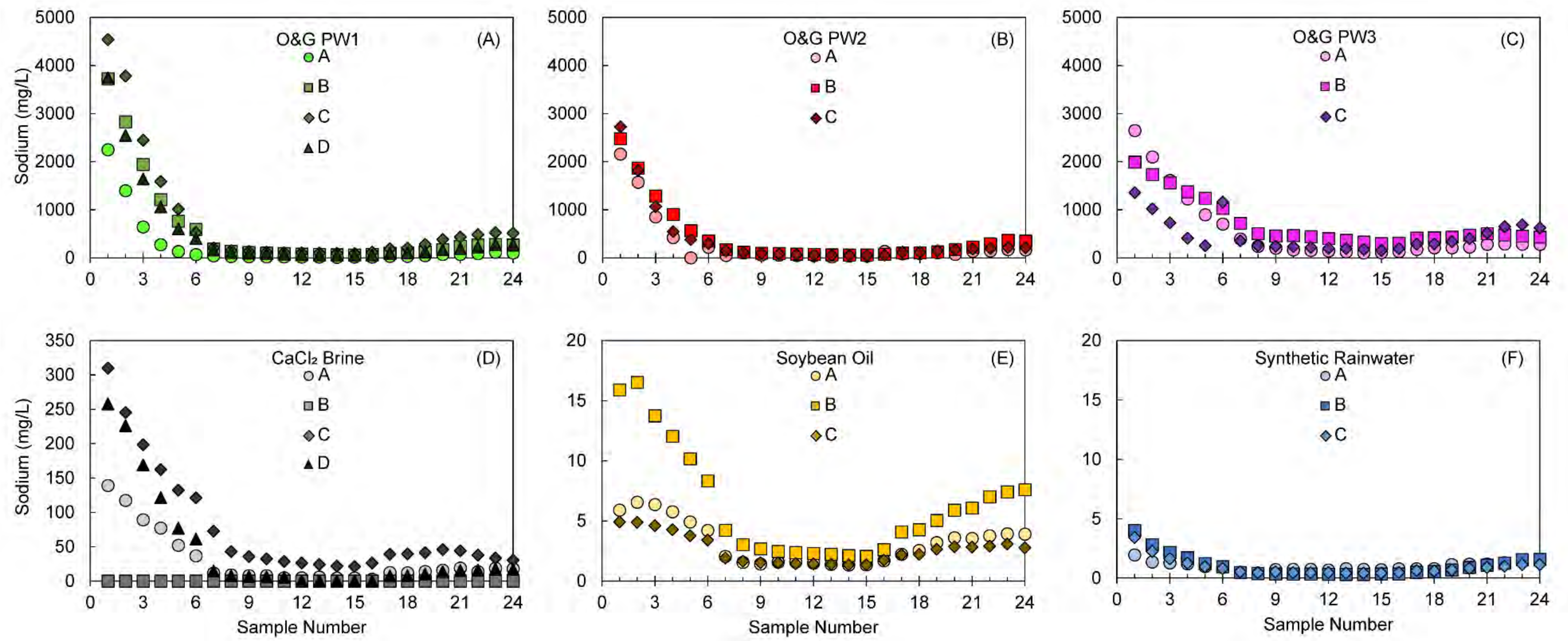

Figure A.11 Comparisons of dissolved sodium (Na) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold is 920 mg/L Na from USDA Irrigation Water Quality Guidelines.

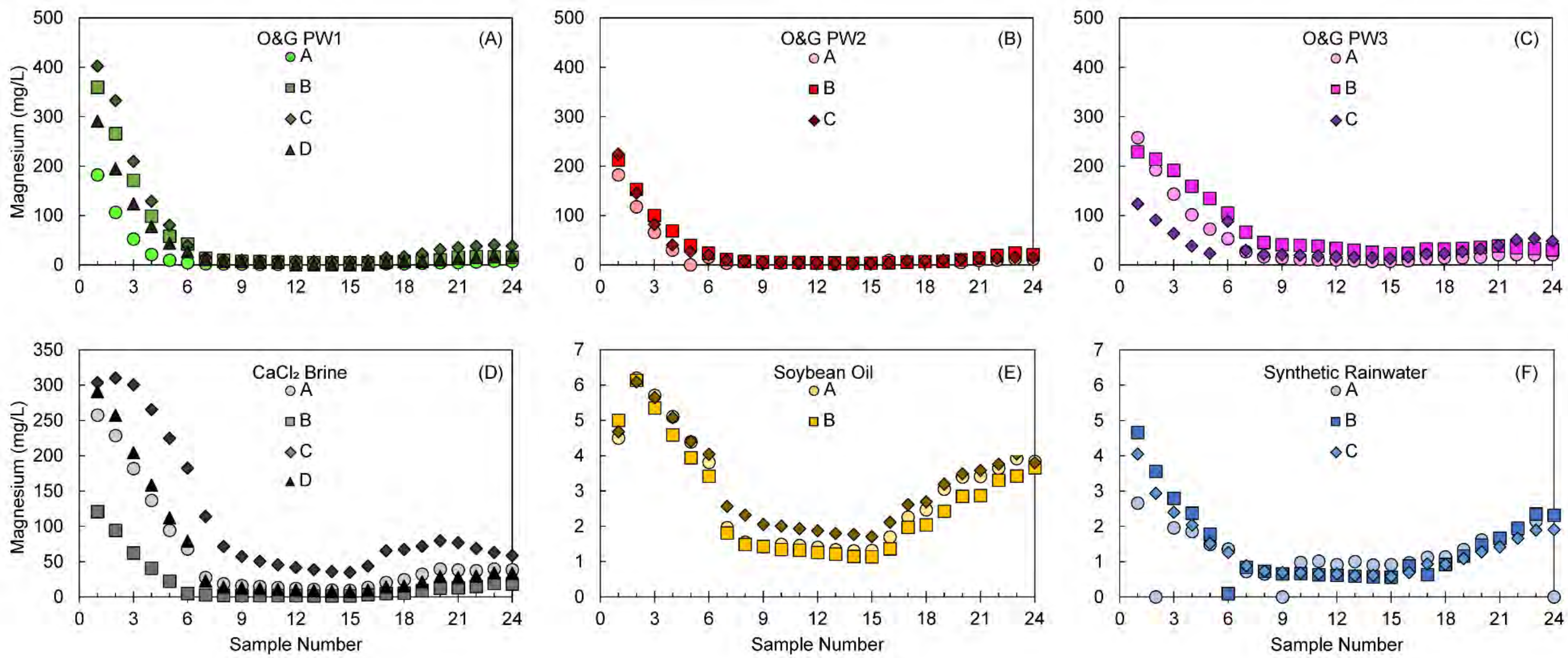

Figure A.12 Comparisons of dissolved magnesium (Mg) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold is 61 mg/L Mg from USDA Irrigation Water Quality Guidelines.

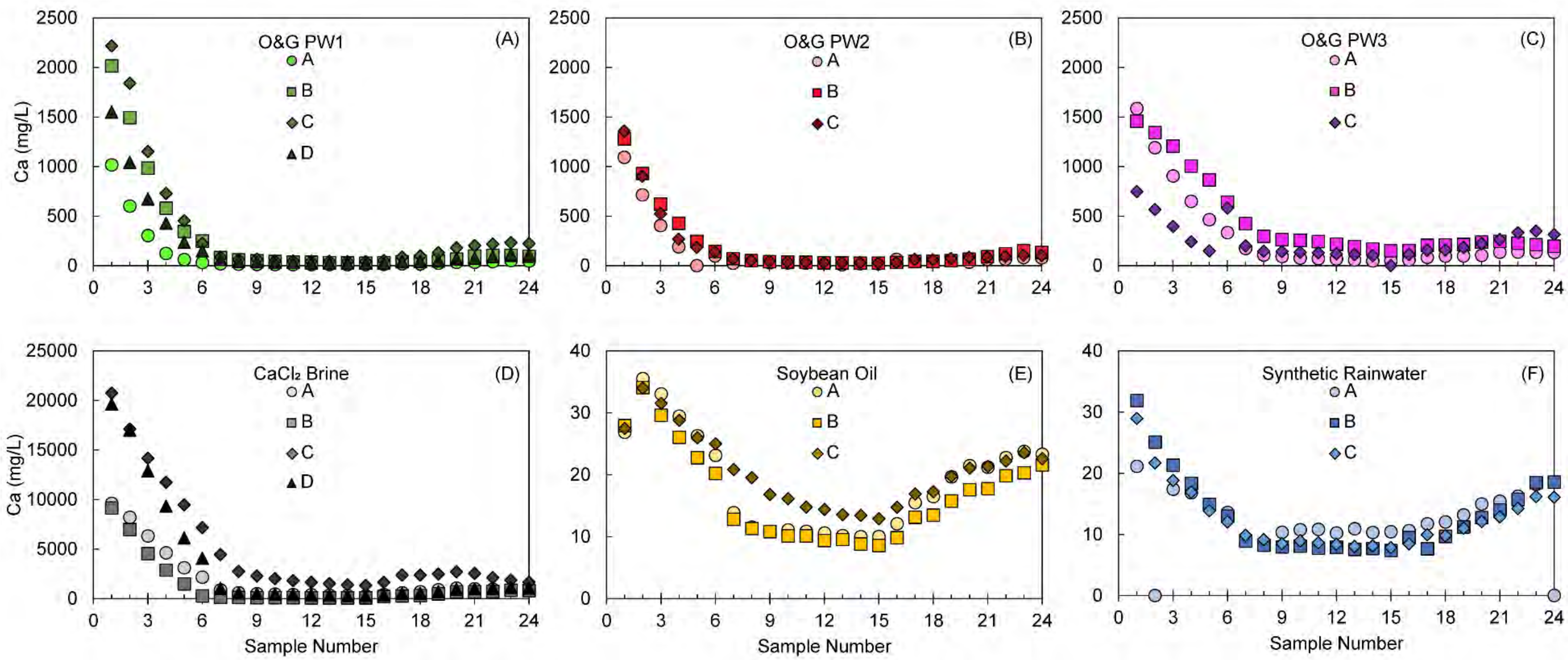

Figure A.13 Comparisons of dissolved calcium (Ca) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. A Regulatory Threshold is 401 mg/L Ca from USDA Irrigation Water Quality Guidelines.

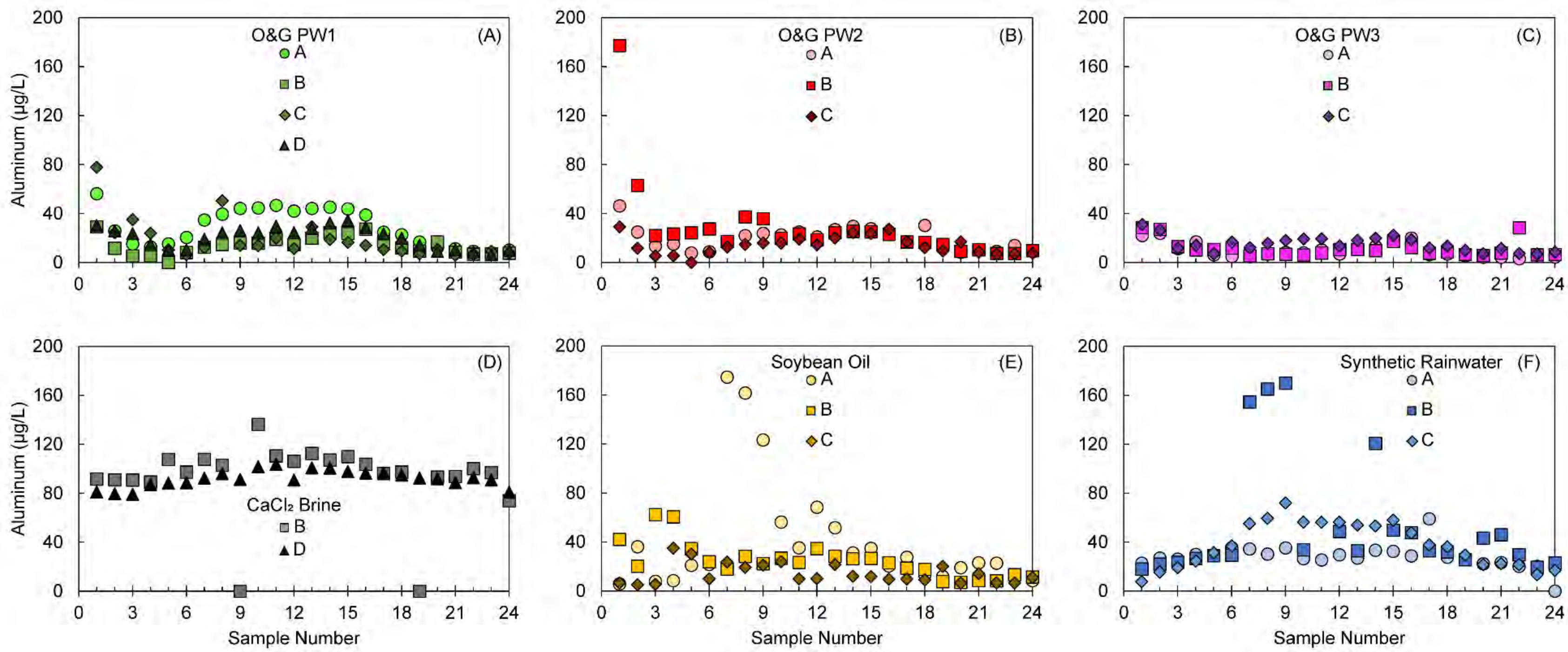

Figure A.14 Comparisons of dissolved aluminum (Al) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. The EPA secondary drinking water standard for aluminum ranges from 0.05 to 0.2 mg/L total Al.

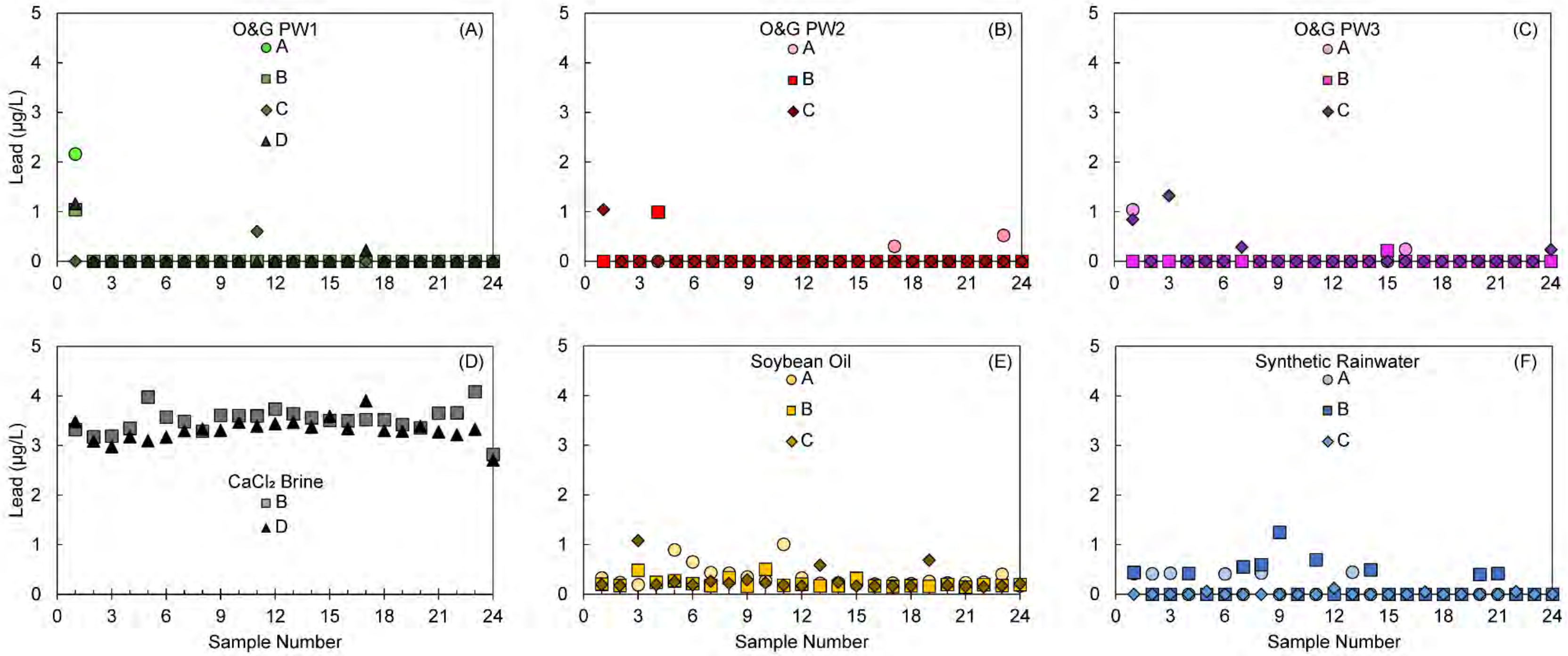

Figure A.15 Comparisons of dissolved lead (Pb) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. The EPA primary drinking water action level for lead is 0.015 mg/L total Pb (= 15 µg/L).

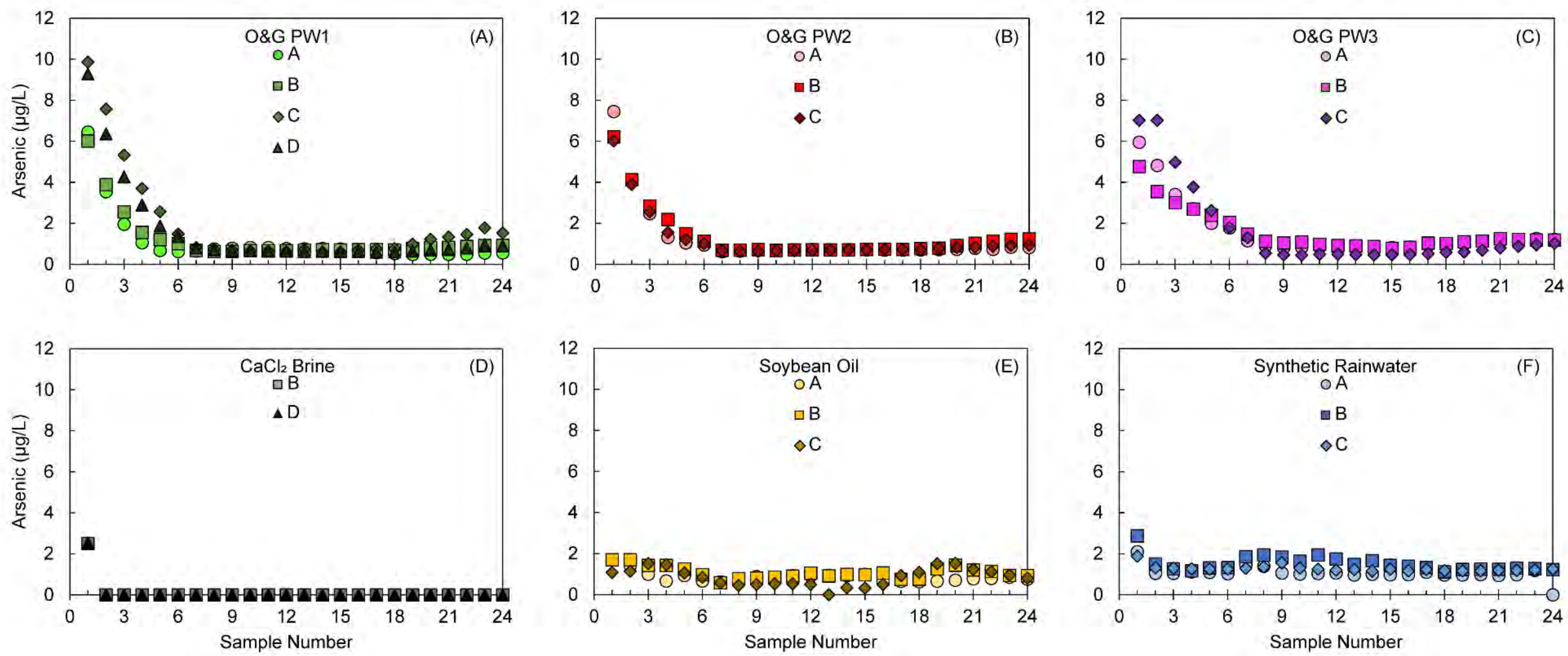

Figure A.16 Comparisons of dissolved arsenic (As) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. The EPA primary drinking water standard for arsenic is 0.01 mg/L total As (= 10 µg/L).

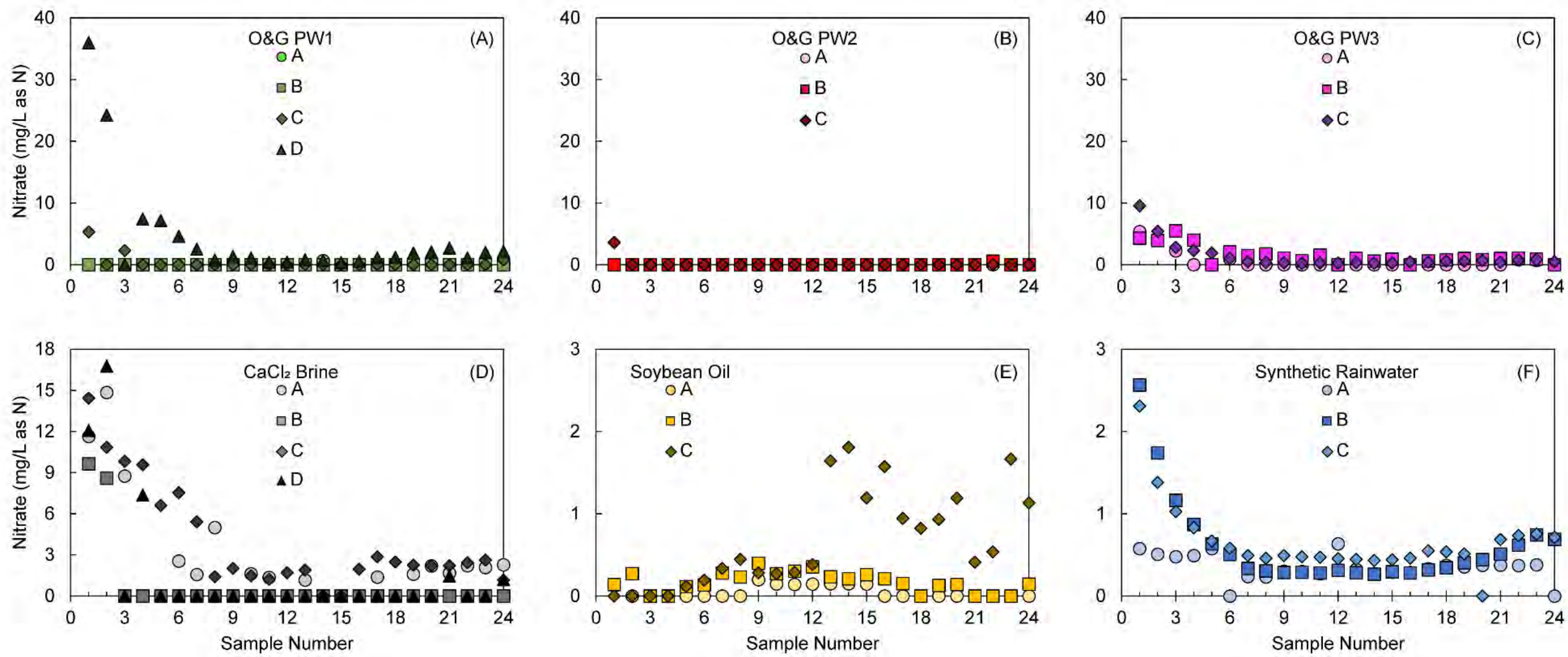

Figure A.17 Comparisons of dissolved nitrate (NO_3^-) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The EPA secondary drinking water standard for nitrate is 10 mg/L N.

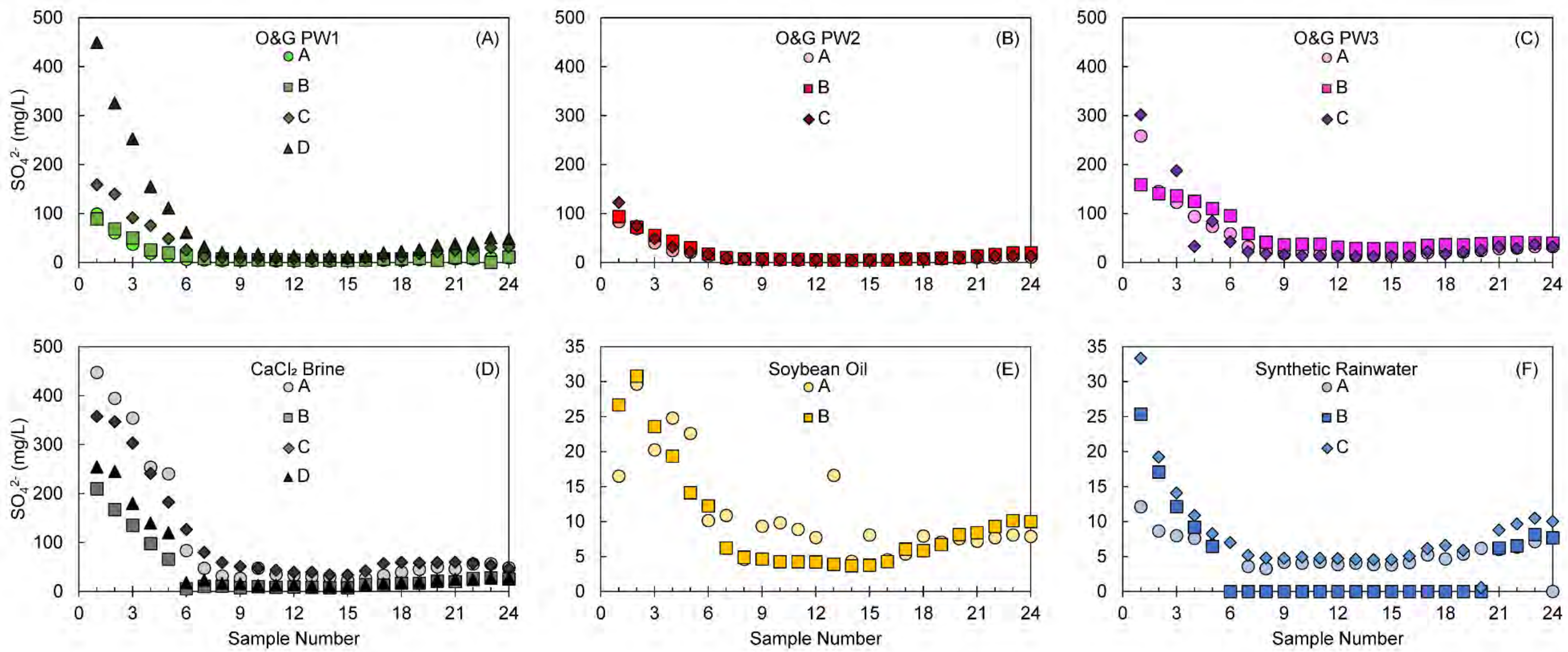

Figure A.18 Comparisons of dissolved sulfate (SO_4^{2-}) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The EPA secondary drinking water standard for sulfate is 250 mg/L SO_4.

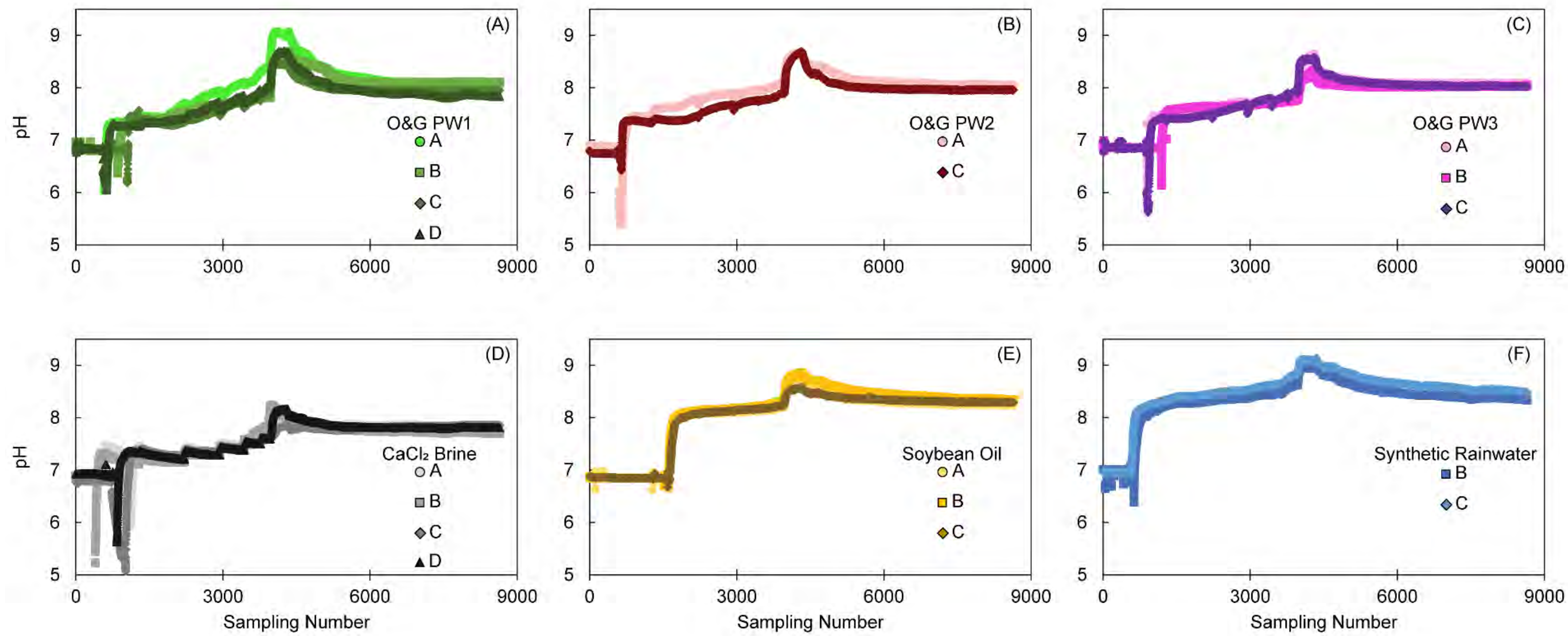

Figure A.19 Comparisons of pH measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected every 10-seconds of the 24-hour storm. A normal range for pH in surface waters is 6.5 to 8.5 and up to 9.5 in limestone systems. The EPA secondary drinking water standard for pH is 6.5 to 8.5.

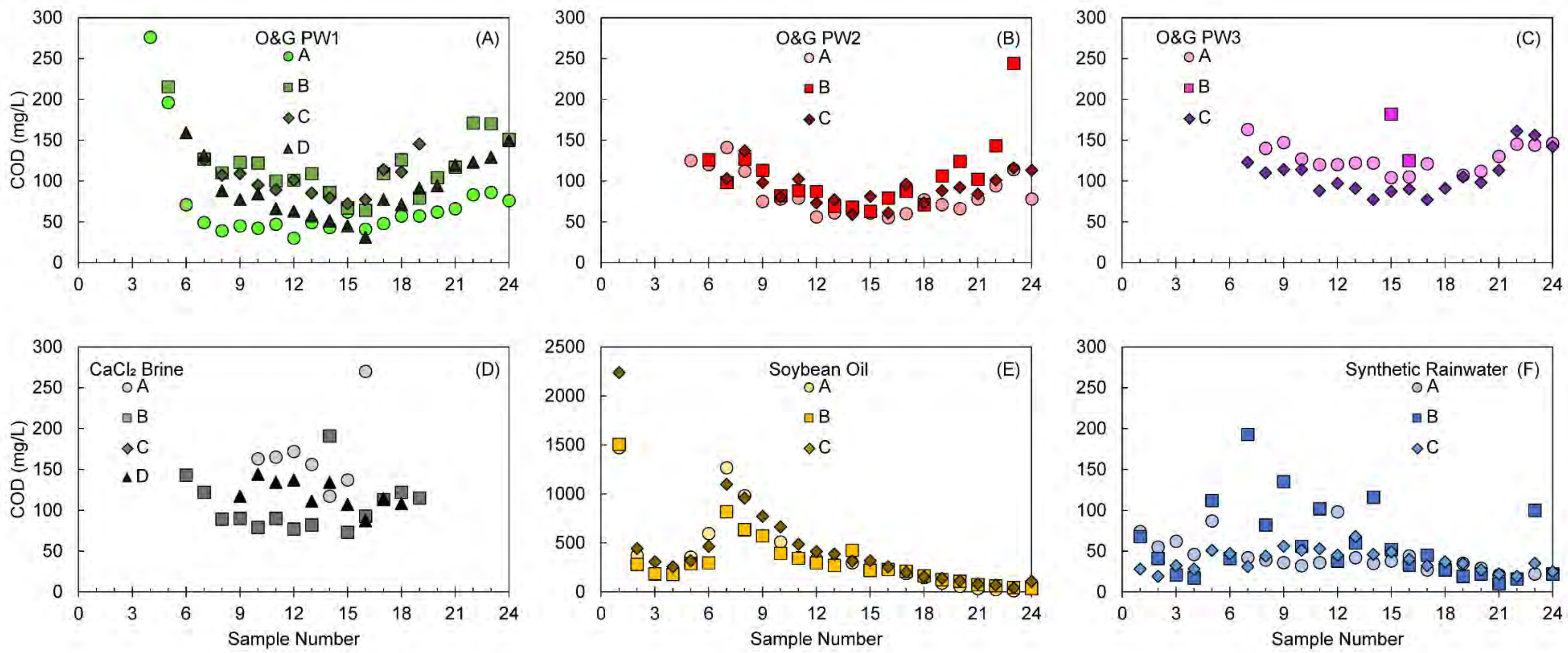

Figure A.20 Comparisons of chemical oxygen demand (COD) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. There are no EPA standards for COD.

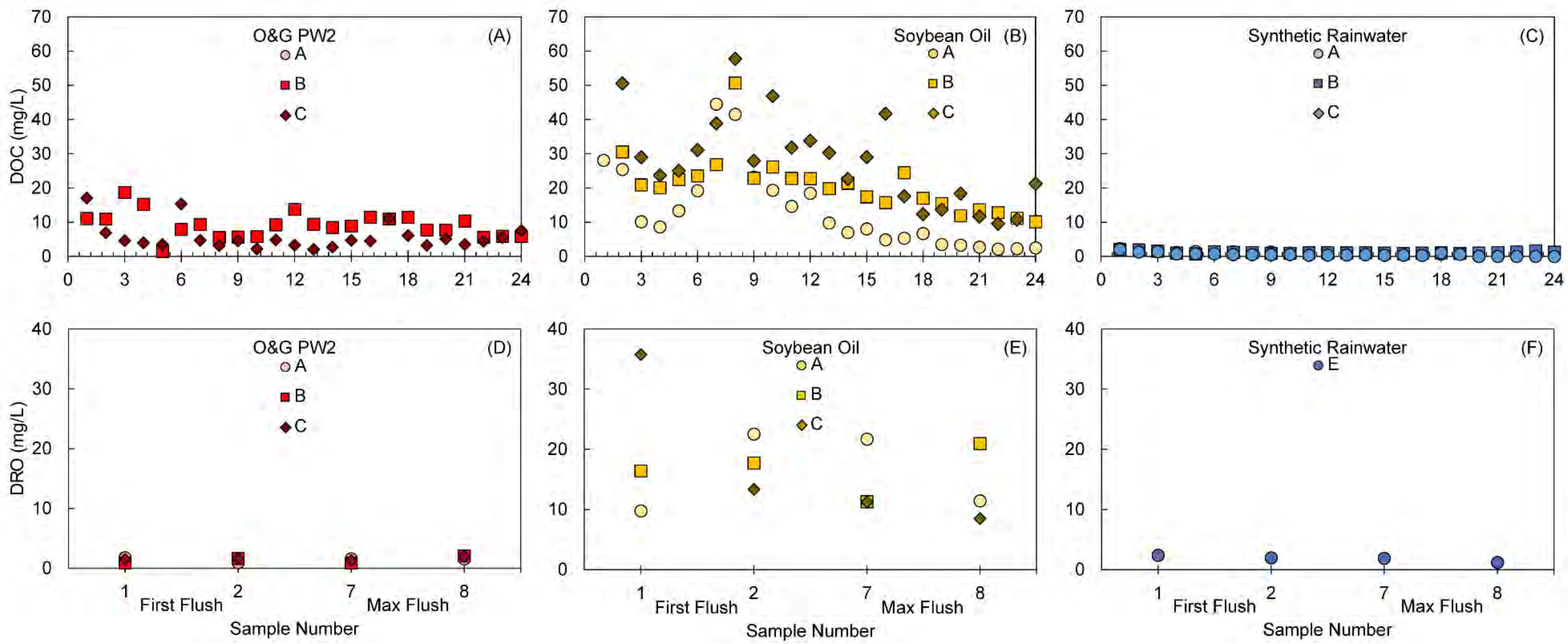

Figure A.21 Comparisons of concentrations of dissolved organic carbon (DOC – panels A – C) and diesel range organics (DRO – panels D – F) measured in runoff from gravel roadbeds treated with three of the dust suppressants used in this study – A) and D) Oil & Gas Produced Water 2; B) and E) Soybean Oil; and C) and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples for DOC measurements were analyzed for every 1/24[th] of the storm volume. Samples for DRO measurements were analyzed for the first flush samples (1,2) and maximum flush samples (7,8).

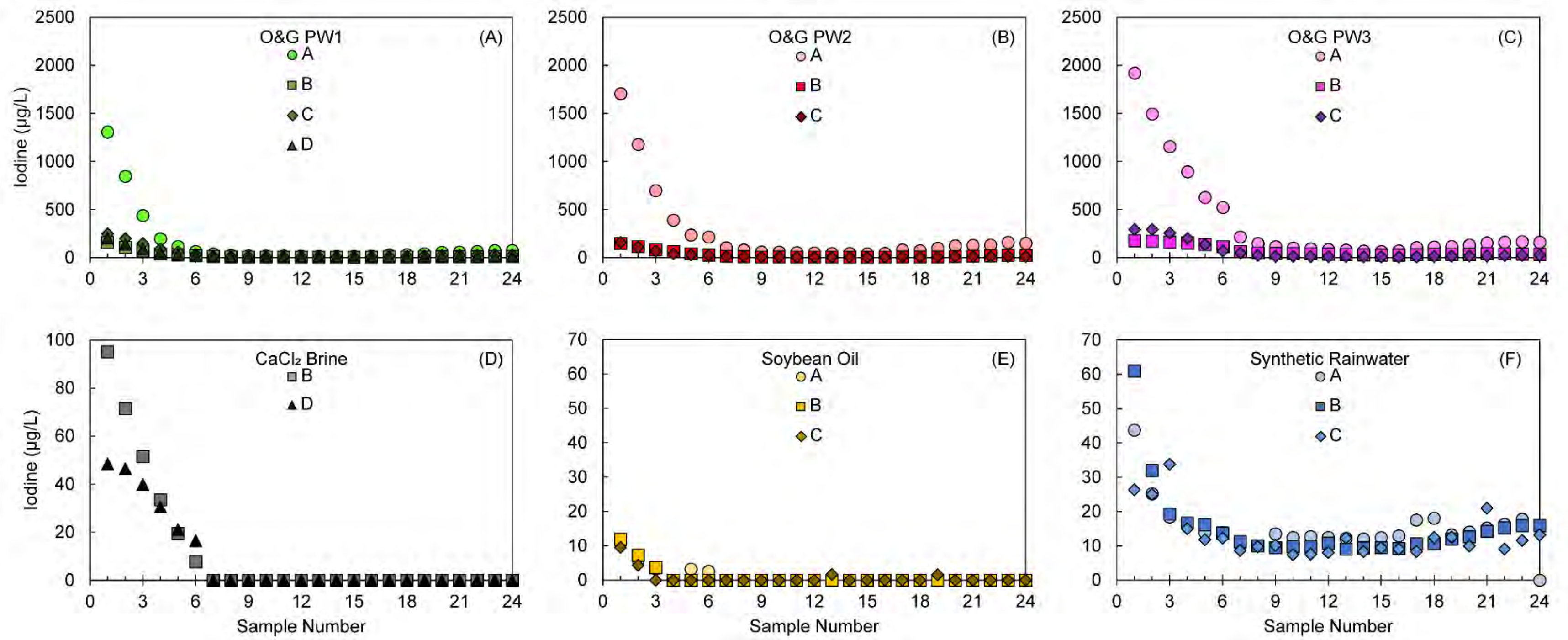

Figure A.22 Comparisons of dissolved iodine concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. There are no EPA standards for iodine.

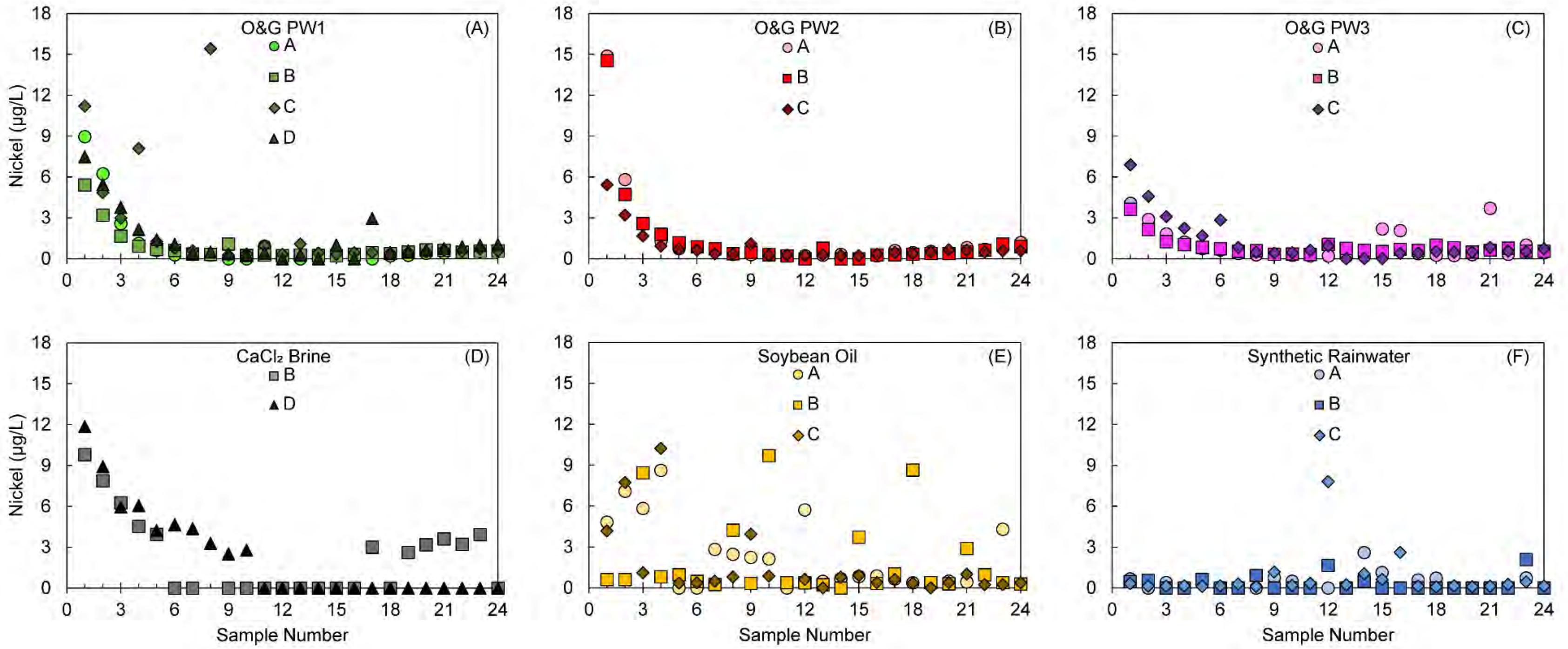

Figure A.23 Comparisons of dissolved nickel (Ni) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. The EPA aquatic life criteria for nickel is 0.052 mg/L total Ni (= 52 µg/L).

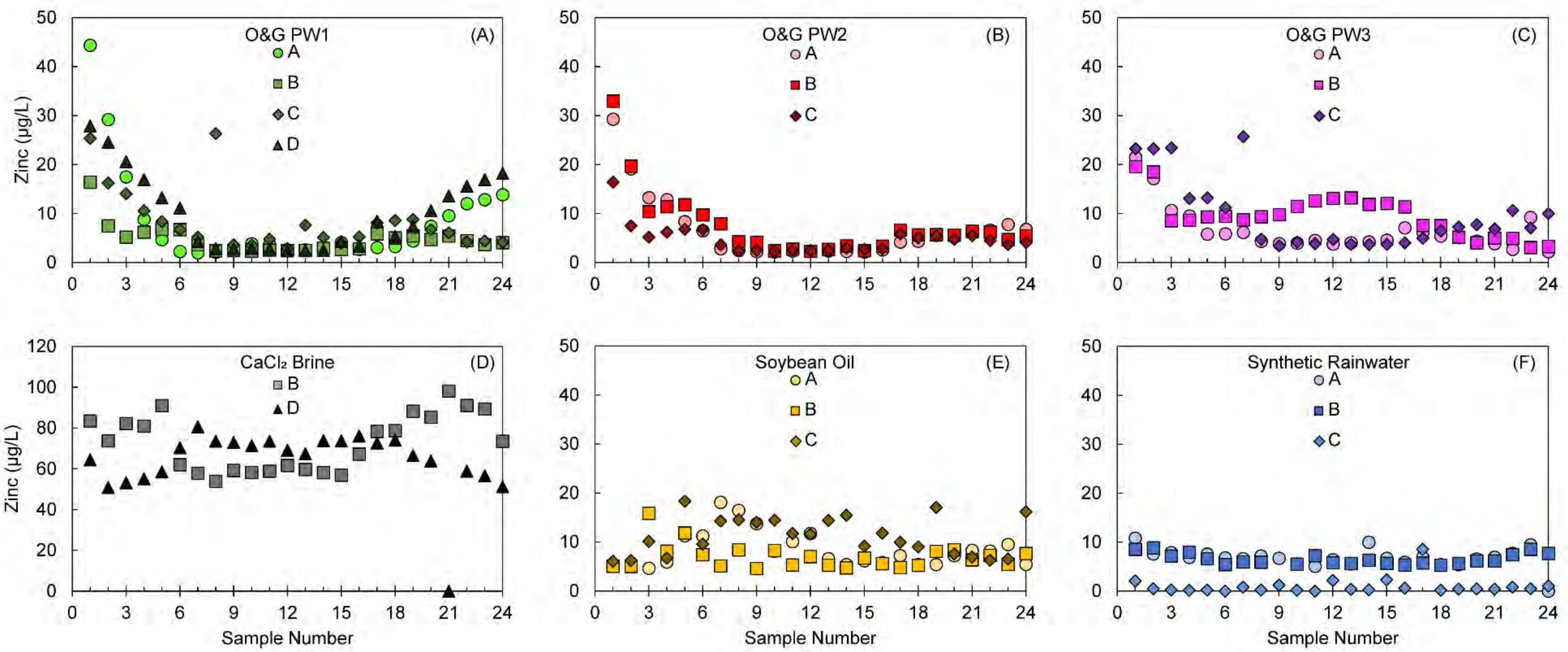

Figure A.24 Comparisons of dissolved zinc (Zn) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scale used panel D. The EPA secondary drinking water standard for zinc is 5.0 mg/L total Zn and the EPA aquatic life criteria for zinc is 0.12 mg/L total Zn (= 120 µg/L).

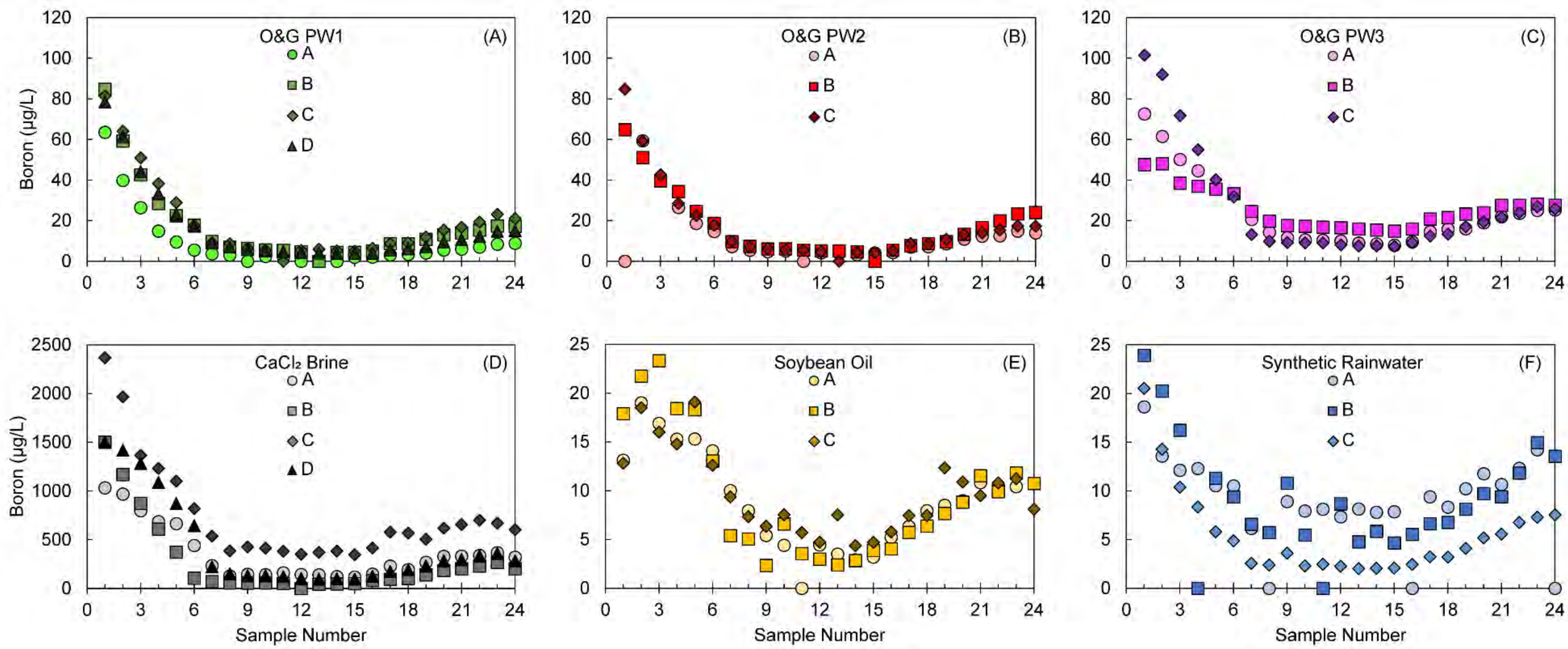

Figure A.25 Comparisons of dissolved boron (B) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scales used in each panel. The WHO drinking water quality guideline for boron is 2.4 mg/L total B.

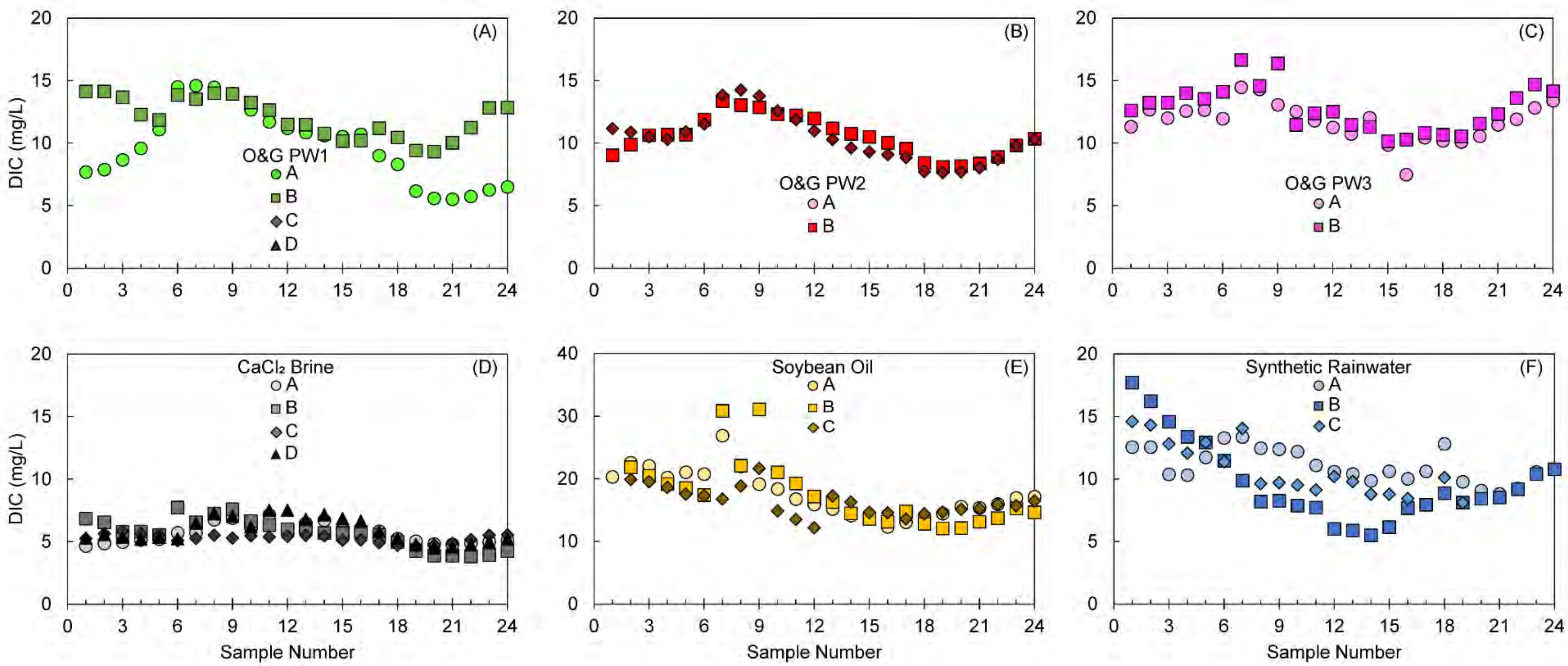

Figure A.26 Comparisons of dissolved inorganic carbon (DIC) concentrations measured in runoff from gravel roadbeds treated with the six dust suppressants used in this study. A) Oil & Gas Produced Water 1, B) Oil & Gas Produced Water 2, C) Oil & Gas Produced Water 3, D) Calcium Chloride Brine, E) Soybean Oil, and F) Synthetic Rainwater. Different letters refer to replicate tests. Samples collected after every 1/24th of the storm volume. Note different y-axis scale in panel E. There are no EPA standards for DIC.

EXHIBIT O

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Efficacy of oil and gas produced water as a dust suppressant

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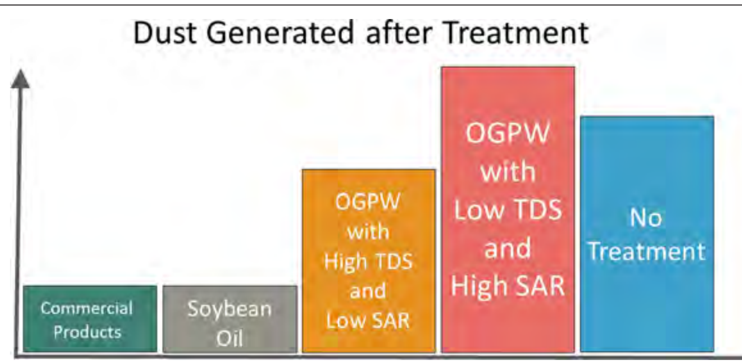
HIGHLIGHTS

- Dust suppression efficacy of all OGPW was less than commercial products.
- Sodium absorption ratio (SAR) and total dissolved solids (TDS) predict efficacy.
- OGPW with low SAR and high TDS performed best as dust suppressants.
- OGPW treated roadways lost dust-suppression efficacy following rain events.

GRAPHICAL ABSTRACT



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ABSTRACT

The effectiveness of oil and gas produced water (OGPW) applied to unpaved roads to reduce particulate matter (PM_{10}) generation has not been well-characterized. Here we quantify the efficacy of OGPW compared to commercial and alternative byproducts as dust suppressants applied to unpaved roads and estimate efficacy of a dust suppressant extrapolated from both lab experiments and published data for OGPW across U.S. states. Both treated and untreated OGPW, simulated brines, and commercial dust suppressants were characterized by major and trace element composition and then applied to road aggregate in the laboratory. PM_{10} generation after treatment was quantified, both before and after simulated rain events to assess the need for multiple applications. We found the dust suppression efficacy of all OGPW to be less than commercial products and alternative byproducts such as waste soybean oil. In addition, OGPW lost efficacy following simulated rain events, which would require repeated applications of OGPW to maintain dust suppression. The dust suppression efficacy of OGPW can be estimated based on two chemical measurements, the sodium absorption ratio (SAR) and the total dissolved solids (TDS). OGPW with the lowest SAR and highest TDS performed best as dust suppressants while high SAR and lower TDS led to greater dust generation.

1. Introduction

There are over one million miles of unpaved roads in the USA (Forman, 2004). In the United States, unpaved roads contribute heavily to particulate matter (PM) pollution, amounting to 47% of fugitive

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emissions of particulate matter less than 10 μm (PM_{10}) (Tasker et al., 2018; U.S.D. of Transportation, 2017). PM_{10} emission potential from unpaved roads is approximately 4-fold greater than paved roads (Kuhns et al., 2005). Inhalable ($<PM_{10}$) and fine PM ($<PM_{2.5}$) have been strongly correlated with impairment of the respiratory system, higher mortality rates, decreased cognitive function, and an estimated 10% of annual deaths worldwide (Dockery et al., 1993; Khan and Strand, 2018; Kim et al., 2015; Zhang et al., 2018).

Suppressing roadway dust can protect human health, improve driver safety, and eliminate unwanted dust deposition in homes or in the environment. Calcium chloride and magnesium chloride are common commercially available dust suppressants; however, the cost of these materials is usually prohibitive for typical road maintenance budgets in rural areas that need these services the most. In an effort to reduce PM_{10} emission from unpaved roads, at least 13 U.S. States allow oil and gas produced water (OGPW) to be spread as a dust suppressant (Tasker et al., 2018). OGPW is economically appealing because it is often available at no cost to the road maintenance operators and a cheap disposal option for oil and gas operators. OGPW, sometimes salty enough to be called brine or oilfield wastewater, often contains high concentrations of calcium and sodium (2530–25,800 mg/L and 23,000–57,300 mg/L, respectively –across the United States) (Lee and Neff, 2011). However, Tasker et al. (2018), showed that some elements of concern, such as lead and radioactive radium (Ra-226 and Ra-228), accumulate with even short-term repetitive treatment of road material with OGPW and have the potential to become airborne; other salts and metals can leach into waterways (Tasker et al., 2018). Additional OGPW components of concern for community members living in the vicinity of dirt roads include trace and heavy metal(loid) pollutants, such as strontium, barium, and arsenic (Pichtel, 2016; Skalak et al., 2014; Tasker et al., 2018). Not all states that allow OGPW spreading regulate or require the quantification of toxic trace elements (e.g., As, Pb, Ra-226, or Ra-228) prior to its use (Goodman, 2017).

There is currently little published research on the effectiveness of OGPW as a dust suppressant, despite its use for this purpose for upwards of 70 years (Payne, 2018). A recent literature review by Payne (2018) suggests that OGPW is not an effective dust suppressant unless spread at a rate well above environmental risk standards (Payne, 2018). High sodium content in OGPW might weaken road aggregate structure and increase dustiness (Payne, 2018; Warrence et al., 2002). Two field studies in North Dakota examined the practice of spreading OGPW. Graber et al. (2017) found that roadways in North Dakota both untreated and treated with OGPW generated similar amounts of PM (Graber et al., 2017). The overall effectiveness of OGPW may be influenced by both the sodium adsorption ratio (SAR) and the total dissolved solids (TDS) of the brine, but the road material clay content may also significantly influence the amount of dispersion of fine materials (Graber et al., 2019). SAR is a water quality indictor (Eq. (1)) often used to describe the potential of irrigation water to damage soils due to high sodium content relative to calcium or magnesium. Stallworth et al. (2020) observed the effects of SAR, TDS, and road aggregate material on synthetic brine dust suppression in a standardized laboratory setting (Stallworth et al., 2020). The authors found greater dust suppression with synthetic brines that contained higher TDS, but lower SAR values. To the authors' knowledge, no studies have systematically analyzed OGPW effectiveness as a dust suppressant, which is increasingly important as the beneficial use of OGPW is increasingly encouraged in research requests for proposals by the U.S. Environmental Protection Agency, U.S. Department of Energy and the U.S. Geological Survey. In addition, no studies have analyzed the longevity of OGPW dust suppressant efficacy following rain events observed in areas where OGPW are typically applied. In this study, rain events were simulated to compare the effectiveness that might be expected in field conditions for three types of treatments: calcium chloride, OGPW, and soybean oil. Finally, if the use of OGPW as a dust suppressant is encouraged, radium removal prior to application on the roadway may be necessary to meet potential regulatory restrictions and to our knowledge no studies have examined the efficacy of treated OGPW as a dust suppressant.

There is a clear need for efficacy studies of OGPW and other dust suppressants as their use may impact human health (Pichtel, 2016). Regulatory agencies, local and state governments, road mangers and oil and gas operators could also use the information to make informed decisions and create regulations regarding beneficial use of OGPW that are protective of human and environmental health. Therefore, the objectives of this research were to 1) quantify the efficacy of OGPW as a dust suppressant compared to commercial and alternative byproducts, and 2) estimate the efficacy of OGPW as a dust suppressant throughout the USA based on state-wide averages of OGPW chemistry. Determining dust suppressant efficacy of treated roadways will help to determine potential human and environmental health effects of using OGPW as a dust suppressant.

2. Methods

2.1. Dust suppressant characterization

Three different types of fluids were investigated for dust suppression efficacy: 1) simulated brines (including $MgCl_2$, $CaCl_2$, and NaCl), 2), OGPW, and 3) alternative products (Table 1). Twenty simulated brines were prepared in the laboratory using metal salts (calcium chloride, magnesium chloride, sodium chloride) and ultrapure water to investigate the mechanistic controls of dust suppression and mimic concentrations of commercial brines (calcium or magnesium chloride). The simulated brine formulations were chosen to reflect a range of observations of SAR and TDS values for OGPW as well as the commercial products such as $CaCl_2$ and $MgCl_2$. Results from a preliminary subset ($n = 9$) of these simulated brines were previously published (Stallworth et al., 2020).

Eight OGPWs, including both untreated conventional and treated unconventional OGPWs were used to benchmark effectiveness relative to simulated brines and alternative products. Three OGPW from conventional wells (vertical wells) that were used for road spreading were collected for this study; one was collected in 2018 from a township in Ohio (identified herein as OHB1) and two were collected from townships in Pennsylvania in 2017, (referred to in this work as PAB1, PAB2). Two conventional OGPWs from Wyoming were used (WYB1, WYB2) (McDevitt et al., 2019, 2020b). Although it is not known if these fluids were ever used for road spreading, Wyoming is a state that allows beneficial reuse of OGPW for agriculture and has a climate that could necessitate dust suppression. Three unconventional OGPW, produced water from wells that were horizontally drilled and hydraulically fractured, were tested. One unconventional OGPW from Colorado was tested (COB1). It was collected from a disposal pond located in Colorado and was reportedly used for dust suppression. Finally, two treated unconventional OGPWs from Pennsylvania were utilized to determine the feasibility of using treated unconventional OGPW as a dust suppressant. One unconventional OGPW was treated minimally, primarily to remove organics (PATO), while the second OGPW was treated to remove radium by mixing with acid mine drainage (PATR) (Ouyang et al., 2019).

Three alternative byproducts were tested including a water treatment plant softening sludge (WTP SS), soybean oil (SOY OIL), and a commercially available product, EnviroKleen®. The water treatment plant softening sludge, from Ohio, was collected after lime softening as was suggested in a survey of dust suppressant options by the South Dakota Department of Transportation (Hua et al., 2016). The pure soybean oil, a byproduct of soybean crushing, is currently used for dust suppression by a township located in northwestern Pennsylvania. The commercially available EnviroKleen® is a synthetic fluid with an added binding agent, which has been approved as a dust suppressant with minimal environmental impacts by the Pennsylvania Center for Dirt and Gravel Roads (Kunz and Little, 2015; Penn State Center for Dirt and Gravel Roads, 2018).

Table 1
Raw data for aerosol generation results of simulated brine-treated, OGPW-treated, and alternative product-treated DSA- road aggregate samples. OGPW include samples from Ohio (OH), Pennsylvania (PA), Wyoming (WY), and Colorado (CO). Alternative products include Water treatment plant softening sludge (WTP-SS), commercial dust suppressant product, Envirokleen, and waste soybean oil (SOY OIL).

Sample ID	SAR	TDS (mg/L)	Log (SAR/TDS)	$AMPM_{10}$ mg/m^3	Std dev mg/m^3	Log $AMPM_{10}$	Std error
No dust suppressant added[a]							
Control - 1	–	–	–	239	16	2.4	0.03
Control - 2	–	–	–	258	15	2.4	0.03
Simulated brines[a]							
$CaCl_2$ - 1	0.12	614,252	−6.7	0.5	0.1	−0.3	0.11
$CaCl_2$ - 2	0.12	614,252	−6.7	0.4	0.4	−0.4	0.48
$CaCl_2$ - 3	0.12	614,252	−6.7	0.4	0.2	−0.4	0.20
$CaCl_2$ - 4	0.12	614,252	−6.7	1.5	0.3	0.2	0.08
$MgCl_2$ - 1	0.13	421,790	−6.5	0.3	0.1	−0.5	0.15
$MgCl_2$ - 2	0.13	421,790	−6.5	0.7	0.2	−0.2	0.15
NaCl - 1	1406	298,701	−2.3	366	33	2.6	0.04
NaCl - 2	1406	298,701	−2.3	267	9	2.4	0.01
High SAR - 1	79	181,232	−3.4	90	8	2.0	0.04
High SAR - 2	79	181,232	−3.4	108	20	2.0	0.08
Mid SAR - 1	14	163,453	−4.1	40	6	1.6	0.06
Mid SAR - 2	14	163,453	−4.1	9	2	0.9	0.11
Low SAR - 1	2	160,141	−4.9	3	1	0.5	0.18
Low SAR - 2	2	160,141	−4.9	6	1	0.7	0.11
Mid SAR/Low TDS - 1	15	24,402	−3.2	296	14	2.5	0.02
Mid SAR/Low TDS - 2	15	24,402	−3.2	349	18	2.5	0.02
Mid SAR/Mid TDS - 1	14	75,080	−3.7	20	3	1.3	0.07
Mid SAR/Mid TDS - 2	14	75,080	−3.7	25	3	1.4	0.05
Mid SAR/High TDS - 1	15	298,911	−4.3	2	0	0.4	0.07
Mid SAR/High TDS - 2	15	298,911	−4.3	3	1	0.4	0.16
Oil and gas produced water samples[b]							
WYB1 - 1	12	5771	−2.7	195	11	2.3	0.03
WYB1 - 2	12	5771	−2.7	196	23	2.3	0.05
WYB2	7	1136	−2.2	171	13	2.2	0.03
OHB1 - 1	59	244,955	−3.6	7	3	0.9	0.16
OHB1 - 2	59	244,955	−3.6	12	3	1.1	0.11
OHB1 - 3	59	244,955	−3.6	15	3	1.2	0.08
OHB1 - 4	59	244,955	−3.6	22	6	1.3	0.12
PAB1 - 1	60	292,000	−3.7	13	4	1.1	0.12
PAB1 - 2	60	292,000	−3.7	8	22	0.9	1.18
PAB2 - 1	106	356,000	−3.5	25	7	1.4	0.11
PAB2 - 2	106	356,000	−3.5	13	3	1.1	0.11
COB1 - 1	42	305,000	−3.9	0.1	0.04	−0.9	0.13
COB1 - 2	42	305,000	−3.9	0.1	0.01	−1.3	0.12
COB1 - 3	42	305,000	−3.9	0.02	0.01	−1.6	0.21
PATR - 1	28	10,079	−2.6	337	20	2.5	0.03
PATR - 2	28	10,079	−2.6	266	26	2.4	0.04
PATO - 1	63	111,073	−3.2	175	11	2.2	0.03
PATO - 2	63	111,073	−3.2	193	13	2.3	0.03
Alternative products							
WTP SS - 1	2	295	−2.2	245	22	2.4	0.04
WTP SS - 2	2	295	−2.2	152	18	2.2	0.05
WTP SS - 3	2	295	−2.2	66	8	1.8	0.05
SOY OIL - 1	–	–	–	0.02	0.01	−1.7	0.23
SOY OIL – 2	–	–	–	0.02	0.01	−1.8	0.24
EnviroKleen® - 1	–	–	–	0.02	0.00	−1.8	0.07
EnviroKleen® - 2	–	–	–	0.02	0.00	−1.7	0.06

[a] Results originally reported in Stallworth et al. (2020).
[b] TDS and values used to calculate SAR originally reported in Tasker et al., 2018.

2.2. Road aggregate characterization

Driving Surface Aggregate (DSA) was obtained from quarry stockpiles in Pennsylvania and had not previously been placed on roadways. DSA meets specifications for particle size distribution and other aggregate testing parameters as described by the Pennsylvania Department of Transportation (PennDOT) and was previously characterized, and consisted almost exclusively of limestone (Stallworth et al., 2020). The DSA used for efficacy testing had a grain size distribution with 81% of grain sizes between 1.18 mm and 9.51 mm. Of the material smaller than 1.18 mm, the grain size distribution for the DSA was 58% sand, 35% silt, and 3% clay.

DSA was used to make representative discs of unpaved road surfaces using the method developed by Stallworth et al. (2020). To create the representative discs, 100 g (dry weight) of homogenized aggregate was moistened to 5% water content, and compacted using a soil Proctor hammer in a cylindrical mold with a diameter of 6.35 cm and a height of 1.5 cm. Samples were compacted with a consistent compaction energy of 13,000 kN-m/m^3 to maintain uniform compression, similar to road beds. Compacted disc samples were then dried for 24 h at 60 °C prior to any dust suppressant application.

2.3. Aerosol generation

Dry road aggregate discs were treated with 5 mL of dust suppressant, using a pipette in 1 mL increments. This application rate corresponds to regulatory agency recommendation rates of 1.6 L/m^2 for $CaCl_2$ and is slightly below the State of Pennsylvania's recommended OGPW spreading rates of 0.5 gal/yard^2 (2.3 L/m^2). Treated samples "cured" for 10 min to allow for liquid penetration through the aggregate, and were then dried for 24 h at 60 °C. After 24 h, samples were placed in a small rotary drum (Model B Rotary Tumbler; Thumler's Tumblers) and tumbled for 3 min. During this time, the PM_{10} concentration in the airspace was measured using an aerosol monitor (DustTrak II Aerosol Monitor 8530; TSI). Measured aerosol concentrations from minute 2:00–3:00 were averaged, resulting in an "Average Maximum PM10" (AM PM_{10}) concentration, which was used to compare efficacy between dust suppressant samples. Road aggregate discs with no dust suppressant treatment represented control samples. Detailed methods of aerosol generation and laboratory measurements were previously described in Stallworth et al. (2020). The 2:00–3:00 min interval generally represented a maximum "plateau" in PM_{10} concentrations that were consistent between replicate tests. In addition, these bench-top tests of DSA material correlated with field measurements of PM_{10}.

2.4. Sodium adsorption ratio and total dissolved solids

OGPWs and alternative treatment samples were filtered using a 0.45 μm cellulose acetate filter and then analyzed for cations (Na, Ca, Mg, Sr and K) by inductively coupled plasma optical emission spectrometry (ICP-OES) and anions (Cl, Br, SO_4^{2-}, PO_4^{3-}) by ion chromatography (IC). A single measurement, Log (SAR/TDS) was calculated based on major anion and cation concentrations in order to evaluate the effects of TDS and SAR together. TDS was calculated based on the sum of all dissolved ion concentrations (all in mg/L).

The SAR was calculated based on dissolved metal concentrations as follows:

$$SAR = \frac{Na^{+}\left(\frac{meq}{L}\right)}{\sqrt{0.5 * \left(Ca^{2+}\left(\frac{meq}{L}\right) + Mg^{2+}\left(\frac{meq}{L}\right)\right)}} \quad (1)$$

2.5. Simulated rain events

Synthetic rainwater (pH = 4.2) was created following the EPA synthetic precipitation leaching procedure (SPLP; SW-846 Test Method 1312). The volume of leaching solution applied for each event was based on precipitation records collected by the National Atmospheric Deposition Program for the Kane Experimental Forest, located in the

Allegheny National Forest in Pennsylvania (NTN Site PA29; 41.598, −78.77) that represents an area with historical OGPW application as a dust suppressant. The 80th percentile rain event was calculated from daily precipitation records for the months of June – August in the years 2008–2017. This rainfall depth, 0.43 cm, corresponds to a rain event that would occur once every 5 days. The depth of rain was converted to a volume by multiplying by the surface area of the road disks (~31.6 cm^2) and was approximately 15 mL. For each round of leaching, the sample was placed in a plastic Buchner funnel, and 15 mL of rainwater solution was poured evenly over the disc. Discs were equilibrated for 12 h to allow for sufficient rainwater contact time. A vacuum pump was then used to remove and collect the standing solution. Next, samples were placed in an oven at 60 °C for 24 h, or until the sample remained at constant weight. Finally, samples were transferred into the mechanical rotary drum and tested for suppressant efficacy. This process was completed three times, for a cumulative 45 mL applied leaching solution to represent moderate rain events over roughly a two-week period.

2.6. Radium removal

To reduce environmental and human health risk, radium can be removed from OGPW prior to spreading on roads. OGPWs were characterized for radium activities of two long-lived radium isotopes (^{226}Ra and ^{228}Ra) using a small anode germanium gamma ray spectrometer (Canberra Instruments). Liquid samples (OGPWs and alternative liquids) were preserved to a pH less than 2 with nitric acid. Solid samples (aggregates) were sieved to <1.18 mm. Samples were equilibrated for 21 days and radium determined using the activity of the daughter products, ^{214}Pb at energy levels 295.2 keV and 351.9 keV and ^{214}Bi at 609.3 keV. ^{228}Ra was determined through the activity of decay product ^{228}Ac at 911 keV. A uranium ore tailing standard (UTS-2) from Canadian Certified Reference Material Project was used to calibrate detector efficiencies (http://www.nrcan.gc.ca/mining-materials/). All methods for determination of radium, including activity corrections for high TDS fluids, were previously described in detail (Ajemigbitse et al., 2019; Tasker et al., 2019).

The dust suppression efficacy of an OGPW, PAB1, was measured before and after three types of radium removal via chemical precipitation experiments, 1) sodium sulfate, 2) magnesium sulfate, and 3) barium sulfate. To remove radium, sodium sulfate or magnesium sulfate solution was added to 100 mL of PAB1 to co-precipitate radium with barium and strontium sulfate. The volume of sodium or magnesium sulfate added was held at 25 mL, and the concentration of the solution corresponded to a 1:1, 2:1, or 3:1 sulfate:(strontium + barium) molar ratio, although for each produced water, strontium was present in the greatest amount. Alternatively, solid barium sulfate was added to the brine samples at a solid (g barite) to liquid (kg brine) ratio of 4:2 to 4:4. The mixture was then slowly stirred for 48 h, to allow for the incorporation of radium (Zhang et al., 2014). The supernatant was then decanted, filtered through a 0.45 μm cellulose acetate filter, and used to treat road disc samples. Radioactivity of both the untreated and treated OGPWs was measured using the techniques described above.

2.7. Estimating OGPW efficacy across the USA

OGPW data for states with active conventional oil and gas drilling was accessed from the publicly available United States Geological Survey (USGS) Produced Water Database (Blondes et al., 2018). To ensure representative data quality, only samples within +/- 15% of the major ion charge balance were retained ($n = 74{,}312$ or 48%). Average major element concentrations were then used to calculate average SAR and TDS values for each state. States highlighted include those which currently regulate the spreading of OGPW for dust/deicing or road maintenance (CO, IL, IN, KS, MI, ND, NE, NY, OH, PA, SD, WV, and WY) (Tasker et al., 2018); those which regulate beneficial spreading of OGPW not exclusively for road spreading (AL, NM, TN, and VA) (Tasker et al., 2018); and states which are studying the potential to increase the beneficial use of OGPW, as encouraged by the U.S. Environmental Protection Agency (EPA), U.S. Department Of Energy (DOE), and USGS (e.g., OK, NM, TX) (USEPA, 2019a; USGS, 2020).

3. Results

3.1. Dust suppressant characterization

Three types of dust suppressant fluids (simulated brines, OGPW, and alternative products) were characterized (Table 1, Table S1). As expected, the simulated brines created to represent commercial products, $CaCl_2$, $MgCl_2$, and NaCl had the highest Ca, Mg, and Na concentrations of any samples in the study, respectively. For the conventional OGPWs, TDS ranged from 1100 to 356,000 mg/L, and SAR values ranged from 7 to 106. These OGPWs were highest in sodium (mean = 29,000 mg/L) > calcium (mean = 20,000 mg/L) > magnesium (mean = 3000 mg/L). The Log (SAR/TDS) value varied from −2.2 to −6.7. The Wyoming brines (WYB1, WYB2) had the lowest SAR values (7 and 12) and TDS (1100 and 5800 mg/L) of all the OGPWs tested in this study (McDevitt et al., 2019, 2020b). An untreated unconventional OGPW (COB1, from Colorado) that had been stored in an evaporation pond had a high TDS (305,000 mg/L) and a moderate to high SAR (42). Two treated unconventional OGPWs were also studied (PATO and PATR). PATO had similar TDS (111,000 mg/L) and SAR (63) values compared to the conventional OGPWs, but PATR had a lower TDS (10,100 mg/L) and SAR (28). Of the three alternative dust suppressants, a softening sludge from a water treatment plant had the lowest SAR and TDS (2 and 295 mg/L, respectively). The soybean oil and the commercial product EnviroKleen® were not characterized for TDS or SAR because they are not brines.

3.2. Aerosol generation

All dust concentrations are reported in terms of the Average Maximum PM_{10} (AM PM_{10}) measured over the last minute ($t =$ 2:00–3:00 min:sec) of the dust generation experiments (Stallworth et al., 2020). The DSA road aggregate samples that were not treated with any dust suppressant (control; $n = 2$) generated 239 to 258 mg/m^3 of dust (Fig. 1; Table 1). Soybean oil and EnviroKleen® generated the least amount of dust (0.02 mg/m^3), while $CaCl_2$ (0.4 mg/m^3) and $MgCl_2$ (0.5 mg/m^3) also generated very little dust. WTP SS generated moderately high amounts of dust (AM PM_{10} = 66 to 245 mg/m^3). The road aggregate samples treated with OGPW ($n = 18$) varied by five orders of magnitude from 0.02–337 mg/m^3 for individual samples. The treated unconventional OGPWs generated dust between 184 and 301 mg/m^3. Notably, NaCl generated the largest amount of dust (267 to 366 mg/m^3) of any type of treatment, which was significantly greater than the untreated control ($p = 0.004$).

3.3. Sodium adsorption ratio and total dissolved solids

For brines, dust suppression efficacy is influenced by both the SAR and TDS of the fluid. In a previous study using simulated brines (Stallworth et al., 2020), strong linear relationships suggested that dust suppression efficacy of synthetic brines can be predicted if the SAR or TDS of a simulated brine are known. In this study, the Log (SAR/TDS) was calculated in order to combine the effects of SAR and TDS into one value that could estimate an OGPW's efficacy as a dust suppressant. A linear relationship (Eq. (2)) based on this singular value for the simulated brines supported the applicability of Log (SAR/TDS) to describe these trends (Table S2). The linear regression using the Log (SAR/TDS) of twenty simulated brines and the Log $AMPM_{10}$ generated from DSA discs produced an r^2 of 0.87 and a significant p-value (2×10^{-9}).

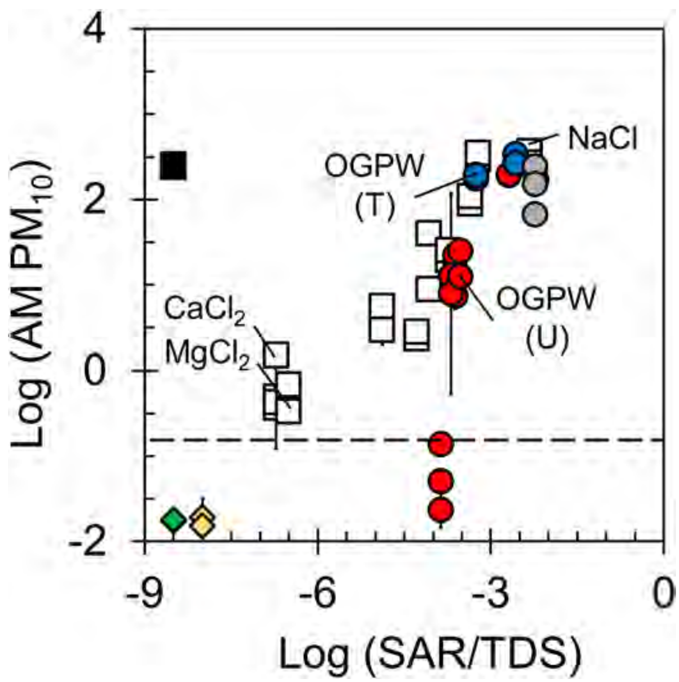

Fig. 1. Lab generated dust concentrations shown on the y-axis as the log of the Average Maximum PM_{10} (AM PM_{10}; mg/m^3) plotted against the log of the quotient of SAR divided by TDS for each dust suppressant. Black squares represent the dust generated by control samples with no treatment; white squares, simulated brines (Stallworth et al., 2020); green diamonds, EnviroKleen®; yellow diamonds, soybean oil; red circles, untreated unconventional OGPW(U); blue circles, treated unconventional OGPW(T); grey circles, water treatment plant sludge (WTP SS). Control, soybean oil, and EnviroKleen® samples were assigned arbitrary Log(SAR/TDS) values to allow for graphing. The dashed horizontal line represents the US EPA 24-h exposure limit for PM_{10}, 0.15 mg/m^3 (Log = −0.92). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

$$Log\ AMPM_{10} = 0.66 * Log\left(\frac{SAR}{TDS}\right) + 4 \qquad (2)$$

Based on values from the USGS produced water Database, OGPW from Texas has an average TDS of 81,064 and an average SAR of 121. Based on Eq. (2) these values predict an $AMPM_{10}$ of 126.

3.4. Influence of rain events

Four of the suppressants, $CaCl_2$, OHB1, PAB1, and soybean oil, were applied to DSA road materials and then subjected to simulated rain events ($n = 3$). Generally, more dust was generated following each simulated rain event. Soybean oil, however, demonstrated minimal dust generation increase after the first rain event and then little additional dust generation between rain events 2 and 3 (Fig. 2; Table S3).

The samples treated with OGPWs (OHB1, PAB1) lost efficacy by the second rain event and generated as much dust as the untreated-control samples. These samples consistently reached the instrument maximum detection of 400 mg/m^3 (Log = 2.60) following a second rain event. Samples treated with $CaCl_2$ lost efficacy with each rain event more slowly than the OGPW-treated samples and generated nearly as much dust as the untreated-control samples after three rain events.

3.5. Influence of radium removal

In the conventional OGPWs, total radium ($^{226}Ra + ^{228}Ra$) activities were between 20 and 1440 pCi/L, consistent with previous reported results (Dresel and Rose, 2010; Haluszczak et al., 2013; McDevitt et al., 2019; Rowan et al., 2011, 2015; Tasker et al., 2018; Zhang et al., 2014). PATO had a total radium value of 5900 pCi/L, more than double that of

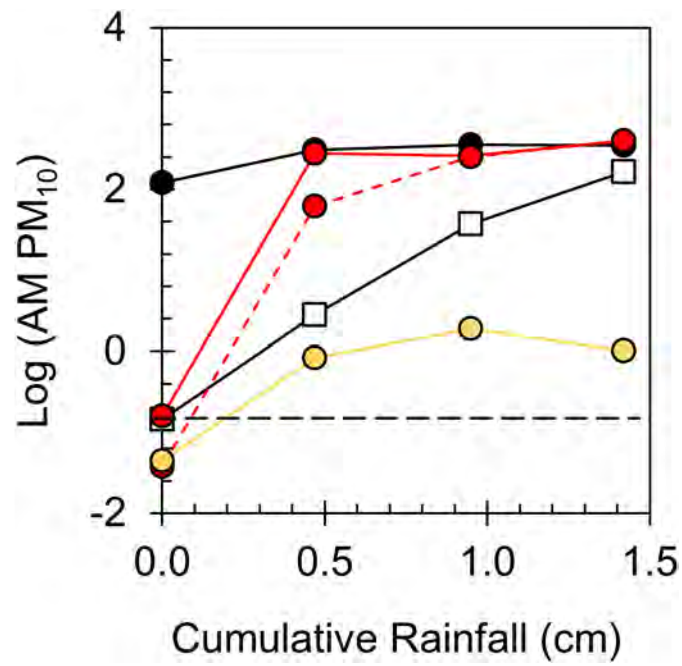

Fig. 2. Efficacy of dust suppressants after moderate summer rain events (0.45 cm) that typically occur every 5–7 days in western PA (i.e., equivalent to the rainfall depth that would fall in 24-h, every 7-days in NW PA). The y-axis shows the dust generated, as Log Average Maximum PM10 (AM PM_{10}), after cumulative increases in applied precipitation (in cm), on the x-axis. Black squares represent the untreated control; red circles connected with a solid line, OHB1; red circles connected with a dashed line, PAB1; white squares, $CaCl_2$; yellow circles, soybean oil. The dashed horizontal line represents the US EPA 24-h exposure limit for PM_{10}, 0.15 mg/m^3. For all conditions, $n = 2$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the conventional OGPWs used in this study, but similar to results reported for unconventional OGPW (Rowan et al., 2011, 2015). Radium was not detected (ND < 20 pCi/L) in PATR, nor in any of the alternative dust suppressants investigated in this study. The complete chemistry data from the dust suppressant characterizations are presented in Table S1.

One conventional OGPW, PAB1, was treated to remove radium using the method described in Zhang et al. (2014) to co-precipitate radium with barium and strontium sulfate using varying doses of barium, sodium, and magnesium sulfate (Zhang et al., 2014). For all doses of barium, sodium, and magnesium sulfate, the total radium decreased after treatment. For 1× the calculated sodium sulfate dose, the Ra decrease was almost 50% (Fig. 3), but activity still remained well above the EPA industrial discharge limit of 60 pCi/L. In contrast, both barite radium-removal doses reduced radium to near 60 pCi/L. Overall, the dust suppression efficacy of the treated brine decreased slightly (Fig. 3) for magnesium and sodium sulfate treatments, but barite treatments demonstrated similar or better reduction of PM_{10}. Two DSA samples treated with PAB1 generated 10 and 14 mg/m^3 PM_{10}. Following barite addition to remove radium, discs treated with radium-reduced PAB1 generated only 0.2 and 1.1 mg/m^3 dust (Fig. 3).

3.6. Estimating OGPW efficacy by state

The USGS Produced Water Database was utilized to calculate a state average OGPW Log (SAR/TDS) to estimate anticipated dust generation (in Log AM PM_{10}) if applied as dust suppressants (Table S4). Results of predicted dust generation from mean values of SAR/TDS calculated for OGPW from each state are presented in Fig. 4. Results for commercial dust suppressants and simulated brines are included for comparison. States were categorized based on the predicted AM PM_{10} values, which are shown across the continental USA (Fig. 5).

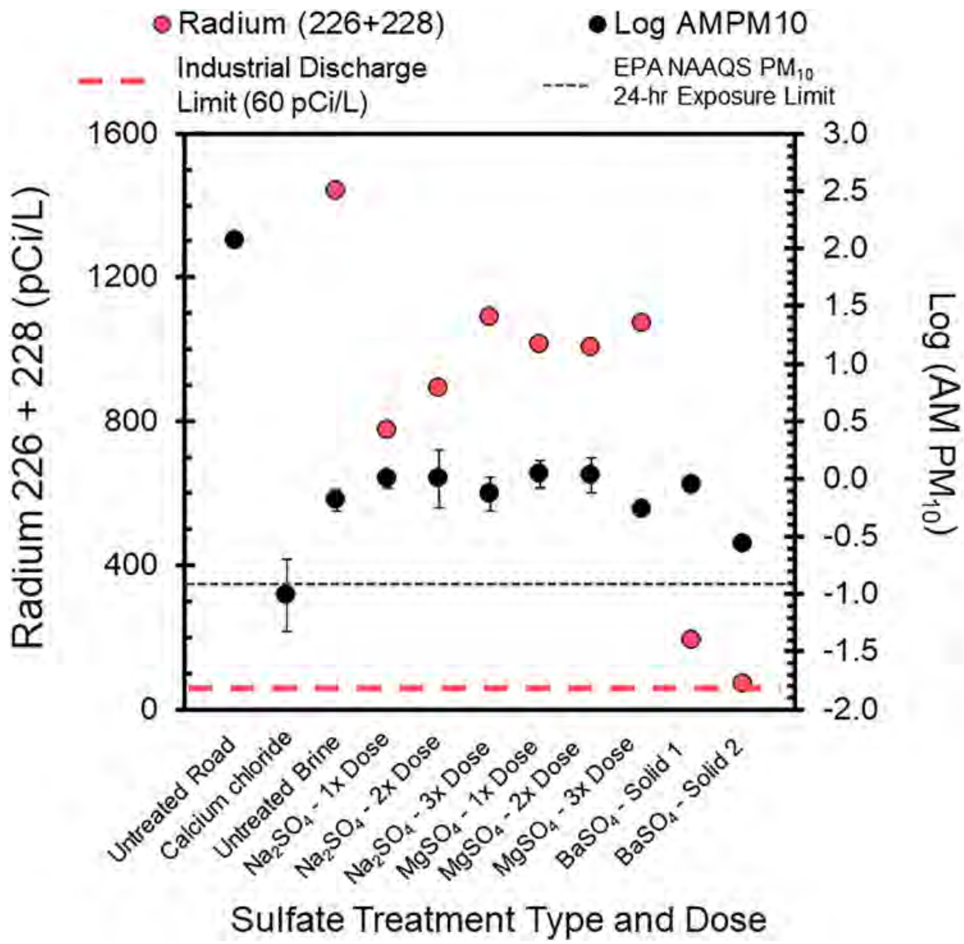

Fig. 3. Total radium (Ra-228 + Ra-226) activities (pCi/L) in treated OGPW (red circles) and resulting effects on dust generation, Average Maximum PM_{10} (AM PM_{10}) (black circles). The untreated road and $CaCl_2$ treatments contained non-detectable activities for total radium. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

4.1. Dust suppressant efficacy

A total of twenty simulated brines were tested, each with varying SAR and TDS values (Table 1). Similar to previous studies of synthetic brines, there was a strong negative relationship between the SAR and dust suppression efficacy (Graber et al., 2019; Stallworth et al., 2020), and a strong positive relationship between the TDS and dust suppression efficacy (Stallworth et al., 2020). Brines highest in sodium (e.g. NaCl) performed worse than brines with little to no sodium (i.e. $CaCl_2$ and $MgCl_2$).

Eight OGPWs were tested, with ranges of TDS from 1100 to 356,000 mg/L, and SAR from 7 to 106 (Table 1). The results demonstrate the divergent effects on efficacy between TDS and SAR that occurs when OGPW is used for dust suppression. Generally, the untreated conventional OGPW samples (PAB1, PAB2, OHB1) suppressed dust most effectively (7–25 mg/m^3) of the OGPWs. These OGPWs had high SAR values (59–106) and high TDS (245,000–356,000 mg/L). Among these brines, while PAB2 had the highest TDS (an indicator of good dust suppression), it did not out-perform the other two brines. PAB2 also had the highest SAR (an indicator of poor dust suppression), which could have counteracted the benefit of high TDS. The OGPWs which suppressed dust least effectively (PATR, WYB1, WYB2; 171–337 mg/m^3) had low to mid/high SAR values (7–28), and low TDS (1100–10,000 mg/L). PATO performed within the range of the least effective OGPWs; however, it had a much higher TDS and SAR. The contrasts observed with PAB2 and PATO further indicate that TDS and SAR are both factors in OGPW dust suppression and suggest there is a limit to the effectiveness of higher TDS (and higher Ca, Mg dosing) on mitigating the detractive effects of sodium in higher SAR fluids. The implication for road managers and State agencies is that SAR and TDS calculations need to be performed to demonstrate dust suppressant efficacy of OGPW from an OG well.

To capture the combined influence of SAR and TDS in one measurement, the Log (SAR/TDS) value was calculated and plotted versus the log of AM PM_{10} (Fig. 1, Table 1). As the Log (SAR/TDS) becomes smaller (more negative), the expected dust generation decreases. The applicability of this measurement is demonstrated by comparing results from the water treatment plant softening sludge (WTP SS) and the NaCl simulated brine. WTP SS had a very low SAR (2), ideal for dust suppression; however, it also had very low TDS (295 mg/L). As such, it suppressed dust minimally (198 ± 14 mg/m^3) compared to the control (248 ± 11 mg/m^3). The Log (SAR/TDS) of the water treatment plant softening sludge was comparable to the sodium chloride simulated brine. The sodium chloride brine, while high in TDS (299,000 mg/L), also had a very high SAR value (1400). In our experiments, the Log (SAR/TDS) explained a high proportion of total PM_{10} produced (R^2 = 0.87) (Table S2). The utility of Log (SAR/TDS) is a valuable tool for road managers and state regulators seeking to rapidly assess the efficacy of OGPW within their regions. Of note, the COB1 results do not appear to fit the Log (SAR/TDS) trend, as this brine suppressed dust more effectively than predicted. COB1 has a high TDS, and was sourced from an evaporation pond which could lead to better humectant (i.e., moisture retention) properties. Evaporative concentration of the source-brine until the time of COB1 collection could have led to better performance, but

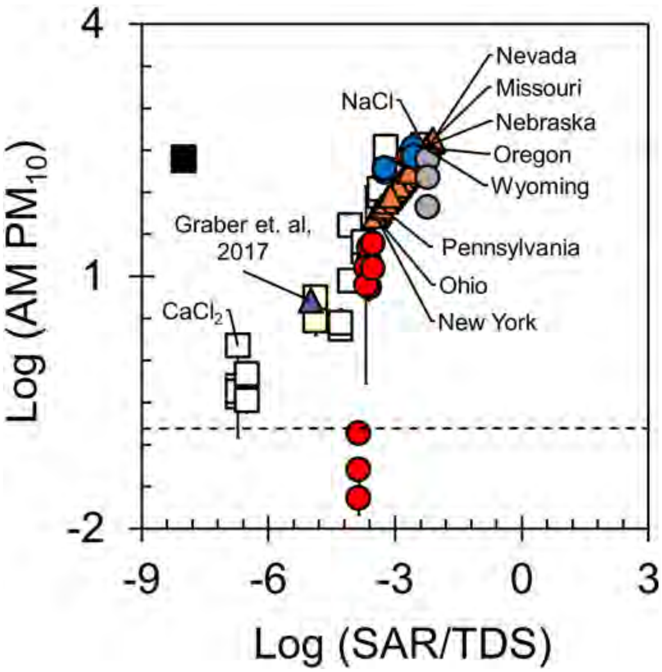

Fig. 4. Dust generated (AM PM_{10}) from laboratory samples during this study and predicted AM PM_{10} of OGPW from selected States based on Log (SAR/TDS). White squares represent simulated brines; red circles, conventional OGPW; blue circles, treated unconventional OGPW; grey circles, water treatment sludge – all laboratory-measured values. Orange triangles represent predicted dust generation for States with data entries in the USGS Produced Water Database. The purple triangle represents the predicted dust generation of the OGPW used in the Graber et al. study (Graber et al., 2017). The dashed horizontal line represents the US EPA 24-h exposure limit for $PM_{10,}$ 0.15 mg/m^3. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

one not predicted by SAR/TDS alone. Alternatively, a significant increase in humidity conditions in the laboratory at the time of testing, as compared to the other samples, could have led to increased suppression efficacy. These results suggest that further tests with the method are needed to explore humidity and other site-specific conditions.

Both the soybean oil (SOY OIL) and EnviroKleen® performed about four orders of magnitude better than WTP SS and three orders of magnitude better than the best performing OGPW (Fig. 1, Table 1). These fluids do not have SAR or TDS values; therefore, they were assigned arbitrary Log (SAR/TDS) values along with the control. Soybean oil is perhaps the most promising alternative product to OGPW because it worked as well as a commercial product and could likely be obtained at a lower price as a byproduct of soybean crushing. Although effective and commercially available, EnviroKleen® would likely be cost prohibitive for many rural road managers with in-place costs ranging from \$4000-\$10,000 per mile per application (Stallworth et al., 2020). Since each fluid has organic components that likely enhance their efficacies, factors not assessed in this study, they should be investigated before widespread use (i.e., to prevent the potential leaching of organic carbon and/or nutrients into nearby waterways during storm events).

4.2. Total dissolved solids and sodium adsorption ratio

Based on a 'state-average OGPW', New York, Ohio and Pennsylvania would generate the lowest amount of dust if their OGPWs were used as dust suppressants. All three of these states currently or previously spread OGPW. However, even the best performing OGPW from these states did not perform as well as alternative waste products such as soybean oil. The regression predicts that Nevada OGPWs would likely generate the most dust if used as a dust suppressant.

As States seek an inexpensive alternative to commercial dust suppressants and deicing agents, and the U.S. EPA seeks to expand beneficial use of OGPW across the U.S. (USEPA, 2019b), predicting efficacy of OGPW as a dust suppressant in other geographical areas remains imperative to maintain human and ecological health. Using the Log SAR/TDS as a predictor of dust generation, we estimated PM_{10} generation for 37 states (Table S4). We found that the use of OGPW from states such as NV, NE, and WY are expected to perform similarly to NaCl brine and untreated controls. Predicted AM PM_{10} values for CO and WY (Table S4) are near the measured values (COB1, WYB-1, and WYB2) (Table 1). Likewise, OGPW from Appalachian Basin states such as OH, PA, WV and NY are predicted to be more effective. A direct comparison for predicted laboratory PM_{10} dust generation based on the regression calculation (52–67 mg/m^3) for these states was close to the observed

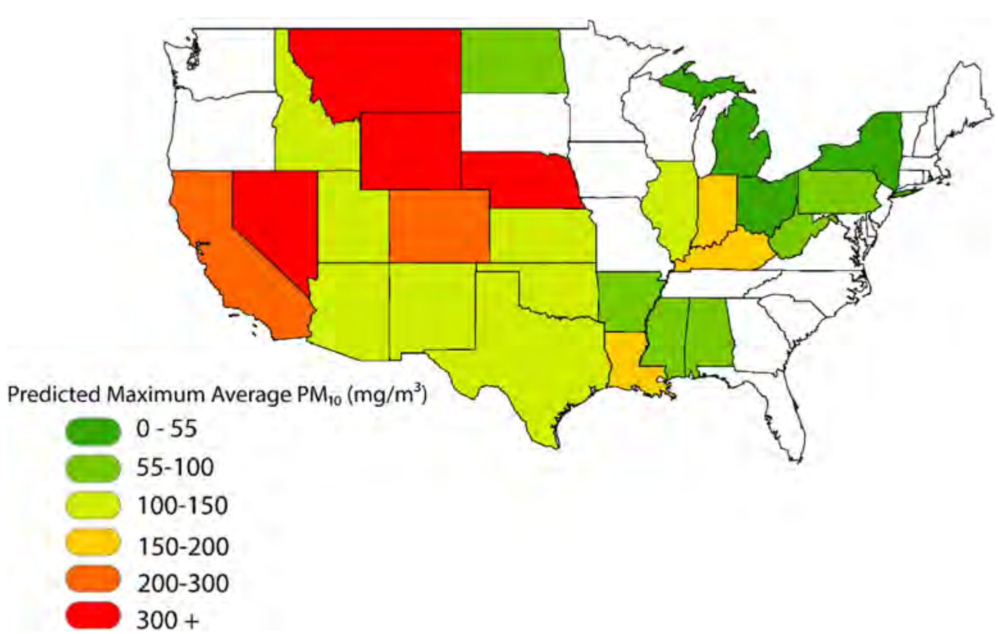

Fig. 5. Predicted dust suppression efficacy across the U.S. based on SAR and TDS values available in the USGS Produced Water Database for each State. States represented in white had less than 50 entries available in the USGS Produced Water Database.

laboratory PM_{10} generation of the tested samples (10–19 mg/m^3) (Table S5). The correlation between concentrations of dust generated in the laboratory and dust generated on roadways is yet to be defined, with additional field scale experiments required.

Due to spatial variability in the TDS and SAR of produced waters across oil and gas plays (Chaudhary et al., 2019; Scanlon et al., 2020), evaluation of OGPW at a finer spatial scale is recommended when considering applicability—especially when considering the high degree of variability within states. States may be able to conduct a similar analysis on a county-level to identify specific counties and/or formations which may be best-suited for OGPW road spreading. For example, a recent field study by Graber et al. (2017) used an ideal OGPW (low SAR, high TDS) from South Dakota in a field test (Graber et al., 2017). While the efficacy results cannot be directly compared, inputting the Log (SAR/TDS) of this OGPW into the regression equation yielded an expected dust generation that was lower than the range observed with the average USGS produced water data for South Dakota. Therefore, analysis at the local level may reveal a wider range of OGPW suitable for use as dust suppressants. However, suppressants used commercially, such as calcium chloride, magnesium chloride, and EnviroKleen®, as well as the alternative soybean oil each outperformed all OGPW tested in this study, which may indicate OGPW application for dust suppression may not be beneficial (Payne, 2018).

4.3. Influence of rain events

While dry conditions motivate the use of dust suppressants, rain events are not uncommon in seasons when suppressants are applied in some regions (e.g., Pennsylvania and Ohio). Therefore, resilience to small rain events that typically occur repeatedly during summer months was investigated for OHB1, PAB1, SOY OIL, and $CaCl_2$. With each rain event, the efficacy of each dust suppressant decreased, excluding SOY OIL, which decreased minimally and then leveled off after the first rain event (Fig. 2, Table S3). The samples treated with OGPW lost efficacy more quickly and to a greater degree than the $CaCl_2$ and SOY OIL samples; by the second rain event, the OHB1 and PAB1 generated as much dust as the untreated-control sample. These samples consistently reached the instrument maximum of 400 mg/m^3. These results further demonstrate the efficacy of an alternative product (soybean oil) relative to the OGPWs, which appear to have limited capacity to suppress dust after typical rain events observed in the summer months.

In a previous study by Tasker et al. (2018), road materials treated with OGPW were leached using the EPA Synthetic Precipitation Leaching Procedure (SPLP) (Tasker et al., 2018). In these simulated rain events on road materials treated with OGPW nearly all sodium, magnesium, and calcium leached out of the road aggregate (Tasker et al., 2018). However, the test was performed on loose, smaller aggregate, with larger volumes of leaching solution and a rotational shaker for equilibration. The method used in the current study attempted to simulate a leaching event closer to what would be observed on a road surface. It is likely that rain events will result in the loss of the constituents responsible for dust suppression over time (Warrence et al., 2002). From this study, roads treated with OGPW may be most susceptible to this loss compared to commercial grade and non-brine alternatives, requiring diligent maintenance (without over-application).

4.4. Influence of radium removal

While several of the regulations that permit the road or land spreading of OGPW specify only conventional OGPW (as opposed to unconventional OGPW generated after hydraulic fracturing (Haluszczak et al., 2013; Tasker et al., 2018)), untreated conventional OGPW still contains levels of radium above regulatory standards, such as the industrial discharge limit of 60 pCi/L (Tasker et al., 2018). The addition of sodium sulfate to OGPW removed about half of the overall radium activity (from PAB1), but also added sodium to the solution, increasing the SAR and limiting its effectiveness as a dust suppressant (Fig. 3). Conversely, the addition of magnesium or calcium sulfate to an OGPW decreased the SAR but did not increase dust suppression efficacy. This decrease in efficacy may be due to dilution – the volume of sulfate solution added had lower TDS and made up 20% of the final volume. Regardless, in all magnesium and sodium sulfate additions, removal of roughly half the radium from OGPW via co-precipitation with barium and/or strontium sulfate led to only a slight decrease in dust suppression efficacy. In contrast, radium removal was optimized with treatments of pre-formed solid barite, which removed around 90% of the radium and maintained SAR and TDS, leading to similar (and in some cases, better) dust suppression efficacy compared to untreated OGPW. Following a single dose with barite, radium values in OGPW (70–140 pCi/L) were near the industrial discharge limit of 60 pCi/L.

4.5. Limitations

Additional contaminants found in OGPW, (i.e. lead, arsenic, radium) may accumulate on roadways and in groundwater (Skalak et al., 2014; Tasker et al., 2018), which raises concerns about the safety of water resources post-application (Chen and Lippmann, 2009; Kim et al., 2015) that were not addressed here. Indeed, brines that are used for road maintenance activities such as deicing and dust suppression raise concerns about increasing the salinity of proximate water resources, because once applied, much of the salt becomes mobile and travels offsite with surface and groundwater (Bair and Digel, 1990; Eckstein, 2011; Piechota et al., 2002) which has negative consequences for agriculture, infrastructure, and aquatic life (Fay and Shi, 2012; Kaushal et al., 2018; Tasker et al., 2018). The removal of heavy metals from OGPW, such as arsenic, has been demonstrated (Akhbarizadeh et al., 2018; Fakhru'l-Razi et al., 2009; McDevitt et al., 2020a). Therefore, removal of metals prior to application on roadways could reduce some of the risks without compromising dust suppression efficacy.

5. Conclusions

Road spreading of OGPW is an established practice that is generating health and efficacy concerns as the practice gains more attention. Compared to commercial counterparts, calcium and magnesium chlorides, the presence of sodium in an OGPW can render an OGPW less effective as a dust suppressant. None of the OGPWs assessed performed as well as the commercial analogs, $CaCl_2$ or $MgCl_2$. Based on average TDS and SAR values for OGPW in each state, the OGPWs tested in this study likely represent the upper limits of efficacy of OGPW as a dust suppressant. If the justification for using OGPW is equivalency with commercial counterparts, evidence points to far less efficacy. However, removal of radium from OGPW to concentrations below regulatory levels that will reduce risk is possible, with minimal impact to efficacy.

CRediT authorship contribution statement

Audrey M. Stallworth: Conceptualization, Methodology, Formal analysis, Validation, Writing – original draft, Writing – review & editing. **Eric H. Chase:** Conceptualization, Methodology, Formal analysis, Validation, Supervision, Writing – review & editing. **Bonnie McDevitt:** Methodology, Formal analysis, Validation, Writing – review & editing. **Katherine Marak:** Methodology, Formal analysis, Validation, Writing – review & editing. **Miriam Arak Freedman:** Methodology, Formal analysis, Validation, Supervision, Writing – review & editing. **Robin Taylor Wilson:** Methodology, Formal analysis, Validation, Supervision, Writing – review & editing. **William D. Burgos:** Conceptualization, Methodology, Formal analysis, Validation, Supervision, Writing – review & editing. **Nathaniel R. Warner:** Conceptualization, Methodology, Formal analysis, Validation, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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EXHIBIT P

COMMONWEALTH OF PENNSYLVANIA

BEFORE THE ENVIRONMENTAL HEARING BOARD

SIRI LAWSON, Appellant	:	
	:	
	:	**EHB Docket No. 2017-051-B**
	:	
COMMONWEALTH OF PENNSYLVANIA, DEPARTMENT OF ENVIRONMENTAL PROTECTION, Appellee	:	
	:	
and	:	
	:	
HYDRO TRANSPORT, LLC, Permittee,	:	
	:	
and	:	
	:	
FARMINGTON TOWNSHIP, Intervenor	:	
	:	
and	:	
PENNSYLVANIA STATE	:	
ASSOCIATION OF TOWNSHIP	:	
SUPERVISORS	:	
Intervenor	:	

***AMICUS CURIAE* BRIEF IN SUPPORT OF APPELLANT**

STATEMENT OF INTEREST OF AMICUS CURIAE

1. Damascus Citizens For Sustainability (DCS) is a nonprofit, grassroots organization dedicated to protecting clean air, land, and water from pollution caused by the fossil fuel extraction industry, primarily looking at oil and gas. DCS works to provide individuals and communities directly threatened by their processes with the tools necessary to defend themselves. To this end, we routinely provide individuals in Pennsylvania and across the country (and internationally) with information about the way fossil fuels are extracted, processed, etc., the risks those processes pose to human health and the environment, and the federal, state, and local laws, regulations, and policies that govern fossil fuel extraction and related processes.

2. Currently, 4,334 people are signed up as members of Damascus Citizens. We don't require our subscribers to provide their home address; of those that do, more than 500 subscribers list a primary address in Pennsylvania. Many other subscribers have a secondary address in Pennsylvania, own property or have relational or business interests in the Commonwealth, or visit regularly to see family or to enjoy Pennsylvania's amenities. Individual supporters contribute close to one-half of DCS' operating budget.

3. DCS's mission is to protect public health and safety from impacts of the oil and gas industry. While it's *raison d'etre* is to respond to hydraulic fracturing, since it's inception it has been highly involved in the impacts of, and the regulation and oversight of natural gas production in Pennsylvania, from production to end user

with attention to the wastes produced at each stage and their subsequent disposal. The spread of brine is a disposal method, which impacts DCS members and impacts DCS's ability to fulfill its mission - i.e., protection public health. The substantial, direct and immediate impact if Ms. Lawson's appeal is denied will be that DCS' members will have more brine health problems. Regulatory oversight would be less even than it has been and water and air impacts would increase.

STATEMENT OF QUESTIONS INVOLVED

4. Damascus Citizens for Sustainability (DCS) is submitting this amicus curiae brief to underscore the constitutional responsibility of the parties and the Board under the Environmental Rights Amendment ("ERA"or "Section 27") to the Pennsylvania Constitution, found at Article 1, Section 27. The ERA declares that:

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of the people.

5. The question presented in this case is whether the practice of disposing of liquid waste from oil and gas development through what is referred to as "brine spreading" violates the Environmental Rights Amendment of the Pennsylvania Constitution.

SUMMARY OF ARGUMENT

6. The oil and gas industry practice of disposing of waste fluids by dumping them on un-paved roads is commonly referred to as "brine spreading," This practice violates the Environmental Rights Amendment of the Pennsylvania Constitution.

The Commonwealth, the Department of Environmental Protection, and the municipality that will allow or permit brine spreading are violating their trustee responsibilities and obligations under the ERA.

ARGUMENT

7. As stated by the Supreme Court in *Payne v. Kassab,* 361 A.2d 263,272 (Pa 1976), "There can be no question that the Amendment itself declares and creates a public trust of public natural resources for the benefit of all the people (including future generations as yet unborn) and that the Commonwealth is made the trustee of said resources, commanded to conserve and maintain them."

8. Municipalities, as agents of the Commonwealth, share trustee duties as they carry out their roles in land use planning and regulation. See, *Community College of Delaware County v. Fox,* 342 A.2d 468, 482 (20 Pa. Cmmw, 1975). Indeed, this Board and all of the other courts in the Commonwealth also share responsibilities under the ERA. As the Supreme Court observed in *Commonwealth v. Parker White Metal Co.* 515 A.2d 1358 (Pa. 1986):

> In declaring sections 606(a) and 606(b) of the Solid Waste Management Act unconstitutional, the lower court has given little, if any, consideration to the strong and fundamental presumption of constitutionality that must attend judicial review of a legislative enactment. That presumption is further strengthened in this case by the explicit purpose of the Act to implement Article I, section 27 of the Pennsylvania Constitution, a remarkable document expressing our citizens' entitlement and "right to clean air, pure water, and -- to the preservation of the natural, scenic, historic and esthetic values of the environment." The courts of this Commonwealth, as part of a co-equal branch of government, serve as "trustees" of "Pennsylvania's public natural resources," no less than do the

> executive and legislative branches of government…. As one of the trustees of the public estate and this Commonwealth's natural resources, we share the duty and obligation to protect and foster the environmental well-being of the Commonwealth of Pennsylvania. Failure to act with vigilance "so as best to achieve and effectuate the goals and purposes" of the Solid Waste Management Act would be detrimental to the public health, safety and welfare, and would be a breach of the public trust. 515 A.2d at 1370-71.

9. The legislative history of the ERA and the environmental background that led to the provisions of Section 27 in Article I of the Pennsylvania Constitution is quite telling. The Supreme Court in *Pennsylvania Environmental Defense Foundation,* No. 10 MAP 2015(Pa. June 20, 2017) ("PEDF") quoted extensively from the Supreme Court's prior plurality opinion in *Robinson Township v. Commonwealth,* 83 A.3d 901(Pa. 2013):

> Section 27 contains an express statement of the rights of the people and the obligations of the Commonwealth with respect to the conservation and maintenance of our public natural resources. In *Robinson Township v. Commonwealth*, 83 A.3d 901(Pa. 2013) (plurality), a plurality of this Court carefully reviewed the reasons why the Environmental Rights Amendment was necessary, the history of its enactment and ratification, and the mischief to be remedied and the object to be attained. At the outset of this opinion, we reiterate this historical background, which serves as an important reminder as we address the issues presented in the present case:
>
> > "It is not a historical accident that the Pennsylvania Constitution now places citizens' environmental rights on par with their political rights. Approximately three and a half centuries ago, white pine, Eastern hemlock, and mixed hardwood forests covered about 90 percent of the Commonwealth's surface of over 20 million acres. Two centuries later, the state experienced a lumber harvesting industry boom that, by

1920, had left much of Pennsylvania barren. "Loggers moved to West Virginia and to the lake states, leaving behind thousands of devastated treeless acres," abandoning sawmills and sounding the death knell for once vibrant towns. Regeneration of our forests (less the diversity of species) has taken decades.

Similarly, by 1890, "game" wildlife had dwindled "as a result of deforestation, pollution and unregulated hunting and trapping." As conservationist John M. Phillips wrote, "In 1890, the game had practically disappeared from our state....

We had but few game laws and those were supposed to be enforced by township constables, most of whom were politicians willing to trade with their friends the lives of our beasts and birds in exchange for votes." In 1895, the General Assembly created the Pennsylvania Game Commission and, two years later, adopted a package of new game laws to protect endangered populations of deer, elk, waterfowl, and other game birds. Over the following decades, the Game Commission sought to restore populations of wildlife, by managing and restocking species endangered or extinct in Pennsylvania, establishing game preserves in state forests, and purchasing state game lands. Sustained efforts of the Game Commission over more than a century (coupled with restoration of Pennsylvania's forests) returned a bounty of wildlife to the Commonwealth. The third environmental event of great note was the industrial exploitation of Pennsylvania's coalfields from the middle of the nineteenth well into the twentieth century. During that time, the coal industry and the steel industry it powered were the keystone of Pennsylvania's increasingly industrialized economy. The two industries provided employment for large numbers of people and delivered tremendous opportunities for small and large investors.

..."[W]hen coal was a reigning monarch," the industry operated "virtually unrestricted" by either the state or federal government. The result, in the opinion of many, was devastating to the natural environment of the coal-rich regions of the Commonwealth, with long-lasting effects on human health and safety, and on the esthetic beauty of nature. These negative effects include banks of burning or non-burning soft sooty coal and refuse; underground mine ires; pollution of waters from acid mine drainage; subsidence of the soil; and landscapes scarred with strip mining pits and acid water impoundments. In the mid–1960s, the Commonwealth began a massive undertaking to reclaim over 250,000 acres of abandoned surface mines and about 2,400 miles of streams contaminated with acid mine drainage, which did not meet water quality standards. The cost of projects to date has been in the hundreds of millions of dollars, and the Department of Environmental Protection

has predicted that an estimated 15 billion dollars is in fact necessary to resolve the problem of abandoned mine reclamation alone. *Id.*

The overwhelming tasks of reclamation and regeneration of the Commonwealth's natural resources, along with localized environmental incidents (such as the 1948 Donora smog tragedy in which twenty persons died of asphyxiation and 7,000 persons were hospitalized because of corrosive industrial smoke; the 1959 Knox Mine disaster in which the Susquehanna River disappeared into the Pittston Coal Vein; the 1961 Glen Alden mine water discharge that killed more than 300,000 fish; and the Centralia mine fire that started in 1962, is still burning, and led to the relocation of all residents in 1984) has led to the gradual enactment of statutes protecting our environment. The drafters of the Environmental Rights Amendment recognized and acknowledged the shocks to our environment and quality of life:

> We seared and scarred our once green and pleasant land with mining operations. We polluted our rivers and our streams with acid mine drainage, with industrial waste, with sewage. We poisoned our 'delicate, pleasant and wholesome' air with the smoke of steel mills and coke ovens and with the fumes of millions of automobiles. We smashed our highways through fertile fields and thriving city neighborhoods. We cut down our

> trees and erected eyesores along our roads. We uglified our land and we called it progress.

1970 Pa. Legislative Journal–House at 2270 (quoting anonymous 1698 description of Penn's Woods air). With these events in the recent collective memory of the General Assembly, the proposed Environmental Rights Amendment received the unanimous assent of both chambers during both the 1969–1970 and 1971–1972 legislative sessions. Pennsylvania voters ratified the proposed amendment of the citizens' Declaration of Rights on May 18, 1971, with a margin of nearly four to one, receiving 1,021,342 votes in favor and 259,979 opposed. The decision to affirm the people's environmental rights in a Declaration or Bill of Rights, alongside political rights, is relatively rare in American constitutional law. In addition to Pennsylvania, Montana and Rhode Island are the only other states of the Union to do so. *See* Pa. Const. art. I, § 27 (1971); Mt. Const. art. II, § 3 (1889); R.I. Const. art. I, §17 (1970). Three other states—Hawaii, Illinois, and Massachusetts—articulate and protect their citizens' environmental rights in separate articles of their charters. *See* Hi. Const. art. XI, §§ 1, 9 (1978); Ill. Const. art. XI, §§ 1, 2 (1971–72); Ma. Const. amend. 49 (1972). Of these three states, Hawaii and Illinois, unlike Pennsylvania, expressly require further legislative action to vindicate the rights of the people. By comparison, other state charters articulate a "public policy" and attendant directions to the state legislatures to pass laws for the conservation or protection of either all or enumerated natural resources. *See, e.g.,* Ak. Const. art. VIII, §§ 1–18 (1959); Colo. Const. art. XXVII, § 1 (1993); La. Const. art. IX, § 1 (1974); N.M. Const. art. XX, § 21 (1971); N.Y. Const. art. XIV, §§ 1–5 (1941); Tx. Const. art. XVI, § 59 (1917); Va. Const. art. XI, §§ 1–4 (1971).

Some charters address the people's rights to fish and hunt, often qualified by the government's right to regulate these activities for the purposes of conservation. *See, e.g.,* Ky. Const. § 255A (2012); Vt.

> Const. Ch. II, § 67 (1777); Wi. Const. art. I, § 26 (2003). Still other state constitutions simply authorize the expenditure of public money for the purposes of targeted conservation efforts. *See, e.g.,* Or. Const. art. IX–H, §§ 1–6 (1970); W.V. Const. art. VI, §§ 55, 56 (1996). Finally, many of the remaining states do not address natural resources in their organic charters at all. *See, e.g.,* Nv. Const. art. I, § 1 *et seq.*
>
> That Pennsylvania deliberately chose a course different from virtually all of its sister states speaks to the Commonwealth's experience of having the benefit of vast natural resources whose virtually unrestrained exploitation, while initially a boon to investors, industry, and citizens, led to destructive and lasting consequences not only for the environment but also for the citizens' quality of life. Later generations paid and continue to pay a tribute to early uncontrolled and unsustainable development financially, in health and quality of life consequences, and with the relegation to history books of valuable natural and esthetic aspects of our environmental inheritance. The drafters and the citizens of the Commonwealth who ratified the Environmental Rights Amendment, aware of this history, articulated the people's rights and the government's duties to the people in broad and flexible terms that would permit not only reactive but also anticipatory protection of the environment for the benefit of current and future generations. Moreover, public trustee duties were delegated concomitantly to all branches and levels of government in recognition that the quality of the environment is a task with both local and statewide implications, and to ensure that all government neither infringed upon the people's rights nor failed to act for the benefit of the people in this area crucial to the well-being of all Pennsylvanians. *Id.* at 960-63 (footnotes and some citations omitted)

10. The Supreme Court in *PEDF* also put to rest the persistent notion that the ERA requires further legislative action because, as opponents of the ERA argued,

Section 27 could be read as not being self executing. The Supreme Court responded:

> "there can be no question that the Amendment itself declares and creates a public trust of public natural resources for the benefit of all the people (including future generations as yet unborn) and that the Commonwealth is made the trustee of said resources, commanded to conserve and maintain them. No implementing legislation is needed to enunciate these broad purposes and establish these relationships."

11. This Board and the courts of Pennsylvania have all found that the various environmental statutes of the Commonwealth must be read in a way that makes them consistent with Section 27. Specifically, each of environmental statutes and regulations implemented and enforced by the Department of Environmental Protection has been interpreted so as to embrace the trustee obligations in the ERA to preserve and defend the people's constitutional rights:

> *Clean Streams Law, 35 P.S.691.1 --* See*, Commonwealth v. Harmar Coal Co. 306 A.2d 308, 311-312 (Pa. 1973)*
>
> *Air Pollution Control Act, 35 P.S. 4001 –* See*, Department of Environmental Res. v. Locust Point Quarries, Inc.,396 A.2d 1205,1206, 1209(Pq. 1979);*
>
> *Solid Waste Management Act, 35 P.S. 6018.101 --* See*, Commonwealth v. Packer, 798 A.2d 192, 198-199(Pa. 2002);*
>
> *Sewage Facilities Act, 35 P.S. 750 –* See*, Community College of Delaware County v. Fox, 342 A.2d 468, 472 (Pa.Comwlth. 1975);*
>
> *Oil and Gas Act, 58 P.S.601.101-102—*See*, Declaration of Purpose,*The purposes of this act are to: (1) Permit the optimal development of the oil and gas resources of Pennsylvania consistent with the protection of the

> health, safety, environment and property of the citizens of the Commonwealth. (2) Protect the safety of personnel and facilities employed in the exploration, development, storage and production of natural gas or oil or the mining of coal. (3) Protect the safety and property rights of persons residing in areas where such exploration, development, storage or production occurs. *(4) Protect the natural resources, environmental rights and values secured by the Pennsylvania Constitution, 58 P.S. § 601.102(emphasis added)*. production occurs. *(4) Protect the natural resources, environmental rights and values secured by the Pennsylvania Constitution.*" 58 P.S. § 601.102

12. When looking at governmental responsibilities under the Environmental Rights Amendment, in the June, 2017 decision on PEDF v. Commonwealth of Pennsylvania, Justice Baer stated,

> "Through today's decision, this Court takes several monumental steps in the development of the Environmental Rights Amendment, Article I, Section 27 of the Pennsylvania Constitution. I agree with many of the Majority's holdings, including Part IV.A.'s dismantling of the Commonwealth Court's Payne1 test, which stood for nearly fifty years, the confirmation that the public trust provisions of the amendment are self-executing in Part IV.C., and the recognition in footnote 23 that all branches of the Commonwealth are trustees of Pennsylvania's natural resources.2 These holdings solidify the jurisprudential sea-change begun by Chief Justice Castille's plurality in Robinson Township v. Commonwealth, 83 A.3d 901, 950-51 (Pa. 2013) (plurality), which rejuvenated Section 27 and dispelled the oft-held view that the provision was merely an aspirational statement. With this, I am in full agreement." [1]

13. It is clear that "all branches of government" includes the courts and the municipalities like townships. All of these governmental bodies are obligated to fulfill their responsibilities as trustees of Pennsylvania's natural resources. In fact,

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[1] The Supreme Court Ruling can be downloaded at: http://bit.ly/2sPyPij

townships are charged with protecting the health and welfare of the people in the municipality in the Township Code section 607 (1) of Second Class Township Code:[2]

> Section 607. Duties of Supervisors.--The board of supervisors shall:
>
> (1) Be charged with the general governance of the township and the execution of legislative, executive and administrative powers in order to ensure sound fiscal management and to secure the health, safety and welfare of the citizens of the township.

14. In order to fulfill the requirements of the Township code the Supervisors have to—as it says in the Robinson decision, perform "anticipatory protection of the environment for the benefit of current and future generations."

15. The soundness of the Commonwealth's acceptance of the ERA becomes evident when one considers both the potential environmental impacts and the potential health effects of oil and gas development (see below about health impacts). For instance, in the context of this case, does Ms. Lawson, as a resident of Pennsylvania who has a constitutionally protected right to clean air and pure water, have a right to have brine spreading stopped because it causes contamination of the air and water she uses? Does the Department of Environmental Protection as a trustee (either individually or jointly with a township where she lives and/or the township from which the brine originated) have a trust obligation to protect her from a loss of clean air or a loss of pure water? Do DEP and /or other regulatory agencies have the duty to reject permit

[2] Second Class Township Code (as a download) is here: www.psats.org/ckfinder/userfiles/files/Township%20Code%201-24-14.doc

applications if the activity to be permitted would contaminate the air or water or compromise other trust resources? Do they even have the right to give these permits? It has become more and more evident that even the most stringent regulation of oil and gas production will not totally prevent the occurrence of adverse health effects. Don't the trustee responsibilities extend to protecting all Pennsylvanians as precautionary measures?

16. The potential environmental and health effects of natural gas drilling are serious and varied. In particular, there are concerns about the environmental impacts on air and on water resources, both quantity and quality, and on habitat. Natural gas drilling and fracking processes require water resources in the millions of gallons; they may introduce large volumes of chemically contaminated water and additives such as friction reducers, biocides, surfactants, scale inhibitors, and hydrochloric acid into the well; and they may also disturb, distribute, and bring to the surface chemicals from various rock formations, including Naturally Occurring Radioactive Materials (NORM) and Technically Enhanced Naturally Occurring Radioactive Material (TENORM). Coming back to the surface are chemicals including benzene, toluene, ethylbenzene and xylenes (BTEX), formaldehyde, polyacrylamides, chromates, diesel fuels, and metals are used in the fracking fluids, drilling muds or are released through diesel exhaust, venting or flaring. It is estimated that 20%-50% of the fracking fluids and the chemicals they contain can remain underground, but the

remainder come back up with other materials from the formation and other geologic layers as waste.

1. As reported by Hayes in 2009;

> "The toxic nature of these waste materials has been well described, despite laws protecting the proprietary nature of the fracking fluids. Produced waters commonly exhibit highly elevated concentrations of bromide, chloride, hardness as calcium carbonate, total dissolved solids, barium, boron, calcium, iron, lithium, magnesium, manganese, potassium, sodium, and strontium. Furthermore, these fluids sometimes also include many additional chemicals including, but not limited to the following: pyridine, ethylbenzene; benzene; toluene; xylenes; 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene, arsenic; assorted phthalates; assorted metals; fluorene; phenol; 2-propanol; butyl alcohol; propylene glycol; ethanol; phenanthrene and other chemical compounds." Other drilling mud and fluid contaminants of note include aluminum, titanium, 2-butanone, and 1,2,4-trimethylbenzene."[3]

2. Oil and gas drilling impacts in western and southern United States, and in western Pennsylvania, have been documented by both interest groups and the news media. Concerns about drilling and related activities is heightened as gas drilling operations are exempt from major provisions of seven protective federal laws[4] including provisions of the federal Clean Air Act, Clean Water Act, RCRA (Resource Conservation and Recovery Act) and Safe Drinking Water Act that regulate underground injection of chemicals. *See*, TDEX, Crosby 25-3 Well –

[3] See, for example, Hayes, 2009: Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas, accessed online 3/30/2018 at https://www.scribd.com/document/111953961/Sampling-and- Analysis-of-Water-Streams)
AND
Hansen Services analysis for Whirley Drink Works in Warren County in Appendix

[4] https://earthworks.org/cms/assets/uploads/archive/files/publications/FS_LoopholesForPollutersNEW.pdf

Windsor Energy, Park County Wyoming, Analysis of Products Used for Drilling, February 25, 2008; Earthworks, Oil and Gas Pollution Fact Sheet, http://tiny.cc/cdgfJ; Peter Gorman, An aquifer is at risk – along with property values, livestock, and dreams – after gas wells move in, Fort Worth Weekly, April 30, 2008, at http://tiny.cc/p2zg2 (Last visited July 8, 2008); Alexandra Fuller, Recovering from Wyoming's Energy Bender, The New York Times, April 20, 2008, at http://tiny.cc/E0O4b (last visited July 7, 2008).[5]

3. In terms of the exemptions, the Bentsen Amendment to the RCRA law[6] is very important. The Bentsen Amendment requires that oil and gas wastes are regarded as 'special' and not regulated as the hazardous wastes that they are, containing toxic materials, because their name was changed to "special".as a result of this amendment. Disposal methods for oil and gas "special" wastes may include road and land spreading in Pennsylvania. These disposal methods can be used without having to verify what is in the materials being spread and whether or not

[5] http://www.delawareriverkeeper.org/sites/default/files/DRN%20Comment%20on%20DRBC%20Draft%20Regulations%20w%20Attachments%20%282018-03-30%29.pdf

[6] see the history of how the oil and gas liquid wastes were made "special" and therefore not subject to the supervision that would be required if they are understood to be the hazardous materials that they actually are here: https://yosemite.epa.gov/oa/eab_web_docket.nsf/Attachments%20By%20ParentFilingId/945EF425FA4A9B4F85257E2800480C65/$FILE/28%20-%20RCRA%20E%26P%20Exemption.pdf
"In December 1978, EPA proposed hazardous waste management standards that included reduced requirements for several types of large volume wastes. Generally, EPA believed these large volume "special wastes" are lower in toxicity than other wastes being regulated as hazardous waste under RCRA. Subsequently, Congress exempted these wastes from the RCRA Subtitle C hazardous waste regulations pending a study and regulatory determination by EPA. In 1988, EPA issued a regulatory determination stating that control of E&P wastes under RCRA Subtitle C regulations is not warranted. Hence, E&P wastes have remained exempt from Subtitle C regulations."

the materials are actually harmful.[7] Release of known toxic materials into the environment, even if called 'special,' is still doing damage to people's health, contaminating air and water and is in violation of the PA Environmental Rights Amendment.

4. True, epidemiological proof of causation is a difficult task, but if each time the wastes are put on the road without fail, in minutes, Ms. Lawson is reacting, then a cause and effect relationship cannot be denied. Ms. Lawson has learned from her neighbors and the Amish people in the area that there are many cancers in the area. Her doctor has told her that there is much more asthma and breathing problems than he had ever seen before.[8]

5. We incorporate in this brief all of what is in Paul Rubin's expert report submitted by counsel for Ms. Lawson. Rubin points out among other items that the liquids being disposed of on the roads have known and unknown environment and health consequences. Although Pennsylvania DEP allows and permits 'conventional' brine (and CWT liquids) to be spread on dirt roads, it prohibits Marcellus derived or unconventional brine for the same activity. In the chart on page 15 in Ruben's report the measured components are compared and show that conventional drilling waste can have higher values than unconventional waste so that waste is not less harmful but is still being allowed. Other sources also note the

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[7] See The EndocrineDisruption Exchange spreadsheet with links to peer reviewed papers linked within the spreadsheets describing impacts here: https://endocrinedisruption.org/audio-and-video/chemical-health-effects-spreadsheets
AND in the Compendium: -view or download here: http://concernedhealthny.org/compendium/

[8] from telephone conversations with Ms.Lawson

similarity of Marcellus (unconventional) and conventional drilling wastes, for example on page 4 to 5 of Tom Myers, hydrogeologist, expert report[9] he says:

> "It is common in the United States to dispose of O&G produced brine by spreading it on roads for dust or ice control. No jurisdictions in Canada allow the spreading of O&G wastewater on roads (Goss et al 2015). The popular press describes the use and unpopularity of the process in northern and western Pennsylvania (for example http://www.newsweek.com/oil-and-gas-wastewater-used-de-ice-roads-new-york-and-pennsylvania-little-310684). However, Pennsylvania does not currently allow the use of brine from unconventional shale deposits for road spreading (PDEP 2017), it does allow brine from conventional deposits. Dr. Avner Vengosh was quoted in the Newsweek article cited above as stating there is not much difference because it is the brine chemicals, salt, ammonium, naturally occurring source of radioactive materials (NORM), and others, that make the brine deleterious to shallow groundwater, not the organic fracking fluid chemicals. Brown (2014) also noted the high levels of NORM, which can be technologically concentrated in brine.
>
> Skalak et al (2014) examined sediments around a series of sites that had received road-spread brine. They found that concentrations in the sediments had increases of radium, strontium, calcium, and sodium of 1.2, 3.0, 5.3 and 6.2 times, respectively, as compared to background concentrations that did not have road spreading of brine. The authors also found a variability of up to 30 times, meaning that some areas could received concentrated runoff. The concentrations could be limited due to surface runoff dissolving the cations or infiltration flushing it to shallow groundwater. These results indicate that road spreading of O&G brine can contaminate soils and that those soils can be a source of contamination to shallow groundwater and surface water."

[9] (pg 149-150 of DRN pdf) http://www.delawareriverkeeper.org/sites/default/files/DRN%20Comment%20on%20DRBC%20Draft%20Regulations%20w%20Attachments%20%282018-03-30%29.pdf

6. Also the dust coming off the road likely will carry all the contaminants with the dust from the brine causing what would be a violation of the Clean Air Act if not for the exemptions, but looking at the potential sullying of the air it is a violation of the ERA. See the picture on page 2 of the PennState Dirt and Gravel pdf for an illustration of road dust raised by a vehicle (link from paragraph 24 below).

7. The historical nature of the disposal of OGW brine on roads is neither science based nor thoughtfully in compliance with the ERA—it is however a cost saving measure used by oil and gas producers as verified by the Pennsylvania Grade Crude Oil Coalition (PGCC) in their brief attempting intervention in this case[10]. By allowing, permitting, the disposal of liquid waste from gas and oil wells the permit is a license to pollute. There is no scientific basis for the practice but as the PGCC said in their request to intervene, that the waste disposal method called brine spreading or 'roadspreading' is necessary to their bottom line and that their bottom line supersedes the interests of the general public. In paragraphs 23, 24, and 25 of their brief, they say:

> "23. If the Board were to find in *favor* of Appellant, the roadspreading approval process could be invalidated, which would eliminate a significant method of brine management for PGCC members.
>
> 24. If the Board's determination results in revision of the standard conditions in Plan Approvals, it could increase the cost of roadspreading and potentially eliminate roadspreading as a cost effective option for PGCC members.

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[10] http://ehb.courtapps.com/efile/documentViewer.php?documentID=38613

> 25. Accordingly, because PGCC's members have a direct interest in the ability to continue providing brine for roadspreading and that right could be eliminated as a result of this appeal, PGCC's interest is greater than that of the general public.

With those statements we have that:

- the oil gas industry's admission that the practice impacts the public interest

and - that the PGCC' financial interests are more important than the people or communities and the land or the future health of the environment - so the Environmental Rights Amendment means nothing to them.

8. Going back to the health impacts, the road dust particles are respirable size particles, PM10 and smaller. They are highly bio-active as they can be breathed deeply into the lungs. Penn State, Center for Dirt and Gravel Road Studies did some measurements for dust coming off an unpaved road surface that contains clay[11] and found considerable respirable dust generated from a vehicle.

They looked at what they called the PROBLEM:

> "The generation, transport, and fate of airborne particulates generated from unpaved road is an area of growing interest and concern across Pennsylvania and the US. The loss of road fines to dust can have negative impacts to road longevity, the surrounding environment, and human health. Within Pennsylvania there are over 20,000 miles of public unpaved roads and approximately 1/3 of the road miles fall within 150 feet of a stream. Due to the close proximity of unpaved roads to streams, there exists the potential for road dust to impact water quality. "

9. Human health is mentioned as it should be, since all of what they measured (Particulate Matter (PM) and the numbers are the micro-gram (µm) size) PM_1, $PM_{2.5}$ and respirable PM_{10} have health impacts. [12]

[11] https://www.dirtandgravel.psu.edu/sites/default/files/General%20Resources/Technical%20Bulletins/IB_Dust_Monitoring.pdf

[12] from Polland in 2016 - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5110587/
Environ Sci Pollut Res Int. 2016; 23(23): 23892–23901.
Published online 2016 Sep 15. doi: 10.1007/s11356-016-7605-1

> "Recent study suggests that 50 % of particles less than 4 µm in diameter penetrate into the lower respiratory tract in children (Brown et al. 2013). Other studies proved that particles with diameters equal or smaller than 2.5 µm (PM2.5) reach the alveoli and up to 50 % of them may remain in the lung tissue (Valavanidis et al. 2008). Fine PM can penetrate deep into the airways and induce alveolar inflammation, which is responsible for release of mediators favoring acute episodes of respiratory diseases (Schwartz 1992). Due to deep deposition they are removed very slowly, increasing the chances of causing cell damage"

10. To summarize there is dust coming off unpaved dirt roads that have clay in the roadbed. This dust is small particles that are respirable—able to be carried deep into the lungs where they can cause cell damage. Further these small particulate dusts can carry contaminants with them. Though not a well studied area, especially in relation to rural settings, there has been some work done looking at metal contamination carried with road dusts in an urban setting. For instance, from the abstract of Heavy Metal Contamination of Road Dust at the Downtown Area in the Metropolitan City of Ulsan, Korea, https://ieeexplore.ieee.org/document/4107361/

> Road dust often contains elevated concentrations of heavy metals and can influence on human health.

and

> The results indicate that the road dust in the study area has elevated concentrations of Cd, Cu, Pb, Zn, and Ni and the concentrations of heavy metals increased with the decrease of particle size.

11. The small particulate matter dusts will likely carry with them the burden of materials in the OGW brine being disposed of on the roads making these dusts particularly dangerous.

12. The OGW brine is being spread on dirt roads with the justification that it is a dust control, but actually it is adding to the dust. In the attached Appendix item, Affidavit from Siri Lawson, the introduction contains calculations revealing that a 3.000 gallon spreader truck could be adding 1 1/4 ton of very small particle size material to the road.

13. The OGW brine has a high salt content (see pg 15 chart in Rubin) which is mostly sodium chloride with some chlorides of calcium and magnesium (and some other metals). The observed tendency of the clay road surface is to become slippery mud and then harden quickly keeping the shapes of the ruts created by passing traffic. This dramatically hardened surface, with the ruts still in place then shatters into dust with additional traffic increasing the dust problems the OGW brine spreading was supposed to cure. It is the high salt content that causes this behavior as has been looked at in peer reviewed papers, such as that by Jonsson and Labbez[13]

> "At low salt, the interaction is strongly repulsive and the dispersion should appear as a solid ("repulsive gel"). With increasing salt concentration, the repulsion is weakened and a liquid phase appears ("sol"). A further increase of the salt content leads a second solid phase ("attractive gel") governed by attractive interactions between the platelets. Finally, at sufficiently high salinity, the clay precipitates..."

14. Materials and expert reports developed looking at un-conventional and/or Marcellus drilling have justified bearing on the harms created by OGW brine spreading on roads due to two factors

[13] https://www.ncbi.nlm.nih.gov/pubmed/18800854

1- the above mentioned comparison (in Rubin's report) of conventional and unconventional measured components of liquid wastes showing conventional wastes with higher contaminant values than average Marcellus values.

and

2- that over 2/3 of all existing gas wells were fracked.[14] and over 1/2 of all existing oil wells were fracked[15] Plus "up to 95% of all new wells" since 2013 are fracked [16]

Therefore, according to the EIA, and DOE, almost all new gas and oil wells today are fracked. and we can use what we know of the substances contained in fracking fluids, materials released from fracked wells and toxicity data from fracked wells and wastes when talking about gas oil well 'brine' (OGW brine).

15. Concerned Health Professionals of New York's Compendium, 5th Edition[17] yields some important documented information on OGW wastes or what are being called "brine" and spread or disposed of on roads:

> on pg 14 - Once in production, a fracked well continues to generate liquid throughout its lifetime. This produced water, which contains many of the same toxic substances as flowback fluid, is a second component of fracking waste, and it also requires containment and disposal.

---

[14] federal Energy Information Agency (EIA) and federal Department of Energy (DOE)https://www.eia.gov/todayinenergy/detail.php?id=26112

[15] https://www.eia.gov/todayinenergy/detail.php?id=25372

[16] - US Dept. of Energy, How is shale gas produced?, Apr. 2013 https://energy.gov/sites/prod/files/2013/04/f0/how_is_shale_gas_produced.pdf

[17] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction) (5th ed.). http://concernedhealthny.org/compendium/

on pg 15 - All of that two billion daily gallons of [wastewater] fluid is toxic,
on pg 17 - Studies reveal inherent problems in the natural gas extraction process, such as well integrity failures caused by aging or the pressures of fracking itself, and in the waste disposal process. These issues can lead to water contamination, air pollution with carcinogens and other toxic chemicals, earthquakes, and a range of environmental and other stressors inflicted on communities.
on pg 23 - University of Iowa researchers documented a variety of radioactive substances including radium, thorium, and uranium in fracking wastewater and determined that their radioactivity increased over time; they warned that radioactive decay products can potentially contaminate recreational, agricultural, and residential areas.
on pg 27 - wells with longer lateral pipelines to access more gas or oil per well, generating more waste even as the pace of drilling slowed. (See footnote 188.) Indeed, according to data provided to investors, the average amount of water used to frack a single well has more than doubled between 2013 and 2016 due to longer laterals and more intensive fracking.
on pg 51 - July 12, 2017 – In western Pennsylvania, a team of researchers looked at sediments in the Conemaugh River watershed downstream of a treatment plant that was specially designed to treat fracking wastewater. The researchers found contamination for many miles downstream with fracking-related chemicals that included radium, barium, strontium, and chloride, as well as endocrine-disrupting and carcinogenic compounds. The peak concentrations were found in sediment layers that had been deposited during the years of peak fracking wastewater discharge. Elevated concentrations of radium were detected as far as 12 miles downstream of the treatment plant and were up to 200 times greater than background. Some stream sediment samples were so radioactive that they approached levels that would, in some U.S. states, classify them as radioactive waste and necessitate special disposal.[146, 147]

[146] Burgos, W. D., Castillo-Meza, L., Tasker, T. L., Geeza, T. J., Drohan, P. J., Liu, X., ... Warner, N. R. (2017). Watershed-scale impacts from surface water disposal of oil and gas wastewater in Western Pennsylvania. *Environmental Science & Technology, 51*(15), 8851–8860. doi: 10.1021/acs.est.7b01696
[147] Johnston, I., (2017, July 12). Fracking can contaminate rivers and lakes with radioactive material, study finds. *The Independent*. Retrieved from http://www.independent.co.uk/news/science/fracking-dangers-environment-water- damage-radiation-contamination-study-risks-a7837991.html

on pg 254 - September 15, 2016 – A systematic review of 45 studies,

> primarily but not exclusively addressing conventional oil and gas activities, showed an emerging body of evidence documenting harm to reproductive health from residential and occupational exposure to these operations. The strongest evidence existed for increased risk of miscarriage, prostate cancer, birth defects, and decreased semen quality. Authors state that there is "ample evidence for disruption of the estrogen, androgen, and progesterone receptors with individual chemicals and waste products related to oil and gas extraction," and "impacts from unconventional oil and gas activities will likely be greater, given that unconventional activities have many similarities to conventional ones and employ dozens of endocrine-disrupting chemicals in the process of hydraulic fracturing."[1075]

16. Besides the extensive contents and references in the Concerned Health Professionals of New York's Compendium[18],[19], the Rubin report and other sources,[20] there is even more new reliable information about the dangers of disposing of OGW brine (produced water from drilling or from CWT plants) into the environment by 'brine spreading' on dirt roads. The recent March 5, 2018 paper by M.A. Chen and B.D. Kocar[21] shows for instance, that: there is a strong likelihood that radioactive radium can adhere to particles of clay from the road - meaning that the road dust will carry a radium burden from the clay road material and the OGW brine disposed of onto these roads, when dust comes off the road. People and animals breath that dust with the highly bio-active radium carried in with the clay particles.. The Chen-Kocar paper describes bonding of radium to particles of a type of clay they looked

[18]view or download here: http://concernedhealthny.org/compendium/

[19] http://concernedhealthny.org/wp-content/uploads/2018/03/Fracking_Science_Compendium_5FINAL.pdf

[20] (see starting on page 81 about oil gas liquid wastes) http://www.delawareriverkeeper.org/sites/default/files/DRN%20Comment%20on%20DRBC%20Draft%20Regulations%20w%20Attachments%20%282018-03-30%29.pdf

[21] https://pubs.acs.org/doi/pdfplus/10.1021/acs.est.7b05443

at, Montmorillonite. Dirt roads are usually primarily clay and the clays in PA are largely mixed illite and Montmorillonite, the studied clay.

17. Also the endocrine disrupting materials in the OGW brines, which are not looked for or quantitatively tested for, are still harmful. See https://endocrinedisruption.org/enews/exploring-endocrine-disrupting-air-pollutants-near-unconventional-oil-and-gas-sites and specifically https://endocrinedisruption.org/audio-and-video/oil-and-gas/webinar-bolden. As explained in those two links and in the paper, Does the Dose Make the Poison,[22] that very small quantities of minerals, organic and inorganic compounds can act as hormones causing biological disruption of processes in the body necessary for health and for life itself.

18. The wastes being put into the environment by OGW brine spreading contain many injurious materials to the extent that they are not compatible with the provisions of the Environmental Rights Amendment, which all branches of Pennsylvania government have a trustee obligation to honor.

CONCLUSION

For the foregoing reasons the Board should grant the Appellant's motion for summary judgement.

Respectfully submitted,

/s/ John J. Zimmerman
John J. Zimmerman
Zimmerman & Associates

[22] http://www.ourstolenfuture.com/Newscience/lowdose/2007/2007-04-30%20Does%20the%20Dose%20Make%20the%20Poison.pdf

13508 Maidstone Lane
Potomac, MD 20854
(240) 912-6685 (office)
zimmermanjj@verizon.net

following is

APPENDIX

containing two items

Hansen Services Analysis
of OGW brine to be spread on the Whirley Drink Works property

and

Affidavit from Ms. Siri Lawson with introduction

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

OG/Brinespreading/Hansen Services

April 6, 2016

Justin Hansen DBA Hansen Svcs.
7 Mead Blvd.
Clarendon, PA 16313

One of 3 licensed to spread in Farmington

Re: 2016 Brine Spreading Plan Review
Approval No. NW5916
Whirley Drink Works, City of Warren,
Sam Harvey Property, Sugargrove Township, Warren County

Dear Operator:

The Department of Environmental Protection (DEP) has reviewed your plan for spreading brine for dust control on the above subject roads/lots. This plan for applying oil and gas well production brine to roads for dust control is approved subject to operating requirements listed below.

This Plan Approval is granted on a calendar year basis and expires on December 31, 2016.

Operating Requirements

1. The application of brine to unpaved roads must be performed in accordance with the approved plan.
2. The brine may only be applied at a rate and frequency necessary to suppress dust and stabilize the road. The rate and frequency of application must be controlled to prevent the brine from flowing or running off into roadside ditches, streams, creeks, lakes and other bodies of water or infiltrating to groundwater.
3. Recommended spreading rates: The road should initially be spread at a rate of up to one-half gallon per square yard (typically after the road has been graded in the spring). The road should subsequently be spread at a rate of up to one-third gallon per square yard no more than once per month unless–based on weather conditions, traffic volume or brine characteristics–a greater frequency is needed to control dust and stabilize the road. The application rate for race tracks and mining haul roads should be determined for each site and should not exceed one gallon per square yard.
4. Only production or treated brines may be used. The use of brine from Marcellus and other non-conventional shale formations is not applicable for roadspreading. The use of drilling, fracing, or plugging fluids or production brines mixed with well servicing or treatment fluids, except surfactants, is prohibited. Free oil must be separated from the brine before spreading.
5. Brine must not be applied within 150 feet of a stream, creek, lake or other body of water.
6. Brine must be spread by use of a spreader bar with shut-off controls in the cab of the truck.
7. Brine must not be placed on sections of road having a grade exceeding 10 percent.
8. Brine must not be spread on wet roads, during rain, or when rain is imminent.
9. Each vehicle used to spread brine shall have a clearly legible sign identifying the applicator on both sides of the vehicle.

10. The company spreading the brine shall notify the appropriate regional Oil & Gas program, brine spreading coordinator the business day before spreading brine.

11. The producing oil and gas wells must be in compliance with the bonding requirements of the Oil and Gas Act.

12. The person who received approval for the roadspreading plan must submit a monthly report (5500-FM-OG0046) to DEP indicating the location and amount of brine spread during the month. This monthly report must be submitted by the 15th day following the month in which the brine was spread. This report must be submitted even if no spreading took place during that month. The monthly report shall be submitted to:

    PA DEP NWRO
    District Oil & Gas Operations
    230 Chestnut St.
    Meadville PA 16335

13. Any revisions to the plan must be submitted to DEP for approval. Approval must be obtained prior to implementation of the revisions.

14. Failure to comply with all these conditions may result in DEP rescinding the plan approval.

Reporting Requirements

Transporters of residual waste must follow the requirements of 25 Pa. Code §299 Subchapter B (Standards for Collecting and Transporting of Residual Waste). Transporters must keep a daily operations record and file an annual operational report with DEP by March of the following year.

Oil and gas operators who generate brine must report the amount in their Annual Production Report.

This plan approval letter and its conditions should be reviewed by all parties involved in the brine spreading activity. A copy should be maintained in the cab of each vehicle used for spreading and its conditions made known to each driver.

If you have any questions, please contact me at 814.332.6173.

Sincerely,

Curtis LeSuer

Curtis LeSuer
Environmental Protection Specialist
Oil and Gas Management

cc: Rick Mader, WQS
Marshall Wurst, OGI
File

Analytical Services, Inc.

P.O. Box 237
Brockway, PA 15824-0237

Laboratory (814) 265-8749
FAX (814) 265-8749

GENERAL CHEMICAL ANALYSIS REPORT

CUSTOMER: Hansen Services
7 Mead Boulevard
Clarendon, PA 16313
Attn: Justin Hansen

SAMPLE DATE: 01/07/16 at 12:50 pm
RECEIPT DATE: 01/07/16 at 5:40 pm

REPORT DATE: 02/10/16
ASI ID#: 140667

DESCRIPTION OF SAMPLE: Hansen Services

TOTAL ANALYSIS RESULTS:

PARAMETER	RESULT	UNIT	QUANTITATION LIMIT	METHOD	BY	DATE & TIME	DATA QUALIFIER
TPH-HEM Oil & Grease	8	mg/L	5	SM 5520B	WB	01/21/16 @ 11:00 am	R3
TPH-DRO	2,450	µg/L	–	EPA 8015D	FL	02/04/16 @ 3:22 pm	3a
TPH-GRO	6,720	µg/L	–	EPA 8015D	FL	02/03/16 @ 9:12 am	3a
Nitrate-N	< 50.0	mg/L	50.0	EPA 300.0	BB	01/16/16 @ 7:47 pm	
Nitrite-N	< 50.0	mg/L	50.0	EPA 300.0	BB	01/16/16 @ 7:47 pm	
Sulfate	701	mg/L	5	EPA 300.0	BB	01/16/16 @ 7:47 pm	E1
Fluoride	<0.5	mg/L	.16	SM 4500 F-C	CC	02/03/16 @ 11:16 am	
Bromide	555	mg/L	0.1	EPA 300.0	BB	01/16/16 @ 7:47 pm	
Dissolved Phosphorus	<.15	mg/L	.15	SM 4500 P-B, 5-E	WB	02/10/16 @ 10:30 am	
Dissolved Vanadium	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Zinc	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Titanium	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Strontium	88.1	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Tin	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Selenium	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Antimony	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Lead	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Nickel	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Sodium	24,700	mg/L	500	EPA 200.8	CH	02/04/16 @ 1:28 pm	
Dissolved Molybdenum	<0.500	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Manganese	5.40	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Magnesium	1,230	mg/L	500	EPA 200.8	CH	02/04/16 @ 1:28 pm	
Dissolved Lithium	4.1	mg/L	--	SM 3111B	CC	02/08/16 @ 4:00 pm	
Dissolved Potassium	89.5	mg/L	10.0	EPA 200.8	CH	02/04/16 @ 12:00 pm	
Dissolved Iron	66.6	mg/L	10.0	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Copper	0.708	mg/L	0.5	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Dissolved Chromium	<0.500	mg/L	0.5	EPA 200.8	CH	02/03/16 @ 4:46 pm	

R3: No duplicate due to insufficient sample volume.
E1: Diluted sample result exceeded the calibrated range and high CCV, but is within the Linear Calibration Range. Concentration is considered an estimate.
3a: this sample was received outside the EPA recommended holding time.

Analytical Services, Inc.

P.O. Box 237
Brockway, PA 15824-0237

Laboratory (814) 265-8749
FAX (814) 265-8749

GENERAL CHEMICAL ANALYSIS REPORT

CUSTOMER: Hansen Services
7 Mead Boulevard
Clarendon, PA 16313
Attn: Justin Hansen

SAMPLE DATE: 01/07/16 at 12:50 pm
RECEIPT DATE: 01/07/16 at 5:40 pm

REPORT DATE: 02/10/16
ASI ID#: 140687

DESCRIPTION OF SAMPLE: Hansen Services

TOTAL ANALYSIS RESULTS:

PARAMETER	RESULT	UNIT	QUANTITATION LIMIT	METHOD	BY	DATE & TIME	DATA QUALIFIER
Dissolved Cobalt	<0.500	mg/L	5	SM 6520B	CH	02/03/16 @ 4:46 pm	
Dissolved Cadmium	<0.100	mg/L	50.0	EPA 300.0	CH	02/03/16 @ 4:49 pm	
Dissolved Beryllium	<0.100	mg/L	50.0	EPA 300.0	CH	02/03/16 @ 4:49 pm	
Dissolved Barium	1.47	mg/L	5	EPA 350.0	CH	02/03/16 @ 4:46 pm	
Dissolved Boron	2.97	mg/L	.15	SM 4500 F-C	CH	02/04/16 @ 12:09 pm	
Dissolved Arsenic	0.646	mg/L	0.1	EPA 300.0	CH	02/03/16 @ 4:46 pm	
Dissolved Aluminum	0.925	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:46 pm	
Total Inorganic Carbon	27.8	mg/L	0.5	SM 5310B	WB	02/09/16	
TOC	211.5	mg/L	0.5	SM 5310B	WB	02/09/16	
Hardness	22,600	mg/L	3310	SM 2340B	CH	02/04/16 @ 1:06 pm	
Alkalinity to pH 4.5 as $CaCO_3$	58	mg/L	1	SM 2320B	PW	01/12/16 @ 12:00 pm	
Barium	1.31	mg/L	0.500	EPA 200.8	CH	02/03/16 @ 4:10 pm	
TDS	81,860	mg/L	10	SM 2540C	PW	01/11/16 @ 9:46 am	
Manganese	5.50	mg/L	.500	EPA 200.8	CH	02/04/16 @ 1:06 pm	
Chloride	63,167	mg/L	5	EPA 300.0	BB	01/18/16 @ 7:47 pm	
Magnesium	1,370	mg/L	500	EPA 200.8	CH	02/04/16 @ 1:06 pm	
Iron	118	mg/L	10.0	EPA 200.8	CH	02/03/16 @ 4:10 pm	
Sodium	23,100	mg/L	500	EPA 200.8	CH	02/04/16 @ 1:06 pm	
Conductivity	110,700	mg/L	0.1	SM 2510B	WB	01/20/16 @ 1:00 pm	
Specific Gravity	1.060	mg/L	--	--	WB	02/08/16	
Sulfide	2.6	mg/L	0.05	SM 4500 S-D	WB	02/10/16 @ 10:00 am	
Temperature	2.4	°C	--	SM 2550B	MC	01/07/16 @ 5:40 pm	
Dissolved Oxygen	1.70	mg/L	--	SM 4500 O-G	MC	01/07/16 @ 5:40 pm	
Density	1,060	0.0	--	--	MC	01/07/16 @ 5:40 pm	
PH (Field)	6.83	--	--	SM 4500 H+-B	MC	01/07/16 @ 5:40 pm	

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GENERAL CHEMICAL ANALYSIS REPORT

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7 Mead Boulevard
Clarendon, PA 16313
Attn: Justin Hansen

SAMPLE DATE: 01/07/16 at 12:50 pm
RECEIPT DATE: 01/07/16 at 5:40 pm

REPORT DATE: 02/10/16
ASI ID#: 140687

DESCRIPTION OF SAMPLE: Hansen Services

TOTAL ANALYSIS RESULTS:

PARAMETER	RESULT	UNIT	QUANTITATION LIMIT	METHOD	BY	DATE & TIME
Iron Bacteria	YES	--	--	Hal	WS	01/07/16 , Ended 01/10/16

We certify that the above reported values were obtained by use of procedures appropriate for the sample as submitted.

By: William Sabatose Date: 02/10/16

For: William J. Sabatose, Chief Chemical Analyst

PADEP LAB ID#: 33-00411

Analytical Services, Inc.

P.O. Box 237
Brockway, PA 15824-0237

Laboratory (814) 265-8749
FAX (814) 265-8749

CHEMICAL ANALYSIS REPORT

CUSTOMER: Hansen Services
7 Mead Blvd.
Clarendon, PA 16313

ATTN: Justin Hansen

ASI ID#: 140687
SAMPLE DATE: 01/07/16 @ 12:50
RECEIVED: 01/07/16 @ 17:40
REPORTED: 02/09/16

SAMPLE DESCRIPTION:

TOTAL ANALYSIS RESULTS:

Parameter	Results	Units	Reporting Limit	Method	Date Analyzed	Time	Qualifier
1,3,5-trimethylbenzene	59.3	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
1,2,4-trimethylbenzene	136	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
Benzene	2090	µg/L	25.0	SW 846-8260B	02/03/16	17:50	3a
Toluene	1870	µg/L	25.0	SW 846-8260B	02/03/16	17:50	3a
Ethylbenzene	90.2	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
Xylenes (total)	957	µg/L	20.0	SW 846-8260B	02/02/16	23:27	3a
Isopropylbenzene	< 10.0	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
Naphthalene	10.2	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
sec-butylbenzene	< 10.0	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a
tert-butylbenzene	< 10.0	µg/L	10.0	SW 846-8260B	02/02/16	23:27	3a

Sample analyzed by Fairway Laboratories, PA Lab # 07-062

Qualifier 3a: This sample was received outside the EPA recommended holding time.

We certify that the above reported values were obtained by use of procedures appropriate for the sample as submitted.

Reviewed and Approved By: *William Sabatose*
For: William Sabatose, Chief Chemical Analyst

PADEP LAB ID#: 33-00411

Analytical Services, Inc.

P.O. Box 237
Brockway, PA 15824-0237

Laboratory (814) 265-8749
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CHEMICAL ANALYSIS REPORT

CUSTOMER: Hansen Services
7 Mead Blvd.
Clarendon, PA 16313

ATTN: Justin Hansen

ASI ID#: 140687
SAMPLE DATE: 01/07/16 @ 12:50
RECEIVED: 01/07/16 @ 17:40
REPORTED: 02/09/16

SAMPLE DESCRIPTION:

TOTAL ANALYSIS RESULTS:

Parameter	Results	Units	Reporting Limit	Method	Date Analyzed	Time	Qualifier
Pyridine	< 40.0	µg/L	40.0	SW 846-8270D	02/03/16	14:53	3a, 2d
Acetophenone	< 20.0	µg/L	20.0	SW 846-8270D	02/03/16	14:53	3a, 2d
3 & 4-methylphenol	124	µg/L	20.0	SW 846-8270D	02/03/16	14:53	3a, 2d
2-methylphenol	101	µg/L	20.0	SW 846-8270D	02/03/16	14:53	3a, 2d

Sample analyzed by Fairway Laboratories, PA Lab # 07-062

Qualifier 3a: This sample was received outside the EPA recommended holding time.
Qualifier 2d: The LCS spike recovery was outside acceptance limits for the noted analyte. Data accepted based on additional batch QC.

We certify that the above reported values were obtained by use of procedures appropriate for the sample as submitted.

Reviewed and Approved By: *William Sabatose*
For: William Sabatose, Chief Chemical Analyst

PADEP LAB ID#: 33-00411

AFFIDAVIT FROM MS. SIRI LAWSON WITH INTRODUCTION

INTRODUCTION

1. Ms. Siri Lawson has been a member of Damascus Citizens for Sustainability (DCS) since 2008 when she found us on the internet and has been a colleague, source of key information and contributor ever since.(paragraph 17, Affidavit of Barbara Arrindell) Contributor by virtue of both her contributions to the knowledge base and her financial contributions through the years to DCS; colleague in that we have been able to share and learn from each other about gas and oil industry practices and important health consequences of those practices both on a personal and a community level. Her Affidavit is being included here as one person's suffering from the disposal of oil gas waste brine (OGW brine) allowed/permitted by Pennsylvania with the excuse that it is a dust control method on dirt roads. Many in her and other communities where OGW brine is 'spread' (disposed of) on roads have health impacts. She represents the human face of the impacts from this practice. Animals are also sickened and the environment is harmed..

2. One interesting example that illustrates the collaborative nature of DCS' interactions with Ms. Lawson was our exercise evaluating if high TDS brine would actually add to the road dust as opposed to controlling it. We assumed for argument's sake (and if you see the chart on page 15 of Rubin's report this is reasonable) 100,000 mg/L of Total Dissolved Solids (TDS). As currently conducted in Warren County PA, often involving at least four passes per road per day a 3.000

gallon spreader-truck is dumping 3,000 gallons = 11,356 liters and we have 100,000 mg/liter of TDS or 11,356liters x 100,000 mg/L = 1,135,600,000mg of TDS in the truck This is equal to 2,503 pounds of TDS being dumped along that road - this is equivalent to 1 and 1/4 tons.

3. definition of TDS:

Total dissolved solids (**TDS**) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form and does not include uncharged materials like motor oil, gasoline, VOCs, many pharmaceuticals, and pesticides which do not contribute to a TDS measurement.

4. The dust coming off the dirt road receiving this waste includes the TDS as TDS is molecular or micro-granular size and will become air-borne with the dust. Looking at the Hanson Analysis of material spread at the Whirley DrinkWorks, there are toxic level contaminants in it that would be in the dust also. Note that this analysis is a very rare item, as Rubin explains, most analyses submitted are very inadequate and not reflective of what is being put on the roads.

Besides his cannot be in compliance with the Environmental Rights Amendment.

What follows is Siri Lawson's Affidavit, originally submitted with the DCS request for intervention in EHB Docket No. 2017-051-B. on February 15, 2018.

I, Siri Lawson, do hereby affirm and state that:

1. In 2009 my husband and I moved to our current residence on Lindell Road which is in Farmington Township, Warren County, PA. Lindell Road is an unpaved, dirt road. Most of the roads in Farmington Township and those surrounding Lindell Road are unpaved dirt roads.

2. In 2011, Farmington Township began allowing Lindell Road to be repeatedly spread with oil and gas wastewater (brine). I counted over 30 loads of brine spread on Lindell Road during 2011.

3. My husband and I complained verbally to Farmington Township about the excessive brine spreading. I wrote complaint letters to to Farmington Township Board of Supervisors, the PA Department of Environmental Protection and the federal Environmental Protection Agency. The local newspaper ran an article about the brine situation. After each complaint Farmington Township would assure us that Lindell Road would not get brined. The brining was not completely stopped and has continued through 2017.

4. I react acutely to the brine spreading with wheezing, infection and many other symptoms. In 2011, when they began the excessive spreading in earnest, I was diagnosed with life-threatening adrenal insufficiency. I developed such acute gastric reflux that radical surgery was prescribed. I developed abnormal nodules and cysts in my thyroid, liver, breasts, ovaries, lungs and sinus. I developed abnormally high ParaThyroid and eosinophil levels.

5. In 2012 the number of loads of brine spread on Lindell Road dropped to seven. In late 2012, my husband,Wayne, had two back to back heart attacks. He was hospitalized for 18 days and received multiple stents. He was asked on the operating table if he had been exposed to chemicals as this was the type of heart attack linked to chemical exposure.

6. By my count, I noted five loads of brine spread on Lindell Road in 2013.; In 2014, I counted seven loads of brine spread. In 2015, there were multiple days in July and August when brine was spread on Lindell road. After each load either my husband or myself contacted the Township to complain. There were multiple occasions when I contacted the PA Department of Environmental Protection. I experienced adverse health impacts similar to those described above and below during each brine spreading event.

7. Despite aggressive treatment, my adrenal insufficiency continued to worsen. Persistent angina sent me to a cardiologist, I developed a fibromyalgia-type syndrome, a rib-cracking cough and neuropathy. I had no ability to fight off respiratory infections. Continued exposure to brine worsened these conditions.

8. In 2016, I was treated by doctors from Cleveland Clinic. My exposure to endocrine disrupting chemicals from brine was noted and discussed. Endocrinologists at Cleveland Clinic changed the diagnosis of adrenal insufficiency to adrenal suppression. I was told I had developed iatrogenic Cushings disease. I had been being treated with high doses of steroids which are

the standard treatment to control inflammatory and allergic reactions like I exhibited after exposure to each brine event. I had began reacting to the high steroid doses. I could **no longer use steroids as a safe treatment for environmental exposures, injuries or illness. Steroids can - or will - now kill me.**

9. In August of 2016, after Lindell Rd got brined, I had a violent response. For nearly 10 days, especially when I got near the road, I reacted with excruciating eye, nose and lung burning. My tongue swelled to the point my teeth left indentations. My sinus reacted with a profound overgrowth of polyps, actually preventing nose breathing. In September of 2016 Lindell Road again got brined. Again I violently reacted. The polyps required surgical intervention and in December 2016 I had sinus surgery, skin cancer surgery and a suspected cancerous cervical polyp removed. Earlier in the year, a large cyst in my leg was removed. During this time period, two of my female dogs each had a large polyp-like growth on their external genitalia.

10. In June of 2017, Farmington Township graded and raked Lindell Rd. They left behind inches of loose brine saturated road dirt. That loose brine saturated road dirt caused a tremendous dust issue. Water courses along Lindell turned nauseating colors after run-off events.

11. I reacted to the dust by re-growing the recently surgically removed nasal polyps. I experienced profound wheezing, coughing and subsequent sinus, ear and lung infections. My Ear Nose and Throat specialist opined the polyp re-growth combined with my inability to tolerate large doses of steroids left me with no viable options for treatment. In July 2017 Lindell Road got brined once. I reacted as I had in prior brine events. I was in misery.

12. My doctor asked me to join a research project at University of ~~Pennsylvania~~ Pittsburgh UPMC Medical Center after the dust exposure, I would be tested for ciliary dyskensia. It was found I had developed severe secondary ciliary dyskensia. I am unable to flush mucus or bacteria or viruses out of my system. It was discovered my lungs were nearly opaque, functional only because I still had a strong cough mechanism. My susceptibility to infection is overwhelming. My lung doctor has suggested treatment (experimental) with Nucala in a last ditch effort to thin mucus.

13. Brine has dramatically impacted our lives in other ways. Brine has caused our vehicles to rust more quickly than normal, often causing dangerous equipment failure and high maintenance costs.

14. From my personal observations and experiences dirt roads that are brined dry out more quickly after brining and result in even more dust than if the roads had not been brined. Vehicular traffic on these brined dried roads produces clouds of dust. This same dust caused by the over-brined roads penetrates our home and barn. It causes items in the home to prematurely rust, it also collects on surfaces such as fans, house siding, and windows.

15. Each time the roads are brined, the brine causes the road to become very slick and difficult to travel over. Vast amounts of sticky brine mud coat vehicles and buggies. Add seasonal moisture and the roads fill with ruts and potholes.

16. Because surface water contamination from brining is very visually apparent, I am worried about ground and well water contamination. In our case, we have a water well with multiple filters that need frequent changes. Because of the appearance of the filters, we drink only bottled water.

17. At public meetings in 2016-17, Hydro Transport, LLC, as well as Farmington Township Supervisors repeatedly invited residents to inspect or photograph Hydro Transport while spreading brine. Residents were repeatedly invited to identify whether or not Hydro Transport was using a spreader bar. In 2017, I encountered Hydro Transport twice and took pictures. Hydro Transport, charged me twice with harassment for taking those pictures while he was spreading on a public road.

18. During the Thanksgiving holiday, 2017, my house was broken into. Notes and pictures related to brine spreading, medical records, test results,and research papers, appeared to be the only items taken. A police report was filed.

I declare subject to the penalties of 18 Pa. C.S. § 4904 regarding unsworn falsification to authorities that the foregoing is true and correct to the best of my personal knowledge.

Siri Lawson

Date 1/31/18

EXHIBIT Q

Catskill Mountainkeeper

Please find attached cover letter containing comments from Kathleen Nolan, MD, MSL, Senior Research Director for Catskill Mountainkeeper, along with referenced attachment "HydroQuestBrineSpreadingReportwithAddendas-20180329.pdf).

We appreciate the opportunity to submit these comments.

Sincerely,
/Kathleen Nolan, MD, MSL/

https://commentinput.com/attachments/projectID_1501/15065/merged//WKpgo.pdf?v=29QRTKA83

March 30, 2018

Commissioners
Delaware River Basin Commission
PO Box 7360
West Trenton NJ 08628-9522

Re: Proposed Special Regulations Part 440 and related documents

Dear Commissioners:

Please accept these comments on behalf of Catskill Mountainkeeper regarding the Delaware River Basin Commission's "Proposed Special Regulations Part 440 – Hydraulic Fracturing in Shale and Other Formations," also announced as "Proposed Amendments to the Administrative Manual and Special Regulations Regarding Hydraulic Fracturing Activities; [and] Additional Clarifying Amendments; 18 CFR Parts 401 and 440."

Catskill Mountainkeeper is a registered 501(c)(3) non-profit organization that advocates for the Catskills region. CMK works with and represents a network of concerned citizens in areas within and surrounding the Delaware River Basin. Through the DRBC's online portal for submission of comments on the proposed regulations, Catskill Mountainkeeper has submitted 2,182 comments collected on behalf of these citizens. We offer here additional comments on specific aspects of the proposed regulations, focused primarily on the hazards of introducing fracking wastes, as well as wastes from conventional oil and gas wells, into the waters of the Basin, including drinking supply waters.

Catskill Mountainkeeper acknowledges and deeply respects the foundational obligations of the Delaware River Basin Commission: to protect water quality in the Delaware River Basin and thereby protect human health and wellbeing. We therefore applaud the careful attention to water quality threats from hydraulic fracturing (fracking) evidenced in the proposed amendments to existing DRBC regulations. We thoroughly endorse the Commission's decision to ban hydraulic fracturing in the Basin, as incompatible with the Commission's mission, due to numerous, irremediable, potential mechanisms for water contamination, including but not limited to well bore casing failure, cement bond failure, casing and pipeline corrosion, spills (during drilling, storage, and transportation), intentional and unintentional releases, pressure bulb events, and seepage over time. These mechanisms lead to widely known and, in 2018, very well documented adverse impacts on water quality,[1] which the proposed amendments reference and address in the

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[1] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction), 5th ed. (accessed online 3/30/2018 at http://concernedhealthny.org/compendium): see Water contamination, pp. 48ff.

proposed ban on fracking. Research reports also increasingly document the related adverse impacts on ecological systems and human health that follow from contamination of water, air, and soils near fracking activities and fracking infrastructure, such as compressor stations, pipelines, pigging stations, and natural gas-fired power plants.[2]

In addition, we urge the Commission to take note of the uncontrolled character of fracking's underground explosions and resulting induced seismicity, that is, earthquakes caused by both fracking itself and by underground injection of wastewater. The primary action of fracking, that is, setting off high-pressure explosions underground and injecting slippery fluids, is described by engineers working for the oil and gas industry – and by text in the proposed amendments – as taking place in shale formations that are "separated from potential freshwater aquifers by thousands of feet of sandstones and shales of moderate to low permeability."[3] However, precise seismologic recordings at the most carefully studied fracking wells in the world, in Greene County, Pennsylvania, contradict such assertions by recording multiple, long induced fractures that extend above the hypothesized "frac barrier."[4] Research conducted earlier this year in New York on hydrocarbon and brine migration[5] confirms earlier modeling studies[6] that faulting creates pathways for migration from deep shale layers to shallower aquifers. Not surprisingly, fracking activity itself can cause earthquakes, as has been seen across the United States and in Canada, and as close to the Delaware River Basin as Lawrence County, Pennsylvania.[7]

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[2] Ibid.: see Public health effects, measured directly, pp. 114ff.

[3] Delaware River Basin Commission. 18 CFR Parts 401 and 440: Proposed Amendments to the Administrative Manual and Special Regulations Regarding Natural Gas Development Activities; Additional Clarifying Amendments

[4] Hammack, R., Harbert, W., Sharma, S., Stewart, B. W., Capo, R. C., Wall, A. J., . . . Veloski, G. (2014). An evaluation of fracture growth and gas/fluid migration as horizontal Marcellus Shale gas wells are hydraulically fractured in Greene County, Pennsylvania. *NETL-TRS-3-2014: EPAct Technical Report Series. US Dept of Energy, National Energy Technology Laboratory*: Pittsburgh PA. Retrieved from http://www.netl.doe.gov/File%20Library/Research/onsite%20research/publications/NETL-TRS-3-2014_Greene-County-Site_20140915_1_1.pdf

[5] Kreuzer, RL et al. (2018). Structural and Hydrogeological Controls on Hydrocarbon and Brine Migration into Drinking Water Aquifers in Southern New York. Groundwater. 56. 10.1111/gwat.12638.

[6] Myers, T. (2012). Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers. Groundwater, 50: 872-882. doi:10.1111/j.1745-6584.2012.00933.x (accessed online 3/30/2018 at https://www.scribd.com/document/244283158/Wiley-Contaminant-pathways-fr-hydraulically-fract-shale-1-pdf)

[7] In Pennsylvania, the Department of Environment Protection (DEP) announced early in 2017 that a series of small earthquakes in Lawrence County had been induced by fracturing of wells in the Utica Shale (http://powersource.post-gazette.com/powersource/policy-powersource/2017/02/16/DEP-Pennsylvania-Lawrence-County-earthquakes-appear-linked-to-fracking-Hilcorp-Energy/stories/201702160176). DEP officials held a webinar to discuss the situation and formulate "procedures to reduce seismic risk going forward," but no formal report or regulatory changes have yet been made public (http://www.ahs.dep.pa.gov/NewsRoomPublic/articleviewer.aspx?id=21145&typeid=1).

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The deliberations of the Commissioners and the draft regulations should reflect these facts. Moreover, since injecting fracking waste underground poses more risk than fracking in terms of generating earthquakes and carries greater risk of contamination of water with a wider variety of toxic compounds, the proposed amendments should directly address induced seismicity and explicitly ban any underground injection of fracking wastewater in the Delaware River Basin.

Non-gaseous oil and gas waste products fall roughly into two categories: liquid waste and solid waste (we will not address gaseous wastes, which include methane, radon, and volatile aromatic compounds but do not generally pose a direct threat to water quality). Both liquid and solid forms of fracking waste, as well as waste from conventional oil and gas development, can contain toxic chemicals, hydrocarbons, brines, heavy metals, and radioactive contaminants. The toxic chemicals originate primarily in the "fracking fluid" injected underground to fracture and keep open natural gas bearing shale deposits, while the hydrocarbons, brines, heavy metals, and radioactive contaminates originate from targeted deep shale layers, or in the case of conventional wells, from sandstone layers. In simple terms, the fracking fluids dissolve the heavy metals and radioactive elements, mobilizing them and potentially contaminating any waste that emerges from the well, whether liquid, solid, or semi-solid material. As described by the United States Environmental Protection Agency (EPA), "Radioactive wastes from oil and gas drilling take the form of produced water, drilling mud, sludge, slimes, or evaporation ponds and pits. It can also concentrate in the mineral scales that form in pipes (pipe scale), storage tanks, or other extraction equipment."[8]

The toxic nature of these waste materials has been well described, despite laws protecting the proprietary nature of the fracking fluids. Produced waters commonly exhibit highly elevated concentrations of bromide, chloride, hardness as calcium carbonate, total dissolved solids, barium, boron, calcium, iron, lithium, magnesium, manganese, potassium, sodium, and strontium. Furthermore, these fluids sometimes also include many additional chemicals including, but not limited to the following: pyridine, ethylbenzene; benzene; toluene; xylenes; 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene, arsenic; assorted phthalates; assorted metals; fluorene; phenol; 2-propanol; butyl alcohol; propylene glycol; ethanol; phenanthrene and other chemical compounds." Other drilling mud and fluid contaminants of note include aluminum, titanium, 2-butanone, and 1,2,4-trimethylbenzene.[9]

Many of these waste products should be quite familiar to us, having been identified as contaminants in soil, sediment, and water at a hazardous waste site that later came to be known as the Love Canal Superfund site in Niagara Falls, New York. The Love Canal property, having been used in the 1930s and 1940s as a landfill for the disposal of over 21,000 tons of various chemical wastes, contaminated nearby groundwater, which then rose to the surface and drained into the Niagara River, contaminating it, as well. Contaminants also migrated from the landfill to

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[8] http://www.mde.maryland.gov/programs/Land/mining/marcellus/Documents/EPA_Radioactive_Wastes_from_Oil_Gas_Drilling(2012).pdf (accessed online 3/30/2018).
[9] See, for example, Hayes, 2009: Sampling and Analysis of Water Streams Associated with the Development of Marcellus Shale Gas, accessed online 3/30/2018 at https://www.scribd.com/document/111953961/Sampling-and-Analysis-of-Water-Streams)

local sewers, which drained into nearby creeks. Eventually, approximately 950 families had to be evacuated from the area surrounding the landfill. Contamination at the site ultimately led to the passage of Federal Superfund legislation.

Radiation was not a major concern at the Love Canal Superfund site, but it is of major concern in regard to fracking waste from the Marcellus Shale. In 2014, a group of leading public health experts wrote to Governor Cuomo, urging his administration to "conduct studies and a human health risk assessment of the occurrence of radon and radium during drilling for natural gas before deciding whether to allow drilling in New York's portion of the Marcellus shale or the distribution to New Yorkers of Marcellus shale gas containing unhealthy levels of radon" and "to make public any and all data collected about the presence of these two carcinogenic elements in Marcellus shale drilling."[10]

Multiple studies have found that waste from fracking can be radioactive — and in some cases, highly radioactive. A report from the United States Geological Survey (USGS) documented that wastewater from unconventionally drilled wells in Pennsylvania and conventionally drilled wells in New York contained thousands of times more radioactivity than the federal limit for drinking water and hundreds of times more radioactivity than allowed by the Nuclear Regulatory Commission for nuclear plant discharges.[11] In 2011, the USGS reported that waste water from oil and gas wells in New York and Pennsylvania, including those in the Marcellus shale, show distinctly higher levels of radium than those reported for other formations.[12]

A study from Penn State's Department of Geosciences also found that fracking wastewater contains high levels of radium, along with the toxic heavy metal barium.[13] Horizontally drilled wells are more likely to produce high levels of radioactive waste than other types of wells, because the horizontal pipe is exposed throughout its roughly mile-long length to whatever levels of radiation are present in the deep shale layers. As summarized by the EPA, "Radionuclides in these wastes [from oil and gas drilling] are primarily radium-226, radium-228, and radon gas. The radon is released to the atmosphere, while the produced water and mud containing radium are placed in ponds or pits for evaporation, re-use, or recovery."[14] The EPA goes on to say that the people most likely to be exposed to this source of radiation are "workers at the site." That may be true, yet the EPA's guidance to workers should give us pause, especially as it applies *a fortiori* to the general public. Under a heading "What you can do to protect yourself," the EPA advises as follows: "Do not re-use or bring home discarded equipment or material such as pipes, devices, bricks, rocks, or **water**" (emphasis added); "Limit exposures and disturbance of the

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[10] http://concernedhealthny.org/wp-content/uploads/2014/05/CuomoLetter-RadiationHazards20140508.pdf (accessed online 3/30/2018)
[11] Rowan, EL et al. Radium Content of Oil- and Gas-Field Produced Waters in the Northern Appalachian Basin (USA): Summary and Discussion of Data. USGS Scientific Investigations Report 2011–5135 (accessed online 3/30/2018 at https://pubs.usgs.gov/sir/2011/5135/pdf/sir2011-5135.pdf)
[12] E.L. Rowan and T.F. Kraemer, U.S. Geological Survey, Radon-222 Content of Natural Gas Samples from Upper and Middle Devonian Sandstone and Shale Reservoirs in Pennsylvania: Preliminary Data, 2012. (Accessed online 3/30/2018 at http://pubs.usgs.gov/of/2012/1159)
[13] Haluszczak, LO, et al. Geochemical evaluation of flowback brine from Marcellus gas wells in Pennsylvania, USA. Appl.Geochem. (2012). (accessed online 3/30/2018 at http://dx.doi.org/10.1016/j.apgeochem.2012.10.002)
[14] http://www.epa.gov/radtown/drilling-waste.html (accessed online 3/30/2018)

production site and any abandoned equipment"; and "Do not handle, dispose or re-use abandoned equipment used at drilling sites."

The public is exposed to wastes from oil and gas development through several mechanisms: 1) fluids delivered to treatment plants unable to remove the contaminants; 2) waste materials inadequately contained at landfills; 3) legally authorized applications to roads and fields; 4) intentional, illegal dumping in fields and streams; 5) toxic spills during transport; 6) leaching from toxic wastes buried underground; and 7) direct contamination of drinking water sources from fracking activities. Almost all of these routes of contamination pose a threat to areas that can be far removed from the site of fracking or conventional oil and gas activities.

Given the toxic composition of fracking waste, which can include brines (with elevated levels of chloride, total dissolved solids, sodium, calcium and magnesium), unknown fracking agents, heavy metals, and radioactive materials, the regulations should, rather than invite case-by-case analysis on individual dockets (see *Sections 440.5(f)* through *(h)*), unequivocally ban the importation of fracking and other oil and gas waste into the Basin, until and unless safe mechanisms of transporting fracking waste are devised and treatment mechanisms and plants become available that provide adequate and effective removal of all regularly encountered toxins in fracking waste, prior to such waste entering the Basin. Moreover, since brines from conventional wells also present major contaminant issues, we urge the Commission to take this opportunity to ban the importation of produced waters and solid waste from both conventional and unconventional wells.

Fracking wastes are materials clearly recognizable in other circumstances as "hazardous wastes"; indeed, many of them are found on the EPA's list of "Priority Chemicals" to be eliminated from or substantially reduced through limiting production, or at a minimum, recovered or recycled. Unfortunately, under federal law, fracking wastes are not treated as hazardous wastes due to exemptions that use the power of pencil and paper – and the human imagination – to wipe out almost all legal obligation to protect the public from what would otherwise be preventable, highly toxic, and potentially lethal exposures. The DRBC should not utilize the Delaware River Basin as a means to relieve the oil and gas industry of its obligations to handle its wastes without harming the public. The DRBC's revised regulations should prohibit the transport of oil and gas waste or waste by-products into the Basin for treatment, discharge, disposal, or storage purposes; prohibit the acceptance of wastewater from oil or natural gas extraction activities at wastewater facilities and landfills in the Basin; and as far as possible under existing federal laws and regulations, treat waste as hazardous waste on the basis of its hazardous characteristics, without regard to its origin.

To provide any mechanism at this point for introducing and discharging oil and gas waste fluids, including produced water, directly into streams, estuaries, and other receiving waters in the Basin, as is proposed in the draft regulations (*Section 440.5 – Produced Water* and *DRBC Guidelines for Determining Background Concentrations in Surface Waters under Special Regulations, Part 440 – Hydraulic Fracturing in Shale and Other Formations*) implies a more advanced state of treatment technology than is currently available, especially in regard to

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dissolved organic compounds and radioactive materials. To attempt to create a mechanism for approving such discharges as "safe" is therefore premature, unnecessary, and likely to lead to unintentional but potentially extremely harmful contamination of Basin waters.

The regulations should therefore expressly forbid transportation of oil and gas waste fluids to any site in the Basin and also forbid storage of such materials, since regularly employed "storage" mechanisms do not provide adequate containment. Materials leaching from landfills or spilled during transport will invariably flow under the pull of gravity down to surface or ground waters. Some of these materials, including the radioactive elements, can, in very small concentrations, cause serious, sometimes life-threatening illness, including tissue and organ damage, neurological disorders, leukemia and solid tumors, miscarriages, stillbirth, and congenital malformations.[15] Worse, in areas that have high background loads of radiation or heavy metals or that have suffered previous toxic contamination, the effects of additional contamination may be cumulative or, worse, synergistic.

Moreover, since spreading fracking waste on roads or on fields is hydrologically equivalent to pouring toxins into surface and ground water, such spreading should also be expressly prohibited in the revised regulations, as is addressed in the attached report, case study, original research, and supporting materials provided by Paul Rubin, hydrogeologist and President of HydroQuest (HydroQuestBrineSpreadingReportwithAddendas-20180329).pdf). These materials focus on the practice of disposing of fracking waste or other oil and gas waste via spreading on roads, fields, and recreation areas, which is allowed or appears to be allowed in at least two Basin states (PA and NY) through permits called "Beneficial Use Determinations" ("BUDs"). While Warren County, the site of the HydroQuest case study, is located in northwestern PA, outside of the Delaware River Basin, its use as a case study area is justified because it is representative of geologic and hydrologic conditions present throughout PA and the northeastern United States where contaminant transport outward from brine disposal sites will adversely impact surface and groundwater resources.

Based on the priority of protecting drinking water resources, Catskill Mountainkeeper also opposes those portions of the proposed regulations that would allow the withdrawal of water from the Delaware River Basin for fracking or any industrial purpose.

Finally, we address the critical issue of the Commission's staffing and resources. To insure that the environment of the Basin and the health of its residents are protected, and to minimize costs of management and enforcement, clear prohibitions should be enacted on not only fracking activities but also the introduction or handling of fracking waste. The Commission can – and must – refrain from finalizing any proposed regulatory program and from processing and issuing permits unless and until questions about resources to enforce adopted regulations have been fully

[15] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018, March). Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction), 5th ed. (accessed online 3/30/2018 at http://concernedhealthny.org/compendium): see Public health effects, measured directly, pp. 148ff

considered and addressed. The same commitment should be made with respect to financial assurances, bonding requirements, and any other measures that the DRBC may identify as necessary for the responsible implementation of these proposed regulations.

In summary, Catskill Mountainkeeper supports the Delaware River Basin's proposed ban on fracking activities in the Delaware River Basin, and we urge the Commission also to ban the importation, storage, or disposal of fracking waste, as well as waste from conventional oil and gas activities, in the Delaware River Basin, and to ban the use of Basin waters for fracking or any industrial purpose. Taking these actions now will continue a bright future for the waters of the Basin and the health and economy of its citizens.

Thank you for your careful attention to these comments.

Sincerely,

Kathleen Nolan, MD, MSL

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Disposal of Oil & Gas Field Produced Waters: A Hydrologic Case Study of PA Brine Spreading Practice

by Paul A. Rubin 3-29-18

Introduction

Surface disposal of chemically-laden produced waters on roads, fields, or other land areas will lead to degradation of surface and groundwater resources. Assuming that produced brine use is ultimately allowed in the State of Pennsylvania, such brine should be treated to concentration levels equal to or below state and federal water quality standards, whichever is stricter. Preferably, surface disposal of produced water should be prohibited. At this time, PA DEP has a set of Operating Requirements that, if met, provide an approval procedure to dispose of poorly or untreated produced water on road and land surfaces. This report examines serious flaws in PA DEP guidance and enforcement, using an area in northwestern PA as a case study to illustrate why spreading of produced waters anywhere in PA (e.g., Warren County, Delaware River Basin, Susquehanna River Basin), or elsewhere, should be banned. This detailed study documents that regulations designed to "*protect and conserve water resources*" cannot be relied upon when permits are and can be obtained that authorize the disposal and dispersal of contaminated wastewater into waterways and aquifers. The principles discussed here apply equally to produced wastewaters, regardless of whether they are derived from unfracked or fracked conventional or unconventional wells.

This case study demonstrates that existing, in-situ, regulations regarding spreading of produced waters from conventional oil and gas wells, as is readily approved by PA DEP, exacerbates pollutant transport into waters of the Commonwealth. PA DEP documents establish their knowledge and concern relative to road salting practices and water quality degradation. Yet, their approvals to spread chemically-concentrated produced water that will only further degrade state water resources is disjunct from their own published environmental findings. Approvals require limited and infrequent chemical assessment of produced waters and fail to adequately consider off-road transport and fate of numerous pollutants. Furthermore, Operating Requirements fail to consider the provenance of shales and interbedded shales and sandstones that are geologically linked and exhibit similar geochemical signatures (e.g., black shales provide hydrocarbon-rich products that migrated upward into overlying sandstone reservoirs). The physical relationship between source rocks and reservoir rocks does little to alter contaminants in produced brine waters.

Spreading of brine-rich produced waters on road and land surfaces serves to worsen the already well-documented mobilization of road salt derived surface and groundwater contamination.

Knowledge of this background information and individual PA DEP Operating Requirements is critical when contemplating special regulations being proposed by the Delaware River Basin Commission (DRBC). The stated purpose of Proposed New 18 CFR Part 440 - Hydraulic Fracturing in Shale and Other Formations (Section 440.1) is:

> "*The purpose of this part is to protect and conserve the water resources of the Delaware River Basin. To effectuate this purpose, this section establishes standards, requirements, conditions and restrictions to prevent or reduce depletion and degradation of surface and groundwater resources and to promote sound practices of water resource management*."

Reference to Section 440.5(b) of the DRBC Subchapter B - Special Regulations reveals that certain approvals relative to the importation and discharge of produced water and Centralized Waste Treatment (CWT) wastewater may not forego cited criteria:

> "*… except in accordance with an approval in the form of a docket issued by the Commission to the owner or operator of the wastewater treatment facility pursuant to Section 3.8* ***OR*** *in accordance with a state permit issued pursuant to a duly adopted administrative agreement between the Commission and the host state*." (emphasis added)

As discussed below using this case study as an example of the poor quality regulations, limited oversight, and flawed hydrologic concepts form the foundation of existing PA regulation of produced water spreading, it would not be prudent to have any non-specific means of obtaining approvals from either the State of Pennsylvania or the DRBC. Instead, it should be recognized that there is no sound rationale for importing, exporting, treating, or disposing of produced waters (or solid oil and gas field wastes) within the Delaware River Basin or anywhere within the state of PA. All potential adverse water quality issues may be judiciously addressed by simply banning all forms of oil and gas industry wastes from the Delaware River Basin. This is the best means of " … *avoiding injury to the waters of the Basin* … and … *protecting and conserving the water resources of the Delaware River Basin*."

Natural Salt Spreading on Roads: An Old Practice with Related Water Contamination - The Forerunner of Produced Brine Spreading

The use of rock salt as a deicing agent is well-established, but not without associated adverse environmental impacts. Water quality degradation attendant to spreading rock salt on roads has been recognized as a major environmental issue since the 1950s, or before (e.g., Transportation

Research Board, 1991). Contamination of streams and private and public water supply wells from off-road transport of rock salt was well documented and known to highway departments and regulating agencies long before the flawed concept of dispersing chemically-laden produced water on roads and fields was coined by the oil and gas industry and regulating agencies (e.g., PA DEP) as a "*beneficial use*". Similarly, recent water quality studies solidly document adverse environmental impacts associated with road salting, including surface and groundwater contamination (e.g., Fortin Consulting, 2014; Minnesota Pollution Control Agency, ~ 2012; U.S. EPA, 2009; U.S. EPA, 2010; Environment Canada, 2013; PA DEP and SPC, 2013). Fortin, for example, addressed chloride in salt as a toxic pollutant that accumulates over time in waters and documents thirty-eight stream reaches, lakes and wetlands that are impaired for aquatic life due to high concentrations of chloride. Similarly, Environment Canada (2013) documents 16 case study examples of water quality degradation and management efforts stemming from road salting, thereby documenting the multi-national nature of the environmental problem. Clearly, documentation of adverse impacts to surface and groundwater quality, as well as to fauna and flora, from brine solutions was established long ago - far before the gas and oil industry and their regulators advanced the concept of disposing of produced water containing brine plus additional contaminants (as discussed below) and therefore worse for water quality on roadways and land under the guise of a "*beneficial use*".

U.S. EPA (2009) summarizes water quality concerns associated with road salt use:

> "*Surface water and ground water quality problems resulting from road salt use are causing concern among both state and local governments. Salt contributes to increased chloride levels in ground water through infiltration of runoff from roadways*[2]*. Also, if runoff containing road salt reaches a stormwater injection well, it can provide a concentrated input of chloride to ground water. Unlike other contaminants, such as heavy metals or hydrocarbons, chloride is not naturally removed from water as it travels through soil and sediments and moves towards the water table. Once in the ground water, it may remain for a long time if ground water velocity is slow and it is not flushed away. Chloride may also be discharged from ground water into surface water. Direct input of salt into surface water from runoff is also problematic*[3]*. Increasing chloride concentrations have been observed over the last few decades in streams, lakes, and ponds in northern climates that receive significant snowfall*[4]*. Reservoirs and other drinking water supplies near treated highways and salt storage sites are especially susceptible to contamination. Thus, regardless of the path that the runoff takes, salt poses a water quality problem. The best chance for long term mitigation is to reduce the application of salt to road surfaces in a manner that does not jeopardize public safety on the roads*."

The PA DEP and Southwestern Pennsylvania Commission Water Resource Center (2013) also acknowledge the need to reduce chlorides in the environment in winter maintenance. They state:

"*Along with the increased use of salt, levels of chloride in surface and groundwater and associated impacts will also increase. Negative impacts have proven to be associated with the use of snow and ice control materials and have become a real concern in some states. … Due to the amounts of deicers used in Pennsylvania during the winter months, it is probable that impairments may exist. … Chloride (Cl^-) is highly soluble, very mobile, and its density allows for it to settle to the bottom of a waterbody. Chloride is toxic to aquatic life at levels above 230 mg/l. There is no natural process by which chlorides are broken down, metabolized or taken up by vegetation. ... Chloride remains in a solution and is not subject to any significant natural removal methods. Chlorides are toxic to aquatic life at high concentrations. ... Chlorides do not degrade in the environment; instead they accumulate and therefore infiltration is not a good practice for addressing chloride impairments specifically.* ***Almost all chloride applied to roads, sidewalks and parking lots will reach our lakes and streams via runoff or infiltration.***" [emphasis added]

The chloride concentration of produced brine spread on roads in Warren County, PA extends upwards of 73,000 mg/L, some 317 times greater than the concentration that is toxic to aquatic life.

PA DEP identifies salt application impacts from roadways as:

- Air Quality,
- Aquatic/Terrestrial Flora,
- Soil Quality, and
- Water Quality.

Furthermore, PA DEP and SPC provide a boxed quote from the MN Pollution Control Agency (below). This is followed with a discussion of BMPs to reduce chlorides in accordance with Total Maximum Daily Load (TMDL) plans. Off-road transport of chlorides and other chemicals into waterways and groundwater degrades water quality, regardless of whether application is associated with winter deicing or for dust suppression at other times of the year.

"*It takes only one teaspoon of road salt to permanently pollute 5 gallons of water. Once in the water, there is no way to remove the chloride, and at high concentrations, chloride can harm fish and plant life. Less is more when it comes to applying road salt.*"

Spreading of Oil & Gas Field Produced Brines on Roads - An Extension of a Practice Known to Contaminate Surface and Groundwater Resources

There is no sound hydrologic basis for believing that spreading produced waters, which are chemically worse than historic rock salt spreading, will not result in increased off-road water quality degradation. This report uses a Warren County, PA (Farmington Township) example to examine the flawed underpinnings of the PA DEP Operating Requirements that form the basis of brine spreading approvals, with emphasis on disposal of conventional well produced waters representative of what might potentially be spread on roads anywhere in PA, including in the Delaware and Susquehanna river basins. **Thus, a Farmington Township case study is used as an analogue to address potential environmental degradation that may occur anywhere in the state of Pennsylvania, and beyond, should road spreading of conventional produced water continue to be permitted.** Spreading of chemically-laden produced waters needlessly jeopardizes surface and groundwater quality. This practice should be stopped immediately.

Hydrologically, it is not possible to regulate the spreading of chemically-laden production brines in a manner that will preclude off-road transport to surface and groundwater resources. In Pennsylvania, the Department of Environmental Protection (PA DEP) regulates the spreading of produced waters on dirt roads (PA DEP, 2015), which they view as "*a beneficial use of the brine*." Because of the potential for contaminants from brine-rich produced water from non-shale formations to leach into surface or ground waters, spreading brine on dirt roads for dust suppression and road stabilization requires DEP's approval and must follow a specific plan.

PA DEP's operating requirements purport to be designed to "*minimize the environmental impact*" of off-road surface and groundwater contamination. The underlying guideline means of achieving this can be summarized as 1) don't spread brine on wet roads, during rain, or when rain is imminent, 2) don't apply on road sections with grades in excess of 10 percent, 3) separate free oil from the brine before spreading, 4) don't spread at rates and frequencies above what is needed to suppress dust and stabilize roads, 5) control the rate and frequency of application to prevent brine from flowing into roadside ditches, waterways, waterbodies, and groundwater, and 6) don't apply brine within 150 feet of a stream, creek, lake or other body of water.

Application approval requires a set of informational details including a signed approval statement from the municipality, identification of the geologic formation from which the brine is produced, and a representative chemical analysis of the brine for the following parameters: calcium, sodium, chloride, magnesium and total dissolved solids. The list does not include any analyses of hydrocarbons or multiple toxic chemical additives that may also be present. [Note: A draft Road Spreading of Brine Approval form (PA DEP, not dated) states that a chemical analysis of the brine should include total dissolved solids, chloride, sodium, calcium, pH, iron, barium, lead, sulfate, oil and grease, benzene, ethylbenzene, toluene, and xylene. The removal of this limited list of hydrocarbon parameters from the brine spreading approval list is telling, as is the omission of testing for Naturally Occurring Radioactive Material (NORM).] From a hydrologic perspective, these operating requirements will not prevent the off-road transport of chemically-laden wastewater (i.e., produced water) to surface and groundwater sources.

PA DEP operating requirements specifically preclude use of produced water brines for dust suppression and road stabilization from unconventional wells in shale formations (§ 78a.70). Yet, as documented here using example chemical data from conventional geologic formations (i.e., Bradford Group sandstones), the risk of potential surface and groundwater contamination is equal to or greater than that of the Marcellus shale. Oil and gas producing formations typically have high salinity values, heavy metals (e.g., barium, strontium), and volatile organic chemicals - including benzene which is a known carcinogen. Some of these Operating Requirements are examined in detail below.

PA DEP Brine Spreading Operating Requirements (OR)

The PA Department of Environmental Protection has a number of Operating Requirements that it deems sufficient for the "*safe*" application of brine on unpaved roads. Operating Requirements 2, 3, 4, 5, 7 and 8 will be discussed here.

Operating Requirement 2: Application Rate to Avoid Contact with PA Water Resources

This Operating Requirement states:

> "*The brine may only be applied at a rate and frequency necessary to suppress dust and stabilize the road. The rate and frequency of application must be controlled to prevent the brine from flowing or running off into roadside ditches, streams, creeks, lakes and other bodies of water or infiltrating to groundwater*."

While the underlying concept behind this operating requirement makes sense, it fails to consider the hydrologic cycle recognized by hydrologists for well over a century. Essentially, rain water falls to the earth's surface and then either runs off into down-gradient surface water receptors (e.g., roadside ditches, streams, creeks, lakes, reservoirs, wetlands, oceans) or infiltrates into underlying sediments and bedrock. Under both scenarios, the water moves down-gradient from where it falls and eventually returns to clouds via a variety of mechanisms (e.g., evapotranspiration, evaporation, sublimation), where it renews the cyclic process again. Thus, any water, brine and soluble chemicals spread on roads must also follow this hydrologic process. If they did not, and roadways somehow functioned as isolated elongate sponges with impermeable bases and walls (e.g., like long fish tanks), all rain water and brine incident to them would stay within the footprint of roads and would result in an increasingly upward rising water column or mound. Clearly, creation of this "hypothetically" bounded wall of brine-rich water does not and cannot exist. Brines, rain water, and produced water contaminants must move down-gradient into surface water bodies and groundwater flow regimes, as can be seen in Figures 1 and 2 below. Whether this occurs on the date of brine spreading or following rain or snowmelt events, unless some filtering event intervenes, it is a hydrologic certainty that down-gradient contamination will occur.

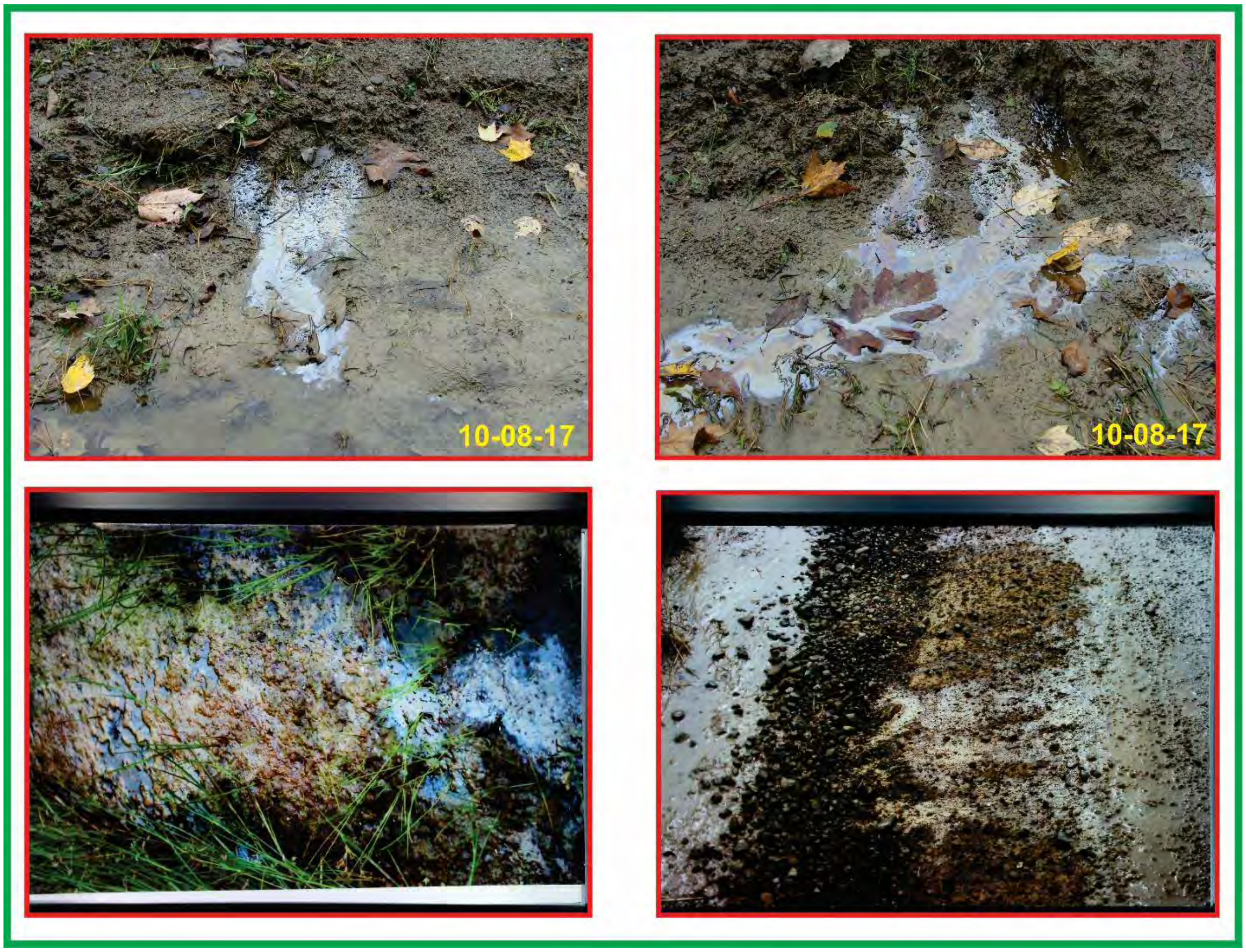

Figure 1. Sediment discoloration along Warren County, PA roadways where brine spreading has occurred. The bottom right photo shows brine flowing from a road surface into a drainage ditch.

Natural subsurface filtering of brine does not occur because salts are almost infinitely soluble. This is why there are numerous contaminated groundwater cases down-gradient of salt and sand/salt piles. Thus, the assumption underlying this operating requirement is based on flawed reasoning. Brine spread contaminants will move outward and downward from roads at rates and frequencies controlled by well-documented hydrologic factors (e.g., hydraulic gradient, soil and bedrock permeability, effective porosity, chemical load), thereby posing a salinization and contaminant threat to headwater watersheds. This will result in contamination of state water resources.

Numerous authors have identified concerns about the potential for compromising drinking water quality near areas of oil and gas development (e.g., Kreuzer et al., 2018; Burgos et al., 2015; Johnson et al., 2015; Rena, 2008). Johnson et al. (2015) warn and document that produced waters associated with active and legacy conventional Upper Devonian oil and gas wells may and have increased total dissolved solids (TDS) in groundwater and streams. They cite the risk to surface and groundwater quality via improper disposal of drilling fluids or produced waters and provide a chemical means of discriminating between road salt sources and natural brine and/or produced water from oil and gas wells. Risk to surface and groundwater quality stemming from off-road transport of produced water brines and chemicals has been recognized and well-studied for over half a century (e.g., U.S. EPA, 1987). The U. S. EPA study found that a variety of pollutants can be released to both surface and groundwaters as a result of the production of oil and gas. These pollutants include high concentrations of total dissolved solids and chloride. This study details disastrous wastewater disposal practices, many by permit, that have or will degrade surface and groundwater quality for decades or centuries to come. Information obtained from this study were to be used, in part, for determining water quality management requirements, presumably key data used in formulating current PA DEP road spreading operating requirements. PA DEP Operating Requirements, DRBC regulations, and any kind of waste disposal permit cannot stop naturally-occurring hydrologic processes that mobilize and transport contaminants away from road surfaces.

Figure 2. Runoff of produced brine into drainage ditches in Warren County, PA.

Operating Requirements 3 and 8: Recommended Spreading Rates & Weather Conditions

Operating Requirement 3 provides recommended brine spreading rates, starting with a rate of up to one-half gallon per square yard and becoming less thereafter. Presumably, the basis for the stated rates is to insure contaminant runoff does not occur at the time of waste spreading, instead delaying off-road transport into surface and groundwater resources following subsequent rain and/or snowmelt events. Reference to Figures 1 and 2 above provide evidence that Operating Requirements are of little value when they are not adhered to, or if rain events occur at any time after brine application. Clearly, excessive brine applications, as currently conducted in Warren County PA, often involving at least four passes per road per day are sufficient to saturate road surfaces with resultant chemical runoff into waters of the Commonwealth. In addition, brine spreading has occurred both during times of precipitation and when it was pending (Lawson, pers. Comm.). This is in violation of PA DEP Operating Requirement 8.

Moreover, since there is no natural subsurface filtering of ionized salts and no documented filtering of most other contaminants in produced water, there is no sound basis for believing that contamination will be reduced by reduced rates of spreading or absence of rain.

The concept of following "*Recommended spreading rates*" as put forth in Operating Requirement 3 is equally flawed. Brine spreading contaminants will eventually be transported to surface and groundwater resources (e.g., creeks and wells). A comparable analogy would be to slowly apply cyanide-rich brine above one's water well. Clearly, neither the rate nor the frequency of applying a contaminant source above water resources will provide a "*safe*" water quality situation. As discussed above, rates of contaminant arrival are a function of hydrologic factors and time. There are no "*safe*" contaminant spreading rates.

Operating Requirement 4: Only Production or Treated Brines May be Used

This Operating Requirement states:

> "*Only production or treated brines may be used. The use of brine from Marcellus and other non-conventional shale formations is not applicable for road spreading. The use of drilling, fracing, or plugging fluids or production brines mixed with well servicing or treatment fluids, except surfactants, is prohibited. Free oil must be separated from the brine before spreading*."

This operating requirement provides no chemical thresholds for evaluating chemical components of brine and no "*acceptable*" contaminant concentrations on a parameter-specific basis. Yet, it clearly states that brine from Marcellus and other non-conventional shale formations is not applicable for road spreading. PA DEP emphasizes that brine produced from any shale formation is not applicable for road-spreading. These shale formations include but are not limited to Marcellus, Rhinestreet, Burket, Geneseo, Mandata, Utica, Huron, Dunkirk, Pipe Creek, Middlesex, Needmore, Girard, and Cabot Head (PA DEP, not dated).

Presumably, then, the PA DEP has evaluated the chemistry of Marcellus produced waters and found it to be unacceptable for brine spreading. Using a January 14, 2016 PA DEP Brine Spreading Plan Review (Approval No. NW1716; PA DEP 1-14-16) as a representative example of DEP's evaluation particulars, their approval review appears to be based on five brine indicator parameters: chloride, total dissolved solids, calcium, magnesium and sodium.

The concentration values for Approval No. NW1716 (PA DEP 4-06-16) are provided on Table 1 below (page 16) for the Hydro Transport ALS Environmental Sample. Additional insight into the source of brine waters considered acceptable for PA DEP approval are found on DEP's April 6, 2016 Approval No. NW5916 issued to Hansen Services. This approval contains the same Operating Requirements. It also provides a listing of geologic formations from which brine waters are produced. It specifically states that all formations are from Upper Devonian Bradford Group sandstone formations including:

- Warren 1st, 2nd, 3rd (Warren First sandstone top marks the base of the Chadakoin)
- Glade/Queen
- Clarendon
- Balltown/Cherry Grove
- Cooper/Klondike

In western PA, the Bradford Group is depicted on PA geologic columns as being stratigraphically above the underlying Middle Devonian Marcellus Shale and below the Upper Devonian Chadakoin Formation. Dodge (Bedrock Lithostratigraphy of Warren County, Pennsylvania Guidebook paper; 1992) states that the Chadakoin Formation averages about 450 feet thick in Warren County and consists of interbedded greenish-gray to light-gray or reddish-purple-gray shale, with some very fine- to fine-grained, light-greenish-gray to light-gray sandstone. Dodge identifies the primary oil-producing strata within the Bradford Group as including the Glade (or Queen), Clarendon, Balltown, Cherry Grove, Cooper, Klondike, and Deerlick sandstones. Oil saturations in Bradford Group reservoirs range from 5 to 45 percent, averaging about 20 to 25 percent (Harper, 1992). It is therefore likely that Bradford Group brines spread on Warren County roads include a hydrocarbon contaminant component. This is borne out in a 1-07-16 brine sample submitted for analysis by Hansen Services (1,3,5-trimethylbenzene: 59.3 ug/L; 1,2,4-trimethylbenzene: 136 ug/l; benzene: 2,090 ug/L; toluene: 1,870 ug/L; ethylbenzene: 90.2 ug/L; xylenes: 957 ug/L; naphthalene: 10.2 ug/L; 3&4 methylphenol: 124 ug/L; 2-methylphenol: 101 ug/L). Therefore, under its current Operating Requirements, PA DEP approves the spreading of oil field brines laced with hydrocarbons. Hydrocarbon contaminants were detected in a Dalyrmple Road brine sample spread and collected on 8-28-17 (acetone: 3,840 ug/L; benzene: 12.6 ug/L; 2-

Butanone (MEK): 798 ug/L; 2-hexanone: 36.1 ug/L; toluene: 2.6 ug/L; xylenes: 7.3 ug/L), documenting spreading of multiple contaminants inclusive of benzene (a known carcinogen).

The high percentage of oil saturation present in Bradford Group produced waters may make its contaminant potential greater than those from the Marcellus Shale. It is interesting to note that PA DEP brine spreading approval is based solely on chemical analysis of sodium, calcium, magnesium, chloride and total dissolved solids, and no hydrocarbon analyses (not even a total organic carbon analysis). Apparently, there are no concentration limits specific to these parameters, just the requirement that they not be derived from the Marcellus Shale and other non-conventional shale formations.

As stated above, PA DEP Operating Requirement No. 4 states that brine produced from any shale formation is not applicable for road-spreading. This broad limitation becomes problematic when evaluating which geologic formations do not contain shale and connate brine waters within them and are exploited for gas and/or oil production. As documented above, produced water from the Bradford Group in Warren County, PA has been approved for road spreading. It is beneficial to examine another location in PA from which produced water might originate that could potentially be approved for road spreading. In this second location, a number of production intervals occur within the Lock Haven Formation which has a significant shale component. The lower portion of the Lock Haven Formation includes Elk Group sandstones overlain by Bradford Group sandstones.

Laughrey et al. (2004) discuss the Council Run gas field situated in north-central Pennsylvania (Centre and Clinton counties). Any brine produced from this gas field would, most likely, be considered for brine spreading because it would be produced from four principal reservoir sandstone formations and not shale formations. The authors identify the gas reservoirs within Upper Devonian sandstones of the Lock Haven and Catskill formations. Sandstones of the Lock Haven Formation that are the most prolific producers are the Fifth Elk, Third Bradford, the basal Bradford and various Elk sandstones. Faill et al. (1977) and Laughrey et al. (2004, by reference and detailed description) define the Lock Haven Formation as gray, brown, and green interbedded shales, mudstones, siltstones, and sandstones that overlie the Brallier Formation and underlie the red beds of the Catskill Formation.

It is particularly important to recognize that Laughrey et al. characterize the potential gas source rocks as the underlying Marcellus shale formation and Burket member of the Harrell Formation. Recall, as discussed above, a draft PA DEP Request for Road-Spreading of Brine Plan Approval form specifically identifies the Burket black shale as a geologic formation from which produced brine is not applicable for road-spreading (PA DEP, not dated).

Specifically, Laughrey et al. state:

> "*Potential source rocks in the study area include the Burket Member of the Upper Devonian Harrell Formation, the Middle Devonian Marcellus Formation, and the Upper Ordovician Utica Shale (Figure 2). These are the only rocks in the region with sufficient total organic carbon to have generated commercial quantities of hydrocarbons (Figure 12). Black shales of the Burket and Marcellus (Devonian) are the likely source of the hydrocarbons produced from the Upper Devonian sandstones at Council Run field*."

> "*Petroleum expelled from the Devonian source rocks* (Marcellus and Burket black shales) *migrated through* (overlying) *permeable beds in the Upper Devonian Brallier Formation between 320 and 290 Ma and accumulated in the sandstones of the Lock Haven and Catskill formations. Dispersive migration paths were probably both lateral and vertical (Mann et al., 1997)*."

> "*We interpret the critical moment at Council Run field, i.e., that point in time when the generation-migration-accumulation of most hydrocarbons in the* ***Marcellus/Burket–Lock Haven/Catskill petroleum system*** *took place, as having occurred between 260 and 240 Ma, when most of the oil in the petroleum system was cracked to gas*." (emphasis added)

Thus, Laughrey et al. (2004) determined that Lock Haven gas producing zones stratigraphically above the Marcellus and Burket black shales are part of the same petroleum system. It also follows, then, that Lock Haven produced water has almost certainly been in contact with Lock Haven shales since most producing wells in the Council Run field are multizone completions and exhibit similar geochemical signatures as the underlying Marcellus and Burket black shale source rocks. As such, spreading of Lock Haven produced waters may be little different from spreading produced waters from the Marcellus shale. The work of Laughrey et al. and the chemical data presented on Table 1 further bear this out. Recognizing these factors, it is difficult to justify road spreading approval of Lock Haven or other similar production brines that originate from similar geologic settings and exhibit similar geochemical signatures.

Major chemical components present in produced waters have been identified by numerous researchers (e.g., Johnson et al., 2015; Vengosh et al., 2015 & 2017). Wastewater produced from both conventional and unconventional oil and gas wells contain a variety of contaminants of concern including salts, metals, NORM, and both reservoir-derived and anthropogenic organic compounds (e.g., Warner et al., 2013; Burgos et al., 2015). NORMs sometimes occur at very high concentrations, including in brines from conventional wells. Elevated concentrations of strontium, barium, and radium have all been detected in flowback and produced waters from unconventional Marcellus Shale gas wells, in CWT plant effluents, and in river sediments downstream of CWT plants (Burgos et al., 2015). Laughrey et al.'s (2004) determination that hydrocarbons in the Marcellus/Burket-Lock Haven/Catskill petroleum system are geochemically related further establishes the likely multi-formational presence of NORMs. The dispersal of radioactive water via road and land spreading practices has not been addressed in the permit approval process. This is a significant omission.

Other authors have also identified NORMs as an environmental threat. Sookdeo (2003), for example, discusses strategies for minimizing impacts on the environment in Trinidad and Tobago where produced water is the single largest waste stream by volume within oil and gas field operations. He identifies the constituents of greatest environmental concern as chlorides, hydrocarbons, heavy metals, radionuclides, treatment/production chemicals, and dissolved solids.

A number of authors review methods to dispose oil and gas field waste. Veil (2002), for example, identifies assorted methods of disposing of drilling wastes (drilling fluids and drill cuttings), including land spreading and land farming. Veil lists current standards for road spreading that often include regulatory restrictions placed on chemical constituents of wastes (e.g., chlorides, TPH), application rates, and the slope of the land. He suggests that substitution of some of the key components of drilling fluids with new, more environmentally friendly products could reduce mass loadings to the environment. The chemistry of produced waters identified by numerous authors establishes that chemical loading remains as an environmental problem.

Operating Requirement 4 precludes the use of brine from Marcellus and other non-conventional shale formation from road spreading. Logically, examination of the chemical concentrations of PA DEP's five chemical "*approval*" parameters should permit characterization of concentrations that are too high and, thus, not suitable for brine spreading approval. This can readily be accomplished by examination of chemical work published by Johnson et al. (2015). As part of their chemical work, these authors culled through the literature for published data on the chemistry of Marcellus Shale produced waters. Table 1 provides the fruit of their analysis, presenting ranges and average concentrations of Marcellus Shale produced water. This table also provides chemical data on Bradford Group brines provided by Hansen Services, Hydro Transport and other Bradford Group brine producers. This data includes the five parameters required by PA DEP for permit approval (bolded in red). It appears that brine wastewater is collected from well sites and disposed of directly on county roads, absent any treatment whatsoever. This waste disposal technique jeopardizes the water quality of surface and groundwater resources and ignores treatment considerations (e.g., Baudendistel et al., 2015; Geza et al., 2013; Hum et al., 2005; Hussain et al., 2014; Lawrence et al., 1993 & 1995; Sookdeo, 2003; Balch et al., 2014; Silva et al., 2017; Oetjen et al., 2017).

Table 1 also includes analyses of two brine samples collected from Warren County roads soon after application, one from Dalyrmple Road and one from Old State Road. These applied brine samples were collected by Bryce Payne on 8-28-17. The locations of these samples are depicted as green hexagons labeled A and B on Figures 3 and 4 of attached Addendum 1. Chemically, based on PA DEP indicator parameters, they are similar to the Hansen and other Bradford

Formation samples, as well as Marcellus Shale samples (inclusive of Ristau and Allen brine samples, 2016). Comparison of chemical concentrations for the five PA DEP brine parameters (Na, Ca, Mg, Cl, TDS) for Marcellus Shale and Bradford Group sandstones reveals that there are NO significant chemical differences, perhaps with the exception of multiple hydrocarbons from Bradford Group oil producers. Approved concentrations of chloride in Bradford formation conventional well produced waters (Table 1 below: to at least 73,000 mg/L) are approximately 21 times the chloride concentration in seawater. **Essentially, the concentrations of brine parameters in Marcellus Shale produced water that PA DEP Operating Requirements state are not applicable for road spreading are matched or exceeded by Bradford Group produced water chemistry concentrations. Based on chemical comparison of Marcellus and Bradford Group brines, there is no chemical/water quality basis for spreading contaminant-rich oil and gas field wastewater from either group where they will flow downward and degrade vulnerable surface and groundwater resources.**

Water Quality Parameters for Produced Water Sources (mg/L)								
Source	**TDS***	Ba	**Ca***	**Mg***	**Na***	Sr	**Cl***	Br
Marcellus Fm Samples								
Published Marcellus Shale Produced Water Range - Johnson et al.	44,800 - 211,400	29 - 12,000	2,278 - 20,800	217 - 1,750	11,747 - 49,400	381 - 5,230	29,000 - 159,000	506 - 1,150
Average Marcellus Shale Produced Water - Johnson et al. 2015	**106,390**	2,224	**7,220**	**632**	**24,123**	1,695	**57,447**	511
Bradform Fm Samples								
Old State Rd Brine Sample 8-28-17; Pace	97,920	NA	**8840#**	**1,510**	**24,700**	NA	52,500	<0.1
Dalyrmple Rd Brine Sample 8-28-17; Pace Analytical	NA	3.8	**9,450**	**1,650**	**29,000**	NA	**69,500**	810
Bradford Group Produced Water from Hansen Services 1-07-16	81,860	1.31	NA	**1,270**	23,100	88.1 (dissolved fraction; value hard to read)	52,167	585
Hydro Transport Brine Sample 12-16-12	105,000	NA	**9,810**	**1,670**	**25,700**	NA	**64,300**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-04	**126,000**	NA	**10,200**	**1,660**	**25,900**	NA	**61,000**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-05	**133,000**	NA	**10,400**	**1,530**	**27,900**	NA	**66,000**	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-01	**112,000**	NA	**8,430**	**1,310**	23,700	NA	55,000	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-02	86,300	NA	6,340	**1,070**	18,800	NA	42,000	NA
Ristau Drilling Brine Sample 4-20-16 16D1798-03	**144,000**	NA	11,900	**1,800**	**30,700**	NA	**73,000**	NA
J&L Allen Brine Tank Sample 4-13-16	**109,000**	NA	8,270	**1,360**	23,900	NA	52,000	NA
*: PA DEP Brine Spreading Approval Parameter **#: Bolded red values are greater than Marcellus Shale average values.**				**Table 1**				

Wastewater Disposal

Burgos et al. (2017) provide an excellent summary of wastewater disposal practice in Pennsylvania:

> "*Depending on the geographic location, Oil & Gas (O&G) wastewaters are typically disposed of into underground injection control (UIC) wells, treated to some extent for in-field reuse, or sent to Centralized Waste Treatment (CWT) plants for treatment and eventual discharge to surface water. Across the U.S., several states, including California, Michigan, Montana, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming, allow produced waters from O&G wells to be discharged to surface water. Recent studies have found that CWT plants often only provide limited treatment of oil and gas wastewater, sometimes resulting in degradation of downstream water quality*."

> "*In August 2010, the Pennsylvania legislature forced new or expanding CWT plants to meet effluent water quality standards of 500 mg/L TDS, 250 mg/L Cl, 10 mg/L Ba, and 10 mg/L Sr. Up until this point, all but one CWT plant in Pennsylvania had only to monitor and report effluent TDS, chloride or osmotic pressure. Eight permitted facilities were listed as exempt from the new TDS standard. In April 2011, the PADEP requested that O&G operators no longer deliver wastewater from unconventional gas wells to CWT plants exempt from the new TDS effluent standard. The net effect of these policy changes dramatically reduced the volume of unconventional O&G wastewater sent to CWT plants and spurred the reuse of produced waters for continued hydraulic fracturing of new wells.*"

Apparently, it also spurred the Oil & Gas industry to convince the PA DEP that wastewater disposal directly on the lands of the Commonwealth was a "*beneficial use*". **Reference to chemical concentrations documented on Table 1 raise the question as to why PA DEP would approve and permit the disposal of brine wastewater onto the lands of the Commonwealth in concentrations upward of 300 times effluent water quality standards (i.e., TDS, Cl).** Clearly, untreated wastewater that exceeds CWT plant effluent water quality standards should not be spread on roads or fields where it will enter surface and groundwater.

Operating Requirement 5: Brine Must Not be Applied within 150 Feet of a Waterbody

PA DEP Operating Requirement 5 states:

> "*Brine must not be applied within 150 feet of a stream, creek, lake or other body of water*."

A detailed analysis of the distance between numerous sections of dirt roads where brine has been applied and nearby streams in Farmington Township was conducted. This work is detailed in attached Addendum 1 titled: *Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment*. Figure 4 of Addendum 1 depicts the surface drainage network with 150-foot buffers outward from streams and ponds. Reference to this figure documents numerous locations where brine has been applied within 150 feet of a stream.

Not only is compliance difficult to attain, but the underlying assumption, as with avoiding rain or wet roads, that risk of water contamination can be eliminated by forbidding spreading within a pre-determined distance from observed water resources is also flawed.

Operating Requirement 7: Avoid Brine Spreading on Roads with Grades >10%

PA DEP Operating Requirement 7 states:

> "*Brine must not be placed on sections of road having a grade exceeding 10 percent.*"

Analysis by HydroQuest of numerous road segments in Farmington Township, Warren County where brine applications have been witnessed or viewed soon after application solidly establish that operators either are not aware of road segments with steep grades or simply continue brine application on steep grades. Addendum 1 to this report titled: *Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment* provides a detailed analysis of road grades where brine has been applied. Work conducted for this analysis documents numerous road segments with grades in excess of 10 percent where brine waste haulers have applied contaminant-rich wastewater. This is in violation of PA DEP Operating Requirements.

Again, poor compliance and flawed hydrologic reasoning underlying the Operating Requirement result in the virtual certainty of contamination of surface and groundwater resources, including those that serve as sources of drinking water.

Discussion

Water quality risks associated with brine application in the State of Pennsylvania and other states have long been recognized as an important environmental issue. I have raised many of the concerns addressed in this report previously in a Nov. 15, 2011 technical report titled: *Natural Gas Brine Dispersal on Roadways and the Risk of Surface and Groundwater Contamination (Comments on DEP Permit # WMGR064),* appended as Addendum 2. As established above, brines from gas and oil fields both have high concentrations of numerous chemical contaminants, making land application of either dangerous from a water quality perspective. As such, water quality/contaminant concerns discussed in the Nov. 15, 2011 report also apply to Bradford Group brines.

All the concerns raised above apply equally to any state in the United States, including Pennsylvania. The PA DEP developed a Fact Sheet that pointedly explains to the public the definition and the potential "*beneficial use*" of brine in the Commonwealth:

> "*Brine is the general term for wastewater produced along with oil or gas; it can be very salty, therefore, injurious to plants and aquatic life.*"

If brines can be injurious to plants and aquatic life, it clearly is not prudent to expose Pennsylvania residents to the same chemicals via ingestion and physical contact. From a hydrologic and water quality standpoint, the certain dispersal of brine wastewater chemicals into our waterways, reservoirs, and freshwater aquifers from intentional brine dispersal is analogous to running a small secondary line from an oil tank and slowly dripping its contents onto the ground surface, close to a drinking water well. While it may be difficult to predict exactly when a homeowner's water supply will be permanently degraded, they may be confident in the knowledge that they will soon need to buy bottled water. Hydrologically, the flow dynamics are the same - application of contaminant-laden brines on our roadways will move into our finite water resources and degrade them.

These brines contain salts that are virtually infinitely soluble in water, as well as other chemicals, some of which are toxic and may potentially have serious adverse health impacts. Concentrated and chemically-laden brines should not be discharged into the environment. This is not a beneficial use. Oil and gas well brines need to be properly treated and disposed of.

Conclusion

The use of untreated brine from any geologic formation that has been subject to oil and/or gas production should be banned as brine-rich fluids and chemicals within them pose a direct water quality threat to streams, creeks, rivers, reservoirs, wetlands, lakes, other water bodies and groundwater, including private, public and municipal wells. The underlying concept that procedures (i.e., Operating Requirements) and open-ended regulation wording may be used to prevent brine from entering surface and groundwater is flawed. At some point in time (e.g., spring runoff) brine accumulations on roadways, fields, tracks and other locations used for brine disposal (under the moniker of "beneficial use") will enter and move with surface water and groundwater flow regimes - thereby degrading water quality. As such, brine applications pose a real risk to the health and safety of people, wildlife, ecosystems and the environment.

The land application of oil and gas field brine waters should be ceased immediately, unless it is first treated to meet or exceed all Centralized Waste Treatment plant effluent water quality standards or, state drinking water standards - whichever is stricter.

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Addendum 1: Spreading of Oil & Gas Well Production Brine on Roads in Farmington Township, PA: Percent Grade & Hydrologic Assessment

Introduction

The Commonwealth of Pennsylvania permits the application of oil and gas well production brine to roads for dust control and stabilization. The Pennsylvania Department of Environmental Protection (DEP) has provided operating requirements regarding the rate and frequency of brine application that, presumably, will afford "*environmental protection*". Their Operating Requirements, as stated in Brine Spreading approvals state:

> "*The rate and frequency of application must be controlled to prevent the brine from flowing or running off into roadside ditches, streams, creeks, lakes and other bodies of water or infiltrating to groundwater*."

Among a number of DEP Operating Requirements (OR), brine spreading approvals state that brine must not be spread on sections of road having a grade exceeding 10 percent (OR No. 7) and must not be applied within 150 feet of a stream, creek, lake or other water body (OR No. 5). Using Farmington Township, PA as an example, this report examines a physical and hydrologic setting where brine has been applied heavily. The February 23, 2018 HydroQuest report titled: *Hydrologic Evaluation of PA DEP Brine Spreading Operating Requirements* addresses the lack of hydrologic foundation available to support the approval of brine spreading on any topographic grades or within watersheds where humans, animals and ecosystems have the potential of ingesting or coming in contact with surface and/or groundwater resources. The findings below were reached to a reasonable degree of scientific certainty.

Percent Grade Analysis

HydroQuest conducted an analysis of the topography and hydrology of a portion of northern Warren County, Farmington Township in northwestern, PA, with emphasis on the slope and percent grade of roads where chemically-laden hydraulic fracturing fluid waste has been spread (i.e., disposed of) on road surfaces. The percentage grade of a road is the slope written as a percent. This slope analysis entailed constructing GIS maps from mosaiced one-meter Digital Elevation Model (DEM) data.

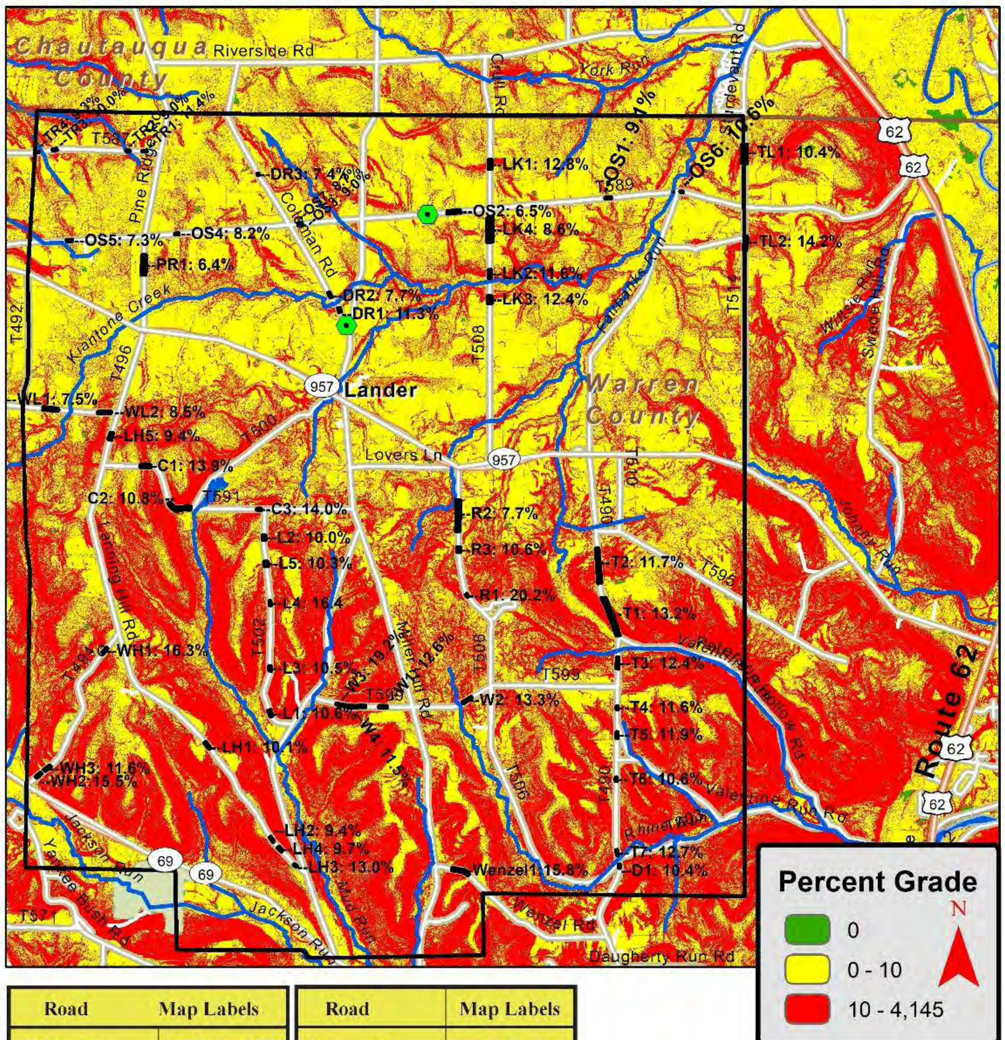
The roads examined were White Road, West Road, Wenzel Road, Lindell Road, Thompson Hill Road, Rhine Run Road, Cemetery Road, Ludwig Road (aka Ludwick Rd.), Wilson Road, Lanning Hill Road, Pine Ridge Road, Dutch Hill Road, Trask Road, Dalrymple Road (aka Coleman Rd.), Old State Road, and Town Line Road. Road nomenclature used follows that depicted on the June 21, 2006 Hass Associates Addressing Services' Farmington Township map. The sources of Digital Elevation Model (DEM) and 2-foot elevation, LiDAR-derived, data are the Pennsylvania Department of Conservation and Natural Resources and the U.S. Geological Survey. Data analysis and map construction were conducted by Paul A. Rubin of HydroQuest.

The percent grade analysis map depicts topographic percent grade broken out into zero percent grade, 0.01 to 10 percent grade, and 10 to 4,145 percent grade (Figure 1). Note that no road in the Township is entirely flat, all roads are shown to have some measurable grade. In addition, more detailed analysis of 55 steep road sections was conducted using higher resolution 2-foot contour map data derived from 2007 Airborne Light Detection and Ranging (LiDAR) Survey data. The locations and percent grade of these road segments are portrayed on Figure 2. The 2-foot contours are not depicted on report maps because the fine contour detail would overwhelm them. Detailed closeup examination of 2-foot contour intervals and distance measurements were conducted while zoomed in on a Geographic Information System (GIS) map base. The values and measurements used to determine slope and percent grade are presented in Tables 1 and 2 below. All elevation and distance values are in feet.

Reference to Figure 2 and the tables establishes that many road segments where brine is applied within Farmington Township exceed a ten percent grade, with at least one measured road segment of 20.2 percent grade. It is important to recognize that while many steep road grade sections documented here equal or exceed the percent grade brine application cutoff value of 10 percent, many road sections in the Township have long steep lengths far in excess of the measured distances documented in Tables 1 and 2.

It is important to recognize that the Operating Requirement value of 10 percent grade has no scientifically valid or defensible empirical basis or foundation. This is an arbitrary percent grade number. Surface and roadside runoff will flow overland at any percent grade in excess of zero. Surface flow outward from salted roads is a well-documented source of surface and groundwater contamination. This is particularly relevant because brine and salt are nearly infinitely soluble in water. Numerous cases of contamination have led municipalities to reduce salting activities proximal to reservoirs and to cover salt and salt/sand storage piles. There is no valid justification for avoiding brine spreading on road grades exceeding 10 percent because brine will be mobilized and will runoff from road surfaces of all grades in adjacent drainageways, if not on the date of application - then on a future date. Brine contaminants may result in adverse environmental impacts (e.g., fishery and ecologic degradation, water quality related impacts to livestock drinking from streams, milk production, aquifer degradation). Land surfaces with low percent grades beyond brined roads have the potential of having high infiltration rates to groundwater, thereby promoting aquifer contamination. Regardless of road grade, disposal of oil and gas industry waste products has the potential of degrading surface and groundwater resources. Figure 2 depicts numerous Farmington Township road sections with percent grades exceeding the PA DEP Operating Requirement value of 10 percent.

Many steep road sections with grades in excess of 10 percent are situated close to streams (Figure 3) with some steep road segments lying on or very close to drainage divides (e.g., LH2, LH3, LH4). In these settings, chemically laden production brine has the potential of adversely impacting water quality in two watersheds at the same time.



Road	Map Labels
White Rd	WH1 to WH3
West Rd	W1 to W4
Wenzel Rd	Wenzel1
Lindell Rd	L1 to L5
Thompson Rd	T1 to T7
Rhine Run Rd	R1 to R3
Cemetery Rd	C1 to C3
Ludwig Rd	LK1 to LK4
Town Line Rd	TL1 & TL2

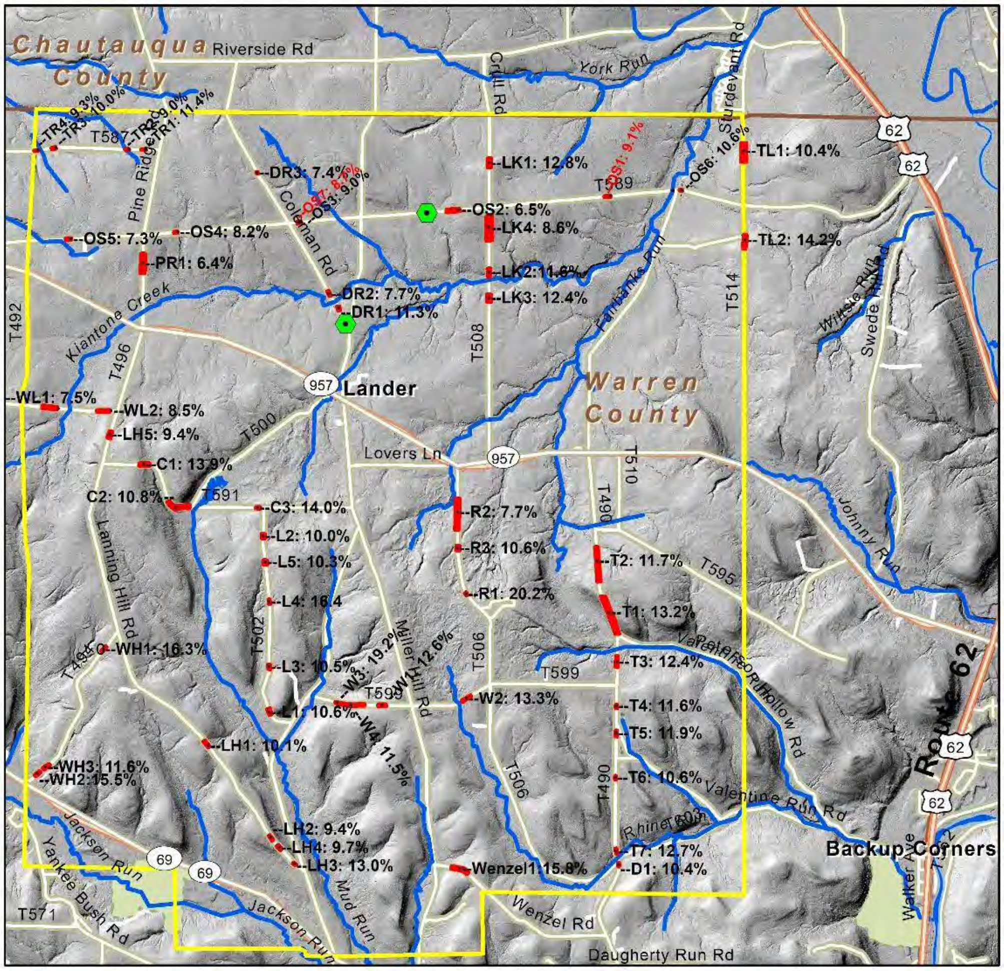
Road	Map Labels
Wilson Rd	WL1 & WL2
Lanning Hill Rd	LH1 to LH5
Pine Ridge Rd	PR1
Dutch Hill Rd	D1
Dalrymple Rd	DR1 to DR3
Old State Rd	OS1 to OS7
Trask Rd	TR1 to TR4

Percent Grade of Topography: Farmington TWP, Warren County, PA

Analysis & Map Construction: Paul A. Rubin:
HydroQuest - November 27, 2017

Miles
0 0.4 0.8 1.6 2.4 3.2

Figure 1. Percent grade of topography in Warren County, PA.



Percent Grade of Select Road Segments: Farmington Township; Warren County, Northwestern Pennsylvania

Road	Map Labels
White Rd	WH1 to WH3
West Rd	W1 to W4
Wenzel Rd	Wenzel1
Lindell Rd	L1 to L5
Thompson Rd	T1 to T7
Rhine Run Rd	R1 to R3
Cemetery Rd	C1 to C3
Ludwig Rd	LK1 to LK4
Town Line Rd	TL1 & TL2

Road	Map Labels
Wilson Rd	WL1 & WL2
Lanning Hill Rd	LH1 to LH5
Pine Ridge Rd	PR1
Dutch Hill Rd	D1
Dalrymple Rd	DR1 to DR3
Old State Rd	OS1 to OS7
Trask Rd	TR1 to TR4

N

Miles: 0 0.4 0.8 1.6 2.4 3.2

Analysis & Map Construction: Paul A. Rubin: HydroQuest - November 27, 2017

Figure 2. Percent grade of select road segments in Warren County, PA.

Table 1. Values and measurements made to determine percent grade of select road sections. Elevation, difference and distance values are in feet.

Map Label	Location	Elev. 1	Elev. 2	Diff.	Distance	Slope	% Grade
WH1	White1	1740	1782	42	258	0.163	16.3
WH2	White2	1506	1542	36	232	0.155	15.5
WH3	White3	1566	1600	34	292	0.116	11.6
W1	West1	1808	1848	40	317	0.126	12.6
W2	West2	1774	1828	54	405	0.133	13.3
W3	West3	1638	1668	30	156	0.192	19.2
W4	West4	1672	1788	116	1012	0.115	11.5
Wenzel1	Wenzel1	1666	1778	112	707	0.158	15.8
L1	Lindell1	1570	1596	26	246	0.106	10.6
L2	Lindell2	1816	1834	18	180	0.100	10.0
L3	Lindell3	1640	1658	18	172	0.105	10.5
L4	Lindell4	1756	1786	30	183	0.164	16.4
L5	Lindell5	1836	1854	18	174	0.103	10.3
T1	Thompson1	1614	1830	216	1634	0.132	13.2
T2	Thompson2	1642	1806	164	1397	0.117	11.7
R1	RhineRun1	1868	1892	24	119	0.202	20.2
R2	RhineRun2	1634	1732	98	1268	0.077	7.7
R3	RhineRun3	1756	1776	20	189	0.106	10.6
C1	Cemetery1	1860	1916	56	402	0.139	13.9
C2	Cemetery2	1652	1756	104	960	0.108	10.8
C3	Cemetery3	1732	1756	24	171	0.140	14.0
LK1	Ludwig1	1570	1618	48	374	0.128	12.8
LK2	Ludwig2	1432	1470	38	329	0.116	11.6
LK3	Ludwig3	1454	1490	36	291	0.124	12.4
LK4	Ludwig4	1518	1600	82	953	0.086	8.6
TL1	TownLine1	1400	1478	78	748	0.104	10.4
TL2	TownLine2	1486	1566	80	562	0.142	14.2

Table 2. Values and measurements made to determine percent grade of select road sections. Elevation, difference and distance values are in feet.

Map Label	Location	Elev. 1	Elev. 2	Diff.	Distance	Slope	% Grade
WL1	Wilson1	1662	1706	44	588	0.075	7.5
WL2	Wilson2	1696	1740	44	519	0.085	8.5
LH1	LanningHill1	1754	1784	30	297	0.101	10.1
LH2	LanningHill2	1694	1716	22	233	0.094	9.4
LH3	LanningHill3	1578	1596	18	138	0.130	13.0
LH4	LanningHill4	1650	1670	20	206	0.097	9.7
LH5	LanningHill5	1800	1826	26	277	0.094	9.4
PR1	PineRidge1	1610	1660	50	786	0.064	6.4
D1	DutchHill1	1526	1540	14	135	0.104	10.4
T7	ThompsonHill7	1512	1536	24	189	0.127	12.7
T6	ThompsonHill6	1658	1674	16	151	0.106	10.6
T5	ThompsonHill5	1730	1758	28	235	0.119	11.9
T4	ThompsonHill4	1740	1756	16	138	0.116	11.6
T3	ThompsonHill3	1640	1696	56	453	0.124	12.4
TR1	Trask1	1654	1674	20	175	0.114	11.4
TR2	Trask2	1610	1624	14	156	0.090	9.0
TR3	Trask3	1506	1522	15	160	0.100	10.0
TR4	Trask4	1502	1516	14	151	0.093	9.3
DR1	Dalrymple1	1502	1520	18	160	0.113	11.3
DR2	Dalrymple2	1504	1520	16	207	0.077	7.7
DR3	Dalrymple3	1668	1674	6	81	0.074	7.4
OS1	OldState1	1450	1472	22	243	0.091	9.1
OS2	OldState2	1550	1584	34	522	0.065	6.5
OS3	OldState3	1586	1600	14	156	0.090	9.0
OS4	OldState4	1634	1646	12	146	0.082	8.2
OS5	OldState5	1576	1592	16	220	0.073	7.3
OS6	OldState6	1334	1344	10	94	0.106	10.6
OS7	Old State7	1592	1600	8	92	0.087	8.7

Hydrology

When characterizing potential adverse water quality impacts to streams, rivers, ponds, lakes, and wetlands functioning as receptors of chemically-laden wastewater applied on roadways and fields, it is important to first fully map the surface drainage pattern. This is especially critical when considering PA DEP brine spreading approvals that state that *"[B]rine must not be applied within 150 feet of a stream, creek, lake or other water body."* Hydrologically, it would be prudent to add "drainage ditches" to this listing because it is common practice to maintain drainage ditches parallel to roadways to rapidly shunt road surface drainage away from roads to streams. Rapid overland transport of brine chemicals directed to surface streams and waterbodies may quickly degrade water quality (e.g., within hours), especially during and following precipitation events.

The DEP Operating Requirement that states *"[B]rine must not be spread on wet roads, during rain, or when rain is imminent.*" fails to consider the accumulation and buildup of contaminants along roadsides and in ditches that may be readily mobilized once significant rain and runoff occur. This hydrologic situation is analogous to the buildup of hydrocarbons on gas station lots or other parking lots (from vehicle leakage) that may remain perched in place until a heavy rain occurs, followed by a chemically-laden first flush of contaminants in a down-gradient direction. In the case of oil and gas well production brine, the list of chemicals posed for off road transport potentially includes sodium, chloride, heavy metals, volatile organics and other contaminants - far more than the two main components of road salt (sodium and chloride). For example, brine samples collected at road locations A & B (Figures 3 and 4) had numerous hydrocarbon contaminants, including benzene (a known carcinogen), and high levels of sodium, chloride, total dissolved solids and high metals concentrations. Table 1 and the text within the attached report provide additional chemical information regarding contaminants posed to runoff into adjacent waterways.

Thus, potential dispersal of brine contaminants into waterways of the Commonwealth should be predicated on full knowledge of the areal extent of the drainageways proximal to roads targeted for chemical disposal via brine spreading. Without a comprehensive map of Township waterways, it is likely that the 150-foot PA DEP Operating Requirement will be and has been breached. To this end, it is important to recognize that existing U.S. Geological Survey topographic quadrangle maps, commonly with 20-foot contour intervals, do not portray the full drainage network present within Townships. Brine haulers operating without comprehensive drainage network maps might inadvertently dispose of gas and oil industry waste fluids on roadways within 150-feet of streams - an apparently arbitrary distance value without empirical supporting justification.

To assess potential contravention of the 150-foot Operating Requirement, a comprehensive photogrammetric analysis of the surface drainage network throughout Farmington Township was conducted (Figure 3). This analysis involved detailed examination of high resolution (1 meter) 1993-1995 black and white Digital Orthophoto Quarter Quadrangle (DOQ) imagery cast on Universal Transverse Mercator Projection (UTM) on the North American Datum (NAD) of 1983. DOQ images analyzed were acquired as part of the USGS National Aerial Photography Program

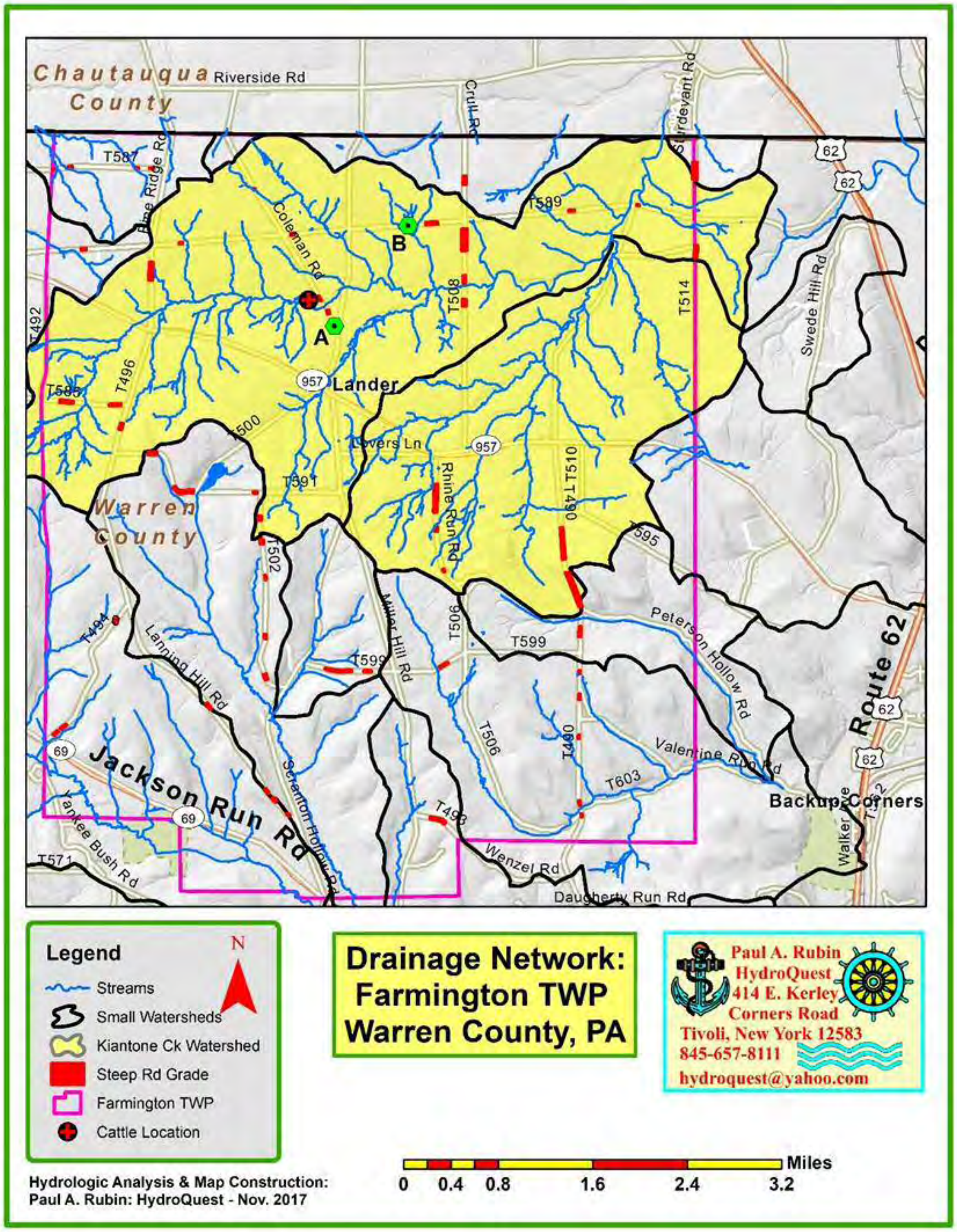


Figure 3. Detailed drainage network in Farmington Township, PA. The Kiantone Creek watershed is highlighted in yellow.

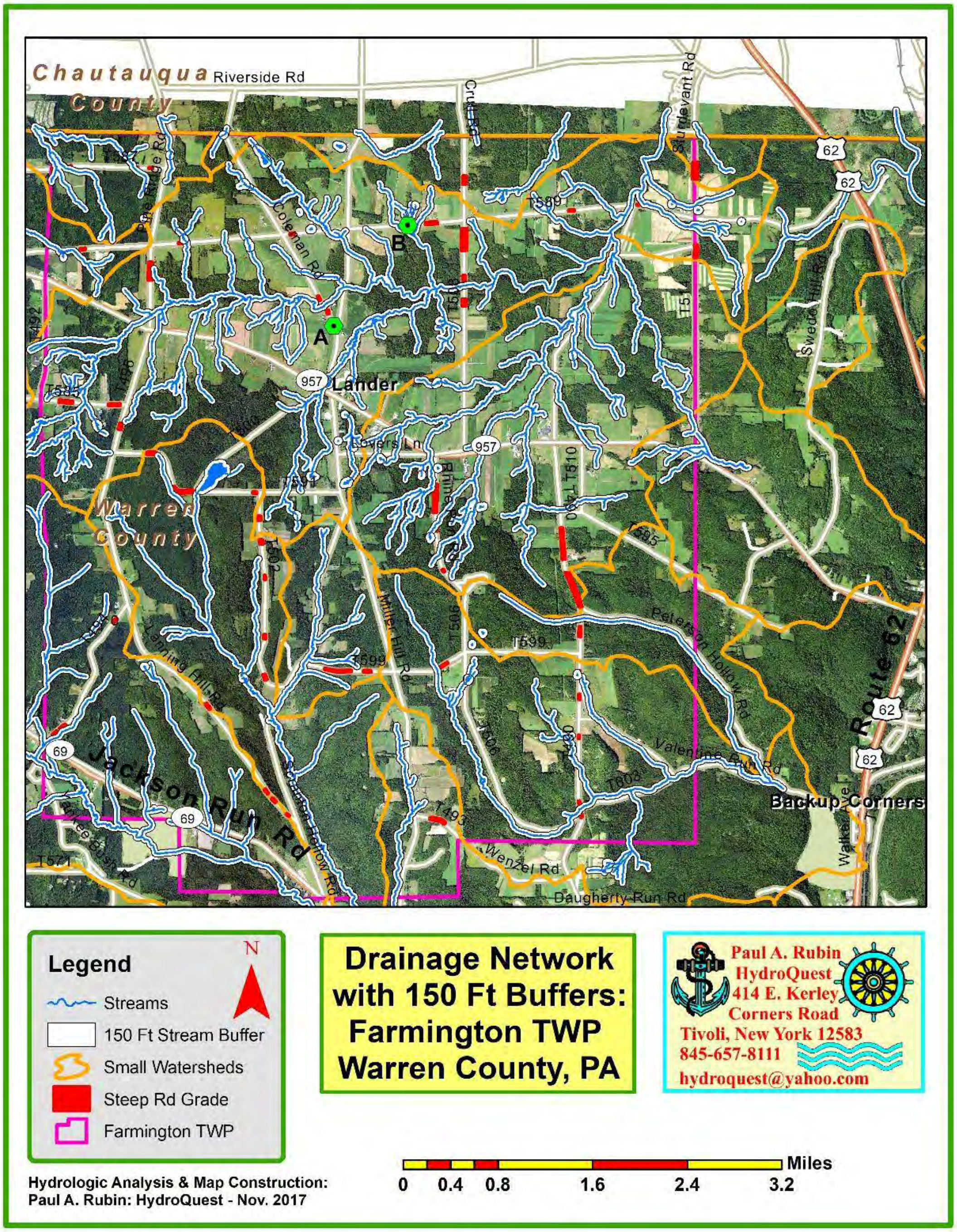


Figure 4. Drainage network with 150-foot buffers outward from streams and ponds.

(NAPP) and were distributed by PA Spatial Data Access (PASDA). The radiometric image brightness values of the images are stored as 256 gray levels which facilitate stream delineation based on tonal differences. Analysis was conducted within the framework of a GIS data base where imagery could readily be examined in a closeup setting. In this manner, stream reaches were digitized. Where tree cover obscured stream segments, reach positioning was reasonably approximated based on USGS topographic contour maps cast in georeferenced Digital Raster Graphic (DRG) format. A comprehensive drainage network map was constructed through this photogrammetric analysis (Figure 3). A 150-foot buffer distance was then applied outward from the drainage network (Figure 4). Figure 4 depicts areas where brined roads are within 150-feet of streams as well as areas where brined road areas are very close to or surrounded by stream reaches. Considering the expansive nature of the well-integrated drainage network present within Farmington Township, the logic behind using Township roads for disposal of oil and gas industry production waste is difficult to comprehend. Brine waste that does not flow directly into streams following major rain or runoff events has a high probability of infiltrating into underlying aquifer water.

Reference to Figure 3 reveals that the stream pattern within Farmington Township is dendritic, resembling that of a spreading oak or chestnut tree. Such patterns form in unconsolidated horizontal sediments in areas having a gentle regional slope at present or at the time of drainage inception. Figure 5 provides an example of unconsolidated sediments along Kiantone Creek.

Figure 5. Kiantone Creek west of Dalrymple Road. Low flow conditions present on October 8, 2017. Cattle and horses drink from this creek. The photo on the left illustrates a normal sequence of floodplain stratigraphy. Note the basal gravel and cobble fluvial deposit indicative of turbulent high flow conditions overlain by fine-grained sediments deposited during overbank flow conditions. Surface runoff from brined roads infiltrates downward into unconsolidated deposits where it may contaminate groundwater resources.

Small headwater watersheds are more vulnerable to contaminant loading than rivers because relatively low stream discharges have lower chemical assimilation potential. Closer examination of the drainage network in and adjacent to Farmington Township documents the headwater setting of the network which drains into Conewango Creek prior to its confluence with the Allegheny River. An excellent example of a headwater setting present in this drainage network is the Kiantone Creek watershed which is highlighted in yellow on Figure 3. Drainage from this watershed occurs as the Kiantone Creek flows northward, crosses into Chautauqua County of New York State, flows to the confluence of Conewango Creek, then turns southeast and flows back into PA, and then flows south to Warren, PA where it joins the Allegheny River. What stands out is that Farmington Township watersheds do not have major rivers flowing into and out of them that might serve to dilute oil and gas industry waste fluids flowing into them. Their headwater settings make surface and groundwater particularly vulnerable to contaminant inputs.

Horses and cattle that ingest water from headwater reaches of Kiantone Creek present an example of livestock that may potentially be adversely impacted by brine waste disposal via spreading on permeable road surfaces (Figure 6). Similarly, people who ingest stream, spring, and well water in the Township also have the potential of ingesting oil and gas industry waste products.

Figure 6. Cows along a low gradient headwater section of Kiantone Creek west of Dalrymple Road (aka Coleman Rd. on some maps). Their location is plotted as a black circle with a red cross within it on Figure 3. Chemically-laden fracking brine may potentially reach these cattle from applications on Wilson, Lanning Hill, Pine Ridge, Old State, and the western section of Cemetery roads. Water quality monitoring during and immediately following runoff events is not conducted.

Sediments removed from drainage ditches along brined roads also pose a risk to surface and groundwater quality when left untreated and placed elsewhere within watersheds (Figure 7).

Figure 7. Drainage ditch sediments pose potential sources of brine related contaminants including metals, volatile organics, and chloride. The practice of spreading contaminated sediments onto fields can result in groundwater and surface water contamination. Land spreading chemically laced sediments is not prudent.

Conclusions

This report documents that many road sections where fracking brine is applied within Farmington Township exceed a ten percent grade, with at least one measured road segment with a grade of 20.2 percent. A number of brined road sections are within 150-feet of streams. Other brined road sections are very close to or surrounded by stream reaches. Small headwater watersheds of Farmington Township are vulnerable to contaminant loading because relatively low stream discharges have low chemical assimilation potential. PA DEPs Operating Requirements for disposal of oil and gas well production brine is not a "*beneficial use*" because it is likely to result in surface and groundwater contamination anywhere it is applied. The flawed hydrologic basis behind PA DEP's Operating Requirements and environmental consequences of brine spreading are further addressed in the attached report titled: Disposal of Oil & Gas Field Produced Waters: A Hydrologic Case Study of PA Brine Spreading Practice.

The disposal of oil and gas industry waste products into the natural resources of Farmington Township and the Commonwealth may be considered to be a violation of Pennsylvania's Environmental Rights Amendment to its Constitution's Declaration of Rights (Article 1, Section 27) that states:

> "*The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.*"

HydroQuest

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November 15, 2011

Scott E. Walters, Chief
General Permits/Beneficial Use Section
Division of Municipal and Residual Waste
Bureau of Waste Management
PO Box 8472
Harrisburg, PA 17105-8472

Delivered via e-mail and overnight USPS

RE: Natural Gas Brine Dispersal on Roadways and the Risk of Surface and Groundwater Contamination (Comments on DEP Permit # WMGR064)

Dear Mr. Walters,

Introduction

On behalf of Damascus Citizens for Sustainability (PO Box 147, Milanville, PA 18443), I have reviewed the Special Conditions General Permit WMGR064 amendment that proposes the authorization of the use of natural gas well brine for roadway pre-wetting, anti-icing, and roadway de-icing. Our comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

I offer comments based on my training as a geologist, hydrogeologist, and hydrologist with 30 years of professional environmental experience which includes work conducted for the New York State Attorney General's Office (Environmental Protection Bureau), Oak Ridge National Laboratory (Environmental Sciences Division), the New York City Department of Environmental Protection, and as an independent environmental consultant as President of HydroQuest. I have conducted detailed assessments of streams, wetlands, watersheds, and aquifers for professional characterizations, for clients, and as part of my own personal research. I have authored numerous reports and affidavits related to this work and have made presentations to judges and juries. In addition, I have published papers and led all day field trips relating to this work at professional conferences. I have also authored extensive comments relating to exploratory wells in the Delaware River Basin, as well other material related to gas drilling and hydraulic fracturing.

This general permit will fail to protect the public and the environment. General Permit WMGR064 paragraph 12 acknowledges the "… *potential for groundwater contamination* …" This permit does not adequately address the short and long-term hydrologic picture and, as such, willingly seeks to conduct "… *an activity that harms or presents a threat of harm to the health, safety, or welfare of the people or the environment*." (Paragraph 14). Similarly, paragraph 6 states that: "*The activities authorized by this permit shall not harm or present a threat of harm to the health, safety, or welfare of the people or environment of this Commonwealth.*" The serious contaminant risk associated with the proposed "beneficial" use of natural gas well brines is accented in paragraph 21 of the Special Conditions:

> *"The permittee/registrant shall immediately notify the Department's Emergency Hotline at (717) 787-4343 and the appropriate DEP regional office in the event of any spill of natural gas well brines in a quantity* ***capable of reaching surface water*** (emphasis added) *and shall take immediate action to protect the health and safety of the public and the environment."*

As a hydrogeologist with 30 years of professional experience I am well aware that road salt which has a high sodium chloride content, like brines, has a long history of contaminating groundwater supplies – often with related litigation. For example, as a hydrogeologist with the New York State Attorney General's Office (Environmental Protection Bureau), I worked with the NYSDEC and NYS Thruway Authority to document the migration of road salt from the road edge to a number adversely impacted homeowner wells. Here, the NYS Thruway Authority ultimately paid to extend a water line to provide potable water to homeowners. This situation spurred extensive research which documented the magnitude of road salt based groundwater contamination cases throughout the United States. This work, in turn, led to drafting legislation oriented toward protecting aquifers from road salt contamination. The proposed application of brines under General Permit WMGR064 would present a similar hydrogeologic risk to groundwater and surface water resources – with the added risk of widespread dispersal of additional and, quite likely, unknown fracking-related chemical compounds. The dispersal of gas well brines on our roadways, potentially laced with toxic and carcinogenic chemical compounds, is completely unnecessary and will needlessly jeopardize our finite freshwater resources. General Permit WMGR064, and any other related permits (e.g., for dust suppression) should be abandoned in deference to traditional means of de-icing our roadways. This permit should be denied.

In part, these comments relate to the potential degradation of freshwater resources stemming from overland transport of gas well brines and contaminants within it to waterways, lakes and reservoirs. In addition, we address the certain likelihood of brine and contaminant infiltration to groundwater resources incident to aquifers, freshwater wells, and surface water.

Production-Related Brines

It is likely that gas well brine wastewater produced along with gas or oil production will be targeted for de-icing, dust suppression, and related uses. In this case, it is likely that an even greater percentage or concentration of fracking-related chemicals will be present vs. further along in the final production life of wells. Concentrated and chemically-laden brines should not be discharged into the environment. This is not a beneficial use. These brines need to be properly treated and disposed of.

Gas Well Closure

Former natural gas wells should be immediately plugged and abandoned following cessation of production. They should not be adapted for yet another use (i.e., brine extraction) that will, without doubt, degrade the water quality in the Commonwealth. General Permit WMGR064 seeks to provide a beneficial use of natural gas well brines for roadway and walkway purposes. Although unclear in the permit description, one underlying premise here may be that gas wells should remain open for a period of time after productivity diminishes. This would require that wells not be fully plugged and abandoned following cessation of gas production. To delay permanent closure of any natural gas well actively accepts and knowingly extends the great environmental and water quality risks attendant to gas production in the Commonwealth and elsewhere. On behalf of Damascus Citizens for Sustainability, the Delaware Riverkeeper Network, and independently on behalf of HydroQuest, HydroQuest has documented the environmental risks to freshwater aquifers stemming from gas wells.

All gas wells should be immediately plugged and abandoned once production is stopped because the durability and mechanical properties of well sealant materials are NOT sufficiently advanced such that freshwater aquifers will be safely protected for hundreds of thousands of years. Existing and so-called "state-of-the-art" plugging and abandonment (P&A) practices and materials are not sufficiently advanced to insure long-term isolation between saline and freshwater zones. The aquifers we enjoy today took about a million years to form and can reasonably be expected to last another one million years (see, for example, attached *Aquifer Protection Expert Fact Sheet*). [This Fact Sheet may also be viewed and downloaded at: http://hydroquest.com/Hydrofracking/] Without unnatural alteration from gas drilling activities, aquifers should be capable of providing potable water for future generations for another one million plus years. Industry documentation establishes that, under the best of circumstances, cement and steel used to effect zonal isolation may last up to 100 years and 80 years, respectively – often far less. Once the inevitable failure of cement sheath and casing sealant material occurs, additional contaminant migration pathways are available. Then, methane released under pressure from failed cement sheaths and casings follows fractures to homeowner wells, water bodies, and the land surface. With continued degradation of cement sheaths, concentrated brine fluid will rise under hydraulic pressure and commingle with freshwater aquifers. Thus, under this scenario, the intended "beneficial use" of natural gas well brines requires that freshwater resources remain at risk for extended periods of time.

As stated in Chapter 7 of Pennsylvania's Well Abandonment Procedures (Section 7.1 Introduction):

> *"Unsealed or improperly sealed wells* ***may threaten public health and safety, and the quality of the groundwater resources*** (emphasis added***)***. *Therefore, the proper abandonment (decommissioning) of a well is a critical final step in its service life. … Proper well abandonment accomplishes the following: 1) eliminates the physical hazard of the well (the hole in the ground), 2) eliminates a pathway for migration of contamination, and 3) prevents hydrologic changes in the aquifer system, such as the changes in hydraulic head and the mixing of water between aquifers."*

Clearly, any action regarding non-producing gas wells, other than immediate plugging and abandonment, should be banned and construed as not following the intent of existing well field regulations. Extended gas well life threatens freshwater resources in the Commonwealth, with the result being the dispersal of contaminants that hydrologically must and will enter surface and groundwater resources if spread in this manner – anything but a "beneficial use". This permit must be denied.

Gas Well Brines

De-icing chemicals commonly enter nearby groundwater flow systems and degrade water quality. State and Federal drinking water standards for groundwater, against which adversely impacted homeowner well waters will be compared for gas well brine chemicals, are limited and do **NOT** adequately require sampling and analysis for all of the many toxic and carcinogenic chemical compounds used in fracking/drilling fluids. As a result, State sign-off on supposedly clean, potable, groundwater will occur while people's health may remain in serious jeopardy from unknown and untested brine chemicals. Therefore, this permit must be denied.

Natural gas well brines are comprised of concentrated solutions of sodium chloride, laced with numerous known and unknown hydrofracking chemicals, many of which may be toxic. The Pennsylvania Department of Environmental Protection developed a Fact Sheet that pointedly explains to the public the definition and the potential "beneficial use" of brine in the Commonwealth:

> *"Brine is the general term used for wastewater produced along with oil or gas; it can be very salty, therefore,* ***injurious to plants and aquatic life*** (emphasis added)."

It is not prudent from a hydrologic and water quality standpoint to intentionally disperse **wastewater** throughout the Commonwealth so that it will flow and infiltrate into our surface water and groundwater resources. Whether brine contaminants are applied on dry days, wet days, 50 or 200 feet from streams or houses, or in one concentration or another is largely irrelevant. The hydrology is simple and straight forward. Under wet hydrologic conditions, and with repeated applications, whether today, tomorrow, or in two months – the contaminants **will move** into our waterways, reservoirs, and aquifers (i.e., toward our drinking water supplies). Once significant precipitation occurs, brines will then be mobilized and transported away from source areas. To categorize gas well brine applications under the term "beneficial use" can only be considered from a financial perspective relative to saving gas companies from having to pay to properly dispose or treat their wastewater. The concept of intentionally dispersing gas well wastewater into our environment defies all common sense. Thus, this permit application should be denied.

General Permit WMGR064, Table 1, provides acceptance criteria (i.e., allowable concentrations) for fourteen chemical parameters, some of which are not typically contaminants when present in normal background concentrations in groundwater. The comparative table provided below readily indicates that this general permit will knowingly allow chemical laden brines to enter contaminant-free surface and groundwater flow systems.

Parameter	Allowable Level Pre-wetting (mg/l except pH)	Primary or Secondary Drinking Water Standard (mg/l except pH)	Minimum number of times in excess of Groundwater Standard
TDS	>170,000	500	>340
Chloride	>80,000	250	>320
Sodium	>40,000	-----	------
Calcium	>20,000	-----	------
pH	5 to 9.5	6.5-8.5	10-50
Iron	<500	0.3	<1,667
Barium	100	2	50
Lead	10	0.005	2,000
Sulfate	<1,000	250	<4
Oil & Grease	< 15	-----	------
Benzene	<0.5	0.005	<1,000
Ethylbenzene	<0.7	0.7	<1
Toluene	<1	1	<1
Xylene	<1	10 (total)	------

Even if we erroneously assume that the only chemicals present in brine-rich waters pumped from gas wells are all included in the above parameter list, many of those present will assuredly contaminate surface and groundwater resources adjacent to and beyond roadways. Chloride, for example, is extremely soluble in water and is readily transported in both surface and groundwater flow systems. It is well-recognized as a contaminant that has degraded numerous homeowner wells. Studies have shown that it often moves coincident with large snowmelt, precipitation, and runoff events. Repeated applications provide regular replenishment of contaminant source material. The addition of fracking-related chemicals to traditional de-icing materials will serve to greatly increase the health risk to the general populous and the environment. To limit permit *acceptance criteria* largely to chemical parameters that have established MCL's would ignore hundreds of other chemicals that are used in underground fracking injection, plus many others that are hidden from public scrutiny by being labeled as "proprietary". This would oppose the best interests of the population at large. A comprehensive listing of hydrofracking related chemicals is provided in the text and many tables of Chapter 5 of the NYS Revised DSGEIS. The material in this chapter (http://www.dec.ny.gov/docs/materials_minerals_pdf/rdsgeisch50911.pdf) is hereby incorporated by reference. Permit acceptance criteria must be greatly expanded to include all toxic and carcinogenic chemicals that may well be within the brine "chemical soup" as indicated within Chapter 5 of the NYS DSGEIS. Allowable levels of these many chemical parameters must be based on detailed toxologic testing and risk assessment evaluations. In addition, individual testing of gas well brines should be conducted at least annually on a well-specific basis.

Many more contaminants that are present in flow back water are also likely to be present in brines pumped from gas production wells. Some of these are extremely toxic, some are carcinogens, and others have not been adequately studied to determine their potential impact on humans and animals (e.g., 2-butoxyethanol, formaldehyde). For example, Dr. Ronald Bishop details many of the toxic qualities and potential health impacts associated with chemicals wastes found in gas well flow back water (http://www.fmce.org/Beyond%20MSDS.pdf; *Beyond MSDS: A Review of Hazardous Materials Used by New York's Natural Gas Industry*). Dr. Bishop's report is hereby incorporated into this comment letter by reference. As discussed above, these and all other hydraulic fracturing and drilling fluid chemicals should be comprehensively assessed by toxicologists and should then be added to the very short and incomplete list above. There are hundreds of chemicals used in the hydraulic fracturing and well drilling process, many not disclosed to the public. To not identify and test for **all** these chemicals and to then exclude them from the "*acceptance criteria*" is short-sighted and irresponsible, especially in light of the many documented and serious public health risks.

Hydrology Discussion

Under 25 Pa. Code § 287.611(a)(3), the Department of Environmental Protection—here through the Bureau of Waste Management—can issue a general permit for beneficial use of residual waste if it can be used "without harming or presenting a threat of harm to the health, safety or welfare of the people or environment" of the Commonwealth. **Hydrologically, this cannot be done.** Slow groundwater flow rates and rapid surface runoff will recharge aquifers and streams with brines and related contaminants. Thus, contaminant plumes will move toward homeowner wells and streams. These plumes, like those present at other contaminant sites, need to be treated as outwardly expanding contaminant plumes that warrant expensive, full-scale, hydrogeologic characterization, groundwater clean-up, and remedial action. Hydrogeologically, overland brine dispersal is short-sighted and virtually guarantees degradation of both surface and groundwater resources. The draft permit regulations need to be modified to reflect characterization and clean-up of brine-rich waters and all related toxic chemicals present and moving within the environment.

Brine application is not needed for dust suppression. Dust suppression can be achieved with the application of clean water and need NOT contain ANY brines or chemical additions that pose an unnecessary threat to clean surface and groundwaters of the Commonwealth. As such, General Permit WGMR064 should be abandoned.

Tracers

Tracer additions to brines would provide a much needed checks and balance type approach to scientifically and legally address claims of brine excursions. On the one hand, tracers would readily allow brine applicators to show they are not behind brine-related contaminant issues that are not of their making, while on the other hand it would remove the oneness of proof from homeowners actually adversely impacted. **Importantly, there is no reason whatsoever that ALL brine applications should not require tracer additions and monitoring <u>effective immediately</u>, even before general Permit WMGR064 is approved. This would demonstrate a good faith effort on behalf of the regulators.**

To reduce the onus of legal and expert consultant costs to homeowners, **all** brine waters/fluids should first have company-specific tracers added to them so contaminant source and responsibility can be properly assigned (should this permit be approved). The addition of gas well company-specific tracers is needed to provide sufficient documentation of uncontrolled non-point source de-icing chemical excursions from roadways and walkways. Otherwise, the limited number of Maximum Contaminant Level (MCL) chemicals may erroneously instill a false sense of potable water quality when people's health may be severely impacted. The enforcement of these provisions is nearly impossible. The department cannot consider approval of this permit application without a highly detailed enforcement plan to be implemented with the completed permit application. An enforcement plan should be part of the permit. Without this, the permit should be rejected.

Proposed Modifications in the Event the Permit Application is Approved

Substantively, the proposed modifications present a risk of damage to human health and the environment and should therefore be rejected. Hydrologically, dispersed/applied brines will enter and degrade the environment in a very non-beneficial manner. Application rates, timing, and set-back distances will do little other than postpone the inevitable. Besides, there is no provision for enforcement in this permit application. Therefore, we recommend rejection of this permit. If, however, the Bureau decides to go ahead with the new uses, it should include the following criteria in the General Permit in order to substantively comply with its mandate to somewhat protect human health and the environment:

- THIS IS <u>THE</u> MOST IMPORTANT NEW CRITERIA. Add company-specific chemical tracers to all gas well fluids prior to brine application so that contaminant responsibility, aquifer restoration and alternate water supply costs may be properly designated. Tracer experts should be used to determine appropriate tracers and concentrations so as to fully allow for detection in degraded surface and groundwater resources of the Commonwealth.

- **NO PERMIT APPROVAL SHOULD BE POSSIBLE WITHOUT THIS CRITICALLY IMPORTANT CRITERIA DESIGNED TO PROTECT BOTH ADVERSELY IMPACTED HOMEOWNERS AND BRINE APPLICATORS. UNWILLINGNESS TO USE TRACERS TO DOCUMENT CONTAMINANT RESPONSIBILITY SHOULD BE CAUSE ALONE TO NOT APPROVE GENERAL PERMIT WMGR064**;

- Develop appropriate acceptance criteria for the new uses that includes all chemicals used in gas well drilling and fracking;

- Conduct comprehensive chemical and toxicological testing of fluids from all gas wells targeted for brine extraction for ALL chemicals previously used in them during construction and development. Sample collection and analysis should be conducted by an independent party;

- Conduct baseline chemical testing of all well water and surface waterways, lakes, and reservoirs for ALL chemicals previously used in the gas wells to a distance of 2,000 feet outward from all roadways and walkways;

- Provide for regular testing of brines including gas well chemicals used every six months or sooner where degraded groundwater and/or surface water is suspected;

- Provide for regular testing of soil and groundwater within 2,000 feet of application for ALL chemicals used in gas well fluids during construction and operation of gas wells;

- Provide criteria to stop all brine spreading should **any** surface or groundwater contamination be documented;

- Establish a 2,000 foot limit on brine application distance from water bodies and streams;

- Special Protection Waters, Caves & Mines. Recognize, locate, investigate, inventory, and characterize rare, threatened, and endangered species and their habitats which are likely to be degraded from brine-related contaminant excursions. Omit these habitat areas from brine applications, inclusive of a large buffer distance. Some of the species of greatest concern are endangered stream dwellers (i.e., Dwarf Wedge mussel [*Alasmidonta heterodon]*) and assorted bat species (e.g., including the federally endangered Indiana bat [*Myotis sodalis]*). There are real environmental, water quality, health, and endangered species concerns regarding brine excursions into carbonate beds, inclusive of in caves and mines. Carbonate formations in portions of the Commonwealth are recognized among karst hydrologists as being karstic or cave/ conduit bearing in nature. Brine and related contaminants that may enter karstic

-

solution conduits, from below or above, would quickly degrade groundwater and surface water quality;

- Add a monitoring section. The General Permit lacks detail on surface and groundwater monitoring. This should be added. Until such time as it can be demonstrated that adequate staffing is present to monitor this general permit, it should not be approved;

- Add an enforcement section. The General Permit lacks provision for enforcement. This should be added. Until such time as it can be demonstrated that adequate staffing is present to regulate and enforce this general permit, it should not be approved;

- Add record keeping detail by PA DEP. Detailed records of the quantity of brine fluids withdrawn and applied should be required;

- Add record keeping detail BY PA DEP. Detailed records of the exact location of brine applications should be required;

- Establish a very substantial escrow or bond type account for all brine applicators to off-set contaminant testing, aquifer restoration, and replacement water supplies costs for adversely impacted parties. This might be set-up on a fee per application basis;

- Establish a rigorous fee structure based on volume of brine application for applicators such that monies are regularly added to the coffers of the Commonwealth. Otherwise, there is no logical reason or beneficial use that may reasonably be attributed to intentionally applying brine wastewater that will threaten and degrade fresh surface and groundwaters of the Commonwealth; and

- Strengthen permit regulations to insure that brine applicators, and/or their suppliers, assume full legal and financial responsibility for contaminating aquifers and fully clean them up to the maximum extent possible **AND** develop permanent alternate water supply systems for all adversely affected water supplies. Permit regulations should be modified to provide for system operation and maintenance costs in perpetuity. As written, permit regulations do not have adequate provision to protect the health and safety of homeowners. The importance of this must be underscored because aquifer restoration from brine and gas field contaminants, even if cost were not an issue, may not be possible. Whereas monetary compensation to adversely affected homeowners may be warranted as settlement for inconvenience, property devaluation, and health issues, any settlements should in no way remove the responsibility of brine applicators to restore the waters of the Commonwealth. Provision of whole house water filtration systems should not be an acceptable means of abdicating responsibility and liability.

Conclusions

The Bureau should reject the permit modifications, ban any and all gas well brine applications, and not allow the additional proposed uses because of the increased risk of contamination of groundwater, surface waters, and soil. The Bureau's proposed modifications, which will likely drastically increase the amount of brine being spread on Pennsylvania roads, present a threat of harm to the health, safety, and welfare of the people and the environment, and therefore the modifications should be denied.

The key to maintaining high quality groundwater and surface water throughout the Commonwealth is to NOT apply concentrated and contaminated brines at any time whatsoever. There is NO sound environmental benefit in applying brines anywhere, as they will eventually reach surface and groundwater resources. Thus, General Permit WGMR064 should be abandoned and gas well brine applications should be banned permanently. The Bureau should therefore deny the proposed modifications and ban gas well brine dispersal into the environment.

Sincerely.

Paul A. Rubin

Paul A. Rubin
Hyrogeologist
HydroQuest

CC: Damascus Citizens for Sustainability

EXHIBIT R

Commonwealth of Pennsylvania

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Office of Oil and Gas Management

Division of Compliance and Data Administration

Oil and Gas Reports Data Dictionary

April 7, 2022
Version 1.8

Disclaimer Information

While the Oil and Gas Program requires accurate data reported by Operators, the Department of Environmental Protection makes no claims, promises or guarantees regarding the accuracy, completeness or timeliness of the data. DEP will make every attempt to correct any errors discovered but expressly disclaims any liability for errors or omissions related to the data contained within these reports.

EXHIBIT S

STATEIMPACT PENNSYLVANIA

Energy. Environment. Economy.

How did fracking contaminants end up in the Monongahela River? A loophole in the law might be to blame

Reid Frazier

Reid R. Frazier / StateImpact Pennsylvania

The Westmoreland Sanitary Landfill, which accepts solid fracking waste, is shown in September 2019. Photo: Reid R. Frazier

SEPTEMBER 11, 2019 | 5:00 AM

Gary Kruppa is in charge of Belle Vernon's sewage treatment plant. He recently discovered that naturally-occurring radioactive material found in the Marcellus shale was making it from the nearby Westmoreland landfill through the treatment plant and into the Monongahela River.

About a year and a half ago, Guy Kruppa realized something was wrong with his bugs.

Kruppa is the superintendent of the Belle Vernon Municipal Authority, and runs the town's small sewage treatment plant on the banks of the Monongahela River, south of Pittsburgh. The plant uses micro-organisms — bugs — to break down raw sewage before it's treated and released into the river.

But in 2018, those bugs stopped doing their job. Levels of bacteria and ammonia in the plant's discharge to the river started going up. The plant began flunking water quality tests for its state pollution discharge permit. Kruppa wondered if a recent upgrade could have something to do with it.

"We thought, was it something we were doing internally? Were we not processing enough sludge, maybe we aren't pumping enough?" Kruppa said. "We went through the whole gamut of things."

Kruppa, who'd only recently started his job as the municipal authority's superintendent, thought about all the places that send waste to the plant.

"We take in a neighboring community — Washington Township, we take in Belle Vernon, North Belle Vernon … but we also take in a landfill."

Reid R. Frazier / StateImpact Pennsylvania

The entrance to the Westmoreland Sanitary Landfill in Rostraver, which accepts solid fracking waste and has sent what's called leachate — liquid waste that comes out of the landfill when rainwater trickles through its piles of garbage — to the Belle Vernon sewage treatment plant.

That would be Westmoreland Sanitary Landfill, about a mile away in the town of Rostraver. For years, the landfill sent Belle Vernon its leachate — liquid waste that collects at the landfill when rainwater trickles through its piles of garbage.

Kruppa began looking at test samples of the leachate. He sent it to an engineer he used to work with.

"He goes, you have some very high numbers and as far as chlorides, conductivity, barium," Kruppa said. "He said these are all indicators of frack waste."

Kruppa discovered the landfill was sending more leachate than the treatment plant was allowed to accept. And he found out **about < https://www.documentcloud.org/documents/6387600-Westmoreland-Landfill-Total-Amounts.html>** 40 percent of the landfill's waste since 2010 had been solid oil and gas waste. That included drill cuttings — dirt and rocks that companies dig up to get to the region's gas-rich shale beds. Those beds are naturally rich in salts and metals.

It turned out, the salts in the leachate were hurting the bugs in Kruppa's sewage system.

"They were killing off our bugs. Our bugs are what treats the water," Kruppa said.

"And that's why we weren't making our permit levels, because we had nothing to work with."

It wasn't just the salts, he said. Gas waste is high in radium, a naturally-occurring radioactive material found in the Marcellus shale. Some of that radium was making it from the Westmoreland landfill through Kruppa's treatment plant and into the Monongahela River.

"We were discharging…into the Mon River higher than drinking water standards," Kruppa said. One discharge test showed levels of radium at 8 picocuries per liter. The EPA standard for drinking water is 5.

The landfill's own waste reports, filed with the state Department of Environmental Protection, say the leachate it was sending the treatment plant had an **"oil like" < https://www.documentcloud.org/documents/6387596-Westmoreland-Landfill-Form-50-Q1-2019.html>** or "**petroleum sheen < https://www.documentcloud.org/documents/6387597-Westmoreland-Landfill-Form-50-Q1-4-2018.html>** ."

Still, the DEP told Kruppa to keep taking the leachate while it got the landfill to fix the problem. And if the plant incurred any fines, the landfill would pick up the tab.

Reid R. Frazier / StateImpact Pennsylvania

The Belle Vernon sewage treatment plant is shown in September 2019.

The DEP asserts that what the plant was putting into the river was safe — that by the time the radium and other contaminants discharged by the plant ended up at the nearest drinking water plant, it was diluted by the river's high volume.

But that explanation didn't sit well with the man in charge of that drinking water plant.

Chad Warfield, director of operations at the Charleroi Water Authority, which **provides drinking water < http://abcwater.net/water-history/>** to around 30,000 people, said he found it "alarming, to say he least" when he learned what was coming down the river from Belle Vernon. He ordered his staff to test the water in nearby streams, but there was one problem: He wasn't sure what to look for.

“The problem was, nobody knows what’s exactly in the leachate,” Warfield said.

Charleroi’s water quality continued to meet federal standards, but, Warfield said, he was still worried.

“You know it’s…frightening, to be blunt, that it went on that long and they were experiencing those issues and…it was let go.”

Eventually Belle Vernon got tired of waiting for the DEP and the landfill to fix the problem. The municipal authority sued, and got a judge to order the landfill to stop sending its leachate to the plant. Currently, the landfill is trucking the leachate to treatment plants in Ohio.

But the case raises a question — are other landfills and treatment plants at risk?

The DEP says no. No one from the agency agreed to be interviewed for this story. But in emails, DEP spokeswoman Elizabeth Rementer said Belle Vernon’s case was “unique.” There are 16 other treatment plants in the state that take leachate from landfills that accept fracking waste. Those landfills are required to “pre-treat” that leachate to make it safe for the sewage plant.

But, StateImpact Pennsylvania found, that’s only in the case of bigger sewage plants that handle five million gallons a day or more; for smaller ones, like Belle Vernon’s, the law is less clear. In those cases, the treatment plants themselves are supposed to know of any changes to the waste they receive from industrial users, like landfills.

“DEP would generally expect that the (treatment plant) would provide adequate notice of this change,” Rementer said in an email. She said the DEP doesn’t consider this a “loophole” in the regulations, but said implementing the requirements was “subject to a certain level of interpretation, including the extent by which a (treatment plant) is expected to investigate potential changes to its…waste stream.”

Kruppa said he learned of the loophole in state law when he told a DEP official that the landfill’s waste was affecting his plant.

“He said, well, that you are the entity that would be responsible for that. I said, so there's nothing you could do for me? He said no. You are the DEP to them, essentially."

The problem is, the landfill has no obligations under state or federal law to tell the treatment plant about changes to its waste stream. So even though the state knew the landfill was taking drilling waste, Kruppa said, no one told anyone at his plant.

"What they were sending us was industrial waste," Kruppa said. "Those things need to be treated differently."

Other plants could find themselves in a situation similar to Belle Vernon's.

According to a review of state pollution permits, **12 other smaller plants fit < https://www.documentcloud.org/documents/6387599-Facilities-Tracked-for-Receiving-OG-WW-Aug-2019.html>** into the same category as Belle Vernon. They're too small to automatically qualify for stricter regulations on leachate, and have to police the landfills themselves. The DEP couldn't immediately say whether those landfills were pre-treating their leachate.

The state insists no one was endangered by the leachate issues in Belle Vernon. Its water quality monitors along the Monongahela River were all below the EPA standards for radiation.

But Avner Vengosh of Duke University, said he sees real problems with the state's practices.

"They never learned anything through the last 10 years of studies," said Vengosh, an environmental chemist who's measured pollutant levels in the stream sediment near treatment plants in Pennsylvania that process liquid oil and gas waste.

He's found **radium levels < https://nicholas.duke.edu/about/news/radioactivity-oil-and-gas-wastewater-persists-pennsylvania-stream-sediments>** in some sediment high enough to qualify as radioactive waste under federal law. He wonders if the same type of accumulation could be happening in the river near Belle Vernon's site, and thinks the sediment should be tested.

"I predict that the radium will start to accumulate on the sediments at the bottom of this discharge site," Vengosh said. "The radioactivity level could be really high. And of course the risk is that once there is high radium in the sediments, there is incorporation into the ecological chain."

A spokeswoman for the landfill didn't answer emailed questions or agree to an interview for this story. The DEP said it's working on installing a pretreatment system to handle the site's leachate. The landfill is negotiating with another sewage plant to accept its leachate. That plant is in Donora, just five miles downstream of Belle Vernon.

EXPLAINERS

The Pennsylvania Guide to Hydraulic Fracturing, or 'Fracking' < https://stateimpact.npr.org/pennsylvania/tag/fracking/>

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