United States Environmental Protection Agency

# Supplemental Technical Support Document for the Effluent Limitations Guidelines and Standards for Unconventional Oil and Gas Operations

EPA-821-R-19-004

June 6, 2019

U.S. Environmental Protection Agency
Office of Water (4303T)
Washington, D.C. 20460

This document was prepared by the Environmental Protection Agency. Neither the United States Government nor any of its employees, contractors, subcontractors, or their employees make any warrant, expressed or implied, or assume any legal liability or responsibility for any third party's use of or the results of such use of any information, apparatus, products, or process discussed in this report, or represents that its use by such party would not infringe on privately owned rights.

Questions regarding this document should be directed to:

U.S. EPA Engineering and Analysis Division (4303T)
1200 Pennsylvania Avenue NW
Washington, DC 20460
(202) 566-1000

# CONTENTS

# LIST OF TABLES

**Page**

# LIST OF FIGURES

**Page**

# 1. EXECUTIVE SUMMARY AND PURPOSE OF THIS DOCUMENT

The EPA promulgated the rule, Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (the unconventional oil and gas or UOG rule), on June 28, 2016. 81 FR 41845. The UOG rule is a national rule which prohibits unconventional oil and gas operations from discharging pollutants in wastewater to POTWs, in other words, a "zero discharge" requirement. The UOG rule defines the term "unconventional oil and gas operations" to include operations involving "crude oil and natural gas produced by a well drilled into a shale and/or tight formation (including, but not limited to, shale gas, shale oil, tight gas, and tight oil)." See 40 CFR 435.33(a)(2)(i). The UOG rule does not include those entities covered under 40 CFR Part 435, Subpart F, the Stripper well category. In promulgating the UOG rule, EPA explained that UOG wastewaters are not typical of POTW influent wastewater, and as a result some UOG extraction wastewater constituents: can be discharged, untreated, from the POTW to the receiving stream; can disrupt the operation of the POTW (e.g., by inhibiting biological treatment); can accumulate in biosolids, limiting their use; and can facilitate the formation of harmful disinfection by-products.

EPA concluded at the time of promulgation of the UOG rule that the zero discharge requirement was technologically available, economically achievable, and had acceptable non-water quality environmental impacts for the industry as a whole, and thus BAT for this industry, because all UOG operators were already meeting this requirement. EPA's record at issuance of the final rule reflected that no unconventional oil and gas operations were discharging to a POTW. Rather, EPA's record indicated that all UOG operations across the country were reusing their wastewater or sending wastewater elsewhere, such as to centralized waste treatment operations (privately-owned facilities that treat industrial waste) or to Class II underground injection control wells (disposal wells). See the Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category (EPA-820-R-16-003, June, 2016).

After the UOG rule was promulgated, several interested parties notified EPA that a number of oil and gas operations in Pennsylvania covered by the rule were in fact discharging wastewater to POTWs at the time of the rulemaking. These parties stated their operations are "conventional" under Pennsylvania law and appear to meet the definition of "unconventional" in the UOG rule. Pennsylvania defines an unconventional formation as: "a geological shale formation existing below the base of the Elk Sandstone or its geologic equivalent stratigraphic interval where natural gas generally cannot be produced at economic flow rates or in economic volumes except by vertical or horizontal well bores stimulated by hydraulic fracture treatments or by using multilateral well bores or other techniques to expose more of the formation to the well bore" (DCN SGE01486). As Pennsylvania's definition of an unconventional formation is narrower than the definition used in the UOG rule, EPA concluded that there were, indeed, some operators in Pennsylvania that sent their wastewater to POTWs that would be subject to the UOG rule.

Based on this post-promulgation information, the EPA extended the compliance date for existing sources that were lawfully discharging to POTWs on or between April 7, 2015 and June 28, 2016, to three years from the effective date of the rule—to August 29, 2019 (compliance date postponement rule). See 81 FR 88126-88127. That rule did not change the compliance date for

all other facilities subject to the final onshore UOG extraction pretreatment standards rule. As it did for the proposal for the UOG rule, in the proposal for the postponement rule, EPA requested information regarding any existing onshore UOG extraction facilities that currently discharge UOG extraction wastewater to POTWs in the U.S. EPA did not receive any information in response to that request.

Pennsylvania Grade Crude Oil Coalition (PGCC) also filed a petition for review of the rule regarding this matter. PGCC indicated that the EPA did not conduct the necessary analyses of Pennsylvania defined conventional facilities that meet the definition of "unconventional" in the UOG rule and that they should not be subject to the UOG requirements. In response, the EPA filed a motion (unopposed by PGCC) for voluntary remand without vacatur on August 31, 2017, which was granted by the Court in October, 2017. In the motion, EPA discussed the post-promulgation information referenced above, acknowledging that this information is inconsistent with the record for the rule. Further, the motion explained that EPA requested the remand to consider any additional evidence relevant to the UOG rule, develop the record, and take any follow-up action as appropriate.

The EPA recently gathered new data and information and performed supporting analyses to update the UOG rulemaking record. Much of the new data is for calendar year 2016 as that was the most recent year with the most complete data to inform these new analyses. This supplemental Technical Support Document describes the new data, methodology, analysis, and results. First, this document describes how EPA re-evaluated oil and gas facilities that discharge to POTWs and that may generate wastewater from wells defined as unconventional under the UOG rule. In particular, it describes how EPA used information reported by oil and gas extraction facilities to Pennsylvania for 2016 and well formation information from multiple sources to identify those oil and gas extraction facilities that discharged any wastewater to POTWs and that are defined as conventional under Pennsylvania's definition, but are defined as unconventional according to the 2016 UOG rule's definition. The UOG rule is not applicable to activities regulated under the Stripper Subcategory (40 CFR 435 Subpart F). The UOG rule applies to onshore unconventional oil and gas extraction facilities regulated under Subpart C. Subpart C excludes facilities regulated under Subpart F.[1] EPA determined that out of 879 oil and gas extraction entities reporting to Pennsylvania in 2016 (and over 6,000 nationwide), 22 entities discharged at least some portion of their wastewater to a POTW from UOG operations as defined by the 2016 UOG rule. Based on the 2016 data, this is the subset of entities that likely need to make changes to comply with the 2016 UOG rule (and incur any associated costs).

For those 22 entities, this document then describes how EPA evaluated alternative wastewater management alternatives to discharge to POTWs and the associated incremental costs to these entities and the industry as a whole. EPA found that wastewater management alternatives were available to all of these entities as many of them reported using another wastewater management alternative in addition to a POTW in 2016. To estimate the potential

[1] Under 40 CFR part 435 subpart F, the definition of a stripper wells is "onshore facilities which produce 10 barrels per well per calendar day or less of crude oil and which are operating at the maximum feasible rate of production and in accordance with recognized conservation practices." Specialized definitions 40 CFR §435.61 (c) "The term "well" shall means crude oil producing wells and shall not include gas wells or wells injecting water for disposal or for enhanced recovery of oil or gas". "(d) The term "gas well" shall mean any well which produces natural gas in a ratio to the petroleum liquids produced greater than 15,000 cubic feet of gas per 1 barrel (42 gallons) of petroleum liquids."

incremental costs of this rule to these facilities (which represent the only entities in the U.S. that may incur costs associated with the nationally applicable rule), EPA calculated any incremental wastewater management costs for these operators to send their wastewater to the nearest alternative technology as well as any associated incremental transportation costs. For each entity, EPA added incremental wastewater management and transportation costs to get the total incremental costs to operators across all UOG wells.

EPA also evaluated incremental non-water quality environmental impacts associated with alternative wastewater management approaches. This includes changes in air emissions, solid waste generation, and energy consumption. The incremental change depends on the alternative wastewater management approach. For example, sludge generation would likely decrease if a UOG facility sends its wastewater to a UIC well and would likely increase if it sends its wastewater to a CWT facility. Even if each operator that currently sends its wastewater to a POTW elected to use a wastewater management approach that incrementally increased air emissions, sludge generation, or energy usage, these changes would be small relative to U.S. totals.

The EPA then estimated potential financial impacts for these entities by conducting a discounted cash flow analysis (modeled future revenue and operation costs) over 10 years on an after-tax basis. Based on this analysis, the EPA found that seven of the 22 entities would have negative profits irrespective of the UOG rule's incremental costs. For the remaining entities, when adding in the incremental costs of the rule, the EPA's analysis shows that none of the 15 entities would be at risk of closure as a result of complying with the UOG rule.

Historically, in conducting ELG analyses, the EPA considers entities with negative profits before the addition of costs to comply with any new ELGs to be baseline closures and removes them from any further analysis (e.g., total costs, total benefits). However, in this case, the seven entities that the data indicate have negative profits in 2016 continued to report wastewater discharge to Pennsylvania in 2017 demonstrating they remain in business. Therefore, the EPA is reporting cost information as a range with the lower value representing EPA's typical approach and the upper value assuming all 22 facilities continue to operate. The EPA's analysis shows that for 2016, the median incremental costs would be between $131 and $279 per entity and the total costs of the UOG rule for 2016 would be approximately $33,000 -$65,000.

# 2. RE-EVALUATION OF OIL AND GAS EXTRACTION ENTITIES POTENTIALLY SUBJECT TO THE UOG RULE AND SUMMARY OF DATA SOURCES

## 2.1 Scope of Analysis

Nationally, United States Census Bureau Statistics of U.S. Businesses (SUSB, 2015) estimates over 6,000 firms that meet the NAICS code 2111 for Oil and Gas Extraction: primarily engaged in operating and/or developing oil and gas field properties and establishments primarily engaged in recovering liquid hydrocarbons from oil and gas field gases (DCN SGE01449).

As explained in the Executive Summary, EPA received notification post-promulgation that, indeed, some oil and gas entities in Pennsylvania that drilled into shale or tight formations were sending wastewater to POTWs (DCN SGE01431; DCN SGE01482). In light of this new information, EPA reviewed its record on operators that discharged any type of oil and gas wastewater to POTWs. In addition to Pennsylvania, some operators in California and Colorado had historically managed oil and gas extraction wastewater at POTWs. EPA re-evaluated the information on the formations into which these operators drilled wells and continued to determine that these wells were not drilled into tight or shale formations and therefore were not subject to the UOG rule (DCN SGE01397; DCN SGE01399). EPA also contacted California and Colorada to confirm its determination. Therefore, EPA has limited the scope of this supplemental analyses to oil and gas extraction operations in Pennsylvania.

The Commonwealth of Pennsylvania requires oil and gas operators to report information on wells located in Pennsylvania. See Pennsylvania Department of Environmental Protection (PA DEP) Title 25, Chapter 78, Subchapter E (well reporting). This data includes: "the amount and type of waste produced and the method of waste disposal or reuse", and "Drillers log that includes the name and depth of formations from the surface to total depth, depth of oil and gas producing zone, depth of fresh water and brines and source of information." During development of the UOG rule, the EPA used this data as compiled by Pennsylvania to support its finding that there were no UOG extraction facilities discharging wastewater to POTWs. Since EPA now has a better understanding that the definition of UOG in the 2016 rule is broader than Pennsylvania's definition, EPA has re-evaluated the available data. To determine which facilities are potentially subject to the UOG rule, in addition to the PA DEP data, EPA used the following datasets and sources, which are briefly described below, with more details provided in Appendix A and Section 2:

- PA DEP Production and Waste Reports. Oil, gas, and condensate production quantities. Waste quantity, waste type and waste management practices used.

- PA DEP Formation Database. This database identifies the oldest, target and/or producing formations for all Pennsylvania oil and gas wells.

- DI Desktop® Database. Compiled by the firm DrillingInfo, DI Desktop® lists all known[2] oil and gas wells in the United States, including well API number, location,

[2] For more detail on what wells may or may not be included in DI Desktop®, see Section A-3 and DI's *Data Coverage* (DCN SGE01171).

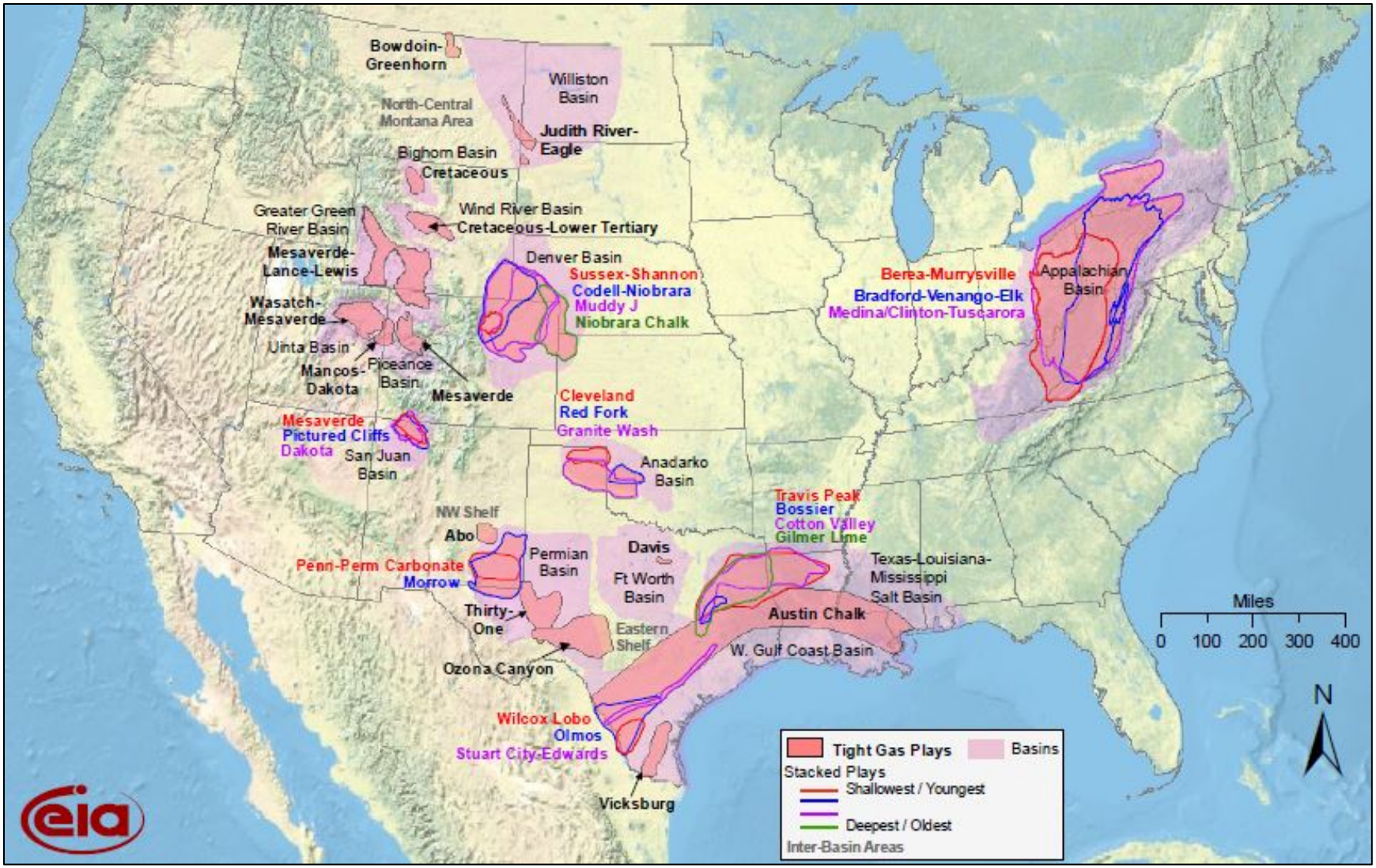
operator, well trajectory, and annual oil and gas production and produced water generation.

- EDWIN Database. The EDWIN database is maintained by the Pennsylvania Department of Conservation and Natural Resources, Bureau of topographic and Geological Survey, providing records for oil and gas wells drilled in Pennsylvania, including scanned oil and gas well documents and associated digital and interpreted data.

- PA DEP SPUD Database. This database compiles Pennsylvania oil and gas SPUD data, including well location.

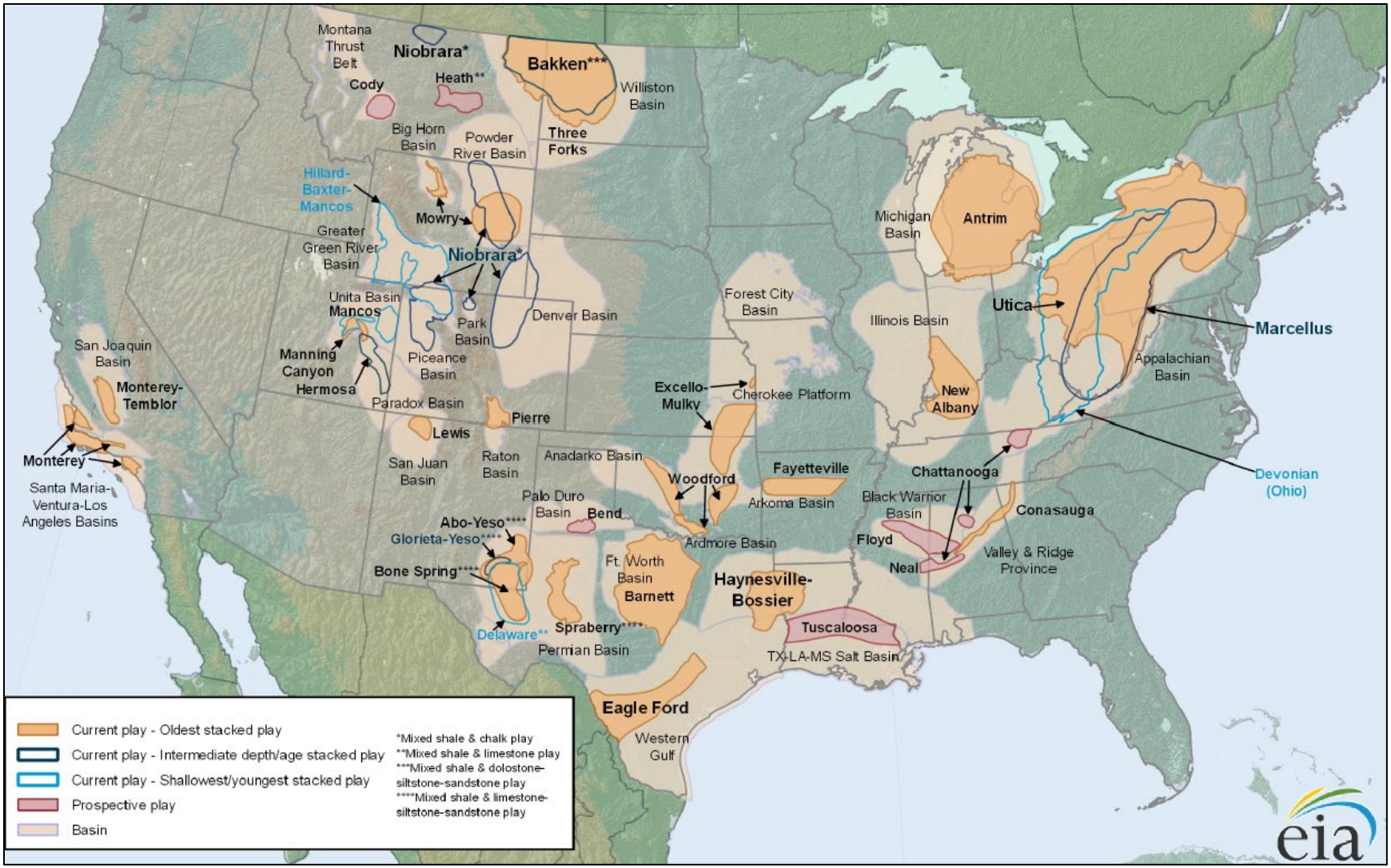
- EIA listings of known tight and shale formations. This includes two maps published by EIA: Major Tight Gas Plays, Lower 48 States (Figure 2-1) and Shale Gas Plays, Lower 48 States (Figure 2-2), and EIA's Assumptions to the Annual Energy Outlook 2015 (Table 2-1 and Table 2-2). Tight and Shale formations identified by EIA in these figures and tables include: Berea-Murrysville, Bradford-Venango-Elk, Medina/ Clinton-Tuscarora, Marcellus, Utica, Clinton-Medina, Tuscarora, and Devonian.

EPA combined these data sources together via well API numbers to have comprehensive information on oil and gas wells in Pennsylvania.




Source: DCN SGE00155.

**Figure 2-1. Major U.S. Tight Plays (Updated June 6, 2010)**




Source: DCN SGE01191.

**Figure 2-2. Major U.S. Shale Plays (Updated June 6, 2010)**

**Table 2-1. UOG Resource Potential: Shale as of January 1, 2013, EIA East Region, Appalachian Basin**

| EIA Region | EIA Basin | UOG Formation Name | Resource Type | Oil EUR (MMbls per Well) | Gas EUR (Bcf per Well) | Oil TRR (MMbls) | Gas TRR (Bcf) | New Well Potential (Number of wells) |
|---|---|---|---|---|---|---|---|---|
| 1—East | Appalachian | Devonian | Shale Gas | 0.000 | 0.061 | 0 | 23,700 | 388,500 |
| | | Marcellus | Shale Gas | 0.003 | 1.581 | 300 | 148,700 | 94,000 |
| | | Utica | Shale Gas | 0.002 | 0.470 | 200 | 53,100 | 112,900 |
| | | | Shale Oil | 0.043 | 0.092 | 700 | 1,500 | 16,300 |

Sources: DCN SGE01179.

Abbreviations: UOG – unconventional oil and gas; EUR—estimated ultimate recovery (per well); MMbls—million barrels; Bcf—billion cubic feet of gas; TRR—technically recoverable resources

**Table 2-2. UOG Resource Potential: Tight as of January 1, 2013, EIA East Region, Appalachian Basin**

| EIA Region | EIA Basin | UOG Formation Name | Resource Type | Oil EUR (MMbls per Well) | Gas EUR (Bcf per Well) | Oil TRR (MMbls) | Gas TRR (Bcf) | New Well Potential (Number of wells) |
|---|---|---|---|---|---|---|---|---|
| 1—East | Appalachian | Clinton-Medina | Tight Gas | 0.002 | 0.058 | 400 | 12,400 | 213,800 |
| | | Tuscarora | Tight Gas | 0.000 | 0.724 | 0 | 4,400 | 6,100 |

Sources: DCN SGE01179.

Abbreviations: UOG – unconventional oil and gas; EUR—estimated ultimate recovery (per well); MMbls—million barrels; Bcf—billion cubic feet of gas; TRR—technically recoverable resources

Section 2 provides step-by-step descriptions of how EPA used the information in the above sources to identify wells that discharged to POTWs in 2016, which EPA then used formation and location data to classify each well reported to Pennsylvania in 2016 as unconventional or conventional as defined by the 2016 UOG rule. Since wells classified by Pennsylvania as unconventional also meet the UOG rule's definition, EPA classified any well categorized as unconventional by Pennsylvania[3] to be similarly unconventional for the UOG rule. For wells classified as conventional by Pennsylvania, EPA reviewed operator reported information on the formation into which the well was drilled in combination with the other data sources identified above to determine if it was a shale or tight formation.

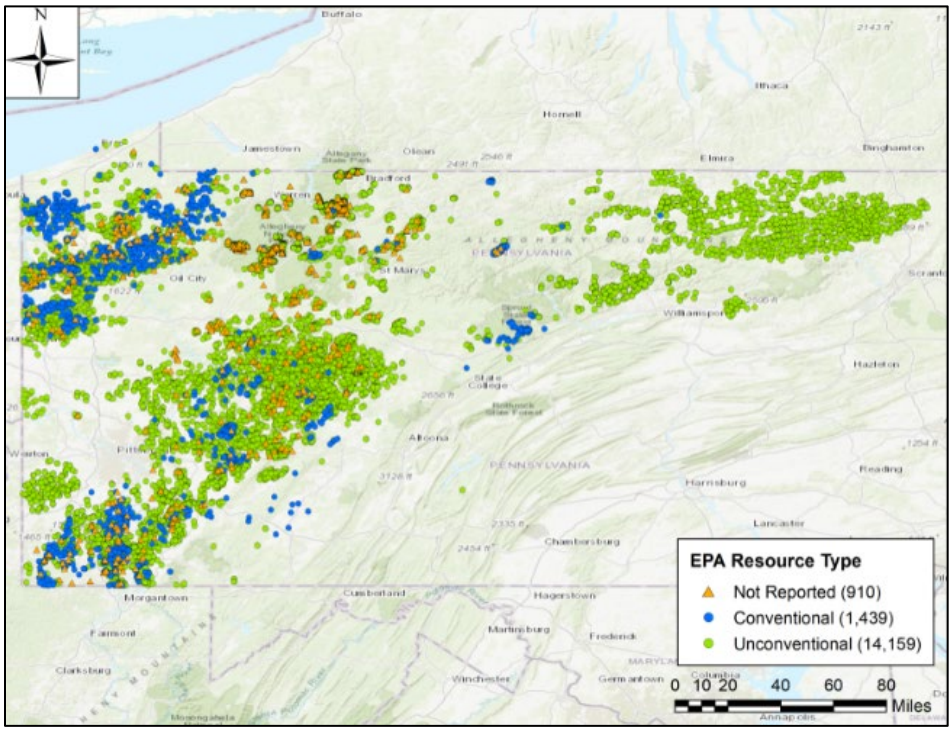
After reviewing all available database records from Pennsylvania, 680 wells that discharged wastewater to POTWs in 2016 did not have formation names reported. EPA searched completion reports for these wells in Pennsylvania's Exploration and Development Wells Information Network (EDWIN) database (DCN SGE01420) to look for the missing information but was unable to determine the formation these wells were drilled into for the majority of the 680 wells [4]. These wells' formations therefore were labeled as "not reported" in EPA's analysis. To be conservative, for purposes of this analysis only, EPA included all 680 "not reported" formation name wells as unconventional.

EPA also reviewed all wells active in 2016 and removed from the analysis wells that met the definition of 40 CFR part 435 Subpart F, the Stripper Well category because these wells are not subject to the UOG rule. 40 CFR §435.60 defines stripper wells as "onshore facilities which produce 10 barrels per well per calendar day or less of crude oil and which are operating at the maximum feasible rate of production and in accordance with recognized conservation practices." These wells cannot be gas wells, as seen in the specialized definitions 40 CFR §435.61 (c) "The term "well" shall means crude oil producing wells and shall not include gas wells or wells injecting water for disposal or for enhanced recovery of oil or gas" and, "(d) The term "gas well" shall mean any well which produces natural gas in a ratio to the petroleum liquids produced greater than 15,000 cubic feet of gas per 1 barrel (42 gallons) of petroleum liquids." Therefore, given the format of the data, EPA reviewed the 2016 oil and gas production data contained in PA DEP's database and excluded any well from the analysis that had less than a ratio of 15,000 cubic feet of gas per 1 barrel of oil, and had less than an average of 10 barrels per day of oil over the year's reported production and number of producing days (note: because these operators report data on an annual basis to Pennsylvania, EPA was limited in determining barrels of oil per day at a finer detail).

[3] The 2016 UOG rule's definition of unconventional is broader than Pennsylvania's definition and therefore inclusive of all Pennsylvania-defined UOG wells.

[4] During a review of well completion reports in the EDWIN database, EPA identified approximately 70 percent of the 680 wells did not have formation names reported in Pennsylvania's database or DI Desktop records. For the majority of the remaining wells, EPA only identified generic formation information. For example, some of the record completion reports included the type of rock (e.g., sandstone), but no formation name. Based on a cursory review of the available well completion reports, EPA only identified UOG formations names for less than 5 percent of the 680 wells. EPA determined this was not sufficient information for purposes of this analysis to identify if the well was drilled into an unconventional formation, as defined by EPA, and therefore decided to report all 680 remaining wells as "not reported", and subsequently, conservatively considered all "not reported" wells as "unconventional wells" for purposes of the analysis..

Figure 2-3 depicts oil and gas wells generating wastewater in 2016 in Pennsylvania, excluding stripper wells, and whether this analysis classifies them as UOG, COG, or not reported. Appendix A-5 describes the database EPA created to identify stripper wells.




Source: PA DEP Databases, see Section 2.2.1.

**Figure 2-3. Map of Wells Generating Oil and Gas Wastewater in Pennsylvania, Excluding Stripper Wells (2016)**

Table 2-3 summarizes data primarily for wastewater production and discharge to POTWs for the same wells depicted in Figure 2-3 (excludes stripper wells). Table 2-3 breaks out the data by EPA resource type, with "COG" representing wells that are conventional according to the 2016 UOG rule's definitions; "UOG" representing wells that are unconventional according to the 2016 UOG rule's definitions; and "Not Reported" representing those wells where the resource type was not reported by operators but were considered unconventional for purposes of EPA's analysis. Out of the 879 operators producing oil and gas in Pennsylvania in 2016, 22 reported discharging UOG wastewater and/or "Not Reported" wastewater to POTWs.[5] Since these are the operators that would potentially incur costs to comply with the UOG rule (including the "Not Reported" category, because EPA, at this time, cannot determine if it is unconventional or conventional and so conservatively categorized it as unconventional for purposes of this analysis), EPA's additional analyses focused on these 22 operators.

[5] 12 out of the 13 operators that reported discharging "Not Reported" wastewater also discharged UOG wastewater. The 2 operators that reported discharging COG wastewater to POTWs in 2016 also reported discharging UOG wastewater from their wells to POTWs in 2016.

**Table 2-3. PA DEP Waste Data for Oil and Gas Wells in 2016**

| EPA Resource Type | Operators Producing Oil and Gas | | | Operators Generating Wastewater (excludes stripper wells) | | | Discharges to POTWs (excludes stripper wells) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of Operators | Number of Wells Producing Oil and Gas | Wastewater Volume Generated (bbls) | Number of Operators | Number of Wells that Generated Wastewater [a] | Wastewater Volume Generated (bbls) | Number of Operators Discharging to POTWs | Number of Wells Discharging to POTWs [a] | Wastewater Sent to POTWs (bbls) |
| COG | Not analyzed by EPA | | | 68 | 1,439 | 591,255 | 2 | 4 | 200 |
| UOG | | | | 191 | 14,159 | 25,555,262 | 21 | 795 | 53,361 |
| Not Reported | | | | 84 | 910 | 114,165 | 13 | 164 | 7,882 |
| Totals | 879 | 80,658 | 30,580,866 | 209 [b] | 16,508 | 26,260,681 | 22 [b] (10.5%) [c] | 963 (5.8%) [c] | 61,443 (0.2%) [c] |

Source: PA DEP Databases, see Section 2.2.1.
a—These wells are shown as dots in Figure 2-3.
b—Totals do not equal the sum of operators as operators generate more than one type of wastewater.
c—Percentages based on the operators generating wastewater in 2016 (middle section of table).

## 2.2 Overview of Data Sources for New BAT Analysis

Once EPA determined the entities that may incur cost to comply with the UOG rule, EPA used the following additional sources to re-analyze whether the zero discharge requirements in the UOG rule are technologically available, economic achievable, and have acceptable non-water quality impacts within the meaning of the CWA.

### *2.2.1 Databases*

EPA also used the PA DEP Production and Waste Reports in combination with the DI cross-reference database described above to create a master database (PA DEP and DI cross-reference database – DCN SGE01418) to use for production data, formation data (where available, see section above), and wastewater management information. For details on how EPA refined the data sources, see Appendix A. This information was particularly helpful in identifying the wastewater management practices currently used by wells in Pennsylvania (POTWs, CWT facilities, disposal wells, etc.)

### *2.2.2 Detailed Study of CWT Category for Facilities Managing Oil and Gas Extraction Wastes*

EPA conducted a study of CWT facilities accepting oil and gas extraction wastewater from 2014 to 2017, which included information on CWT facilities in Pennsylvania that accept such wastewater and their associated costs.

### *2.2.3 Clean Water Act Section 308 Letters*

EPA used information from selected operators on wastewater management costs and their financials to assess the financial impacts of the final rule on entities that likely need to make changes to comply with the 2016 UOG rule (affected entities). EPA requested information from

nine Pennsylvania oil and gas operators through an information request pursuant to Section 308 of the Clean Water Act to augment data available from publicly available sources.

#### 2.2.3.1 Entity Selection Criteria

As described above, EPA identified entities that operated UOG wells and discharged wastewater to POTWs in 2016 and therefore may experience financial impacts from the UOG rule. EPA evaluated if a census of all entities would be necessary to assess those impacts. EPA reviewed information about the entities and found that there was enough similar about these entities a census was not needed. For example, since all of the entities are small businesses (less than 1,250 employees), there would be enough similarity in their financial portfolios, that a response from some of the entities could be extrapolated to all of the entities reasonably so (i.e., an entity with 1,300 employees has a different corporate structure than an entity with 10 employees). Another example is that all of the entities were located in Pennsylvania, and so a response from some of the entities could be extrapolated to all of the entities reasonably so (i.e., if the entities were located in different states, they may need to meet different state fees or different tax structures and so EPA would need a census of the entities to accommodate the differing tax structures in order to best understand financial impacts of the UOG rule). Using this reasoning, that entities were similar enough that with only information from some entities, EPA could use that to model the other entities appropriately for purposes of this analysis, in addition to EPA's desire to minimize burden on the industry (and thereby, request only the information that is needed), EPA determined it did not need a census. Rather, EPA elected to use its authority under Section 308 of the CWA to collect information from nine or fewer entities to support its current analyses

To obtain information across a diverse set of entities and to capture enough costing information for wastewater management, EPA ranked the entities based on several factors, with equal weight given to each factor (DCN SGE01433):

- Number of wells discharging to POTW.
- Volume of wastewater being sent to POTWs.
- Estimated Revenue of all wells.
- Estimated Revenue of wells discharging to POTWs.
- Estimated incremental costs.
- Volume of wastewater being sent to CWT facilities.

EPA sent letters, including data requests, to the nine top ranked entities based on these factors. Since the entities ranked in the top nine category had wastewater volumes an order of magnitude higher than entities ranked lower, EPA wanted to capture any wastewater management decisions that may differ because of significant wastewater volume differences across the entities (e.g., EPA didn't know if an entity with higher wastewater volume may have longer term contracts with trucking entities than an entity with lower wastewater volume, thereby having an effect on their business decisions that may warrant a different modelling structure in EPA's analysis), so EPA substituted two of the top entities with two lower ranked entities to make the data more representative of all entities.

To reduce the response burden, EPA asked a limited number of questions (six). Also, EPA followed up with the recipients to answer any questions or provide further data, as needed (DCN SGE01434). Eight of the nine entities responded.

#### 1.2.2.2 Engineering, Cost, and Production Information

In order to assess the incremental cost of the rule, EPA requested recipients to report wastewater volumes generated, wastewater management employed, and associated costs. To reduce burden to respond to this request, EPA summarized the quantity of oil and gas wastewater generated from wells and transferred to POTWs, CWT facilities, or disposal wells as reported to PA DEP (described above) for reporting periods 2013 through 2016. EPA asked entities to verify this information and to also provide information on associated costs for 2013-2016. EPA requested the following information related to wastewater management costs from those entities that received EPA's data request:

- Any payment to any wastewater management facility (e.g., payment to a POTW, CWT facility, or disposal well) for wastewater management cost (overall cost and $ per barrel).
- Transportation costs to any wastewater management facility.
- Metric upon which the facility is billed for transportation costs (e.g., $ per mile, $ per hour).

EPA did not request costs for all aspects of wastewater management because (1) EPA was minimizing respondent burden, and (2) EPA found it reasonable to make assumptions on certain wastewater management baseline costs (i.e., EPA already had cost information on some aspects of wastewater management (e.g., renting tanks for temporary storage) from site visits and call records from the 2016 UOG rule record and the 2017 CWT study record), further described below. This production, wastewater management, and cost data provide key information for the baseline and post-compliance cost analysis presented in Section 2.

To further verify the datasets from Pennsylvania with more current information, EPA requested each entity provide the total number of wells nationwide and in Pennsylvania as of January 1, 2018. Three of the eight facilities provided corrected information on the quantity of wastewater they had reported in Pennsylvania's datasets. EPA used this corrected quantity of wastewater in its analyses. Once EPA was made aware of these corrections, EPA noted two other entities that may have misreported their data to Pennsylvania. EPA contacted PA DEP regarding these two entities' wastewater data, who followed up with both, confirming the need to correct the quantity of wastewater reported. These two entities subsequently resubmitted corrected 2016 data to PA DEP database (DCN SGE01450; DCN SGE01451). Those corrections are reflected in the PA DEP online database and in EPA's analyses.

#### 1.2.2.3 Entity Financial Information

EPA collected financial information to assess economic achievability of the rule. EPA solicited the following financial data for the year 2016:

- Revenue attributable to oil operations.
- Revenue attributable to gas operations.

- Other revenue.
- Operating costs attributable to oil operations (not including wastewater management costs).
- Operating costs attributable to gas operations (not including wastewater management costs).
- Depreciation.
- Impact fees paid to Pennsylvania Public Utility Commission.
- Other costs.
- Interest.
- Federal and state income taxes.

Six entities responded with these data items; the remaining two provided their federal tax return for 2016 instead. In addition, EPA requested total employment to confirm if the small business threshold is met, and oil and gas threshold prices, if they existed, below which the facility would cease oil or gas operations.

The financial data listed above provide key information for the baseline and post-compliance financial analysis presented in Section 4. In addition, EPA used this data to model the non-surveyed entities that are expected to incur compliance costs under the rule.

### *2.2.4 Locational Analysis*

In order to determine the closest wastewater management alternative (for purposes of this analyses: CWT facility or disposal well) instead of a POTW, EPA used the well locations to conduct a GIS analysis for each 2016 UOG rule defined UOG well discharging to POTWs in 2016. Specifically, EPA used ArcGIS Online to calculate the driving distances and times from the well locations to the POTWs as a baseline. Next, EPA used ArcGIS Online to calculate driving distances and times from the wells to the nearest CWT facilities and disposal wells using the "Find Nearest" tool, optimized using the "Trucking Time" function. EPA used the driving distances and times generated by the GIS Analysis to calculate the transportation cost component of the Alternative Wastewater Management Analysis.

### *2.2.5 Oil and Gas Prices, and Other General Financial Information*

In addition to the financial data received in the response to EPA's data request, EPA also used EIA data on historical West Texas Intermediate (WTI) crude oil spot prices (DCN SGE01439), Pennsylvania crude oil first purchase prices (DCN SGE01441), and Henry Hub natural gas spot prices (DCN SGE01440); EIA Annual Energy Outlook WTI (DCN SGE01438) and Henry Hub price projections (DCN SGE01437); and the Bureau of Economic Analysis GDP price deflator index (DCN SGE01436). The use of these data is discussed in more detail in Sections 4.2 and 4.3.

# 3. ALTERNATIVE WASTEWATER MANAGEMENT ANALYSIS

This section describes in detail the methodology EPA used to determine the facilities that will likely need to make changes to comply with the 2016 UOG rule, the available alternatives, and the incremental costs associated with those alternatives.

## 3.1 Alternative Wastewater Management Analysis

Figure 3-1 illustrates the steps EPA used to conduct the Alternative Wastewater Management Analysis using the data sources described in Section 2.2. Each of these steps is described below with additional detail.

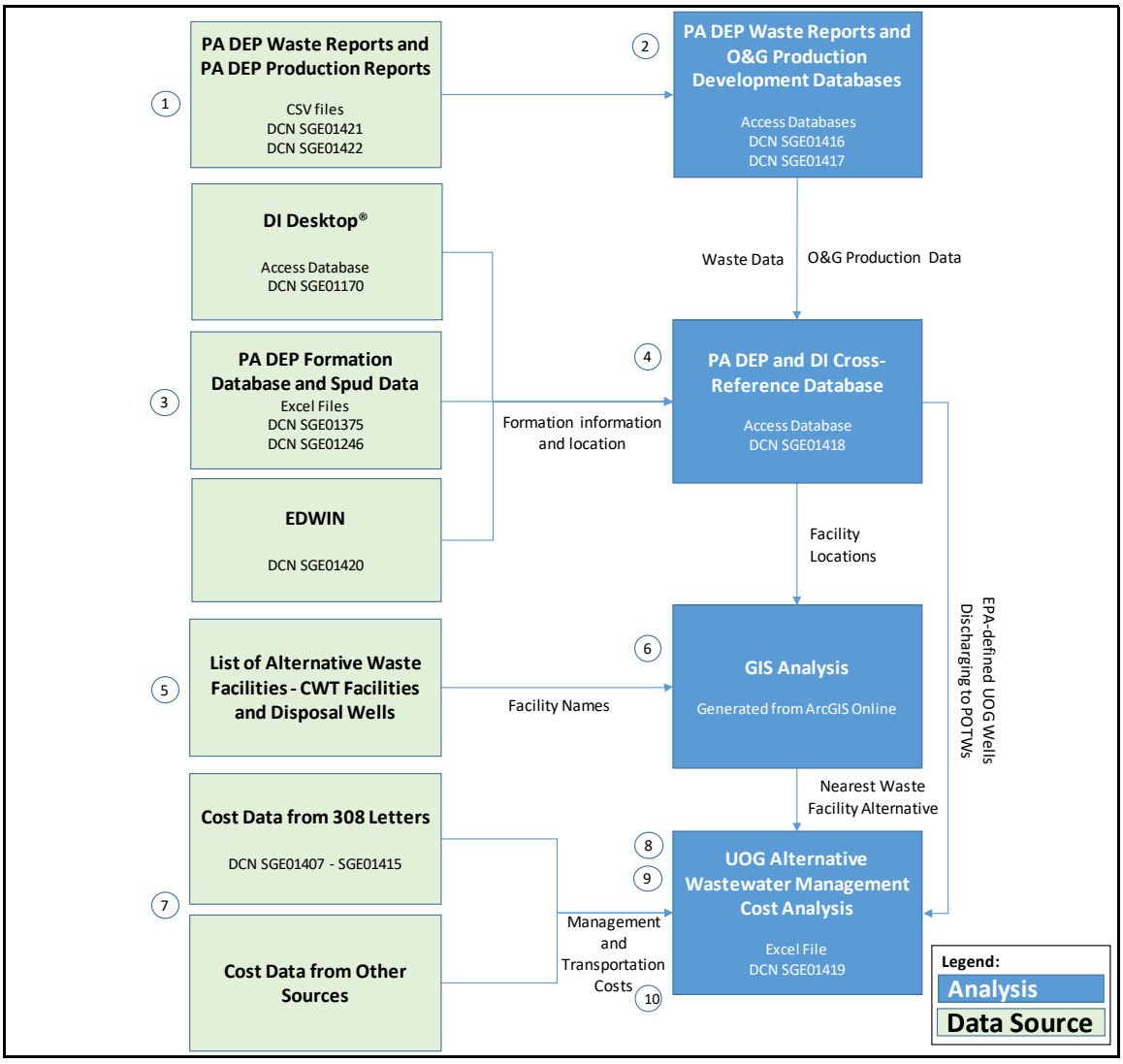



**Figure 3-1. UOG Alternative Wastewater Management Analysis Work Flow Diagram**

### *3.1.1 Step 1 – PA DEP Waste and Production Reports*

EPA downloaded individual PA DEP Waste Reports and PA DEP Production Reports in comma separated values (CSV) files for 2004 through 2016 on February 12, 2018 and January 8, 2018, respectively. Table A-1 in Appendix A lists and describes the report fields.

### *3.1.2 Step 2 – Prepare PA DEP Waste and Production Report Development Databases*

EPA developed Access databases to compile and store the individual PA DEP Waste and Production Report CSV files downloaded from PA DEP's website (Step 1), and to prepare the data for subsequent analyses. EPA developed and populated the databases using a series of Access queries described in Tables A-2 and A-3 in Appendix A for the PA DEP Waste and Production Reports, respectively.

The PA DEP Waste Reports include a variety of naming conventions, spelling errors, and missing information. Two of the database development queries function to correct and standardize the *Waste Type*, *Waste Disposal Method*, *Waste Facility Name*, and *Waste Facility Permit Number* fields to facilitate subsequent data analysis. EPA created two consolidation crosswalk tables to execute the data standardization queries. Table 3-1 shows a small subset of the >2,000 entries from the crosswalk tables to illustrate the data standardization. For example, reported waste types such as "Drilling Fluid" and "Drilling" were standardized in the *Consolidated Waste Type* field as "Drilling wastewater," and reported facilities names such as "Mccutcheon Enterprise," "Mccutcheon Enterprises Inc," and "Mccutcheon Enterprises, Inc." were standardized in the *Consolidated Waste Facility Name* field as "Mccutcheon Enterprise." In some cases, EPA used best professional judgment to standardize the data fields. For example, one of the records in Table 3-1 reports "Municipal Sewage Treatment Plant" as *Disposal Method* and "Mccutcheon Enterprises, Inc." (a known CWT facility) as *Waste Facility Name*. In this example, EPA populated the *Consolidated Disposal Method* as "CWT Facility" for this record. EPA included the complete consolidation crosswalk tables within the PA DEP Waste Development Database (DCN SGE01416).

### *3.1.3 Steps 3 and 4 – Prepare PA DEP and DI Cross-Reference Database and Identify Wells/Entities that Will Likely Incur Costs*

EPA developed the PA DEP and DI Desktop® Cross-reference Database (Step 4) to identify the subset of wells that likely need to make changes to comply with the 2016 UOG rule (those discharging to POTWs in 2016 and that meet the 2016 UOG rule's definition of UOG). Specifically, the database links the waste and production data from the PA DEP Waste and Production Report Development Databases, which are used to identify those wells that discharged to POTWs in 2016, with formation and location data from other data sources (Step 3), which are used to identify those wells that meet the 2016 UOG rule's definition of UOG.

The PA DEP and DI Desktop® Cross-reference Database (DCN SGE01418) also prepares the well data that EPA included in the industry data requests (discussed in Section 0) and to populate well location data used in the GIS Analysis (Step 6).

## Table 3-1. Example Crosswalk of PA DEP Waste Facility Record Standardization

| Report Fields, As Reported by Operators | | | | Report Fields, As Standardized by EPA | | | |
|---|---|---|---|---|---|---|---|
| **Reported Waste Type** | **Reported Management Method** | **Reported Waste Facility Name** | **Reported Waste Facility Permit Number** | **Consolidated Waste Type** | **Consolidated Management Method** | **Consolidated Waste Facility Name** | **Consolidated Waste Facility Permit Number** |
| Drilling Fluid | Centralized Treatment Plant For Recycle | Mccutcheon Enterprise | PAD013826847 | Drilling wastewater | CWT Facility | Mccutcheon Enterprise | PAD013826847 |
| Drilling | Centralized Treatment Plant For Recycle | Mccutcheon Enterprises Inc | PAD013826847 | Drilling wastewater | CWT Facility | Mccutcheon Enterprise | PAD013826847 |
| Frac Flowback | Residual Waste Transfer Facility | Mccutcheon Enterprises Inc | PAD013826847 | Flowback | CWT Facility | Mccutcheon Enterprise | PAD013826847 |
| Fracking Fluid | Municipal Sewage Treatment Plant | Mccutcheon Enterprises, Inc. | --[a] | Flowback | CWT Facility | Mccutcheon Enterprise | PAD013826847 |
| Drilling Fluid | Public Sewage Treatment Plant | Dornick Point Wwtp | PA0026034 | Drilling wastewater | POTW | Johnstown STP | PA0026034 |
| Drilling Fluid | Public Sewage Treatment Plant | Johnstown Sewage Treatment Plant | PA0026034 | Drilling wastewater | POTW | Johnstown STP | PA0026034 |
| Drilling | Brine Or Industrial Waste Treatment Plt | Johnstown Stp | --[a] | Drilling wastewater | POTW | Johnstown STP | PA0026034 |
| Brine | Municipal Sewage Treatment Plant | Johnstown Stp | --[a] | Long-term produced water | POTW | Johnstown STP | PA0026034 |
| Produced Fluid | Reuse Other Than Road Spreading | Johnstown Stp | --[a] | Long-term produced water | POTW | Johnstown STP | PA0026034 |
| Drilling Fluid | Brine Or Industrial Waste Treatment Plt | Ridgeway Borough | --[a] | Drilling wastewater | POTW | Ridgeway Borough STP | PA0023213 |
| Drilling Fluid | Centralized Treatment Plant For Recycle | Ridgway Borough Sewage Plant | PA0023213 | Drilling wastewater | POTW | Ridgeway Borough STP | PA0023213 |
| Drilling Fluid | Public Sewage Treatment Plant | Ridgway Borough Sewage Treatment Plant | PA0023213 | Drilling wastewater | POTW | Ridgeway Borough STP | PA0023213 |
| Brine | Injection Disposal Well | Carper Well Svc Bryane Smith 1 | 34-121-23390 | Long-term produced water | Underground Injection | N/A | N/A |
| Produced Fluid | Centralized Treatment Plant For Recycle | Carper Well Svc Bryane Smith 1 | 34-121-23390 | Long-term produced water | Underground Injection | N/A | N/A |

N/A – Not applicable; EPA did not standardize disposal well facility names or permit numbers.

a—No permit number was reported for these records. EPA assigned the correct permit number during data consolidation.

EPA's primary data source for formation data is DI Desktop®; Table A-4 in Appendix A lists and describes the DI Desktop® fields. Where formation data are unavailable from DI Desktop®, EPA supplemented with formation data from PA DEP's Formation and EDWIN Databases. Data sources for well location include the PA DEP Waste and Production Reports, DI Desktop®, and PA DEP SPUD data.

EPA developed and populated PA DEP and DI Desktop® Cross-reference Database using a series of Access queries described in Table A-5 in Appendix A. In summary, the queries perform the following actions:

1. Compiles data from applicable data sources (PA DEP Waste and Production Report Development Databases, DI Desktop®, PA DEP Formation Database, PA DEP SPUD Data, EDWIN) using Well API number as the link.
2. Populates well formation names using formation names from DI Desktop®. Where well formation names are blank in DI Desktop®, populates well formation names using formations names from the PA DEP Formation Database.
3. Identifies those formations that are "Tight" or "Shale" using publications by EIA listing known tight and shale formations. This includes two maps published be EIA: Major Tight Gas Plays, Lower 48 States (Figure 2-1) and Shale Gas Plays, Lower 48 States (Figure 2-2), and EIA's Assumptions to the Annual Energy Outlook 2015 (Table 2-1 and Table 2-2).
4. Determines and identifies UOG, COG, and Unreported wells based on the 2016 UOG rule's definitions of these terms. Specifically:
    a. **The 2016 UOG rule defined Unconventional Wells**
    The 2016 UOG rule defined UOG wells are those that PA DEP categorized as UOG, as well as those with a reported formation name that identified as Tight or Shale (even if PA DEP categorized them as conventional).
    b. **The 2016 UOG rule defined Conventional Wells**
    The 2016 UOG rule defined COG wells are those that PA DEP did not define as UOG and that were not identified as either Tight or Shale based on formation name.
    c. **Not Reported Wells**
    Not reported wells are those that PA DEP did not define as UOG and that lack formation names from DI Desktop®, PA DEP Formation, and EDWIN Databases. EPA considered these wells as UOG wells in its analysis to be conservative. This assumption could result in over-estimation of the incremental compliance costs attributable to these wells, as some may not be 2016 UOG rule defined UOG wells.
5. Populates well location (latitudes and longitudes) using the following hierarchy of data sources:
    a. PA DEP Waste and Production Report data. These reports provided latitude and longitudes for approximately 95% of wells generating

wastewater in 2016. It is EPA's preferred data source because it's publicly available.

b. DI Desktop®. This supplemental data source provided locations for approximately 2% of wells generating wastewater in 2016.

c. PA DEP SPUD Data. This supplemental data source provided locations for less than 1% of wells generating wastewater in 2016.

d. Average Farm location. For those wells that lacked location data from the previous data sources, EPA calculated and populated the average location of all wells located within the same farm as identified by the PA DEP Waste Reports (see Appendix A for data fields). EPA used this methodology to maximize that number of wells modeled by the GIS Analysis (Step 5) and ultimately included in its analysis. EPA estimated locations for less than 1% of wells generating wastewater in 2016 using this methodology.

e. Average Municipality location. For those wells that lacked location data from the previous data sources, EPA calculated and populated the average location of all wells located within the same municipality and county, regardless of the operator, as identified by the PA DEP Waste Reports (see Appendix A for data fields). EPA used this methodology to maximize that number of wells modeled by the GIS Analysis (Step 5) and ultimately included in its analyses. EPA estimated locations for approximately 2% of wells generating wastewater in 2016 using this methodology.

6. Identifies the oil and gas operators and wells in Pennsylvania that discharged to POTWs in 2016 and that meet the 2016 UOG rule's definition of UOG in 40 CFR 435 Subpart C. Collates summary information about these operators such as number of active wells, other wastewater management practices, and oil and gas production.

### *3.1.4 Step 5 – Develop List of Wastewater Management Alternatives to POTW Discharge*

EPA prepared an initial list of CWT facilities and disposal wells[6] accepting all oil and gas extraction wastewater by reviewing the *Disposal Method* and *Waste Facility Name* fields in the PA DEP Waste Reports for 2016 and 2017 (i.e., EPA started with a list of only CWT facilities and disposal wells that all operators in Pennsylvania reported themselves as using in 2016 and 2017). EPA developed the final list of alternative wastewater management facilities by removing those known to have shut down, accept only small volumes of wastewater, or that otherwise lack capacity to receive additional wastewater. For example, EPA conservatively removed all Pennsylvania disposal wells from the list of available alternative facilities because

[6] In addition to CWT facilities and disposal wells, the 2016 UOG rule listed recycle/reuse as one of the wastewater management alternatives to POTWs. EPA did not analyze the costs for recycle/reuse as an alternative to management at POTWs because EPA would need to know information such as the future exploration and production plans for operators and the associated wastewater demand for activities such as drilling. EPA expects that the cost of recycle/reuse would be less than or comparable to management at POTWs, particularly if water is reused close to where it is produced. In addition, recycle/reuse offsets the need to purchase fresh water resulting in potential additional savings for operators. Also, to a certain extent recycle/reuse is captured within the CWT facility option as some portion of wastewater managed at some CWTs is reused by other operators.

they may not have capacity to accept additional UOG wastewater. EPA made these adjustments to ensure that wastewater management alternatives are available. Finally, EPA reviewed the cost model outputs to confirm that reception facilities have enough capacity to receive the modeled wastewater volumes (see correspondence with facilities for capacity questions: DCN SGE01452 and DCN SGE01453). EPA received information from PGCC noting that some specific wastewater management facilities were unavailable to at least some portion of the operators that likely need to make changes to comply with the UOG rule (DCN SGE01494). In response, EPA reviewed again the 2016, 2017 and newly available 2018 data and identified several operators, categorized as conventional under Pennsylvania's definition and categorized as unconventional under the 2016 UOG rule's definition, that were sending their wastewater to said facilities (DCN SGE01494). Table 3-2 and Table 3-3 list the CWT facilities and disposal wells, respectively, that EPA used in this analysis (DCN SGE01419).

**Table 3-2. Available CWT Facilities**

| Waste Facility Name or Operator | Permit Number | Facility City | Facility State | Latitude | Longitude |
|---|---|---|---|---|---|
| CARES McKean (Now Highland Field Services) | 4212201; WMGR123NW005 | McKean County | PA | 41.661944 | -78.636667 |
| Fluid Recovery Service, Josephine | PA0095273 | Josephine | PA | 40.482583 | -79.171882 |
| Hydro Recovery (Burgettstown) | WMGR123SW019 | Burgettstown | PA | 40.420084 | -80.418137 |
| Fluid Recovery Service, Franklin | PA0101508 | Franklin | PA | 41.37292 | -79.798357 |
| Mccutcheon Enterprise | PAD013826847 | Apollo | PA | 40.588989 | -79.61189 |
| Green County Water Treatment, LLC | WMGR123SW010 | Telford | PA | 39.908288 | -80.141133 |
| Reserved Environmental Services (Butler) | WMGR123NW009 | Renfrew | PA | 40.813222 | -79.936506 |
| Hydro Recovery (Antrim) | WMGR123NC010 | Wellsboro | PA | 41.644016 | -77.285987 |
| 4K Martins Ferry Facility | OH0011339 | Martins Ferry | OH | 40.100216 | -80.712527 |
| Reserved Environmental Services (Mount Pleasant) | WMGR123SW005 PA0254185 | Mount Pleasant | PA | 40.160788 | -79.55889 |
| Clearmont Storage Facility | WMGR123NW011 | | PA | 41.619444 | -78.426389 |
| Riverside Park Recycling Facility (Buckeye Brine) | ORDER 2014-04 | UHRICHSVILLE | OH | 40.38616 | -81.394476 |
| PETTA Enterprises - Cambridge Facility | ODNR 2015-29 | Cambridge | OH | 40.035077 | -81.599078 |
| Fairmont Brine | WVR000521948 | | WV | 39.507345 | -80.126338 |
| Appalachian Water Services Llc (also Shallenberger Construction/Ronco Facility) | PA0253723; WMGR123SW001 | Masontown | PA | 39.853611 | -79.924722 |
| Eureka Resources (Standing Stone) | WMGR123NC018 | Standing Stone | PA | 41.7457484 | -76.350338 |
| Eureka Resources (Williamsport 1) | WMGR123NC005; WMGR119 | Williamsport | PA | 41.237689 | -77.008517 |
| Fluid Recovery Service, Kingsley | WMGR123NE004 | | PA | 41.701128 | -75.674304 |
| Hydro Recovery (Blossburg) | WMGR123 | Blossburg | PA | 41.671495 | -77.073048 |

Source: DCN SGE01419.

## Table 3-3. Available Disposal Wells

| Waste Facility Name or Operator | Permit Number | Facility City | Facility State | Latitude | Longitude |
|---|---|---|---|---|---|
| MONROE #1 | 34-007-24523 | WOOSTER | OH | 41.8200300 | -80.5445400 |
| KLEESE #1 (SWIW #18) | 34-155-21438 | VIENNA | OH | 41.2392500 | -80.6385600 |
| NORTHSTAR LUCKY #4 (SWIW #12) | 34-099-23158 | NORTH LIMA | OH | 40.9627400 | -80.6636300 |
| CLEARWATER 111 (SWIW #15) | 34-059-2-3986 | CAMBRIDGE | OH | 40.0273000 | -81.5111700 |
| RE-HYDRO #1 (SWIW #10) | 34-157-25506 | DENNISON | OH | 40.4084240 | -81.2953570 |
| RITCHIE HUNTER WATER DISPOSAL (GREEN HUNTER) | 2D0859721 | ELLENBORO | WV | 39.2584280 | -81.0999970 |
| PETROWATER INC. | 3192 | JEFFERSON | OH | 41.6808130 | -80.7222390 |
| RENSHAW / BRADNAN #1 (B&R) DISPOSAL WELL | 34-007-20919 | PIERPOINT | OH | 41.7678570 | -80.5696940 |
| RHOA #3 (SWIW #8) | 34-007-21847 | JEFFERSON | OH | 41.6132130 | -80.7828350 |
| CLINTON OIL CO UNIT 1-973 (SWIW #30) | 34-007-2-3097 | GARRETTSVILLE | OH | 41.5615100 | -80.9932300 |
| CLINTON OIL #2 (SWIW #21) | 34-007-23262 | GARRETSVILLE | OH | 41.2878680 | -81.0960960 |
| MILLER & CO #1 (SWIW #32) | 34-007-2-3692 | GARRETTSVILLE | OH | 41.5540600 | -80.9903000 |
| MILLER & CO #3 (SWIW #28) | 34-007-24355 | GARRETTSVILLE | OH | 41.5532790 | -80.9914540 |
| K & H PARTNERS LLC #1 (SWIW #8) | 34-009-23821 | COOLVILLE | OH | 39.2260800 | -81.7614000 |
| ADAMS #1 (SWIW #10) | 34-031-27177 | COSHOCTON | OH | 40.3008300 | -81.8481800 |
| DEVCO UNIT #1 (SWIW #11) | 34-059-24067 | CAMBRIDGE | OH | 39.9412800 | -81.6737900 |
| SOS-D #1 (SWIW #12) | 34-059-24202 | CAMBRIDGE | OH | 39.9936100 | -81.5729700 |
| ROSCOE MILLS #1 (SWIW #19) | 34-105-23619 | MEIGS | OH | 38.9404800 | -81.7875900 |
| GOFF #1 (SWIW #27) | 34-119-28776 | NORWICH | OH | 39.9773700 | -81.8069000 |
| KEMBLE #1-D (SWIW #28) | 34-119-28780 | NORWICH | OH | 39.9749500 | -81.8453900 |
| PATTISON TRUST # 1-D (SWIW #30) | 34-119-28803 | NORWICH | OH | 39.9736400 | -81.8257300 |
| WARREN DRILLING CO #1 (SWIW #6) | 34-121-23995 | DEXTER CITY | OH | 39.6538100 | -81.4753100 |
| WILCOX #1 | 34-133-20114 | ROOTSTOWN | OH | 41.0960300 | -81.1995400 |
| BLAZEK #2 SWIW | 34-133-20525 | HIRAM | OH | 41.3312000 | -81.1842300 |
| MYERS #1 UNIT (SWIW #31) | 34-133-21076 | ATWATER | OH | 41.0762170 | -81.1392560 |
| MILLER #1 DISP WELL | 34-133-22523 | WINDHAM | OH | 41.2522200 | -81.0204700 |
| PLUM CREEK #1 DISPOSAL WELL | 34-133-23614 | KENT | OH | 41.1050900 | -81.3584000 |
| GROSELLE INECTION WELL # 2 | 34-133-24096 | GARRETTSVILLE | OH | 41.3458800 | -81.0897800 |
| MEYERS #2 (SWIW #33) | 34-133-24189 | ATWATER | OH | 41.0756000 | -81.1429400 |
| SOINSKI #1 (SWIW # 37) | 34-133-24462 | WINDHAM | OH | 41.2586300 | -81.0246000 |
| BELDEN & BLAKE WELL # 2 | 34-151-23420 | HARTVILLE | OH | 40.9502500 | -81.2488500 |

**Table 3-3. Available Disposal Wells**

| Waste Facility Name or Operator | Permit Number | Facility City | Facility State | Latitude | Longitude |
|---|---|---|---|---|---|
| WOLF #1 DISP WELL | 34-155-21893 | NEWTON FALLS | OH | 41.2025900 | -80.9989800 |
| WOLF #2 DISPOSAL WELL | 34-155-21894 | NEWTON FALLS | OH | 41.1985200 | -81.0006400 |
| ANNAROCK D-1 | 34-155-22403 | FOWLER | OH | 41.3156900 | -80.6184900 |
| NATALE #1 (SWIW #28) | 34-155-23196 | WARREN | OH | 41.2683500 | -80.8915300 |
| WOLF #4 DISPOSAL WELL | 34-155-23203 | NEWTON FALLS | OH | 41.2022380 | -81.0023580 |
| NATALE #2 (SWIW #29) | 34-155-23223 | VIENNA | OH | 41.2649100 | -80.8914300 |
| PANDER R & P #2 (SWIW #16) | 34-155-2-3794 | NEWTON FALLS | OH | 41.1987700 | -80.9940800 |
| PANDER #1 (SWIW #15) | 34-155-23795 | NEWTON FALLS | OH | 41.2003850 | -80.9917880 |
| JOHNSON DISPOSAL #1 | 34-155-24063 | NORTH BLOOMFIELD | OH | 41.4623100 | -80.7219800 |
| B & J NO 1 INJECTION (SWIW #33) | 34-155-24079 | VIENNA | OH | 41.2492080 | -80.6649740 |
| DENNISON DISPOSAL 1 (SWIW #11) | 34-157-25507 | DENNISON | OH | 40.4075400 | -81.3117100 |
| MOZENA #1 (SWIW #13) | 34-157-25511 | NEWCOMERSTOWN | OH | 40.2832900 | -81.5780700 |
| NICHOLS #1 (SWIW #13) [HECKMAN WATER RES(CVR)INC] | 34-167-23862 | BELPRE | OH | 39.3478700 | -81.5906800 |
| VOCATIONAL SCHOOL #2 (SWIW #20) | 34-167-29543 | MARIETTA | OH | 39.4262780 | -81.5023790 |
| VOCATIONAL SCHOOL UNIT #2 (SWIW#20) | 34-167-2-9543 | MARIETTA | OH | 39.4262800 | -81.5023800 |

Source: DCN SGE01419.

### *3.1.5 Step 6 – GIS Analysis*

EPA conducted an analysis to determine the proximity of each of the UOG wells that discharged to POTWs (developed in Step 4) to alternative wastewater management practices consisting of CWT facilities and disposal wells. EPA conducted this analysis using ESRI ArcGis Online and used ESRI's built-in analysis tools for calculating distance and travel time between locations. The analysis components are as follows:

1. EPA created GIS layers containing the latitude/longitude of the analysis entities: 2016 UOG rule defined UOG wells discharging to POTWs; POTWs receiving wastewater from UOG wells; disposal wells, and CWT facilities.

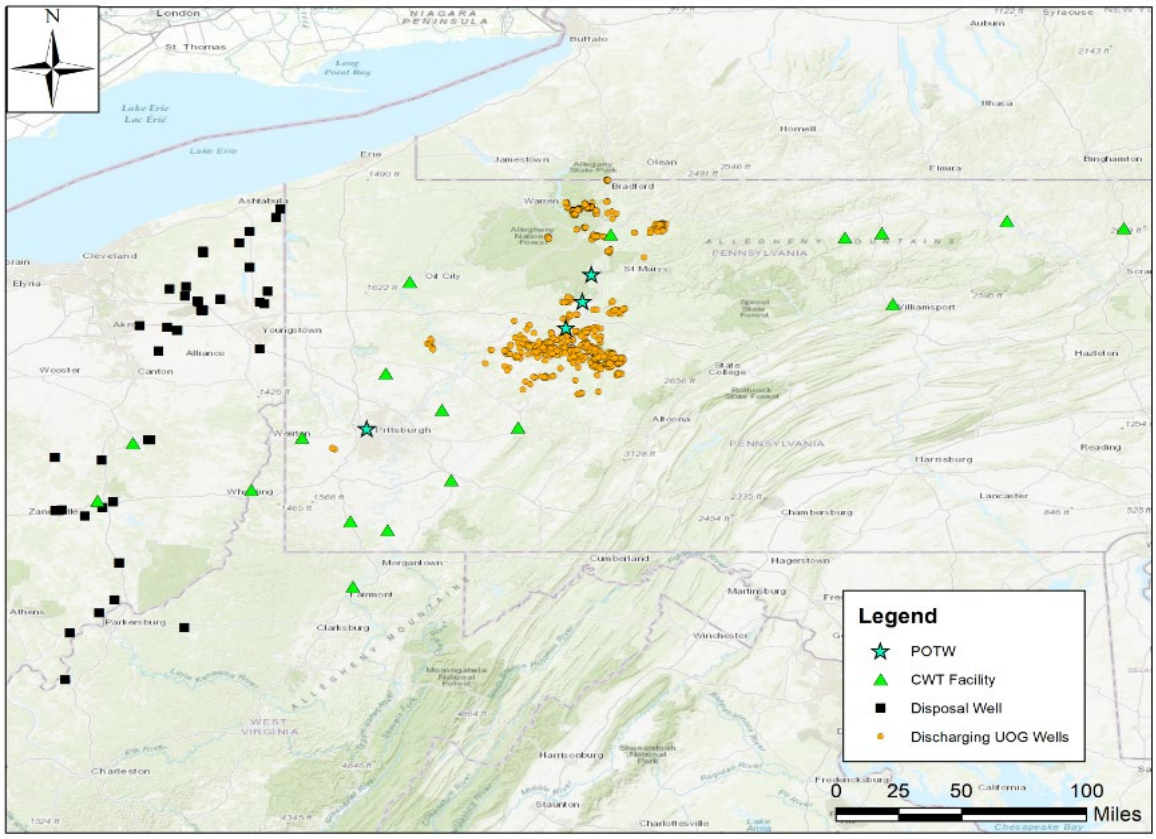
2. Using the "Proximity" analysis tool, and the "Find Nearest[7]" function, EPA determined the shortest trucking time, and the associated trucking distance, between each UOG well and the POTW that accepted wastewater from that well.
3. EPA repeated this process for each well to determine the closest (measured by trucking time) CWT facility and the closest disposal well.
4. EPA generated and exported Results files containing the closest alternative management options to Excel for further analysis in Step 8 (see Table A-6 in Appendix A for a list of results files generated).[8]

Figure 3-2 shows the location of the UOG wells of interest (in orange), the four POTWs that received wastewater from these wells (in blue), available CWT facilities (in green) and available Class II disposal wells (in black). EPA notes that eight entities used only a POTW to manage their wastewater in 2016; the remaining 14 entities used alternative wastewater management approaches in addition to POTWs in 2016.

As an example of one of the steps of the analysis, Figure 3-3 shows the trucking routes from each UOG well (in orange) to the Reynoldsville POTW for the subset of wells that discharge to the Reynoldsville POTW.

[7] This function: "Models basic truck travel by preferring designated truck routes and finds solutions that optimize travel time. Routes must obey one-way roads, avoid illegal turns, and so on. When you specify a start time, dynamic travel speeds based on traffic are used where it is available, up to the legal truck speed limit. Follows rules applicable to heavy trucks." (DCN SGE01485)

[8] The analysis toolkit using ArgGIS online is limited to 1,000 entities per run, so the Ridgeway dataset was broken into three subsets for GIS analysis purposes.




Source: PA DEP Databases, see Section 2.2.1.

**Figure 3-2. Wastewater Management Alternatives Used in EPA's Analysis and EPA-defined UOG Wells Discharging to POTWs in Pennsylvania in 2016**

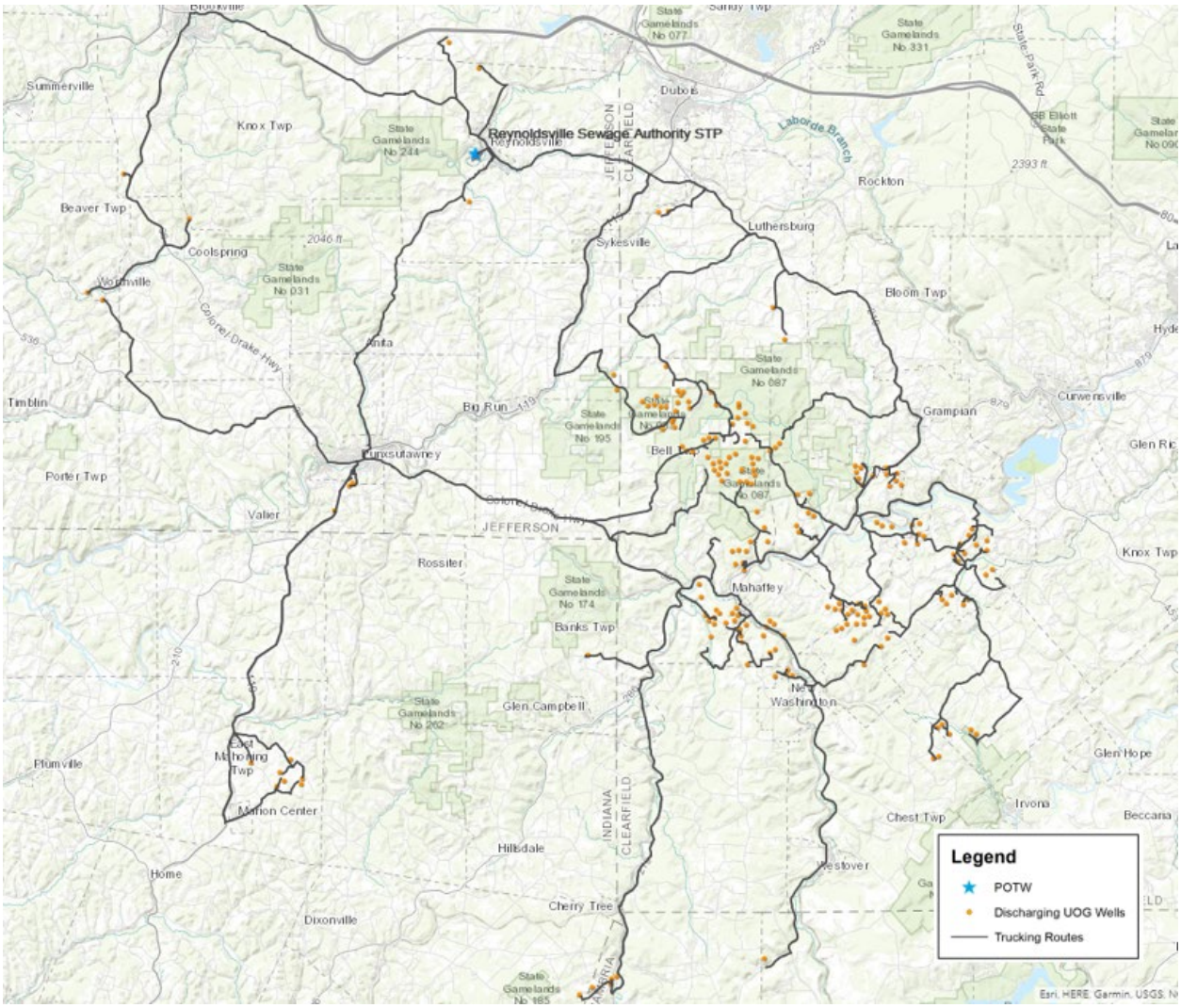



**Figure 3-3. Example GIS Analysis Trucking Routes from Wells to Reynoldsville POTW**

### *3.1.6 Step 7 – Cost Data Compilation*

*Wastewater Management Cost ($/bbl) Compilation*

Oil and gas operators provided their wastewater management costs for POTWs, CWT facilities, and disposal wells in their responses to EPA's data request. Operators typically reported these costs in units of dollars per barrel ($/bbl). EPA also extracted available information on costs that CWT facilities charge to treat oil and gas wastewater (cost data) from reports EPA prepared from meetings or site visits to CWT facilities and oil and gas operators from the Detailed Study of the CWT Category for Facilities Managing Oil and Gas Extraction Wastes (2017) and the UOG final rule (2016). The sources of all wastewater management cost data used in the analysis are identified within Step 8 and these sources are available in the UOG rulemaking record. EPA calculated the average wastewater management cost ($/bbl) for each POTW, CWT facility and disposal well, using available site-specific cost data. For facilities that lacked site-specific cost data, EPA used the average cost for all facilities of the same type. For

example, if EPA lacked cost data for a specific CWT facility, then EPA used the average cost for all CWT facilities.

*Transportation Cost Data Compilation*

Oil and gas operators provided their wastewater transportation costs in their responses to EPA's data requests. EPA used the components defined below the equations to calculate a trucking cost factor in units of $/bbl/hr. EPA used Equation 1 to calculate *Truck Load Hours (hours)*, assuming a *Truckload Capacity* of 100 bbl of wastewater per truck. EPA completed a GIS analysis to determine the *Estimated Driving Time (min)* (See Step 6 for more detail). EPA used these data (i.e., weighted average of 2013 – 2017 data for all 7 operators who responded to data request letters) and Equation 2 to develop a trucking cost factor of $3.35 $/bbl/hr. EPA used this trucking cost factor for EPA's analysis. A step-by-step description of the transportation cost assumptions and calculations can be found in the "Cost Assumptions and Calcs." worksheet in the Alterative Wastewater Management Analysis (DCN SGE01419).

**Equation 1**

*Truck Load Hours = Estimated Driving Time (min) × (1 hr / 60 min) / (Vol WW (bbl) / Truckload Capacity)*

**Equation 2**

*Trucking Cost Factor = Annual Transp Cost / Vol WW / Truck Load Hours × Total Number Truck Loads*

where:

| | | |
|---|---|---|
| Annual Transp Cost ($) | = | Annual transportation cost reported by an operator for a specific waste facility (e.g., a POTW, a CWT facility, or a disposal well) they used between 2013 to 2017. |
| Vol WW (bbl) | = | Volume of wastewater generated by a specific well and sent to a specific waste facility (e.g., a POTW, a CWT facility, or a disposal well) between 2013 and 2017. |
| Truck Load Hours (hours) | = | Number of driving hours per truck required by an operator to send wastewater to a specific waste facility (e.g., a POTW, a CWT facility, or a disposal wells) (2013-2017). |
| Total Number Truck Loads (trucks) | = | Vol WW (bbl) divided by Truckload Capacity, which EPA assumed to be 100 bbl of wastewater per truck. |

### *3.1.7 Step 8 – UOG Alternative Wastewater Management Analysis - Baseline Costs*

In order to model all operating costs for each entity for the economic analysis (Section 4), EPA chose to estimate all costs for an entity, even those costs not associated with wastewater going to a POTW. Therefore, if an entity was identified as sending any of their 2016 UOG rule defined UOG wastewater to a POTW, EPA chose to estimate all of the costs that entity incurred for all of their wastewater management portfolio, including all wastewater management approaches used (e.g., storage). As can be seen in the UOG Alternative Wastewater Management Analysis (DCN SGE01419), many entities sent their wastewater to more than just POTWs. EPA

prepared the UOG Alternative Wastewater Management Analysis spreadsheet (DCN SGE01419) to estimate the baseline costs incurred by the entity identified in Step 4 to manage all of their wastewater generated in 2016, regardless of management method. EPA developed and populated the spreadsheet as described in Table A-7 in Appendix A. The assumptions are described below:

*Baseline Transportation Costs*

EPA estimated transportation costs for all 2016 wastewater managed by an operator who discharged at least some portion of their wastewater to POTWs in 2016. As applicable, this included transportation costs to POTWs, CWT facilities, disposal wells, reuse/recycle, storage pending disposal or reuse, road spreading, and landfills. In general, EPA used Equation 3 below to calculate baseline transportation costs for each wastewater management approach employed for each well by an entity and then summed the transportation costs for all wells operated by each entity.

**Equation 3**

$$\textit{Baseline Transp Cost} = \textit{Baseline Transp Time} \times \textit{1hr. /60 min} \times \textit{Trucking Cost Factor} \times \textit{Vol WW}$$

where:

| | | |
|---|---|---|
| Baseline Transp Cost ($) | = | Baseline transportation cost for 2016 for a specific record[9] |
| Baseline Transp Time (min) | = | GIS calculated trucking time to transport generated wastewater from a specific well to a specific waste facility in 2016. |
| Trucking Cost Factor ($/bbl/hr) | = | Fee paid by operators for trucking wastewater. Calculated in Equation 2. |
| Vol WW (bbl) | = | Volume of wastewater generated by a specific well and sent to a specific waste facility in 2016. |

EPA used slightly different assumptions for the "Baseline Transp Time" variable in Equation 3 above depending on the baseline management approach.

- POTWs, CWT Facilities, and Disposal Wells – EPA calculated the transport time using ArcGIS (see Step 6) with the well and waste facility latitude and longitudes reported in the PA DEP waste reports as inputs.

- Reuse/Recycle – For wells where generated wastewater is reported as reuse/recycle, the location for wastewater reuse/recycle is not reported. In lieu of well-specific reuse/recycle location, EPA calculated trucking times from the well that generated the wastewater to the average latitude and longitude

[9] A "record" refers to a waste record in PA DEP's Oil & Gas Waste Reports. A specific waste report provides a listing of waste produced by a given well for a specific waste stream and waste facility. This information is reported to PA DEP by oil and gas operators.

for all the wells owned by the operator. This methodology assumes that wastewater is not shared with other operators.

- Road spreading – Some road spreading records included exact latitude and longitudes for the road spreading location, which EPA used to estimate trucking times. For those that did not, EPA estimated latitudes and longitudes for trucking using the county and municipality name that accepted the wastewater for road spreading.

- Storage Pending Disposal or Reuse – EPA assumed zero transportation costs based on the assumption that wastewater is stored at the well pad.

- Landfill – Since some operators reported sending waste to landfills, EPA included these costs in calculating their baseline costs. Wastes managed at landfills include materials such as drill cuttings. EPA calculated the transport time using ArcGIS (see Step 6) and the well and landfill latitudes and longitudes reported in the PA DEP waste reports as inputs. Because all waste sent to landfills was solid, reported in units of tons, EPA converted the trucking cost factor from units of $/bbl/hr to $/ton/hr by multiplying by a factor of 10 barrels/ton. This methodology assumes that the hourly rate for trucks hauling solid waste are the same as those for trucks hauling wastewater, and that each truck can haul 10 tons of solid waste.

*Baseline Management Costs*

For each record, EPA used Equation 4 to calculate the baseline management costs paid for wastewater management (e.g., to a CWT facility for treatment) by entity in 2016. EPA summed the baseline management costs for all wells operated by each entity.

**Equation 4**

$$Baseline\ Mgmt\ Costs = Vol\ WW \times Mgmt\ Fee$$

where:

| | | |
|---|---|---|
| Baseline Mgmt Cost ($) | = | Baseline management cost for 2016 for a specific record. |
| Vol WW (bbl) | = | Volume of wastewater generated by a specific well and sent to a specific waste facility in 2016. |
| Mgmt Fee ($/bbl) | = | $ per barrel fee charged to an operator for a specific waste facility or wastewater management approach. |

EPA used slightly different assumptions for the "Mgmt Fee" in Equation 4 above depending on the baseline wastewater management approach.

- POTWs, CWT Facilities, Disposal Wells – EPA used the wastewater management costs determined in Step 7.

- Reuse/Recycle – All reuse/recycle records from PA DEP in EPA's 2016 baseline analysis included the comment "REUSE WITHOUT PROCESSING AT A PERMITTED FACILITY" indicating that these wastewaters were not treated prior to reuse in exploration and production activities. However, EPA conservatively assumed that operators did treat a portion of this wastewater using non-TDS removal treatment technologies (i.e., relatively low-cost physical/chemical technologies that are incapable of removing total dissolved solids) because literature reports that such treatment is frequently done prior to reuse (DCN SGE00575; DCN SGE00635; DCN SGE00275; DCN SGE00625; DCN SGE00636; DCN SGE00276). EPA obtained costs for non-TDS removal treatment from EPA's report *Unconventional Oil & Gas Extraction Wastewater Treatment Technologies* (DCN SGE01186). EPA assumed that 50 percent of wastewater was treated, and that 50 percent was not treated. This assumption is based on citations in literature and EPA site visits to UOG operators, including Petroleum Equipment & Services Association's 2012 survey (DCN SGE00575), where UOG operators reported that 54 percent of produced water reused/recycled by the UOG industry in 2012 for fracturing requires minimal or no treatment. In addition, the EPA conducted several site visits and conference calls with operators that have increasingly reused/recycled wastewater with no treatment (DCN SGE00635; DCN SGE00275; DCN SGE00625; DCN SGE00636; DCN SGE00276).

- Storage Pending Disposal or Reuse – EPA assumed zero management cost because this wastewater was not yet transferred to a management location in 2016. Instead, EPA estimated a cost that operators paid to store the wastewater (see *Baseline Storage* section).

- Road spreading – EPA assumed zero management cost as there is no treatment cost associated with road spreading.

- Landfill – EPA assumed an average management fee of $47.10 per ton of solid waste that was sent to landfills in 2016. This assumption is based on values reported for landfills accepting drilling solid waste in an Argonne National Laboratory report (DCN SGE00139).

*Baseline Storage*

For each record where reuse/recycle or storage pending disposal management approaches were used, EPA used Equation 5 to calculate the baseline storage costs. EPA used storage costs associated with renting tanks to store wastewater before it is reused within the oil and gas extraction industry. EPA obtained tank rental fee and tank capacity values during site visits and conference calls with UOG operators for the UOG final rule (2016). EPA assumed storage costs to be zero for all other baseline management approaches (CWT facilities, POTW, landfill, road spreading) based on the assumption that wastewater is stored in permanent storage tanks located on each well pad. EPA assumed the costs for these permanent storage tanks are attributed to well development investment prior to 2016, and there is no current cost in 2016. This assumption is reasonable given that most of the wells have spud dates prior to 2010, and capital costs for permanent storage tanks would have been paid off in less than 5 years.

Rental costs for storage tanks are dependent on the number of days storage is required. EPA assumed that storage tanks would be required for 30 days.

**Equation 5**

$$Baseline\ Storage\ Cost = Vol\ WW / Storage\ Tank\ Capacity \times Storage\ Tank\ Rental\ Fee \times Number\ of\ Days$$

where:

| | | |
|---|---|---|
| Baseline Storage Cost ($) | = | Baseline storage cost for 2016 for a specific record. |
| Vol WW (bbl) | = | Volume of wastewater generated by a specific well and reported as re-used and/or stored by an operator in 2016. |
| Storage Tank Capacity (bbl/tank) | = | Average tank volume reported by operators during EPA site visits and conference calls. |
| Frack Tank Rental Fee ($/tank/day) | = | Average $ per tank per day rental fee charged to an operator for renting a storage tank, reported by operators during EPA site visits and conference calls. |
| Number of Days | = | Number of days wastewater must be stored. |

*Total Baseline Costs*

For each record, EPA used Equation 6 to calculate total baseline costs by entity in 2016.

**Equation 6**

$$Total\ Baseline\ Costs = Baseline\ Mgmt\ Cost + Baseline\ Transp\ Costs + Baseline\ Storage\ Costs$$

where:

| | | |
|---|---|---|
| Total Baseline Cost ($) | = | Total baseline cost for 2016 for a specific record in 2016. |
| Baseline Mgmt Cost ($) | = | Baseline management costs for 2016 for a specific record, calculated in Equation 4. |
| Baseline Transp Cost ($) | = | Baseline transportation costs for 2016 for a specific record, calculated in Equation 3. |
| Baseline Storage Cost ($) | = | Baseline storage costs for 2016 for a specific record, calculated in Equation 5. |

### *3.1.8 Step 9 – UOG Alternative Wastewater Management Analysis - Incremental Costs*

EPA prepared the UOG Alternative Wastewater Management Analysis spreadsheet to estimate the incremental costs that would be incurred by the operators identified in Step 4 to eliminate discharging UOG wastewater to POTWs and instead send their wastewater to the closest available CWT facilities or disposal wells. EPA developed and populated the spreadsheet

as described in Table A-7 in Appendix A. The remainder of this section provides a brief overview of these activities.

EPA estimated incremental costs as the difference in cost between the baseline wastewater transportation and management for UOG discharges to POTWs compared to an alternative management approach (i.e., CWT facility or disposal well). All remaining cost components (e.g., onsite storage) are not expected to vary post-compliance, because for purposes of this analysis EPA assumes that wastewater sent to a POTW would be replaced only by sending wastewater to a CWT facility or disposal well, and therefore the other cost components are not expected to contribute to the incremental costs. EPA used the following steps:

*Incremental Transportation Costs*

EPA used the following steps to calculate incremental transportation costs. EPA performed these steps for both the nearest alternative CWT facility and disposal well determined in step 6.

1. For each record, EPA used Equation 7 to calculate the incremental transport time as the difference between the time to truck the wastewater to the POTW (baseline) and the time to truck the wastewater to the alternative wastewater management approach (i.e., the nearest CWT facility and nearest disposal well determined in Step 6). Note that the incremental transport time can be positive or negative, depending on whether the closest alternative CWT facility or disposal well is closer or further away from the well than the POTW.

2. For each record, EPA calculated the incremental transportation cost ($) by multiplying the incremental transport time by the trucking cost factor, and then multiplying by the volume of wastewater discharged to a POTW in 2016.

**Equation 7**

$$Incr\ Transp\ Time = Alt\ Transp\ Time - Baseline\ Transp\ Time\ to\ POTW$$

**Equation 8**

$$Incr\ Transp\ Cost = Incr\ Transp\ Time \times 1\ hr\ /60\ min \times Trucking\ Cost\ Factor \times Vol\ WW_{POTW}$$

where:

| | | |
|---|---|---|
| Incr Transp Time (+/- min) | = | Time difference between transporting generated wastewater to an alternative waste treatment site (CWT facility or disposal well) versus POTW, can be + or –. |
| Alt Transp Time (min) | = | GIS calculated time per well to transport generated wastewater to alternative treatment site. |

| | | |
|---|---|---|
| Baseline Transp Time to POTW (min) | = | GIS calculated time per well to transport generated wastewater to POTW. |
| Incr Transp Cost (+/- $) | = | Difference in transportation cost per well between alternative (CWT facility/disposal well) and POTW. |
| Trucking Cost Factor ($/bbl/hr) | = | Weighted average fee paid by operators for trucking wastewater. Calculated in Equation 1<br>Truck Load Hours = Estimated Driving Time (min) × (1 hr / 60 min) / (Vol WW (bbl) / Truckload Capacity)<br><br>Equation 2 of Step 7. |
| Vol WW $_{POTW}$ (bbl) | = | Reported volume of wastewater per well discharged to a POTW in 2016. |

*Incremental Wastewater Management Costs*

EPA used the following steps to estimate incremental wastewater management costs charged by CWT facilities and disposal wells. EPA performed these steps for both the nearest alternative CWT facility and disposal well determined in Step 6.

1. For each record, EPA identified the management fee, in $/bbl, for the alternative waste facility (i.e., nearest CWT facility and disposal wells) identified in Step 6. However, EPA did not have facility-specific management prices for 12 out of 24 CWT facilities and for 37 out of 48 disposal wells. Instead, EPA used an average of all CWT facility cost data when estimating costs for these CWT facilities without specific management costs, and EPA used an average of all disposal well cost data when estimating costs for these disposal wells without specific costs(i.e., for CWTs without specific management fees, an average of all CWT facility fees is used instead for that CWT facility fee, and for disposal wells without a specific managment fee, an average of all disposal well fees is used instead for that disposal well management fee).

2. For each record, EPA used Equation 9 to calculate the difference between this alternative management fee and the baseline management fee (i.e., the $/bbl charge from the POTW).

3. For each record, EPA used Equation 10 to calculate the incremental wastewater management costs ($) for the nearest alternative CWT facility and nearest disposal well. This excludes transportation costs.

**Equation 9**

$$Incr\ Mgmt\ Fee = Alt\ Mgmt\ Fee - Baseline\ Mgmt\ Fee$$

**Equation 10**

$$Incr\ Mgmt\ Costs = Incr\ Mgmt\ Fee \times Vol\ WW_{POTW}$$

where:

| | | |
|---|---|---|
| Incr Mgmt Fee (+/- $) | = | Difference in price charged by POTW compared to the alternative CWT facility and disposal well. |
| Alt Mgmt Fee ($/bbl) | = | Price charged to operators for sending wastewater to the alternative CWT facility and disposal well. |
| Baseline Mgmt Fee ($/bbl) | = | Price charged to operators for sending wastewater to the POTW in 2016. |
| Incr Mgmt Costs (+/- $) | = | Incremental management cost for sending wastewater to the nearest CWT facility and disposal well instead of a POTW. |
| Vol WW $_{POTW}$ (bbl) | = | Reported volume of wastewater per well discharged to a POTW in 2016. |

*Final Incremental Costs*

1. For each record, EPA calculated the total incremental wastewater management cost for wastewater management alternatives ($) by summing the incremental transportation and incremental management costs to alternatively send the wastewater to the nearest CWT facility and to the nearest disposal well as shown in Equation 11.

2. For each record, using the results from step 1 above, EPA selected the least expensive wastewater management alternative for each well by comparing the total incremental wastewater management costs for each alternative (i.e., CWT facility versus disposal well). See Equation 12.

**Equation 11**

$$CWT\ Cost = Incr\ CWT\ Transp\ Cost + Incr\ CWT\ Mgmt\ Cost$$

$$Disposal\ Well\ Cost = Incr\ Disposal\ Well\ Transp\ Cost + Incr\ Disposal\ Well\ Mgmt\ Cost$$

**Equation 12**

$$If\ CWT\ Cost > Disposal\ Well\ Cost,\ choose\ Disposal\ Well$$

$$If\ CWT\ Cost < Disposal\ Well\ Cost,\ choose\ CWT$$

where:

| | | |
|---|---|---|
| CWT Cost ($) | = | Total cost per well to dispose of wastewater at CWT facilities. |
| Incr CWT Transp Cost (+/- $) | = | Difference in transportation cost per well between CWT facility and POTW. |
| Incr CWT Mgmt Costs (+/- $) | = | Incremental management cost for sending wastewater to the nearest CWT facility instead of a POTW. |

| | | |
|---|---|---|
| Disposal Well Cost ($) | = | Total cost per well to dispose of wastewater at disposal wells. |
| Incr Disposal Well Transp Cost (+/- $) | = | Difference in transportation cost per well between disposal well and POTW. |
| Incr Disposal Well Mgmt Costs (+/- $) | = | Incremental management cost for sending wastewater to the nearest disposal well instead of a POTW. |

### *3.1.9 Step 10 – Identify and Remove Stripper Wells*

EPA added 2016 oil and gas production data to the Alterative Wastewater Management Cost Analysis spreadsheet (DCN SGE01419) to identify and remove stripper wells from the cost analysis because stripper wells (as defined at 40 CFR 435.60) are not subject to the UOG rule. Oil and gas production data include separate production data fields for each well including oil quantity (bbl), oil production days (days), gas quantity (MCF), gas production days (days), condensate production (bbl), and condensate production days (days). EPA used these fields to identify stripper wells using the following steps:

1. Calculated the average quantity of oil produced per day in 2016 by dividing oil quantity by the oil production days.

2. Calculated the average gas to oil ratio in 2016 by dividing gas quantity by the oil quantity in 2016.

3. Identified wells as stripper wells if they generated less than 10 barrels per day of oil (Step 1) and had a gas to oil ratio less than 15,000 cubic feet to barrels (Step 2).

4. Removed the identified stripper wells from the overall cost analysis because they would not be subject to the UOG rule.

## 3.2 Alternative Wastewater Management Analysis Results

Table 3-4 presents summary statistics of the results of the Alternative Wastewater Management Analysis. Outputs from the Alternative Wastewater Management Analysis are key inputs to EPA's economic achievability analysis described in Section 4.

**Table 3-4. Alternative Wastewater Management Analysis Results**

| Cost Output | Result |
|---|---|
| **Baseline Costs** | |
| A. Operators Discharging 2016 UOG Rule Defined UOG Wastewater to POTWs | 22 |
| B. Total Oil and Gas Wells (UOG and COG) Producing Oil or Gas Owned by (A) Operators | 18,136 |
| C. Total Oil and Gas Wells (UOG and COG) Generating Wastewater Owned by (A) Operators | 5,863 |
| D. Total Baseline Costs for (B) Wells | $6,043,000 |
| **Incremental Costs** | |
| A. Total Wells with Incremental Costs | 959 |
| B. Total Incremental Transportation Cost ($) | $21,109 |
| C. Total Incremental Management Cost ($) | $43,798 |

**Table 3-4. Alternative Wastewater Management Analysis Results**

| Cost Output | Result |
|---|---|
| D. Total Incremental Transportation and Management Cost ($) (B+C=D) | $64,907 |

Source: DCN SGE01419.

## 3.3 Cost Analysis Uncertainties and Limitations

EPA identified uncertainties and limitations in the Alternative Wastewater Management Analysis:

- As described in Section 3.1.4, some operators incorrectly reported wastewater volumes to PA DEP. Where EPA had updated information, it incorporated that information in its analyses. Other entities may have similar errors; however, a review of the data did not indicate any obvious errors.

- As described in Section 3.1.3, EPA assumed wells with formation information "not reported" are UOG and estimated incremental costs for these wells if they discharged to POTWs in 2016. This would lead to an overestimation of costs to the extent that these unknown facilities are not UOG under the 2016 UOG rule's definition of UOG. Seven percent of the total costs to comply (Table 3-4) are attributed to unknown formations.

- EPA used GIS analysis to estimate real world driving distances and times. Real world driving distances and times may be greater or fewer.

- EPA assumed the closest CWT facility or disposal well would be used as an alternative to discharging to POTWs. While EPA has no data to indicate that these alternatives are not available, EPA performed a sensitivity analysis to estimate the cost impact or transporting to the second closest CWT facility/disposal well instead (see Appendix B). This analysis demonstrated that while total costs to would increase under this scenario, economic impacts as described in Section 4 would remain the same.

- One CWT facility (Clearmont Storage Facility) was not identified by the GIS analysis as the closest alternative management approach for any UOG wells, even though it is located closest to a number of these wells. This is likely due to a factor such as an incomplete GIS layer, as this facility was recently constructed, and therefore the map layer used at the time of the analysis may not have contained a viable trucking route to the facility. This may lead to an overestimation of the incremental compliance costs for some undetermined number UOG wells.

# 4. ECONOMIC IMPACT ANALYSIS

## 4.1 Overview of Discounted Cash Flow Analysis

EPA used a discounted cash flow (DCF)-based analysis to assess the economic achievability of the rule. This analysis tests the effects of the costs of compliance on the financial performance and business value of the regulated entities, based on changes in after-tax cash flow (ATCF) and the discounted present value of ATCF. The discounted present value of cash flow provides a measure of business value. Reduction in business value, specifically when business value would become negative because of incremental compliance costs, is an indicator of potential adverse financial impact of the rule's requirements.

EPA performed the impact analysis in two steps:

1. **Baseline analysis,** to assess business condition and value before changes in regulatory requirements. A key purpose of this analysis is to identify entities that appear to have negative profits independent of increased regulatory costs.
2. **Post-compliance analysis**, to asses change in business value due to regulatory requirements. This analysis assesses the reduction in business value from compliance costs, focusing on whether some entities' business value is positive in the baseline but turns negative because of compliance requirements.

### *4.1.1 Analysis Period and Dollar Year*

EPA relied on financial data reported for 2016 in its data requests to 9 entities (described in Section 2) to analyze the financial health of the entities that will likely need to make changes to comply with the UOG rule (regulated entities). For this analysis, EPA adjusted this financial data, and all financial data values used in the analysis, to 2017 dollars using the Gross Domestic Product (GDP) price deflator index (DCN SGE01436). EPA analyzed each entity over a ten-year analysis period.

### *4.1.2 Baseline Analysis Methodology*

EPA performed the business value analysis on the basis of after-tax cash flow (ATCF), including an allowance for ongoing capital outlays, that is available to an entities' providers of capital – i.e., its creditors and equity owners.[10] When discounted over an analysis period using an appropriate cost of capital for calculating present value, this metric yields an estimate of business value based on accepted financial analysis conventions.

A key component of the ATCF calculation is operating cash flow, which is the cash, on an after-tax basis, provided by a business' ongoing operations and before payments to providers of capital. The provision for ongoing capital outlays is then subtracted from operating cash flow to yield the after-tax cash flow measure that is used in analyzing business value. EPA calculated operating cash flow (*OPCF*) for each entity in each year of the analysis period as follows:

[10] This metric of after-tax cash flow, when defined to include an allowance for ongoing capital outlays, is often referred to as *free cash flow*.

**Equation 13**

$$OPCF = Rev - FclCost - Tax$$

where:

| | | |
|---|---|---|
| OPCF | = | Operating cash flow (defined as pre-interest, but after-tax). |
| Rev | = | Total revenue. |
| FclCost | = | Total facility costs, excluding depreciation and interest. |
| Tax | = | Federal and state corporate income taxes. |

In this calculation, depreciation is excluded to account for the fact that depreciation is a non-cash charge.

Because a business needs to replace and/or refurbish its capital equipment to maintain operations, the operating cash flow value described above will generally overstate the cash flow that is available to providers of capital – creditors and equity owners – and that would be the basis for estimating business value as a going-concern. Accordingly, for assessing business value, it is appropriate to adjust operating cash flow for ongoing capital expenditures. One approach is to estimate the ongoing capital outlay as equal to depreciation; EPA used this approach for this analysis. EPA finds this reasonable because depreciation is meant to reflect the cost over time from consumption – i.e., using up – of capital equipment and even though depreciation would still reflect historical purchase values, which could be quite old, the value is close in concept to the value needed as a replacement/refurbishment value, on a steady state basis (i.e., ongoing capital outlay). Using this approach, EPA estimated ATCF, with allowance for ongoing capital replacement (i.e., depreciation, in this approach) for each facility using the following equation:

**Equation 14**

$$ATCF = Rev - FclCost - Tax - Depr$$

where:

| | | |
|---|---|---|
| ATCF | = | After-tax cash flow. |
| Rev | = | Total revenue. |
| FclCost | = | Total facility costs, excluding depreciation and interest. |
| Tax | = | Federal and state corporate income taxes. |
| Depr | = | Depreciation as a proxy for capital replacement. |

EPA used the resulting ATCF values in the DCF-based analysis of business value. EPA calculated the ATCF for each year of the analysis period,[11] then calculated the baseline present value of after-tax cash flow ($DCF_{BL}$) by taking the present value of the ATCF time series. In performing the discounted present value analysis, EPA used the OMB recommended real discount rate of 7 percent to discount the 10-year cash flow series. EPA calculated the present value of the cash flow series as follows:

[11] A description of how EPA projected costs and revenues over the analysis period can be found in Section 4.2.

**Equation 15**

$$DCF_{BL} = \left( \sum_{i=0}^{9} \frac{ATCF_i}{(1+r)^i} \right)$$

where:

| | | |
|---|---|---|
| $DCF_{BL}$ | = | Baseline present value of after-tax cash flow. |
| $ATCF_i$ | = | After-tax cash flow for year i. |
| i | = | The given year in the 10-year analysis period beginning with the year of compliance (i=0). |
| r | = | The OMB recommended real discount rate of 7 percent (DCN SGE01444). |

EPA recorded the results for each entity and did not carry forward entities with negative DCF value in the baseline to the post-compliance impact analysis because those entities are shown to be negative in profit without any post-compliance incremental costs, and so the effect of the incremental costs affecting an entity's profits from positive to negative cannot be demonstrated.

### *4.1.3 Post-Compliance Analysis Methodology*

EPA performed an analysis of compliance impact on regulated entities using a DCF-based analysis of the change in business value of facilities resulting from an occurrence of compliance costs. EPA considers entities with a positive business value in the baseline, but that turns negative after accounting for compliance costs, as potential closures due to the regulation.

As described in Section 3, EPA developed incremental cost estimates for complying with the UOG rule for all entities for non-surveyed entities and surveyed entities. To estimate the impact these costs may have on regulated entities, EPA estimated the after-tax present value of compliance costs on a constant dollar basis. To adjust the entity compliance costs from a pre-tax basis to an after-tax basis, EPA determined the tax reduction associated with the annual compliance expense. EPA used the following equation to calculate the combined tax rate ($\tau_c$) for each entity in order to adjust compliance costs to an after-tax basis:

**Equation 16**

$$\tau_c = \tau_f + \tau_s - \tau_f * \tau_s$$

where:

| | | |
|---|---|---|
| $\tau_c$ | = | Combined tax rate. |
| $\tau_f$ | = | Federal corporate income tax rate[12]. |
| $\tau_s$ | = | State of Pennsylvania corporate income tax rate[13]. |

[12] The federal corporate income tax rate is 21 percent (https://www.irs.gov/pub/irs-pdf/i1120.pdf).

[13] Pennsylvania's corporate income tax rate is 9.99 percent (http://www.revenue.pa.gov/GeneralTaxInformation/News%20and%20Statistics/ReportsStats/TaxCompendium/Documents/2017_tax_compendium.pdf).

EPA then calculated the present value of after-tax compliance costs ($CmplC_{pv}$) over the analysis period as follows:

**Equation 17**

$$CmplC_{pv} = \left( \sum_{i=0}^{9} \frac{OM_i - \tau_c * OM_i}{(1+r)^i} \right)$$

where:

| | | |
|---|---|---|
| $CmplC_{pv}$ | = | Present value of after-tax compliance costs. |
| $OM_i$ | = | O&M costs in year i. |
| i | = | The given year in the 10-year analysis period beginning with the year of compliance (i=0). |
| $\tau_c$ | = | Combined tax rate. |
| r | = | The OMB recommended real discount rate of 7 percent (DCN SGE01444). |

EPA subtracted the present value of after-tax compliance costs ($CmplC_{PV}$) from the baseline present value of after-tax cash flow ($DCF_{BL}$) to estimate the post-compliance business value of the facility ($DCF_{PC}$):

**Equation 18**

$$DCF_{PC} = DCF_{BL} - CmplC_{pv}$$

where:

| | | |
|---|---|---|
| $DCF_{PC}$ | = | Post-compliance business value of the entity. |
| $DCF_{BL}$ | = | Baseline present value of after-tax cash flow. |
| $CmplC_{pv}$ | = | Present value of after-tax compliance costs. |

EPA then evaluated each entity's post compliance DCF: a post-compliance DCF of zero or less would indicate a possible post-compliance closure while a positive value would indicate that the entity would continue to operate after compliance.

## 4.2 Assumptions for Projecting Over the Ten-Year Analysis Period for Surveyed Facilities

EPA conducted the DCF analysis over a ten-year analysis period, beginning in 2016, by projecting data over the analysis period based on data provided by entities in response to EPA's data request. As described in Section 2, EPA requested data from a subset of entities that will likely incur costs to comply with the UOG rule. This section describes how EPA projected each data item over the analysis period for the eight entities that responded to EPA's data request. Section 4.3 describes how EPA modeled the non-surveyed entities, and how these projections differ for non-surveyed entities.

### *4.2.1 Projecting Crude Oil and Natural Gas Prices*

A key consideration in this analysis is the expected price for crude oil and natural gas. Since the WTI oil price peak of 2008-2014 and Henry Hub gas price peak of 2005-2009, prices have been lower in more recent years, reaching their lowest values in the first year of the analysis, 2016. However, since 2016, prices have increased and are expected to continue to increase over the analysis period, according to EIA. Using publicly available data, EPA accounted for this expected increase in oil and gas prices over time by developing oil and natural gas price projections based on analyses from EIA's 2018 Annual Energy Outlook reference case. EPA used the following data to calculate crude oil and natural gas price projections:

- Historical Pennsylvania crude oil first purchase prices[14] (DCN SGE01441).
- Historical Henry Hub natural gas spot prices (DCN SGE01440).
- Henry Hub and WTI Reference case price projections, for the period 2016-2050, from 2018 Annual Energy Outlook (DCN SGE01439).

EPA began the crude oil price projection from EIA's reported 2016 and 2017 Pennsylvania crude oil first purchase price. EPA then applied the projected year-to-year percentage change in WTI prices from Annual Energy Outlook's reference case to estimate crude oil prices in years 3-10 of the analysis period.

An appropriate basis for modeling the price facilities will receive for their natural gas would be wellhead prices in Pennsylvania. However, because EIA only publishes Henry Hub natural gas prices, which are downstream from the wellhead and thus not the appropriate price concept for modeling the price at the facility, EPA relied on natural gas production and revenue from natural gas operations as reported in responses to EPA's data requests. EPA estimated an average natural gas price from these data and used this estimate as a starting point for the first year of the analysis.[15] EPA then applied the projected year-to-year percentage change in Henry Hub prices from Annual Energy Outlook's reference case to estimated natural gas prices in years 2-10 of the analysis period.

### *4.2.2 Projecting Crude Oil, Natural Gas, and Condensate Production*

EPA used reported production levels for 2016 and 2017 as production in the first two years of the analysis period. Production in years 3-10 was assumed to be on a constant trend, equal to 2017 production. EPA decided to assume constant production after testing several models using historical 2006-2016 PA oil production and PA crude oil first purchase prices for all impacted entities. These models used historical price and production data to estimate price-production models that could be used to estimate future production given future prices. EPA developed the following price-production models based on historical 2006-2016 data:

- Entity-specific linear trend line.

[14] EIA defines first purchase price as "the price for domestic crude oil reported by the entity that owns the crude oil the first time it is removed from the least boundary" (https://www.eia.gov/tools/glossary/index.php?id=F).

[15] EPA excluded one outlier data point from the estimated average natural gas price received by surveyed entities in 2016.

- Entity-specific quadratic trend line.
- Entity-specific constant production based on 2016 production.
- Entity-specific linear trend line assuming averaged prices.[16]
- Linear fit using average production per entity.

In order to determine which price-production model was the most appropriate to use, EPA used each model to estimate 2017 oil production (as an example of all factors) and compared the estimate to the actual 2017 production value. The constant production model resulted in the lowest total error (i.e., difference between estimated and actual oil production) across all entities. The model with the second lowest total error (i.e., difference between estimated and actual oil production) was the entity-specific linear trend line. EPA tested these two models using natural gas production and prices as well, and, again, the constant production model resulted in the smallest error when predicting 2017 natural gas production. EPA therefore assumed constant 2017 oil, gas, and condensate production over the remainder of the analysis period (years 3-10).

### *4.2.3 Projecting Revenue*

Revenue in the first year of the analysis period was as reported in EPA's data request. EPA calculated oil and gas revenue in years 2-10 of the analysis period as the product of projected oil prices and oil production, and gas prices and gas production. EPA estimated revenue from condensate production would be equal to the product of projected condensate production and price of oil.[17] EPA assumed all other non-oil, non-gas, and non-condensate revenue would remain constant over the analysis period because EPA had no basis/data to increase or decrease it, and given that, assuming this other revenue was constant seemed more reasonable than changing it.

### *4.2.4 Projecting Operating Costs*

EPA received data on operating costs attributable to oil operations and to gas operations in responses to EPA's data request. EPA used operating costs in year 1 as reported. Together with oil and gas production data, EPA used reported oil and gas operating costs to calculate unit operating costs ($/bbl oil, and $/Mcf gas). EPA assumed a constant unit operating cost over the analysis period since most of these wells have been operating for years (if not decades) with nearly a 'steady-state' currently in place for costs. In years 2-10 of the analysis period, EPA calculated oil and gas operating costs as the product of the unit operating cost and projected production.

### *4.2.5 Projecting Quantity of Wastewater*

EPA assumed that production of wastewater per unit of oil or natural gas would remain constant over the analysis period. This is an appropriate assumption because (1) EPA had no other data, and (2) it is reasonable to assume operators will continue to generate a similar amount

[16] EPA averaged prices between each local minimum and maximum. Prices in 2006-2008 were set equal to the average over the same period; the 2009 price was set equal to the 2008-2009 average; prices in 2010-2013 were set equal to the 2009-2013 average; and prices in 2014-2016 were set equal to the 2013-2016 average.

[17] Condensate removed from natural gas is classified as crude oil by regulatory agencies, and refiners pay almost as much for condensate as crude oil (DCN SGE01445).

of wastewater relative to oil over the life of the well. EPA made this assumption for all oil and gas wells (UOG and COG), based on EPA's review of PA DEP Production and Waste Report data over a 5-year time period (DCN SGE01419). Using 2016 oil production, gas production, and wastewater production, EPA calculated unit wastewater production based on both oil and gas production for each facility (i.e., barrels of wastewater per barrel of oil, barrels of wastewater per Mcf of gas). EPA calculated wastewater production in years 2-10 as unit wastewater production times oil or gas production. To estimate the quantity of wastewater generated at facilities that produce both oil and gas, EPA conservatively used the unit wastewater production that resulted in the highest wastewater quantity (and thus the highest wastewater management and transportation costs).

### *4.2.6 Projecting Wastewater Management and Transportation Costs*

EPA received 2016 data on wastewater management and transportation costs for wastewater sent to a POTW, CWT facility, or disposal well by the 8 respondents to EPA's data request. EPA calculated the costs per barrel of wastewater and assumed this unit cost remained constant over the analysis period (in years 2 through 10) given that EPA had no other data or basis to assume it would increase or decrease. For example, a CWT may increase its price to accept wastewater if it sees oil and gas entities are receiving a higher price for selling their oil and gas product (assuming a cost pass through) over time or it may decrease its price to accept wastewater if the oil price decreases and entities decide not to bring their wastewater to the CWT because of prices that do not take into account the lower oil prices. Since EPA does not have knowledge of business decisions from CWTs, EPA assumed it was more reasonable to assume a constant unit cost than to increase or decrease it. Furthermore, SGE01452 does document that in the past, some CWTs have maintained prices for oil and gas entities in order to keep their business, even when costs for the CWT increased. EPA calculated total wastewater management and transportation costs as the product of this unit cost and project wastewater quantity, as described above.

### *4.2.7 Projecting Impact Fees, Other Costs, Depreciation, and Interest*

Impact fees, other (non-oil and gas operating) costs, deprecation, and interest in year 1 of the analysis period were as reported in the response to EPA's data request. EPA assumed each would remain constant over years 2 through 10 of the analysis period. It is appropriate to assume impact fees will remain constant since this is Pennsylvania law. It is appropriate to assume non-oil and gas operating costs are constant because EPA had no basis to increase or decrease it, and assuming this other cost was constant seemed more reasonable than changing it (e.g., personnel costs). It is appropriate to assume depreciation is constant in this approach because depreciation is meant to reflect the cost over time from consumption – i.e., using up – of capital equipment and even though depreciation would still reflect historical purchase values, which could be quite old, the value is close in concept to the value needed as a replacement/refurbishment value, on a steady state basis (i.e., ongoing capital outlay). It is appropriate to assume interest in year 1 is constant because generally a loan is negotiated as a long-term contract with the interest rate locked in for the life of the loan.

### *4.2.8 Projecting Federal and State Taxes*

EPA received data on 2016 federal and state taxes paid by surveyed entities. In some cases, entities reported taxes of zero. EPA assumed these facilities are S-corporations that do not pay corporate income taxes and would therefore have zero taxes over the analysis period.[18] If an entity reported paying taxes in 2016, EPA calculated taxes in years 2-10 as the product of earnings before taxes (EBT) and the combined tax rate (unless EBT is less than zero, in which case taxes are zero).

## 4.3 Assumptions for Modeling Non-Surveyed Facilities

EPA performed a baseline and post-compliance DCF analysis on entities that are expected to incur compliance costs but that did not receive a data request (non-surveyed entities). To do so, EPA modeled each non-surveyed entity using known production data and by assigning a model facility from among the surveyed entities. EPA assigned a model facility to each non-surveyed entity as follows:

- Compiled existing data on 2016 oil and natural gas production data for all survey and non-surveyed entities that likely need to make changes to comply with the 2016 UOG rule pulled from Pennsylvania datasets.
- Estimated 2016 revenue for non-surveyed entities as the product of production and price.
- Compiled existing data on revenue as reported for eight surveyed entities.
- Calculated the production mix for all entities as the ratio of oil production to gas production.
- Matched each non-surveyed entity to the closest surveyed entity based on estimated revenue and production (oil and gas) mix, because those factors would be fundamental to determining similarity across entities. In order to match on two variables, EPA minimized the sum of squared errors between the non-surveyed entity and each surveyed entity. First, EPA scaled revenue and production mix by that metric's average value across surveyed and non-surveyed entities to ensure that each metric contributed equally to the sum of squared errors. EPA then calculated the sum of squared errors for the two scaled metrics between each non-surveyed entity and each surveyed entity. The surveyed entity that resulted in the minimum sum of squared errors is that non-surveyed entity's "model facility".

Similar to how EPA analyzed impacts for surveyed entities that reported their information, EPA performed a DCF-based analysis on each non-surveyed entity. However, since EPA did not have specific financial information on the non-surveyed entities, EPA used financial

[18] EPA performed a sensitivity analysis to determine what impact, if any, this assumption had on the results of the DCF closure analysis. EPA determined the assumption has no impact on the results – assuming all facilities paid corporate income taxes resulted in the same number of baseline and post-compliance closures.

information from a surveyed entity that most closely matched it, which we call its model facility. To adjust the model facility's data to reflect the non-surveyed entity, EPA calculated a model adjustment factor as the non-surveyed entity's estimated 2016 revenue (product of production and price) divided by the model facility's reported 2016 revenue. EPA used the model adjustment factor to scale several data items, as described below.

To analyze non-surveyed entities, EPA used the same DCF analysis and assumptions described in the previous sections, with the following exceptions:

- Revenue in year 1 calculated as price times actual (2016) production (because EPA had 2016 production, a modeled adjustment factor wasn't needed).
- Oil and gas operating costs calculated as the model facility's unit operating cost ($/bbl, $/Mcf) times production at the non-surveyed entity (because EPA had 2016 production, a modeled adjustment factor wasn't needed).
- Impact fees in year 1 calculated as the model facility's reported impact fees times the model adjustment factor (because EPA did not have actual data for this factor of the modeled entity, the model adjustment factor is used).
- Other (non-oil and gas operating) costs in year 1 calculated as the model facility's reported other costs times the model adjustment factor (because EPA did not have actual data for this factor of the modeled entity, the model adjustment factor is used).
- Depreciation in year 1 calculated as the average ratio of depreciation to total revenue among all surveyed entities times the total revenue of the analysis entity.[19]
- Interest in year 1 calculated as the average ratio of interest to total revenue among all surveyed entities times the total revenue of the non-surveyed entity.[19]
- Federal and state taxes in year 1 calculated as the model entity's reported taxes times the model adjustment factor (because EPA did not have actual data for this factor of the modeled entity, the model adjustment factor is used). In year 2-10, if the analysis facility has positive EBT and the model entity reported paying taxes, taxes are calculated as the non-surveyed entity's EBT times the combined tax rate.

[19] Relative to other line items that are more closely related to the scale of production at a facility (e.g. operating costs), there is a much weaker relationship between depreciation and revenue, or interest and revenue. Model facility depreciation-to-revenue (and interest-to-revenue) is therefore not likely to be a reasonable metric for calculating depreciation at non-surveyed entities. As such, EPA did not adjust these items according to the model adjustment factor. Instead, EPA used an average value over the set of modeled entities as an approximation of the depreciation and interest relative to the size of UOG facilities.

## 4.4 Baseline Analysis Results

EPA performed the DCF baseline analysis for all entities. Based on the baseline analysis, seven entities are shown to be negative in profit without any post-compliance incremental costs, and so the effect of the incremental costs affecting an entity's profits from positive to negative cannot be demonstrated. EPA did not carry these entities forward to the post-compliance closure analysis, leaving 15 entities expected to incur compliance costs for the post-compliance analysis.

## 4.5 Post-Compliance Analysis Results

EPA found that none of the 15 entities expected to incur compliance costs would be at risk of closure because all continue to have positive profit after incurring the costs to comply. Table 4-1 summarizes the results of the DCF baseline and post-compliance closure analysis.

**Table 4-1. Results of Baseline and Post-Compliance Analysis**

| Title | Title |
|---|---|
| Baseline Closures | 7 of 22 Entities |
| Post-Compliance Closures | 0 of 15 Entities |

Source: DCN SGE01484.

## 4.6 Uncertainties and Limitations

- EPA based all oil and gas price projections on the price projections provided by the EIA. These price projections may be higher or lower over a 10-year period and given that the oil and gas market is a cyclical market, the prices may actually go down, as opposed to how EIA projected the prices as going up, over a 10-year period. While uncertain, EPA assesses the price projections based on EIA modelling to be reasonable because EIA's Annual Energy Outlook is a publicly published documentation of future price modelling. EIA includes the following documentation of EIA projections: "[1] Projections in the Annual Energy Outlook 2018 (AEO2018) are not predictions of what will happen, but rather modeled projections of what may happen given certain assumptions and methodologies. [2] The AEO is developed using the National Energy Modeling System (NEMS), an integrated model that captures interactions of economic changes and energy supply, demand, and prices. [3] Energy market projections are subject to much uncertainty, as many of the events that shape energy markets and future developments in technologies, demographics, and resources cannot be foreseen with certainty." (DCN SGE01438)

- EPA assumed a constant trend in modelling out 10 years for several elements of the model: oil, gas, and condensate production; operation costs; and unit costs of water. Over a 10-year timeframe, several factors may influence deviations from a constant trend for each of these elements. EPA does not have any future data to determine if any of these elements may change and found it more reasonable, for purposes of this analysis, that when in doubt, to keep factors constant if there is no other source to tell EPA if it will increase or decrease. As is discussed in EIA's projections, energy market projections are subject to much uncertainty, as many of the events that shape energy markets and future

developments in technologies, demographics, and resources cannot be foreseen with certainty.

# 5. COST TO REVENUE

The Regulatory Flexibility Act (RFA) requires federal agencies to consider the impact of their rules on small entities. The RFA describes the regulatory flexibility analyses and procedures that must be completed by federal agencies unless they certify that the rule, if promulgated, would not have a significant economic impact on a substantial number of small entities. This certification must be supported by a statement of factual basis, e.g., addressing the number of small entities affected by the proposed action, expected cost impacts on these entities, and evaluation of the economic impacts. Although this notice is not a proposal rulemaking, since EPA has consistently done a cost-to-revenue analysis in developing effluent limitations guidelines and standards EPA is providing an analysis in this notice as to whether the UOG rule would have "a significant impact on a substantial number of small entities" (SISNOSE) for this impact analysis. This assessment involved the following steps:

- Determining which of those entities are small entities, based on Small Business Administration (SBA) size criteria.

- Assessing the potential impact of the regulatory requirements on those small entities by comparing the estimated annualized compliance cost to revenue; the cost-to-revenue ratio indicates the magnitude of economic impacts. EPA used threshold compliance costs of 1 percent or 3 percent of revenue to categorize the degree of significance of the economic impacts on small entities.

- Assessing whether those small entities incurring potentially significant impacts represent a substantial number of small entities. EPA determined whether the number of small entities impacted is substantial based on (1) the estimated absolute numbers of small entities incurring potentially significant impacts according to the two cost impact criteria, and (2) the percentage of small entities in the relevant entity categories that are estimated to incur these impacts.

## 5.1 Analysis Approach

EPA identified the Small Business Administration (SBA) size threshold (https://www.sba.gov/document/support--table-size-standards) guidelines (2017). For the NAICs codes under Subsector 211 – Oil and Gas Extraction, employee size of 1,250 is considered a small business. EPA reviewed the employee count of the facilities that responded to its data request and found an average of 10 employees per entity. Given that the other entities reviewed for this analysis are also likely to have employee size below 1,250 (PGCC self-identified entities considered COG under Pennsylvania's definition as small businesses, DCN SGE01494), the other entities don't have 125X the oil or gas production that the surveyed entities have, so likely don't have 125X the employees the surveyed entities have, making them meet the SBA threshold, and over 99% of the oil and gas industry is considered small businesses according to Census, DCN SGE01449), all entities analyzed in this impact analysis are considered small businesses under the SBA guidelines.

As outlined in the introduction to this chapter, two criteria are assessed in determining whether a regulation would qualify for a no-SISNOSE finding:

- Is the absolute number of small entities estimated to incur a potentially significant impact, substantial?
- Do these significant impact entities represent a substantial fraction of small entities in the industry that could potentially be within the scope of a regulation?

A measure of the potential impact of a regulation on small entities is the fraction of small entities that have the potential to incur a significant impact. For example, if a high percentage of potentially small entities incur significant impacts even though the absolute number of significant impact entities is low, then the rule could represent a substantial burden on small entities. To assess the extent of economic/financial impact of a regulation on small entities, EPA compares estimated compliance costs to estimated entity revenue (also referred to as the "sales test"). The analysis is based on the ratio of estimated annualized after-tax compliance costs to annual revenue of the entity. EPA categorizes entities according to the magnitude of economic impacts they may incur as a result of the rule. EPA identifies entities for which annualized compliance costs are at least 1 percent and 3 percent of revenue. EPA then evaluated the absolute number. The Agency assumes that entities incurring costs below 1 percent of revenue are unlikely to face significant economic impacts, while entities with costs of at least 1 percent of revenue have a higher chance of facing significant economic impacts, and entities incurring costs of at least 3 percent of revenue have a still higher probability of significant economic impacts. For this analysis, EPA assumed that oil and gas entities would not be able to pass any of the increase in their production costs to consumers (zero cost pass-through). This assumption is used for analytic convenience and provides a worst-case scenario of regulatory impacts to oil and gas entities.

## 5.2 Results

Table 5-1 summarizes the results of the analysis for the UOG rule. EPA estimates that 1 small entity would incur costs exceeding 1 percent of revenue, and 0 small entities would incur costs of at least 3 percent of revenue. On the basis of percentage of small entities in the oil and gas extraction industry, given that there are over 6,000 entities in the oil and gas industry meet the SBA size standard for small business in this industry, the analysis shows a small fraction of small businesses of 0 percent incurring an impact at the 1 percent of revenue levels (DCN SGE01449).

**Table 5-1: Entity Annualized Cost-to-Revenue (CTR) Results**

| | Number of Entities with CTR <1% | Number of Entities with CTR 1-3% | Number of Entities with CTR >3% |
|---|---|---|---|
| Revenue – Year 1 | 21 | 1 | 0 |

Source: DCN SGE01484.

# 6. NON-WATER QUALITY ENVIRONMENTAL IMPACTS

EPA also evaluated the potential change in non-water quality environmental impacts that may occur when oil and gas entities eliminate discharging UOG wastewater to POTWs in Pennsylvania. For these analyses, EPA looked at the potential incremental effect on air pollution, solid waste generation, and energy consumption.

## 6.1 Air Pollution

Oil and Gas wastewaters contain organic compounds. When these wastewaters are treated at a POTW, they often pass through a series of collection and treatment units. These units are typically open to the atmosphere and allow wastewater containing organic compounds to contact ambient air. Atmospheric exposure of the organic-containing wastewater may result in significant water-to-air transfers of volatile organic compounds (VOCs). In general, POTWs have not installed air or wastewater treatment technologies designed to control the release of VOCs to the atmosphere. Additionally, POTWs do not typically employ best management practices designed to control VOC emissions (such as covering their treatment tanks). Therefore, as soon as these VOC- containing wastewaters contact ambient air, volatilization will begin to occur. Thus, volatilization of VOCs from oil and gas wastewater may begin immediately on receipt, or as the wastewater is treated.

The wastewater management alternatives that form the basis of the pretreatment standards are sending the wastewater to a CWT facility, underground injection, or recycle/re-use. EPA does not project incremental increases in air emissions for these alternatives. As is the case for POTWs, as soon as these VOC-containing wastewaters contact ambient air, volatilization will begin to occur. As a result, any wastewater management approach that include contact with ambient air, will similarly lead to air emissions. To the extent that produced water disposed of in underground injection results in less contact with ambient air than at POTWs, incremental VOC emissions may decrease.

## 6.2 Solid waste

Solid waste will be generated due to a number of treatment technologies that may be in place at POTWs such as gravity separators and biological treatment systems. The incremental quantity of solid waste generated from an alternative method, depends on the method. For example, UIC would likely lead to a decrease in sludge generation. Similarly, as most oil and gas wastewater that is re-used within the industry undergoes minimal treatment, sludge generation would likely decrease or remain the same. CWT facilities will likely generate additional solid waste over and above what would be generated at a POTW. The actual amount of sludge generation is dependent on the treatment processes in place. For example, chemical precipitation would likely result in additional sludge. However, even if all of the UOG wastewater currently sent to POTWs is alternatively managed by a CWT facility, because the volume of UOG wastewater is relatively small compared to the total volume of wastewater treated at CWT facilities, any additional sludge generated would similarly be small. When EPA promulgated the CWT rule in 2000, it estimated that the additional solid waste disposed in landfills would be less than 0.19% of the annual tonnage of waste currently disposed in landfills. See Development Document for Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry (EPA-821-R-00-020, August 2000).

## 6.3 Energy Requirements

As is the case for solid waste generation, the incremental change in energy requirements depends on the alternative wastewater management approach as well as the location of that alternative. Energy is required in transporting UOG wastewater to a POTW and also in operating the wastewater treatment systems at a POTW. To the extent that transportation distances increase or decrease for a non-POTW management approach, fuel usage will similarly be affected. EPA estimates the total incremental miles as a result of the alternative wastewater management approach are 3,700 miles, which correlates to approximately 600 gallons of fuel (DCN SGE01419). According to EIA, on-highway vehicles consumed approximately 40 billion gallons of distillate fuel in 2016 (DCN SGE01523). Regarding energy needed for treatment, whether energy needs increase or decrease depend on the alternative wastewater management method. For example, as most oil and gas wastewater that is re-used within the industry undergoes minimal treatment, energy usage for treatment may decrease. CWT facilities will likely require additional energy for treatment over and above what would be needed at a POTW. The actual incremental amount of energy depends on the treatment processes in place at the CWT. For example, chemical precipitation would likely result in additional energy requirements. However, even if all UOG wastewater currently sent to POTWs is alternatively managed by a CWT facility, because the volume of UOG wastewater is relatively small compared to the total volume of wastewater treated at CWT facilities, any additional energy requirements would similarly be small. When EPA promulgated the CWT rule in 2000, it estimated that the additional energy requirements associated with treatment would equate to 4,210 barrels of oil per day while overall consumption of oil in the United States at the time was 18.3 million barrels of oil per day. See Development Document for Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry (DCN SGE01534).

# 7. WATER QUALITY PARAMETERS IN SHALE, TIGHT, AND CONVENTIONAL OIL AND GAS WASTEWATER

To better understand why EPA included oil and gas wastewater extracted from tight and shale in the definition of unconventional, EPA is including this section to describe characteristics of these wastewaters. EPA analyzed produced water characterization data from the U.S. Geological Survey (USGS) National Produced Waters Geochemical Database v2.3 (DCN SGE01447; DCN SGE01446) to compare the concentrations of pollutants in wastewater generated by conventional, shale, and tight oil and gas well operations. EPA reviewed a subset of the formation and basin combinations reported in the USGS data[20] and assigned an EPA resource type based on EPA's definition of UOG. EPA also incorporated national and state water quality standards (WQS) data and POTW performance data to provide context to the produced water characterization data (DCN SGE01454).

## 7.1 Analysis Approach

The USGS Produced Water Geochemical Database v. 2.3 (USGS database) contains geochemical and other information for produced waters from oil and gas wells (DCN SGE01447; DCN SGE01446). The database contains over 114,000 records where each record represents a well for which produced water was sampled and analyzed. Each record includes basic well identification information such as API number, basin, and geological formation and includes up to 130 pollutant concentration measurements. While the database contains some records for produced water generated by geothermal and injection wells, over 113,000 of the 114,000 records are for produced water from oil and gas extraction wells. Some oil and gas extraction wells were sampled multiple times such that they have more than one record.

There are approximately 9,000 formation and basin combinations reported in the USGS data. EPA reviewed these formation and basin names to determine whether they meet the 2016 UOG rule's definition of UOG (i.e., tight gas, tight oil, shale gas, shale oil), but limited the review to the subset of formation and basin combinations with the greatest number of associated records. EPA's review included approximately 70 percent of the total well records from 600 different formations/basins. To conduct this review, EPA assigned an EPA resource type by searching for the basin and formation combination in EIA's Annual Energy Outlook (DCN SGE01190), shale map (DCN SGE01191), and tight map (DCN SGE00155). If the combination was listed by EIA as tight or shale, EPA assigned it a tight or shale resource type, respectively.

The "EPA Resource Type Crosswalk" tab in the USGS Produced Water Characterization Analysis Spreadsheet (DCN SGE01446) includes details on which formation and basin combinations EPA reviewed. Table 7-1 summarizes these resource type assignments. Well types reported by USGS as "Geothermal", "Injection", or "Undefined" were all given an EPA resource type "Indeterminate". In addition, for well types reported by USGS as "Conventional Hydrocarbon", EPA assigned a "Conventional Hydrocarbon" resource type if the formation name was complete (e.g., not reported as an acronym or number or blank) and if it was not found in any list of tight or shale formations reported by EIA. For well types reported by USGS as

[20] EPA reviewed over 600 out of approximately 9,000 formation and basin combinations, representing approximately 70% of the total USGS well records throughout the United States.

"Conventional Hydrocarbon", EPA assigned an "Indeterminate" resource type if the formation name was incomplete.

A number of concentration values in the USGS database were reported as "MDL" or "PQL". In the past for the effluent guidelines program, EPA has used one-half of the MDL in calculating summary statistics for data. However, since EPA did not know the MDL for data reported in the USGS database EPA instead excluded these results when preparing the tables in Section 7.2 as there is no feasible way to include the data. The number of MDL or PQL values reported in the database for each pollutant are indicated in the oil and gas wastewater characterization summary tables in Section 7.2.

## 7.2 Results

Table 7-1 presents data and statistics on select constituents in produced water from conventional, shale, and tight oil and gas operations in the Appalachian basin alongside relevant WQS data and typical POTW removal efficiencies. The shale formations in the Appalachian basin include the Marcellus. The tight formations in the Appalachian basin include the Bradford, Berea, Clinton, Medina, Tuscarora, and Venango. As shown in Table 7-1, the median values of concentrations of select pollutants found in produced water generated by conventional, shale, and tight oil and gas wells, exceed the maximum WQS.

POTW performance data indicate that POTWs do not effectively treat the pollutants shown in Table 7-1 (as well as other pollutants). Typical concentrations of untreated domestic wastewater are approximately 900 mg/L for TDS and approximately 100 mg/L for chloride (DCN SGE00167). Table 7-1 shows that TDS concentrations in samples of produced water from conventional, shale, and tight oil and gas wells in the Appalachian basin are orders of magnitude higher than these typical POTW influent concentrations, which could interfere with POTW operations or result in pass-through and discharge to the environment.

Table 7-2 presents the concentrations (excluding MDL/PQL values) of select constituents in produced water from conventional and unconventional oil and gas operations across the entire United States (as defined by the UOG rule). TDS in UOG produced water consists of dissolved matter including salts (e.g., sodium, chloride, nitrate, bromide), group II alkaline earth metals (e.g., calcium, strontium, barium), and other minerals and organic material. Table 7-2 shows that concentrations of TDS and its constituents are found in similar ranges in conventional and unconventional produced water.

**Table 7-1. Select Pollutants in Produced Water from Conventional, Shale, and Tight Oil and Gas Operations in the Appalachian Basin**

| | | Conventional[a] | | | | Shale[b] | | | | Tight[c] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Units | Range[d] | Median | Number of Data Points | Number of Data Points Reported as Below MDLs/PQLs[e] | Range[d] | Median | Number of Data Points | Number of Data Points Reported as Below MDLs/PQLs[e] | Range[d] | Median | Number of Data Points | Number of Data Points Reported as Below MDLs/PQLs[e] | Range of Water Quality Standards[f] | POTW Percent Removal (%)[g] |
| TDS | mg/L | 6,690 - 353,000 | 153,000 | 949 | 0 | 1,410 - 273,000 | 107,000 | 337 | 0 | 69,000 - 385,000 | 273,000 | 455 | 0 | 250 - 1,000 | 8 |
| Bromide | mg/L | 20 - 2,240 | 615 | 671 | 25 | 10 - 2,470 | 608 | 281 | 5 | 429 - 2,920 | 1,670 | 377 | 0 | N/A | N/A |
| Calcium | mg/L | 79 - 46,400 | 11,400 | 900 | 1 | 124 - 24,000 | 8,070 | 382 | 0 | 4,670 - 51,100 | 28,300 | 453 | 2 | N/A | 9 |
| Chloride | mg/L | 3,970 - 205,000 | 92,000 | 908 | 1 | 168 - 158,000 | 64,400 | 325 | 0 | 44,200 - 208,000 | 149,000 | 471 | 0 | 250 | 57 |
| Sodium | mg/L | 2,130 - 82,300 | 37,300 | 884 | 2 | 239 - 57,900 | 28,000 | 353 | 0 | 20,500 - 75,600 | 55,400 | 443 | 2 | N/A | 3 |
| Barium | mg/L | 7 - 1,870 | 342 | 395 | 70 | 1 - 9,320 | 1,060 | 323 | 0 | 1 - 864 | 10 | 45 | 7 | 1.00 - 2.00 | 16 |
| Boron | mg/L | 10 - 135 | 41 | 8 | 1 | 0 - 37 | 13 | 136 | 0 | 17 - 119 | 39 | 69 | 0 | N/A | 30 |
| Strontium | mg/L | 7 - 2,030 | 176 | 386 | 56 | 6 - 5,330 | 1,380 | 364 | 0 | 118 - 1,480 | 959 | 424 | 5 | N/A | N/A |
| Gross alpha | pCi/L | N/A | N/A | 0 | 0 | 56 - 20,600 | 5,700 | 103 | 2 | N/A | 10,400 | 1 | 0 | N/A | N/A |
| Gross beta | pCi/L | N/A | N/A | 0 | 0 | 64 - 7,940 | 1,630 | 101 | 2 | N/A | 11,600 | 1 | 0 | 1,000 | N/A |
| Radium-226 | pCi/L | 124 - 4,840 | 690 | 11 | 0 | 12 - 10,300 | 1,270 | 98 | 3 | 59 - 1,360 | 370 | 43 | 2 | N/A | N/A |
| Radium - 228 | pCi/L | 129 - 2,080 | 1,170 | 10 | 0 | 1 - 1,110 | 143 | 94 | 5 | 54 - 6,170 | 500 | 27 | 2 | N/A | N/A |

Source: EPA analysis (DCN SGE01446) of USGS National Produced Waters Geochemical Database v2.3 (DCN SGE01447).
N/A – Not Available.
a—Conventional oil and gas in the Appalachian basin represented in this table includes over 20 different formations.
b—Shale formations in the Appalachian basin represented in this table include the Marcellus.
c—Tight formations in the Appalachian basin represented in this table include the Bradford, Berea, Clinton, Medina, Tuscarora, and Venango.
d—The lower range represents the 5$^{th}$ percentile and the upper range represents the 95$^{th}$ percentile.
e—EPA excluded these data from statistics presented in this table because EPA did not know the MDL for data contained in the USGS database and therefore cannot calculate statistics that include consideration of these data (i.e., the "number of data points" columns do not include the "number of data points reported as below MDLs/PQLs").
f—Data source: State Water Quality- Human Health Standards for Pollutants of Concern in Oil and Gas Wastewater (DCN SGE01454). Where the Water Quality Standard is reported as "N/A", criteria for these pollutants may not have been developed and therefore no standards may exist.
g—Typical percent removal capabilities from POTWs with secondary treatment (DCN SGE00600).

**Table 7-2. Select Pollutants in Produced Water from Conventional and Unconventional Oil and Gas Operations Across the United States**

| | | Conventional[a] | | | | Unconventional[b] | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Units | Range[c] | Median | Number of Data Points | Number of Data Points Reported as Below MDLs/PQLs[d] | Range[c] | Median | Number of Data Points | Number of Data Points Reported as Below MDLs/PQLs[d] |
| **Total Dissolved Solids (TDS) and Primary Anions and Cations Contributing to TDS** | | | | | | | | | |
| TDS | mg/L | 2,730 - 323,000 | 62,300 | 42,943 | 0 | 2,390 - 262,000 | 21,900 | 14,270 | 0 |
| Bromide | mg/L | 19 - 4,890 | 300 | 1,639 | 155 | 10 - 2,410 | 535 | 1,212 | 38 |
| Calcium | mg/L | 21 - 28,700 | 2,280 | 40,747 | 135 | 12 - 21,800 | 222 | 15,645 | 30 |
| Chloride | mg/L | 190 - 197,000 | 36,300 | 41,266 | 17 | 472 - 152,000 | 9,000 | 15,663 | 0 |
| Sodium | mg/L | 458 - 103,000 | 19,800 | 35,269 | 13 | 730 - 68,200 | 6,440 | 13,251 | 2 |
| **Metals** | | | | | | | | | |
| Barium | mg/L | 0.1 - 682 | 20 | 2,761 | 2,682 | 0.33 - 1,410 | 10.6 | 2,903 | 630 |
| Boron | mg/L | 3 - 204 | 43 | 745 | 15 | 0.7 - 118 | 18.8 | 548 | 12 |
| Strontium | mg/L | 3 - 2,080 | 109 | 2,425 | 182 | 6 - 2,870 | 680 | 1,526 | 50 |
| **Radioactives** | | | | | | | | | |
| Gross alpha | pCi/L | N/A | N/A | 0 | 0 | 57 - 20,500 | 5,740 | 104 | 2 |
| Gross beta | pCi/L | N/A | N/A | 0 | 0 | 65 - 7,940 | 1,650 | 102 | 2 |
| Radium-226 | pCi/L | 3 - 4,010 | 194 | 26 | 0 | 17 - 6,950 | 562 | 149 | 5 |
| Radium-228 | pCi/L | 134 - 2,070 | 930 | 11 | 0 | 2 - 1,620 | 215 | 128 | 7 |

Source: EPA analysis (DCN SGE01446) of USGS National Produced Waters Geochemical Database v2.3 (DCN SGE01447).

N/A – Not available because no data were reported for this pollutant and resource type in the USGS database based on EPA's review.

a—Conventional oil and gas represented in this table includes over 130 different formations.

b—Unconventional formations represented in this table includes over 160 different formations.

c—The lower range represents the 5$^{th}$ percentile and the upper range represents the 95$^{th}$ percentile.

d—EPA excluded these data from statistics presented in this table because EPA did not know the MDL for data contained in the USGS database and therefore cannot calculate statistics that include consideration of these data (i.e., the "number of data points" columns do not include the "number of data points reported as below MDLs/PQLs").

According to Pennsylvania Code 95.10[21], oil and gas produced water may be discharged to a POTW if the discharges are first treated by a CWT facility and do not exceed specified monthly average concentrations developed to maintain receiving water quality (DCN SGE00187). As shown in Table 7-3, the median concentrations for TDS, chloride, barium, and strontium in tight oil and gas produced water in the Appalachian Basin (excluding MDL/PQL values) are at or above the monthly average limits in the Pennsylvania Code.

**Table 7-3. Naturally Occurring Radium Isotope Concentrations**

| | Appalachian Basin Tight Oil and Gas Wastewater Concentrations[a] | | | | |
|---|---|---|---|---|---|
| Constituent | Range (pCi/L)[b] | Median (mg/L) | Number of Data Points | Number of MDLs/PQLs Excluded from Analysis | Monthly Average Pretreatment Standard set by PA Code 95.10 (mg/L)[c] |
| TDS | 69,000 - 385,000 | 273,000 | 455 | 0 | 500 |
| Chloride | 44,200 - 208,000 | 149,000 | 471 | 0 | 250 |
| Barium | 1 – 864 | 10 | 45 | 7 | 10 |
| Strontium | 118 - 1,480 | 959 | 424 | 3 | 10 |

a—EPA analysis (DCN SGE01446) of USGS National Produced Waters Geochemical Database v2.3 (DCN SGE01447).
b—The lower range represents the 5th percentile and the upper range represents the 95th percentile.
c—PA Code Chapter 95 DCN SGE00187.

The constituents and concentrations of constituents in unconventional produced water varies based on geographic location. For example, Table 7-4 shows median TDS concentrations ranging from approximately 100,000 to 300,000 mg/L for specific tight oil and gas formations found in Pennsylvania. These median concentrations exceed the conventional and unconventional produced water median concentrations of 62,300 mg/L and 21,900 mg/L, respectively, shown in Table 7-2 and are within the range presented for conventional, shale and tight oil and gas produced water in Table 7-1.

**Table 7-4. TDS Concentrations in Produced Water from Pennsylvania Tight Oil and Gas Formations**

| Tight Formation[a] | Median TDS Concentration (mg/L)[b] | Number of Data Points | Number of MDLs/PQLs Excluded from Analysis |
|---|---|---|---|
| Clinton | 285,000 | 326 | 0 |
| Berea | 94,000 | 49 | 0 |
| Medina | 297,000 | 47 | 0 |
| Bradford | 108,000 | 16 | 0 |
| Venango | 120,000 | 14 | 0 |
| Tuscarora | 286,000 | 3 | 0 |

[21] PA Code 95.10 is titled, "Treatment requirements for new and expanding mass loadings of Total Dissolved Solids (TDS)".

**Table 7-4. TDS Concentrations in Produced Water from Pennsylvania Tight Oil and Gas Formations**

| Tight Formation[a] | Median TDS Concentration (mg/L)[b] | Number of Data Points | Number of MDLs/PQLs Excluded from Analysis |
|---|---|---|---|
| All Formations | 272,500 | 455 | 0 |

Source**:** Source: EPA analysis (DCN SGE01446) of USGS National Produced Waters Geochemical Database v2.3 (DCN SGE01447).
a—These formations are classified as tight by EIA and meet the 2016 UOG rule's definition of UOG (DCN SGE00155).
b—No MDL results were reported in the USGS database for TDS in tight formations in the Appalachian Basin.

Metals such as boron and strontium and radioactive constituents are also found in oil and gas produced water (see Table 7-1 and Table 7-2). As shown in Table 7-1, POTWs with secondary treatment are typically able to remove only thirty percent of boron, the remainder of which would likely be discharged into surface waters by the POTW.

Oil and gas formations contain varying levels of naturally occurring radioactive material (NORM) resulting from uranium and thorium decay, which can be transferred to oil and gas produced water. In Table 7-5, EPA compared tight oil and gas produced water data from Table 7-1 for radium-226 and radium-228 to data from a 2014 International Atomic Energy Agency (IAEA) report that included radium isotope concentrations in rivers, lakes, groundwater, and drinking water from public water systems (DCN SGE00769). Except for two MDL values, all the concentrations of radium-226 and radium-228 reported in the USGS Database for tight oil and gas produced water in the Appalachian basin were above the naturally occurring concentrations. Refer to "Radioactive Materials in the Unconventional Oil and Gas (UOG) Industry" (DCN SGE01185) for more information about concerns with radioactive materials in UOG produced water.

**Table 7-5. Naturally Occurring Radium Isotope Concentrations**

| | Appalachian Basin Tight Oil and Gas Wastewater Concentrations[a] | | | | Naturally Occurring Radium Isotope Concentrations in Groundwater[b] | | |
|---|---|---|---|---|---|---|---|
| Constituent | Range[c] (pCi/L) | Median (pCi/L) | Number of Data Points | Number of MDLs/PQLs Excluded from Analysis | Range (pCi/L) | Maximum (pCi/L) | Maximum Sample Location |
| Radium-226 | 59 - 1,362 | 370 | 43 | 2 | 0.032 - 6.5 | 170 | Texas groundwater |
| Radium-228 | 54 - 6,167 | 500 | 27 | 2 | N/A[c] | 12 | South Carolina well water |

a—Source: EPA analysis (DCN SGE01446) of USGS National Produced Waters Geochemical Database v2.3 (DCN SGE01447).
b—Source: IAEA, 2014 (DCN SGE00769).
c— The lower range represents the 5$^{th}$ percentile and the upper range represents the 95$^{th}$ percentile.
d—IAEA, 2014 (DCN SGE00769) did not report any average concentration data for radium-228.

## 7.3 Uncertainties and Limitations

- Fewer data points were available for shale and tight produced water concentrations than were available for conventional hydrocarbon produced water concentrations for most constituents.

- The USGS data did not contain readily available information about the analytical method used for each sample analysis. Therefore, EPA excluded results reported as "MDL" or "PQL" in the USGS database when calculating summary statistics as it is uncertain as to what value to assign to such results.

- The USGS data had limited available data for radioactive constituents. For example, the USGS data lacked gross alpha and gross beta data for conventional hydrocarbon produced water and contained only one data point for gross alpha and gross beta for tight oil and gas produced water.

# 8. CONCLUSION

At the time EPA promulgated the 2016 rule, it established zero discharge pretreatment standards for UOG extraction facilities based on alternative wastewater management approaches. Consistent with the factors identified in the Clean Water Act and described in the preamble to the 2016 rule, EPA found these alternatives to be technologically available, have acceptable non-water quality environmental impacts, and be economically achievable. Further, such standards would prevent some UOG extraction wastewater constituents largely from "passing through" the POTW untreated and discharged from the POTW to the receiving stream. Further, EPA concluded that no existing UOG facilities were discharging pollutants to POTWs at the time of the 2016 rule.

As described in this document, EPA has supplemented the rulemaking record to account for the UOG facilities in Pennsylvania, that were in fact, discharging wastewater to POTWs at the time of the rulemaking. The UOG rule is not applicable to activities regulated under the Stripper Subcategory (40 CFR 435 Subpart F). The UOG rule applies to onshore unconventional oil and gas extraction facilities regulated under Subpart C. Subpart C excludes facilities regulated under Subpart F. This analysis indicates that there are 22 entities that discharged at least some portion of their wastewater to a POTW from UOG extraction operations as defined by the UOG rule in 2016. As is described in the UOG final rule and supplemented by this analysis, all of these entities have a portfolio of wastewater management approaches currently available other than POTWs.

EPA calculated the incremental wastewater management costs for these operators to send their wastewater to the nearest alternative technology as well as any associated incremental transportation costs.

EPA evaluated the economic impacts of the UOG rule. The 22 entities in Pennsylvania that may incur costs associated with this rule is less than 0.1% of oil and gas extraction nation-wide entities. The EPA then estimated potential financial impacts for these entities by conducting a discounted cash flow analysis (modeled future revenue and operation costs) over 10 years on an after-tax basis. Based on this analysis, the EPA found that seven of the 22 entities would have negative profits irrespective of the UOG rule's incremental costs. For the remaining entities, when adding in the incremental costs of the rule, the EPA's analysis shows that none of the 15 entities would be at risk of closure as a result of complying with the UOG rule.

Historically, in conducting ELG analyses, the EPA considers entities with negative profits before the addition of costs to comply with any new ELGs to be baseline closures and removes them from any further analysis (e.g., total costs, total benefits). However, in this case, the seven entities that the data indicate have negative profits in 2016 continued to report wastewater discharge to Pennsylvania in 2017 demonstrating they remain in business. Therefore, the EPA is reporting cost information as a range with the lower value representing EPA's typical approach and the upper value assuming all 22 facilities continue to operate. The EPA's analysis shows that for 2016, the median incremental costs would be between $131 and $279 per entity and the total costs of the UOG rule for 2016 would be approximately $33,000 -$65,000.

EPA also evaluated incremental non-water quality environmental impacts associated with alternative wastewater management approaches. This includes changes in air emissions, solid

waste generation, and energy consumption. The incremental change depends on the alternative wastewater management approach. For example, sludge generation would likely decrease if a UOG facility sends its wastewater to a UIC well and would likely increase if it sends its wastewater to a CWT facility. Even if each operator that currently sends its wastewater to a POTW elected to use a wastewater management approach that incrementally increased air emissions, sludge generation, or energy usage, these changes would be small relative to U.S. totals.

Lastly, EPA reviewed available data on the concentration of pollutants in wastewater generated from shale, tight, and conventional oil and gas formations as well as POTW performance in removing these pollutants. This data demonstrates that all of these wastewaters can generate concentrations of pollutants that are not typically received by POTWs. POTW performance data continue to indicate that POTWs do not effectively treat some of these pollutants and that they will pass through untreated and be discharged from the POTW.

After accounting for the new information and analyses described above, EPA concludes that the zero discharge of pollutants standard is technologically available, economically achievable and has acceptable non-water quality environmental impacts. EPA also notes that the rule would prevent some UOG extraction wastewater constituents from being discharged, untreated, from the POTW to the receiving stream. Based on this information, the EPA will not revise the 2016 rule.

# 9. REFERENCES

**Table 6. Reference List**

| DCN | Reference |
|---|---|
| SGE00139 | Puder, M.G. and Veil, J.A. 2006. Offsite Commercial Disposal of Oil and Gas Exploration and Production Waste: Availability, Options, and Costs |
| SGE00155 | United States Department of Energy (U.S. DOE). 2010. United States Energy Information Administration (EIA). Major Tight Gas Plays, Lower 48 States. Available electronically at: https://www.eia.gov/oil_gas/rpd/tight_gas.pdf |
| SGE00167 | Metcalf & Eddy. 2003. Wastewater Engineering: Treatment and Reuse |
| SGE00187 | Pennsylvania Department of Environmental Protection. 2010. 25 PA Code Chapter 95 40 PA.B.4835 |
| SGE00275 | United States Environmental Protection Agency (U.S. EPA). 2012. Site Visit Report for Citrus Energy Corporation Marcellus Shale Gas Operations |
| SGE00276 | United States Environmental Protection Agency (U.S. EPA). 2012. Meeting with XTO Energy, Inc. about Unconventional Oil and Gas Sanitized |
| SGE00575 | Petroleum Equipment Suppliers Association. 2012. Outlook for Domestic Unconventional Resources |
| SGE00600 | United States Environmental Protection Agency (U.S. EPA). 2003. Development Document for the Final Effluent Limitations Guidelines and Standards for the Metal Products and Machinery Point Source Category |
| SGE00625 | United States Environmental Protection Agency (U.S. EPA). 2015. Site Visit Report for Southwestern Energy Fayetteville Shale Gas Operations |
| SGE00635 | United States Environmental Protection Agency (U.S. EPA). 2012. Site Visit Report Chesapeake Energy Corporation Marcellus Shale Gas Operations Sanitized |
| SGE00636 | United States Environmental Protection Agency (U.S. EPA). 2012. Talisman Marcellus Operations Overview |
| SGE00763 | Pennsylvania Department of Environmental Protection (PA DEP). 2014. Oil and Gas Reporting – Electronic (OGRE) Public Reporting Data Dictionary, v1.0 |
| SGE00769 | International Atomic Energy Agency (IAEA). 2014. The Environmental Behavior of Radium: Revised Edition |
| SGE01170 | DrillingInfo, Inc. 2015. DI Desktop®. Downloaded on March 30, 2015 |
| SGE01171 | DrillingInfo, Inc. 2015. DI Desktop® Data Coverage |
| SGE01179 | Eastern Research Group, Inc. (ERG). 2016. Data Compilation Memorandum for the Technical Development Document (TDD) |
| SGE01185 | Eastern Research Group, Inc. (ERG). 2016. Radioactive Elements in the Unconventional Oil and Gas (UOG) Industry |
| SGE01186 | United States Environmental Protection Agency (U.S. EPA). 2016. Unconventional Oil and Gas Wastewater Treatment Technologies |
| SGE01188 | United States Environmental Protection Agency (U.S. EPA). 2016. Technical Development Document for the Effluent Limitations Guidelines and Standards for the Oil and Gas Extraction Point Source Category. EPA-820-R-16-003. Available electronically at: https://www.epa.gov/sites/production/files/2016-06/documents/uog_oil-and-gas-extraction_tdd_2016.pdf |
| SGE01190 | United States Department of Energy (U.S. DOE). 2015. United States Energy Information Administration (EIA). Assumptions to the Annual Energy Outlook 2015 |

## Table 6. Reference List

| DCN | Reference |
|---|---|
| SGE01191 | United States Department of Energy (U.S. DOE). 2015. United States Energy Information Administration (EIA). Shale Gas Plays, Lower 48 States |
| SGE01246 | Pennsylvania Department of Environmental Protection (PA DEP). 2015. Spud Data Report |
| SGE01375 | Pennsylvania Department of Environmental Protection (PA DEP). 2016. Pennsylvania Oil and Gas Well Formations. Downloaded on August 8, 2016 |
| SGE01397 | Eastern Research Group, Inc. (ERG). 2016. POTWs Accepting Oil and Gas Wastewater in Los Angeles County |
| SGE01399 | Eastern Research Group, Inc. (ERG). 2016. POTWs Accepting Oil and Gas Wastewater in Colorado |
| SGE01407 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Catalyst Energy |
| SGE01408 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Mead Oil |
| SGE01409 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - MSL Oil & Gas |
| SGE01410 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - New Century Energy |
| SGE01411 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - PVE Oil |
| SGE01412 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Snyder Brothers |
| SGE01413 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Alliance Petroleum |
| SGE01414 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Fairman Corporation |
| SGE01415 | United States Environmental Protection Agency (U.S. EPA). 2018. Final Unconventional Oil and Gas Data Gathering Letter - Dannic Energy |
| SGE01416 | Eastern Research Group, Inc. (ERG). 2018. PA DEP Waste Reports Development Database |
| SGE01417 | Eastern Research Group, Inc. (ERG). 2018. PA DEP O&G Production Development Database |
| SGE01418 | Eastern Research Group, Inc. (ERG). 2018. PA DEP and DI Desktop Cross-Reference Database |
| SGE01419 | Eastern Research Group, Inc. (ERG). 2018. UOG Alternative Waste Management Cost Analysis – Sanitized |
| SGE01420 | Pennsylvania Department of Conservation and Natural Resources (PA DCNR). 2018. Bureau of Topographic and Geologic Survey. Exploration and Development Wells Information Network (EDWIN). Downloaded on June 5, 2018 |
| SGE01421 | Eastern Research Group, Inc. (ERG). 2018. Pennsylvania Department of Environmental Protection's (PA DEP) Statewide Oil and Gas Waste Reports Memorandum. |
| SGE01421. A01 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Waste Reports. WasteExport2004-2009_COG and UOG. |
| SGE01421. A02 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Waste Reports. WasteExport2010-2016_Conventional. |
| SGE01421. A03 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Waste Reports. WasteExport2010-2016_Unconventional |

## Table 6. Reference List

| DCN | Reference |
|---|---|
| SGE01422 | Eastern Research Group, Inc. (ERG). 2018. Pennsylvania Department of Environmental Protection's (PA DEP) Statewide Oil and Gas Production Reports Memorandum. |
| SGE01422.A01 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Production Reports. 1-Oil_Gas_Well_Production 2016 |
| SGE01422.A02 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Production Reports. 2-Oil_Gas_Well_Production 2015 |
| SGE01422.A03 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Production Reports. 3-Oil_Gas_Well_Production 2010-2014 |
| SGE01422.A04 | Pennsylvania Department of Environmental Protection (PA DEP). Statewide Oil and Gas Production Reports. 4-Oil_Gas_Well_Production 2017 |
| SGE01431 | Thompson G. 2016. Letter from U.S. Congress to Administrator McCarthy |
| SGE01433 | United States Environmental Protection Agency (U.S. EPA). 2018. Well Production and Waste Summary by Producer |
| SGE01434 | United States Environmental Protection Agency (U.S. EPA). 2018. EPA follow up letter to Catalyst |
| SGE01436 | United States Bureau of Economic Analysis (U.S. BEA). 2018. Table 1.1.9 Implicit Price Deflators for Gross Domestic Product (GDP Deflator). Accessed on May 25, 2018. Available online at: https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=2#reqid=19&step=3&isuri=1&1921=sur.vey&1903=13 |
| SGE01437 | United States Energy Information Administration (EIA). 2018. Annual Energy Outlook 2018 with Projections to 2050: Natural Gas Production: Dry Gas Production |
| SGE01438 | United States Energy Information Administration (EIA). 2018. Annual Energy Outlook 2018 with Projections to 2050: Petroleum and Other Liquids Prices: Crude Oil – Reference Case |
| SGE01439 | United States Energy Information Administration (EIA). 2018. Cushing, OK WTI Spot Price FOB (Dollars per Barrel). Accessed May 25, 2018. Available electronically at: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rwtc&f=a |
| SGE01440 | United States Energy Information Administration (EIA). 2018. Henry Hub Natural Gas Spot Price: Annual. Accessed May 29, 2018. Available electronically at: https://www.eia.gov/dnav/ng/hist/rngwhhdA.htm |
| SGE01441 | United States Energy Information Administration (EIA). 2018. Pennsylvania Crude Oil First Purchase Price (Dollars per Barrel). Accessed May 25, 2018. Available electronically at: https://www.eia.gov/dnav/pet/pet_pri_dfp1_k_a.htm |
| SGE01443 | United States Environmental Protection Agency (U.S. EPA). 2018. Detailed Study of the Centralized Waste Treatment Point Source Category for Facilities Managing Oil and Gas Extraction Wastes |
| SGE01444 | United States Office of Management and Budget (OMB). 2003. Circular A-4. September 17, 2003. Available online at: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf |
| SGE01445 | Hyne, Norman J. 2012. Nontechnical Guide to Petroleum Geology, Exploration, Drilling & Production: Third Edition. Tulsa, OK: PennWell Corporation |
| SGE01446 | Eastern Research Group, Inc. (ERG). 2018. USGS Produced Water Characterization Analysis |
| SGE01447 | United States Geological Survey (USGS). 2018. U.S. Geological Survey National Produced Waters Geochemical Database v2.3 |

## Table 6. Reference List

| DCN | Reference |
|---|---|
| SGE01449 | U.S. Census Bureau. 2018. U.S. Census Bureau, Number of Firms, Number of Establishments, Employment, and Annual Payroll by Enterprise Employment Size for the United States, All Industries: 2015 |
| SGE01450 | Pennsylvania Department of Environmental Protection (PA DEP). 2016. Revised 2016 PA DEP Waste Reports - Moyer |
| SGE01451 | Pennsylvania Department of Environmental Protection (PA DEP). 2016. Revised 2016 PA DEP Waste Reports - HighPoint |
| SGE01452 | Mittal D. 2018. FRS Facilities Capacities |
| SGE01453 | Kepler D. 2018. Question on Kane Facility |
| SGE01454 | Eastern Research Group, Inc. (ERG). 2018. Water Quality Standards relevant to the Appalachian Basin |
| SGE01461 | Eastern Research Group, Inc. (ERG). 2019. Stripper Well Analysis database 2016 |
| SGE01462 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging To Alcosan - Trucking Time to POTWs |
| SGE01463 | United States Environmental Protection Agency (U.S. EPA). 2018. Nearest CWTs to all wells |
| SGE01464 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Alcosan – Trucking Time to UICs |
| SGE01465 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Brockway – Trucking Time to POTWs |
| SGE01466 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Brockway – Trucking Time to UICs |
| SGE01467 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Reynoldsville – Trucking Time to POTWs |
| SGE01468 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Reynoldsville – Trucking Time to UICs |
| SGE01469 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Ridgeway 1 – Trucking Time to Ridgeway |
| SGE01470 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells to Ridgeway 1 – Trucking Time to UICs |
| SGE01471 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Ridgeway 2 – Trucking Time to Ridgeway |
| SGE01472 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells to Ridgeway 2 – Trucking Time to UICs |
| SGE01473 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Ridgeway 3 – Trucking Time to Ridgeway |
| SGE01474 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells to Ridgeway 3 – Trucking time to UICs |
| SGE01475 | United States Environmental Protection Agency (U.S. EPA). 2018. 0817 origins 1 to 0817 destinations 1 |
| SGE01476 | United States Environmental Protection Agency (U.S. EPA). 2018. 0817 origins 2 to 0817 destinations 2 |
| SGE01477 | United States Environmental Protection Agency (U.S. EPA). 2018. Origins 1 to Destinations 1 |

## Table 6. Reference List

| DCN | Reference |
|---|---|
| SGE01478 | United States Environmental Protection Agency (U.S. EPA). 2018. Origins 2 to Destinations 2 |
| SGE01479 | United States Environmental Protection Agency (U.S. EPA). 2018. Origins 3 to Destinations 3 |
| SGE01480 | United States Environmental Protection Agency (U.S. EPA). 2018. 0824 Last GIS data for EPA Results (003) |
| SGE01481 | United States Environmental Protection Agency (U.S. EPA). 2018. Wells Discharging to Brockway – Trucking Time to Nearest CWTs |
| SGE01482 | Oberlander D. 2016. Letter from Commonwealth of PA House of Representatives Oil and Gas Caucus to Administrator McCarthy |
| SGE01484 | United States Environmental Protection Agency (U.S. EPA). 2019. EPA UOG Financial Impact Analysis - Sanitized. |
| SGE01485 | ESRI. 2019. Find Nearest - ArcGIS Online Help. https://doc.arcgis.com/en/arcgis-online/analyze/find-nearest.htm. Accessed on February 6, 2019 |
| SGE01486 | Common Wealth of Pennsylvania. 1987. Pennsylvania Code CHAPTER 78. OIL AND GAS WELLS |
| SGE01494 | United States Environmental Protection Agency (U.S. EPA). 2019. Response to Handouts from EPA Site Visit. |
| SGE01523 | U.S. EIA. 2019. Distillate Fuel Oil and Kerosene Sales by End Use. |
| SGE01534 | U.S. EPA. 2000. Development Document for Final Effluent Limitations Guidelines and Standards for the Centralized Waste Treatment Industry. EPA-821-R-00-020. |

# APPENDIX A
# Alternative Wastewater Management Analysis Database and Spreadsheet Structures

# APPENDIX A. ALTERNATIVE WASTEWATER MANAGEMENT ANALYSIS DATABASE AND SPREADSHEET STRUCTURES

The following subsections describe the structures and contents of the underlying data files used to perform the Alternative Wastewater Management Analysis described in Section 3.

## A-1. PA DEP Waste and Production Reports Table Field Descriptions (Step 1)

PA DEP requires all operators to report oil, gas, and waste generation for oil and gas wells, including waste generated at wells in Pennsylvania that is transferred to another state. For waste generation, operators must report waste quantity, waste type, and waste management information for each well they operate. For production, operators must report oil, gas, and condensate production quantities for each well they operate. Both the production and waste reports include other identifying information such as well API number, production period, well configuration (horizontal, vertical), and resource type (UOG or COG) as defined by PA DEP. PA DEP periodically publishes aggregated reports containing these waste and production data henceforth referred to as PA DEP Waste Reports[22] and PA DEP Production Reports[23], respectively.

Table A-1 describes the report data fields from PA DEP, which are used in all the databases and spreadsheets EPA created for this cost analysis.

**Table A-1. PA DEP Waste Reports Table Field Descriptions**

| Field Name | Description |
|---|---|
| Well Permit # | The number of the permit that was issued to the oil and gas operator for this well by the PA DEP. This is equivalent to well API number. |
| Period Id | A code value indicating the 4-digit reporting year and a number indicating the report period, where: 0=Annual; 1=Marcellus 6-month from Jan-June; 2=Marcellus 6-month from July-December; and 3=Initial Marcellus 12-month reporting period from 7/1/2009 through 6/30/2010. |
| Well Status | An indicator of the well's current status, where: Inactive=not drilled yet and Active=producing. Other acceptable values for this field are "Plugged" and "Abandoned." |
| Farm Name | The name given to a well by the well operator. Name usually corresponds with the landowner at the time of permitting, which does not change. The farm name and well # normally produce a unique identifier for the well. |
| Well # | The number of the well assigned by the well operator. Usually follows the farm name (above). |
| Waste Type | The type of waste that was generated at the well. |
| Waste Quantity | The amount of the waste product that was generated at the well. |
| Units | The unit of measure that was used for the generated waste. |
| Disposal Method | The method used to dispose of the waste generated at the well. |

[22] EPA downloaded these reports on 2/12/2018 (see DCN SGE01421).

[23] EPA downloaded 2006 through 2016 production data on 1/3/2018 and downloaded 2017 production data on 6/15/2018 (see DCN SGE01422).

## Table A-1. PA DEP Waste Reports Table Field Descriptions

| Field Name | Description |
|---|---|
| Averaged | This Y/N field indicates whether the production and waste amounts were averaged (Y) or not (N). If Y, they were averaged based on the group of wells to which the belongs. If N, the reported amounts are specific to the well. |
| Operator Name | The organizational name of the well operator reporting well production during all or a portion of the reporting period. Several operators may report during the reporting period based on their period of control. |
| OGO # | The oil and gas operator (OGO) Id of the operator of the well during the report period. Several operators may report during the reporting period based on their period of control. |
| Well County | The County in which the well is located. |
| Well Municipality | The Municipality in which the well is located. |
| Well Latitude | The latitude value, in decimal degrees, for the permitted well location. |
| Well Longitude | The longitude value, in decimal degrees, for the permitted well location. |
| Unconventional | A yes or no indicator that identifies a bore hole drilled or being drilled to be used to produce natural gas from an unconventional formation as defined by PA. **Note: see Section 2.1 for discussion of the differences between PA DEP's and the 2016 UOG rule's definitions of UOG.** |
| Well Configuration Code | An indicator code that describes whether a well is horizontal, vertical, or intentionally deviated. A value of "HORIZ" indicates that the well is a horizontal well, meaning a well is initially drilled vertically then curved to become horizontal (or near horizontal) to parallel a particular geologic formation. Intentionally deviated wells are indicated by a value of "DEVIA", whereas vertical wells are indicated by a value of "VERTI". |
| Home Use | A yes or no indicator that represents whether the well has been identified as a home use well or not. Home use wells have no commercial production, and the product is used entirely on the property. |
| Waste Facility Permit # | The permit number of the waste facility that the waste product was taken to if the facility was permitted by DEP. |
| Waste Facility Name | Name of the facility that accepted and treated the waste products from the well. |
| Facility Address 1 | The primary address of the waste facility. |
| Facility Address 2 | The optional second line of the address of the waste facility. |
| Facility City | The municipality in which the waste facility is located. |
| Facility State | The state in which the waste facility is located. |
| Facility Zip Code | The zip code of the waste facility. |
| Facility Phone | The phone number of the waste facility. |
| Facility Latitude | The latitude value, in decimal degrees, for the waste facility location. |
| Facility Longitude | The longitude value, in decimal degrees, for the waste facility location. |
| Reporting Period | The date range of the production or waste report that is being reviewed. |
| Comment Reason | Well operator comment on the well or group of wells, typically indicating why no production data were reported. |
| Comment Text | Well operator comment on a well or group of wells, typically indicating why no production data were reported. |
| Formation | A name assigned to a geological section of the earth crust. |
| Parent Formation | A higher classification of a rock formation. |

Source: DCN SGE00763.

## A-2. PA DEP Waste Report and Production Report Development Databases (Step 2)

EPA used the PA DEP reports to identify oil and gas wells in Pennsylvania that discharged wastewater to POTWs in 2016 and to extract their relevant characteristics such as production quantities, wastewater quantities, and whether the well meets the 2016 UOG rule's definition of UOG.

For both the PA DEP Waste and Production Reports, the information is collected directly from operators and contains a variety of naming conventions, spelling errors, and some missing or inaccurate information. In addition, PA DEP periodically updates the Waste and Production Reports to incorporate new and/or corrected data reported by operators. These updates are not scheduled or announced, which means that new or updated data may have been added after EPA's download dates of January 3 and February 12, 2018 for the Production and Waste reports, respectively.

EPA conducted data clean-up activities for information contained in certain data fields that are key to this cost analysis. These activities included standardizing certain naming conventions (e.g., waste type, management method, waste facility name), confirming production data and resolving inconsistent production data (for operators that received data requests), and filling data gaps in well latitude and longitude and resource type to the extent possible using other data sources. Data clean-up activities are described and documented in Section 3 and Appendix A of this report and in supporting documentation in the UOG rulemaking record. For example, EPA verified that all latitude and longitudes reported by PA DEP fell inside the state of Pennsylvania before using them for the GIS analysis. Most data were used as downloaded and assumed accurate because they are reported directly by the operators.

### *PA DEP Waste Report Development Database*

Table A-2 lists and describes the Access queries used to develop and populate the PA DEP Waste Report Development Database and to format the data for use in future analyses. The queries perform two primary functions that ultimately create the final database:

1. Combine all waste reports from PA DEP's website (2004 through 2016) into a single table titled "PA DEP Waste Data" and format the data by removing dashes from the reported years (queries 000 through 114 in Table A-2).

2. Standardize data reported by operators in select fields using the crosswalk database tables described below (queries 200 and 201 in Table A-2).

**Table A-2. PA DEP Waste Report Development Database Queries**

| Query Name | Description |
|---|---|
| 000 – Create PA DEP Waste Table | Creates the shell of the final PA DEP Waste Data. |
| 001 – Append Waste 2004-2009_All | Appends the 2004 through 2009 waste reports for all oil and gas wells to the PA DEP Waste Data table (DCN SGE01421.A01). |
| 002 – Append Waste 2010-2016_COG | Appends the 2010 through 2016 waste report for COG wells to the PA DEP Waste Data table (DCN SGE01421.A02). |

**Table A-2. PA DEP Waste Report Development Database Queries**

| Query Name | Description |
|---|---|
| 003 – Append Waste 2011-2016_UOG | Appends the 2011 through 2016 waste report for UOG wells to the PA DEP Waste Data table (DCN SGE01421.A03). |
| 100 – Fix 2010 Waste Period ID | Fixes the error associated with the Period ID for 2010 reports (the query changes values where the period was reported as "#NUM!" to 2010). |
| 101 – Remove Waste dashes-2004 | Changes "2004-0" to "2004" in the Period ID field. |
| 102 – Remove Waste dashes-2005 | Changes "2005-0" to "2005" in the Period ID field. |
| 103 – Remove Waste dashes-2006 | Changes "2006-0" to "2006" in the Period ID field. |
| 104 – Remove Waste dashes-2007 | Changes "2007-0" to "2007" in the Period ID field. |
| 105 – Remove Waste dashes-2008 | Changes "2008-0" to "2008" in the Period ID field. |
| 106 – Remove Waste dashes-2009 | Changes "2009-0" to "2009" in the Period ID field. |
| 107 – Remove Waste dashes-2010 | Changes "2010-0", "2010-1", and "2010-2" to "2010" in the Period ID field. |
| 108 – Remove Waste dashes-2011 | Changes "2011-0", "2011-1", and "2011-2" to "2011" in the Period ID field. |
| 109 – Remove Waste dashes-2012 | Changes "2012-0", "2012-1", and "2012-2" to "2012" in the Period ID field. |
| 110 – Remove Waste dashes-2013 | Changes "2013-0", "2013-1", and "2013-2" to "2013" in the Period ID field. |
| 111 – Remove Waste dashes-2014 | Changes "2014-0", "2014-1", and "2014-2" to "2014" in the Period ID field. |
| 112 – Remove Waste dashes-2015 | Changes "2015-0", "2015-1", and "2015-2" to "2015" in the Period ID field. |
| 113 – Remove Waste dashes-2016 | Changes "2016-0", "2016-1", and "2016-2" to "2016" in the Period ID field. |
| 114 – Delete blank Rows | Removes records with a blank permit number from the PA DEP Waste Data table. |
| 200 – Update Consolidated Waste Type | Uses the *Waste Type Consolidation* crosswalk table developed by EPA to standardize and populate the *Consolidated Waste Type* data field. |
| 201 – Update Consolidated Disposal Method and Facility | Uses the *Facility Type Consolidation* crosswalk table developed by EPA to standardize and populate the *Consolidated Disposal Method*, *Consolidated Waste Facility Name* and *Consolidated Waste Facility Permit Number* data fields. |

### *PA DEP Production Report Development Database*

Table A-3 lists and describes the Access queries used to develop and populate the PA DEP Production Report Development Database (DCN SGE01417) and to format the data for use in future analyses. The queries perform two primary functions that ultimately create the final database:

1. Combine all production reports from PA DEP's website (2006 through 2016) into a single table titled "PA O&G Production Raw Combined" and format the data by removing dashes from the reported years (queries 001 through 111 in Table A-3).

2. Consolidate data reported by operators to remove any wells producing zero oil, gas, and condensate (query 200 in Table A-3).

**Table A-3. PA DEP Production Report Development Database Queries**

| Query Name | Description |
|---|---|
| 001 – Make Raw Combined Table and Add Download 1 | Creates the shell of the PA O&G Production Raw Combined table using the 2016 production report (DCN SGE01422.A01). |
| 002 – Append Download 2 | Appends the 2015 production report to the PA O&G Production Raw Combined table (DCN SGE01422.A02). |
| 003 – Append Download 3 | Appends the 2010 through 2014 production reports to the PA O&G Production Raw Combined table (DCN SGE01422.A03). |
| 004 – Append Download 4 | Appends the 2006 through 2010 production reports to the PA O&G Production Raw Combined table. |
| 005 – Append Download 5 | Appends the 2017 production reports to the PA O&G Production Raw Combined table (DCN SGE01422.A04). |
| 100 – Update Report ID 2016 | Changes "2016-0", "2016-1", and "2016-2" to "2016" in the Period ID field. |
| 101 – Update Report ID 2015 | Changes "2015-0", "2015-1", and "2015-2" to "2015" in the Period ID field. |
| 102 – Update Report ID 2014 | Changes "2014-0", "2014-1", and "2014-2" to "2014" in the Period ID field. |
| 103 – Update Report ID 2013 | Changes "2013-0", "2013-1", and "2013-2" to "2013" in the Period ID field. |
| 104 – Update Report ID 2012 | Changes "2012-0", "2012-1", and "2012-2" to "2012" in the Period ID field. |
| 105 – Update Report ID 2011 | Changes "2011-0", "2011-1", and "2011-2" to "2011" in the Period ID field. |
| 106 – Update Report ID 2010 | Changes "2010-0", "2010-1", and "2010-2" to "2010" in the Period ID field. |
| 107 – Update Report ID 2009 | Changes "2009-0" to "2009" in the Period ID field. |
| 108 – Update Report ID 2008 | Changes "2008-0" to "2008" in the Period ID field. |
| 109 – Update Report ID 2007 | Changes "2007-0" to "2007" in the Period ID field. |
| 110 – Update Report ID 2006 | Changes "2006-0" to "2006" in the Period ID field. |
| 111 – Update Report ID 2017[a] | Changes "2017-0", "2017-1", and "2017-2" to "2017" in the Period ID field. |
| 200 – PA DEP O&G Production by Well | Creates final PA DEP O&G Production Cleaned Up table by removing wells with zero oil, gas, and condensate production. |

a—2017 data were only partially complete for the year at the time EPA downloaded the data.

## A-3. PA DEP and DI Desktop® Cross-reference Database (Steps 3 and 4) DI Desktop®

Drillinginfo is an oil and gas research firm located in Austin, Texas. DI Desktop® is a comprehensive database generated by Drillinginfo that contains a record for each oil and gas well drilled in the United States. Basic well data contained in DI Desktop® for each well includes: well API number, latitude, longitude, operator, and well trajectory. DI Desktop® also includes annual oil, gas, and produced water production per well. DI Desktop® includes records for wells that are no longer active (i.e., shut in), disposal wells, COG wells, coal bed methane (CBM) wells, and UOG wells. It does not contain a field that indicates if wells are COG or UOG.

Drillinginfo uses oil and gas databases maintained by individual state oil and gas agencies to create DI Desktop®. For this analysis, EPA downloaded DI Desktop® on March 30, 2015. For the most part, the downloaded database that EPA used reflects wells drilled as of 2014, but it varies by state. State-level information such as the oil and gas agency names, last production date, production start date, and update frequency (e.g., monthly, quarterly) is provided by Drillinginfo (DCN).

EPA used this data source to capture the geological formation in which wells discharging to POTWs were completed. The geological formation information was subsequently used to determine whether wells in PA DEP's Waste Reports are defined as UOG by the 2016 UOG rule's definition of UOG.

EPA assumed that geological formations reported in DI Desktop® were accurate, albeit incomplete for some wells. EPA spot checked geological formations using EDWIN (EDWIN data source discussed below); note, however, that EDWIN is the foundation of DI Desktop® for Pennsylvania oil and gas extraction wells and not an independent data source.

EPA also used DI Desktop® as a supplemental data source to fill data gaps in well latitude and longitude when not available from other PA DEP data sources, thereby improving the completeness of 2016 UOG rule defined UOG wells included in EPA's cost analysis.

***DI Desktop®***

Table A-4 lists the fields in DI Desktop® along with their descriptions.

**Table A-4. DI Desktop® Field Descriptions**

| Field Name | Description |
|---|---|
| ENTITY_ID | DI assigned ID unique to a given property. A well is referred to as a "property" in DI Desktop®. |
| API_NO | API assigned number of a well on the property. |
| PROPERTY_TYPE | Property type (e.g., lease, unit, well, completion, other, unknown). |
| PRODUCTION_TYPE | Production type (e.g., oil, gas, injection). |
| PROD_TYPE_CLASS | Classification of production type into D&A (drilled and abandoned), gas, injection, O&G (oil and gas), oil, and other. |
| PROD_FLAG | Production flag to indicate whether the well should be producing liquids. This is "Yes" for "Gas," "Oil," and "O&G" production type classification. |
| LIQUID_PROD_TYPE | Liquid production type (i.e., unknown, condensate, or oil) based on the production type classification and well test data. |
| WELL_NAME | Operator assigned well/lease name of the property. |
| FIELD | Field name the property is reporting from. |
| CURR_OPER_NAME | Current operator name. |
| SPUD_DATE | Date drilling commenced on property. |
| COMMON_OPER_NAME | Corporate entity that is determined by DI to own the current operator. |
| LATITUDE_NAD27 | Surface latitude the property is located in; for multi-well properties DI Desktop® picked a well to designate the location of the property, in NAD27 format. |
| LONGITUDE_NAD27 | Surface longitude the property is located in; for multi-well properties DI Desktop® picked a well to designate the location of the property, in NAD27 format. |
| LATITUDE_NAD83 | Surface latitude the property is located in; for multi-well properties DI Desktop® picked a well to designate the location of the property, in NAD83 format. |
| LONGITUDE_NAD83 | Surface longitude the property is located in; for multi-well properties DI Desktop® picked a well to designate the location of the property, in NAD83 format. |
| COUNTY | County the property is located in. |

**Table A-4. DI Desktop® Field Descriptions**

| Field Name | Description |
|---|---|
| FIPS_CODE | Federal Information Processing Standard (FIPS) county code based on county or GIS analysis using latitude and longitude. |
| DISTRICT | District within a given state the property is assigned. |
| STATE | State the property is located in. |
| EPA_REGION | EPA region the property is located in. |
| OFFSHORE | Offshore waters indicator. |
| RESERVOIR | Reservoir, formation, zone, or pool that the property is reported as producing from. |
| BASIN | The basin the property is located in. |
| FORMATION | Formation that the property is reported as producing from. |
| STATUS | Current status of the well (e.g., active, inactive, shut in). |
| TOTAL_DEPTH | Total depth the well was drilled to. |
| PLUG_DATE | Date the well was plugged. Note: for instances where duplicate API numbers were combined, the maximum value was selected. |
| COMPLETION_DATE | Most recent completion date of the well. |
| COMPLETION_YEAR | Year of the completion date. |
| Well Trajectory | This is the configuration of the wellbore. Options include: H – Horizontal; D – Directional; V – Vertical; U – Unknown. |
| FIRST_PROD_DATE | First date of reported production for the property. Note: for instances where duplicate API numbers were combined, the minimum value was selected. |
| LAST_PROD_DATE | Last date production was reported for the property. |
| LATITUDE_BOTM | Bottom hole latitude of the property. |
| LONGITUDE_BOTM | Bottom hole longitude of the property. |
| SumOfLIQ[xx] | Annual oil production in barrels. A separate column is provided for each year from 2000 (i.e., "SUMOFLIQ00") through 2014 (i.e., "SUMOFLIQ14"). |
| SumOfGAS[xx] | Annual Gas production in thousand cubic feet. A separate column is provided for each year from 2000 (i.e., "SUMOFGAS00") through 2014 (i.e., "SUMOFGAS14"). |
| SumOfWTR[xx] | Annual produced water production in barrels. A separate column is provided for each year from 2000 (i.e., "SUMOFWTR00") through 2014 (i.e., "SUMOFWTR14"). |
| PROD[xx]_FLAG | Yes/No flag indicating if oil and/or gas production was greater than zero for a given year. A separate column is provided for each year from 2000 (i.e., "PROD00_FLAG") through 2014 (i.e., "PROD14_FLAG"). |
| ACTIVE_FLAG | Yes/No flag indicating whether or not a well is active based on production. |
| ACTIVE_PROD_FLAG | Yes/No flag indicating whether the entity (i.e., property) is active (using the ACTIVE_FLAG field) and had production in 2014 (using the PROD14_FLAG field). |

### *PA DEP and DI Desktop® Cross-Reference Database Queries*

Table A-5 lists and describes the Access queries used to develop and populate the PA DEP and DI Desktop® Cross-reference Database and to format the data for use in future

analyses. The queries perform three primary functions key to creating the final database for use in the Alternative Wastewater Management Analysis:

1. Identify the subset of wells that are the subject of this Alternative Wastewater Management Analysis (i.e., those discharging to POTWs in 2016 and that meet the 2016 UOG rule's definition of UOG) (queries 000a through 108c in Table A-5).

2. Populate well location data for use in the GIS analysis (Step 5) (queries 110a through 115c in Table A-5).

3. Collate summary information about the operators of the wells subject to the Alternative Wastewater Management Analysis, such as number of active wells, other wastewater management practices, and oil and gas production from 2006 to 2016 (queries 200 through 203 in Table A-5).

**Table A-5. PA DEP and DI Desktop® Cross-Reference Database Queries**

| Query Name | Description |
|---|---|
| 000a – Make PA DEP Waste Data Table | Creates the shell of the PA DEP Waste Data table using the PA DEP Waste Data table from the PA DEP Waste Reports Development Database (DCN SGE01416). |
| 000b – Update API | Adds the Well API number to the PA DEP Waste Data table using the Well Permit Number listed in that table. |
| 000c – delete empty row | Removes records with a blank permit number from the PA DEP Waste Data table. |
| 001 – Update No to N for PA DEP UOG Flag | Revises the PA DEP UOG Flag field to "N" where it says "No." |
| 002 – Update Yes to Y for PA DEP UOG Flag | Revises the PA DEP UOG Flag field to "Y" where it says "Yes." |
| 100 – Update with DI Desktop® Info | Adds DI Desktop® data to the PA DEP Waste Data table using the Well API number as the link (DCN SGE01170). |
| 101 – Update with PA DEP Formation Info | Adds PA DEP Formation data to the PA DEP Waste Data table using the Well API number as the link (DCN SGE01375). |
| 102a – Update EDWIN for Tight | Adds tight flag to EDWIN formation records that are listed as tight by EIA. |
| 102b – Update EDWIN for Shale | Adds shale flag to EDWIN formation records that are listed as shale by EIA. |
| 102c – Update EDWIN for COG | Adds COG flag to all EDWIN formation records that are not listed as shale or tight by EIA. |
| 102d – Find EDWIN UOG Wells | Finds wells identified as tight or shale and assigns them as UOG. |
| 102e – Find EDWIN COG Wells | Finds wells not identified as UOG and assigns them as COG. |
| 102f – Update PA DEP Table with EDWIN UOG | Updates PA DEP Waste Data table with wells in EDWIN identified as UOG |
| 102g – Update PA DEP Table with EDWIN COG | Updates PA DEP Waste Data table with wells in EDWIN identified as COG |
| 103a – Update Consolidated Formation – Step 1 | Updates the formation name to the formation name listed in the DI Desktop® data. |

## Table A-5. PA DEP and DI Desktop® Cross-Reference Database Queries

| Query Name | Description |
|---|---|
| 103b – Update Consolidated Formation | Where the formation name is blank in the DI Desktop® data, updates the formation name to the formation name listed in the PA DEP Formation Database (DCN SGE01375). |
| 103c – Update Consolidated Formation | Where the formation name is blank in the DI Desktop® data, updates the formation name to the formation name listed in EDWIN, if reported. |
| 105 – Update Tight Flag | Updates the EIA Tight/Shale Flag to "Tight" when the formation name contains a known tight formation. A list of known tight formations is provided in the query design table. |
| 106 – Update Shale Flag | Updates the EIA Tight/Shale Flag to "Shale" when the formation name contains a known shale formation, or the PA DEP Waste Data Unconventional Flag is "Y." A list of known shale formations is provided in the query design table. |
| 107 – Update Unknown Formations | Updates the EIA Tight/Shale Flag to "Unknown" when the formation name is blank or listed as unnamed. |
| 108a – Update UOG resource Flag | Updates the EPA Resource Type field to "UOG" when the PA DEP Waste Data Unconventional Flag is "Y," or the EIA Tight/Shale Flag is "Shale" or "Tight." |
| 108b – Update Unknown resource Flag | Updates the EPA Resource Type field to "Unknown" when the PA DEP Waste Data Unconventional Flag is "N," and the EIA Tight/Shale Flag is "Unknown." |
| 108c – Update COG resource Flag | Updates the EPA Resource Type field to "COG" when the PA DEP Waste Data Unconventional Flag is "N," and the EIA Tight/Shale Flag is blank. |
| 109 – Update 308 Letter Flag | Adds a flag to operators that were selected to receive 308 letters. |
| 110a – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 110b – Update Lat Long Source | Changes the source blank latitudes and longitudes to PA DEP Waste Reports. |
| 111a – Update Missing Lat Longs Using PA DEP Prod Data | Updates blank latitudes and longitudes to latitudes and longitudes listed in the PA DEP Production Reports (DCN SGE01422). |
| 111b – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 112a – Update Missing Lat Longs Using PA DEP Spud Data | Updates blank latitudes and longitudes to latitudes and longitudes listed in the PA DEP Spud Data (DCN SGE01246). |
| 112b – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 113a – Update Missing Lat Longs Using DI Desktop® | Updates blank latitudes and longitudes to latitudes and longitudes listed in DI Desktop® (DCN SGE01170). |
| 113b – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 114a – Avg lat long by farm name | Averages all latitudes and longitudes for a given farm name. |
| 114b – Update Missing Lat Longs Using Farm Values | Updates blank latitudes and longitudes to the average latitude and longitude determined using farm name. |
| 114c – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 115a – Avg lat long by municipality | Averages all latitudes and longitudes for a given municipality. |
| 115b – Update Missing Lat Longs Using Municipality Values | Updates blank latitudes and longitudes to average latitude and longitude determined using municipality name. |
| 115c – Update Bad Lat Longs | Removes latitudes and longitudes that are outside of Pennsylvania. |
| 200 – List of Operators Discharging to POTWs in 2016 | Finds operators discharging wastewater to POTWs in 2016 using their oil and gas operator number. |

**Table A-5. PA DEP and DI Desktop® Cross-Reference Database Queries**

| Query Name | Description |
|---|---|
| 201 – Discharging Operators – All Waste Data | Groups the data from the PA DEP Waste Data table to show all waste data consolidated in the POTW-Dischargers - All Waste Data table. |
| 202 – Discharging Operators – 2016 POTW Waste Data | Groups the data from the POTW-Dischargers - All Waste Data table to show 2016 data in the POTW-Dischargers - 2016 POTW Waste Records table. |
| 203 – Discharging Operators – All O&G Production | Groups the data from the PA DEP Production Reports based on operators discharging in 2016 to make the POTW-Dischargers - All O&G Production table. |

### *Additional PA DEP Data*

The PA DEP Oil and Gas Well Formations Report (DCN SGE01375)[24] lists all oil and gas wells and the oldest, target, and/or the producing formations. EPA used this data source to fill data gaps in formation names provided by DI Desktop® (DI Desktop® data source discussed below). EPA considers the PA DEP Oil and Gas Well Formations Report the best available alternative data source to fill data gaps, thereby improving the completeness of 2016 UOG rule defined UOG wells included in EPA's cost analysis.

Exploration and Development Well Information Network (EDWIN) (DCN SGE01420) is maintained by the Pennsylvania Department of Conservation and Natural Resources, Bureau of topographic and Geological Survey, providing records for more than 104,000 oil and gas wells drilled in Pennsylvania. EDWIN provides access to both scanned oil and gas well documents and associated digital and interpreted data through a single web-based application. EPA considers EDWIN to be the best available data source to fill remaining formation data gaps, thereby improving the completeness of 2016 UOG rule defined UOG wells included in EPA's cost analysis.

The PA DEP SPUD Data Report (DCN SGE01246)[25] is a database that contains Pennsylvania oil and gas SPUD data through December 2018. EPA used this data source to replace inaccurate (i.e., outside Pennsylvania) and missing well latitudes and longitudes in the PA DEP Production and Waste Reports for this analysis. EPA considers the PA DEP SPUD Data Report to be the best available data source to fill location data gaps, thereby improving the completeness of 2016 UOG rule defined UOG wells included in EPA's cost analysis.

## A-4. GIS Analysis Output Results File (Step 6)

Table A-6 lists the GIS analysis output results file which are contained in the docket. Each record in these files contains a starting location (e.g., discharging UOG well), ending location (e.g., POTW, CWT), and the resulting travel distance and time estimated by EPA using ArcGIS Online.

[24] Downloaded on 8/8/2016 from www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Well_Formations.

[25] Downloaded on 1/2/2018.

**Table A-6. Analysis Output Results Files**

| Destination(s) | Filename | DCN # |
|---|---|---|
| POTWs Receiving Wastewater | Wells_Discharging_To_Alcosan_-_Trucking_Time_to_POTWs.xlsx | SGE01462 |
| CWT Facilities | Nearest_October_02_2018_CWTs_to_October_02_2018_wells_all.xlsx | SGE01463 |
| Disposal Wells | Wells_Discharging_to_Alcosan_-_Trucking_Time_to_UICs.xlsx | SGE01464 |
| POTWs Receiving Wastewater | Wells_Discharging_to_Brockway_-_Trucking_Time_to_POTWs.xlsx | SGE01465 |
| Disposal Wells | Wells_Discharging_to_Brockway_-_Trucking_Time_to_UICs.xlsx | SGE01466 |
| POTWs Receiving Wastewater | Wells_Discharging_to_Reynoldsville_-_Trucking_Time_to_POTWs.xlsx | SGE01467 |
| Disposal Wells | Wells_Discharging_to_Reynoldsville_-_Trucking_Time_to_UICs.xlsx | SGE01468 |
| Ridgeway POTW | Wells_Discharging_to_to_Ridgeway_1_-_Trucking_Time_to_Ridgeway.xlsx | SGE01469 |
| Disposal Wells | Wells_to_Ridgeway_1_-_Trucking_Time_to_UICs.xlsx | SGE01470 |
| Ridgeway POTW | Wells_Discharging_to_Ridgeway_2_-_Trucking_Time_to_Ridgeway.xlsx | SGE01471 |
| Disposal Wells | Wells_to_Ridgeway_2_-_Trucking_Time_to_UICs.xlsx | SGE01472 |
| Ridgeway POTW | Wells_Discharging_to_Ridgeway_3_-_Trucking_Time_to_Ridgeway.xlsx | SGE01473 |
| Disposal Wells | Wells_to_Ridgeway_3_-_Trucking_time_to_UICs.xlsx | SGE01474 |
| All Disposal Methods | 0817origins1_to_0817destinations1.xlsx | SGE01475 |
| All Disposal Methods | 0817origins2_to_0817destinations2.xlsx | SGE01476 |
| CWT, POTW, or Disposal Wells | Origins_1_to_Destinations_1.xlsx | SGE01477 |
| CWT, POTW, or Disposal Wells | Origins_2_to_Destinations_2.xlsx | SGE01478 |
| CWT, POTW, or Disposal Wells | Origins_3_to_Destinations_3.xlsx | SGE01479 |
| Townships for road spreading | 0824 Last GIS data for EPA Results (003).xlsx | SGE01480 |
| CWT Facilities | Wells_Discharging_to_Brockway_-_Trucking_Time_to_Nearest_CWTs.xlsx | SGE01481 |

## A-5. UOG Alternative Wastewater Management Analysis (Step 8, 9, and 10)

EPA's primary data source for transportation and management costs are the responses completed by the eight facilities that responded to EPA's data request. EPA also used management costs obtained during EPA site visits and conference calls with oil and gas, CWT facility, and disposal well operators. These site visits and conference calls were conducted by EPA in support of the UOG rulemaking (DCN SGE01188) and CWT Study (DCN SGE01443). The management costs reported by these operators are often reported in general ranges because management costs vary by other factors that are determined on a case-by-case scenario. EPA assumes that cost information provided in responses to EPA's data request and collected during site visits and conference calls are accurate because they are reported directly by the operators and wastewater management facilities.

The "Cost Assumptions and Calcs." worksheet in the Alterative Wastewater Management Analysis (DCN SGE01419) describes the origin of data and assumptions used throughout this

analysis. Specifically, it provides a description of the data used to develop baseline costs for operators who discharged UOG wastewater to POTWs in 2016 and the data used to estimate incremental costs for these operators to eliminate UOG wastewater discharges to POTWs.

## A-6. Stripper Well Analysis for Table 2-3 and Figure 2-3

Table A-7 lists and describes the Access queries in EPA's Stripper Well Analysis database (DCN SGE01461) used to identify and flag stripper wells oil and gas wells in PA DEP's waste and production reports. EPA created this database to create Table 2-3. The queries perform two primary functions:

1. Identify stripper wells in PA DEP's 2016 waste and production databases (queries 00 through 03). Section 3.1.9 also describes the detailed criteria used to identify stripper wells.

2. Calculate summary statistics for Table 2-3 (queries 04 through 23).

**Table A-7. Stripper Well Database Query Descriptions**

| Query | Description |
|---|---|
| 00 | Filters PA DEP's O&G Production well data to only include wells producing in 2016 and creates the "2016 O&G Producing Wells" table. |
| 01 | For each well in the in "2016 O&G Producing Wells" table, this query calculates gas to oil ratio for each well by dividing 2016 gas quantity (cubic feet) by 2016 oil production quantity (barrels). |
| 02 | For each well in the in "2016 O&G Producing Wells" table, this query calculates oil production per day for each well by dividing 2016 oil quantity (barrels) by 2016 number of oil production days. |
| 03 | For each well in the in "2016 O&G Producing Wells" table, this query populates the "stripper well" column using EPA's stripper well criteria: wells that produce less than 10 barrels per day and do not have a gas to oil production ratio greater than 15,000 cubic feet per day. |
| 04 | This query finds the unique number of operators producing oil and gas in 2016. |
| 05 | This query finds the unique number of operators producing oil and gas in 2016, excluding stripper wells. |
| 10 | Filters "PA DEP Waste Data" for 2016 records and sums wastewater volume by well. All wells are included. |
| 11 | Groups query 10 results by operator by summing the wastewater volume by operator and by well resource type and counting the number of wells. |
| 12 | Groups query 11 results by counting the number of operators, summing the number of wells, and summing the wastewater volume by well resource type. |
| 13 | Groups query 11 results by OGO number (i.e., operator ID) to identify the number of operators producing wastewater in 2016. |
| 20 | Filters "PA DEP Waste Data" for 2016 records and sums wastewater volume by well (stripper wells excluded). |
| 21 | Groups query 20 results by operator by summing the wastewater volume by operator and by well resource type and counting the number of wells (stripper wells excluded). |
| 22 | Groups query 21 results by counting the number of operators, summing the number of wells, and summing the wastewater volume by well resource type (stripper wells excluded). |
| 23 | Groups query 11 results by OGO number (i.e., operator ID) to identify the number of operators producing wastewater in 2016 (stripper wells excluded). |

# APPENDIX B
# Cost Sensitivity Analysis

# APPENDIX B COST SENSITIVITY ANALYSIS

Sensitivity analysis is an important component in the production of robust cost analysis results. These sensitivity analyses assess the effects of alternative assumptions regarding the effects of the UOG final rule under an alternative scenario. For this cost analysis, EPA performed a sensitivity analysis on choosing the second rather than the first closest alternative CWT facility or disposal well. All other cost analysis methodologies and assumptions remain the same as those described in Section 3.

Table B-1 presents summary statistics of the cost results from the sensitivity analysis, together with the change as compared to the original cost results. Conducting the Alternative Wastewater Management Analysis by mapping wells to send wastewater to the second nearest CWT facility or disposal well, instead of the nearest, increases transportation costs by $128,000 and decreases management costs by $8,300. Overall, managing wastewater using the second closest facility versus the closest resulted in total incremental costs of $184,619 as compared to $64,907, respectively.

**Table B-1. Sensitivity Scenario (Second Closest CWT Facility/Disposal Well) Alternative Wastewater Management Analysis Results (2016)**

| Cost Output | Result | Sensitivity Analysis Result | Change (+/-) |
|---|---|---|---|
| **Baseline Costs** | | | |
| A. Operators Discharging 2016 UOG Rule Defined UOG Wastewater to POTWs | 22 | 22 | 0 |
| B. Total Oil and Gas Wells (UOG and COG) Producing Oil or Gas Owned by (A) Operators | 18,136 | 18,136 | 0 |
| C. Total Oil and Gas Wells (UOG and COG) Generating Wastewater Owned by (A) Operators | 5,863 | 5,863 | 0 |
| D. Total Baseline Costs for (B) Wells | $6,043,304 | $6,043,304 | 0 |
| **Incremental Costs** | | | |
| A. Total Wells with Incremental Costs | 959 | 959 | 0 |
| B. Total Incremental Transportation Cost ($) | $21,109 | $149,120 | +$128,011 |
| C. Total Incremental Management Cost ($) | $43,798 | $35,499 | -$8,299 |
| D. Total Incremental Transportation and Management Cost ($) (B+C=D) | $64,907 | $184,619 | +$119,712 |

Source: DCN SGE01419.

For the impacts analysis, results of the sensitivity analysis show 7 entities will be baseline closures, and 0 of the remaining 15 will close because of incremental compliance costs. Therefore, the sensitivity analysis shows no change in entity closures as compared to the original analysis.

**Table B-2. Sensitivity Scenario (Second Closest CWT Facility/Disposal Well): Results of Baseline and Post-Compliance Analysis (2016)**

| | Results of Baseline and Post-Compliance Analysis |
|---|---|
| Baseline Closures | 7 of 22 Entities |
| Post-Compliance Closures | 0 of 15 Entities |

Source: DCN SGE01484.

Table B-3 summarizes the results of the sensitivity scenario on the cost-to-revenue analysis. EPA estimates that 7 small entities would incur costs exceeding 1 percent of revenue but less than 3 percent of revenue, and 1 small entity would incur costs of at least 3 percent of revenue.

**Table B-3. Sensitivity Scenario (Second Closest CWT Facility/Disposal Well): Entity Annualized Cost-to-Revenue (CTR) Results**

| | Number of Entities with CTR <1% | Number of Entities with CTR 1-3% | Number of Entities with CTR >3% |
|---|---|---|---|
| Revenue – Year 1 | 14 | 7 | 1 |

Source: DCN SGE01484.