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Water Management Technologies Used by Marcellus Shale Gas Producers

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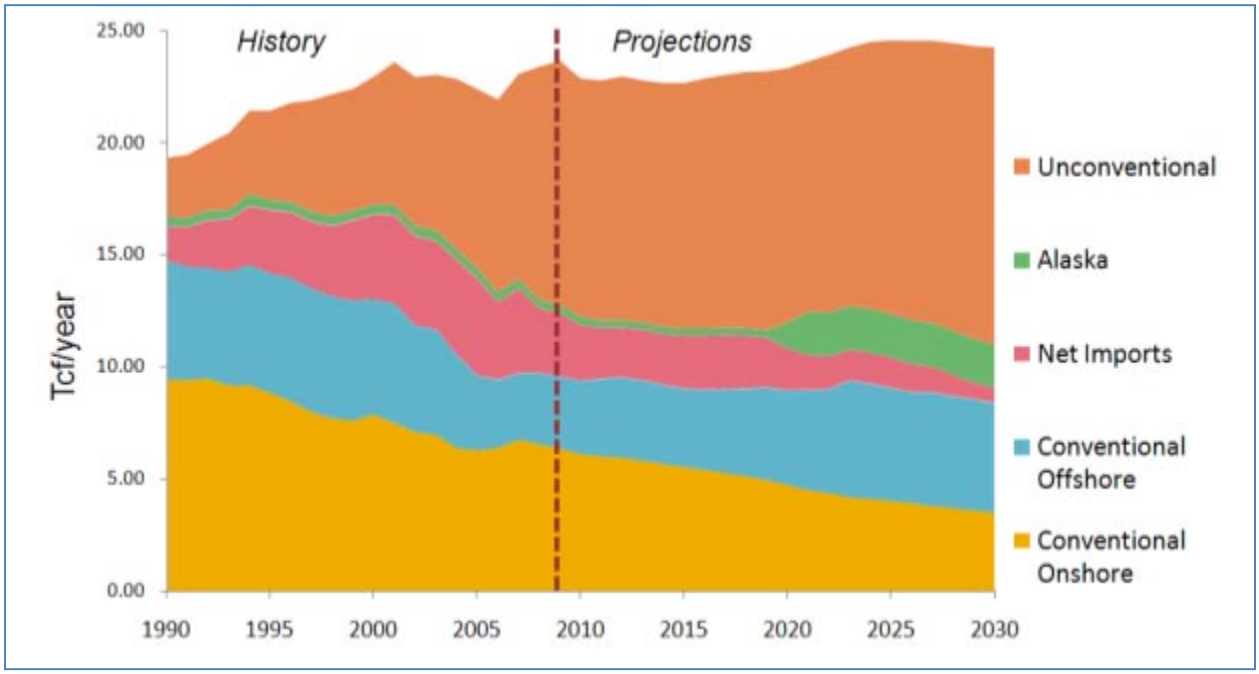
Chapter 1 – Introduction

Natural gas represents an important energy source for the United States. According to the U.S. Department of Energy's (DOE's) Energy Information Administration (EIA), about 22% of the country's energy needs are provided by natural gas. Historically, natural gas was produced from conventional vertical wells drilled into porous hydrocarbon-containing formations. During the past decade, operators have increasingly looked to other unconventional sources of natural gas, such as coal bed methane, tight gas sands, and gas shales.

Figure 1 shows EIA projections of the source of natural gas supplies through 2030. Unconventional gas supplies are anticipated to play an increasingly important role. Some of the busiest and most productive oil and gas activities in the country today are shale gas plays.

Figure 1 – U.S. Natural Gas Supply by Source



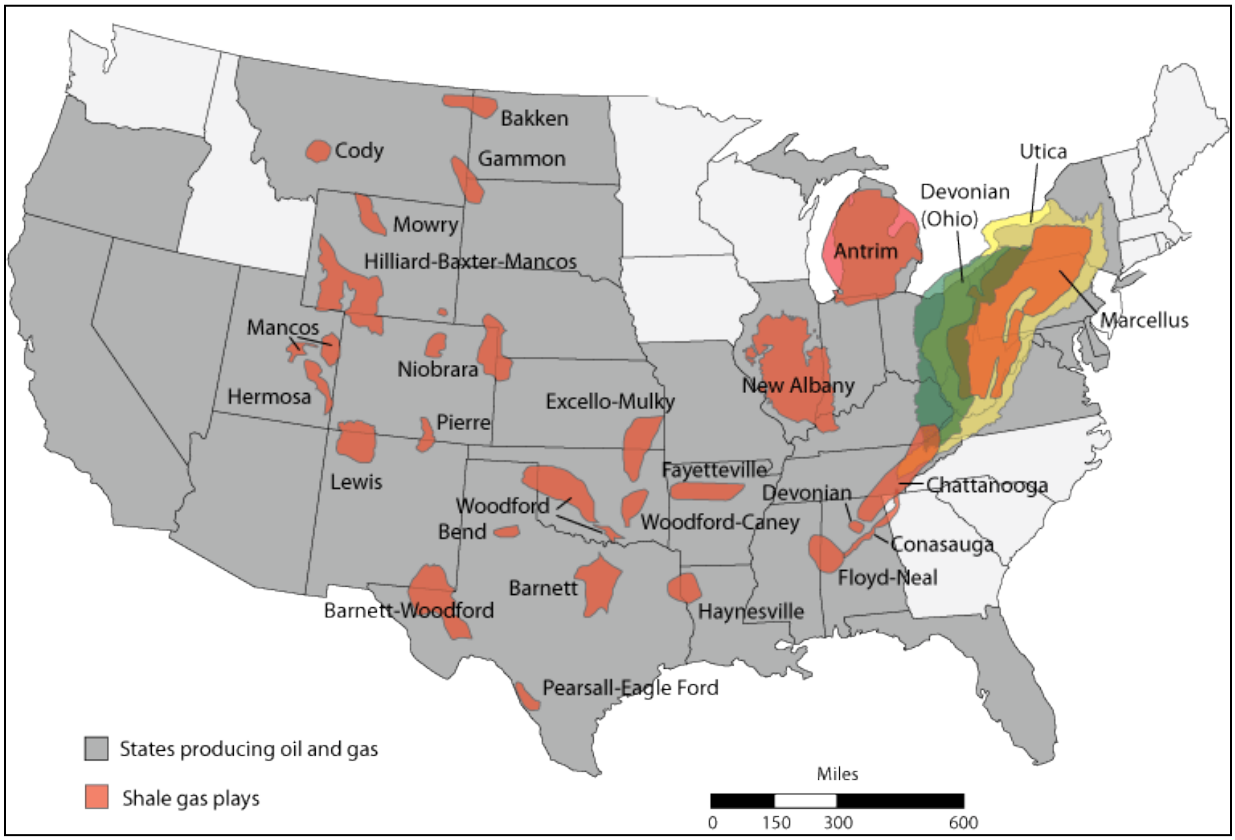
Source: DOE/EIA Annual Energy Outlook 2009. Note that Tcf refers to trillion cubic feet.

Shale Gas Resources in the United States

Important shale gas formations are found in many parts of the United States, as shown on the map in Figure 2. Much of the early rapid growth in shale gas production took place in the Barnett Shale formation near Fort Worth, Texas. As the technology evolved, operators began to explore other large shale formations in other parts of the country. The most active shales to date are the Barnett Shale, the Fayetteville Shale, the Antrim Shale, the Haynesville Shale, the Marcellus Shale, and the Woodford Shale. A 2009 Shale Gas Primer, sponsored by DOE, includes a chart

showing the gas production from several major shale gas formations (GWPC and ALL 2009 – see page 10).

Figure 2 – U.S. Shale Gas Plays



Source: Provided by staff from DOE's Office of Fossil Energy.

Technologies That Enable Shale Gas Production

Unlike conventional natural gas, which has been produced for more than a century, shale gas is more difficult to remove from the ground. Shale formations contain very tight rock, with less pore space than traditional oil and gas formations, such as sandstone and limestone. Conventional drilling and production methods typically cannot produce enough natural gas from shale formations to make the wells economically viable.

Because of the tight nature of the shale formations, gas producers have relied on more advanced technologies in order to extract sufficient volumes of natural gas to make the wells profitable. The two technologies that have lead the way in allowing economical production of shale gas are horizontal drilling and multistage hydraulic fracturing.

Horizontal drilling is an advanced technology that allows a well to be drilled vertically to a desired depth, then turned sideways to reach out hundreds to thousands of feet laterally. Horizontal drilling is critical for producing shale gas because it creates a well that penetrates

through a long section of the shale formation, allowing for the collection of gas throughout a much longer horizontal run.

The hydraulic fracturing process (a "frac job") injects water, sand, and other ingredients at very high pressure into the well. The high pressure creates small fractures in the rock that extend out as far as 1,000 feet away from the well. After the fractures are created, the pressure is reduced. Water from the well returns to the surface (known as flowback), but the sand grains remain in the rock fractures, effectively propping the fractures open and allowing the gas to move. Frac jobs on traditional vertical wells are usually done in one stage. However, given the length of horizontal wells, the frac jobs are often conducted in limited linear sections of the well known as stages. In a long horizontal well, stages are fractured sequentially, beginning with the outermost section of the well. There is a useful video animation clip at http://www.pamarcellus.com/web/ that shows how horizontal wells are drilled and then hydraulically fractured.

Various types of "frac fluids" and additives have been used. Most frac fluid used in shale gas wells consists of water, a proppant (generally sand), a friction reducing agent ("slick water" — water containing some surfactant additives to help the flow-back water return from the well at the end of the frac job), and other chemicals used to protect the well and to optimize performance. GWPC and ALL (2009) lists the major additives, the types of chemicals found in the additives, and their functions.

DOE/NETL Research Program

DOE's National Energy Technology Laboratory (NETL) administers an Environmental Program that aims to find solutions to environmental concerns by focusing on the following program elements:

1. Produced water and fracture flowback water management, particularly in gas shale development areas,
2. Water resource management in oil and gas basins,
3. Air quality issues associated with oil and gas exploration and production (E&P) activities,
4. Surface impact issues associated with E&P activities,
5. Water resource management in Arctic oil and gas development areas,
6. Decision making tools that help operators balance resource development and environmental protection, and
7. Online information and data exchange systems that support regulatory streamlining.

There are currently 27 extramural projects in the Environmental Program, with a total value of roughly $32 million (not including participant cost-share). Approximately $10 million of this total is directed toward projects led by industry, $9 million to projects led by universities, $11 million to state agencies and national non-profit organizations, and $2 million to national laboratories for technical support to other project partners. The project portfolio is balanced between projects focused on technology development, data gathering, and development of data management software and decision support tools.

Some of these projects are referenced in this report. Program and individual project information can be found at the following NETL links:

- Technology Solutions for Mitigating Environmental Impacts of Oil and Gas E&P Activity http://www.netl.doe.gov/publications/factsheets/program/Prog101.pdf
- Natural Gas and Petroleum Projects, Environmental Solutions, Produced Water Management http://www.netl.doe.gov/technologies/oil-gas/Projects/ENV_TOC.html#Produced

Chapter 2 – Water Issues Associated with Shale Gas Production

Water plays a role in different aspects of shale gas production. Three important water issues are discussed in this chapter.

Stormwater Runoff from Disturbed Areas

In order to create an area for drilling a new well, the operator clears and grades an area that can accommodate one or more wellheads; several pits for holding water, drill cuttings, and used drilling fluids; and space for the many trucks used to complete a frac job. Typically, this space will be 3 to 5 acres in size, plus any area disturbed to create an access road from the nearest public road to the well pad. Most of the figures in this chapter are photos taken by the author at several different Marcellus Shale well sites in southwestern Pennsylvania on a rainy day in May 2009 (photos from other locations are identified).

Figure 3 shows a well pad while the well is being drilled, Figure 4 shows a pad while the well is undergoing a frac job, and Figure 5 shows a pad with a completed wellhead. Figures 6 and 7 show examples of access roads at well sites in the same area. Figure 6 is taken at a recently completed well, while Figure 7 is taken at a much older well.

Figure 3 – Well Pad Showing Drilling Rig

Figure 4 – Well Pad Showing Equipment Used for Frac Job

Figure 5 – Well Pad Showing Completed Wellhead

Figure 6 – Access Road at Recently Completed Well

Figure 7 – Access Road at Older Well

These photos give an idea of the amount of disturbed land there is at a well site. Most operators employ appropriate management practices to control stormwater runoff. Figures 8 through 10 show some of the stormwater management structures that are used to capture offsite stormwater and divert it around the disturbed well pad area. This reduces the amount of water that carries sediment. The water falling on disturbed areas of the site can be controlled through the application of gravel to the well pad and road surfaces or through onsite collection pits. The Pennsylvania Department of Environmental Protection (PADEP), Bureau of Oil and Gas Management website contains presentations from a January 2010 training course (http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/Marcellus/2010%20MarcellusTraining.htm). Several of the presentations relate to erosion and sediment control plans. The information and graphics contained in the presentation are useful.

Figure 8 – Stormwater Diversion Ditch to Collect Offsite Water

Figure 9 – Lower End of Stormwater Diversion Ditch

Figure 10 – Stormwater Control Structure

Water Supply for Drilling and to Make Up Frac Fluids

The second important water issue involves finding an adequate and dependable supply of water to support well drilling and completion activities. Water used for drilling and making up frac fluids can come from several sources: surface water bodies, groundwater, municipal potable water supplies, or reused water from some other water source (most commonly this is flowback water from a previously fractured well).

GWPC and ALL (2009) provide estimates of water requirements for four of the major shale gas plays. The water required for drilling a typical shale gas well ranges from 1,000,000 gallons in the Haynesville Shale to 60,000 gallons in the Fayetteville Shale, depending on the types of drilling fluids used and the depth and horizontal extent of the wells. The Marcellus Shale drilling volume falls near the lower end of this range at 80,000 gallons per well. The volume needed to fracture a well is considerably larger. According to GWPC and ALL (2009), the frac fluid volume ranges from 3,800,000 gallons per well in the Marcellus Shale to 2,300,000 gallons per well in the Barnett Shale.

Another source of information on the amount of water used per well is a presentation given by a representative of the Susquehanna River Basin Commission (SRBC) on volumes of water withdrawn for Marcellus Shale gas well development. A large portion of the Marcellus Shale underlies the Susquehanna River basin watershed. Any water usage within the watershed is subject to oversight by the SRBC. Hoffman (2010) notes, that as of January 2010, the SRBC had data for 131 wells. The total volume of water withdrawn through that date is 262 million gallons, with 45% coming from public water supplies and the other 55% coming from surface water sources. The average total volume of fluid used per well is 2.7 million gallons, with 2.2 million gallons of that coming from freshwater sources and 0.5 million gallons coming from recycled flowback water. No information was provided by Hoffman (2010) concerning whether the wells in the SRBC data set were vertical or horizontal wells (a vertical well requires much less water for a frac job than does a horizontal well).

Water can be brought to the site by numerous tank trucks or, where another source of water is available within a mile or so, it can be piped to the site. Figure 11 shows tank trucks similar to those used to haul water. The photo on the left of a large semi-style tank truck was taken in the Barnett Shale region of Texas, and the photo on the right of two smaller tank trucks was taken in western Pennsylvania. Figures 12 through 14 show pipes conveying water to a well undergoing a frac job. Figures 12 and 13 were taken in southwestern Pennsylvania. Figure 12 shows a pump withdrawing water from a storage pond and the rubber hose used to convey it up a hill to a well site. Figure 13 shows the same pipe near the top of the hill approaching the well site. Figure 14 shows aluminum pipes used to convey water at a site in the Fayetteville Shale region of Arkansas.

Figure 11 – Tank Trucks Similar to Those Used to Deliver Water to a Well Site

Figure 12 – Pumping Unit Used to Move Water to Next Well Site

Figure 13 – Pipe Shown at the top of a Hill after Pumping

Figure 14 – Aluminum Pipe Used to Convey Water

Management of Water Flowing to the Surface from the Well

The third important water issue involves managing the water that comes to the surface from the gas well. During the frac job, the operator injects a large volume of water into the formation. Once the frac job is finished, the pressure is released, and a portion of the injected water flows back to the surface in the first few days to weeks. This water is referred to as flowback or flowback water. Over a much longer period of time, additional water that is naturally present in the formation (i.e., produced water) continues to flow from the well. While some authors consider flowback to be just one part of the produced water, this report distinguishes flowback from the ongoing produced water. Both flowback and produced water typically contain very high levels of total dissolved solids (TDS) and many other constituents. Over an extended period of time, the volume of produced water from a given well decreases.

Not all of the injected frac fluid returns to the surface. GWPC and ALL (2009) report that from 30% to 70% of the original frac fluid volume returns as flowback. However, anecdotal reports from Marcellus operators suggest that the actual percentage is at or below the lower end of that range. The rest of the water remains in pores within the formation. The SRBC data set described in the previous section shows that about 13.5% of the injected frac fluid is recovered (Hoffman 2010).

Operators must manage the flowback and produced water in a cost-effective manner that complies with state regulatory requirements. The primary options are:

- Inject underground through a disposal well (onsite or offsite),
- Discharge to a nearby surface water body,
- Haul to a municipal wastewater treatment plant (often referred to as a publicly owned treatment works or POTW),
- Haul to a commercial industrial wastewater treatment facility, and
- Reuse for a future frac job either with or without treatment.

Chapter 3 describes each of these different processes in more detail and identifies those options that are actually being used by gas operators in the Marcellus Shale region.

Chapter 3 – Water Management Technologies Used in the Marcellus Shale

The last portion of Chapter 2 describes the range of potential options for managing flowback and produced water from shale gas wells. This chapter reviews these options and identifies which of the options are currently being used by Marcellus Shale gas operators.

Data Collection Approach

In order to identify the water management options that are actually being used, Argonne National Laboratory (Argonne) contacted the Marcellus Shale Coalition, a group of companies involved with natural gas production in the Marcellus Shale region. Although the Coalition is primarily focused on gas development in Pennsylvania, many of the companies are currently working in or plan to work in the other Marcellus Shale states too. A representative of the Coalition provided a list of eight major companies operating in the Marcellus Shale along with the names of contact persons. Argonne wrote to each of these companies, plus another three companies with which Argonne is currently working on other Marcellus water projects. Argonne received replies from eight companies, including one reply that indicated the company's water management practices were confidential at that point.

In addition, the author made visits during May 2010 to four commercial industrial wastewater treatment facilities that accept water from Marcellus Shale gas wells. These facilities employ different processes to treat the flowback and produced water. The facilities are described in Chapter 4.

Underground Injection

GWPC and ALL (2009) list the water management options employed at several different shale gas plays. All of the plays employ injection wells as a *primary* means of disposal except for the Marcellus. Few, if any, onsite injection wells are used in Pennsylvania or New York, nor are there any commercial disposal wells used for Marcellus Shale flowback and produced water located in these states.

Where injection is available (e.g., at the other shale gas plays and in portions of Ohio or West Virginia for Marcellus Shale flowback and produced water), the injection wells can be either onsite wells operated by the gas producer or offsite third-party commercial disposal wells. To give readers a sense of what a commercial disposal well looks like, Figure 15 shows a commercial flowback and produced water disposal well in the Barnett Shale region of Texas. Flowback and produced water are delivered by tank truck and are transferred into the storage tanks. As necessary, the flowback and produced water are injected into a deep formation that has sufficient porosity and injectivity to accept the water.

Figure 15 - Injection Well and Tank Battery at Commercial Disposal Facility in Texas

At least some of the Marcellus Shale gas operators are sending flowback and produced water to commercial disposal wells located in Ohio. The author contacted the Ohio Department of Natural Resources, Division of Mineral Resources Management (DMRM), to learn which commercial wastewater disposal companies were operating injection wells in eastern and central Ohio to receive flowback and produced water from Pennsylvania. Tom Tomastik, an Underground Injection Control program manager with the Ohio DMRM, replied:

> "Ohio does not distinguish between commercial and non-commercial Class II injection wells. So basically, it's the operator who determines if they will take other operator's oil and gas fluids. Although we track brine hauling from cradle to grave, it would be a huge process right now to go through and delineate the fluids from the Marcellus. Starting on June 30th, however, passage of Ohio Senate Bill 165 will require a 20 cent per barrel fee for out-of-district oilfield fluids to be paid to us, so we will start tracking out-of-state fluids more closely (mostly Marcellus) then." (Tomastik 2010).

Mr. Tomastik provided two tables listing Ohio's permitted injection wells. The first table listed companies that operate commercial disposal wells. The second table listed all permitted Class II injection wells (those used for injecting oil and gas fluids). This information was combined into Table 1, which shows the companies that operate commercial saltwater (flowback and produced water) injection wells and the counties in which those wells are located.

Additional information on 2009 injection volumes was provided by Gregg Miller of the Ohio DMRM (Miller 2010). That information, for each injection well, is shown in the right-hand column of Table 1.

Table 1 – Commercial Saltwater Disposal Wells in Ohio and 2009 Injection Volume

County	Operator	Lease	2009 Disposal Volume (bbl/yr)
Ashtabula	B & B Oilfield Services, Inc.	Miller & Co. #3	75,212
Ashtabula	B & B Oilfield Services, Inc.	Clinton Oil SWIW #2	75,211
Athens	Carper Well Service	H. Ginsburg #1	49,163
Guernsey	David R. Hill, Inc.	Devco Unit #1	312,753
Guernsey	Dover Atwood Corp.	Kopolka #1	76,311
Guernsey	Arvilla Oilfield Services LLC	Slifko #1	14,835
Holmes	OOGC Disposal Company	Killbuck Disposal Well #1	164,202
Holmes	Mac Oilfield Service, Inc.	F. Hawkins #1	95,061
Licking	OOGC Disposal Company	Ronald F. Moran #1	190,437
Mahoning	Brineaway, Inc.	Salty Dog #1	26,940
Mahoning	Brineaway, Inc.	Salty Dog #3	45,019
Mahoning	Brineaway, Inc.	Jenkins #1	52,181
Morgan	Broad Street Energy	Cook #2-A	15,442
Morrow	Fishburn Producing, Inc.	J.F. Mosher #1	11,585
Morrow	Fishburn Producing, Inc.	Fishburn #1	90,739
Morrow	Fishburn Producing, Inc.	Clinger Unit #1	47,250
Morrow	Fishburn Producing, Inc.	Power (Fegley) #1	20,853
Noble	Arvilla Oilfield Services LLC	H. Dudley #1	153,307
Noble	Triad Resources, Inc.	Warren Drilling #1	230,731
Noble	Carper Well Service	Bryan-Smith Unit #1	188,055
Perry	R.C. Poling	Rushcreek Partners et at #1	181,470
Portage	Ray Pander Trucking, Inc.	J. & D. Blazdek #2	81,206
Portage	Ray Pander Trucking, Inc.	Plum Creek #1	59,362
Portage	William S. Miller, Inc.	Wilcox #1	245,519
Portage	Salty's Disposal Wells, LP	Myers #1 Unit	206,535
Portage	Salty's Disposal Wells, LP	Groselle #2	176,989
Portage	B & B Oilfield Services, Inc.	Long #1	103,438
Stark	Ray Pander Trucking, Inc.	Belden & Blake Corp. SWDW #5	96,127
Stark	Ray Pander Trucking, Inc.	Ed Lyons (Genet) #1	171,790
Stark	Brineaway, Inc.	The Salty Dog #2	187
Stark	Brineaway, Inc.	J & E Walker #2	30,645
Stark	Brineaway, Inc.	Kolm #1	30,645
Trumbull	Ray Pander Trucking, Inc.	Eva Root Wolf #1	8,323
Trumbull	Ray Pander Trucking, Inc.	Wolf #2	104,443

Table 1 – Commercial Saltwater Disposal Wells in Ohio and 2009 Injection Volume (Cont.)

County	Operator	Lease	2009 Disposal Volume (bbl/yr)
Trumbull	Ray Pander Trucking, Inc.	Pander #1	113,941
Washington	Carper Well Service	Davis-Huffman #2	1,744
Washington	Carper Well Service	Davis-Huffman #3	9,180
Washington	Virco, Inc.	Helen Hall #1-19	121,978
Washington	Broad Street Energy	H.L. Flower #1	147,728
Washington	OOGC Disposal Company	Long Run Disposal #1	611,725
Wayne	Mac Oilfield Service, Inc.	Weldon Mohr #2	29,651
		Total Injected Volume	**4,467,913**

Note that Ohio has active oil and gas production from many wells that are not part of the Marcellus Shale. Some of the injection wells in Table 1 may dispose of water from these other oil and gas wells rather than from Marcellus Shale wells.

Figure 16 is a map of Ohio with the county boundaries delineated. Each county that has a permitted commercial saltwater disposal well is indicated with a star. Nearly all of the counties in which the disposal wells are located are in the eastern half of the state.

Argonne asked for similar information concerning commercial injection wells from the West Virginia Department of Environmental Protection (WVDEP) but did not receive any information. Puder and Veil (2006) report that three facilities in West Virginia operated commercial injection wells that accepted produced water in the time period between October 2005 and April 2006. However, only two of them provided information that could be used in that study. These were Base Petroleum in Charleston, West Virginia, and Danny Web Construction in Brenton, West Virginia.

Current Practices from Surveyed Gas Companies: Four of the surveyed gas companies indicated that they have sent produced water to commercial disposal wells. Three of the replies mentioned disposal wells in Ohio, while the fourth reply did not specify any location.

Figure 16 – Ohio Counties in Which Commercial Disposal Wells Are Located (indicated by star)

Source: Ohio Department of Transportation website at http://www.dot.state.oh.us/maps/Pages/CountyMap.aspx; accessed May 28, 2010.

Discharge to Surface Water Body

Many types of industrial wastewater are discharged to streams, rivers, and other surface water bodies. Permission to discharge wastewater is made through National Pollutant Discharge Elimination System (NPDES) permits issued by state agencies. However, discharging flowback or produced water directly from a well site presents various challenges. First, the water typically contains high levels of TDS (salinity) and other constituents that would require treatment.
In response to concern over flowback and produced water discharges, the PADEP, in April 2009, proposed a new strategy that would add effluent standards for oil and gas wastewaters of 500 mg/L for TDS, 250 mg/L for sulfates, 250 mg/L for chlorides, and 10 mg/L for total barium

and total strontium.[1] On May 17, 2010, the Pennsylvania Environmental Quality Board approved the new discharge requirements as revisions to the Pennsylvania regulations.[2] According to the material released on that date, these revisions will go into effect upon publication in the *Pennsylvania Bulletin* as final rulemaking (as of June 30, that publication has not yet occurred).

Second, the U.S. Environmental Protection Agency (EPA) has adopted national discharge standards for many industries (known as effluent limitations guidelines or ELGs). The ELGs for the oil and gas industry are promulgated at 40 CFR Part 435 (Title 40, Part 435 of the *Code of Federal Regulations*). The ELGs specify zero discharge of produced water from onshore wells, but do allow two exceptions. The first applies to facilities located west of the 98th meridian (roughly the western half of the country) and the second applies to oil wells with very low production (less than 10 barrels of crude oil per day). Since all Marcellus Shale wells are located in the eastern United States and produce gas rather than oil, neither of these exceptions applies.

The May 17 rule revisions state that no discharge of oil and gas wastewater can be made directly from an oil and gas site to surface waters. Oil and gas wastewater can be sent to either a centralized treatment facility (referred to in this report as a commercial industrial wastewater treatment plant) or to a POTW. Those POTWs that accept wastewater from this category will be required to have an EPA-approved pretreatment program, which addresses TDS through local limits on these sources and at the above standards.

Reportedly, representatives of the West Virginia Department of Environmental Protection announced on May 19, 2010, that the agency would soon propose a new water quality standard for TDS of 500 mg/L.[3]

Current Practices from Surveyed Gas Companies: Argonne did not identify any Marcellus Shale gas producers that are directly discharging flowback or produced water from their well sites. There are several commercial wastewater disposal facilities that accept flowback and produced water, treat it, and discharge the water under their own NPDES permits. These facilities are discussed in a later section.

Haul to POTWs

Prior to the recent rapid development in the Marcellus Shale region, the oil and gas development activities in the region generated relatively small volumes of produced water. Some POTWs accepted limited quantities of produced water from oil and gas operators. The produced water was trucked from tanks or pits at the well site and discharged into the treatment facility. The

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[1] The draft strategy can be downloaded at http://files.dep.state.pa.us/Water/Wastewater%20Management/WastewaterPortalFiles/MarcellusShaleWastewaterPartnership/high_tds_wastewater_strategy_041109.pdf; accessed April 29, 2010.

[2] The May 17 revisions to the rule can be downloaded at http://files.dep.state.pa.us/PublicParticipation/Advisory%20Committees/AdvCommPortalFiles/WRAC/Preamble%20TDS%20Final%20Rulemaking%20to%20WRAC.pdf; accessed May 20, 2010.

[3] This information was reported in a May 19 article in the *Charleston Gazette*; http://wvgazette.com/News/201005190834; accessed May 21, 2010.

treatment processes found at most POTWs are designed to remove suspended solids and biodegradable materials, but not salinity or TDS.

As the Marcellus Shale development grew in popularity, operators sought permission to bring more truckloads of salty flowback and produced water to the treatment plants. The increased input of TDS resulted in increased levels of TDS in the discharge. The May 17 revisions to the PADEP discharge regulations mentioned in the previous section will place restrictions on the volume of flowback and produced water that POTWs can accept.

Argonne obtained a list from PADEP of the POTWs and other commercial wastewater treatment facilities that currently accept or have applied for permits to accept flowback and produced water (Furlan 2010). A version of that table (edited to fit on a single-page width) is provided as Appendix A of this report. The table lists 15 POTWs that currently receive oil and gas water or have received it in the past. Many of those POTWs have conditions in their NPDES permits requiring that the volume of wastewater from oil and gas sources may not exceed 1% of the average daily flow. The table lists 4 other POTWs that receive treated water from commercial wastewater treatment companies that discharge to the municipal sewer system rather than discharging directly into surface water bodies.

Current Practices from Surveyed Gas Companies: Three of the surveyed gas companies are currently sending flowback and produced water to POTWs or have done so in the past. One of the replies indicated that it had sent its flowback and produced water to the New Castle, Pennsylvania, wastewater treatment plant. The other two replies did not identify the municipality receiving the water.

Haul to Commercial Industrial Wastewater Treatment Plant

Several Pennsylvania companies have provided wastewater disposal service to the oil and gas community for many years. As the volume of flowback and produced water has increased rapidly over the past few years, new commercial disposal companies are opening their doors, while still others are applying for permits from PADEP.

Argonne obtained a list of commercial industrial wastewater treatment plants that currently accept flowback and produced water from the PADEP (Furlan 2010). This list is part of the large table provided in Appendix A. Twenty-seven commercial wastewater treatment facilities (noted as CWT in Appendix A) are permitted by the PADEP to treat flowback and produced water and then discharge the treated water to surface water bodies. Four other commercial facilities treat the water and then discharge it to municipal sewers that flow to POTWs. The PADEP list also includes 25 other commercial wastewater treatment facilities that have applied for permits but have not yet received permission to operate and discharge.

Additional information about the commercial wastewater treatment industry in Pennsylvania was obtained from an earlier Argonne report. Puder and Veil (2006) report that eight facilities in Pennsylvania were accepting produced water in the time period between October 2005 and April 2006. However, only four of them provided information that could be used in that study. Table 2 shows the Pennsylvania facilities that were listed in Puder and Veil (2006). The costs listed in Table 2 represent the costs during 2005-2006 and may not be representative of costs now.

These four companies are still providing wastewater disposal service to the oil and gas industry. The May 17 revisions to the PADEP discharge regulations include an important provision relating to existing commercial industrial disposal companies. Any commercial industrial disposal company with a valid NPDES permit as of the date on which the rule revisions are finalized (presumably during the summer of 2010) is allowed to continue discharging at the permitted levels until such time as the facility seeks an increase in discharge allowance. This provision was included in the rule revisions to allow the existing disposal capacity to remain in place. Each facility has permit limits that were calculated to allow TDS discharges without violating surface water quality.

Table 2 – Commercial Disposal Facilities in Pennsylvania that Accepted Produced Water in the 2005-2006 Time Frame (based on Puder and Veil 2006)

Disposal Facility Name	Location	Disposal Cost	Comments	Throughput Capacity*
Castle Environmental Inc. (name changed to Advanced Waste Services of Pennsylvania in 2010)	New Castle, PA	$0.025–$0.050/gal	The facility operates a nonhazardous wastewater processing facility. Treatment involves chemical precipitation and filtration. The resulting water from the process is discharged to the New Castle Sanitation Authority's Wastewater Treatment Plant.	Daily volume on 6/28/10 was ~260,000 gal/day; this was slightly lower than average
Hart Resource Technologies	Creekside, PA	$0.0525/gal	Treatment involves chemical precipitation and removal of oils and heavy metals. Surface water discharge occurs under an NPDES permit issued by PADEP.	18,000 gal/day of produced water; 45,000 gal/day of flowback; total from 11/08 to 10/09 = 23.2 million gal
Pennsylvania Brine Treatment	Franklin, PA	$ 0.055/gal	Facility uses chemical precipitation and generates nonhazardous residual sludge that is land-filled offsite at a PADEP-permitted facility. The treated water is then discharged to surface waters under an NPDES permit.	140 gpm; total from 11/08 to 10/09 = 53 million gal
Tunnelton Liquids	Saltsburg, PA	$0.045/gal	Facility uses an innovative process to treat pit water (containing some oil-based muds and cuttings). It combines acid mine drainage from an abandoned coal mine with the produced water. Sulfates in the mine drainage help remove contaminants from the produced water. Following several treatment steps, the treated water is discharged to a river under the authority of an NPDES permit.	Total of 1 million gal/day; ~100,000 gal/day of oil and gas water; ~900,000 gal/day of acid mine drainage

* The estimate for Castle Environmental was provided by phone on June 29, 2010 (Meahl 2010). The other estimates were provided during the May 2010 site visits described in Chapter 4.

To get a first-hand look at how some of these facilities operate, the author visited four facilities located in different parts of Pennsylvania during May 2010. Those site visits are described in Chapter 4.

Current Practices from Surveyed Gas Companies: Five of the companies noted that they are currently sending some of their flowback and produced water to commercial disposal companies. Most of the disposal companies are located in Pennsylvania, but one was located in West Virginia.

Reuse for a Future Frac Job

The gas companies are interested in finding water to use in frac jobs and in managing the subsequent flowback and produced water from those wells in ways that minimize costs and environmental impacts. One way to accomplish this goal is to collect the flowback water and reuse it for frac fluids in other wells. Several gas companies are currently using this approach.

The May 17 revisions to the PADEP discharge regulations also include a requirement that any oil and gas wastewater having TDS of less than 30,000 mg/L cannot be discharged but must be recycled and reused.

The chemical composition of frac fluids is designed to optimize the performance of the frac job. Generally, the TDS concentration of the flowback and produced water is higher than the desired TDS range for new frac fluids. Several Marcellus Shale operators start with flowback and produced water and blend it with enough freshwater from some other source to reduce TDS and other constituents to fall within an acceptable concentration range. At least one other Marcellus Shale operator is using a thermal distillation process to treat the salty flowback and produced water to make very clean water. After passing through the treatment unit (known as the AltelaRain® system — described in Veil [2008]), the water is segregated into a freshwater stream and a concentrated brine stream. The concentrated brine stream is hauled offsite for disposal at a commercial disposal facility while the clean water can be reused for a future frac job or possibly some other use.

Other technology providers are attempting to find niches in the Marcellus Shale water treatment market. For example, several Aqua-Pure thermal distillation units (described in Veil [2008]) were licensed in 2009 by Eureka Resources, a commercial wastewater treatment facility in northern Pennsylvania, to provide a high degree of TDS removal when needed. Another flowback and produced water treatment operation was opened for business in 2009 in West Virginia by AOP Clearwater. Its website[4] does not provide any details about the actual treatment process, but it does indicate that the process results in "distilled water," suggesting that some type of thermal distillation process is used.

In April 2010, the PADEP issued general permit WMGR121 for Processing and Beneficial Use of Gas Well Wastewater from Hydraulic Fracturing and Extraction of Natural Gas from the

[4] http://aopclearwater.com/The_Clearwater_Process.html; accessed May 3, 2010.

Marcellus Shale Geological Formation.[5] The PADEP list included in Appendix A shows two facilities that operate under authorization by the general permit.

One of the projects funded by the DOE/NETL in September 2009 will assemble a trailer containing various types of flowback and produced water treatment devices. The trailer will be deployed to several Marcellus Shale locations for tests on the flowback and produced water from gas wells. The project is headed by Texas A&M University. This research, when completed, will contribute additional data and experience with other types of treatment processes.

Current Practices from Surveyed Gas Companies: Six of the seven companies indicated that they are reusing at least some of their flowback and produced water for future frac jobs. Several of these companies are attempting to recycle all of the flowback and produced water they generate. The seventh company is operating only a single Marcellus Shale well at this time. That company noted that it plans to recycle its flowback and produced water in the future as it develops more wells.

Results from Operator Survey

The options actually used by Marcellus Shale gas operators were briefly mentioned at the end of each of the previous sections. In this section, more detailed information is attributed to particular operators and is compiled into a single table (Table 3).

Table 3 – Water Management Options Used by Selected Marcellus Shale Operators

Company	Information Provided by the Company Contact
Chesapeake Energy	Chesapeake Energy manages its flowback and produced water generated in accordance with local, state, and Federal regulations applicable in each state within the Marcellus Play. It conducts ongoing research to identify environmentally safer methods of byproduct management. At various locations, Chesapeake has transported flowback and produced water offsite to a commercial wastewater disposal company, transported it offsite to a sewage treatment plant, and has treated the water for reuse. Injection wells are also used where practical; however these wells are not on the same location as the producing well (Gillespie 2010).

[5] http://files.dep.state.pa.us/Waste/Bureau%20of%20Waste%20Management/WasteMgtPortalFiles/SolidWaste/Residual_Waste/GP/WMGR121.pdf; accessed July 3, 2010.

Table 3 – Water Management Options Used by Selected Marcellus Shale Operators (Cont.)

Company	Information Provided by the Company Contact
Range Resources	Range Resources is trying to reuse 100% of its flowback, production brine, and drill pit water. The only "processes" involved are settling and dilution. Working backwards from the well performance it sees that it gets just as good of a result with diluted reuse water as with all freshwater. Range Resources has no indication of issues with frac fluid stability, scaling, or bacteria growth downhole. It uses conventional slickwater fracturing additives and designs its fracs based upon the final diluted fluid (Gaudlip 2010a). During 2009, Range Resources completed 44 wells and did frac jobs involving 364 stages. The total volume of frac fluid used was 158 million gallons, with 28% of the volume made up of recycled water from a previous well. The estimated cost savings from avoided disposal fees, less freshwater purchased, and less trucking costs was $3.2 million. The wells that included recycled water accounted for 17% of Range Resources' Marcellus wells. Fifty percent of the wells that used recycled water are in the company's top 25 producing wells (Gaudlip 2010b).
EQT	EQT reuses all of its flowback water without treating it. Flowback water is trucked to the next well location where it is blended with freshwater. Some of the ongoing produced water is hauled to a commercial disposal facility in West Virginia (AOP Clearwater), while other produced water is hauled to a commercial disposal well in Ohio (Babich 2010).
East Resources	East Resources recycles all of its produced water and drilling pit fluids into frac fluids used in other wells. The produced water is not treated for TDS but is blended with freshwater. A typical well uses 3.5 million gallons of water in frac fluids. East Resources generally gets 18% to 20% of the water back to the surface. The company is looking at alternate sources of freshwater such as mine water, produced water from shallow formations, and treated POTW effluent (Blauvelt 2010).
BLX	BLX is a small producer and does not drill as many wells as some larger companies. Therefore, the treatment of water for reuse does not work for them because of the length of time between frac jobs. BLX has hauled water to another site, if available, and basically diluted it with freshwater. The rest of the water goes to a disposal well, a sewage plant in New Castle, Pennsylvania, or one of the offsite commercial disposal facilities (Berdell 2010). BLX is involved with at least two wells that are using the AltelaRain® thermal distillation technology to treat produced water. One of these wells is described in a presentation made to the Pennsylvania Senate (Kohl 2010). The other well is part of a DOE/NETL funded project that will characterize the results of the AltelaRain treatment process when used to treat flowback and produced water from a Marcellus Shale well.

Table 3 – Water Management Options Used by Selected Marcellus Shale Operators (Cont.)

Company	Information Provided by the Company Contact
Norse Energy	Norse Energy operates in New York and currently has only one operating Marcellus well. Additional wells have been proposed, but are being delayed, awaiting approval from the New York Department of Environmental Control. For its existing Marcellus well, Norse has disposed of the fluid at two facilities located in Warren, Pennsylvania and Franklin, Pennsylvania. Norse is looking at additional disposal sites in the Williamsport, Pennsylvania, area for future wells. Regardless of the current facility Norse is using, trucking costs are a major portion of the total disposal cost. Norse would also consider transporting the flowback and produced water to a sewage treatment plant, if available, in order to reduce transportation costs (Keyes 2010). Norse Energy would consider several other options. If injection were possible, Norse would most likely use a centralized injection well with a water-gathering system from several producing wells or pads. Norse is also looking at treating and reusing the water in future wells (Keyes 2010).

To summarize, many options are currently being employed to manage flowback and produced water. Most of the operators are recycling some, to all, of their flowback and produced water. The flowback and produced water that is not being recycled is hauled offsite to POTWs, commercial wastewater disposal facilities, or commercial injection wells.

Chapter 4 – Site Visits to Commercial Wastewater Disposal Facilities

During May 2010, the author visited four commercial wastewater disposal facilities in Pennsylvania. All of these facilities accept flowback and produced water from Marcellus Shale gas production. Figure 17 shows the location of each facility.

Figure 17 – Locations of Commercial Wastewater Treatment Facilities Visited

1. Eureka Resources
2. Pennsylvania Brine – Franklin
3. Tunnelton Liquids
4. Hart Resource Technologies

<u>Eureka Resources</u>

Eureka Resources operates a commercial wastewater treatment facility in Williamsport, Pennsylvania. Dan Ertel provided a tour of the facility on May 10. Figures 18 through 23 are photos taken during the tour. Trucks unload into one of four settling tanks to allow settling of heavy solids and removal of any free oil. The water is sent to treatment tanks where the pH is raised using sodium sulfate (Na_2SO_4) or lime to facilitate the removal of dissolved barium and other metals. Coagulants are added to aid in settling; then the water flows to clarifiers to settle. Solids are dewatered in a type of filter press called a "membrane squeeze press." The treated water is discharged to the Williamsport municipal sewer system and sent to the city's wastewater treatment plant. The current process removes metals, but it does not remove TDS. The throughput of the plant is 300,000 gallons per day.

Eureka Resources is in the process of installing two Aquapure NOMAD evaporators that are expected to go into service during June 2010. The NOMAD units (Veil 2008) will remove nearly all of the TDS from the water. The concentrated brine solution produced by the NOMAD units will be either transported to a disposal well in Ohio or sent to a local company that will evaporate the brine to produce salt.

Figure 18 – Unloading Area - Eureka Resources

Figure 19 – Treatment Tanks – Eureka Resources

Figure 20 – Additional Treatment Tank – Eureka Resources

Figure 21 – Filter Press – Eureka Resources

Figure 22 – View of Part of NOMAD Unit – Eureka Resources

Figure 23 – Additional View of NOMAD Unit – Eureka Resources

Pennsylvania Brine

Pennsylvania Brine operates two commercial wastewater treatment facilities in western Pennsylvania (in the towns of Franklin and Josephine). Elton Delong provided a tour of the Franklin facility on May 10. Figures 24 through 27 are photos taken during the tour. The facility was not processing any water that day as it was undergoing renovations. Mr. Delong described the process units that will be in place once the renovations are completed.

Trucks unload on a pad. The flowback and produced water is screened to remove large objects, then flows into a settling tank to allow settling of heavy solids and removal of any free oil. The water continues to an aeration tank, then moves to another tank where lime is added. Following the renovations, Na_2SO_4 will be added to the water, prior to moving it to the lime tank. Next, the water flows to a tank where polymers are added to promote coagulation; then it moves to a clarifier to settle. Solids are dewatered in a filter press. Acid is added to the treated water to return the pH to a neutral range. Finally, the treated water is discharged to the Allegheny River under an NPDES permit issued by the PADEP. The current throughput of the plant is about 140 gallons per minute. According to data supplied by the company, in the one-year period from November 2008 to October 2009, the facility processed about 53 million gallons of water. The process removes metals, but does not remove TDS.

Figure 24 – Unloading Area – Pennsylvania Brine

Figure 25 – Settling Tank – Pennsylvania Brine

Figure 26 – Treatment Tank – Pennsylvania Brine

Figure 27 – Clarifier – Pennsylvania Brine

Tunnelton Liquids

Tunnelton Liquids operates a commercial wastewater treatment facility in Saltsburg, Pennsylvania. The facility was originally constructed to treat acid mine drainage from a coal refuse pile located uphill from the treatment plant. Bruce Bufalini provided a tour of the facility on May 14. Figures 28 through 33 are photos taken during the tour.

Trucks unload at two different pads. Flowback and produced water are sent to an oil/water separator first to remove any free oil. The separator effluent flows to a large pond called the "raw pond." Water from onsite pits flows directly to the raw pond as does leachate from the coal refuse pile. Water is pumped from the raw pond to a treatment plant. The first stage at the plant is an aeration tank where lime is added. If the aeration creates excessive foaming, an anti-foaming chemical is added to the tank. The water then flows to a clarifier. The collected solids are removed periodically and they are disposed of in a deep mine where they help to neutralize the acidic mine pool water. The treated water flows to a final polishing basin that has several days of retention time. Finally, the treated water is discharged to the Conemaugh River under an NPDES permit issued by the PADEP.

The plant has an average discharge of about one million gallons per day. Only about 100,000 gallons are oil and gas flowback and produced water — the rest is acid mine drainage. The process removes metals, but does not remove TDS.

Figure 28 – Unloading Area – Tunnelton Liquids

Figure 29 – Oil/Water Separator – Tunnelton Liquids

Figure 30 – Raw Pond – Tunnelton Liquids

Figure 31 – Aeration Tank – with and without Anti-Foaming Chemical – Tunnelton Liquids

Figure 32 – Clarifier – Tunnelton Liquids

Figure 33 – Polishing Pond (visible behind trees) – Tunnelton Liquids

Hart Resource Technologies

Hart Resource Technologies operates a commercial wastewater treatment facility in Creekside, Pennsylvania. Like the Tunnelton facility, the Hart facility was originally constructed to treat acid mine drainage. Paul Hart and Becky Snyder provided a tour of the facility on May 14. Figures 34 through 37 are photos taken during the tour. The plant operates two separate, but equivalent, treatment systems. One system treats "low-salt" water (defined as lower than about 40,000 mg/L TDS) and the other system treats "high-salt" water.

From the unloading pad, the flowback and produced water passes through a strainer to remove large debris. It then flows to a settling pit, followed by an oil/water separator. If any of the water contains oil/water emulsions, it is further treated by some combination of heat, demulsifying chemical, and increased retention time. Water next moves into a storage tank where blending of water from several truckloads occurs. From here, the water is treated in batches in a treatment tank. Several sequential steps occur in the treatment tank (agitation, aeration, and pH adjustment with lime). The low-salt treatment system receives a flocculant, while the high-salt system receives Na_2SO_4. Following these steps, the water is allowed to settle in the same tank. The water then flows to a clarifier. The sludge from the settling processes and the clarifier are treated in a thickener and then dewatered in a filter press. Solids are sent to a local landfill.

Finally, the treated water is discharged to McKee Run under an NPDES permit issued by the PADEP. The pH is not neutralized — the high pH in the discharge helps to neutralize the low instream pH caused by local acid mine drainage. The plant has an average discharge of about 18,000 gallons per day of produced water and 45,000 gallons per day of flowback water. The process removes metals but does not remove TDS. Mr. Hart and Ms. Snyder indicated that the facility processed more water from shallow gas wells in the region than water from Marcellus Shale wells.

Figure 34 – Unloading Area, Settling Pit, and Blending Tank – Hart Resource Technologies

Figure 35 – Treatment Tank – Hart Resource Technologies

Figure 36 – Clarifier – Hart Resource Technologies

Figure 37 – Filter Press for Solids – Hart Resource Technologies

Chapter 5 – Findings and Conclusions

Findings

There is a great deal of interest in natural gas production in the Marcellus Shale. The Marcellus offers hope of substantial energy resources and economic benefits, but also creates various environmental and societal issues. This report describes three types of water issues that arise from shale gas development in the Marcellus Shale. Those three issues are:

- Controlling the stormwater runoff from disturbed areas,
- Obtaining sufficient freshwater supply to conduct frac jobs on new wells, and
- Managing the flowback water and produced water from the well.

In particular, the report focuses on the third of these issues. Some of the key findings are listed below:

1. Marcellus Shale frac jobs typically inject several million gallons of frac fluids (which are mostly water). In some of the other shale gas plays around the country, the flowback volume can be 30% to 70% of the initial volume of injected fluids. But in the Marcellus, the flowback volume appears to be lower than that — often lower than 25%.

2. After the initial return of flowback water, within a few weeks following completion of the frac job, most wells continue generating formation water (produced water) at a lower rate for many years.

3. Historically, oil and gas operators in Pennsylvania transported their produced water offsite to disposal wells in Ohio, POTWs, or commercial industrial disposal facilities. These practices continue today. However, the increased volume of flowback and produced water from the expanding Marcellus shale gas industry has taxed the capacity of facilities to manage the water and has occasionally resulted in elevated levels of TDS in some of Pennsylvania's rivers and streams. As a result, more treatment facilities are coming on-line or are being permitted.

4. In May 2010, Pennsylvania adopted new, more-stringent discharge requirements for oil and gas flowback and produced waters. Commercial disposal companies that already hold discharge permits are grandfathered to discharge at their current levels. New dischargers face much more restrictive limits on TDS.

Conclusions

Gas production in the Marcellus Shale region is expanding rapidly. State agencies face new challenges in managing and regulating a growing number of wells. New policies and regulations continue to evolve (e.g., Pennsylvania's May 2010 revisions to discharge regulations for oil and gas wastewater). This report examines the available flowback and water management technologies and methods used today and likely to be used in the next few years. Some of the conclusions that follow from the report include:

1. Unlike shale gas plays in arid states (e.g., the Barnett Shale play in Texas), the Marcellus Shale occurs in a part of the country that generally has sufficient water supplies. Obtaining water for frac jobs, while necessitating coordination with various agencies, including the SRBC and the Delaware River Basin Commission (DRBC), has not yet proven to be a barrier. If the number of new shale gas wells continues to rise rapidly, water supplies could become a barrier.

2. Several of the Marcellus gas operators have begun recycling their flowback water into new frac fluids. They have experimented with mixing the high-TDS flowback with low-TDS freshwater to make intermediate-TDS frac water. The early results from this work seem promising. If recycling can be practiced more widely throughout the region, companies can save costs on disposal fees and trucking fees, while reducing the volume of freshwater used for new frac fluids.

3. The regulatory environment is contentious and evolving. Opponents of gas drilling, landowners hoping to gain substantial income from leasing mineral rights, gas companies, and politicians seeking jobs for their constituents will continue to debate how and where gas should be produced within the Marcellus region.

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Appendix A

Pennsylvania Facilities Permitted to Accept Oil and Gas Wastewaters and Other Facilities that Have Applied for Permits to Accept Oil and Gas Wastewater

Source: Based on PADEP spreadsheet (Furlan 2010).

Facility Name	Permit Number	Receiving Stream	Design Flow (MGD)	Oil & Gas Wastewater Flow (MGD)	County	TYPE[a]	Status / NOTES	Facility Designation[b]
Clairton Municipal Authority	PA0026824	Peters Creek	6.0	0.035	Allegheny	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order.	O&G, MSW
Municipal Authority City of McKeesport	PA0026913	Monongahela River	11.5	0.102	Allegheny	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order.	O&G, MSW
Allegheny Valley Joint Sanitary Authority	PA0026255	Allegheny River	5.5	0.025	Allegheny	POTW	Limiting O&G waste flow to 25,000 gpd and chlorides to 24,000 mg/l	O&G, MSW
CNX Gas Co LLC	PA0253588	Crooked Creek	0.15	0.15	Armstrong	CWT	n/a	CBM
Somerset Regional Water Resources	PA0233901	North Branch Susquehanna	0.5	0.5	Bradford	Proposed CWT	Metals precipitation, filtration (reverse osmosis), and thermal evaporation for RO concentrate.	PMSW
Vavco LLC	Approval 1009001 under GP PAG310001	Little Connoquenessing Creek	0.0009	0.0009	Butler	Proposed CWT	Proposed facility to treat only oil well production fluids from own stripper oil wells. Approval issued 7/1/2009. Part II WQM application received 3/31/2010. Technical deficiency letter sent May 27, 2010.	SW, PO&G
Johnstown Redevelopment Authority - Dornick Point STP	PA0026034	Conemaugh River	12.0	0.076	Cambria	POTW	Limiting O&G waste flow to 1% of Avg Daily flow.	O&G, MSW
Great Lakes Energy Partners, LLC	PA0253103	Clearfield Creek	0.2	0.2	Cambria	CWT	n/a	CBM
Keystone Clearwater Solutions, LLC	PA0233951	Moshannon Creek	0.504	0.504	Centre	Proposed CWT	Metals precipitation and filtration treatment (nanofiltration and RO). Had some land use issues that are now resolved. This application was returned, but has been resubmitted with appropriate treatment proposal.	PMSW

Facility Name	Permit Number	Receiving Stream	Design Flow (MGD)	Oil & Gas Wastewater Flow (MGD)	County	TYPE[a]	Status / NOTES	Facility Designation[b]
Clearfield Municipal Authority	PA0026310	West Branch Susquehanna River	4.5	0.01	Clearfield	POTW	This facility has claimed to have historically taken O&G wastewater. Submitted an amended NPDES application to take wastewater until December 31, 2010.	O&G
Dannic Energy Corp.	PA0233790	Hawk Run	0.25	0.25	Clearfield	Proposed CWT	Metals precipitation and vacuum evaporator for treatment.	PMSW
Keystone Clearwater Solutions, LLC	PA0233960	West Branch Susquehanna River	0.504	0.504	Clinton	Proposed CWT	Metals precipitation and filtration treatment (nanofiltration and RO). This application was returned, but has been resubmitted with appropriate treatment proposal.	PMSW
Dannic Energy Corp.	PA0233781	West Branch Susquehanna River	0.25	0.25	Clinton	Proposed CWT	Hyner Drilling Fluid Recycling Facility. Metals precipitation and vacuum evaporator for treatment.	PMSW
Central PA Wastewater, Inc.	PA0233706	Unnamed tributary to West Branch Susquehanna River	0.4	0.4	Clinton	Proposed CWT	Discharge is proposed to intermittent stream less than 0.5 miles from the river. Metals precipitation is the proposed treatment technology. Application needs to be updated to show advanced treatment to meet stringent TDS limits.	PMSW
Ridgway Borough	PA0023213	Clarion River	2.2	0.02	Elk	POTW	n/a	O&G, MSW
ProChemTech International-Blue Valley Hydrofrac Recycle Facility	PA0268305	Unnamed tributary to Brandy Camp Creek	0.0125	0.3	Elk	Proposed CWT	Proposed permit to accept 300,000 gallons per day of Marcellus Shale wastewater for treatment and recycle. Proposing to discharge a maximum of 12,500 gallons per day of distilled water.	PMSW

Facility Name	Permit Number	Receiving Stream	Design Flow (MGD)	Oil & Gas Wastewater Flow (MGD)	County	TYPE[a]	Status / NOTES	Facility Designation[b]
Veolia ES Greentree Landfill LLC	PA0103446	Little Toby Creek	0.25	0.04808	Elk	CWT	Facility treats 48,000 gallons of natural gas well brine water per year from American Refining and Exploration, Inc. and 60-80 gallons of natural gas well brine water per year from Destiny, Inc. - both non Marcellus natural gas wells.	O&G
Shallenberger Construction – Rankin Run Facility	PA0253669	Rankin Run	0.125	0.125	Fayette	Proposed CWT	Facility not constructed. Shallenberger Construction proposes to construct the facility to treat 125,000 gpd of tophole water. The proposed method of treating the wastewater is a series of two detention ponds. The NPDES permit for this facility was issued by the Oil and Gas Program on September 12, 2008. The NPDES permit does not contain effluent limitations for TDS. The Water Quality Management Part II permit application was administratively deficient and revisions were received. The Part II permit has not been reviewed, pending resolution of TDS effluent limitations.	PMSW, PO&G

Facility Name	Permit Number	Receiving Stream	Design Flow (MGD)	Oil & Gas Wastewater Flow (MGD)	County	TYPE[a]	Status / NOTES	Facility Designation[b]
Shallenberger Construction – Ronco Facility	PA0253723	Monongahela River	0.5	0.5	Fayette	CWT	Part II permit issued for Phase I of the treatment plant. Consent Order and Agreement (COA) includes compliance schedule. Water Quality Management Part II permit was issued on August 28, 2009 for the construction of Phase I of this treatment facility, which does not include treatment units for TDS. An appeal of the issuance of the Part II permit and the COA was filed on behalf of Clean Water Action. The draft NPDES permit amendment, incorporating TDS and other effluent limitations was sent for publication. Facility is currently in operation, with treated wastewater being hauled to the next drill site.	MSW, O&G
Shallenberger Construction	PA0253863	Youghiogheny River	1.0	1.0	Fayette	Proposed CWT	Oil and Gas wastewaters-CWT—Proposed Facility	PMSW, PO&G
Municipal Authority of Belle Vernon	PA0092355 and PA0092355 -A1	Monongahela River	0.5	0.0	Fayette	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of O&G wastewater.	O&G, MSW
Brownsville Municipal Authority	PA0022306	Dunlap Creek	0.96	0.0	Fayette	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of O&G wastewater.	O&G, MSW
Green Earth Wastewater	PA0253821	Dunkard Creek	0.25	0.25	Greene	Proposed CWT	O&G wastewaters-CWT—Proposed Facility	PMSW, PO&G
Waynesburg Borough	PA0020613	South Fork Tenmile Creek	0.8	0.0	Greene	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of O&G	O&G, MSW

Facility Name	Permit Number	Receiving Stream	Design Flow (MGD)	Oil & Gas Wastewater Flow (MGD)	County	TYPE[a]	Status / NOTES	Facility Designation[b]
							wastewater.	
Franklin Township Sewer Authority/Tri-County Wastes (CWT)	PA0046426	South Fork Tenmile Creek	1.25	0.05	Greene	POTW receiving indirect discharge from CWT	O&G waste flow will be limited to 50,000 gpd by DEP order. Waste is pretreated but not for TDS or Chlorides.	O&G, MSW
CNX Gas Co LLC	PA0252611	Blockhouse Run	0.007	0.007	Greene	CWT	n/a	CBM
CNX Gas Co LLC	PA0252832	Pennsylvania Fork Fish Creek	0.0111	0.0111	Greene	CWT	n/a	CBM
CNX Gas Co LLC – Rogersville Treatment Facility	PA0253286	South Fork Tenmile Creek	0.202	0.202	Greene	Proposed CWT	CNX proposes to construct the Rogersville Treatment Facility to treat waters associated with natural gas production at its Greenhill Production Area. The proposed plant will be able to treat 201,600 gpd. The site will have two mobile reverse osmosis treatment plants on site along with 12 concentrate storage tanks and one clean water impoundment. This is a recycle and reuse plant. The applicant has not submitted an NPDES permit application for the overflows from the impoundment. The application does not meet the residual waste regulations. A technical deficiency letter will be sent to the applicant.	PMSW, PO&G
PA Brine Josephine (Franklin Brine)	PA0095273	Blacklick Creek	0.12	0.12	Indiana	CWT	O&G wastewaters. Currently under detailed compliance review.	O&G, MSW

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Hart Resource	PA0095443	McKee Run	0.045	0.045	Indiana	CWT	O&G wastewaters. Currently under detailed compliance review.	O&G, MSW
Tunnelton Liquids	PA0091472	Conemaugh River	1.0	1.0	Indiana	CWT	n/a	O&G, MSW
Frontier Energy Services	PA0254207	Yellow Creek	0.9	0.9	Indiana	Proposed CWT	Proposed 0.9 mgd CWT for drilling wastes. Applicant proposed to treat wastes through reverse osmosis and evaporation.	PMSW, PO&G
Belden and Blake	PA0219339	Blacklick Creek	0.6	0.6	Indiana	CWT	n/a	CBM
CNX Gas Co LLC	PA0253596	Blacklegs Creek	0.035	0.035	Indiana	CWT	n/a	CBM
Canton Oil & Gas Company	PA0206075	Blacklick Creek	0.48	0.48	Indiana	CWT	n/a	CBM
CNX Gas Co LLC	PA0253995	Kiskiminetas River	0.21	0.21	Indiana	Proposed CWT	Application currently under review process.	PMSW, PO&G
Punxsutawney Borough	PA0020346	Mahoning Creek	2.2	0.02	Jefferson	POTW		O&G
Brockway Area Sewage Authority	PA0028428	Toby Creek	1.5	0.014	Jefferson	POTW	Currently 14,000 GPD to POTW. Request to increase brine volume withdrawn. NPDES renewal drafted 6/19/09. EPA issued a general objection letter and 90-day time extension on July 17, 2009.	O&G
Reynoldsville Boro	PA0028207	Sandy Lick Creek	0.8	0.011	Jefferson	POTW	Have taken in approx. 14,000 gpd of brine to POTW for a long time.	O&G
Dominion Transmission Corp - Div V	PA0101656	Stump Creek	0.01008	0.0077	Jefferson	CWT	Facility only treats Dominion's own wastewater. Most likely no Marcellus Shale water.	O&G
New Castle City / Advanced Waste Services	PA0027511	Mahoning River	17	0.55	Lawrence	POTW receiving discharge from CWT	The CWT, Advanced Waste Services discharges O&G wastewater to New Castle POTW. Possible expansion plans from 0.2 MGD to 2.2 MGD	O&G, MSW

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Williamsport Sanitary Authority / Eureka Resources	PA0027057	West Branch Susquehanna River	8.4	0.12	Lycoming	POTW receiving discharge from CWT	Town has an EPA approved pretreatment program. Installing mechanical vapor recompression evaporation for treatment summer 2010. Is already pretreating for metals prior to discharge to WSA. WSA submitted application to take limits in November 2009.	MSW
Water Treatment Solutions	PA0233838	Daugherty's Run	0.05	0.05	Lycoming	Proposed CWT	Metal precipitation and thermal distillation/crystallizer treatment; limited information submitted.	PMSW
Dannic Energy Corp.	PA0233765	Pine Run	0.25	0.25	Lycoming	Proposed CWT	Pine Run discharges to W. Branch Susquehanna. Metals precipitation and vacuum evaporator for treatment.	PMSW
TerrAqua Resource Management	A0233650	West Branch Susquehanna River	0.4	0.4	Lycoming	Proposed CWT	Metals precipitation and thermal distillation is the proposed treatment technology. Part I NPDES permit issued; awaiting Part II WQM application	PMSW
TerrAqua Resource Management LLC	WMGR121	None	0.4	0.4	Lycoming	RW Processing	Batch chemical processing - treated wastewater returned to well sites for reuse	MSW
Minard Run Oil Company	PA0105295	Lewis Run	0.016	0.004	McKean	CWT	Existing facility which treats only oil well production fluids from own wells. NPDES renewal issued 10/28/2009.	O&G
Sunbury Generation	PA0008451	Susquehanna River	3.7	0.08	Snyder	CWT	Taking 80,000 gpd, approved by letter. Application submitted in 10/09 to accept up to 250,000 gpd. Proposing to cease taking wastewater by 12/31/2010. The NPDES amendment application was withdrawn 5/10 and may be resubmitted.	MSW

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Somerset Regional Water Resources, LLC (SRWR)	PA0253987	East Branch Coxes Creek	1.0	1.0	Somerset	Proposed CWT with 500 mg/L TDS limitation in the permit	The NPDES permit for this facility was issued on December 17, 2009. The Water Quality Management Part II permit application was deficient. The applicant supplied additional information, and the Part II permit is currently under review. SRWR plans to treat for TDS. RO and evaporators are proposed to treat O&G and mine drainage.	PMSW, PO&G
Penn Woods Enterprises, LLC	PA0254037	Casselman River	0.5	0.5	Somerset	Proposed CWT	This application is for issuance of an NPDES permit to discharge treated process water from the Casselman Waterworks Water Treatment Plant in Summit Township, Somerset County.	PO&G, PMSW
Dannic Energy Corp.	PA0233773	Tioga River	0.25	0.25	Tioga	Proposed CWT	Metals precipitation and vacuum evaporator for treatment.	PMSW
Big Sandy Oil Company	PA0222011	Allegheny River	0.006	0.004	Venango	CWT	Existing facility which treats only oil well production fluids from own wells.	O&G
Titusville Oil and Gas Associates, Inc. - Hilton Hedley Lease	Approval 6106001 under GP PAG310001	Allegheny River	0.002	0.002	Venango	Proposed CWT	Proposed facility to treat only oil well production fluids from own wells. Approval under general NPDES issued 1/16/2007, no Part II issued and facility not built.	SW, PO&G
PA Brine Treatment - Franklin Facility	PA0101508	Allegheny River	0.205	0.144	Venango	CWT	Renewed permit issued 2/27/2009 authorizing increased discharge rate to 300,000 gpd while maintaining same load limits for chlorides. WQM Permit amendment to reflect modifications necessary to increase discharge rate to 300,000 gpd issued 10/23/2009. The 10/09 Amendment No. 1 to Water Quality Management	O&G, PMSW

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							Permit No. 6182201-T3 authorized the modification and operation of the O&G wastewater treatment facility.	
PA Brine Treatment - Rouseville Facility	PA0263516	Oil Creek	0.08	0.08	Venango	Proposed CWT	Second draft of permit published in PA Bulletin 3/13/2010. EPA withdrew general objection 3/17/2010 based on redraft. Water quality protection report (WQPR) currently being redrafted to reflect proposed TDS regulation changes.	PO&G
ARMAC Resources	Approval 6295001 under GP PAG310001	Brokenstraw Creek	0.001	0.001	Warren	CWT	Existing facility which treats only oil well production fluids from own wells.	SW, O&G
Waste Treatment Corporation	PA0102784	Allegheny River	0.213	0.199	Warren	CWT	Renewal application received 10/14/08. Request to increase discharge rate to 400,000 gpd withdrawn. Draft permit published for 30 day comment 1/30/2010.	O&G, PMSW
Mon Valley Brine	PA0253782	Monongahela River	0.2	0.2	Washington	Proposed CWT	O&G wastewaters-CWT	PMSW, PO&G
Borough of California	PA0022241	Monongahela River	1.0	0.0	Washington	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of O&G wastewater.	O&G, MSW
Authority of the Borough of Charleroi	PA0026891	Monongahela River	1.6	0.0	Washington	POTW	O&G waste flow limited to 1% of Avg Daily flow at POTW by DEP order. This facility no longer accepts large volumes of oil and gas wastewater.	O&G, MSW
The Washington-East Washington Joint Authority	PA0026212	Chartiers Creek	9.77	0.0977	Washington	POTW	Limiting O&G waste flow to 1% of Avg Daily flow.	O&G, MSW

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Reserved Environmental Services, LLC (RES)	PA0254185	Sewickley Creek and Belson Run	Phase I - No Discharge. All water will be recycled to well site. Phase II - 1.0 MGD	1.0	Westmoreland	CWT	CWT using municipal drinking water as dilution with recycle back to well sites. RES has a contract with the Westmoreland Water Authority to purchase up to three million gallons of potable water per day to be used as "make-up" water to adjust the concentration of chlorides in the recycled water. RES intends, in Phase I, to treat drilling fluids at the facility and produce an "engineered" controlled fluid/water for recycle to the drilling sites.	MSW, O&G
CB Energy	PA0252646	Conemaugh River	0.2	0.2	Westmoreland	CWT	n/a	CBM
CNX Gas Co LLC	PA0252867	Youghiogheny River	0.08	0.08	Westmoreland	CWT	n/a	CBM
CNX Gas Co LLC	PA0253049	Crawford Run / Youghiogheny River	0.08	0.08	Westmoreland	CWT	n/a	CBM
CB Energy Inc	PA0219312	Sewickley Creek	0.2	0.2	Westmoreland	CWT	n/a	CBM
Belden and Blake	PA0218898	Conemaugh River	0.6	0.6	Westmoreland	CWT	n/a	CBM
CB Energy Inc	PA0219452	Crabtree Creek	0.2	0.2	Westmoreland	CWT	n/a	CBM
Belden and Blake	PA0218073	Jacobs Creek	0.6	0.6	Westmoreland	CWT	n/a	CBM
Kiski Valley WPCA/McCutcheon Enterprises (CWT)	PA0027626	Kiskiminetas River	7	0.09	Westmoreland	POTW receiving discharge from CWT	Existing CWT facility (McCutcheon Enterprises, which is treating O&G wastewater for discharge to the Kiski Valley WPCA.	PO&G, PMSW
Reserved Environmental Services LLC	WMGR121 SW001	Sewickley Creek	1.0	0.25	Westmoreland	RW Processing	Batch physical & chemical processing – treated wastewater returned to well sites for reuse.	MSW

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North Branch Processing, LLC (NBP)	PA0065269	Susquehanna River	0.5	0.50	Wyoming	Proposed CWT	NPDES draft permit mailed 8/4/09. Public hearing held 10/6/09. Working on comment response document. NBP anticipates redrafting and republishing the NPDES permit upon completion of the comment response document.	PMSW
Wyoming-Somerset Regional Water Resources LLC (W-SRWR)	PA0065293	Meshoppen Creek at the SR 29 Bridge	0.38	0.38	Wyoming	Proposed CWT	NPDES draft permit mailed 8/4/09. Public hearing held 10/20/09. Working on comment response document. W-SRWR anticipates redrafting and republishing the NPDES permit upon completion of the comment response document.	PMSW

a POTW – publically-owned treatment works; CWT – commercial wastewater treatment facility; RW – residual waste.
[b] MSW – Currently accepts Marcellus Shale wastewater; O&G – Currently accepts oil and gas wastewater from formations other than Marcellus Shale; P – proposed facility; CBM – coal bed methane wastewater; SW – water from stripper wells.

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