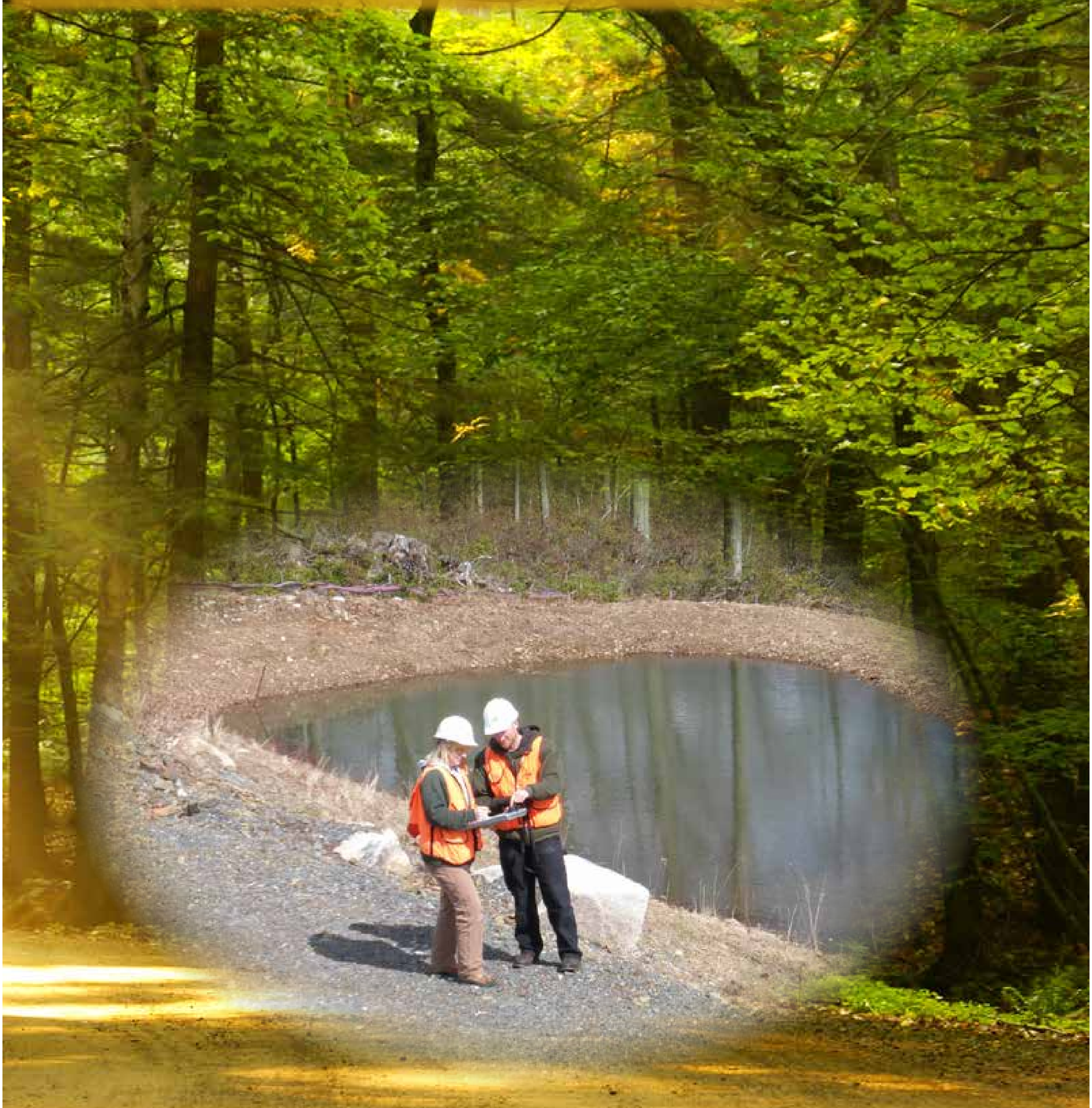
Shale Gas Monitoring Report



pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

JULY 2018

Preface

Approximately eight years ago, DCNR Bureau of Forestry established a new program to monitor shale gas development activity on state forest lands. Monitoring, which can be defined as repeated measurements over time to determine trends or patterns, helps us as resource managers better understand the activity, how to best manage it, and its impact on other uses and values of the state forest system. Article 1 Section 27 of the Pennsylvania constitution affirms DCNR's role as a trustee of the commonwealth's public natural resources, charged with conserving and maintaining them for current and future generations.

Ensuring sound management of the natural resources on our state forests and park lands is one of the ways we carry out this responsibility. Using science to monitor how we manage our lands, specifically in the context of oil and natural gas development currently permitted on certain areas of our state forest lands, is an important way to assess the impacts of this activity and employ adaptive resource management to ensure natural gas is sustainably extracted and protections are in place to minimize impacts to our treasured state forests.

Since 2010, no new leases have been issued for natural gas development in state forests. In 2015, at the recommendation of the DCNR Secretary, this policy was formalized by Governor Wolf in an Executive Order. The Order stated that in order to protect the lands of the Commonwealth held in trust for its citizens and future generations no State Park and State Forest lands owned or managed by DCNR shall be leased for oil and gas development. None-the-less, significant tracts of state forest land remain subject to development due to severed mineral rights or leasing prior to 2011. Understanding the impacts of existing development, in order to inform our management approach going forward, is critical.

What follows is the second comprehensive shale gas monitoring report that represents significant efforts of Bureau of Forestry staff. The purpose of the report is to communicate our data and findings as objectively and credibly as possible to help our stakeholders and the public better understand the development that has taken place to date and target or adjust management accordingly.

This report builds off data and information from the 2014 Shale-Gas Monitoring Report. When possible, we compare the different time periods to illustrate changes and trends. While after more than eight years we can begin to see some trends, natural resource monitoring is a long-term endeavor, and it may take longer to discern other trends in resource change and conditions.

While we strive to report our data as objectively as possible, natural resource values are still a reflection of human values. How people view and interpret information can reflect their point-of-view. For example, people who value interior forest conditions or undeveloped recreational experiences might find an increase in road mileage troubling. However, people who value improved access might view the increase more positively. What we value reflects how we view information.

While each chapter contains a depth of information and data about the activity on state forest land, there are a few key learnings from the report that I'd like to highlight.

- Development has slowed considerably since the 2014 report, when we reported that approximately 1,425 acres had been converted for shale gas infrastructure. Since then, we are reporting a conversion of 334 acres. This is one of the primary indicators of development, and it demonstrates the decrease of activity on state forest land due largely to market forces and to a lesser extent the prohibition on new leasing.
- We need to continue to work to balance shale gas development with the full range of recreational experiences on state forest. While shale gas infrastructure can increase visitor access and improve roads and bridges, it can also have the potential to impact the recreational experiences of visitors who may seek more primitive, undeveloped recreational experiences.
- Invasive plants are of increasing concern as their presence and quantities are on the rise. Disturbed sites are ideal for the establishment of invasive plants that often emerge early in the spring and outcompete native plants through their rapid reproduction. The bureau is constantly on the look-out for invasive plants and prioritizing the control of these plants based on the species and population size.
- Water quality monitoring efforts by the bureau and its partners have not raised significant concerns on state forest headwater streams to date. However, these are still relatively short-term results and may not be indicative of long-term or cumulative effects that can only be detected through long-term monitoring efforts.
- We have thus far, through planning and careful siting, minimized forest fragmentation caused by additional shale gas infrastructure. Many areas of state forest subject to shale gas development are also valued from a statewide and regional level for interior forest conditions and habitat. As development proceeds under historic leases or where mineral rights are not owned by the commonwealth, we need to continue our efforts to minimize forest fragmentation.
- Shale gas development will be an activity on the state forest for many years to come. While there is currently a moratorium of the leasing of additional acres, many tracts of state forest are subject to gas activity through severed mineral rights ownership. Additionally, many state forest leased tracts are only built out by approximately 30 to 35 percent.

These are just a few observations from the report. There are many others, and I invite you to read the report and draw your own conclusions about how the activity affects the state forest system and the values or activities you care about most. We welcome your feedback and observations as we continue to adapt our management and monitoring practices to balance uses and values and sustain our forests for current and future generations.

Ellen M. Shultzabarger
Pennsylvania State Forester

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Executive Summary

DCNR's mission is to conserve and sustain Pennsylvania's natural resources for present and future generations' use and enjoyment. DCNR's primary responsibility in managing state forest lands is to sustain their long-term health, viability, and productivity for current and future generations — maintaining what the public cherishes most about the forests of Pennsylvania; their natural beauty, serenity, and wildness that cannot be found in other residential, commercial, or industrial landscapes of the commonwealth. The DCNR Bureau of Forestry is broadly responsible for conserving the forests and native wild plants of the commonwealth. One of its most significant roles is to act, in the public trust, as stewards of the commonwealth's 2.2-million-acre state forest system. The bureau strives to balance and provide opportunities to experience the diverse, and often competing, uses and values of state forests.

The bureau strives to balance and provide opportunities to experience the diverse, and often competing, uses and values of state forests. The bureau's management is guided by its mission statement: *"...to ensure the long-term health, viability and productivity of the Commonwealth's forests and to conserve native wild plants."* Part of the bureau's mission is to accommodate the environmentally sound utilization of mineral resources on state forest land.

Shale gas development on state forest land in the Marcellus shale fairway began in 2008 with the lease of approximately 74,000 acres. The period between 2008-2012 was marked by the rapid exploration and development of Marcellus shale resources. Due to the quantity of natural gas being sent to market during this period, gas prices decreased leading to a marked slowdown in new development and infrastructure construction on state forest land during the 2013-2016 time period.

This second DCNR Shale Gas Monitoring Report summarizes the context, the extent, and the effects shale gas development has on the resources, uses, and values of state forest land.

Chapter I: Introduction

Oil and gas development has been part of state forest management since 1947.

- Since 1947, there have been 74 oil and gas lease sales resulting in more than 2,000 conventional and unconventional wells being drilled on state forest land.
- There are approximately 1,542,810 acres of state forest land in the Marcellus Shale fairway and some of this acreage has been leased for shale gas development.

- There are three types of oil and gas ownership on state forest lands: Severed Gas Rights (the commonwealth owns the surface rights, but a private interest(s) own the subsurface rights and the commonwealth must give reasonable access to exercise these rights); Leased Gas Rights (the commonwealth owns the subsurface rights and leases these rights to a private entity that is bound to the conditions of the lease agreement); and Non-leased Gas Rights (the commonwealth owns the subsurface rights and has not leased these areas to a private entity).
- The bureau uses a robust and comprehensive lease agreement along with its Guidelines for Administering Oil and Gas Activity on State Forest Land to manage gas activity on state forest land.
- As of 2016, current buildout of shale gas leases in the core forest districts is at approximately 30 to 35 percent.
- It is projected that at full buildout of current leased acreage for shale gas development in the core gas forest districts, there could be as many as 1,475 wells on state forest land.
- Since 2010, there has not been any additional leasing of state forest land for shale gas development.

Chapter II: Gas Monitoring Program

Monitoring is a long-term endeavor with a goal of tracking, detecting, and reporting on the effects of shale gas development on state forest lands in an integrated, comprehensive manner to provide credible information for improving management practices.

- DCNR put into place a shale gas monitoring program in 2011 that consists of an integrated monitoring team, on-the-ground management activities, and research and external partner collaborations.
- The program monitors a suite of values that were identified through the assistance of external advisory groups to identify the effects of oil and gas development on state forest land, inform management decisions, and develop best management practices for administering oil and gas development.
- The suite of 15 values include:

1 Water	9 Air
2 Plants	10 Revenue
3 Animals	11 Incidents
4 Invasives	12 Forest Landscapes
5 Soil	13 Forest Health
6 Recreation	14 Timber Products
7 Infrastructure	15 Energy
8 Community Engagement	

- In addition to the internal monitoring program, DCNR coordinates with the PA Department of Environmental Protection (DEP) for information regarding compliance with environmental regulations.

Chapter III: Shale Gas Production and Administration

Production of natural gas from state forest land has contributed to meeting energy demands of Pennsylvania and the U.S. and providing revenues to the commonwealth, but has placed a larger demand on the Bureau of Forestry in its administration of shale gas development.

- In 2016, Pennsylvania produced 5.26 Tcf of natural gas with 8.9 percent of that volume coming from state forest land.
- The revenues generated from gas development on state forest land is $1,162,510,774 between 1947 and 2016.
- Revenues are allocated to the Oil and Gas Lease Fund that is used to support numerous conservation programs and efforts within DCNR.

Chapter IV: Shale Gas Infrastructure and Landscape Effects

Accommodating shale gas development on state forest land has led to changes in the core gas forest districts (Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, Tioga, and Loyalsock State Forests). Shale gas infrastructure is the most visible impact. Existing native vegetation is often cleared to build new roads, pipelines, and pads. Beyond the visual impact of clearing forest, shale gas infrastructure development can increase forest fragmentation, reduce the amount of core forest habitat, and alter the recreational experience of some forest users.

- Approximately 1,769.5 acres of state forest land have been converted from forest to shale gas infrastructure since 2008.
- Between 2013-2016, there were 333.9 acres converted from forest to shale gas infrastructure, 1,435.6 acres converted between 2008-2012.
- The reduction in conversion is attributed to the reduced amount of development activity from 2013-2016 as compared to the level of activity that occurred between 2008-2012.
- There has been an additional 9,913 acres of forest edge created, a reduction in the amount of large core forest blocks (forests greater than 200 hectares in size), and an increase in the amount of smaller forest blocks (forests 100-200 hectares and less than 100 hectares in size) from 2013-2016.
- Site rehabilitation has occurred on sites in the Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, and Tioga State Forests.
- A demonstration site was constructed in the Tiadaghton State Forest through a partnership with researchers from Penn State to test and better understand how different site preparation techniques, seed mixes, and tree and shrub plantings influence site rehabilitation.

Chapter V: Ecosystem Condition

The bureau monitors for changes and impacts to state forest water, air, soil, flora, wildlife, and forest health related to gas development. Changes in each of these facets of forest ecosystems can provide indications of effects to forests due to natural gas development.

- The bureau implements a robust water quality monitoring program on state forest land and partners with DEP, the Susquehanna River Basin Commission (SRBC), and the U.S. Geological Survey (USGS).

- Over 85 percent of streams in the core gas forest districts are classified as Exceptional Value (EV) or High Quality (HQ).
- In response to stakeholder feedback and recommendations, Bureau of Forestry

monitoring staff has been certified to collect macroinvertebrates for monitoring water quality.

- Water chemistry analysis from continuous water monitoring and the widespread monitoring efforts do not suggest that at the monitored sites, shale gas development has impacted water quality.
- Follow-up surveys by DEP have been scheduled on streams where the bureau measured Index of Biological Integrity (IBI) score was outside of precision ranges.
- The number of invasive plant species found on High Gas Traffic roads that were monitored increased from eight species in 2012 to 13 species in 2016.
- On gas related rights-of-way in the core gas forest districts, the most abundant invasive plant species (based on average percent cover) were Japanese stiltgrass, crown-vetch, tall fescue, and Canada thistle.
- Of the 238 infrastructure pads monitored, only 29 (12.1 percent) were found to be free of invasive plants. The most common invasive plant species found on infrastructure pads were bull thistle, crown-vetch, and spotted knapweed. Once populations of these species are established, their seeds can rapidly spread to access roads and new pad sites.
- Implementation of the Early Detection and Rapid Response program has detected 71 populations of high-threat invasive plants.

Crown Vetch.

Chapter VI: Forest Use: Wild Character, Recreation, and Community Engagement

State forest land continues to provide a diverse range of uses and experiences for forest users. Because state forest land has many uses, the bureau strives to balance and manage the differing activities, values, and experiences. Recognizing that shale gas development has the potential to affect forest users, the bureau's shale gas monitoring program uses several metrics to quantify features that can serve as indicators.

- The bureau monitors the public's use and experiences on state forest land through the Visitor Use Monitoring survey. 15.5 percent of respondents reported that shale gas activities have affected their use of state forest land and 18.7 percent reported it affected their experience.
- Bureau of Forestry comment card responses indicate that traffic, dust, litter, and a general increase in activity on previously isolated/uncrowded places is a concern.
- In the core gas forest districts, approximately 14.1 miles of non-motorized trails have been directly affected by the placement of gas infrastructure and 105.5 miles have infrastructure located within 400 feet.
- Between 2013-2016, approximately 140.5 miles of snowmobile trails have been closed due to plowing for gas related vehicular traffic.

These are but a few highlights of the information contained in this second comprehensive Shale Gas Monitoring Report. In the years to come, the bureau will continue to faithfully manage and monitor the resources, uses, and values of state forest lands in relation to shale gas development, and all other state forest land uses, and will continue to effectuate its mission in accordance with its trustee responsibilities for the benefit of present and future generations.

Chapter I. Introduction

Key Points

- Since 1947, there have been 74 oil and gas lease sales resulting in more than 2,000 wells being drilled on state forest land.
- The bureau's Position Statement addressing the July 29, 2015 Executive Order expresses that DCNR will not issue additional oil and natural gas leases on state forest lands where DCNR controls the subsurface rights.
- There are 1,542,810 acres of state forest land in twelve state forests in the Marcellus Shale fairway of Pennsylvania.
- There are 312,893 leased tract acres, 331,287 severed rights acres, and 68,483 gas storage leased acres on state forest lands.
- Since 2008, approximately 61,000 leased tract acres have been surrendered or terminated.
- The bureau utilizes a robust and comprehensive lease agreement along with its Guidelines for Administering Oil and Gas Activity on State Forest Land to manage gas development.
- Development of leased acres of state forest lands for unconventional shale gas development in the core gas forest districts is estimated at 30 to 35 percent with full buildout resulting in an estimated potential of 1,475 wells.

Introduction

The Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (herein, "the bureau") is broadly responsible for conserving the forests of the commonwealth. While the bureau's forest conservation responsibility extends across all ownerships in Pennsylvania, one of its most significant roles is to act, in the public trust, as stewards of the commonwealth's 2.2-million-acre state forest system. The state forest system of Pennsylvania comprises approximately 13 percent of the forested area in the commonwealth and represents one of the largest expanses of public forest land in the eastern United States; making it a truly prized public asset.

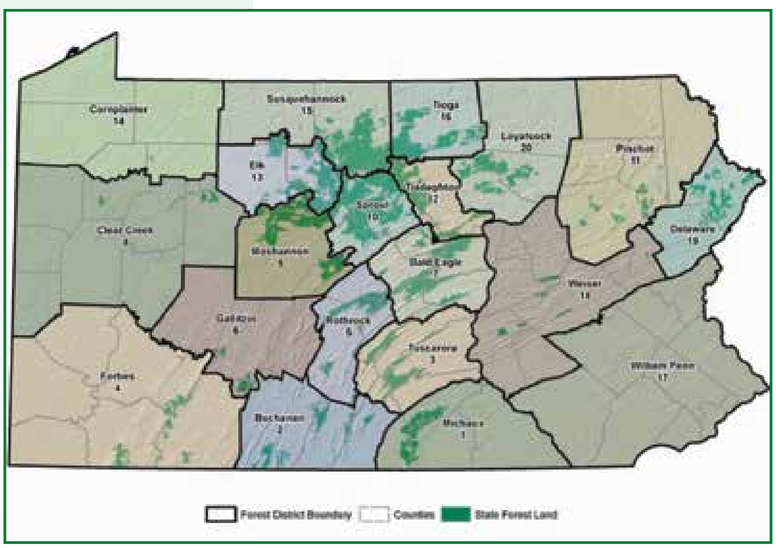


Figure 1.1 Map of state forest and state forest districts.

Pennsylvania's state forests are found in 49 of the state's 67 counties (Figure 1.1) and provide a multitude of resources, uses, and values. State forests provide water and air purification, recreational opportunities, aesthetic beauty, plant and animal habitats, and economic benefits to society.

The bureau's management is guided by its mission "to ensure the long-term health, viability and productivity of the commonwealth's forests and to conserve native wild plants." The bureau will accomplish this mission, in part, through the "environmentally sound utilization of mineral resources." The details for accomplishing the components of the bureau's mission are found in its strategic plan, Penn's Woods[1]. The State Forest Resource Management Plan[2] (SFRMP) guides the management of the 2.2 million acre state forest system. A listing of pertinent goals and objectives related to shale gas development is in Table 1.1.

The bureau has a shale gas monitoring program to monitor, evaluate, and report on the effects of shale gas development to the state forest system and its stakeholders. This document represents the bureau's effort to report on these findings and to communicate to stakeholder's information about this activity on state forest land.

Natural Gas Development on State Forest Land

Oil and gas development has been part of state forest management since 1947. During this time, DCNR (or its predecessor agencies) has conducted 74 oil and gas lease sales (Figures 1.2 and 1.3), resulting in more than 2,000 wells being drilled on state forest lands.
Prior to targeting the Marcellus Shale formation, operators targeted several geologic formations at various depths. Some of these formations have characteristics that enable them to be used as gas storage fields with many still in use today.

The bureau held its first lease sale targeting the Marcellus Shale in 2008. Approximately 74,000 acres were leased for $168 million. In 2010, there were two lease sales totaling 64,843 acres and generating approximately $128 million. There have been no other lease sales since 2010, when the department issued a study determining that further leasing of the state forest for gas development could compromise the mission of the bureau without assessing and understanding the impacts of existing development. In 2016, the 4th edition of the Guidelines for Administering Oil and Gas Activity on State Forest Lands was issued

Bureau of Forestry Mission

Contained in Article1, Section 27 of the Pennsylvania Constitution are these words: "Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people."

The mission of the Bureau of Forestry is to ensure the long-term health, viability and productivity of the Commonwealth's forests and to conserve native wild plants.

The Bureau of Forestry will accomplish this mission by:

Managing State Forests under sound ecosystem management, to retain their wild character and maintain biological diversity while providing pure water, opportunities for low density recreation, habitats for plants and animals, sustained yields of quality timber, and environmentally sound utilization of mineral resources.

Protecting forestlands, public and private, from damage and/or destruction by fires, insects, diseases and other agents.

Promoting forestry and the knowledge of forestry by advising and assisting other government agencies, communities, landowners, forest industry, and the general public in the wise stewardship and utilization of forest resources.

Protecting and managing native wild flora resources by determining status, classifying, and conserving native wild plants.

Goals	Objectives
1. To allow no new leasing for oil and gas development on state forest land subject to future advice and recommendations by DCNR.	1.1 Manage the ongoing extraction of oil and natural gas, from existing leases and severed lands, by implementing best management practices and careful oversight.
	1.2 Continue the shale-gas monitoring program to assess potential effects of shale-gas development on state forest resources, uses, and values.
	1.3 Gather and evaluate public input regarding past and ongoing effects of oil and gas development as well as public sentiment toward potential future leasing for oil and gas development.
2. To provide technical guidance and oversight when geologic resources are developed on state forest lands.	2.1 Monitor the effects of shale-gas development on state forest resources, uses, and values, and continuously adapt guidelines based on monitoring results and other experiences.
	2.2 Continuously adapt guidelines based on monitoring results and other experiences.
	2.3 Communicate and promote the use of current best management practices consistent with bureau guidelines.
	2.4 Enforce current lease terms and conditions.
	2.5 Collaborate with the DEP and other organizations on monitoring, training, and research.
3. To pursue opportunities for the bureau to cooperatively manage geologic resource development where the commonwealth is not the fee-simple land owner.	3.1 Endeavor to obtain a voluntary bonded surface-use agreement from the operator to conserve state forest resources in severed-rights situations.
	3.2 Pursue the strategic acquisition of privately owned oil, gas, coal, or hard mineral rights coincident with state forest surface ownership when funding is available.
	3.3 Give preference to fee-simple land purchases for new acquisitions, whenever possible.

Table 1.1. Partial listing of the goals and objectives for Geologic Resources Management from the SFRMP.

to provide consistent, reasonable, and appropriate direction for managing oil and gas activity on state forest lands in accordance with the bureau's mission.

On January 29, 2015, Governor Wolf issued an Executive Order that states: "As of the date of this Executive Order, to protect the lands of the commonwealth that are held in trust for its citizens and for future generations, and subject to future advice and recommendations made by DCNR, no State Park and State Forest lands owned and/or managed by DCNR shall be leased for oil and gas development."

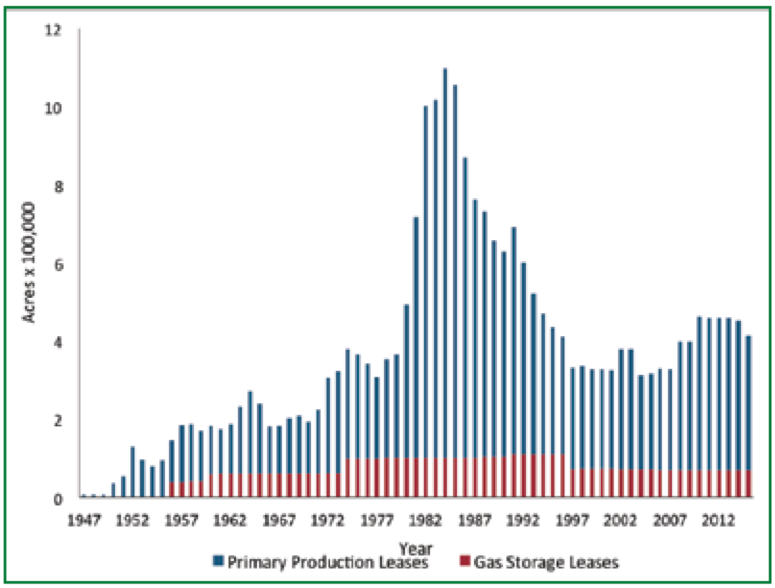


Figure 1.2. Acres under oil and gas lease since 1947.

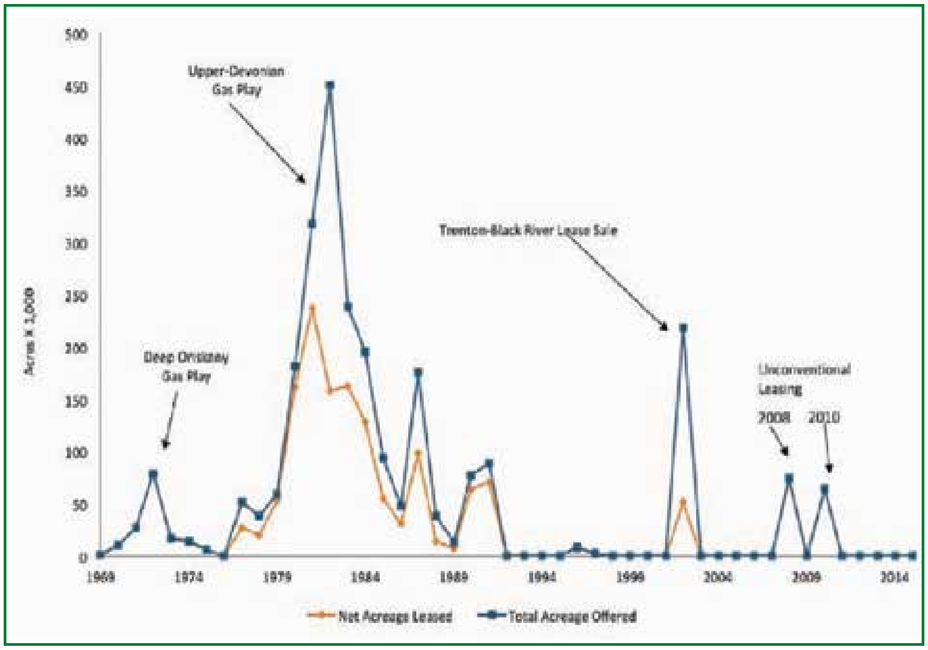


Figure 1.3. Historical oil and gas lease sale acreage offerings since 1969.

In support of the Executive Order, DCNR has developed a position statement[3] that outlines how DCNR addresses natural gas development on state forest and state park lands. The position statement reflects ongoing work by DCNR and incorporates public input received during SFRMP revision processes. The position statement expresses that DCNR will not issue additional oil and natural gas leases on state forest and park lands where DCNR controls the subsurface rights.

Gas Ownership Types

The shale gas play within Pennsylvania covers most of the northern and western portions of the commonwealth. While many state forests fall within the play, most of the gas development on state forests is occurring on the Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, Tioga, and Loyalsock State Forests. These forests are referred to as the core gas forest districts. Mineral rights ownership types within these districts affect how much shale gas development will occur. Land ownership can include the rights to the surface acreage and the rights to subsurface minerals (limestone, sandstone, etc.) and various fluids (oil and gas). In Pennsylvania, the vesting owner can reserve those rights in a property sale resulting in a severance of the subsurface estate from the fee interest. Additionally, the owner of the subsurface rights can lease those rights to companies that will develop those resources. The subsurface owner must be given reasonable surface access to develop the minerals or fluids.

Pennsylvania's state forests have three categories of ownership in relation to ownership of gas rights:

- Severed Gas Rights – The commonwealth owns the surface rights, but a private entity owns all, or part, of the subsurface oil and gas rights. The bureau must allow reasonable surface access to extract the oil and gas for these acres. Reasonable surface access includes, but is not limited to, construction of well pads, roads, and pipelines on state forest property.
- Leased Gas Rights – The commonwealth owns the rights to oil and gas and a private company leases those rights. The lessee can extract oil and gas from the acres they lease in accordance with the provisions of the lease agreement.
- Non-leased Gas Rights - The commonwealth owns the rights to oil and gas and has not leased those rights.

Marcellus Gas

Overall, 1,542,810 acres of state forest land, in twelve state forests, are within the Marcellus fairway (Figure 1.4). The bureau owns the mineral rights on 1,211,523 acres within the fairway and leases 312,893 of those acres for gas development or gas storage (Table 1.2 and Figure 1.5). The bureau has gas storage leases on 68,483 acres with 36,470 acres of gas storage leases

Land & Water Conservation Fund (LWCF)

The LWCF was established to safeguard natural areas, water resources, and cultural heritage, and to provide recreation opportunities to all citizens. The LWCF is managed by the federal Department of the Interior, National Park Service (NPS). LWCF grants are provided to and through the states to local government units (counties, cities, townships, and other municipalities), on a matching basis for up to 50 percent of the total project-related allowable costs for the acquisition and/or development of land and facilities for public outdoor recreation.

The LWCF program has strict requirements in place to ensure that LWCF recreation areas remain protected for open public outdoor recreational use. Changes to other than public outdoor recreational use require the NPS approval and the substitution of replacement land.

State Forest and State Park lands, as well as lands governed by local municipalities, may be subject to a variety of non-recreational uses, including energy development. Energy development may include wind farms to produce electricity; oil and gas development; the installation of pipelines to accommodate the movement of natural gas and other products. The development of traditional and alternative forms of energy may not be consistent with the LWCF protection of land for public outdoor recreational use.

In cases where the development of energy on LWCF protected lands is proposed or being considered, the DCNR or LWCF assisted jurisdiction should evaluate whether it needs to undergo the conversion process with the NPS to remove the affected lands from LWCF protection and place those protections on new additions to the state forest, the state park system or local park.

More information on LWCF can be found on DCNR's webpage[4].

occurring on lands where the commonwealth does not own all subsurface rights. Most of the state forest land acreage in the Marcellus fairway (1,357,762, 88 percent) are within the seven core gas forest districts. The Sproul State Forest has the most acres within the fairway and the most leased acreage. The Elk and Susquehannock State Forests have the most severed rights acres (Figure 1.6).

Figure 1.4. Marcellus fairway in PA.

Table 1.2. District acreages in entire Marcellus fairway.

State Forest	District Acreage in Marcellus Shale Fairway	Leased Tract Acres	Severed Rights Acres*	Gas Storage Leases on Lands Where Commonwealth Owns Subsurface Rights	Gas Storage Leases on Severed Rights Ownerships	Total Acreage Subject to Gas Development	Non-leased Gas Rights
Forbes	59,498	8,846	9,604	0.4	911.0	18,449	41,049
Gallitzin	24,437	1,376	3,376	720	1,353	4,033	20,404
Clear Creek	16,103	463	12,844	0	0	13,306	2,797
Moshannon	190,802	33,612	42,404	0	24	76,016	114,787
Sproul	307,138	96,545	32,550	9,033	9,223	127,532	179,606
Tiadaghton	106,001	49,667	1,387	1,206	1,206	51,054	54,948
Elk	217,181	4,816	71,305	214	528	76,122	141,059
Cornplanter	1,491	0	1,362	0	0	1,362	129
Susquehannock	260,125	56,752	92,923	20,840	23,225	119,945	140,180
Tioga	161,904	40,704	17,747	0	0	58,451	103,453
Delaware	83,519	0	4,321	0	0	4,321	79,198
Loyalsock	114,611	20,113	41,462	0	0	61,575	53,036
Total	**1,542,810**	**312,893**	**331,287**	**32,013**	**36,470**	**612,166**	**930,644**

*** SFL where the commonwealth owns less than fee (100%) in the subsurface estate.**

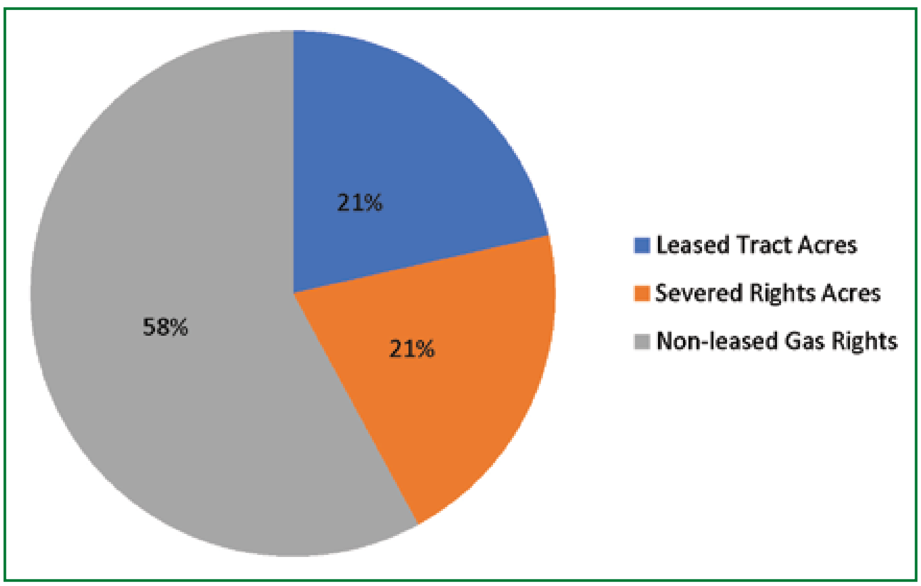
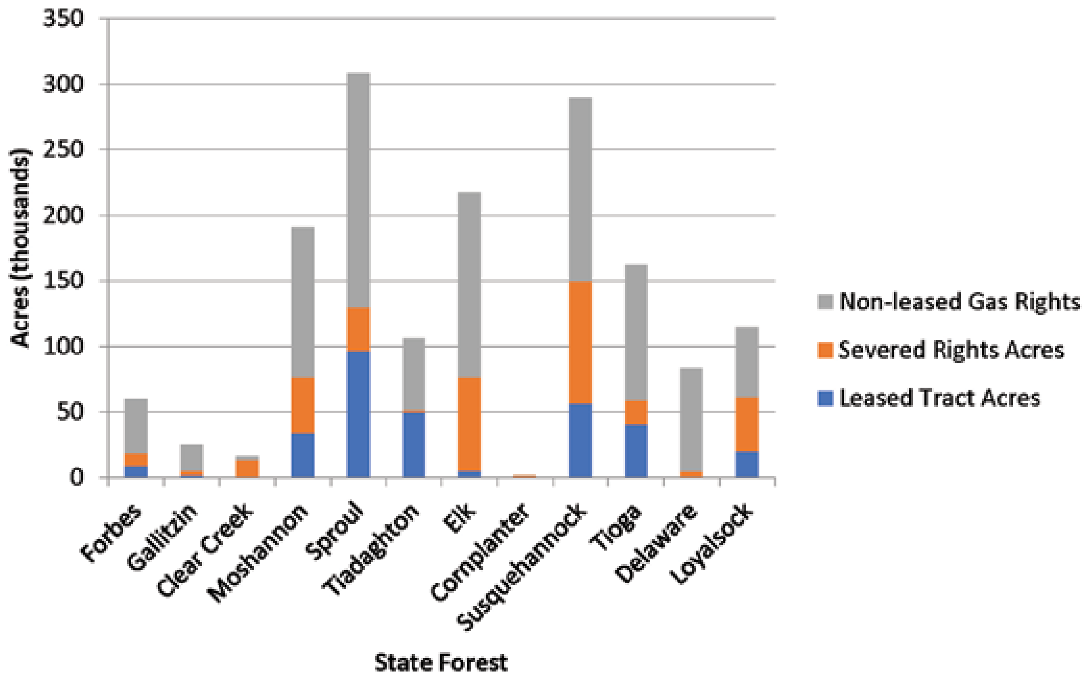
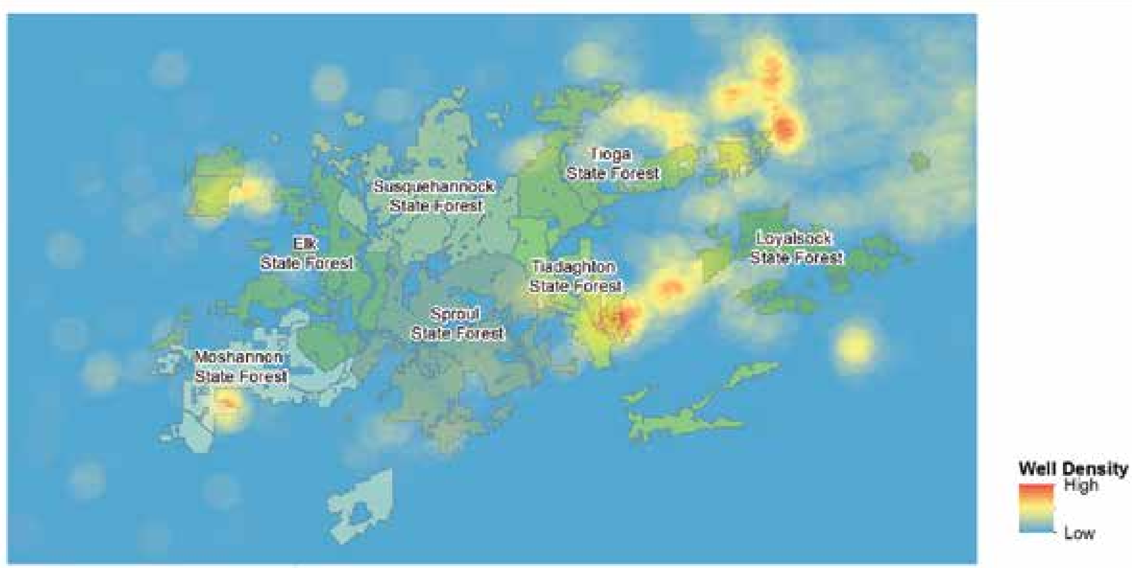


Figure 1.5. Percent of state forest land by mineral rights ownership within the Marcellus fairway.

Figure 1.6. Total acres by mineral rights ownership for each state forest within the Marcellus fairway.



There is a high density of shale gas wells on portions of the Moshannon, Tiadaghton, Elk, and Tioga State Forests (Figure 1.7). Over the shale gas region, shale gas well density was not consistent across state forests or within individual forests.



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Available download URL: http://maps.carnegiemnh.org/index.php/projects/unconventional-wells/. Accessed: 2016 Q3.

Figure 1.7. Shale gas well density.

Since 2008, approximately 61,000 acres of leased tracts were surrendered or terminated. This acreage is based on the deeded acres that are utilized in the legal agreements.

As of 2016, shale gas development can occur on less than half of the state forest acres that are within the Marcellus fairway. The total acreage subject to gas development in the Marcellus fairway is 612,166 acres (from Table 1.1, this is the 'Leased Tract Acres' + 'Severed Rights Acres' – 'Gas Storage Leases on Lands Where Commonwealth Owns Subsurface Rights'). The mineral rights on many of these acres are owned by a private entity, which reduces the control the bureau has on surface disturbances. However, the bureau actively negotiates with gas development companies to reduce, minimize, and mitigate impacts on those acres.

Oil and Gas Leasing

In the past, the department has engaged in lease offerings of state forest land. The most recent lease offering was in 2010. The department is currently under the Governor's Executive Order that places a moratorium on additional gas leasing of state forest.

When leasing did occur, the department followed a transparent process. Identified tracts went through an extensive State Forest Environmental Review (SFER). This bureau process is designed to assess impacts to a variety of forest resources for projects that may or will disrupt, alter, or otherwise change the environment. Tracts were evaluated by a diverse group of bureau staff from numerous perspectives to evaluate the benefits and potential cumulative effects of the development. Non-Development Areas and Areas of Special Consideration within the lease tract offerings were delineated. Non-Development Areas precluded disturbances where sensitive resources, uses, and values are known to exist; unless justified through a waiver request approved by the State Forester or designee. Areas of Special Consideration typically required additional planning, coordination, and inventory to substantiate sensitive resources and minimize potential adverse impacts.

Once the SFER was completed and the Non-Development Areas and Areas of Special Consideration were identified, the lease offerings underwent a public review. The public review for lease offerings occurred through the PA Bulletin.

The successful bidder of the lease offering then entered into a lease agreement. The oil and gas lease utilized by DCNR to manage the oil and gas exploration, development, and production on state forest lands was the result of experience and knowledge gained since the first leases were issued in 1947. DCNR developed this agreement in 2004 with advice from its Ecosystem Management Advisory Committee, along with discussion with the gas industry. This lease agreement is robust, comprehensive, and used numerous approaches to minimize surface impacts, e.g., maximum permissible disturbance thresholds within the lease tract. It contains strong environmental safe-guards, structured business protocols, and substantial measures intended to conserve state forest resources, uses, and values. In addition, the lease ensures the commonwealth is compensated correctly and on time. State forest oil and gas leases provide economic returns to the commonwealth through annual rental and monthly royalty payments.

Surface Use Agreements

On lands where the oil and gas rights have been previously severed from the surface, the deeded reservation language is used as the primary guidance for management of the lands by the bureau. In most cases, the reservations are such that the commonwealth has little to no ability to directly control gas management activities on the surface. In these cases, the bureau attempts to secure a voluntary surface use agreement (SUA) with the private owner or lessee, which has advantages to both parties. With an agreement in place, both parties know with certainty that operations can be scheduled and carried out with minimal difficulty prior to their commencement. The SUA typically includes environmental guidance, best management practices, and surface impact mitigation provisions. Participation in SUAs has been limited, but the bureau continues to promote this type of mutually beneficial agreement.

Guidelines for Administering Oil and Gas Activity on State Forest Lands

The administration of oil and gas development on state forest lands is complicated by a myriad of existing ownership rights, the quantity and various vintages of existing lease agreements, the number of private operators involved, and the rapid advancements in oil and gas technologies. The objective of the guidelines document is to establish and communicate a set of "guidelines" and best management practices (BMP's) that provide consistent, reasonable, and appropriate direction for managing oil and gas activity on state forest lands in accordance with the bureau's mission.

Specifically, these guidelines provide information for:

Bureau staff: to manage oil and gas activities consistently across state forest districts.

Operators: to clearly communicate the bureau's mission, expectations, and protocols for managing natural gas development activities in an environmentally sound manner.

Public: to provide transparency in the management of their state forest lands.

The guidelines were developed by the bureau to provide consistency in gas lease administration across state forest districts and identifying deviations that require written waivers. The guidelines are not contractually binding or legally enforceable.

Guidelines for Administering Oil & Gas Activity on State Forest Lands[5]

Development Plan Review and Negotiation Process

On state forest land, it is the responsibility of the bureau to ensure that oil and gas exploration and development is conducted in a manner that minimizes impacts to water, soil, flora, and fauna resources while being compatible with other uses of state forest land; such as timber management, watershed protection, and recreational activities. As with other development on state forest lands, the bureau uses the general approach of avoidance, minimization, mitigation, and monitoring to manage any undesirable effects of natural gas development. Bureau staff is uniquely positioned to balance the needs of the gas industry and trustee responsibilities of the agency.

Exploration and development on state forest land leases begins with gas operators evaluating the subsurface geology. An infrastructure development plan is then proposed by the operator based on the evaluation of the geological constraints.

The following materials aid the bureau when reviewing development plans:

- Original conceptual development plans (includes pads, roads, pipelines, compression needs, laterals, and pad infrastructure and placement when possible).
- Water sourcing, storage, handling, and disposal plan.
- Erosion and sedimentation plans for all facilities as they become available.
- Completed ecological surveys.
- Permit applications.
- Geological or seismic data.

Areas of concern or potential conflicts are identified, along with avoidance and mitigation alternatives, and communicated with the operator.

Staff then coordinates with the operator to develop an infrastructure layout that satisfies the needs of both parties and serves as the framework for future tract development. Comprehensive site plans may be dynamic, but they afford the opportunity to consider potential effects from a landscape perspective and allow the application of best management practices found in the guidelines document.

The last portion of the review focuses on the on-the-ground siting of individual infrastructure components. These comprehensive reviews are performed by the forest district and central office program areas. The objectives of this review include: minimizing potential adverse impacts; balancing competing and sometimes conflicting state forest resources, uses, and values; confirming that well sites are geologically sound and in compliance with lease terms; and assuring the efficient extraction of gas resources.

The review process is interactive and dynamic. Original operator proposals are routinely modified to address bureau concerns and potential conflicts with state forest resources, uses, and values. These beneficial changes are often very difficult to quantify. For example, it is common during construction to disturb significantly more acreage than will be maintained once the infrastructure is built. This is very apparent during rights-of-way construction. Operators need room for the trench, spoil pile, pipe lay down area, and equipment travel lanes. It has also been a common industry practice for operators working on private lands to secure enough area to protect their interests and allow for additional future expansion. The bureau has worked diligently to minimize the limits of disturbance to the extent that workability and safety are not jeopardized while significantly reducing the operational footprint that will be maintained for the life of the infrastructure. Rights-of-way licenses specifically describe the as-built infrastructure while precluding the ability to add future infrastructure. Such requests require comprehensive review of the proposed project and the negotiation of a new license agreement.

Permitted Wells and Buildout Projections

The development of gas resources requires well bores to be constructed to produce the gas and move it to the market through pipelines. This critical construction activity drives the installation of all the infrastructure necessary to support the gas development. As wells are drilled, pipeline capacity is needed for fresh water delivery to stimulate the well and transport gas to market. Additionally, gas compression is needed for pressure maintenance and there must be sufficient leased acres available to efficiently drain the gas reserves in an economic and controlled manner.

Over the entire time frame of the gas program there have been approximately 2,400 wells drilled to all depths and horizons for both exploration and development on state forest lands. About 1,066 wells have been properly plugged and abandoned over time, leaving about 1,334 wells active on state forest lands. Approximately 250 are in gas storage operations, with 1,084 in gas production in all depths and horizons. The Marcellus play has about 640 horizontal wells drilled to the end of 2016, leaving approximately 444 vertical legacy wells producing from other horizons (Oriskany and Upper Devonian).

In general, there are two main drilling targets for shale gas in Pennsylvania; the Marcellus Shale and the Utica Shale (also known as the Point Pleasant or Antes Shale) (Figure 1.8), with a third minor target in the Burkett Shale. It is believed it is possible to drill all three targets from a single well pad if the pad is optimized before construction for the additional target zones. However, at present only the Marcellus is known to be pervasive and economic in nature over most of state forest land. The Utica is still in the exploration phase of investigation and may be limited in economic extent to just the northern reaches of state forest land in Elk, Cameron, Potter, and Tioga counties.

The average gas pad has six wells, but could host up to 24, that may be drilled to the Marcellus or Utica formations. Marcellus and Utica may be developed from the same well pad location and use the same gas production equipment, pipelines, and compressors. Wells are drilled vertically until they reach the target depth and then laterally between 4,000 and 10,000 feet from the pad. A pad with six wells will typically have three north and three south wells. Since the beginning of Marcellus development in 2008, the well laterals have greatly increased in length and the well pads have remained about the same size. Both these developments

Figure 1.8. Drilling targets (source: Marcellus Shale Coalition).

mean less surface conversion per well drilled. Refer to Figure 1.9 for a plan view and cross section view of a typical modern development plan for Marcellus/Utica. Each pad and its network of wells forms a unit. The unit concept is used to ensure the correct amount of lease land is committed to the development and each well has the appropriate area to drain.

Older shale gas wells were generally spaced 750 feet apart and drilled to a lateral length of 3,500 feet. These wells were set up to drain approximately 60 acres. However, newer wells are being drilled to an 8,000 feet lateral length, or greater, and are spaced at 1,000 feet apart as in Figure 1.9. These newer wells are designed to drain approximately 180 acres or more. Therefore, a current six well pad can drain approximately 1,100 acres or 1.7 square miles. Future wells will likely take advantage of longer laterals and be optimized for 1,000 feet spacing and may drain substantially greater areas from a single well pad.

Operators try to space the units and pads such that no area is left undrained on a lease. However, highway access, topographic limitations, and geologic constraints, e.g., faults and reservoir complications, may limit drainage efficiency. These factors and others place limits on the drainage efficiency the gas operator can expect when planning a development scheme for any given tract of lease land. State forest lands are no exception to these limitations with the main advantage being the typically large acreage sizes of the state forest tracts, which are usually many times larger than adjacent private tracts. It is estimated that 10 to 15 percent of the leased acreage is inaccessible by development drilling. Given that the distance gas can migrate in the subsurface is less than 500 feet to a well bore due to the extremely low native permeability of the shales, the "stranded" gas will likely never be economically extracted (Figure 1.10).

There are approximately 265,839 acres of state forest lands currently under leases, not including river and storage leases, issued by the commonwealth and subject to possible Marcellus/Utica development when tabulated from the written legal lease agreements. The following is the target shale analysis for potential future development on state forest leased lands. The possible wells on severed lands are not counted in this calculation, nor are gas storage and river lands leases.

Figure 1.9. Plan view and cross section view of typical modern development plan for Marcellus/Utica.

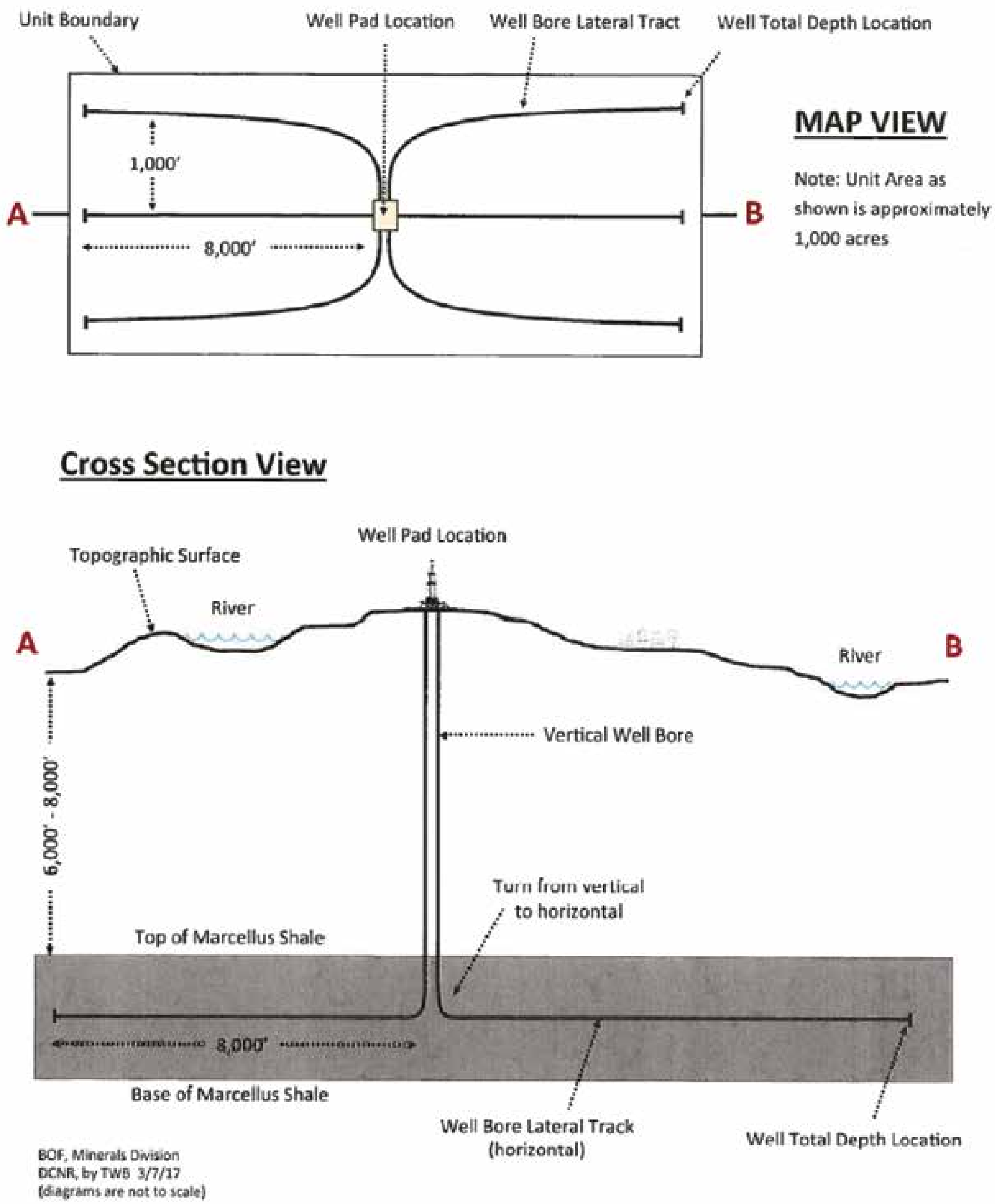
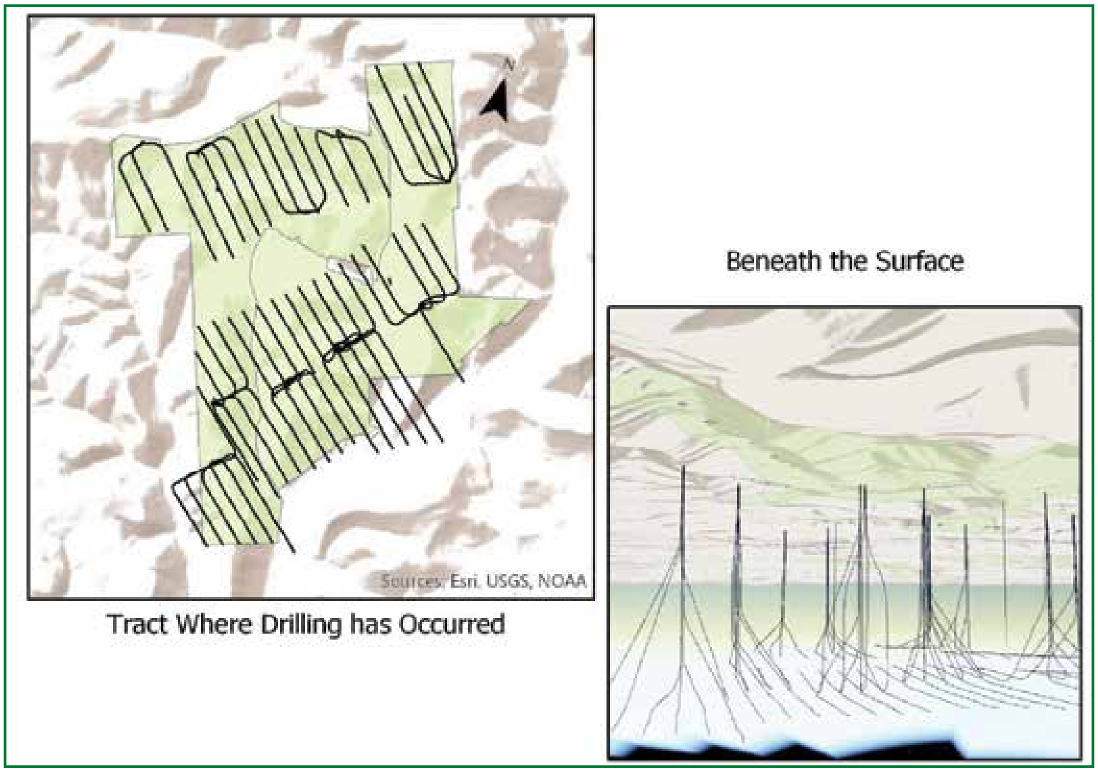


Figure 1.10. Plan view and cross section showing that not all gas from a tract can be captured.



For the Marcellus, the maximum number of wells that might be expected to be drilled going forward for 100 percent development of the 265,839 acres is approximately 1,475 wells using the 180 acre/well drainage area number. However, this estimate is an upper end estimate that does not include acreage that may be bypassed or undrilled due to geometric and topographic issues with the tracts configuration. Assuming about 10 percent of any given lease tract is inaccessible, the number may be as low as 1,327 wells in total. If the existing 473 wells already drilled on state forest issued leases is subtracted, the remaining wells to be drilled is approximately 854 wells. Essentially, full development of the existing lease acreage would involve more than twice the development activity that has occurred to date. In percentage terms, the range is from around 30 to 35 percent developed, depending on the efficiency in the development layout across the lease tracts on state forest land.

The Utica has been tested on state forest lands and found to be productive, but the limits of economic production are not currently identified closely enough for an accurate estimate to be made. Therefore, it is difficult with any confidence to project how many Utica wells might be drilled going forward, but it may be assumed some will be drilled. However, it is projected to be far less in total than the Marcellus play. Additionally, it is anticipated that the infrastructure put into place for the Marcellus play can be utilized for the Utica.

Website Links

[1] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20026631.pdf
[2] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032045.pdf
[3] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032020.pdf
[4] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031414.pdf
[5] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032134.pdf

Chapter II. Gas Monitoring Program

Key Points

- DCNR put in place a shale gas monitoring program in 2011 that consists of an integrated monitoring team, on-the-ground management activities, and research and external partner collaborations.
- The bureau monitors for a suite of values (infrastructure, flora, forest health, invasive species, water, soil, air, incidents, fauna, recreation, community engagement, timber, energy, revenue, and the forest landscape) that was developed in 2010.
- Between 2013-2016, DEP has conducted 3,101 inspections of unconventional gas infrastructure on state forest land.
- Between 2013-2016, DEP has issued a total of 47 Notice of Violations related to unconventional gas infrastructure on state forest land.
- Between 2013-2016, DCNR Ranger recorded incident reports related to gas development activity totaled 141.

Introduction

Shale gas development necessitates consideration of effects to a wide range of environmental and social values of the state forest system. This includes water quality and quantity, integrity of plant and animal habitats, core forest areas, recreation and aesthetics, control of invasive plants, noise levels, and potential changes in air quality. Shale gas development involves the clearing of forests to construct well pads, roads, pipelines, and other infrastructure. This clearing directly affects forestland by increasing habitat fragmentation and reducing the overall amount of forest cover. Construction activities, and the resultant development, can affect plants and animals and their habitat, such as forest-interiors and early successional woodlands. Common bird species, reptiles, amphibians, and species of concern, e.g., timber rattlesnakes, bats, Allegheny woodrats, and an array of native plant species, can be affected by these habitat changes across the landscape.

In addition to environmental concerns, shale gas development can alter the character of northcentral Pennsylvania, an area known as the “Pennsylvania Wilds,” that abounds with scenic beauty and outdoor recreational opportunities. Understanding the effects of shale gas development to state forest visitors is critical to sustaining tourism and the ability to provide healthful outdoor recreation opportunities to Pennsylvanians.

Shale gas development has also provided benefits to some users of state forest lands.

Road improvements and construction associated with development has promoted increased access to state forest land for recreation activities and reduced maintenance where upgrades were made by the gas operator. The increased forest edge around well pads and pipeline corridors may provide additional habitat for edge-frequenting wildlife species and seeded pipeline corridors have the potential to increase sightings of popular wildlife species such as turkeys and white-tailed deer. Restoring cleared and disturbed forestlands may also bring additional opportunities to increase habitat diversity within large blocks of mature forest. In addition, there is a substantial income stream from gas development.

DCNR's Shale Gas Monitoring Program

Given the host of potential impacts of shale gas development to the state forest system and its associated uses and values, DCNR put into place a shale gas monitoring program to monitor, evaluate, and report on the effects of shale gas development to the state forest system in 2011. The program aims to inform and improve shale gas management efforts and provide objective and credible information to stakeholders.

Monitoring is defined as "…the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 1998). A well-designed monitoring program can evaluate whether current management practices are working.

It is important to note that monitoring data are sometimes of limited value in conclusively identifying the exact cause of detected changes. Identifying the exact cause of change falls into the realm of "research," where great effort is made in isolating and testing the responses from potential change agents in a controlled environment through a rigorous experimental design. However, monitoring data and information remains an important part in identifying trends, guiding research, and the evaluation of management guidelines and practices.

Depending on the monitoring value and indicator, the amount of time and data necessary to detect change or trends varies significantly. Quantifying acres of cleared forest, fragmentation, visitor attitudes, and certain water quality parameters can be accomplished in a short time frame. However, other data related to invasive species spread, aquatic communities, tree mortality, soil impacts, and forest health – to name a few – may take longer for change to be noted or for any clear trends to emerge, which is why monitoring must be approached from a long-term perspective.

DCNR's Monitoring Approach

To help guide its monitoring program, DCNR identified a suite of "monitoring values." These values, developed in 2010 with input from its Ecosystem Management Advisory Committee, help focus monitoring efforts on values that relate to the sustainability of the state forest system; the effects of natural gas drilling on state forest to stakeholders and communities; and DCNR and the bureau's mission.

These values include:

- Water
- Wildlife
- Plants
- Invasive Species
- Incidents
- Air
- Land-use (Forest Landscapes)
- Soils
- Revenue
- Energy
- Recreation
- Local Communities (Community Engagement)
- Forest Health
- Timber Products
- Infrastructure

These monitoring values may change over time as more is learned about the activity and its potential effects on state forest lands.

To systematically monitor these values, the bureau takes a three-tiered approach, recognizing that an effective, long-term monitoring program must be multi-faceted. These tiers include 1) An integrated monitoring team; 2) On-the-ground management activities; and 3) Research and external partner collaboration. These tiers form the foundation for its shale gas monitoring program.

An Integrated Monitoring Team

The core of the shale gas monitoring program consists of 15 staff positions embedded in various program areas of the bureau. Staff is in the Rachel Carson State Office Building in Harrisburg; Mira Lloyd Dock Resource Conservation Center in Spring Mills; and at the Tiadaghton Forest Resource Management Center in Waterville. Monitoring involvement is not; however, limited to these staff. Since monitoring is a bureau-wide program, staff at many levels – from field to central office – are actively engaged in the program.

The core monitoring staff positions and their program area are outlined below.

- Forest Assistant Manager – Resource Inventory and Monitoring Section
- Forester (3 positions) – Resource Inventory and Monitoring Section
- Forest Technician (3 positions) – Resource Inventory and Monitoring Section
- Biometrician – Resource Inventory and Monitoring Section
- Plant Specialist – Resource Inventory and Monitoring Section
- Plant Specialist – Ecological Services Section
- Wildlife Specialist – Ecological Services Section
- Water Specialist – Minerals Division
- Infrastructure Specialist – Recreation Section
- Social Specialist – Resource Planning Section
- GIS Specialist – Geospatial Applications Section

(As of 2017, the Water, Infrastructure and Social Specialist positions were vacant due to budgetary constraints.)

Coordination of monitoring personnel efforts are the responsibility of the forest program manager for the Forest Resource Inventory and Monitoring Section. The organizational structure is shown in Figure 2.1.

The shale gas monitoring program has compiled and/or developed numerous monitoring protocols to address specific monitoring values. These protocols undergo a rigorous development process prior to becoming operational. Details regarding each protocol can be found in the Shale Gas Monitoring Manual[1].

Monitoring data used in this report are not limited to these targeted protocols. The bureau and its partners regularly collect data and compile information on forest resources that are useful in discerning trends and analyzing potential effects. Where appropriate, these data sources are used to support the monitoring of values outlined in this report.

While the shale gas region in Pennsylvania covers almost two-thirds of the state and many state forest districts, the bureau currently focuses its monitoring efforts on what it refers to as the "core gas forest districts" (Figure 2.2). While conventional gas activity has occurred outside these defined districts, and shale gas activity may occur outside the region in the future, the region consisting of the Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, Tioga, and Loyalsock State Forests are currently the area of concentration for most shale gas activity. Monitoring efforts, data collection, and reporting are focused on this seven-district region. The composition of this core area may change over time if there are changes in the patterns of gas exploration and development.

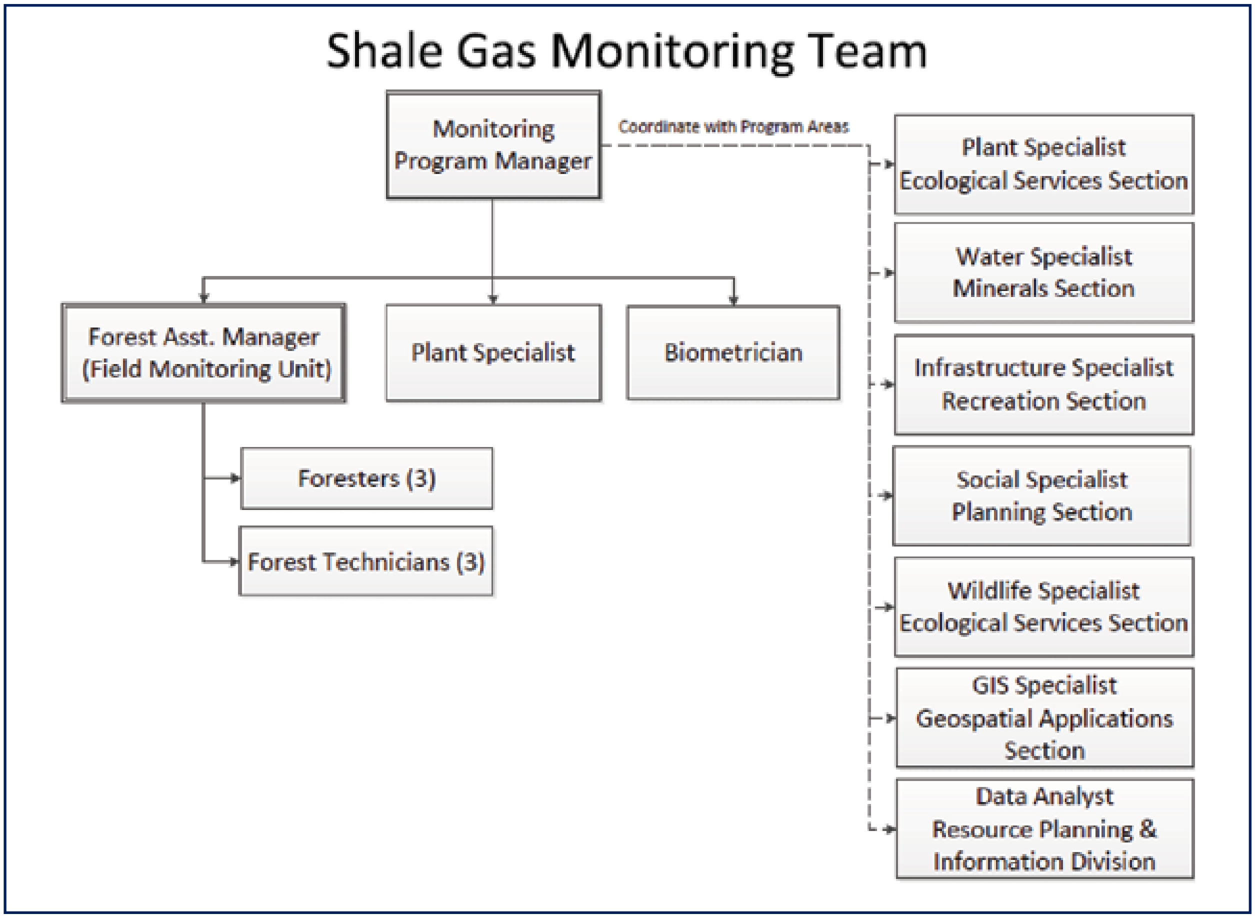


Figure 2.1. Organizational structure of the Shale Gas Monitoring Team.

Figure 2.2. Core gas forest districts.

Protocol Development Process

1. Monitoring Team proposes component to monitor.
2. Appropriate specialist, or group of specialists, conduct literature review and draft protocols.
3. Working group meets with field crews to refine the draft protocols and create the data sheets.
4. Field meeting is held with the entire Monitoring Team to review the protocols. Careful walkthrough of protocol with accompanying discussion.
5. Working group refines protocol based on team discussion.
6. Final walkthrough of revised protocol. Group discusses scope of the protocol and site selection.
7. Pilot field season of protocol begins.
8. Refine and move into full implementation.
9. Review and refine based on implementation.

On-the-Ground Management Activities

The bureau incorporates monitoring mechanisms as part of its oil and gas management administration. These mechanisms include planning, on-the-ground management, and the tracking and reporting of activities and accomplishments.

The bureau has seven forester positions whose duties include administering the Marcellus shale gas programs in the core gas forest districts. These "gas foresters" are responsible for:

- Maintaining district mineral records and reviewing mineral exploration permits.
- Monitoring compliance to various specific terms of the lease.
- Reviewing lease development plans and providing recommendations.
- Administration and monitoring of infrastructure construction.
- Administration of Right-of-Way Agreements and monitoring the implementation and compliance to terms of the agreement.
- Administration of Road Use Agreements and monitoring the implementation and compliance to specific terms of the agreement.
- Monitoring and mitigating impacts to other forest uses by negotiating restricted gas traffic during peak recreational use periods, e.g., hunting seasons, joint-use snowmobile trails, etc.

The major components of the bureau's approach to on-the-ground management are formally detailed in Guidelines for Administering Oil & Gas Activity on State Forest Lands[2] and include:

Proactive planning to avoid sensitive resource areas. This planning occurs at various points in time ranging from the SFERs that occur prior to lease sales to the review and the approval process for locating specific infrastructure. Proposed locations for well pads, rights-of-way, access roads, compressor stations, and water impoundments are thoroughly reviewed by the bureau prior to approval and construction. In certain situations, additional field surveys are conducted by bureau experts or environmental consultants. Overall, this effort represents a significant and critical process as potential negative impacts are avoided or minimized prior to construction. Significant measures are taken to protect, minimize, avoid, and mitigate effects to water quality, wetlands, vernal ponds, spring seeps, sensitive habitats, trails, recreation features, and other special resources.

Field management and inspections. Once approval is granted and construction begins, on-the-ground management and inspections are done for protecting special natural resources and state forest uses. Weekly inspections are recommended and occur for most construction activities. Deficiencies are recorded and corrective measures are implemented accordingly.

Incidents. The bureau tracks environmental incidents and violations to state forest rules and regulations associated with oil and gas infrastructure (e.g., pipelines and storage tanks) or activities (e.g., trucks hauling materials to a well pad). Both the bureau and DEP conduct regular inspections of gas related activities. Incidents outside the jurisdictional authority of the bureau are referred to DEP for investigation. DEP maintains inspection records and notices of violation (NOV) on its eFACTS[3] website. Incidents that fall within the bureau's jurisdictional authority, typically violations to the state forest rules and regulations, are investigated by the bureau.

A NOV or Consent Assessment of Civil Penalty (CACP) may be issued based on the results of a DEP investigation. A DEP NOV serves as a notification to the responsible party (typically the operator) of the details of the violation. A CACP is a consensual document authored by DEP and agreed to by the operator for the assessment of a civil penalty resulting from violations identified during an inspection. There are two categories of NOVs and CACPs: 1) Administrative and 2) Environmental Health and Safety. Examples of Administrative NOVs and CACPs include failure to post a permit and failure to post an erosion and sedimentation plan. Examples of Environmental Health and Safety NOVs and CACPs include inadequate silt fences, residual waste discharge, and brine or diesel fuel spills.

Between 2013-2016, DEP conducted 3,101 inspections on unconventional gas infrastructure on state forest land (Table 2.1). These inspections resulted in the issuance of 47 NOVs and one CACP issued to operators (Table 2.2).

The bureau maintains a confidential database that stores all incidents on state forest land in accordance with Visitor Services and Protection Directive #9, Incident Reporting. Incidents recorded in this system include those related to all activities on state forest land. Incidents related to oil and gas activity or infrastructure are noted regardless of whether the incident involves industry personnel or members of the public, e.g., a forest visitor vandalizing a gas pad identification sign would be noted as an incident related to gas activity. Between 2013-2016, a total of 141 incidents related to oil and gas activity or infrastructure have been recorded. This is down from 264 recorded between July of 2009 and 2012. Table 2.3 shows the top 15 incident types and number of incident reports related to oil and gas between 2013-2016 along with the corresponding number of incident reports between July 2009 and 2012.

Waivers. Operators may submit waiver requests to the bureau for certain conditions specified in the lease, e.g., buffer distances, non-development areas, viewshed areas, spacing, offsets, production reporting, drilling requirements, insurance, and well plugging. Any deviation from conditions specified in a lease or agreement requires a waiver. Requests must be justified and submitted in writing to the State Forester, or designee, for review and approval. The bureau reviews the waiver requests on a case-by-case basis and considers waivers only where it will provide greater protection for environmental or social values and is in the best interest of the commonwealth. For example, allowing for the reroute of a road to encroach upon an aesthetic trail buffer rather than impact a recently identified vernal pond. The tracking and review of waivers aid in the refinement of future lease terms and management practices.

Between 2013-2016, a total of 10 project waiver packages associated with oil and gas activity were submitted to address 18 individual situations. The most common waiver was for stream buffer encroachments.

DEP Inspection Type	Number of Inspections
Administrative/File Review	266
Compliance Evaluation	13
Drilling/Alteration	536
Follow-up Inspection	65
Incident- Response to Accident or Event	77
Plugging (Includes Plugged/Mined Through)	31
Pre-operation Inspection	6
Routine/Complete Inspection	1,818
Routine/Partial Inspection	126
Site Restoration	163
Total	**3,101**

Table 2.1. Total number of DEP inspections on state forest land unconventional gas infrastructure between 2013-2016.

Violation Category	Enforcement Type	Number
Administrative	NOV - Notice of Violation	17
Environmental Health & Safety	CACP - Consent Assessment of Civil Penalty	1
Environmental Health & Safety	NOV - Notice of Violation	30
Total	**---**	**48**

Table 2.2. NOVs and CACPs issued by DEP from inspections of unconventional gas infrastructure on state forest land between 2013-2016.

Incident Type	No. of Incident Reports (2013-2016)	No. of Incident Reports (2009-2012)
Criminal Mischief	16	15
Operation closed areas	14	4
Closure	13	21
Miscellaneous (not otherwise classified)	11	22
Motorized Vehicles (excluding ATVs/snowmobiles)	10	2
Crimes Code	9	20
Motor Vehicle Code (Title 75)	9	15
No Injury	8	20
Hunting	4	1
Reckless/Negligent operation	3	4
Littering	3	4
Theft	3	8
Vandalism	3	8
ATV Operation unauthorized areas	3	4
Hazards (man-made)	2	18
TOTAL	**111**	**166**

Table 2.3. Summary of top 15 incident types related to oil and gas and the number or incident reports from 2013-2016.

Type of Waiver	Number of Waivers (2008-2012)	Number of Waivers (2013-2016)
Wetland Buffer	15	2
Road Buffer	9	5
Lease Boundary Buffer	5	2
Trail Buffer	2	1
Natural Area Buffer	1	0
Stream Buffer	0	6
Other	3	2
Total	**35**	**18**

Table 2.4. Number of waivers by type.

The number of waivers in this period is down from the 35 waivers between 2008-2012 (Table 2.4). The decrease is likely due to the reduced amount of gas development activity between 2013-2016.

Forest Stewardship Council (FSC) Certification Audit. This audit represents a third-party, independent assessment against a set of accepted environmental and social indicators of sustainable forest management. PA state forests are one of the largest certified public forests in North America; a designation the bureau has earned every year since 1998.

Research and external partner collaboration

When appropriate and as resources become available, the bureau seeks to fund and cooperate with research entities in a coordinated fashion to address specific The bureau needs related to shale gas development. The intent is to leverage opportunities and resources for work that the bureau would not be able to accomplish otherwise, or work that is best suited for a research effort. The bureau is currently working with several partners and research entities. Table 2.5 lists research and partner collaborations.

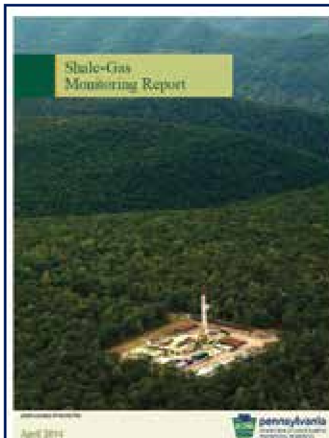
In addition to funded research and partner collaborations, the bureau also provides opportunities for researchers to conduct independent studies on state forest land. To conduct this type of work on state forest land, researchers must be granted permission by the bureau. Permission is granted or denied through the bureau's State Forest Research Agreement (SFRA) process. In this process, a project proposal and formal request is submitted to the bureau. The bureau then evaluates the request based on potential impacts the work may have on the state forest resource or staff. As a condition of the SFRA, annual progress reports, a final report, products, and publications are required to be submitted to the bureau.

Shale Gas Monitoring Reports

An essential function of the shale gas monitoring program is to regularly compile, analyze, and report on findings. As mentioned previously, this reporting serves two functions. It assists the bureau in evaluating effects and adjusting, if necessary, its management planning and practices. And it communicates to the public the effects of shale gas activities on state forest lands.

In 2014, the bureau released the first Shale-Gas Monitoring Report[4]. This report summarized data prior to Marcellus development in 2008 and for the 2008-2012 period. This report presented information based on the suite of 15 values identified for monitoring.

This second comprehensive report is an opportunity to communicate change on state forest land as well as discuss the bureau's adaptive management. To facilitate this, the report is organized by broad chapters that encompass each of the 15 values. The bureau will periodically issue additional reports as more data are collected and information is compiled.



Title/Work Description	Principle Investigator(s)	Institution	Reports/Publications
Evaluating Storm Water and Erosion and Sedimentation Control Measures Associated with Shale Gas Infrastructure in Forested Landscapes	Dr. Barry Evans	Penn State University	
Quantifying Soil and Landform Change Across Shale Gas Infrastructure in Northern Pennsylvania	Dr. Patrick Drohan	Penn State University	Drohan, P.J., Brittingham, M., Bishop, J. and Yoder, K. 2012. Early Trends in Landcover Change and Forest Fragmentation Due to Shale Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians. Environmental Management 49: 1061. doi:10.1007/s00267-012-9841-6. Drohan, P.J. and M. Brittingham. 2012. Topographic and soil constraints to Shale Gas development in the Northcentral Appalachians. Soil Science Society of America Journal, 76:1696-1706. Fink, C.M., Drohan, P.J. 2015. Dynamic Soil Property Change in Response to Reclamation following Northern Appalachian Natural Gas Infrastructure Development. Soil Science Society of America Journal.
Quantifying the Cumulative Effects of Multiple Disturbance Regimes on Forested Ecosystems in Northern Pennsylvania	Dr. Patrick Drohan, Dr. James Finley and Dr. James Grace	Penn State University	
Effects of Natural Gas Pipelines and Infrastructure on Forest Wildlife	Dr. Margaret Brittingham	Penn State University	Barton, E., Pabian, S. and Brittingham, M. 2016. Bird Community Response to Marcellus Shale Gas Development. The Journal of Wildlife Management; DOI: 10.1002/jwmg.21117. Langlois, L.A., Drohan, P.J., Brittingham, M.C. 2017. Linear infrastructure drives habitat conversion and forest fragmentation associated with Marcellus shale gas development in a forested landscape. Journal of Environmental Management.
Assessing Landscape Change due to Marcellus Shale Drilling Operations and Devising Landscape Remediation Strategies to Minimize Site Impacts	Dr. Margaret Brittingham and Dr. Patrick Drohan	Penn State University	http://groundwork.iogcc.ok.gov/sites/default/files/brittingham-101013093530-phpapp01_0.pdf
Assessing Potential Impacts of Marcellus and Utica Shale Energy Development on the Timber Rattlesnake (Crotalus horridus) in North Central Pennsylvania	Dr. Gian Rocco and Dr. Robert Brooks	Penn State University	
Pennsylvania State Forest Visitor Use Monitoring (VUM) Program	Dr. Alan Graefe[1], Dr. Andrew Mowen[1], Dudley Kyle Olcott[1], Dr. David Graefe[2], Dr. Donald English[3]	[1]Penn State University, [2]Marshall University and [3]US Forest Service	Tioga & Tiadaghton (2008) http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20030740.pdf Sproul & Susquehannock (2011-12) http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20030739.pdf Tioga & Tiadaghton (2013-14) http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20031327.pdf Elk & Moshannon (2014-15) http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20032034.pdf Marcellus Summary (2016) http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_20032659.pdf

Title/Work Description	Principle Investigator(s)	Institution	Reports/Publications
Acoustic Noise from Natural-Gas Compressor Stations on State Forest Land: Pilot Study	Dr. Thomas B. Gabrielson	Penn State University	Acoustic Noise from Natural-Gas Compressor Stations On State Forest Land: Pilot Study (Final Report)
Well Pad Invasive Species Surveys	Dr. David Mortensen and Kathryn Barlow	Penn State University	2012 and 2013 data sets Barlow, K.M., Mortensen, D.A., Drohan, P.J., Averill, K.M. 2017. Unconventional gas development facilitates plant invasions. Journal of Environmental Management.
Comparing Lepidopteran Communities Around Native and Non-Native Reclamation	Betsy Leppo	Western Pennsylvania Conservancy	
Tiadaghton State Forest 'Mock Pad' Reclamation	Dr. Patrick Drohan and Kathryn Barlow	Penn State University	https://stateimpact.npr.org/pennsylvania/2015/05/12/as-gas-boom-cuts-into-forests-scientists-study-how-to-put-it-back-together/
Vegetation Analysis on Dominion ROW in Tuscarora and Rothrock State Forests	Dr. David Mortensen and Karthryn Barlow	Penn State University	
Water Quality and Macroinvertebrate Assemblages	Dr. Adam Mumford	US Geological Survey	
Water Quality	Michael (Josh) Lookenbill	PA Department of Environmental Protection	
Water Quality	Dawn Hintz	Susquehanna River Basin Commission	http://mdw.srbc.net/remotewaterquality/ http://mdw.srbc.net/remotewaterquality/reports.htm Evaluation of Macroinvertebrate Communities in Exceptional Value and High Quality Streams Within the Remote Water Quality Monitoring Network (2016) RWQMN – DCNR Technical Summary (June 2016)
Road Maintenance	David Shearer	Penn State Center for Dirt and Gravel Roads Studies	
Plant Monitoring and Identification Training	Dr. Timothy Block	Morris Arboretum	

Table 2.5. DCNR research and collaborative efforts.

Website Links

[1] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20033429.pdf

[2] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032134.pdf

[3] http://www.ahs.dep.pa.gov/eFACTSWeb/default.aspx/default.aspx

[4] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20029147.pdf

Literature Cited

Elzinga, Caryl L., D. Salzer, and J. Willoughby. 1998. Measuring & Monitoring Plant Populations. US Department of Interior, Bureau of Land Management, National Applied Resource Sciences Center. BLM/RS/ST-98/005+1730. Pg. 492.

Chapter III. Shale Gas Production and Administration

Key Points

- 2016 United States energy consumption was 97.4 quadrillion Btu.
- In 2016, 5.26 Tcf of natural gas was produced and brought to market by PA, with 8.9 percent of that volume coming from state forest land.
- Cumulative income from 1947 to 2016 from oil and gas activity on state forest land is $1,162,510,774.
- Revenues from oil and gas activity are allocated to the Oil and Gas Lease Fund.
- In general, shale gas development has not been impacting the bureau's implementation of its timber harvesting schedules and vice versa.

Introduction

Various forms of energy have been extracted and utilized throughout history to meet the needs of society. The U.S. Energy Information Administration (EIA) is an agency within the U.S. Department of Energy that provides independent and impartial energy information and statistics. EIA collects, analyzes, and disseminates energy estimates on coal, petroleum, natural gas, electric, renewable, and nuclear energy to promote sound policy making decisions and public understanding of energy and its interaction with the economy and the environment.

United States Energy Consumption

Energy consumption in the United States in 2016 was 97.4 quadrillion Btu. A Btu is defined as a British thermal unit, which is the energy required to raise one pound of water by one-degree Fahrenheit. Energy consumption is also expressed in quads, with one quad equaling one quadrillion Btu. This 2016 estimate of energy consumption by EIA is about the same as was reported in 2011 (Table 3.1). An illustration of estimated energy usage within the U.S. from 1776 to 2015 is in Figure 3.1.

Table 3.1. 2011 and 2016 U.S. energy consumption.

Primary Source	2016 quadrillion Btu	2016 Percent	2011 quadrillion Btu	2011 Percent
Coal	14.2	15%	19.9	20%
Natural Gas	28.5	29%	24.9	26%
Petroleum	35.9	37%	35.3	36%
Renewable Energy	10.2	10%	9.1	9%
Nuclear Electric Power	8.4	9%	8.3	9%
Total	**97.4**	**100%**	**97.5**	**100%**

The modern energy mix within the United States consists chiefly of five energy sources: oil or petroleum, natural gas, coal, various renewable energy sources, and nuclear energy (Figure 3.2). The second largest source of energy in the U.S. is natural gas or methane at 28.5 quads, or 29 percent of U.S. consumption.

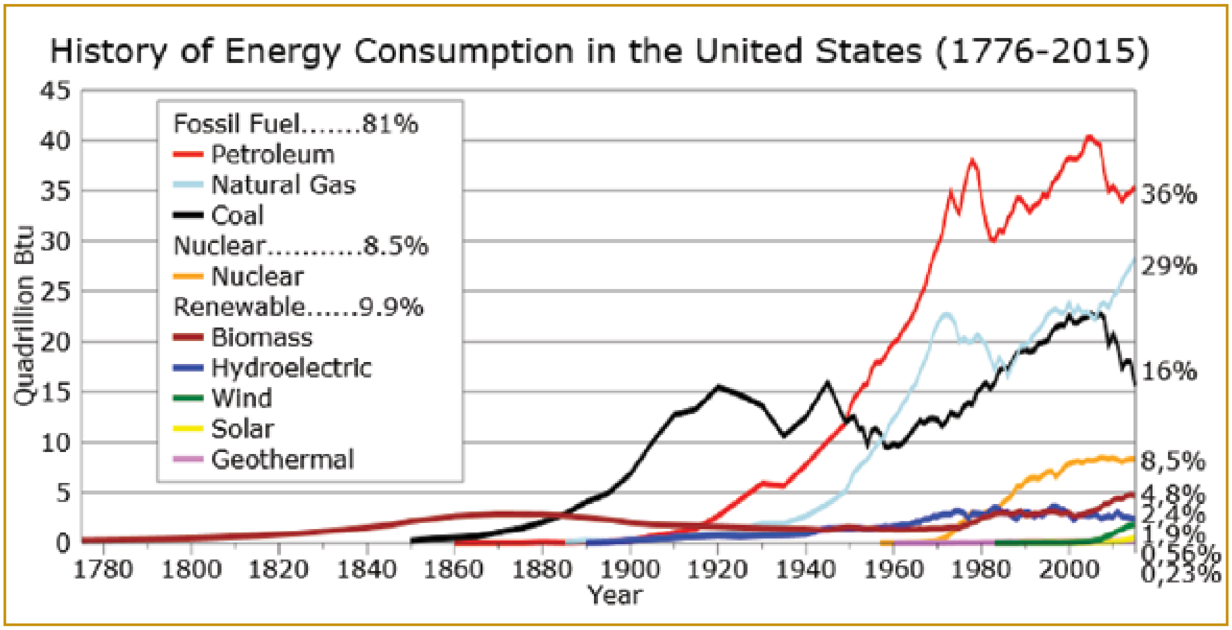


Figure 3.1. Estimated energy usage with the U.S. from 1776 to 2015.

Natural gas is a fuel of choice for heating, industrial processes, and electrical production where available in large quantities at a competitive price.

Since 2011, natural gas has increased market share in U.S. consumption from 24.9 to 28.5 quads. This is approximately a 4 percent increase since 2011. During this same time, coal has decreased in market share by approximately 5 percent.

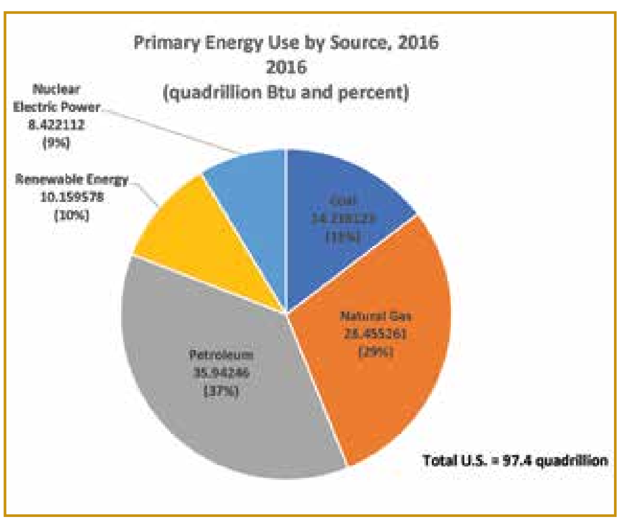


Figure 3.1. Estimated energy usage with the U.S. from 1776 to 2015.

Energy consumed in the U.S. continues to outpace production (Figure 3.4). The widest gap in consumption verses production occurred in 2005 when U.S. consumption was approximately 30% percent higher than production. In 2016, U.S. production met approximately 86 percent of consumption indicating the U.S. need for imported energy has decreased. Projections by EIA suggest that U.S. production may exceed consumption by the year 2026.

Pennsylvania Volume Estimates

Pennsylvania has a long history of providing natural gas to market. The EIA tracks reported gas production from all PA gas wells. From 2000 to 2007, prior to Marcellus, volumes produced in PA ranged from 0.15 to 0.18 Tcf annually. Marketed production increased from 0.2 Tcf in 2008 to 5.26 Tcf in 2016 (Figure 3.5). Production in years post 2007 reflect Marcellus shale development. Overall, production has increased during the 2000 to 2016 period. However, the increase in annual production has not been steady over this period. By looking at annual increases – or production growth – marketed production growth was modest from 2000 to 2009. Between 2010 and 2014, as developed Marcellus

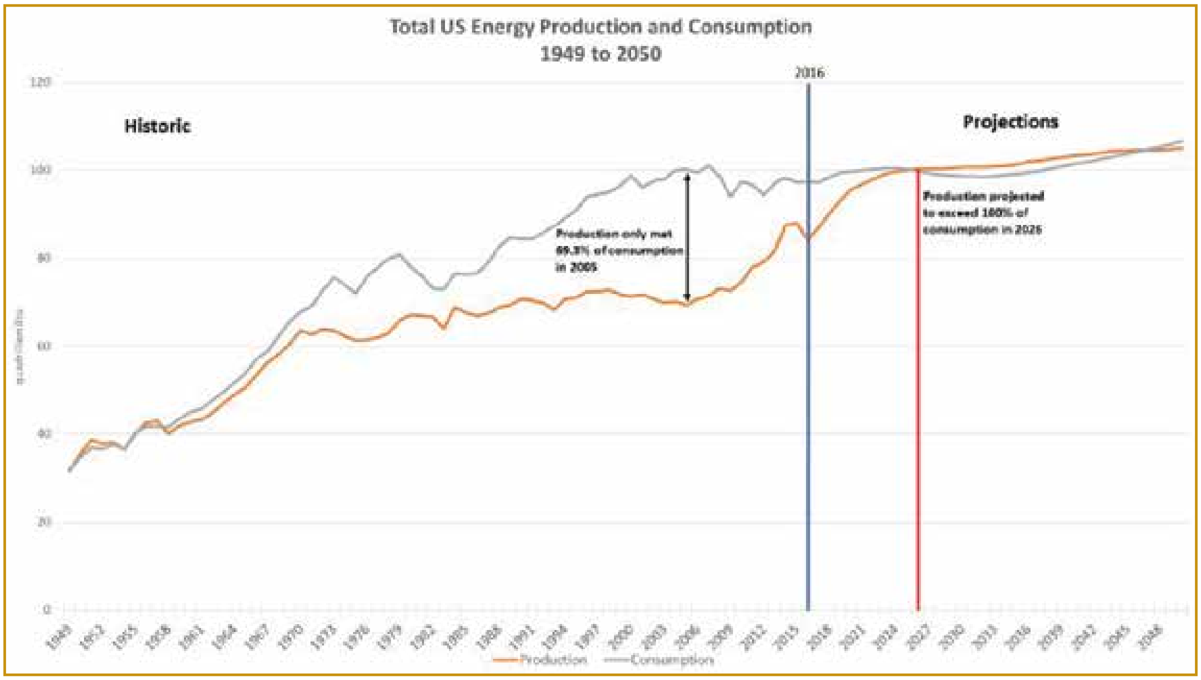


Figure 3.4. Total U.S. energy production and consumption.

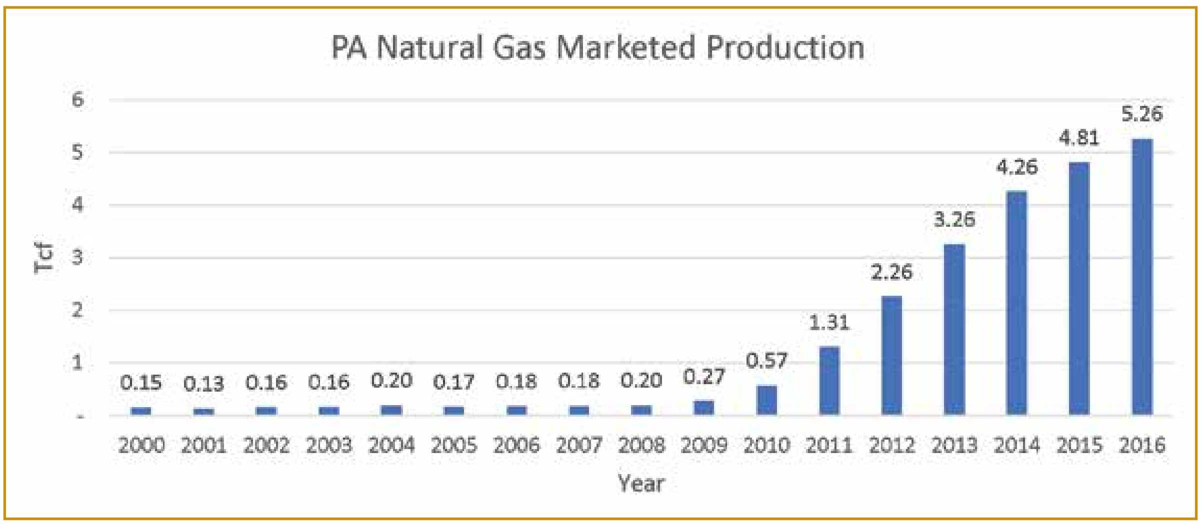


Figure 3.5. PA natural gas marketed production.

wells began moving gas to market, production growth increased substantially before trailing off in 2015 and 2016.

Pennsylvania Bureau of Forestry Gas Leases, Production, and Revenues

Since the first bureau issued gas leases in 1947, the development of natural gas resources on state forest land provided gas to market and a steady, increasing revenue stream. Natural gas leasing and development on state forest land can be broken into four main periods; deep Oriskany sandstone (1950's through 1970's), shallow Upper Devonian (1980's and 1990's), Trenton Black River (early 2000's), and Marcellus (2008 to present). Figure 3.6 illustrates historic levels of acreage under lease since 1947.

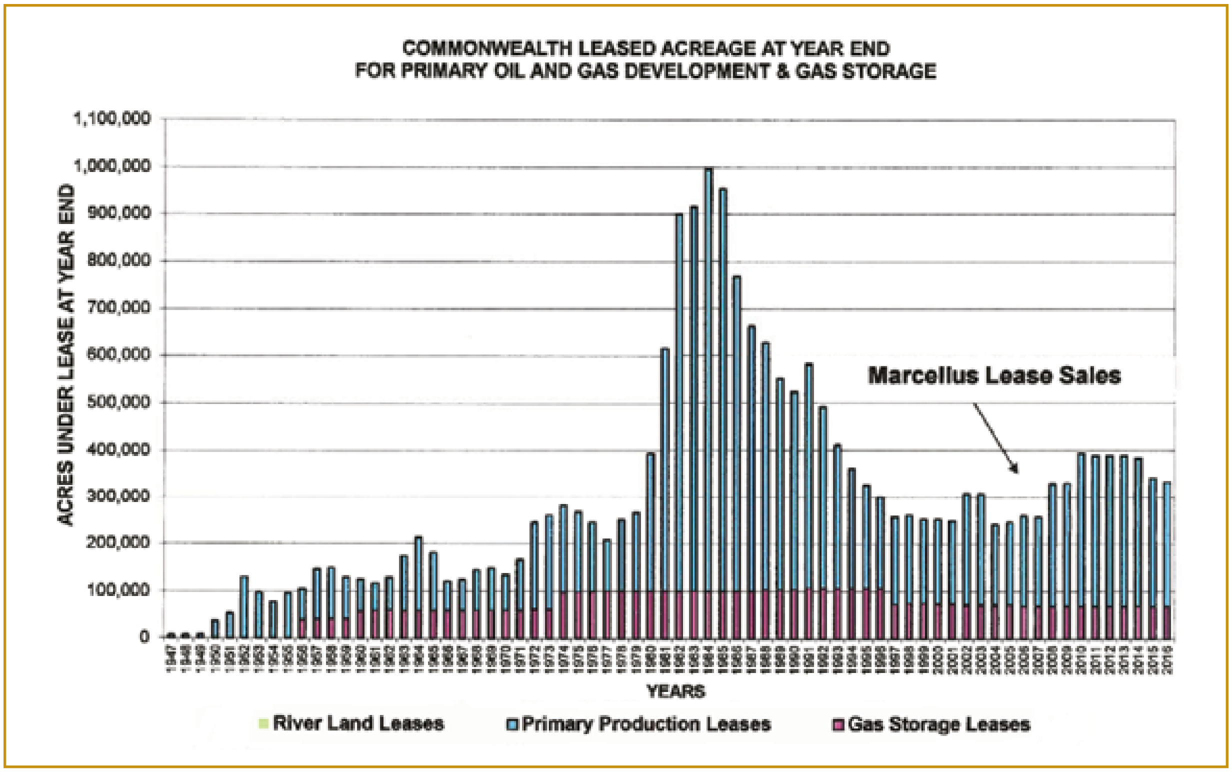


Figure 3.6. Commonwealth leased acreages.

The volume of natural gas produced from state forest land has historically made up a small percentage of overall PA production. From 1967 to 1992, natural gas volumes from state forest land have made up approximately 1 percent of overall production from PA. In the mid-90's, natural gas volumes from state forest land accounted for approximately 3.3 percent of overall PA production. Volume contributions of natural gas ranged from approximately 1-2 percent in the early 2000's leading up to Marcellus wells beginning to produce in 2010. Since Marcellus wells have begun producing, state forest land volume contributions of natural gas production have increased to over 8 percent of the total PA production (Table 3.2).

Decade	U.S. Total Tcf	PA Total Tcf	State Forest Gas Tcf	State Forest % PA Total
1940's	15.2	NA	0.007	NA
1950's	91.9	NA	0.285	NA
1960's	161.6	0.26	0.039	1.2
1970's	211.5	0.852	0.008	1.3
1980's	181.5	1.457	0.002	<1.0
1990's	193.5	1.353	0.030	2.6
2000's	201.5	1.793	0.024	1.4
2010 - 2016	182.1	21.783	1.977	8.9

Table 3.2. Pennsylvania natural gas production from state forest land.

Gas development on state forest land has generated substantial revenues from rentals and royalties associated with natural gas activities. Prior to Marcellus, the commonwealth received approximately $153,659,522 in total revenues related to gas activities from 1947 to 2007. Income from gas activities from 2000 to 2007 was approximately $5 million per year. From 2008-2016 the commonwealth received approximately $832,158,315 in revenues from gas activities on state forest land. This provided a revenue stream of approximately $80 million per year during this time (Table 3.3). In December of 2014, the total cumulative income from the program since 1947 exceeded one billion dollars in income.

Over the years, oil and gas revenues have been used to fund different commonwealth and department programs and projects. These include augmenting the commonwealth's general fund expenditures, land acquisition, recreation infrastructure additions and improvements, botanical surveys, equipment, and employee salaries. As revenues from oil and gas increased over the years, the rules for how these funds are allocated and spent have also evolved.

From 1947 to 1955 all income from state forest land leases was deposited into the state general fund. General fund money is allocated to support a broad array of government programs; including staff salaries, infrastructure, and equipment to maintain these programs. Because the revenues were put directly into the general fund, the funds were not readily available to the department for use on environmental projects.

As revenues from oil and gas increased through the 1950's, income was accumulated in a special fund. Act 256 of 1955, or the Oil and Gas Lease Fund, was created to allow oil and gas revenues to be deposited into this fund with spending authority granted to the Secretary of DCNR. The Oil and Gas Lease Fund allowed for four broad categories of expenditures; conservation, recreation, dam construction and maintenance, and flood controls on state forest and park lands.

From 1955 to 2008 the Oil and Gas Lease Fund remained unchanged and allowed DCNR and its predecessors to use the funds at the discretion of the Department Secretary. During this time the fund accumulated just over $150 million that was allocated for the following purposes:

- Land acquired for state forests (over 200,000 acres incrementally over time).
- Land acquired for 26 state parks (incrementally over time).
- Purchase oil and gas development rights under existing state forest lands (2,000 acres).
- Pine Creek Rail Trail acquisition and development.
- Numerous Heritage and Botanical Survey projects.
- Bureau field office vehicles (1980 onward).
- Computers for use by the bureau (1990 onward).
- Forest management and maintenance equipment.
- Staff salaries and materials for the management of the Oil and Gas Lease Fund.

Following the first Marcellus lease sale in 2008, DCNR received revenues surpassing those generated in the past. The Oil and Gas Lease Fund was modified to allow oil and gas revenues to be directed to the general fund. In total, $383 million were used to fill PA state budget gaps in the general fund over two budget years.

In 2012, the Oil and Gas Lease Fund authority was again changed to include fund distributions to several special funds and a definitive set-aside for DCNR. This legislation is known as Act 13 of 2012. The distribution was the Marcellus Legacy Fund ($35 million annually) and the Hazardous Sites Cleanup Fund ($15 million in addition to the $50 million annually allotted to DCNR). Table 3.4 illustrates the broad category expenditure and amounts from the Oil and Gas Lease Fund from 2008 through 2016 fiscal years.

Decade	Gas Storage Rentals	O&G Lease Rentals	O&G Lease Royalties	Total Income	Cumulative Income
1940's	$0	$4,671	$407,433	$412,104	$412,104
1950's	$291,951	$3,753,964	$21,774,636	$25,820,551	$26,232,655
1960's	$1,134,812	$1,700,169	$4,689,749	$7,524,730	$33,757,385
1970's	$2,855,941	$5,795,016	$1,391,068	$10,042,025	$43,799,410
1980's	$8,693,593	$25,918,737	$10,225,488	$44,837,818	$88,637,228
1990's	$13,198,747	$5,971,032	$14,825,508	$33,995,287	$122,632,515
2000's	$19,691,657	$171,842,932	$18,163,451	$209,698,040	$332,330,555
2010 - 2016	$18,791,731	$293,022,352	$518,366,136	$830,180,219	$1,162,510,774
Total	$64,658,432	$508,008,873	$589,843,469	$1,162,510,774	$1,162,510,774

Table 3.3. State forest land oil and gas income by decade.

Expenditure	Amount
General Fund Transfer	$383,000,000
DCNR Parks Operations	$223,978,000
DCNR Forestry Operations	$173,315,000
Marcellus Legacy Transfer	$105,000,000
DCNR Gen Govt Operations	$47,135,050
Vehicles & Equipment	$29,481,045
Services	$26,435,243
Personnel Services	$16,920,968
IT Equip, Software & Hardware	$7,511,378
Land Purchases	$6,992,395
Grants	$6,158,676
Aggregate, fuel, signs, uniforms, vehicle repair	$5,710,039
Supplies	$2,948,490
Printing, Postage, Freight	$1,482,864
Rent/Lease	$787,714
Capital Improvements	$663,762
Utilities	$650,959
Fixtures & Other Equipment	$321,560
Other	$317,932
Training	$301,345
Travel	$80,896
2008-2016 Fiscal Year Total	**$1,039,193,317**

Table 3.4. Oil and Gas Lease Fund category expenditure and amounts from 2008-2016 fiscal years.

Timber Harvesting Related to Gas Activities

According to the bureau's strategic plan, Penn's Woods, the state forest timber policy is: "State forest lands should provide a sustained yield of high quality timber consistent with the principles of ecosystem management." The bureau uses silviculture as a tool for regenerating the forest by following a timber harvest scheduling model that leads toward the goal of balancing the age class distribution; securing a sustainable flow of timber products; conserving and perpetuating underrepresented forest community types; and creating or improving specific types of wildlife habitat. The state forest system has been third-party certified by FSC as "well managed." To maintain forest certification and market harvested timber products from state forest land as "certified" wood, the bureau must show that its timber harvesting levels can be sustained and that harvesting levels are achieving desired future conditions. Meeting the timber harvest schedule's acreage targets is important to the sustainability of the timber industry in Pennsylvania, which relies heavily on sustained yields of forest products from state forest lands. A continuous, steady supply of quality timber from state forest lands is essential to the survivability of the hardwood industry and the economy of some regions of Pennsylvania.

Gas development has implications for the bureau's timber management program. A key question in evaluating the effects of shale gas development is whether the activity is affecting the attainment of annual harvest targets and placement of timber sales in the core gas forest districts. It may be possible, with additional monitoring, to discern any reductions in total acres harvested and/or acres harvested within areas now under shale gas lease that may occur in the future.

In general, shale gas development does not appear to be impacting timber harvesting activity and placement. Prioritizing areas for oak and ash salvage operations is one explanation for the current placement of timber sales. This is a common practice within the bureau when large tracts of timber succumb to a forest pest such as gypsy moth or emerald ash borer.

The deterioration of state highways from gas related activity throughout the shale gas region and associated road bonding is a potential concern for the forest products industry, upon whom the bureau depends to implement harvests plans and its long-term management plan. The weight, timing, and markedly increased frequency of shale gas development-related payloads contrasts to the traditional use of these highways by logging contractors, which involves fewer loads and attention to seasonal conditions. As a result, roads in this region have suffered accelerated wear. The Pennsylvania Department of Transportation (PennDOT) has responded by instituting increased road bonding requirements and damage assessments. In addition, the gas industry has funded highway upgrades and repairs in some areas. The Oil and Gas Act (Act 13 of 2012) provides certain protections to the timber industry and other at-risk industries regarding road bonding. Additionally, the transportation bill passed in 2013 addresses road bonding issues across Pennsylvania. The bureau works with PennDOT and other partners to address these impacts on state forest lands and the forest products industry.

A positive effect of natural gas development has been the use of gas development access roads for timber sales. Timber is transported from the forest to the mill by trucks that require road systems. If a timber sale is not adjacent to an existing state forest road, a haul road must be constructed. The cost of a haul road is deducted from the value of the timber being sold and is incurred by the bureau. Conversely, gas access roads are constructed at a cost to the gas company requiring the access. The bureau has leveraged these roads for timber removal whenever possible.

Crossing gas pipelines with heavy equipment associated with timber harvesting has created issues regarding pipeline integrity and safety. Gas operators are responsible for protecting their property in a manner that does not impede the bureau from utilizing the surface. In some cases, pipelines were not buried to a depth considered adequate for heavy equipment crossing. In these cases, temporary padded crossings were utilized for the duration of the timber harvesting activity.

In addition to revenues generated directly from leases and gas royalties, the bureau also receives revenues from the sale of the timber associated with natural gas infrastructure development. Both subsurface ownership rights and state forest gas leases allow for the infrastructure necessary to develop mineral resources, such as pad clearings, compressor stations, roads, and pipelines. The construction of infrastructure may require the clearing and conversion of forest land. The commonwealth must be compensated for assets including timber and pulpwood and loss of future growth. Depending on the agreements or lease terms, operators have the option of compensating the commonwealth for the value of the timber based on a timber cruise or through a flat per acre rate. Either method results in the volume being sold at double the stumpage value. Although timber removed to facilitate gas activities is not FSC certified wood, 10 percent of revenues from these sales are deposited into the bureau's regeneration fund. This fund reinvests in projects on state forest land to establish new forest. Table 3.5 illustrates revenues from timber sales associated with gas development activities since 2008.

Agreements, Documentation, and Infrastructure Management

To manage infrastructure on state forest land, many legal documents, records, agreements, and licenses must be prepared, maintained, and continuously updated. With the onset of shale gas development, many of these tasks increased in frequency and complexity. Additionally, the bureau had to adapt to the novel components and considerations unique to shale gas development. See Table 3.6 for a description of several of the common components of documentation and management of state forest infrastructure.

The combined number of road use agreements (RUA) and right-of-way agreements (ROW) have decreased in the last 10 years (Figure 3.7). However, there has been an expanded workload due to the increased complexity of distinct types of agreements that have been issued during recent years. For information on requesting ROWs please see DCNR's Right of Way[1] webpage.

	Sawtimber		Pulpwood		Firewood		Payment In Lieu Of Volume Estimation	Total
Year	Board Foot Volume	$	Cubic Foot Volume	$	No. of Cords	$	$	$
2008	1,736,548	$1,797,505.38	127,410	$14,767.89	0	$0.00	$7,584.50	**$1,819,857.77**
2009	1,862,827	$1,637,112.27	101,039	$18,119.31	0	$0.00	$319,900.00	**$1,975,131.58**
2010	897,447	$847,474.36	47,124	$12,632.27	58	$514.00	$2,616,140.00	**$3,476,760.63**
2011	566,669	$647,863.79	44,636	$10,858.83	0	$0.00	$3,342,107.85	**$4,000,830.47**
2012	237,641	$160,373.66	57,343	$18,411.46	455	$9,206.30	$1,746,545.82	**$1,934,537.24**
2013	763,066	$715,343.19	34,030	$8,591.50	0	$0.00	$813,755.11	**$1,537,689.80**
2014	607,871	$798,141.96	16,734	$4,745.52	0	$0.00	$484,289.28	**$1,287,176.76**
2015	538,201	$610,190.45	10,800	$2,428.00	0	$0.00	$194,503.70	**$807,122.15**
2016	205,154	$134,813.11	10,631	$2,439.56	0	$0.00	$17,993.50	**$155,246.17**
Total	**7,415,424**	**$7,348,818**	**449,747**	**$92,994**	**513**	**$9,720**	**$9,542,820**	**$16,994,352.57**

Table 3.5. Timber sale revenues associated with gas development activities.

Task/Document	Description
Road Use Agreements	Agreements to use state forest roads to conduct commercial activities; includes provisions for compensation of the commonwealth for this use and protections for the safety of the visitors, as well as the natural resources within the state forest
License for Right of Way (ROW) Agreements	Pipeline or electrical lines to gas facilities require clearance of vegetation; these agreements outline the expectations and requirements of users/lessees
Communication tower requests	Currently a mortarium on communication towers except as part of gas lease or for purpose of public safety; for shale gas development, primarily at pad sites or Main Transmission Tie-in Interconnect sites
Licensee change of asset ownership: Assignments and transfers	As assets are sold and exchanged, all legal documents must be updated to reflect these changes
Agreement of Consent to Use of ROW	Agreements to define parameters and requirements of use, where 2 parties are sharing the same ROW or portions thereof
Accounting	Updates/changes to internal tracking system for payments, etc.
Comptroller Reports of Delinquent Accounts	Follow-up contact with lessees regarding delinquent payments for rental accounts

Table 3.6. Description of common components of documentation and management of infrastructure.

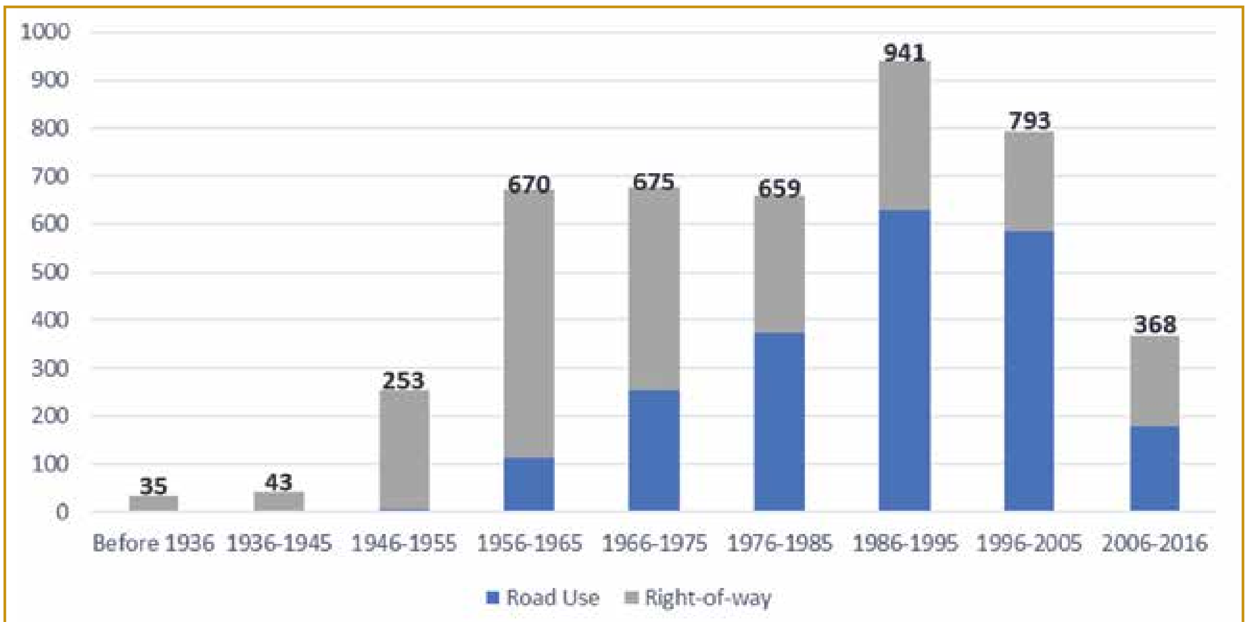


Figure 3.7. Total number of Road Use and Right-of-way agreements issued by 10-year blocks.

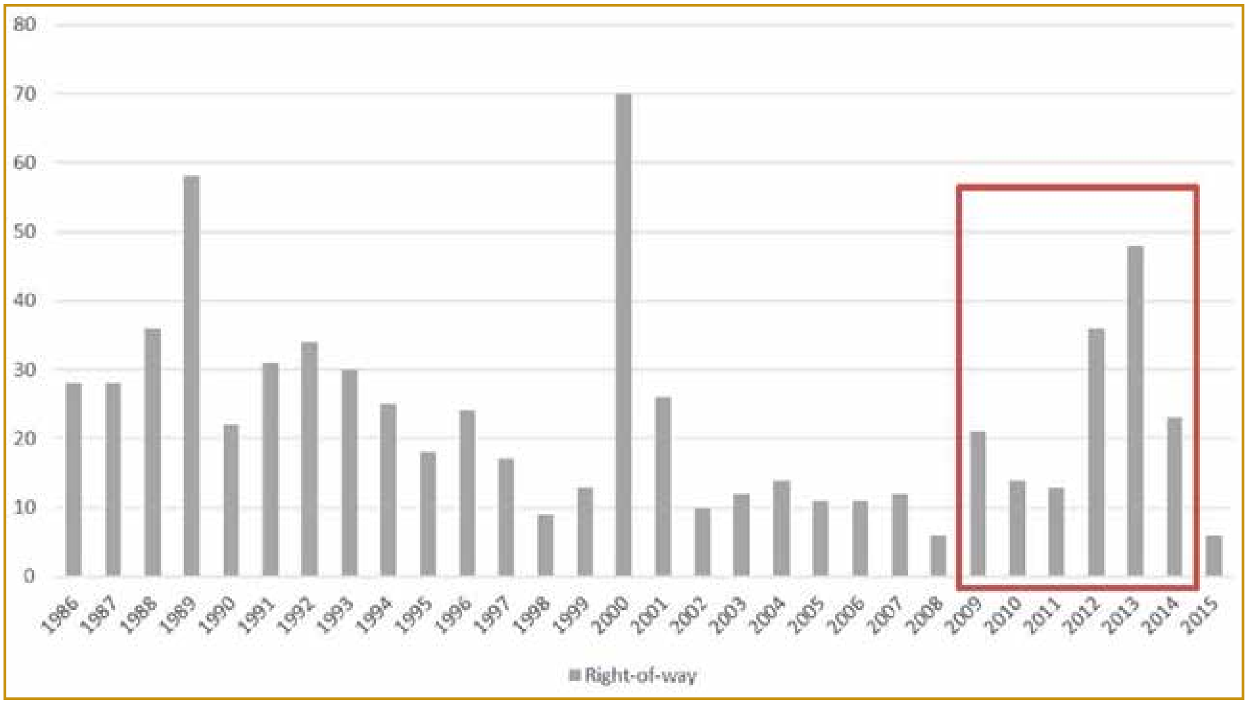


Figure 3.8. Right-of-way agreements by year for the past 30 years. Red box indicates increased number of right-of-way agreements issued, which coincides with shale gas development.

With the increased volume of natural gas being extracted from state forests came the need for additional pipelines. The leasing of state forest land for shale gas development brought an increase in the number of ROW agreements issued by the bureau (Figure 3.8). ROW agreements include electrical facilities for gas development, which existed prior to shale gas development to service meters, valves, etc., but increased with the onset of shale gas development. In addition, there are numerous agreements for large main gas transmission system upgrades and new lines along existing corridors that required expansion and construction.

In addition to the increase in number, agreements also became more complex. The standard template for such agreements required adjustment to address modern concerns in energy development. Prior to these updates in 2009, the template had not been revamped since the early 1990's. Many changes to management of the state forest system had occurred in this time and needed to be reflected in the new parameters in the template. For example, during this time, the state forest system became certified by FSC, and many FSC standards have implications for gas infrastructure development, such as requirements for species composition of seed mixes or adhering to a list of approved herbicides. The update to the template provided an opportunity to include incentives for minimizing environmental impacts, such as placing electrical lines underground.

Another of the major new provisions included updated language regarding the prevention and removal of invasive plant species that were introduced because of infrastructure installation and maintenance. This new provision was only used on the large regulated gas transmission systems. In addition, threatened and endangered species considerations were updated as well. In the provisions, incentives for minimizing habitat fragmentation and environmental impacts, such as using existing rights-of-way or disturbed areas, were included.

Standard annual rental rates were adjusted to reflect actual project expenditures. These updated rates are based on actual project expenditures on adjacent private lands as reported in the Oil & Gas Journal.

Additionally, timber compensation numbers were also updated to reflect recent market values in the updated provisions.

Transactions between companies often result in the transfer of agreements the companies hold with the bureau. Transfers represent a continuous part of the workload to keep paperwork up-to-date, but also provide the bureau with an opportunity to address issues and insert additional requests or conditions based on lessons learned. Thus, continuously adapting to the most recent science and information.

RUAs have existed for many years and are common in other operations on state forest land, such as timber extraction. Unlike ROW agreements, the main template did not change with the onset of shale gas development, but the supplementary provisions have become more diverse with gas as opposed to previous forest uses. Although a decrease in the number of agreements is seen in the past 10 years (Figure 3.9), the road needs for shale gas development are generally more demanding than traditional forms of road use, due to the quantity of truck traffic and the heavy hauling required for drilling operations. In general, all road use on lease tracts is granted by the lease agreement and not in a separate RUA, which is likely the reason for the decrease in formal RUA's. These recent RUAs have included more detailed supplementary provisions for the alterations and special considerations that may be needed to prepare a road for use during shale gas development. New provisional requirements are included to address specific aspects of use, such as culverts, trenching over vs. boring under roads, temporary pipeline protection to allow continuation of other activities, and any number of issues addressed in case-by-case addendums. However, the bureau recognizes there may be a need for additional agreement provisions because the time scale of the agreement for shale gas development may necessitate RUAs that span decades, where the traditional RUAs were generally written to address issues on a scale of months to years. To fully account for this new dynamic, a multi-disciplinary group was assembled and is currently working on how to transition from the short-term development type RUA to a longer-term agreement that includes provisions such as road maintenance for long-term gas access.

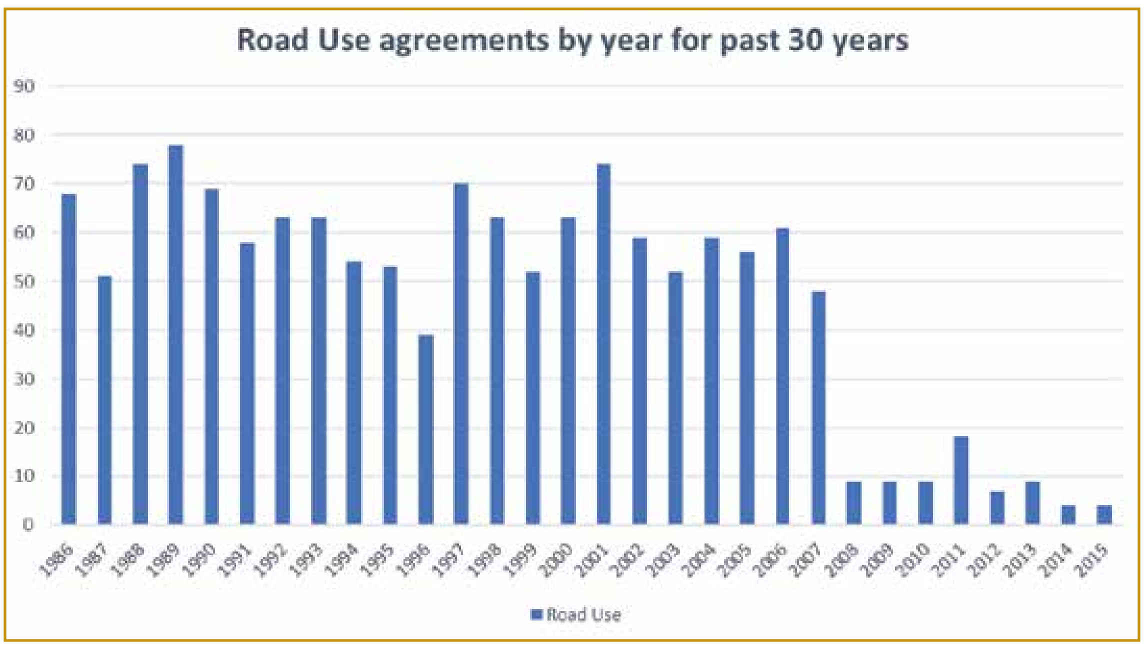


Figure 3.9. Road use agreements by year for the past 30 years.

The bureau may secure road bonds from companies for shale gas development if the activity is not on a tract that the company leased through the bureau that has a surety bond. The purpose of the bureau retaining bond for use of a road is to cover the cost of any necessary repairs resulting from the hauling activity. Road bonding guarantees that the appropriate funds are available to keep the road in is as good as, or better, condition than prior to the commercial use of the road. The bureau determines rates for proper road bonding based on two categories of hauling for commercial activities defined by gross vehicle weight. These two categories are light hauling and heavy hauling. Beyond vehicle weight, the bureau also takes into consideration the length or mileage of road(s) being used, the number of bridges crossed within that area, and the existing road surface materials. The figures are evaluated periodically to determine if updates or changes to current rates are necessary. As an example of the importance of this measure, one instance occurred in which a company needed truck traffic during thawed winter conditions. This did extensive damage to a road. The bureau worked with the company to correct the damage and the company went beyond baseline requirements to correct the damage. Bonding for this road was previously $30,000, but this incident illustrated the need to raise the rate to an amount that was more proportional to the true costs. It was then raised to over $300,000 to properly protect the bureau's investment.

In addition to RUAs and ROW agreements, the bureau has communication tower agreements. Currently, there is a moratorium on new communications towers on state forest land established in 2000, but exemptions for public safety are made. Also, the moratorium does not apply to gas leases since towers are part of the lease. Agreements for communications towers were promoted in shale gas development because off-site monitoring means less personnel and truck traffic on state forest roads, which is a public safety benefit. To address shale gas development specifically, additional guidelines have been developed to address unique situations, such as towers on severed rights lands vs. leased lands or restoration requirements at the end of the life of the tower.

Adaptation is crucial to effective management of the increased demands and novel considerations that come from the commercial use of state forest land. The bureau has had to adapt many processes to continue being good trustees of the commonwealth's resources.

Large Projects Committee

Even before shale gas extraction began on state forests, the uptick in the gas energy market created a need to transport increasing volumes of product. With existing pipelines nearing full capacity around 2006, new main gas transmission system pipeline requests began to inundate the bureau, beginning around 2008. To ensure due diligence and to examine the impacts, benefits, and appropriateness of each pipeline ROW project, the bureau created a formal internal review and approval process based on the FERC Pre-File Environmental Review Process[2]. This process fosters the "avoidance, minimization, mitigation, and monitoring" approach to energy development and to provide transparent documentation of the bureau's decision-making procedures. The reviewers, named the Large Projects Committee, consists of an interdisciplinary team. This committee examines proposals and negotiates alterations to avoid or minimize impacts to state forest land and its users. After each project is approved by the committee, it undergoes an additional round of review via the State Forest Environmental Review process (SFER). In this process, staff across the bureau can provide feedback and express concerns with aspects of the project. The entire review process typically takes between 18-24 months.

At the peak of activity, as many as 60 proposals were in the queue for review. These were mostly main gas transmission systems in existing corridors. But in recent years, the number of projects under review at any given time has been fewer than ten.

Currently, the committee meets weekly to discuss current proposals. Nearby states that also process pipeline ROW requests have contacted the bureau to learn more about this process to include in their state's review protocols.

Website Links

[1] http://www.dcnr.pa.gov/Business/Rights-of-Way/Pages/default.aspx

[2] https://www.ferc.gov/resources/processes/flow/lng-1.asp

Chapter IV. Shale Gas Infrastructure and Landscape Effects

Key Points

- 1,769.5 acres of state forest have been converted to accommodate shale gas infrastructure from 2008-2016.
- The amount of state forest acres converted to accommodate shale gas infrastructure from 2013-2016 (333.9 acres) was less than 2008-2012 (1,435.6 acres), which is indicative of the slow-down in development.
- 174.1 acres of state forest were converted to accommodate shale gas pad infrastructure, 124.1 acres for pipeline corridors, and 35.7 acres for road corridors between 2013-2016.
- The co-location of pipelines and roads has led to an increase in corridor width for roads that were improved to accommodate shale gas development.
- Fragmentation of large blocks of core forests resulted in a decrease of core forest greater than 200 hectares in size by 15,134 acres and increases in smaller category core forests (100-200 hectares and <100 hectares) since 2008.
- The fragmentation of forest leads to an increase in edge forest habitat. Since 2008, an additional 9,913 acres of edge forest have been created in the shale gas forest districts.
- Site rehabilitation (the act of reducing infrastructure pad footprints by revegetating no longer needed cleared areas) of shale gas infrastructure has taken place in six forest districts: Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, and Tioga. Twelve well pads, two impoundment sites, two monitoring well sites, and one meter station have been subject to site rehabilitation.
- To better understand how Marcellus shale well pad construction techniques impact the effectiveness of forest reclamation practices, the bureau, in partnership with researchers from Penn State, constructed a 1-acre "mock well pad" demonstration site in May of 2015.
- Ongoing data collection on the "mock well pad" will be used to test different techniques, seed mixes, and tree and shrub species survival.

Introduction

Shale gas infrastructure is the most visible impact of shale gas development on state forests. Existing native vegetation often is cleared to build new roads, pipelines, and pads. Many existing roads are also expanded and widened so they can handle higher volumes of traffic and larger vehicles. Beyond the visual impact of clearing forest, shale gas infrastructure development can increase forest fragmentation, reduce the amount of core forest habitat, and alter the recreational experience of some forest users.

Roads

Most state forest roads are improved dirt roads constructed for small vehicle traffic and occasional use by log trucks. They are not adequate for the heavy use of large vehicles involved in shale gas development. Therefore, existing roads must be modified to handle traffic associated with extraction of shale gas resources. Typical modifications involve widening the road and increasing the depth of the road base material. Additionally, new roads are created to reach pads located away from existing roads.

Road Construction and Modification

Road construction and modification for gas development declined from the 2008-2012 period (220.5 total miles) to the 2013-2016 period (42.3 total miles). The Elk State Forest was the only forest district where the miles of new roads constructed or modified increased for these periods (Figure 4.1). The increase in the Elk State Forest is partially attributed to the steady development that has occurred in the district over the years, severed rights development, and the unusually large land acquisitions.

Acres converted to road use were calculated using the final ROW width. The road ROW includes the road and the area adjacent to the road that is maintained as non-forest. When roads are modified, the road ROW may not be expanded. From 2008-2012, 197.5 acres were converted to accommodate shale gas roads and 35.7 acres were converted between 2013-2016. Three state forests (Moshannon, Sproul, and Susquehannock) did not have any acres converted to road ROWs from 2013-2016 (Figure 4.2). Additionally, the Elk State Forest was the only state forest with an increase in acres converted to road ROWs from 2008-2012 to 2013-2016.

Road Surveys

The bureau assesses conditions on roads used for shale gas annually. The road profile, slope, cross-section width, cross section slope, drainage/infiltration features, running surface width, canopy gap width, limit of clearance width, and ditch widths are measured at permanent plots every ¼ mile. From 2012 to 2014, 215 improved or new roads have been surveyed (2012-119, 2013-85, 2014-11). In 2015, 33 of those roads were resurveyed and in 2016, 17 roads were resurveyed. Roads will be resurveyed periodically to determine trends and longevity of materials used.

Treadway, road surface, cross section, and limit of clearance widths have all increased from gas development (see Figure 4.3 for illustration of these measurements). Limit of disturbance is a bureau designation that is negotiated with the gas operator and falls within the limit of disturbance (the separation between the areas that can be disturbed and those that will not be disturbed based on the specifications of the DEP approved permit) where actual removal of predominant vegetation cover, including overstory, midcanopy or understory vegetation, and/or original soil substrate will occur. The increase in road widths occurred on public use roads, administrative roads, and drivable trails (Figures 4.4, 4.5, and 4.6). The largest increase occurred when comparing the limit of clearance. For example, the limit of clearance for public use roads was ~30 feet prior to improvement and ~52 feet after improvement. Increases in limit of clearance for all road types were primarily due to the co-location of pipelines in the same corridor as roads. Wider cross sections and limit of clearances relate to more open tree canopies over the roadway which negatively affects habitat connectivity, wild character, and increases fugitive dust. The greatest change in road character occurred on drivable trails and gated administrative roads. Typically, drivable trails and gated roads are very narrow with complete canopy cover and receive only very limited maintenance. However, after upgrades for shale gas activities they resemble improved public use roads (Figure 4.7). Road

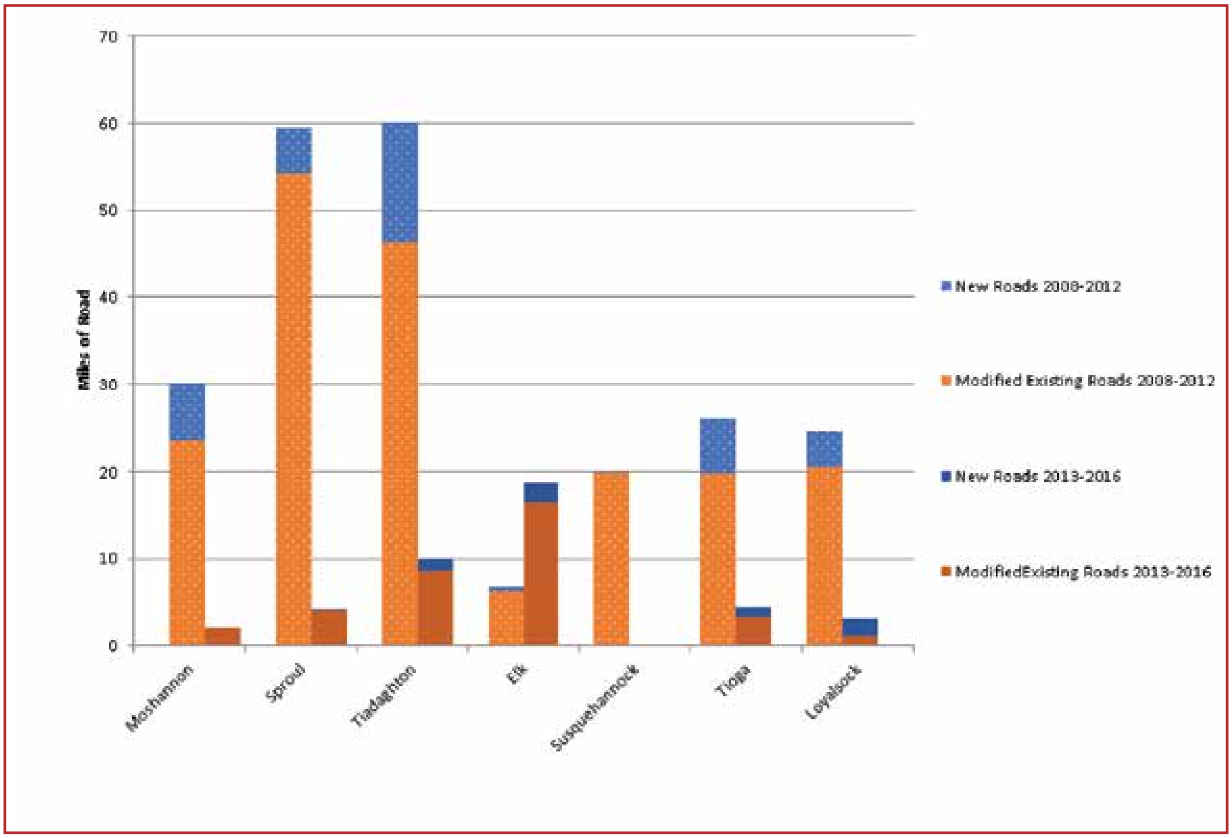


Figure 4.1. Miles of new road construction and existing road modification for 2008-2012 and 2013-2016 by state forest in the core gas forest districts.

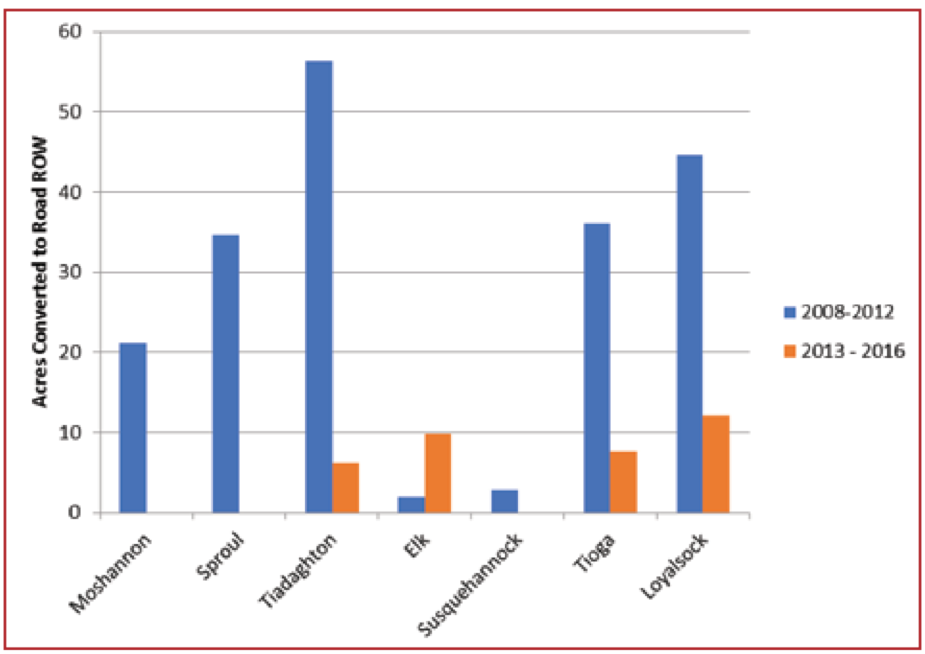


Figure 4.2. Acres converted to road right-of-way 2008-2012 and 2013-2016 by state forest in the core gas forest districts.

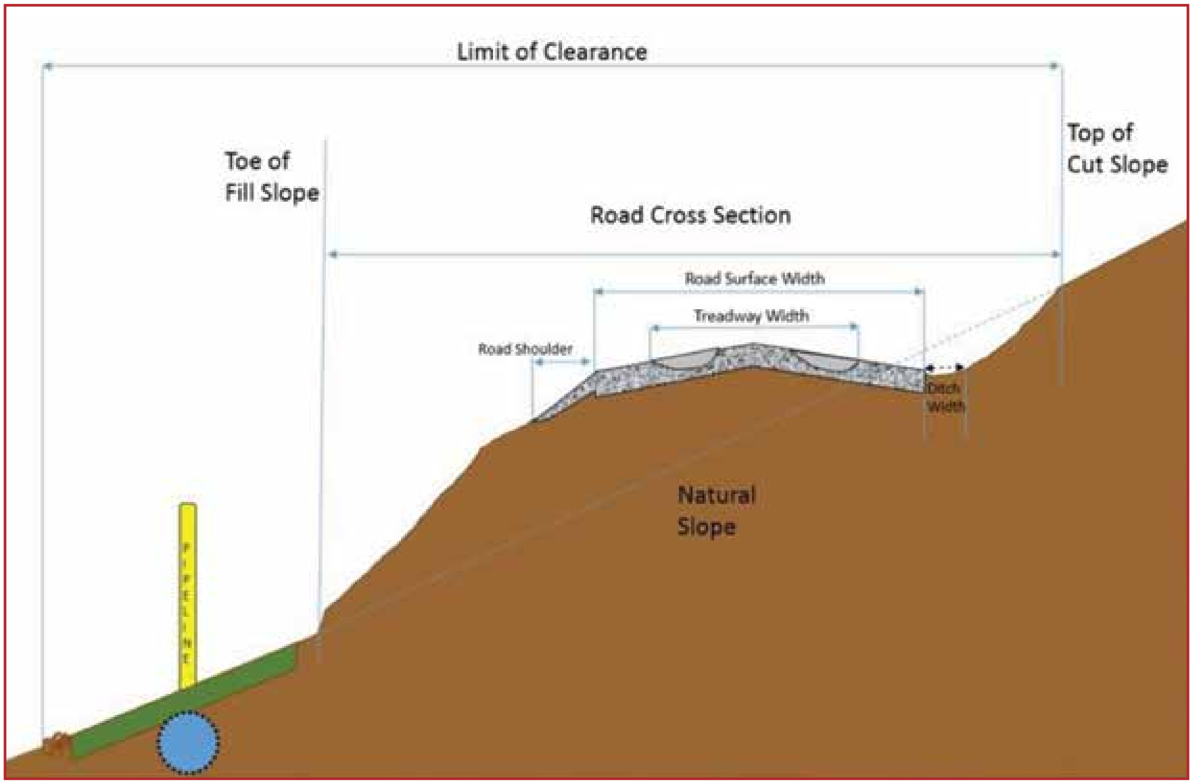


Figure 4.3. Diagram of road width measurements on road surveys.

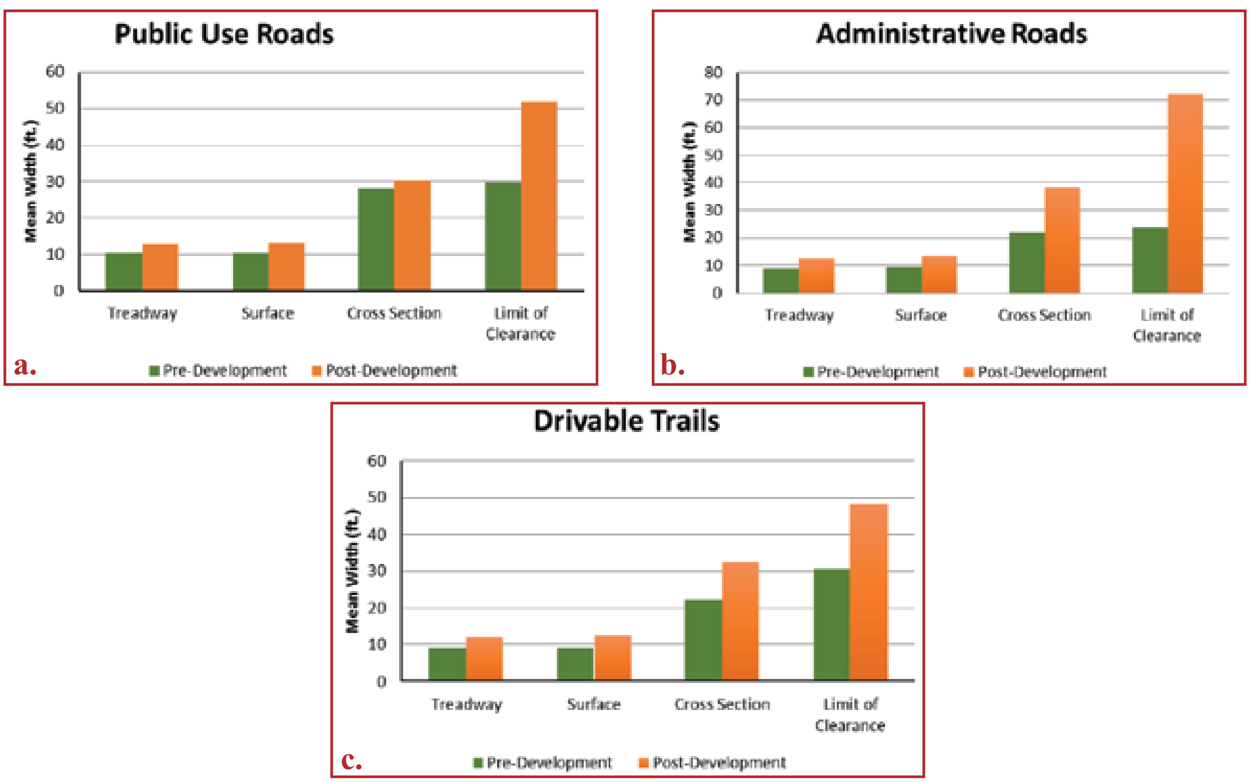


Figure 4.4. Treadway, road surface, cross section, and limit of clearance widths (ft.) for public use roads (a.), administrative roads (b.) and drivable trails (c.) on state forest land prior to and after improvement for oil and gas use.

Figure 4.5. Typical high use public road before (left) and after (right) improvement for oil and gas use.

Figure 4.6. Typical low use public road (left) and typical low use gas road with pipeline adjacent to road (right).

Figure 4.7. Typical gated administrative road (left) and typical administrative road used for oil and gas (right).

widths and conditions are affected by several factors including topography, size of vehicles, and amount of traffic. For instance, roads improved for pickup truck access are not widened as much as roads improved for heavy equipment use. The number and type of pipelines installed adjacent to roads and the adjacent topography also affect the limit of clearance and how much space is needed for equipment and soil maneuverability.

Pre- and post-gas roads had similar surface conditions. Post-development roads showed a slightly higher percentage of poor plots (6 percent) than pre-development roads (3 percent). Roads are considered in poor condition if you must brake or drive around a condition (e.g., potholes, ruts, and erosion) on the road or if a road condition causes loss of traction (e.g., rills and washboards). Roads with adequate conditions (good condition, but it could use attention in the future in some manner) for pre-development were 6 versus 10 percent for post-gas development roads. The primary reasons for poor ratings were potholes and inadequate depth of top cover aggregate to base material.

Dust Control

Increased traffic on roads used for shale gas can lead to increased road dust. Road dust is a nuisance to recreationists that can cause decreased visibility and increase wear on vehicle parts. Additionally, dust can alter soil chemistry out to ten meters from the roadway (Brown 2009) which may alter forest floor soil ecology. Limestone road dust can also increase soil pH which is conducive to the establishment of invasive plant species. The use of dust suppressants has been requested by various companies to help control dust on state forests roads.

Dust suppressants can have negative effects on the environment and road. Penn State's Center for Dirt and Gravel Road Studies (CDGRS) maintains a list of approved suppressants that are deemed safe for the environment. Most of these suppressants are derived from petroleum emulsions. These products bind the fine soil particles tightly enough that the road becomes like pavement. Potholing and other issues can still arise where an inadequate subbase or improper drainage are present. Potholes, rills, ruts, and drainage issues that are in the road prior to application remain in the road and are then very difficult to remove due to the hard surface.

Some types of road surface materials can reduce dust issues. Many common road surface materials are made of high proportions of clay or very fine particles. These particles are easily lifted into the air when dry and when vehicles pass over them (Figure 4.8). Driving Surface Aggregate (DSA) developed by CDGRS and PennDOT contains fine crushed rock as a binder rather than soil/clay particles and produces less dust. Any of the finer rock particles that do lift will readily drop back out whereas clays and fine soil particles suspend in the air for long periods of time. Other factors that increase dust are vehicle speed, daylight, and moisture. The bureau recommends maintaining canopy cover, reducing speeds, and applying water to help reduce dust.

Since 2013, one request was submitted for the application of a chemical dust suppressant. Ultrabond 2000®, a petroleum emulsion, was applied to 1.1 miles of Okome Road in the Tiadaghton State Forest. While the product has greatly reduced dust, it has also resulted in a pavement-like hardening of the road surface that will make future maintenance more challenging (Figure 4.9).

Road Closures

Complete or partial state forest road closures are sometimes necessary to safely accommodate shale gas activities. Unfortunately, road closures can be inconvenient for state forest users or nearby landowners. The bureau works closely with companies to keep closures to a minimum. In areas with partial road closures, one-way traffic is allowed using multiple methods. One method is to use staggered one-way traffic like a PennDOT road project. In this case, gas companies typically coordinate the traffic control through flaggers. However, in one instance a company used portable red lights to alternate traffic direction.

Figure 4.8. Dust on a wide surface open canopy road with traditional 2A-Modified surface aggregate.

Figure 4.9. Gravel road after application of a petroleum emulsion to control dust, notice the road surface has hardened like pavement.

Another method is to incorporate temporary one-way traffic where a road loop system can work. One-way traffic reduces the risk of meeting large vehicles coming from the opposite direction and keeps traffic in motion. Utilizing these methods helps to keep the permanent road corridor narrow and maintains tree canopy connectivity.

Since 2013, there were three instances where one-way traffic was utilized. One area in the Elk State Forest is still being utilized as a one-way loop (Boundary Line Rd-Doe Run Rd-North Fork Rd) from October 2015 to present. In the Loyalsock State Forest, a one-way road loop (Hagerman-Long Run-Gray's Run) was utilized in May 2016. One administrative road in the Tioga State Forest was opened for fall hunting seasons and was made a one-way loop (Sawmill Trail-Matson Rd) to reduce traffic conflicts.

Some complete road closures may still be necessary such as for the installation of a pipeline in the road shoulder or a pipeline crossing a road. The bureau attempts to keep these closures brief and outside of popular times to visit state forest, e.g., evenings and weekends. There have been three total road closures on state forest since 2013. These have been temporary closures in the Tiadaghton State Forest (Big Spring Road – Aug. 2015, 3 weeks; Boone Road – Sept. 2015, 8 hours; and Huntley Road – Sept. 2015, 10 hours). Additionally, though not a state forest road, there was a township road (Kato-Orviston) that traverses through the Sproul State Forest that was closed for short periods from May to September 2015 for the installation of a pipeline in the road shoulder. This road remained open on evenings and weekends.

Bridges

The bureau has worked diligently to ensure the effects shale gas roads have on streams is minimized. Many bridges on state forest roads needed replacement due to age or were not suitable for large heavy loads. In these cases, companies have been required to pay for upgrades. New and replaced bridges are added into PennDOT's bridge database system and are scheduled for periodic field inspection for safety and structural analysis. Bridges are inspected about every five years and are either inspected by DCNR Bureau of Facility Design and Construction engineers or certified contractors.

Between 2013-2016, two new bridges have been installed and three existing bridges were replaced and/or upgraded. The two new bridges were on an administrative road for well pad access and were for the same stream crossing in the Elk State Forest. The crossing was a braided stream and alternate routes required crossing wetlands and increasing forest fragmentation. The three existing bridges were replaced in 2015 in the Tiadaghton and Elk State Forests (administrative roads), and the Loyalsock State Forest (public use road).

Through field visits of past bridge replacements and installations, the bureau has noted obstructions to aquatic organism passages (AOP). Types of obstructions include perched pipes (Figure 4.10), clean fill placed in the stream channel (Figure 4.11), structures too narrow for the stream channel, or improper placement. As a result, the bureau has begun official surveys of these structures following the North Atlantic Aquatic Connectivity Collaborative (NAACC) protocols in addition to structural assessments to specifically identify any potential issues related to AOP and stream/riparian habitat connectivity. Using information from field visits and these new monitoring inspections, the bureau has updated guidelines that include criteria for the type of structures to use (emphasizing open bottom), span criteria, bank stability and structure angle, and material used for stabilization as well as aesthetic requirements.

Figure 4.10. Pipe on first order stream perched and too narrow for the natural stream bed. The company has agreed to replace the pipe with an open bottom arch.

Figure 4.11. Example of bridge on first order stream with clean fill in the stream channel impeding aquatic organism passage. Water passes under the substrate causing disconnected habitat. In clean mountain streams it can take years for the open substrate to fill in.

Pads

The term "pad" is used to reference well pads, compressor stations, freshwater impoundments, storage pads, stone pits, and meter valve or tap stations. Summaries of the number and acreage of pads are given for 2008-2012 and 2013-2016.

Multiple pad types can occur within the same cleared area. For example, a company may clear a portion of forest and then place a well pad and freshwater impoundment in the cleared area. The cleared area is divided between the two pad types. There are inconsistencies between the 2008-2012 pad data in this report and the first Shale Gas Monitoring Report. These inconsistencies occurred because pad boundaries have been refined/corrected over time using updated data and imagery (Figure 4.12).

Newly constructed pads within the core gas forest districts declined from 224 pads in 2008-2012 to 41 in 2013-2016. The acres converted to pads decreased from 665.7 to 174.1 along with the acres cleared (1126.2 to 303). The Elk State Forest was the only forest district with an increase in pad and cleared acreage between 2008-2012 and 2013-2016 (Figure 4.13). The increase in the Elk State Forest is partially attributed to the steady development that has occurred in the district

Figure 4.12. Illustration of how the digitally represented pad boundaries have been corrected over time. In the first report the latest aerial image for this site (left side) was taken prior to construction. The actual pad boundary, number of pads, and limit of clearance is unknown. Therefore, this site was classified as one well pad. The well pad limit of clearance (white dashed line) was used as the pad acreage. In 2013 (right side), a new aerial image was available, and three separate pad types were clearly visible (in black); a well pad, a freshwater impoundment, and a storage pad. Each of these pads is given its own limit of clearance (white dashed line). This results in more pads and less total pad acreage/

over the years, severed rights development, and the unusually large land acquisitions. The greatest number of acres converted to pads was for well pads followed by freshwater impoundments (Figure 4.14). From 2013-2016, 18 pads (23.5 acres) were no longer being used and have been reclaimed.

Well Pads

Well pads are the areas where drilling and hydraulic fracturing occur. Typical shale gas well pads have one to ten wells and are approximately 3.5 to 7 acres in size. Well pads may also have small compressor stations or freshwater storage tanks associated with them. Wells for multiple shale targets (e.g., Marcellus, Burkett, and Utica) may be drilled from the same pad site if pre-planning is done by the operator.

Well pads are the most abundant type of shale gas pad on state forests. The number of new well pads declined for all districts from 2008-2012 to 2013-2016. This was the biggest decline for all pad types. Well pad acres and cleared acres declined for all districts except the Elk State Forest. The Elk State Forest also had the greatest number of well pads, most well pad acres, and most cleared acres of all the gas forest districts for 2013-2016 (Table 4.1).

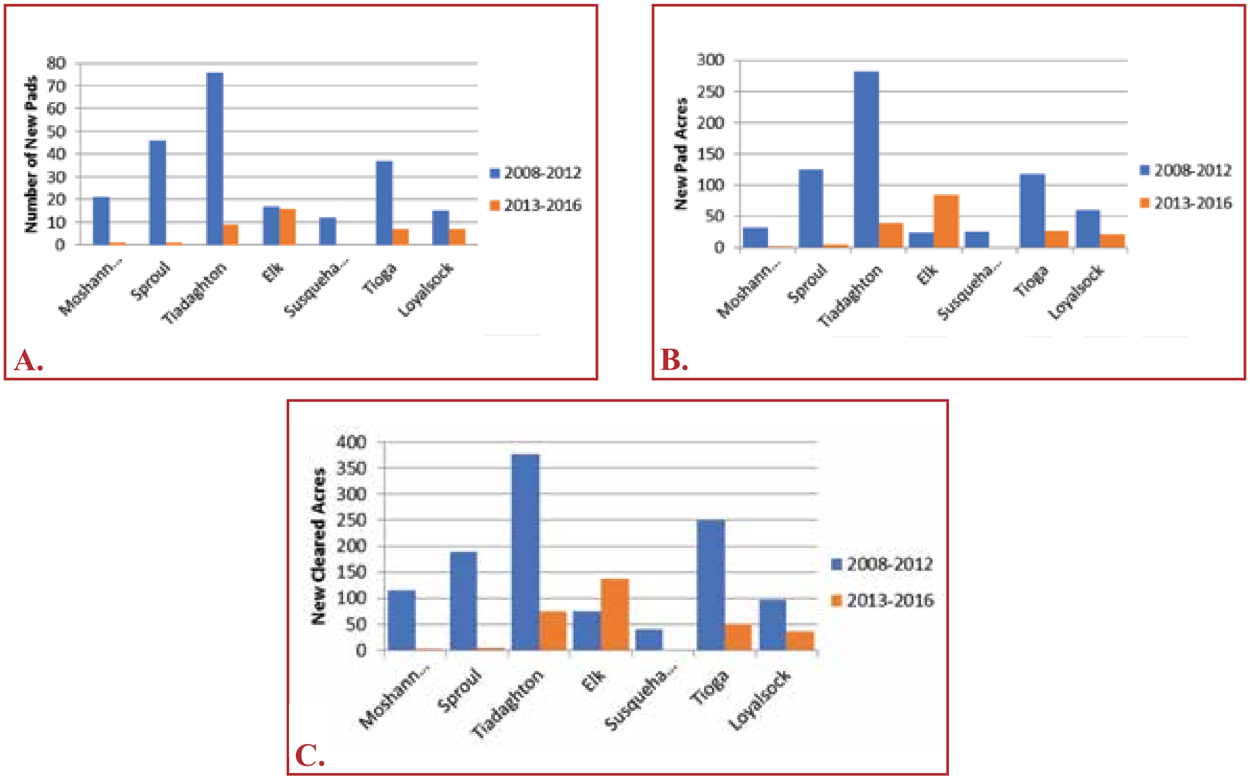


Figure 4.13. Number of new pads constructed (A), total new pad acres (B), and total cleared acres (including temporary limit of clearance) (C) by state forest district for 2008-2012 and 2013-2016.

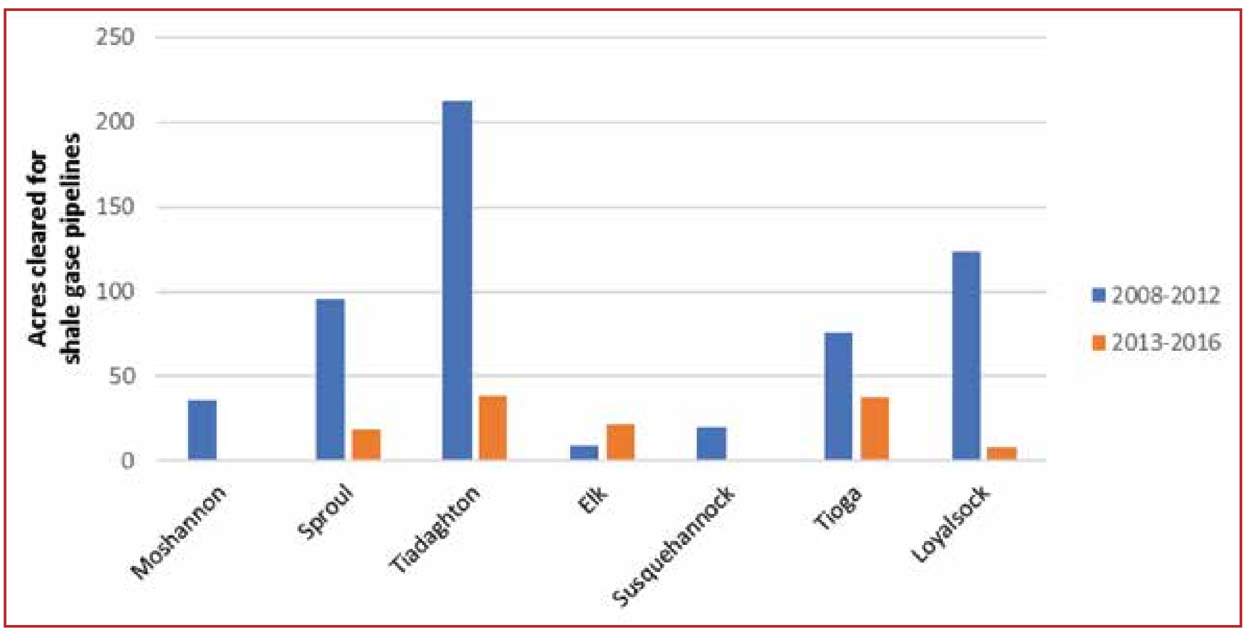


Figure 4.14. Acres of new pads by pad type for 2008-2012 and 2013-2016.

This is due to the steady pace of development and land acquisitions in this state forest.

Compressor Stations

Compressor stations are used to increase pressure within pipelines and can service multiple well pads. Compressors stations may also have separators, which remove undesirable particles or liquids from the gas, or chemical storage located on the site.

Five new compressor stations requiring 40.1 cleared acres, were constructed from 2013-2016. New constructions, acres, and cleared acres declined from 2008-2012 to 2013-2016 (Table 4.1). The Tiadaghton State Forest had the largest increase in number of compressor pads and cleared acres.

Freshwater Impoundments

Hydraulic fracturing requires an average of 5 million gallons of water to complete a well. Freshwater storage impoundments in proximity to well pads are needed to ensure a consistent and adequate supply of water to the well. There are three types of water storage that are included as freshwater impoundments:

- Earthen Impoundments – Non-portable, open pits that are typically five to 14 acres in size. Dams are constructed using soil and require a permit if they are over 15 feet high.
- PortaDams – Semi-portable above ground impoundments made of heavy-duty liners on a steel framework. They are typically three to five acres in size.
- Above-ground storage tanks – Semi-portable cylindrical tanks that are often set on concrete slabs.

Five new freshwater impoundments requiring 59.9 cleared acres, were constructed from 2013-2016. New constructions, acres, and cleared acres declined from 2008-2012 to 2013-2016 (Table 4.1). The Elk State Forest had the only increase in number of freshwater impoundments, acres, and cleared acres.

Other pads

The following pads are also used to support shale gas infrastructure:

- Storage pads – facilities that provide temporary storage for equipment and materials for developing shale gas infrastructure.
- Meter stations – facilities that measure the amount of natural gas being supplied or withdrawn to pipelines.
- Valve stations – facilities used to isolate segments of gas pipelines. They are typically located every 15-20 miles along a pipeline.
- Tap stations – facilities that direct gas from a gathering system to a transmission pipeline. They typically only have pressure regulating equipment.
- Stone pits – facilities where stone is extracted to support shale gas development activities.

Four new other pad types requiring 5.3 cleared acres, were constructed for 2013-2016. New constructions, acres, and cleared acres declined from 2008-2012 to 2013-2016 (Table 4.1). The Elk State Forest had the only increase in number of other pads, acres, and cleared acres.

Pipelines

Pipelines are an efficient method to move oil and gas from wells to market. Most wells have gathering pipelines that carry gas to larger transmission pipelines. Transmission pipelines then transport oil and gas to markets within a state or even across state lines. Some wells also use pipelines to carry water from offsite storage facilities to wells for hydraulic fracturing.

Building and maintaining underground pipelines requires clearing the ROWs of trees and other woody vegetation. The impact of pipeline ROWs on state forests can be minimized based on where they are built. In an analysis of fragmentation of core forest habitat, Langlois et al. (2017) found that pipeline ROWs comprised the highest

Table 4.1. Number of pads, pad acres, and cleared acres for each pad type and state forest 2008-2012 and 2013-2016.

Pad type	State Forest District	Number of new pads		New Pad Acres		New Cleared Acres	
		2008-2012	2013-2016	2008-2012	2013-2016	2008-2012	2013-2016
Well Pads	Elk	15	12	21.0	59.3	66.8	95.6
	Loyalsock	9	4	37.1	10.1	59.2	23.1
	Moshannon	13	0	21.5	0	72.9	0
	Sproul	34	1	96.9	3.7	143.5	3.7
	Susquehannock	4	0	15.0	0	22.2	0
	Tiadaghton	52	5	183.5	19.4	230.3	33.9
	Tioga	25	5	88.1	21.3	185.3	41.4
	Sub Total:	**152**	**27**	**463.1**	**113.7**	**780.2**	**197.6**
Compressor Stations	Elk	1	1	1.8	5.2	3.0	6.9
	Loyalsock	1	1	10.4	2.2	13.0	3.3
	Moshannon	1	0	1.8	0	2.1	0
	Sproul	3	0	6.5	0	9.0	0
	Susquehannock	1	0	0.03	0	1.1	0
	Tiadaghton	2	3	5.2	14.8	6.1	29.9
	Tioga	3	0	9.0	0	16.4	0
	Sub Total:	**12**	**5**	**34.7**	**22.2**	**50.7**	**40.1**
Freshwater Impoundments	Elk	1	2	1.3	17.6	4.6	33.1
	Loyalsock	4	1	10.2	7.1	16.8	8.1
	Moshannon	2	0	6.6	0	19.4	0
	Sproul	3	0	19.8	0	32.1	0
	Susquehannock	5	0	7.8	0	11.8	0
	Tiadaghton	13	1	83.1	5.0	126.9	11.3
	Tioga	5	1	15.0	4.5	35.4	7.4
	Sub Total:	**33**	**5**	**144.0**	**34.2**	**247.0**	**59.9**
Other Pads	Elk	0	1	0	1.7	0	1.7
	Loyalsock	1	1	1.4	1.0	3.0	1.0
	Moshannon	5	1	2.2	0.8	10.8	0.8
	Sproul	6	0	2.0	0	3.5	0
	Susquehannock	2	0	2.4	0	4.0	0
	Tiadaghton	9	0	10.3	0	14.7	0
	Tioga	4	1	5.7	0.5	12.4	1.9
	Sub Total:	**27**	**4**	**23.9**	**3.9**	**48.3**	**5.3**
	Grand Total:	**224**	**41**	**665.7**	**174.1**	**1126.2**	**303.0**

State Forest District	Pre-existing Pipelines	Years	Shale-Gas Pipelines	Co-Located Pipelines	Total
Moshannon	175.6	2008 to 2012	22.0	4.3	**201.9**
		2013 to 2016	0	0	**0**
Sproul	190.3	2008 to 2012	19.3	12.0	**221.6**
		2013 to 2016	1.4	0	**1.4**
Tiadaghton	18.5	2008 to 2012	42.4	2.4	**63.2**
		2013 to 2016	7.8	0	**7.8**
Elk	169.0	2008 to 2012	1.7	23.5	**194.3**
		2013 to 2016	9.7	0	**9.7**
Susquehannock	179.7	2008 to 2012	3.2	0	**182.9**
		2013 to 2016	0	0	**0**
Tioga	35.1	2008 to 2012	17.0	0	**52.1**
		2013 to 2016	3.3	0	**3.3**
Loyalsock	8.9	2008 to 2012	16.2	0	**25.1**
		2013 to 2016	1.8	0	**1.8**
Total:	**777.2**		**145.8**	**42.2**	**965.2**

Table 4.2. Miles of non-shale gas pipelines, shale gas pipelines and shale gas pipelines co-located within existing utility corridors by forest district, 2008-2012 and 2013-2016.

portion of total gas development footprint within their study area of Lycoming County and had the largest effect on habitat fragmentation. When possible, the bureau encourages companies to co-locate pipelines within existing corridors (roads, pipelines, or electrical) and avoid high quality streams, wetlands, and steep slopes. When this is not possible, the bureau recommends following BMP's (Oil and Gas Management Guidelines[1]) that can reduce potential impacts, such as encouraging scrub/shrub habitat in the pipeline corridor to reduce impacts to wildlife.

Within the core gas forest districts, 188 miles of pipeline corridors have been constructed since 2008. Of those 188 miles, approximately 22 percent were co-located within an existing utility ROW. Most shale gas pipelines were installed prior to 2013 (142 miles). The Elk State Forest was the only state forest district with more new pipeline miles from 2013-2016 than 2008-2012. The Elk State Forest also had the most miles of pipelines installed (9.7) from 2013-2016 (Table 4.2).

The acres cleared to install new pipelines for shale gas development can be calculated in a geographic information system (GIS). For shale gas pipelines co-located within existing utility corridors, only the acres added to the corridor are counted for shale gas pipelines. Approximately 696 acres of forest have been cleared for shale gas pipelines: 572.4 acres were cleared from 2008-2012 and 124.1 acres were cleared from 2013-2016. The Elk State Forest was the only state forest district with more new cleared acres from 2013-2016 than 2008-2012. However, the Tiadaghton State Forest had the most acres cleared for both time periods (Figure 4.15).

The bureau recommends new pipelines be constructed on gentle slopes to help reduce erosion. Approximately 126 miles of shale gas pipeline corridor within the core gas forest districts occur on slopes less than 10 percent. When steep slopes can not be avoided, 5.3 miles of shale gas pipelines were built on slopes greater than 20 percent (Table 4.3). Erosion and sedimentation control measures are required for all pipelines, but they are especially important for pipelines on steep slopes. The bureau and DEP regularly monitor the effectiveness of these control measures on pipelines.

Pipeline Stream Crossings

Clearing pipeline rights-of-way and installing pipelines across streams may lead to bank erosion and long-term impacts on streamside vegetation within the ROW. To reduce long-term negative impacts on the streams, pipeline installation companies working on state forest land are required to follow Post Construction Storm Water Management (PCSM) and Erosion and Sedimentation Control BMPs.

The bureau assessed topography, vegetation, and stream bank characteristics at 14 pipeline stream crossings in 2016 (Figure 4.16). The bureau has also developed pipeline stream crossing BMPs incorporating information from DEP and the Pennsylvania Fish and Boat Commission (PFBC).

At the 14 pipeline stream crossings evaluated, the average ROW width (measured 25' from the stream bank) was 82.3' (minimum-37', maximum-180'). The average slope from the stream bank to 25' uphill was 14 percent (minimum-0 percent, maximum-48 percent) and the average slope from the stream bank to the horizon was 15 percent (minimum-2 percent, maximum-45 percent). The width and slope were measured on both sides of the streams, but the results were combined because there was not a difference by side.

The stream bank cover for both banks was recorded upstream, downstream, and within the ROW. Most stream banks upstream, downstream, and within the ROW were covered with naturally occurring vegetation. However, many streams also had Erosion and Sedimentation (E&S) vegetation on the banks within the ROW, but not outside the ROW (Table 4.4). E&S vegetation are plant species that were planted in the ROW to quickly grow and stabilize the disturbed soil when installing the pipeline.

Bank sloughing was the only erosion detected and it was found on 3 stream crossings. The erosion on the

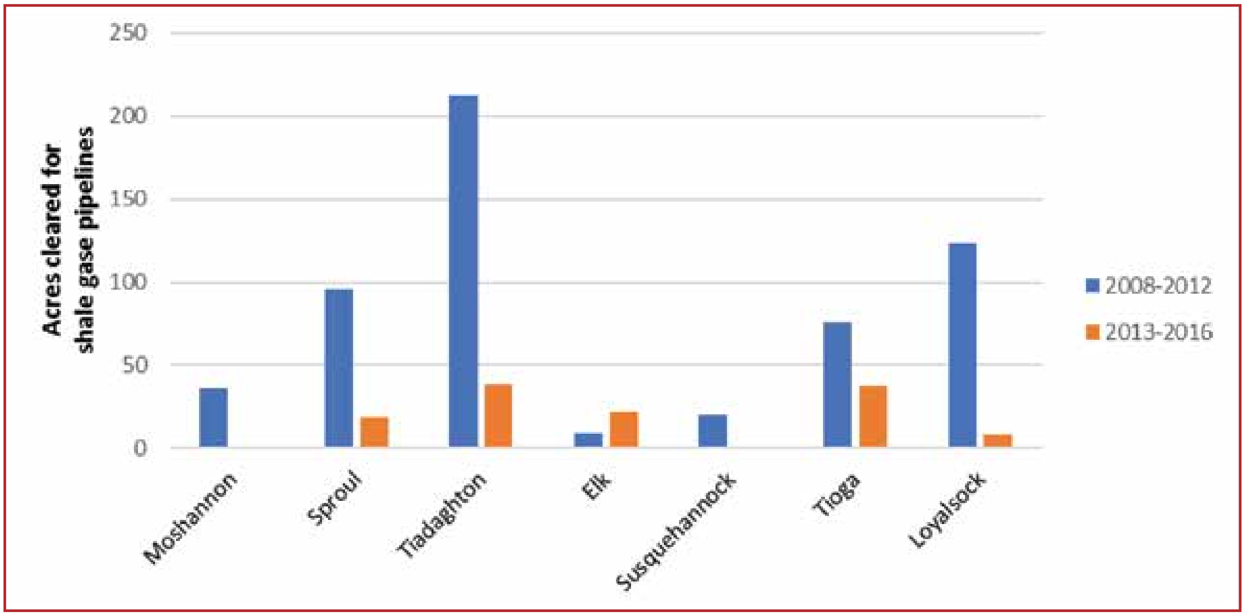


Figure 4.15. Acres of forest cleared for shale gas pipelines by forest district, 2008-2012 and 2013-2016.

State Forest District	Years	0 to 10%	10 to 20%	20 to 30%	30 to 40%	40 to 50%	> 50%	Total
Moshannon	2008-2012	20.4	1.5	0.1				**22.0**
	2013-2016							**0.0**
Sproul	2008-2012	17.9	1.4					**19.3**
	2013-2016	1.4						**1.4**
Tiadaghton	2008-2012	36.5	4.5	0.6	0.3	0.2	0.2	**42.4**
	2013-2016	7.6	0.2	0.1				**7.8**
Elk	2008-2012	1.7						**1.7**
	2013-2016	9.6	0.1					**9.7**
Susquehannock	2008-2012	1.2	1.5	0.3	0.2			**3.2**
	2013-2016							**0.0**
Tioga	2008-2012	16.1	0.7	0.2				**17.0**
	2013-2016	2.7	0.4	0.2				**3.3**
Loyalsock	2008-2012	10.6	2.8	1.1	1.7			**16.2**
	2013-2016	0.8	1.0					**1.8**
	Total:	**126.4**	**14.1**	**2.6**	**2.2**	**0.3**	**0.2**	**145.8**

Table 4.3. Miles of new shale gas pipeline corridors by percent slope by forest district, 2008-2012 and 2013-2016.

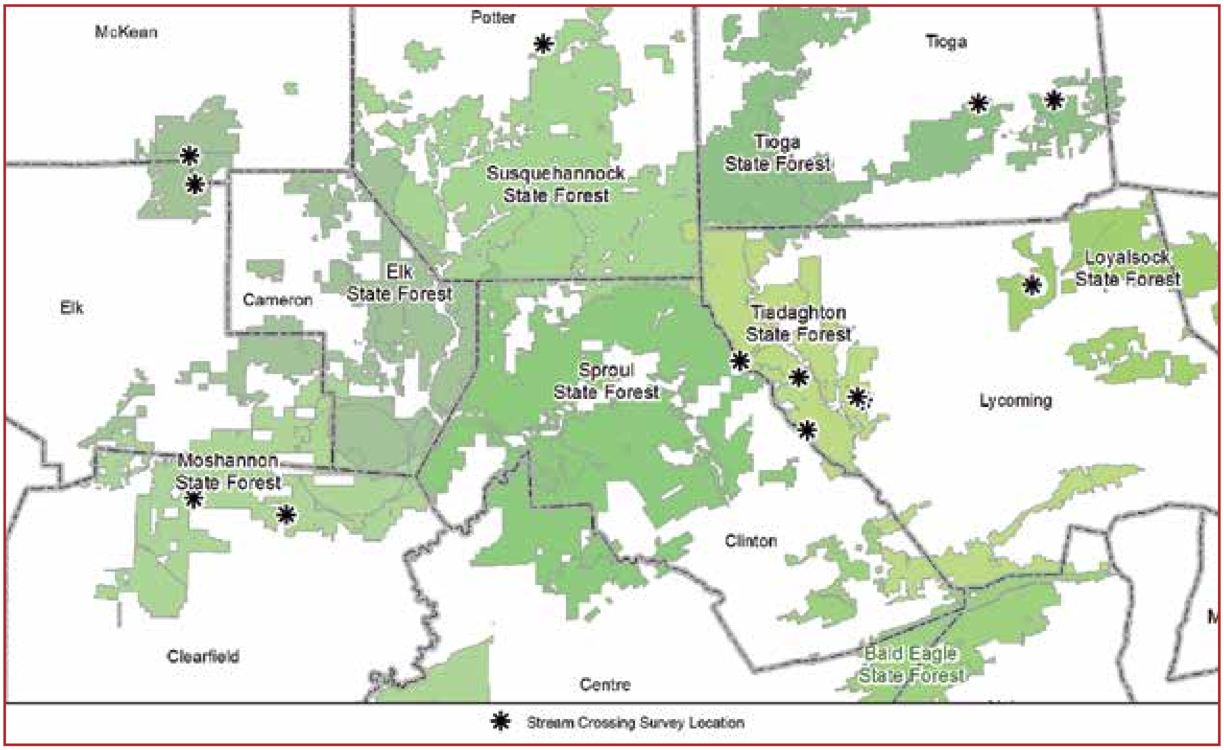


Figure 4.16. Location of pipeline right-of-way stream crossings that were assessed in 2016.

Stream Bank Cover	Within ROW	Outside ROW
Rock Armor	4	1
Erosion Control Materials (Mat, Sock, etc.)	2	1
Naturally Occurring Vegetation in good condition	8	14
Erosion and Control Vegetation in good condition	5	0
Dense root coverage (may or may not be undercut)	0	1
Exposed bank with little or no root coverage	0	1
Other: Road and Culvert	0	1
Other: Bridge and Culvert	0	1

Table 4.4. Number of streams with each bank cover type within and outside the pipeline rights-of-way for 14 streams assessed in 2016. Stream bank sections could have multiple cover types.

crossing in the Tiadaghton State Forest was on one bank within the ROW and was considered light (Figure 4.17). Erosion on the crossing in the Loyalsock State Forest was also considered light, but occurred on both stream banks within the pipeline ROW (Figure 4.18). Erosion on the crossing in the Moshannon State Forest was considered moderate, but did not occur within the pipeline ROW. The erosion occurred on an outside bend in the stream within a power line ROW that is adjacent to the pipeline ROW. The pipeline at this crossing was installed in 2011. However, erosion can be seen at that site in a 2006 aerial photo (Figure 4.19). Therefore, the erosion was not caused by the installation of the pipeline.

Efforts taken to reduce stream bank erosion within pipeline ROWs appear to be working. Vegetation along all banks was in good condition and artificial methods of stabilizing the bank were still present. Erosion was rare and when it was present within the pipeline ROW it was light. The only case of moderate erosion was present prior to the pipeline installation and was outside the pipeline ROW and was known to be there prior to the construction of the pipeline.

Figure 4.17. Light bank sloughing on the left bank of the right-of-way in the Tiadaghton State Forest.

Figure 4.18. Left and right banks of the right-of-way in the Loyalsock State Forest. Light bank sloughing was observed on both banks.

Figure 4.19. A 2006 aerial photograph of the power line right-of-way adjacent to the crossing in the Moshannon State Forest. This photograph was taken 5 years prior to the installation of the pipeline. Bank sloughing that was detected in the 2016 assessment is also seen in this photograph.

Post Construction Stormwater Management

New roads and pads increase the amount of impervious surface on state forest lands. Impervious surfaces can increase and concentrate surface water runoff which may lead to erosion, heavier flooding, or introduce pollution into streams. The Federal Clean Water Act (CWA) prohibits the discharge of pollutants in waterways without a permit. Within Pennsylvania, the CWA permitting process is administered by DEP. In 2012, DEP changed the permitting to include new standards for post construction storm water management (PCSM). All new construction projects since 2012 are required to follow the new guidelines and some older projects have been required to update their stormwater management to the new standards.

Water gardens, infiltration basins, infiltration trenches, and infiltration berms (earthen or media sock) are used to control stormwater runoff (Figure 4.20). Water gardens allow water to percolate through the soil and have wetland vegetation growing in them. This slows water flow and allows water to be removed through evapotranspiration. Infiltration basins are similar except they do not have wetland vegetation. Berms and trenches are designed to slow or capture water and move it to basins or PCSM structures. However, PCSM practices can have unintended repercussions. They may involve clearing more forest (Figure 4.21), change the natural process of water infiltration in the forest, and may impact habitat for amphibians. The bureau began documenting where PCSM structures were installed on pads in 2013 and along roads in 2016.

Four roads were surveyed for PCSM structures: Matson Road and Oak Ridge Trail in the Tioga State Forest and Narrow Mountain and Sugar Camp roads in the Loyalsock State Forest. These roads received substantial PCSM practices to account for road stormwater runoff. Ten infiltration basins were installed on these roads. They were, on average, one-half acre in size with average widths (distance beyond road footprint) of 93 feet and average lengths (parallel to road) of 240 feet. One infiltration berm 30 ft. wide by 265 ft. long was installed. One trench 70 ft. wide for the length of the road was installed (approximately 0.8 acres).

Six gas well pads were surveyed in 2016 that held 12 PCSM structures. Of those structures two were designed to hold water (rain gardens). Three structures, which are not supposed to hold water (one infiltration berm and two conveyance channels), were holding water during the survey. Standing water in these structures may affect amphibian populations.

Total Infrastructure Development

A total of 1,769.5 acres of state forest have been converted to accommodate shale gas infrastructure

Figure 4.20. Post construction stormwater management practices. A. Water garden, B. Retaining pond with overflow, infiltration trench and basins, C. Infiltration basin, and D. infiltration berm.

Figure 4.21. Pre-existing administrative roads. Red lines depict the limit of clearance if there were no infiltration structure.

(1,435.6 acres 2008-2012 and 333.9 acres 2013-2016). This includes the acreage of the pad footprint and the limit of clearance for pipeline and road corridors. The Tiadaghton State Forest has had the most number of acres converted to accommodate shale gas infrastructure but saw a large decline from 2008-2012 and 2013-2016. The Elk State Forest was the only state forest with increase conversion to shale gas infrastructure from 2008-2012 and 2013-2016 (Figure 4.22).

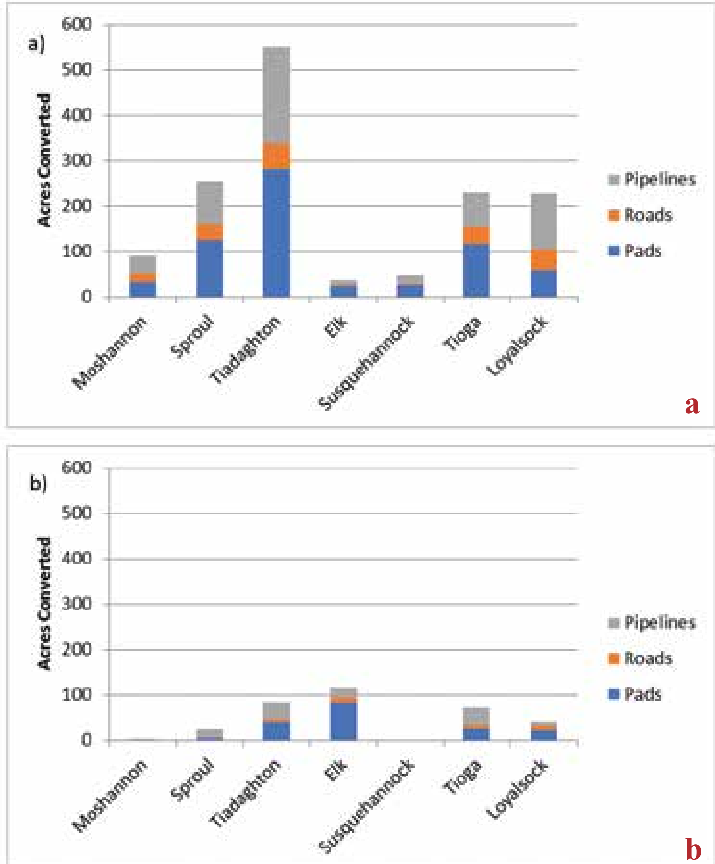


Figure 4.22. Acres converted to accommodate shale gas development from forest to shale gas infrastructure by state forest and infrastructure type, for 2008-2012 (a) and 2013-2016 (b).

Fragmentation and the Forest Landscape

State forests in the shale gas region make up part of the largest block of core forest habitat in Pennsylvania. Shale gas development reduces forest cover and causes fragmentation. Forest fragmentation is the process by which a continuous forest habitat becomes separated into smaller or more isolated forest patches (Halia, 1999). These smaller habitat patches are more vulnerable to further disturbance and degradation, have more forest edge habitat, and greater separation between forest patches. As core forests are fragmented by non-forest, remaining patches become more susceptible to invasion by exotic species and pathogens due to increased forest edge. The loss of connectivity between patches of forest habitat can result in a loss of biodiversity and genetic variation across a landscape.

Forest edges are the area from the edge of a disturbance up to 100 meters into the forest. A human-created edge, such as a timber sale boundary or the limit of clearance for a ROW, is often abrupt, forming straight lines that can cut across landscape features. Natural disturbances; however, often cause ragged, feathered, and non-symmetrical boundaries that often follow landscape features like ridge tops or creeks. Microclimate differences in air temperature, wind speed, light availability, and relative humidity often contribute to edge forests that can be hotter and drier than the interior forest (Gelhausen, et al., 2000). They have also been shown to increase plant species richness; however, some of the species richness is from more non-native, invasive plant species such as garlic mustard (*Alliaria petiolata*), honeysuckles (*Lonicera spp*.), or privets (*Ligustrum spp*.) (Haila, 1999). The effects of fragmentation and an increase in forest edge on wildlife vary. Some species of songbirds, such as golden winged warblers prefer the thick shrubby vegetation found on edges (Patton et al. 2010). Soule et al. (1988) found that edges benefited mesopredators (such as possums, raccoons and bobcats) and led to the decline of vulnerable prey species.

The bureau recognizes that forest fragmentation and forest edges may affect biodiversity and ecosystem health. A stated goal in the State Forest Resource Management Plan (2016) is to "consider forest fragmentation, connectivity, and patch distribution in management decisions affecting state forest resources." Additionally, the bureau's Guidelines for Administering Oil and Gas Activity on State Forest Lands[1] address the potential effects of forest fragmentation. It recommends co-locating new infrastructure, like roads and pipelines within existing corridors, and minimizing the footprint of infrastructure pads to the furthest extent possible. Langlois et al. (2017) recommends siting new well pads as close as possible to existing pipelines to further reduce core forest fragmentation. Bureau land managers work with operators to place new infrastructure near adjacent infrastructure when practical and reduce construction disturbance to the greatest extent possible. However, other factors including underlying geology and lease tract boundaries also influence the placement of pads. As part of shale gas monitoring efforts, the

Co-location of waterline right-of-way and improved road on Tiadaghton State Forest.

bureau recognized the need for a landscape level analysis to describe the change in the structure of forest habitat since the onset of gas development on state forest lands. After reviewing a variety of methods and types of analysis, the bureau selected the Landscape Fragmentation Tool v 2.0 developed by the University of Connecticut Center for Land Use Education and Research (CLEAR) was selected to perform an assessment of the change in forest habitat in the core gas forest districts (Parent & Hurd, 2008). This tool is based on research completed by Vogt et al. (2007) which proposed a pixel-based approach to quantifying fragmented forested landscapes. The Landscape Fragmentation Tool (LFT) uses ArcGIS Spatial Analysis technology to classify forest into four categories: patch, edge, perforated, and core forest. One drawback of this tool is that it can only distinguish forest from non-forest and cannot assess early successional forest or shrublands from mature forest. In this model, edge is defined as the first 100 meters of forest along the outside edge of a forest patch. This distance of 100 meters was also accepted for use in the landscape tool by Drohan et al. (2012) to describe forest land cover change due to shale gas development in Pennsylvania. Core forest is forest habitat not subject to disturbance or the edge effect and are split into three size classes by the Tool: small (less than 100 hectares or 247 acres), medium (between 100 and 200 hectares or 247 and 495 acres), and large (greater than 200 hectares or 495 acres). Forest patches are small areas of forest surrounded by non-forest (Parent & Hurd, 2008) that are completely subject to edge effects. Perforated forests are areas around a disturbance that are surrounded by core forest (Figure 4.23).

The CLEAR Landscape Fragmentation Tool (LFT) utilizes raster data that are reclassified to forest or non-forest pixels. The bureau modeled forest fragmentation for the core gas forest districts as of December 2008-2012. High resolution imagery was not available close to these "cutoff" dates so vector data were used to create a dataset representing non-forest and forest conditions. These vector data were then converted to raster data for use in the LFT. Forest and non-forest habitats were identified using the 2016 Bureau of Forestry Forest Communities Classification data. Community classes were reclassified to forest or non-forest. This data layer was then updated with shallow-gas development, roads open to the public, other rights-of-way data, and other non-forest features as of December 2008 to provide additional non-forest information. If the actual width of the linear feature was not available, default values, such as 20 feet width for roads, were assigned. Since timber harvests are temporary and rarely result in non-forest, they were considered forest for the analysis. In many cases, the available data stopped at the state forest boundary so the 2005 National Land Cover Data (NLCD) were added to provide a buffer around the state forest boundary to minimize false edge effects. A second base map was created using data as of December 2012. Shale gas related features were added to the 2012 base map using the area cleared for development. The base maps were then converted to raster with 15 feet by 15 feet pixel size. The CLEAR Forest Fragmentation Tool was run on both base maps using a 100-meter distance to delineate edge effect. Raster results from the tool were then converted to polygons and clipped to the core gas forest districts.

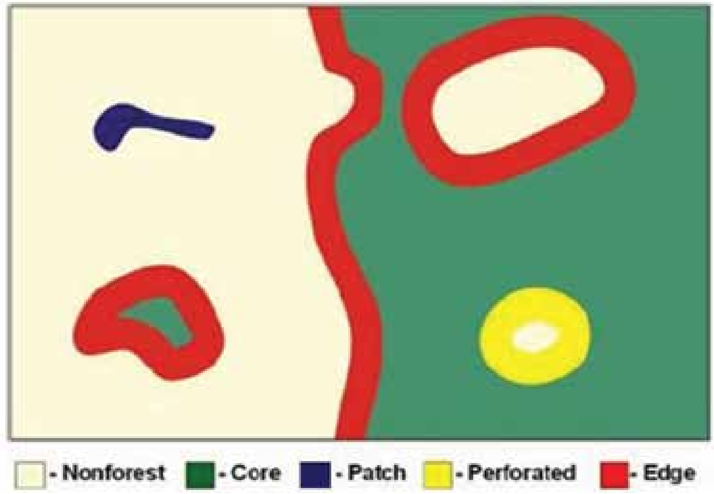


Figure 4.23. Visual representation of non-forest, core forest, patch forest, perforated forest, and forest edge in CLEAR tool analysis (Available at: http://clear.uconn.edu/tools/lft/lft2/method.htm).

There have been many updates, corrections, and revisions to the Forest Communities Classification data and the state forest boundaries, along with the roads and rights-of-way data since 2008. Some roads previously designated as drivable trails have been reclassified to administrative roads. Administrative roads not related to shale gas development typically do not receive regular maintenance and the forest canopy can grow over the road; potentially reducing fragmentation. In some cases, pipeline ROW holders have provided more accurate pipeline data. Re-creating a 2016 base map using the same method used for the 2012 report would have included these data changes and made it very difficult to isolate effects of shale gas development since 2012.

To model only the effect of shale gas development in the core gas forest districts, the raw results from 2012 (posted to the PASDA website) were updated with shale gas development data and the results summarized. To do this, all shale gas development cleared areas (limits of clearance) were buffered by 100 meters. The limits of clearance were classified as non-forest and the buffers were classified as edge due to their contiguous nature. These results were then used to update the 2012 raw results. The area of core forests was checked to determine whether they had changed from one core forest size category to another. The 2008/2012 boundaries of analysis were replicated as closely as possible and the 2016 results clipped. This method used the same criteria as the CLEAR Forest Fragmentation Tool, but it does not utilize the tool to generate the results.

Updating the 2012 analysis resulted in changes to the core forest category near development and conversion of perforated to edge forest. The conversion of perforated to edge illustrates locating new disturbance near existing non-forest areas. See Figure 4.24.

The analysis results provided by the LFT are based on conditions before shale gas development (Table 4.5) and as of December 31, 2016 (Table 4.6) on the seven core gas forest districts. Prior to shale gas development, the Sproul State Forest had the most acres of non-forest (9,362 acres), due in part to the amount of shallow natural gas exploration that had historically occurred. Additionally, the Sproul and Moshannon State Forests had the highest amount of edge forest acres

Figure 4.24. Example of perforated forest converted to edge. Gray – non-forest, mango - perforated forest, yellow – edge, diagonal hatch- new edge forest, and red- perforated forest now classified as edge.

(53,485 and 35,808, respectively) primarily due to shallow gas development and large rights-of-way that pre-date shale gas activity. Perforated forest acreage was consistent across districts, except for the Sproul State Forest, which had 8,535 acres of perforated forests — nearly 4,800 acres more than the next highest district. Again, this is due in part to the history of shallow natural gas extraction on this district.

Table 4.6 describes the results of the updated landscape analysis where the 2012 results were updated with the new shale gas development limits of disturbance. In total, there are 31,600 acres of non-forest lands in the core gas forest districts. Of the core gas forest districts, the Sproul State Forest had the most acres of non-forest (9,453) and edge forest (54,544). This is due primarily to historic shallow gas development, but also includes significant acres of rights-of-way.

After eight years of gas development and infrastructure creation on state forest lands, noticeable changes to the forest landscape are evident (Tables 4.7 and 4.8). The largest increase overall was in edge forest. Since 2008, an additional 9,913 acres of edge forest (35 percent change in the Elk State Forest specifically) has been created in the core gas forest districts. This is due primarily to the creation and expansion of pipeline rights-of-way and in some cases, the expansion of state forest roads to accommodate heavy hauling or to co-locate pipeline infrastructure. Co-location of infrastructure is likely the explanation for the decrease of 172 acres in forest patches and 258 acres in perforated forests from 2008-2016. The acreage of forest patches has declined by 10.9 percent in the Tioga and 9.5 percent in the Moshannon State Forests. Perforated forest acres decreased by 14.1 percent in the Tiadaghton State Forest. Overall since 2008, core forests greater than 200 hectares have decreased slightly in all the core gas forest districts, with the Tiadaghton State Forest — a state forest with some of the largest development areas — showing the greatest decrease (3.4 percent). All core gas

Forest District	Total Acres	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	183,955	6,155	35,808	3,747	1,045	116,229	11,052	9,919
Sproul	302,937	9,362	53,485	8,535	1,111	209,879	8,947	11,618
Tiadaghton	145,153	1,989	17,888	1,156	401	114,249	5,315	4,155
Elk	190,472	3,649	21,033	3,696	449	153,230	4,056	4,359
Susquehannock	257,840	4,032	30,638	2,532	1,310	209,266	5,583	4,479
Tioga	157,321	3,094	19,846	1,972	248	120,316	7,848	3,997
Loyalsock	114,449	1,049	11,938	1,608	262	97,105	1,760	727
Total	**1,352,127**	**29,330**	**190,636**	**23,246**	**4,826**	**1,020,274**	**44,561**	**39,254**

Table 4.5. Landscape Analysis Results – Pre-Marcellus Landscape Conditions (all values in acres)

Forest District	Total Acres	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	184,069	6,109	36,809	3,811	946	114,588	11,619	10,187
Sproul	302,451	9,453	54,544	8,538	1,092	208,448	8,171	12,205
Tiadaghton	145,330	2,735	20,857	993	387	110,422	5,362	4,574
Elk	190,055	3,782	22,063	3,557	439	151,832	4,056	4,326
Susquehannock	257,844	4,132	30,828	2,552	1,307	208,690	5,855	4,480
Tioga	157,779	3,867	21,961	1,924	221	116,888	8,457	4,461
Loyalsock	114,586	1,522	13,486	1,615	262	94,272	2,487	942
Total	**1,352,115**	**31,600**	**200,549**	**22,988**	**4,654**	**1,005,140**	**46,008**	**41,175**

Table 4.6. Landscape Analysis Results – December 31, 2016 Landscape Conditions (all values in acres)

Forest District	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	-46	1,001	64	-99	-1,641	567	268
Sproul	91	1,059	3	-19	-1,431	-776	587
Tiadaghton	746	2,969	-163	-14	-3,827	47	419
Elk	133	1,030	-139	-10	-1,398	0	-33
Susquehannock	100	190	20	-3	-576	272	1
Tioga	773	2,115	-48	-27	-3,428	609	464
Loyalsock	473	1,548	7	0	-2,833	727	215
Total	**2,270**	**9,913**	**-258**	**-172**	**-15,134**	**1,447**	**1,921**

Table 4.7. Landscape Analysis Results – Total Change from Pre-Marcellus to December 31, 2016 (in acres)

Forest District	Non-forest	Edge	Perforated	Patch	Core Forest (>200 ha)	Core Forest (100-200 ha)	Core Forest (<100 ha)
Moshannon	-0.74	2.80	1.70	-9.46	-1.41	5.13	2.70
Sproul	0.97	1.98	0.03	-1.72	-0.68	-8.67	5.05
Tiadaghton	37.48	16.60	-14.08	-3.45	-3.35	0.89	10.09
Elk	3.63	4.90	-3.77	-2.13	-0.91	0.00	-0.76
Susquehannock	2.49	0.62	0.78	-0.24	-0.28	4.88	0.01
Tioga	25.00	10.66	-2.45	-10.93	-2.85	7.75	11.62
Loyalsock	45.08	12.97	0.42	-0.04	-2.92	41.32	29.58

Table 4.8. Landscape Analysis Results – Percent Change from Pre-Marcellus to December 31, 2016.

		Pre-Marcellus		December 31, 2016		Change	
Forest District	Total Acres	Core Forest (>200 ha)	Core Forest (<100 ha)	Core Forest (>200 ha)	Core Forest (<100 ha)	Core Forest (>200 ha)	Core Forest (<100 ha)
Moshannon	184,069	116,229	9,919	114,588	10,187	-1,641	268
Sproul	302,451	209,879	11,618	208,448	12,205	-1,431	587
Tiadaghton	145,330	114,249	4,155	110,422	4,574	-3,827	419
Elk	190,055	153,230	4,359	151,832	4,326	-1,398	-33
Susquehannock	257,844	209,266	4,479	208,690	4,480	-576	1
Tioga	157,779	120,316	3,997	116,888	4,461	-3,428	464
Loyalsock	114,586	97,105	727	94,272	942	-2,833	215

Table 4.9. Landscape Analysis Results – Changes to Core Forest acres per District

	Pre-Marcellus (in acres)	December 2012 (in acres)	December 2016 (in acres)	Change 2008-2016 (in acres)	Total % Change 2008-2016
Non-forest	29,330	31,020	31,600	2,270	7.7
Edge	190,636	194,991	200,549	9,913	5.2
Perforated	23,246	23,835	22,988	-258	-1.1
Patch	4,826	5,037	4,654	-172	-3.6
Core Forest (>200 ha)	1,020,274	1,011,033	1,005,140	-15,134	-1.5
Core Forest (100-200 ha)	44,561	45,808	46,008	1,447	3.2
Core Forest (<100 ha)	39,254	40,404	41,175	1,921	4.9

Table 4.10. Landscape Analysis Results –Change from Pre-Marcellus to December 31, 2016, including 2012 results (all core gas forest districts combined).

forest districts lost core forest greater than 200 hectares. The fragmentation of these large blocks resulted in increases in the smaller category core forests in almost all districts, with the Loyalsock State Forest experiencing a 41.3 percent change in core forests between 100 and 200 hectares in size and a 29.6 percent change in core forests less than 100 hectares in size.

Table 4.9 summarizes the changes to the largest and smallest core forest blocks. As a general practice, the bureau attempts to minimize new disturbances in the largest core forests and attempts to locate new infrastructure in areas that have been previously disturbed. Lessees choose areas to target for development of well pads that they believe will yield significant gas returns. While the bureau works with companies to locate pads to avoid negative ecological effects, the selection of the general area for the pads is made based on the presence of gas. Once a core forest has been fragmented, co-location of waterlines, pipelines, impoundments, and compressors is attempted to consolidate these landscape effects to as few locations as possible. The decrease in core forest blocks is largest in areas with more leased and severed tracts such as the Tiadaghton (loss of 3,827 acres of core forest greater than 200 hectares) and Tioga State Forests (loss of 3,428 acres of core forest greater than 200 hectares). As one would expect, the decrease in acreage in the largest class of core forest directly translates to an increase in smaller core forest blocks. Since 2008, gains in new large core forest blocks were from state forest land acquisitions.

Table 4.10 summarizes the changes from pre-Marcellus conditions to December 2016. Included as a reference in this table are the changes in acreage reported in the 2012 report. Overall, forest disturbance decreased from 2012 to 2016, with only 580 new non-forest acres created during that period. While non-forest has only slightly changed, more edge acres were created from 2013-2016 (5,558 acres) than from 2008-2012 (4,355). This is due primarily to the fact that while well pad creation has slowed on state forest lands, pipeline rights-of-way are still actively being constructed. Since 2008, state forest has lost 15,134 acres of core forest greater than 200 hectares in size, which is a percent decrease of 1.5 percent.

This analysis provides valuable insight into trends in forest acres being changed to non-forest or fragmented forest and how the size of the core forest is being altered. However, a more refined approach at an individual species level is necessary to get a true picture of how gas development may be affecting forest ecosystems. Due to the variation of wildlife and plant responses to an increase in forest edge or a loss of habitat connectivity, species-specific studies would be helpful in evaluating how these landscape level changes are affecting species residing within the state forest.

Site Rehabilitation

The bureau's Guidelines for Administering Oil and Gas Activity on State Forest Lands[1] provide guidance for oil and gas operators to rehabilitate sites. These guidelines encourage tree species diversity, appropriate species selection for ecological goals, and maintenance of habitat structure for target wildlife species. All site rehabilitation projects are evaluated and decided upon at the site level and within the context of the surrounding forest landscape. Full ecological restoration in many cases will take decades, which underscores the need to look at every step in the process as an opportunity for restoration and enhancement of habitat.

The terms revegetation, reclamation, restoration, and rehabilitation are often used interchangeably, but have different meanings to the bureau. The definitions become important when discussing expectations with operators and determining final goals for a site.

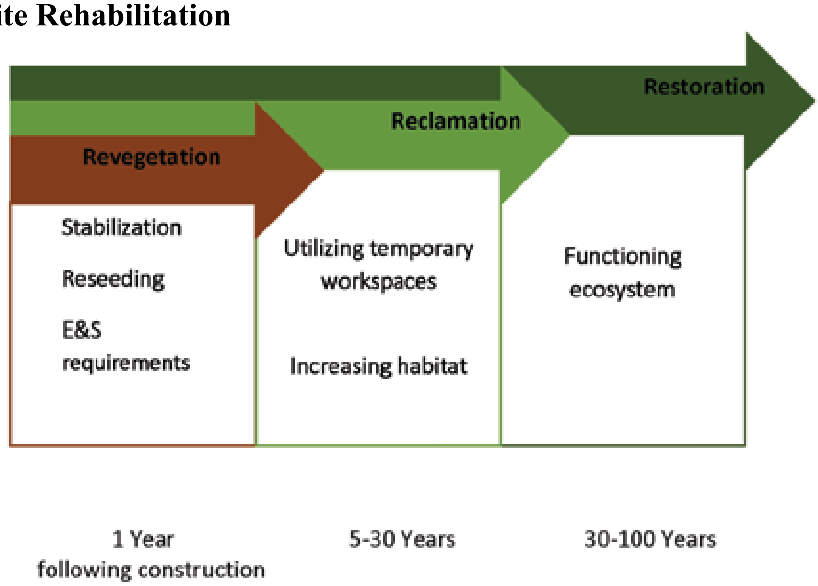
Site rehabilitation refers to the overarching act of mitigating some type of land-use change or disturbance.

Rehabilitation is a sliding scale, with required stabilization, at the "low" end and functional ecological restoration at the "high" end. The bureau uses the term site rehabilitation to refer to any project that seeks to reduce the footprint of natural gas infrastructure and improve ecosystem health at the infrastructure site. Within infrastructure sites, passive rehabilitation is common. This is where opportunistic forb, shrub, and tree species colonize the site without human aid. Active rehabilitation includes soil stabilization, grass establishment, invasive plant control, and shrub or tree planting. The general goal of site rehabilitation efforts is to assist the recovery of an ecosystem or the ecosystem services that have been lost or degraded. Rehabilitation goals take into consideration the need and level of rehabilitation and what was found during pre-project monitoring. The work to achieve this goal takes many forms and is a step-wise process over the life of the site.

Revegetation refers to planting grasses and legumes over a disturbed site or bare soils. This is the site stabilization required by DEP regulations to protect exposed soils from accelerated erosion and sedimentation. All gas infrastructure that has been constructed and all land cleared for development must be revegetated following completion of construction. The bureau recommends the use of native legumes, grasses, and forbs to meet revegetation regulations. However, no regulatory mandate exists in Pennsylvania for operators to use only Pennsylvania native plant species during revegetation efforts. As a result, some seed mixes used for these projects include a mix of native and non-native species or are made up of non-native cool season grasses such as orchardgrass (*Dactylis glomerata*) and timothy (*Phleum pratense*).

Completed *Revegetation* project in Moshannon State Forest. Well pad acreage was reduced, and the site was seeded with non-native cool season grasses and clover.

Site Rehabilitation



Reclamation reduces the overall size of the disturbed area and uses native plants to rebuild organic topsoil, improve native plant diversity, and encourage site use by native insects and wildlife. Reclamation projects often seek to re-establish the original form of the vegetation community at the site and begin the process of regaining ecological function. Interim reclamation refers to minimizing the original disturbance footprint by rehabilitating all portions of the site not needed for immediate production operations. Final reclamation refers to the practice of reclaiming a majority or the entire disturbed site by removing infrastructure, fencing, and aggregate material; spreading topsoil and re-contouring the site; and planting native grasses, shrubs, and trees. Final reclamation is the first step to full restoration. At this point, the site can proceed through natural processes toward the final restoration of ecosystem functions that existed prior to the initial disturbance.

To date, much of site rehabilitation work on state forest lands has been interim reclamation (i.e., reclamation of unused pad space that may need to be cleared and utilized again for future gas development). On pipelines, these projects often take place within the areas designated as the temporary workspace and involves tree and shrub plantings. On pad infrastructure, similar plantings have occurred on areas of the temporary workspace. Only a small fraction of well pads have undergone interim reclamation. The reasons cited for not reclaiming portions of pad infrastructure vary, but two reasons are common: 1) the pad needs to remain developed to accommodate further unconventional development targeting different shale formations below the Marcellus shale and 2) bureau guidelines seek to minimize the infrastructure footprint during construction which leaves little unnecessary workspace to reclaim.

Example of site *reclamation* on pipeline right-of-way. Note scrub-shrub habitat in temporary workspace on right side of pipeline right-of-way.

Fink and Drohan (2015) found soils on unconventional gas infrastructure sites were often too compacted for plant roots to grow through. Therefore, reducing soil compaction and creating variable micro-topography during reclamation is essential for successful establishment of native plants. The bureau has adopted soil dumping methods like those published by the Appalachian Regional Reforestation Initiative (ARRI, 2007) or simple soil ripping of at least eight inches. These methods have been found to be adequate for restoring necessary soil function. Soil ripping at various depths is currently being tested and compared to techniques that do not reduce soil compaction at the bureau's mock well pad site in the Tiadaghton State Forest.

Partial well pad reclamation in Sproul State Forest, following the use of methods similar to ARRI soil dumping (compare to soil ripping photo below).

Pad reclamation study site Tiadaghton State Forest, following soil ripping methods: 8" ripping depth on left, compared to 20" ripping on right (compare to ARRI dumping method photo above).

The bureau defines *restoration* as the return of a disturbed site to the functioning ecosystem state prior to disturbance. Ideally, this functioning state would be the same as what existed at the site prior to the disturbance. However, depending on the ecological conditions this may not be possible. In this case, the bureau may seek to restore the site to provide a completely different suite of ecosystem services. This type of site rehabilitation accelerates the recovery of an ecosystem's health and provides the appropriate pathways for ecosystem functions to become self-sustaining. To date, no gas infrastructure sites have reached the final restoration stage.

Site Rehabilitation efforts (by state forest) as of September 2017:

Site rehabilitation of Marcellus infrastructure has taken place in six forest districts: Moshannon, Sproul, Tiadaghton, Elk, Susquehannock, and Tioga. Twelve well pads, two impoundment sites, two monitoring well sites, and one meter station have been subject to site rehabilitation.

Moshannon State Forest:

Two Marcellus well pads on leased areas have been subject to site rehabilitation. One pad was reduced from 2.6 acres to 0.5 acres and was reseeded with a seed mix that included white clover and wildflowers. The same reseeding process was used on another 5-acre well pad. A 16.5-acre impoundment site was reduced to 5.2 acres and the impoundment was removed. At this site, both red pine and white pine seedlings were planted, as well as American hazelnut and shagbark hickory. An impoundment fence is now being used at the site to exclude white-tailed deer to improve survival of the tree and shrub seedlings.

In addition, one well pad and one impoundment in areas with severed rights have been subject to efforts to reach the interim reclamation stage. The well pad had its size reduced from 3.5 to 1.3 acres and had 2,000 red pine seedlings planted. The 10.6-acre impoundment site was recontoured and planted with a mix that included clover and wildflowers. Additionally, a one-half acre area cleared for a meter site, that was not constructed, was reseeded and 20 apple trees were planted.

Eleven conventional gas wells have also been plugged in the Moshannon State Forest and their respective pads have been subject to site rehabilitation practices. Pads, which are typically a half acre in size, have been planted with seed mixes that include clover and wildflowers. Plantings of hardwood and white pine seedlings are planned for 2019.

Sproul State Forest:

Most reclamation has taken place on former strip mine areas. However, reclamation techniques such as the ARRI soil dumping methods have been applied to some shale gas infrastructure. Four well pads have been subject to site reclamation methods and converted into wildlife food plots, one of which was planted specifically to benefit elk. A fifth well pad has been subject to partial reclamation practices that included tree plantings. Additionally, efforts are on-going to plug and restore historic shallow gas wells across the Sproul State Forest.

Tiadaghton State Forest:

One well pad has been subject to interim reclamation efforts to go from a size of four acres down to two acres. Five pipeline sites have had their temporary workspace areas planted with conifers and fenced enclosures of native shrubs to create feathered, early successional habitat along pipeline limits of disturbance.

Native tree and shrub plantings along pipeline corridor in Tiadaghton State Forest.

Elk State Forest:

Three well pads have been subject to interim reclamation methods which reduced their total footprint size from six combined total acres down to approximately three. Many pads on the Elk State Forest have been built to accommodate not only Marcellus shale development, but also Utica shale development and cannot be reclaimed currently. Several stone pits that were originally used for shallow gas development from the 1980s to early 2000s have also been reclaimed.

Susquehannock State Forest:

Two monitoring well pads have reached a reclaimed state. The 2.3-acre Horton Run Colony Road site was planted with a native seed mix and efforts are ongoing to plant white pine seedlings. The 1.6 acre monitoring well pad near Big Fill Hollow has also been reclaimed.

Tioga State Forest:

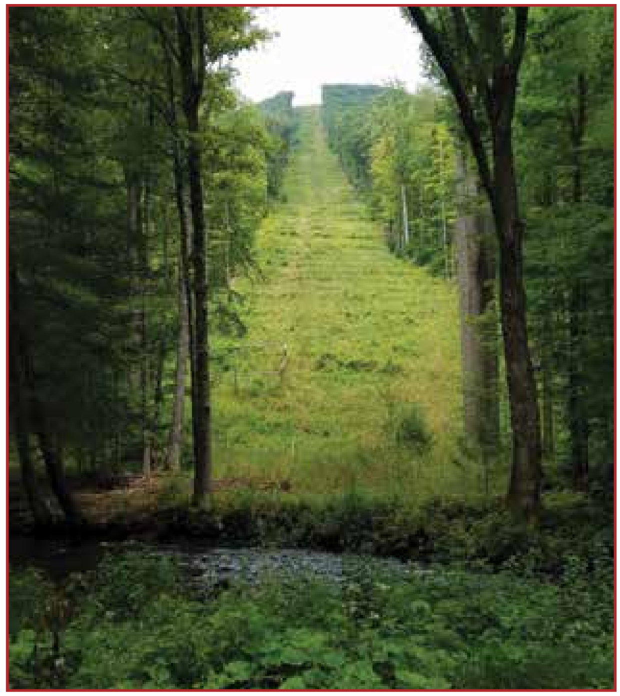
One operator has reduced the footprint of some well pads, but only through spreading topsoil and planting cool season grasses rather than reclaiming the site with native species. A second operator has reseeded three monitoring well pads (each two acres in size) that are no longer needed. Two of these sites were planted with seedlings that have shown poor survival.

Loyalsock State Forest:

Planting of native trees and shrubs has occurred in riparian areas on two pipelines that cross Grays Run and Long Run. To date, no pad infrastructure has been subject to site rehabilitation actions.

"Mock Well Pad" Reclamation Demonstration Site

The uncertain timeframe of gas extraction makes full site restoration unlikely in the short term. Therefore, interim site reclamation is essential to re-establishing some ecosystem functions at well pad sites. However, there are several challenges to ecologically significant site reclamation in and around Marcellus shale development sites. Typically, there are very compacted soils and subsoils due to the necessary grading to create well pads.



Grays Run Pipeline crossing in Loyalsock State Forest. Note reduced width at stream crossing and planting areas along pipeline edge.

In some portions of the state forest where development is occurring, topsoil is lacking and subsoils are extremely rocky. This makes seed mix establishment a challenge during site reclamation.

To better understand how Marcellus shale well pad construction techniques affect the effectiveness of forest reclamation practices, the bureau, in partnership with researchers from Penn State, constructed a one-acre "mock well pad" demonstration site in May of 2015. The demonstration site is in the Tiadaghton State Forest in an area that was previously used as temporary workspace during construction of a nearby pipeline ROW. The overarching goal of this work is to evaluate and demonstrate interim reclamation techniques that can be applied at relatively low costs to improve the ecological function of sites utilized for Marcellus gas infrastructure within forested landscapes. The three objectives of this work are: 1) demonstrate next-generation BMPs for soil preparation, native grass plantings, and reclamation practices on retired sites,

2) demonstrate the viability of "soft edge" creation using native tree and shrub species, and 3) create an educational opportunity for bureau staff, regulators, gas operators, and the public along with providing field-tested Marcellus site reclamation guidance.

Once the site had been selected, the area was cleared to accommodate a one-acre pad. The soil was removed and stockpiled as per typical construction practices and a vibratory roller was used to compact the subsoil to industry well pad standards. A nuclear density gauge was used to ensure soil bulk density of the mock pad site was the same as the average bulk density of well pads on state forest lands.

Cleared and compacted mock well pad surface prior to soil compaction remediation.

Severely compacted soils are a limitation to planting success on well pad sites that are to be reclaimed. In addition to the compacted subsoils, the pad is usually covered with a significant amount of limestone that serves as a secure running surface for equipment and vehicles. One reclamation option is to simply spread stockpiled topsoil over this running surface and plant over top. Another option is to remove the limestone, re-spread topsoil, and plant over the compacted subsoil layer. A third option is to remove the limestone, rip the subsoil layer with equipment to reduce compaction, then spread, and reincorporate topsoil. To test the success of various soil treatments, the well pad site was split into four treatment areas: 1) topsoil spread over compacted rock and subsoil, 2) rock removed, topsoil spread over compacted subsoil, 3) rock removed, 8"-deep ripping to alleviate subsoil compaction, topsoil re-spread over area, and 4) rock removed, 20"-deep ripping to further alleviate deep subsoil compaction, topsoil re-spread over area.

Aerial view of mock pad site with four soil treatments – from left to right: (1) topsoil spread over compacted rock and subsoil, (2) topsoil spread over compacted subsoil, (3) 8" ripping, and (4) 20" ripping.

In addition to testing soil compaction alleviation techniques, the mock well pad site is also being utilized to test the establishment success of three different seed mixes. The first mix is the typical native and non-native species mix that is used in many gas development projects. The second mix is made up entirely of native plant species and the third mix is the all-native mix with four native wildflower species added (Table 4.11). After initial establishment of all planted sites, comparisons of initial establishment success could be compared between soil treatments.

Mock well pad site planting map.

One limitation to native, perennial warm season grasses being used for site reclamation involves the wording of some existing erosion and sedimentation regulations. The regulations require “70% perennial cover” 45 days after initial planting. Typically, native warm season grasses exhibit root growth prior to shoot growth, which limits the leaf growth present immediately following planting, but does not limit the ability of these species to hold soil with their root systems. Grass mixes that are typically used and include predominately cool season grasses show a significant amount of “green-up” 45 days after planting, but the grasses lack a well-developed root system. Native seed mixes at the mock well pad clearly show that if planted correctly, this drawback of native mixes is not as prevalent as once thought.

“Typical” Native/Non-native Mix

Rate (in lbs/ac)	Species
2	Timothy (*Phleum pretense*)
6	Perennial ryegrass (*Lolium perenne*)
6	Virginia wild-rye (*Elymus virginicus*, PA Ecotype)
2	Little bluestem (*Schizachyrium scoparium*)
2	Big bluestem (*Andropogon gerardii*)
6	White clover (*Trifolium repens*)
4	Partridge pea (*Chamaecrista fasciculata*)
0.5	Black-eyed Susan (*Rudbeckia hirta*)

All Native Species Mix

Rate (in lbs/ac)	Species
30	Oats (*Avena fatua*) ***Cover Crop***
6	Virginia wild-rye (*Elymus virginicus*, PA Ecotype)
4	Indiangrass (*Sorghastrum nutans*, PA ecotype)
4	Big Bluestem (*Andropogon gerardi)*
3	Switchgrass (*Panicum virgatum*)
3	Deer-tongue grass (*Dicanthelium clandestinum*)
4	Partridge Pea (*Chamaecrista fasciculata*, PA ecotype)
0.5	Black-eyed Susan (*Rudbeckia hirta*)

All Native Species Mix with Native Wildflowers

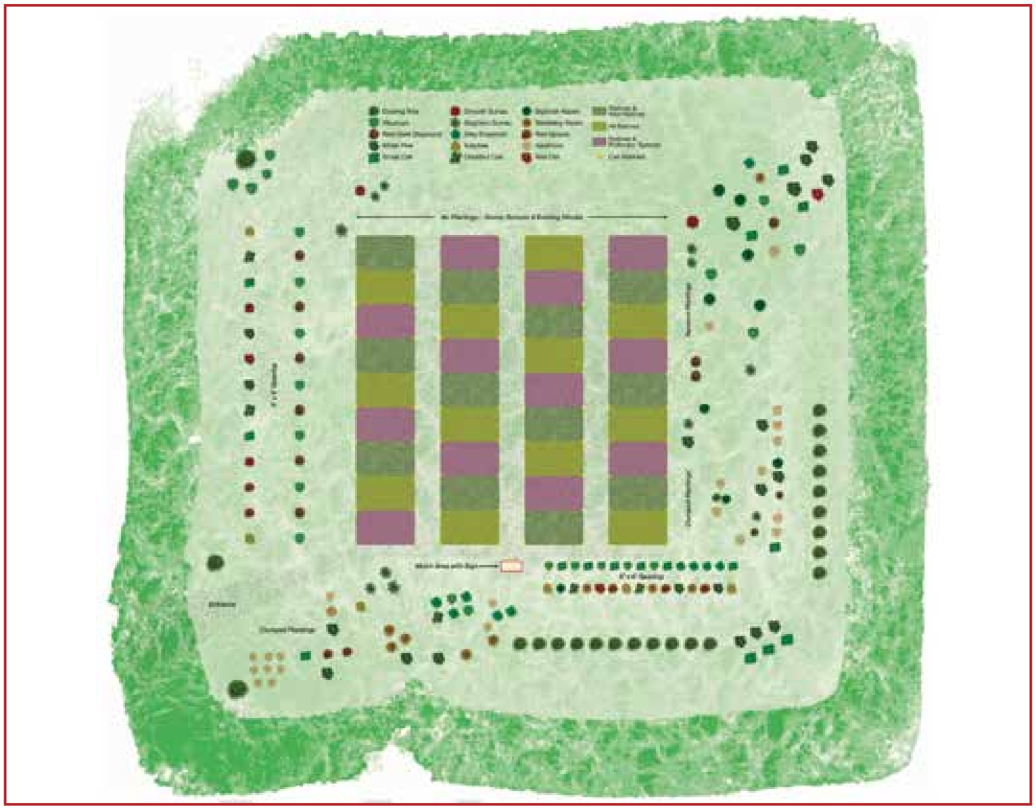
Rate (in lbs/ac)	Species
30	Oats (Avena fatua) ***Cover Crop***
*	Virginia wild-rye (*Elymus virginicus*, PA Ecotype)
4	Indiangrass (*Sorghastrum nutans*, PA ecotype)
4	Big Bluestem (*Andropogon gerardi)*
3	Switchgrass (*Panicum virgatum*)
3	Deer-tongue grass (*Dicanthelium clandestinum*)
6	Partridge Pea (*Chamaecrista fasciculata*, PA ecotype)
0.5	Black-eyed Susan (*Rudbeckia hirta*)
0.5	Wild bergamot (*Monarda fistulosa*)
0.5	Canada goldenrod (*Solidago canadensis*, PA ecotype)
0.5	Common milkweed (*Alclepias syriaca*)
0.5	Showy-tick trefoil (*Desmodium canadense*)

Table 4.11. Seed mix treatments at mock well pad project.

Hand-seeding of native species at mock well pad study site.

Typically, native warm season grasses take two to three growing seasons to fully establish and mature on a given site. As of Fall 2017, the seed mixes have been growing on site for three growing seasons. Annual cover data has been collected for a subset of the planted demonstration cells across all seed mixes and soil treatments for all three growing seasons. Data analysis is ongoing, but general observations suggest that wild bergamot (*Monarda fistulosa*), partridge pea (*Chamaecrista fasciculata*), and Indiangrass (*Sorghastrum nutans*) appear to be the most prevalent species in the areas planted with native seed mixes. Crown-vetch (*Coronilla varia*) is the most abundant invasive plant species at the mock pad site and is actively being controlled to reduce its prevalence in some places. This species was present in the seed bank at the edges of the opening prior to construction of the mock pad.

To further utilize the mock pad reclamation site, pad



“edges” were used to test success of native trees and shrubs in a variety of planting configurations. Native tree species planted include: tulip poplar, red spruce, eastern white pine, bigtooth aspen, trembling aspen, chestnut oak, and northern red oak. Native shrub species planted include: silky dogwood, gray dogwood, Washington hawthorn, scrub oak, smooth sumac, staghorn sumac, and arrowwood viburnum. These plantings were arranged in four different ways: 6’ x 6’ spacing, 8’ x 8’ spacing, clumps, and random placement. In addition, one of the four edges of the well pad were not seeded or planted and will be permitted to succeed naturally as a comparison to the planted areas. After three growing seasons, the total average survivorship was 71 percent. Some individual species, such as Washington hawthorn (45 percent survivorship) and white pine (55 percent survivorship), have not fared well. However, others such as silky dogwood, smooth sumac, and staghorn sumac have 100 perecent survivorship after three growing seasons (Table 4.12). Neither planting configuration or pad side showed significant differences in survivorship after three years.

Ground-level photo of all native seed mix cover 45 days after planting, note vegetative cover approaching 70 percent.

Initial establishment of seed mixes 45 days after planting. Topsoil spread over compact subsoil treatment (on left) versus topsoil spread over compact rock and subsoil (on right). Note increased height of grasses on left.

Native warm season grass and wildflower plantings (foreground) and native shrub and tree plantings (background) at mock well pad site.

Species	Surviving Stems / Total Stems	Survivorship
Rhus typhina	12/12	100%
Cornus amomum	11/11	100%
Rhus glabra	5/5	100%
Viburnum dentatum	18/22	82%
Cornus racemosa	8/10	80%
Quercus rubra	4/5	80%
Populus tremuloides	7/9	78%
Quercus illicifolia	10/15	67%
Populus grandidentata	6/9	67%
Liriodendron tulipifera	4/6	67%
Picea rubens	5/8	63%
Quercus montana	3/5	60%
Pinus strobus	11/20	55%
Crataegus phaenopyrum	10/22	45%

Table 4.12. Tree survivorship, by species, at the mock well pad site three years following planting.

In addition to the reclamation data collection that will continue to take place at the mock pad site, the area will be used as a demonstration site for bureau staff, regulators, gas operators, and the public. When this project was proposed, the intent was to use this site to develop field-tested management guidance for use on and off state forest lands in areas being developed for unconventional gas. The bureau is committed to adaptive management on state forest lands in all facets of gas development, including site restoration and reclamation. By demonstrating these next-level management practices, the bureau and cooperators from Penn State believe that guidelines that improve ecological function in and around gas development areas using native plants are now feasible across the commonwealth.

Website Links

[1] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032134.pdf

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Chapter V. Ecosystem Condition

Key Points

- Impacts to stream water quality from shale gas development at the sampled water monitoring sites were not detected for the period of 2008-2016.
- Over 85 percent of streams in the core gas forest districts are classified as Exceptional Value (EV) or High Quality (HQ).
- In response to stakeholder feedback and recommendations, bureau monitoring staff has been certified to collect aquatic macroinvertebrates for monitoring water quality.
- Twenty-four of 37 macroinvertebrate collection sites sampled by the department had IBI (Index of Biotic Integrity) score comparisons that were within tolerance. DEP has conducted follow-up work on three of 13 sites that were identified as falling outside of comparison tolerances and found the scores have rebounded.
- Short-term air quality studies by DEP have demonstrated that gas-related compounds, particularly odor-causing compounds, are present near shale gas operations.
- As of December 2016, 238 infrastructure pads and an additional 66 associated access roads have been surveyed for invasive plant species. Bull thistle, crown-vetch, and spotted knapweed were the top three encountered invasive plant species.
- The most abundant invasive plant species (based on average percent cover) on rights-of-way were Japanese stiltgrass, crown-vetch, tall fescue, and Canada thistle.
- Only 29 infrastructure pads out of 238, or 12.1 percent of all pads, were found to be free of invasive plant species. The most common invasive species found were bull thistle (142 pads), crown-vetch (98), and spotted knapweed (91).
- Early Detection and Rapid Response efforts from 2013-2016 have resulted in detection of 71 populations of high-threat invasive plants.
- Three of ten Post Construction Stormwater Management (PCSM) structures were monitored and found to contain amphibian eggs indicating they hold water long enough for breeding.
- Of the five road culverts assessed for facilitating aquatic organism passage, three were rated as allowing limited aquatic organism passage and two were rated as allowing full aquatic organism passage. No assessed culverts blocked all aquatic organism passage.

Introduction

The bureau monitors state forests for changes and impacts to water, air, soil, flora, wildlife, and forest health related to gas development. Changes in each of these facets of forest ecosystems can provide indications of effects to forests due to natural gas development.

Water

The development of shale gas wells requires large amounts of freshwater; typically, 5 million gallons per well. Due to economic and logistic constraints, the source for much of this water is local – drawn from nearby streams or groundwater wells. Most forest land within the core gas forest districts drain to the Susquehanna River (97.7 percent), with a small portion flowing to the upper Allegheny River. Because of this, freshwater use for shale gas development on state forest lands is primarily regulated by the Susquehanna River Basin Commission (SRBC). Accordingly, the bureau depends on SRBC to properly manage the extraction of freshwater from streams that flow within and through state forest lands within the basin. Additionally, Act 13 requires all gas well applicants to submit and obtain a water management plan from DEP, outlining where water will be obtained, how water will be reused, and wastewater treatment plans. Presently, there are no groundwater withdrawals for shale gas development on state forest leases. More information on SRBC's project review regulations, which apply to shale gas development, can be found at SRBC's[1] website.

DEP estimates that approximately 3,500 miles of stream traverse state forest lands within the core gas forest districts, including many of the best-known fishing and boating waters in Pennsylvania. Maintaining and protecting the quality of water in these streams is one of the bureau's highest priorities. Therefore, one of the objectives of the shale gas monitoring program is to evaluate the potential effects of shale gas development on water resources within state forest lands.

Most streams found on state forest land are similar to this first-order stream.

As described in the first Shale-Gas Monitoring Report, streams and rivers in Pennsylvania can be classified in several ways. One informative classification is stream order, which is the position of a stream within the hierarchy of tributaries in a drainage network. Table 5.1 and Figure 5.1 provide the distribution of stream orders on state forest lands in the core gas forest districts. It is important to note that stream mileages vary according to the data source and scale used by the jurisdictional agency that manages the classification. Most of the streams (>70 percent) are first-order streams. This means that the streams on state forest land are generally small, headwater streams that can be influenced greatly by the surrounding forest. These first-order streams have the potential to affect many others downstream.

Another important stream designation is that promulgated under Chapter 93 of DEP regulations. Chapter 93 pertains to water quality standards and protected uses of state waters. The water uses protected under Chapter 93 for a given water body are designated within the regulations (i.e., in a list of streams found throughout the state) and the designation from this classification can be updated by DEP if deemed appropriate based on new data. Based on the rules and criteria, this DEP classification system represents a good indicator of both the quality of a water body and the protection it receives under regulations. Table 5.2 and Figure 5.2 show the DEP Chapter 93 classification of streams throughout the shale gas forest districts. Over 85 percent of stream miles fall within one of the higher protection waters, i.e., High Quality (HQ) or Exceptional Value (EV). The total number of stream miles is greater for this dataset than for the NHD Plus Stream Order dataset because a finer scale of mapping is used.

Stream Order	Miles of Stream	Percentage of Stream Miles
1st	1,570.4	72.3%
2nd	379.6	17.5%
3rd	170.5	7.8%
4th	27.9	1.3%
5th	25.0	1.2%
Total	**2,173.4**	**100.0%**

Table 5.1. Distribution of stream orders within the core gas forest districts.

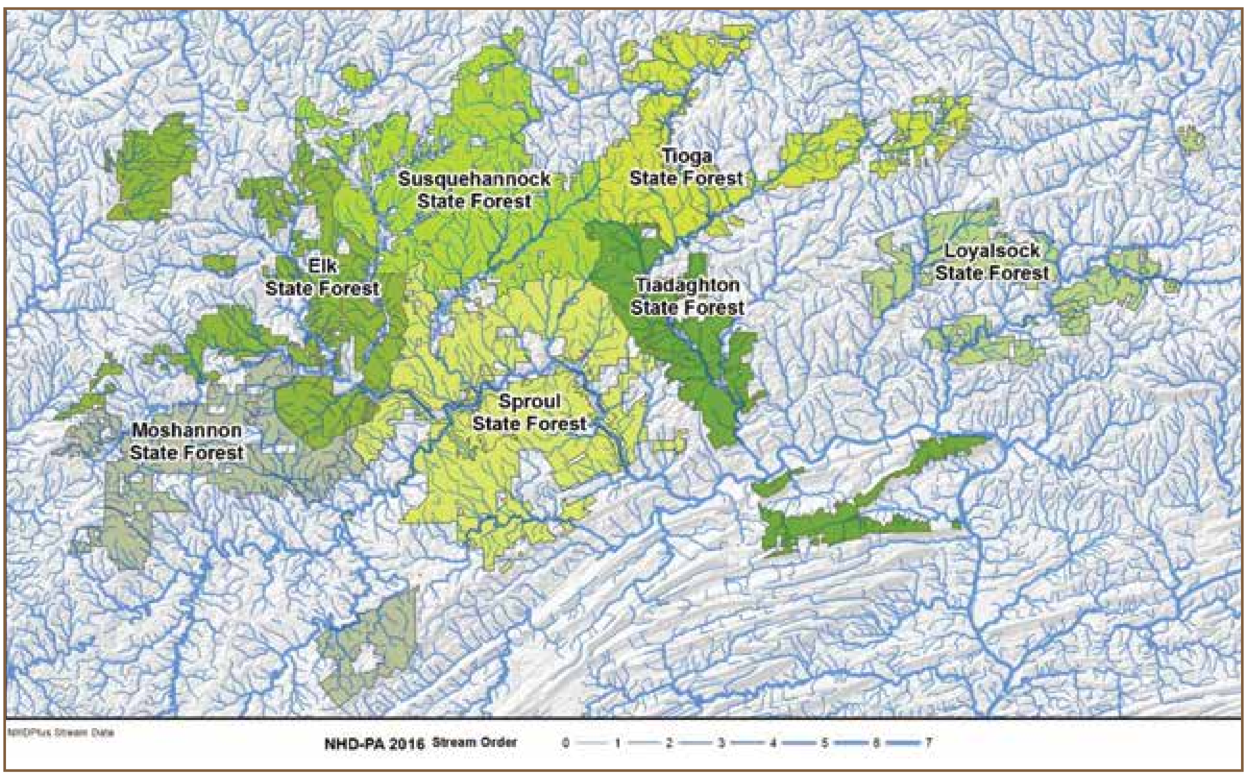


Figure 5.1. Map of stream orders of the shale gas forest districts based on the U.S. Environmental Protection Agency's National Hydrography Dataset Plus, 2016.

Chapter 93 Classification	Miles of Stream	Percentage of Stream Miles
WWF (WARM WATER FISHES)	2.8	0.1%
TSF (TROUT STOCKING)	36.3	1.0%
HQ-TSF (HIGH QUALITY-TROUT STOCKING)	2.6	0.1%
HQ-CWF (HIGH QUALITY-COLD WATER FISHES)	1348.7	39.0%
EV (EXCEPTIONAL VALUE)	1685.5	48.7%
CWF (COLD WATER FISHES)	386.1	11.2%
Total	**3462.1**	**100.0%**

Table 5.2. Classification of streams within the shale gas forest districts based on Pennsylvania Department of Environmental Protection Regulations Chapter 93 designations.

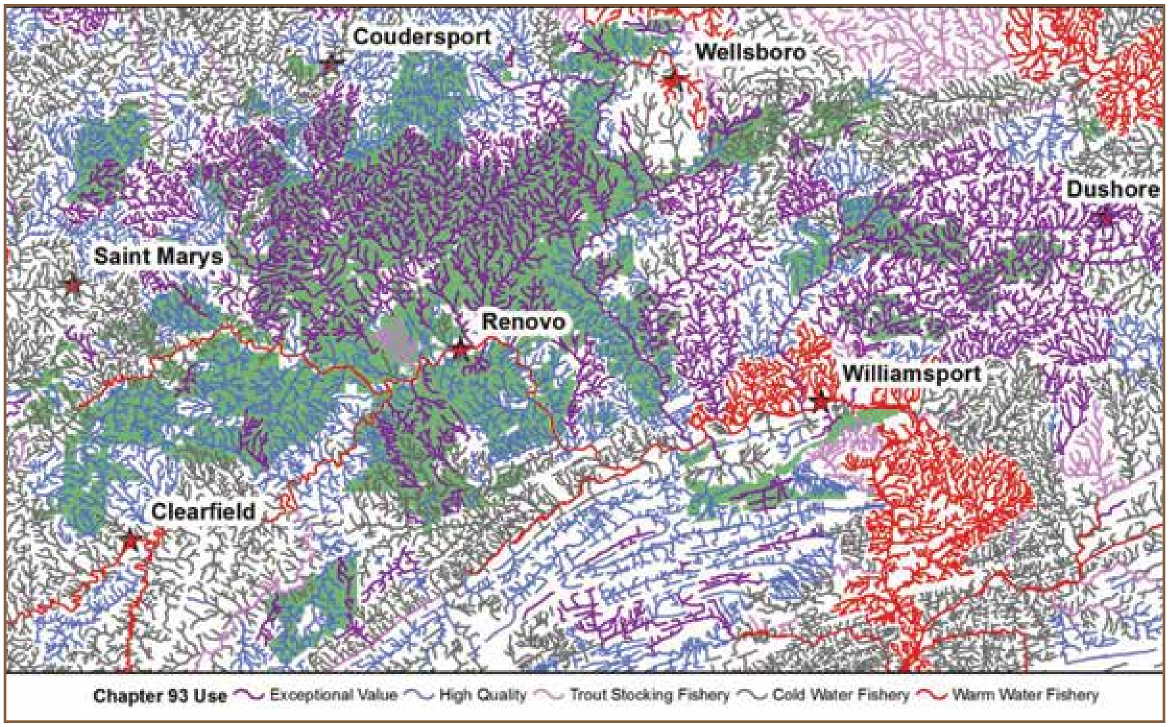


Figure 5.2. Map of streams in the shale gas forest districts with Pennsylvania Department of Environmental Protection Regulations Chapter 93 designations.

A third important stream classification is based on designations by the PA Fish and Boat Commission (PFBC). PFBC classifies certain water bodies in several ways, including trout-stocked streams, naturally reproducing trout streams, Class A wild trout streams, and wilderness trout streams. These PFBC classifications are valuable not only as an indicator of the health of the trout population, and thereby of the water quality, but also as an indicator of the recreational experience available to state forest users. Table 5.3 and Figure 5.3 show the PFBC trout classification of streams throughout the shale gas forest districts.

Water Quality Monitoring

The main concerns regarding water quality in areas subject to gas development are from chemicals and salts that can be spilled during transportation or during

PFBC Classification	Miles of Stream	Percentage of Stream Miles
Trout-stocked	287.1	10.3%
Naturally Reproducing Wild Trout	1,953.5	70.1%
Class A Wild Trout	421.2	15.1%
Wilderness Trout	126.0	4.5%
Total	**2,787.8**	**100.0%**

Table 5.3. Classification of streams within the shale gas forest districts based on the Pennsylvania Fish and Boat Commission designations.

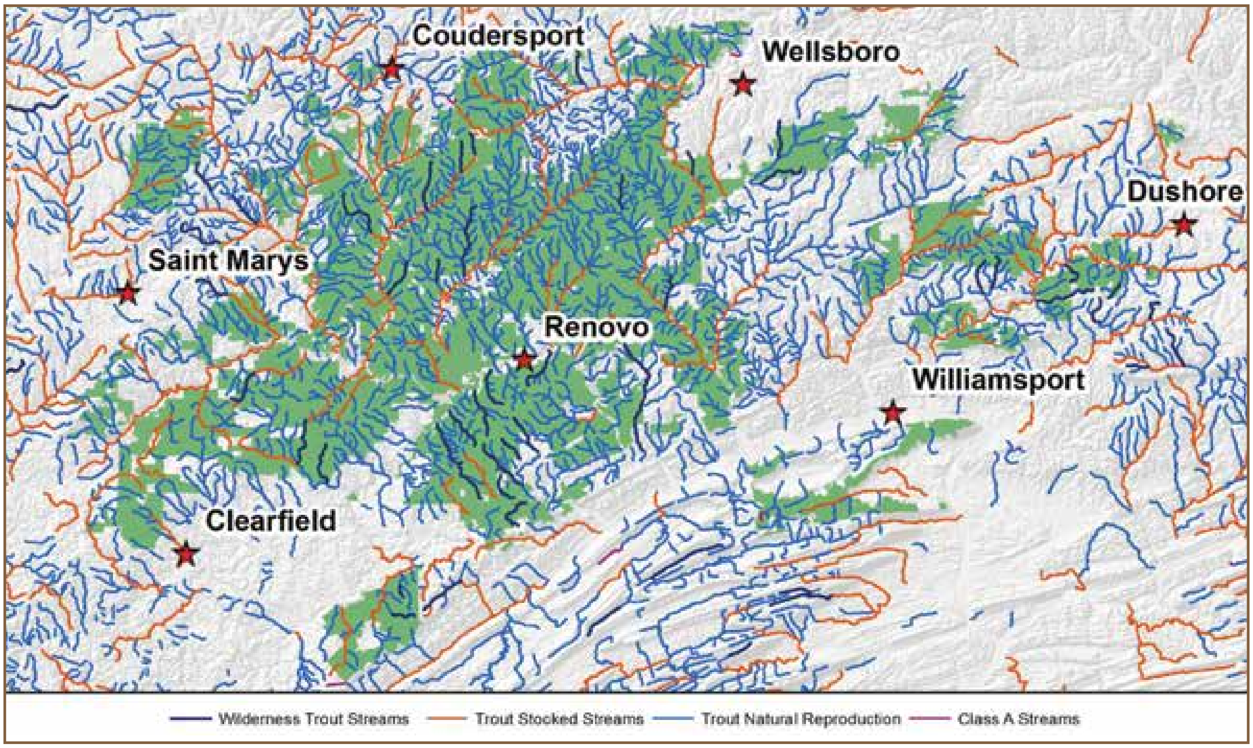


Figure 5.3. Map of streams in the shale gas forest districts with Pennsylvania Fish and Boat Commission designations.

drilling activities. Increases in water temperature, soil erosion, sedimentation, and turbidity (a measure of water's relative clarity or cloudiness) from construction of infrastructure and roads improved to accommodate heavy hauling also pose concerns. Existing monitoring is in place to attempt to detect water chemistry changes that may be due to these and other shale gas development activities on state forest lands.

Shale Gas Related Chemicals

During the hydraulic fracturing process, water is mixed with fracturing fluids and proppants, which is a solid material, typically sand, that hold open the fractures within the tightly bedded shales allowing gas to flow from higher to lower pressure areas. This mix of water and chemicals is injected into wells to release gas from the shale. These fracturing fluids can pose a potential spill risk during transportation to well sites or during well development operations. Monitoring for such potential impacts is achieved in two ways: by inspecting the pad and operations occurring on site and by conducting more testing at sites identified for additional monitoring, such as testing nearby waters for the materials of concern (e.g., hydrocarbons and glycols). In addition to the monitoring performed by the bureau, DEP enforces regulations regarding spills at well sites. DEP may perform or require an operator to perform additional monitoring related to a specific spill event. It should also be noted that DEP adopted significantly enhanced well construction and casing and cementing standards to protect water supplies in 2011.

Once the well is completed, 10 to 30 percent of the water used in the process returns to the surface and must be reused or disposed. This water is typically referred to as flowback water. Flowback water contains hydraulic fracturing fluids as well as other chemicals, such as metals (e.g., barium and strontium) and salts (e.g., chloride and bromide), that are picked up from the shale formation while the water is underground. These metals and salts can also be found in some waterways as certain rock formations at the surface are weathered through natural erosion processes. Approximately 70 to 90 percent of the injected water remains in the shale formation with only a small percentage returning to the surface with the flowing gas. The returned water is removed from the gas with dehydration units at the pad site and stored in steel tanks. This formation water may or may not have similar characteristics to flowback water.

Preparing Water Samples for Testing.

Monitoring streams for the presence of fracturing fluids or flowback water can be achieved in two ways. First, water samples can be tested by accredited laboratories for the presence of metals and other chemicals typically known to occur in flowback water. The bureau's continuous in-stream monitoring (BOF CIM), the DEP continuous in-stream monitoring (DEP CIM), the SRBC Remote Water Quality Monitoring Network (RWQMN), and the USGS Toxic Substances Hydrology Program (TSHP) collect surface water grab samples that are tested for the presence of these chemicals. Second, waters can be tested for more general parameters, such as total dissolved solids or specific conductance, that serve as indicators of the high salinity typically associated with flowback water. The metrics are measured using the bureau's widespread water sampling protocol, continuous monitoring devices, the DEP CIM, the RWQMN, and the TSHP. These general parameters can indicate potential problems, which will then necessitate more specific tests to be completed to better identify and isolate any sources of contamination. Water chemistry is dynamic and complex, often requiring more frequent and sophisticated testing methods to attempt to identify where contamination originated. However, the bureau's monitoring program and its partners are positioned to find irregularities in water quality and initiate the necessary steps to identify the source of the change.

Most streams within northcentral Pennsylvania forests will have good water quality with relatively low conductivity, cool temperatures, and moderate pH. This general observation allows the use of expected ranges for these parameters which can be compared to measured values. Values that fall outside of expected ranges may require a more intensive inspection by the bureau and/or DEP.

Erosion and Sedimentation Associated with Development

Throughout the shale gas development process, there are numerous occasions where land clearing or earth disturbance is required, such as pad, road, and pipeline construction. Each of these construction activities requires an erosion and sedimentation control permit from DEP. DEP monitors the installation and maintenance of erosion and sedimentation control measures. Monitoring for sediment pollution, which can affect aquatic organisms such as benthic macroinvertebrates and fish, can be conducted by testing waters for the content of suspended sediment or by testing waters for turbidity. These characteristics are measured using the DEP CIM, RWQMN, TSHP and the bureau's macroinvertebrate sampling. Lastly, erosion potential can be assessed at the source by examining conditions on-the-ground, such as vegetative cover and the effectiveness of erosion and sedimentation control measures. Figure 5.4 provides a visual overview of the bureau's water monitoring program outlining ongoing work completed by field crews on the Shale Gas Monitoring Team as well as work completed by other organizations that partner with the bureau (External Partnerships & Collaborations).

Macroinvertebrate collection.

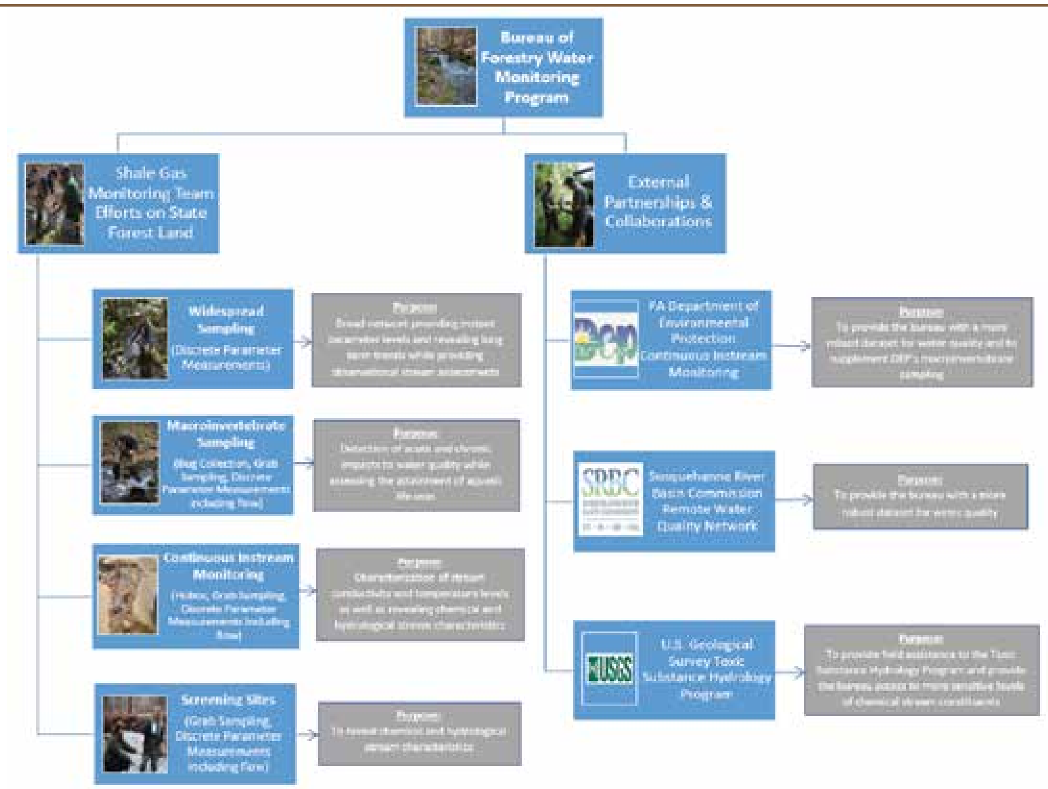


Figure 5.4. Overview of the bureau's water monitoring program.

BOF Continuous In-stream Monitoring (CIM)

The bureau deployed CIM devices at select sites on 18 different streams in the Loyalsock and Tiadaghton State Forests between 2013-2016 (Figure 5.5). Devices (manufactured by Onset Computer Corporation called a "Hobo") collected temperature and conductivity data on 15-minute intervals along with periodic field chemistry, surface water grab samples, and flow measurements collected by on-site field staff. As described in the 2014 Shale-Gas Monitoring Report, field chemistry, grab sampling, and flow measurements are employed to obtain a discrete analysis of chemical constituents and flow at a given point in a stream. Field chemistry is collected using a YSI ProPlus multi-parameter meter to measure the following parameters: temperature, pH, dissolved oxygen, conductance, and specific conductance. A Hach 2100Q is used to measure turbidity. Grab samples are collected in bottles and sent to the DEP Bureau of Laboratories for analysis on a specified suite of parameters (Table 5.4). Flow measurements are taken using a Hach FH950 flow meter and top-set wading rod. The flow meter is then able to calculate a flow/discharge rate based on the USGS mid-section method (Rantz, 1982).

A continuous in-stream monitoring device utilized by the bureau, called a "Hobo", shown here deployed in a stream and out for cleaning during a maintenance visit.

Grab Sampling Parameters
Specific Conductance
pH
Alkalinity
Barium
Strontium
Chloride
Bromide
Total Suspended Solids
Total Dissolved Solids
Methane

Table 5.4. List of parameters tested for grab samples collected at Bureau of Forestry continuous in-stream monitoring sites. Samples were tested by the Pennsylvania Bureau of Laboratories.

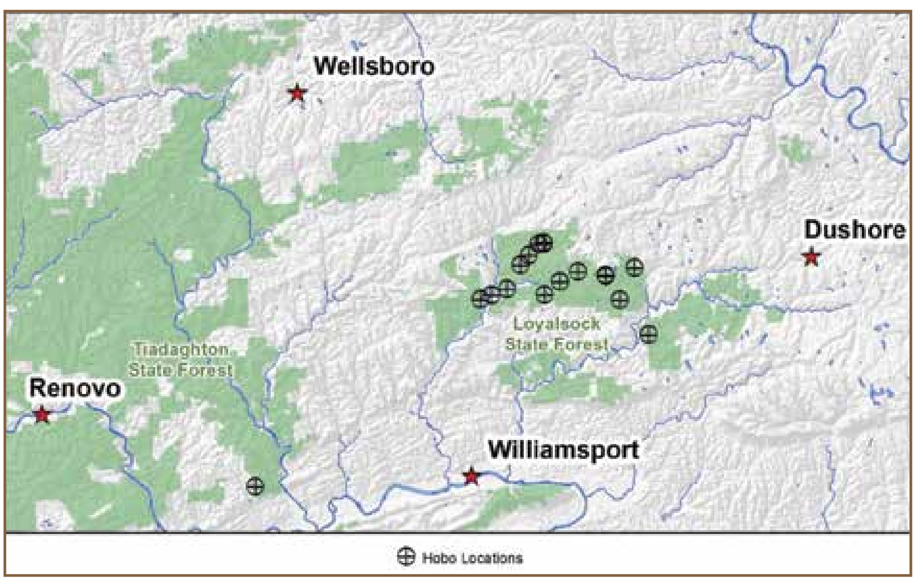


Figure 5.5. Deployment sites of Pennsylvania Bureau of Forestry continuous in-stream monitoring devices (Hobos).

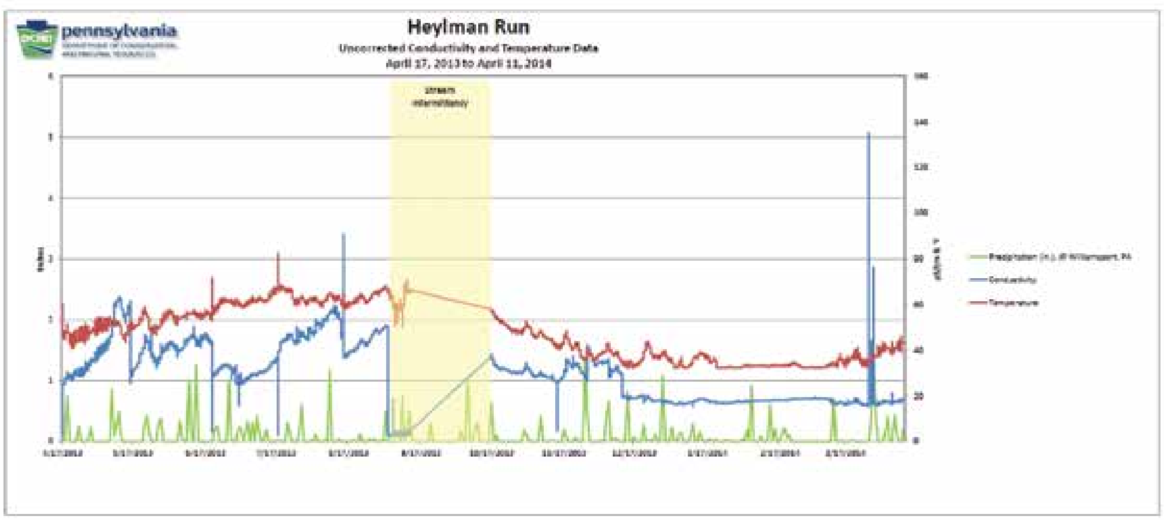
Over the four-year period that Hobos were deployed in the various streams, there were no occasions requiring more intensive monitoring of these streams. The report for Heylman Run is found in Figure 5.6 and links to other reports can be found in Table 5.5.

Note that data in the reports are uncorrected and the spikes in temperature and conductivity coincide with Hobo maintenance visits. All results and analyses were consistent with expectations of each stream and within levels of concern.

Collecting a water grab sample.

DEP Continuous In-stream Monitoring (CIM)

The DEP Division of Water Quality Standards uses deployable instream monitors called "Sondes" that collect measurements on a near-continuous basis. DEP commonly configures instream monitors like Sondes to measure four parameters: water temperature, specific conductance, pH, and dissolved oxygen. Monitors can also be configured to measure additional stream properties such as turbidity and water depth. DEP has developed protocols based on the USGS Guidelines and Standard Procedures for Continuous Water Quality Monitors: Station Operation, Record Computation, and



Water Chemistry	pH (accept. range - 5.0 to 9.0)	Specific Conductivity* (umhos/cm) (LOC** - >800) RL*** - 1	Dissolved Oxygen (mg/L) (LOC** - <4.0)	Turbidity (NTU) (LOC** - >50)	Flow (cfs)	Alkalinity* (mg/L)	Barium* (ug/L) (LOC** - >2000)	Bromide* (mg/L)	Strontium* (ug/L) RL*** - 10	Chloride-ion* (mg/L) (LOC** - >250) RL*** - 0.5	Total Dissolved Solids* (mg/L) (LOC** - >500) RL*** - 5	Total Suspended Solids* (mg/L) RL*** - 5	Methane* (ug/L) RL*** - 11.6
min	5.8	28.7	4.4	0.3	0.0	5.4	15	0.2	13	0.5	5	5	25.3
max	6.86	49.2	13.1	2.1	2.9	5.4	25	0.2	22	1.4	50	12	25.3
avg	6.4	36.9	9.9	0.9	0.7	5.4	20.8	0.2	16.9	0.9	29.9	5.9	25.3
# obs (n)	10	12	10	9	10	1	12	11	12	12	12	12	1

* Values determined through analysis by PA DEP Bureau of Laboratories.
** LOC – level of concern. Values from 25 Pa. Code § 93.
*** RL – reporting limit for PA DEP Bureau of Laboratories.

Figure 5.6. Report from a Pennsylvania Bureau of Forestry continuous in-stream monitoring device (Hobo) site on Heylman Run showing conductivity/temperature data and summarized periodic discrete and grab sample results.

Forest District	Stream	Report Link
Loyalsock	Bear Trap Hollow Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032826.pdf
Loyalsock	Big Dry Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031147.pdf
Loyalsock	Bovier Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031146.pdf
Loyalsock	Buck Run Conductivity Data, 2015	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031145.pdf
Loyalsock	Butternut Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031144.pdf
Loyalsock	Doe Run Conductivity Data, 2015	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031143.pdf
Loyalsock	Doe Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032831.pdf
Loyalsock	East Branch Mill Creek Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031157.pdf
Loyalsock	Hawk Run Conductivity Data, 2015	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031156.pdf
Loyalsock	Hawk Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032830.pdf
Loyalsock	Heylman Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031155.pdf
Loyalsock	Little Dry Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031154.pdf
Loyalsock	NB Rock Run Conductivity Data, 2015	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031153.pdf
Loyalsock	Pleasant Stream Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032828.pdf
Loyalsock	Pleasant Stream Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032827.pdf
Loyalsock	Potash Hollow Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032825.pdf
Loyalsock	Potash Hollow Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032824.pdf
Loyalsock	Rock Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031151.pdf
Loyalsock	Rock Run Conductivity Data, 2015	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031152.pdf
Loyalsock	Rock Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032823.pdf
Loyalsock	Rock Run Conductivity Data, 2016	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20032829.pdf
Tiadaghton	UNT Chatham Run Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031149.pdf
Loyalsock	UNT Mill Creek Conductivity Data, 2014	http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_20031150.pdf

Table 5.5. Continuous in-stream monitoring device (Hobo) reports.

Data Reporting Manual (Wagner et al., 2006). This allows DEP to produce verified data that will be used to assess water quality for aquatic life use. Aquatic life is grouped into use categories, each having its own water quality standards. Aquatic life use assessments determine and/or verify that surface water is meeting the water quality standards and maintaining the conditions necessary to support that category of aquatic life.

A continuous in-stream monitoring device utilized by PA DEP, called a "Sonde", shown here during a maintenance visit.

The bureau has partnered with DEP to implement continuous instream monitoring (CIM) at 13 sites on state forest lands (Table 5.6). Initial efforts in 2010, including Horton Run in the East Fork Sinnemahoning basin, were one-year deployments to complete aquatic life use assessments as well as documenting baseline conditions prior to any oil and gas development activities. Since 2010, nine of these one-year deployments have been implemented on or near state forest lands. In addition, most recent and ongoing deployments on Rock Run (a tributary to Lycoming Creek) in Lycoming County, Hyner Run in Clinton County, Pine Creek in Lycoming County, and Kettle Creek in Potter County have been implemented as part of the DEP Water Quality Network (WQN). This allows DEP to monitor these sites for a minimum of five years with the addition of routine biological and chemical monitoring.

CIM baseline results indicate that the targeted deployment locations are pristine surface waters with little to no impacts to water quality. The results will be used in future monitoring efforts to determine any changes in water quality over time. DEP publishes CIM reports on its webpage[2].

Stream Name	County	District	Period
Horton Run	Potter	Susquehannock	Spring '10 - Spring '11
Kettle Creek	Potter	Susquehannock	Fall '10 - Present
Asaph Run	Tioga	Tioga	Spring '12 - Spring '13
Straight Run	Tioga	Tioga	Spring '12 - Spring '13
Canada Run	Tioga	Tioga	Spring '12 - Spring '13
Hyner Run	Lycoming	Sproul	Summer '14 - Present
Pine Creek	Lycoming	Tiadaghton	Fall '10 - Present
Wallis Run	Lycoming	Tiadaghton	Summer '11 - Summer '12
Browns Run	Lycoming	Tiadaghton	Fall '12 - Fall '13
Grays Run	Lycoming	Tiadaghton	Fall '12 - Fall '13
Rock Run	Lycoming	Tiadaghton	Summer '14 - Present
Loyalsock Creek	Lycoming	Loyalsock	Summer '08 - Summer '13
Clear Shade Creek	Somerset	Gallitzin	Summer '11 - Summer '12

Table 5.6. Pennsylvania Department of Environmental Protection continuous in-stream monitoring sites on or near state forest lands.

SRBC Remote Water Quality Monitoring Network (RWQMN)

Within the shale gas region there are ten SRBC RWQMN stations on state forest land (Figure 5.7) and an additional six with catchment areas that substantially drain state forest land (Table 5.7 and Figure 5.8). These stations were installed in 2011 and are part of a larger network of >60 stations in the Susquehanna River Basin. The SRBC RWQMN is a network of continuous in-stream monitoring devices (Sondes) that monitor pH, temperature, dissolved oxygen (DO), specific conductance, and turbidity at 15-minute intervals. The locations have telemetry capabilities which enable data to be transmitted and posted directly to the SRBC website[3] on an approximate "real-time" basis.

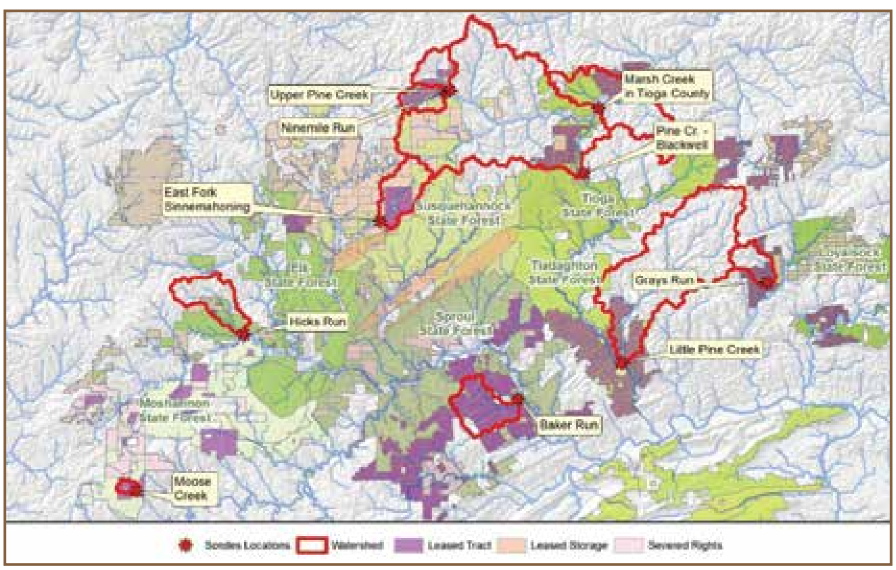


Figure 5.7. Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations on state forest land.

Watershed	Percent Forest Cover	Percent of Watershed Comprised of State Forest Land	Monitored Drainage Area (mi²)
	(*sonde located on state forest land*)		
Baker Run	99	86	35
East Fork Sinnemahoning Creek	89	94	33
Grays Run	94.5	34	16.2
Hicks Run	92	34	34.1
Little Pine Creek	83	13	180
Marsh Creek in Tioga County	71.5	34	78
Moose Creek	95	98	3.3
Ninemile Run	84.5	73	15.7
Pine Creek	80.4	36	385
Upper Pine Creek	75	28	18.6
	(*sonde located off of state forest land*)		
Hunts Run	90.8	74	30.7
Kettle Creek	80.4	68	81.2
Pleasant Stream	88.8	82	20.6
Sterling Run	89.5	11	24.5
West Branch Pine Creek	86.4	67	70
Young Womans Creek	96.8	98	41

Table 5.7. Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations on or near state forest land.

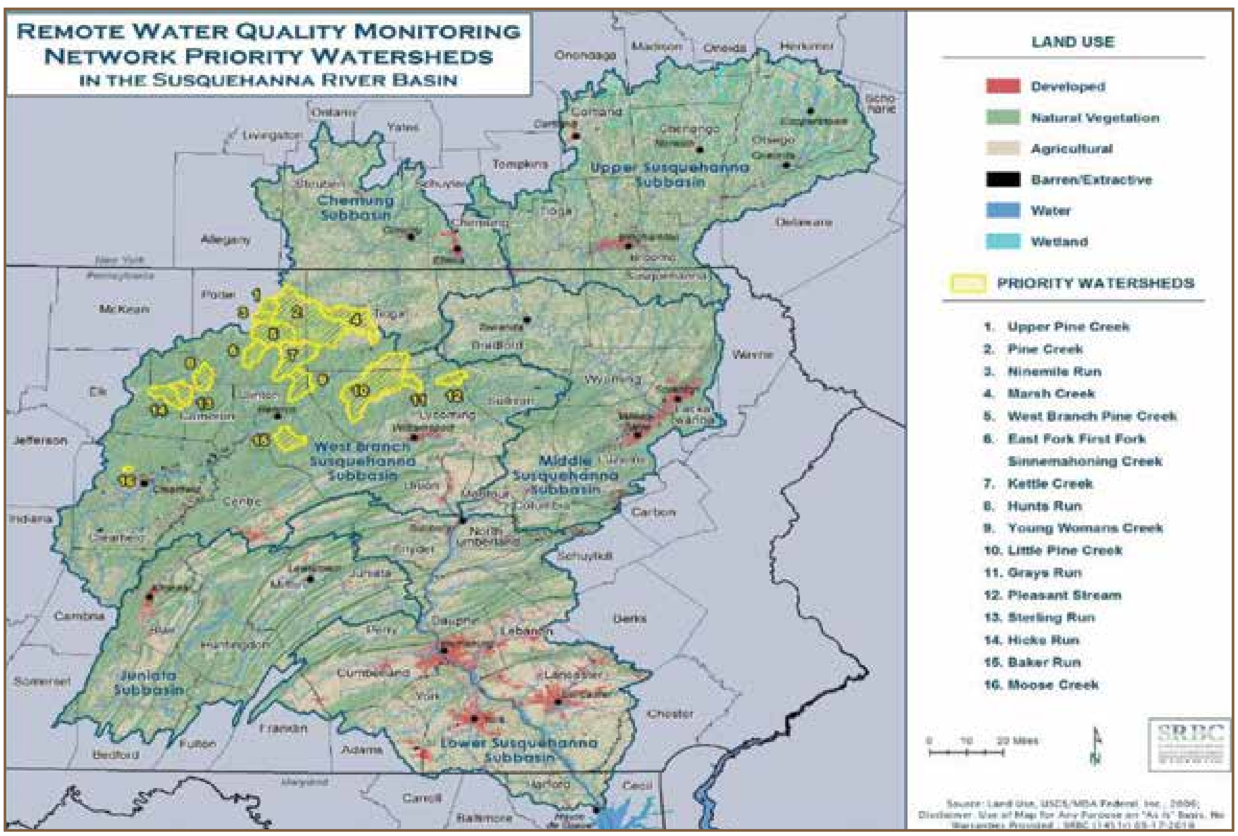


Figure 5.8. Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations in the shale gas region on or near state forest land.

SRBC has brought three of the five continuous parameters collected at these stations to the forefront of the discussion regarding natural gas drilling in the Susquehanna River Basin: specific conductance, turbidity, and water temperature (Table 5.8). Overall, continuous parameter levels captured from the Sondes were found to be consistent with anticipated levels of the densely-forested watersheds where the stations are located. The few stations that showed some drift from "normal" were understood by taking a closer look at the natural circumstances surrounding the watershed. For example, Marsh Creek in Tioga County showed an average specific conductance value of 175 µS/cm. However, the station is located downstream of Wellsboro which has numerous permitted discharges. This is not an unexpected observation. Marsh Creek also features the highest average turbidity value at 20.595 NTU. It is a slow, meandering stream impacted by agriculture and urban influences. For more information about the other stations showing some drift from "normal" see RWQMN – DCNR Technical Summary (June 2016)[4].

Watershed	Specific Conductance (µS/cm)	Turbidity (NTU)	Temperature (°C)
(sonde located on state forest land)			
Baker Run	28	4.35	9.201
East Fork Sinnemahoning Creek	43	2.939	9.47
Grays Run	31	2.911	9.262
Hicks Run	53	8.441	9.841
Little Pine Creek	119	4.506	11.488
Marsh Creek in Tioga County	175	20.595	10.644
Moose Creek	150	2.192	8.909
Ninemile Run	59	6.796	9.357
Pine Creek	89	23.843	10.198
Upper Pine Creek	79	3.457	9.437
(sonde located off of state forest land)			
Hunts Run	35	2.639	8.899
Kettle Creek	56	4.205	9.728
Pleasant Stream	38	5.559	8.845
Sterling Run	78	5.647	9.625
West Branch Pine Creek	47	5.415	10.412
Young Womans Creek	39	2.012	9.149

Table 5.8. Average continuous parameter values from Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations.

Along with CIM at these stations, quarterly water grab samples are also collected. These samples represent a point-in-time and are analyzed for metals, nutrients, major cations and anions, and radionuclides to monitor stream conditions. A total of 26 water chemistry parameters are analyzed in the grab samples (Table 5.9).

Water Chemistry Parameters	
Alkalinity	Lithium
Alkalinity, Bicarbonate	Magnesium
Alkalinity, Carbonate	Manganese
Aluminum	Nitrate
Barium	pH
Bromide	Phosphorus
Calcium	Potassium
Carbon Dioxide	Sodium
Chloride	Specific Conductance
Gross Alpha	Strontium
Gross Beta	Sulfate
Hot Acidity	Total Dissolved Solids
Iron	Total Organic Carbon

Table 5.9. List of water chemistry parameters tested from grab samples collected at Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations.

Of the 26 water chemistry parameters collected, only three parameters exceeded the level of concern. Nitrate exceeded the level of concern at two stations and sodium was found exceeding the level of concern at one station.

These occurrences were found in watersheds with particular circumstances that influence these results. For example, Moose Creek in Clearfield County was found exceeding the water quality standard for sodium (20 mg/L). It had an average concentration of 21.9 mg/L. One source of sodium to water includes road salt. Considering land use and activities in Moose Creek, road salt is the likely source of sodium to the system as Interstate 80 borders the watershed. In addition, low alkalinity (<20 mg/L) was found at 14 of the 16 stations, but this is not unexpected due to the naturally low buffering capacity of most headwater streams. For more details see RWQMN – DCNR Technical Summary (Jun2016)[4].

Dam Run in the Tiadaghton State Forest, Lycoming County.

BOF Widespread Sampling

In 2011, 345 sampling points were established across state forest land in the core gas forest districts to get an initial qualitative visual inspection of many stream reaches along with basic field chemistry measurements. Locations were selected based on geographic extant and proximity to existing or planned shale gas development pads (Figure 5.9). From 2012 to 2016, new sites were added, and original sites have been revisited based on field crew availability (Table 5.10). Since 2011, there has been a total of 807 individual site visits among 368 sample locations. As of 2016, a revisit schedule has been developed to ensure each watershed that may be affected by gas development is entered annually and no sampling location goes longer than three years between visits.

Stream reach characteristics and field chemistry data are collected during the visits. The qualitative visual assessment of the stream reach includes noting stream bank erosion, odors, or any stream characteristics that are out of the ordinary. This is extremely important as many of the sampling locations are in areas that are not traversed by bureau staff on a regular basis. Additionally, parameters such as pH, conductivity, and temperature are collected using an YSI Professional Plus device along with a surrogate measure of stream flow (estimated by measuring stream width and average stream depth). Alkalinity was collected for a brief time using handheld colorimeters, but due to the naturally very low alkalinity concentrations found in most of the streams in the shale gas region and error observed in colorimeters, it will be very difficult to establish long-term trends. Therefore, the bureau no longer uses colorimeters to collect alkalinity at widespread sampling points.

Water testing at a widespread sampling location.

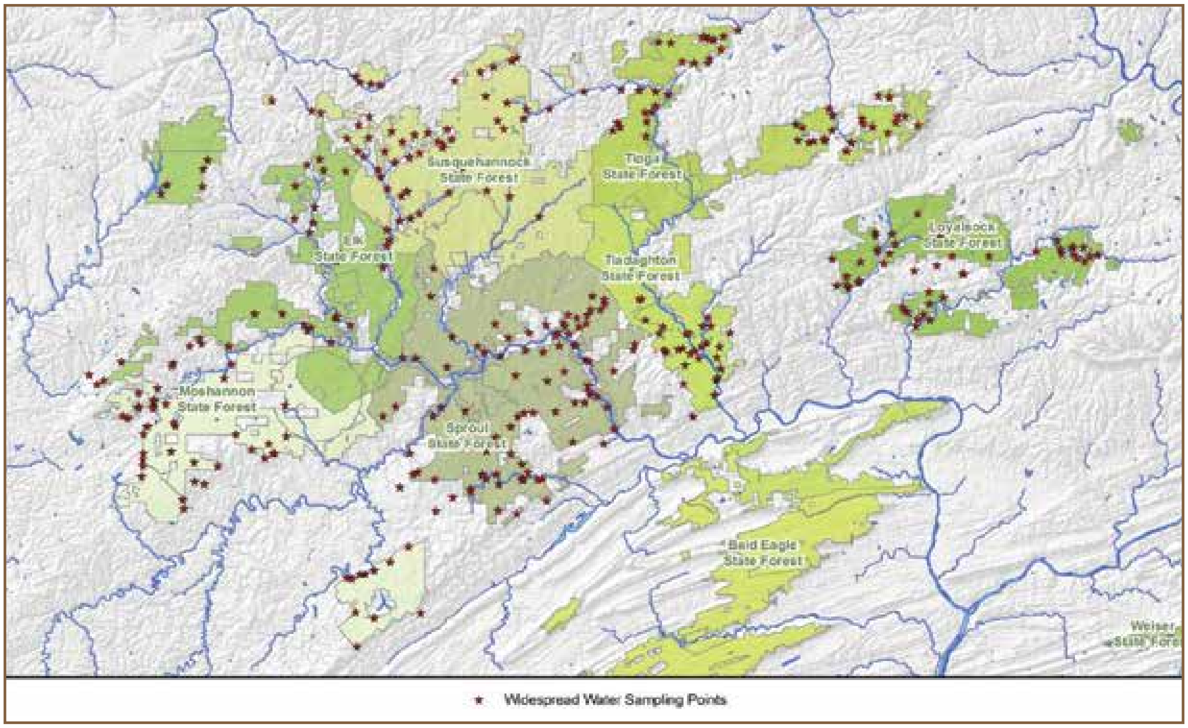


Figure 5.9. Widespread water sampling point locations on state forest lands.

Forest District	Year 2011	2012	2013	2014	2015	2016	Total Number of Sampling Sites	Total Number of Visits
Moshannon	50		23	20	20	11	51	124
Sproul	83	1	30	20	35	22	84	191
Tiadaghton	28	16	5	8	12	5	40	74
Elk	38		14	17	18	12	40	99
Susquehannock	56		11	14	23	12	56	116
Tioga	49	5	18	6	19	16	52	113
Loyalsock	41		8	8	17	16	45	90
Total	345	22	109	93	144	94	368	807

Table 5.10. Sampling frequency of widespread water sampling points by forest district.

From the visual qualitative stream reach inspections, there have not been any issues noted that have warranted a more intensive inspection of the stream.

During the most recent visit to the 368 sample locations, measurements indicate that most of the streams were within acceptable pH ranges (Table 5.11). Greater than 75 percent of the site locations fall within the circumneutral (pH 6.5 – 7.5) range. The extremes were a high of 8.17 and a low of 2.82. Sites where pH measures below five, were in streams that DEP has deemed impaired. This suggests that the low pH values are attributed to abandoned mine drainage or atmospheric deposition.

In general, a large majority of streams in the shale gas forest districts experience conductivity levels below 100 µS/cm. During the most recent visit to the 368 sample locations, conductivity measurements indicate that approximately 99.5 percent of the most recent conductivity measurements were under 500 µS/cm (Table 5.12 and Figure 5.10). The 500 µS/cm threshold is commonly considered the high end for supporting diverse aquatic life in freshwater streams. The two sites that were over 500 µS/cm were streams that are listed by DEP as being impaired. The distribution of conductivity is shown graphically in Figure 5.10.

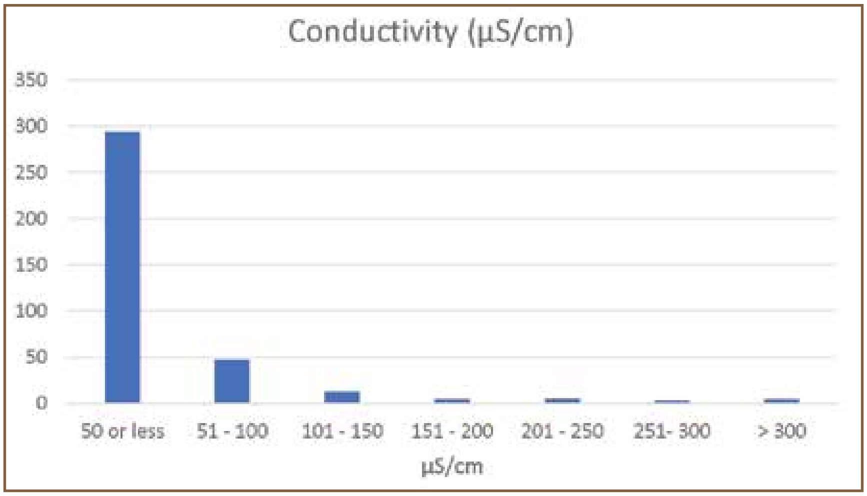


Figure 5.10. Conductivity measurements at water sample points collected since baseline year 2011.

Forest District	Circumneutral 6.5 - 7.5 pH Range	6.5 - 8.0 pH Range	5.0 - 9.0 pH Range
Moshannon	57%	57%	88%
Sproul	73%	74%	90%
Tiadaghton	88%	90%	98%
Elk	90%	90%	98%
Susquehannock	96%	100%	100%
Tioga	67%	67%	85%
Loyalsock	76%	78%	98%
All Locations	77%	79%	93%

Table 5.11. Percentage of water sample points within acceptable pH ranges by forest district.

Forest District	µS/cm							Total Sites
	50 or less	51 - 100	101 - 150	151 - 200	201 - 250	251- 300	> 300	
Moshannon	34	8	3	2	2		2	51
Sproul	69	6	3		3	1	2	84
Tiadaghton	32	5	3					40
Elk	31	7	1	1				40
Susquehannock	41	15						56
Tioga	43	5	2	1		1		52
Loyalsock	44	1						45
All Locations	294	47	12	4	5	2	4	368

Table 5.12. Conductivity measurements at water sample points, by forest district, since baseline year 2011.

Macroinvertebrate Sampling

Varying species of benthic macroinvertebrates (i.e., bottom-dwelling organisms in a stream that lack backbones and are visible to the naked eye) can tolerate a wide variety of water conditions. Sensitive species require prolonged periods of high quality water with very low concentrations of pollutants (like sediments, metals, and nutrients) to maintain healthy and diverse communities. Other species can thrive in and dominate communities where water conditions are relatively heavy with pollutants.

By examining the macroinvertebrate communities in a stream, an IBI score can be calculated to determine the health of the community and thereby infer the quality of the stream water. IBI scores range from 0-100, with higher scores indicating a healthy and diverse community and lower scores indicating a compromised community. In 2013, DEP developed a macroinvertebrate IBI for use in evaluating the biological health of Pennsylvania's wadable freestone, riffle-run streams which dominate the shale gas forest districts (PADEP, 2013).

The life cycles of benthic macroinvertebrates vary seasonally with larval growth occurring through some seasons and adult emergence occurring in others. As a result, benthic IBI scores indicating healthy conditions can vary depending upon the season. In general, a biological community sampled from May to September will usually have lower diversity and abundance reflected by a lower IBI score. A biological community sampled from November through May typically have higher diversity and abundance reflected by a higher IBI score (PA DEP 2013b, PA DEP 2015).

As mentioned previously, over 85 percent of streams throughout the shale gas forest districts are classified with special protection status (i.e., Exceptional Value (EV) and High Quality (HQ)). For complete criteria that qualifies a surface water for EV or HQ special protections, see Chapter 93 Section 4b of the Pennsylvania Code for Water Quality Standards[5].

Baseline macroinvertebrate IBI scores have been established for these streams. To determine if any degradation has occurred, DEP indicates that special protection surveys must be conducted between November and May. Any macroinvertebrate IBI score calculated for a stream during a special protection survey is compared to the baseline IBI score. In general, impairment is indicated if a resulting IBI score that is greater than a precision estimate of 10.0 points below the baseline IBI score. DEP can apply a more restrictive 8.0- or 9.0-point precision estimate if certain conditions are met (PADEP, 2013). Regardless of the baseline IBI score, any IBI score calculated for an EV or HQ stream less than 63.0 will be considered impaired without compelling reasons otherwise (PA DEP, 2015).

If a stream being assessed is not EV or HQ, a resulting macroinvertebrate IBI score is run through a rigorous methodology to determine impairment. This methodology uses the sampling season in conjunction with a series of qualifier questions to evaluate whether the stream is impaired (PADEP, 2013).

A kicking sequence during a macroinvertebrate collection.

Bureau staff collected 64 benthic macroinvertebrates samples in 56 streams on state forest lands (Figure 5.11) from 2014 through 2016 using DEP Instream Comprehensive Evaluation Survey (ICE) protocol (PA DEP, 2013a). Samples were collected in the Mosquito Creek basin (Clearfield County), Sinnemahoning Creek basin (Clearfield, Elk, and Potter Counties), Hyner Run basin (Clinton County), Pine Creek basin (Potter, Tioga, and Lycoming Counties), Lycoming Creek basin (Lycoming County), Loyalsock Creek basin (Lycoming County), and the Tioga River basin (Tioga County). A total of 33 samples were collected in the spring and fall of 2014, nine samples in the spring of 2015, and 22 samples in the spring of 2016. Samples from the spring of 2016 were part of an ongoing project with USGS.

DEP is responsible for monitoring and assessing water quality across the commonwealth. DEP has collected benthic macroinvertebrate samples as part of ongoing statewide monitoring and assessment efforts that coincide with some of the stream reaches targeted by bureau staff. This provides an opportunity to assess water quality and measure any changes in water quality over time.

A review of aquatic life use assessments and existing/designated uses was performed for stream segments sampled by the bureau. DEP has completed recent aquatic life use assessments for the Mosquito Creek basin (2012), Sinnemahoning Creek basin (2011), Hyner Run basin (2011), Lycoming Creek basin (2011-2012), Loyalsock Creek basin (2010), and the Tioga River basin (2008). An effort to sample and assess the Pine Creek basin has been underway in the past few years, but a complete assessment may not be available until 2020.

The Mosquito Creek basin has a designated use of HQ-CWF (Cold Water Fishes) except for Cole Run and Twelvemile Run tributaries, which are designated EV. The bureau collected a single sample on a tributary to Gifford Run in the spring of 2016 that coincides with a spring 2012 DEP sample (Table 5.13). IBI scores are within precision estimates and are interpreted as

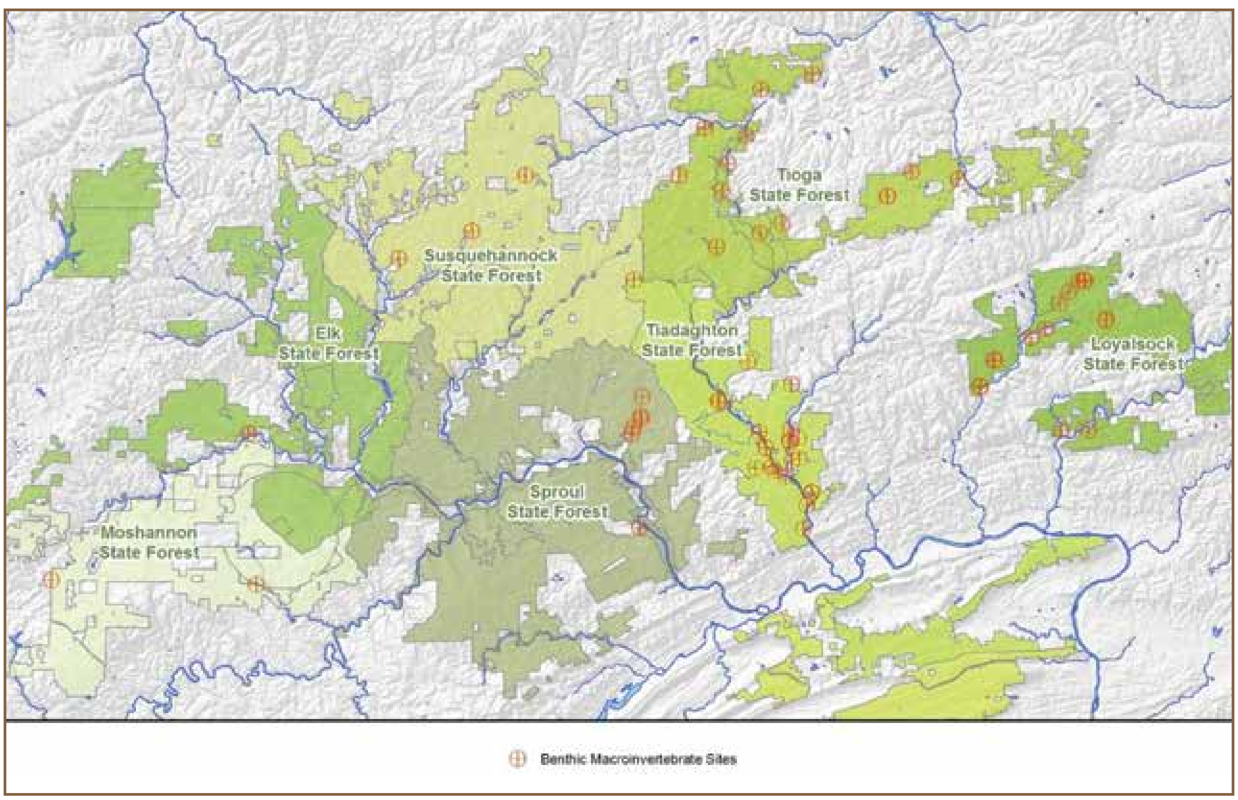


Figure 5.11. Location of benthic macroinvertebrate samples collected by DNCR staff.

no change in water quality over the period (PA DEP, 2015).

Emptying a net after a kicking sequence during a macroinvertebrate collection

The entire Hyner Run basin currently has an existing use of EV, this determination was made based on a 2011-2012 DEP survey that included samples collected at five locations throughout the basin. The bureau collected samples at six locations throughout the basin. All DEP and bureau samples indicate attainment of the EV aquatic life use (Table 5.13). Three bureau sample locations coincide with DEP sample locations including Baker Run, Right Branch Hyner Run, and the East Branch of Hyner Run. IBI scores are within precision estimates (PA DEP, 2015).

A significant portion of the Sinnemahoning Creek basin has an existing/designated use of HQ or EV. The bureau collected a single sample on both Bark Camp Run and Hicks Run within the Bennett Branch Sinnemahoning Creek subbasin as well as samples from Right Branch Big Nelson Run and East Fork Sinnemahoning within the First Fork Sinnemahoning Creek subbasin (Table 5.13). Bark Camp Run is currently listed as impaired due to metal contamination from acid mine drainage. The IBI score of 54.0 is above the impairment threshold for CWF waters and should be further evaluated by DEP. Hicks Run, Right Branch Big Nelson Run, and the East Fork Sinnemahoning Creek samples coincide with DEP samples from 2011. IBI scores for the East Fork Sinnemahoning Creek are not within precision estimates and should be further evaluated by PA DEP.

The Lycoming Creek basin is currently undergoing a Stream Redesignation Evaluation because of a petition received by DEP from the Lycoming Creek Watershed Association in 2009. The petition is to redesignate portions of the basin from an aquatic life use for CWF to a protected use of EV. Basin-wide surveys in response to the petition were conducted in 2009, 2011 and 2012. The surveys indicate that the existing use for various reaches throughout the basin were inconsistent with the designated use (see DEP website for discussion of existing and designated uses). The surveys also indicated that significant tributary reaches did not meet the aquatic life use because of acid deposition. The bureau collected 11 samples in the spring of 2014 and two samples in the spring of 2016 (Table 5.13). One sample collected on Doe Run had an IBI score of 58.4, which is below the IBI impairment threshold of 63 for samples collected on HQ and EV streams. Another sample collected on Buck Run in the spring of 2014 is also below the IBI impairment threshold. The small watershed area of Buck Run and the lack of prior samples may indicate ephemeral or intermittent conditions and should be evaluated further. Four bureau samples collected in the spring of 2014 and two collected in spring of 2016 coincide with DEP sample locations including Hawk Run, Bovier Run, Potash Hollow Run, Grays Run, and Hagerman Run. IBI scores from Hawk Run, Potash Hollow Run, and Grays Run are within precision estimates. IBI scores from Bovier Run and Hagerman Run are not within precision estimates and should be further evaluated by DEP. A follow-up investigation by DEP in 2017 on Hagerman Run had an IBI score of 91.1.

Most of the Loyalsock Creek basin has an existing use of EV and is attaining the aquatic life use. The bureau collected samples from Little Bear Creek and Wallis Run in the spring of 2016 (Table 5.13). Wallis Run has had four samples collected by DEP prior to the 2016 bureau sample. Wallis Run was targeted by DEP in 2008 in response to a petition requesting redesignation of portions of Loyalsock Creek, and 2011-2012 as part of a CIM effort (DEP CIM reports[2]). Decreasing IBI scores from 2008-2012 were noted in the DEP CIM report. The bureau sample collected in 2016 had an IBI score of 95.7.

The Pine Creek basin is currently undergoing a Stream Redesignation Evaluation due to the results of the recent DEP aquatic life use monitoring and assessment efforts. Portions of the basin currently have an existing use of EV including most of Pine Creek mainstem, Elk Run (Tioga Co.), portions of Babb Creek basin, and portions of Little Pine Creek basin. The bureau collected 37 samples in 2014 through 2016 throughout the Pine Creek basin. A total of 29 samples coincide with prior DEP samples and samples from nine sites have IBI scores that are not within precision estimates of baseline scores and should be reevaluated (Table 5.13). Follow-up investigations by DEP in 2016 on Lower Pine Bottom Run and in 2017 on Upper Pine Bottom Run had IBI scores within precision estimates.

The Tioga River basin has an existing use of HQ-CWF in the farthest upstream reaches. Additionally, other named sub-basins have an existing use of EV, but most of the basin has a designated use of CWF. The bureau collected a sample on Boone Run in the spring of 2016 (Table 5.13) that does not coincide with any prior DEP samples. Boone Run has a designated use of CWF and the IBI score from the 2016 survey is above the impairment threshold of 43 for CWF streams.

Processing and sub-sampling a macroinvertebrate sample before identification.

Basin	Stream Name	Season/Year	IBI	Aquatic Life Use	Existing/ Designated Use
Mosquito Creek	Gifford Run	Spring 2016	85	Attaining	HQ-CWF
	Gifford Run	Spring 2012*	78.5	Attaining	HQ-CWF
Hyner Run	Cougar Run	Spring 2014	90.4	Attaining	EV
	Abes Run	Spring 2014	88.5	Attaining	EV
	R. Br. Hyner Run	Spring 2014	92.1	Attaining	EV
	R. Br. Hyner Run	Spring 2012*	92.5	Attaining	EV
	Long Fork	Spring 2014	91.5	Attaining	EV
	E. Br. Hyner Run	Spring 2014	85.8	Attaining	EV
	E. Br. Hyner Run	Spring 2011*	93.9	Attaining	EV
	Baker Run	Spring 2016	90.4	Attaining	HQ-CWF
	Baker Run	Spring 2011*	97.5	Attaining	HQ-CWF
Sinnemahoning Creek	Bark Camp Run	Spring 2016	54	Impaired	CWF
	Hicks Run	Spring 2016	78.4	Attaining	HQ-CWF
	Hicks Run	Spring 2011*	79.1	Attaining	HQ-CWF
	RB Br. Big Nelson Run	Spring 2016	81.4	Attaining	EV
	RB Br. Big Nelson Run	Fall 2011*	84.9	Attaining	EV
	East Fork Sinnemahoning	Spring 2016	79.7	Attaining	EV
	East Fork Sinnemahoning	Spring 2011*	92.1	Attaining	EV
Lycoming Creek	N. Br. Rock Run	Spring 2014	86.3	Attaining	EV
	Rock Run	Spring 2014	93.1	Attaining	EV
	Hawk Run	Spring 2014	86.1	Attaining	EV
	Hawk Run	Fall 2009*	87.8	Attaining	EV
	Doe Run	Spring 2014	58.4	Impaired	HQ-CWF
	Buck Run	Spring 2014	37.8	Attaining	EV
	Pleasant Stream	Spring 2014	82.1	Attaining	EV
	Bovier Run	Spring 2014	75.7	Attaining	EV
	Bovier Run	Fall 2009	94.5	Attaining	EV
	Potash Hollow Run	Spring 2014	90	Attaining	EV
	Potash Hollow Run	Fall 2009*	93.6	Attaining	EV
	Bear Trap Hollow	Spring 2014	80.5	Attaining	EV
	Dry Run	Spring 2014	82	Attaining	HQ-CWF
	Grays Run	Spring 2016	86.1	Attaining	HQ-CWF
	Grays Run	Fall 2013*	93.6	Attaining	HQ-CWF
	Hagerman Run	Spring 2017*	91.1	Attaining	HQ-CWF
	Hagerman Run	Spring 2016	82.6	Attaining	HQ-CWF
	Hagerman Run	Spring 2014	81.8	Attaining	HQ-CWF
	Hagerman Run	Fall 2009*	96.1	Attaining	HQ-CWF

Basin	Stream Name	Season/Year	IBI	Aquatic Life Use	Existing/ Designated Use
Loyalsock Creek	Little Bear Creek	Spring 2016	84.9	Attaining	EV
	Wallis Run	Spring 2016	95.7	Attaining	EV
	Wallis Run	Spring 2012*	86	Attaining	EV
	Wallis Run	Fall 2011*	93.3	Attaining	EV
	Wallis Run	Spring 2011*	95.3	Attaining	EV
	Wallis Run	Fall 2008*	95.1	Attaining	EV
Pine Creek	Sunken Branch	Spring 2016	80.1	Attaining	HQ-CWF
	Sunken Branch	Spring 2011*	74.3	Attaining	HQ-CWF
	Elk Run	Spring 2015	83.3	Attaining	EV
	Elk Run	Spring 2014*	89.8	Attaining	EV
	Painter Run	Spring 2016	84	Attaining	HQ-CWF
	Painter Run	Spring 2015	85	Attaining	HQ-CWF
	Painter Run	Fall 2012	98	Attaining	HQ-CWF
	Baldwin Run	Spring 2015	94.1	Attaining	HQ-CWF
	Straight Run	Spring 2015	80	Attaining	HQ-CWF
	Straight Run	Spring 2012*	94.8	Attaining	HQ-CWF
	Darling Run	Fall 2014	76.6	Impaired	HQ-CWF
	Darling Run	Fall 2012*	88.9	Impaired	HQ-CWF
	Fourmile Run	Fall 2014	82.5	Attaining	HQ-CWF
	Fourmile Run	Spring 2013*	93.9	Attaining	HQ-CWF
	Little Slate Run	Fall 2014	89.8	Attaining	HQ-CWF
	Pine Island Run	Fall 2014	86	Attaining	EV
	Pine Island Run	Spring 2013*	86	Attaining	EV
	Sand Run	Spring 2015	62.6	Attaining	EV
	Babb Creek	Spring 2016	78.8	Attaining	EV
	Babb Creek	Spring 2015	92.6	Attaining	EV
	W. Br. Stony Fork	Fall 2014	79.1	Attaining	EV
	W. Br. Stony Fork	Spring 2010*	81.9	Attaining	EV
	Francis Br. Slate Run	Spring 2016	78.4	Attaining	EV
	Sebring Branch	Spring 2016	80.4	Attaining	EV
	Trout Run	Spring 2016	75.4	Attaining	HQ-CWF
	Trout Run	Spring 2014	77.2	Attaining	HQ-CWF
	Trout Run	Spring 2012*	89.7	Attaining	HQ-CWF
	Callahan Run	Spring 2014	95.1	Attaining	HQ-CWF
	Callahan Run	Spring 2012*	86.9	Attaining	HQ-CWF
	Browns Run	Spring 2016	95.4	Attaining	HQ-CWF
	Browns Run	Fall 2014	92.9	Attaining	HQ-CWF
	Browns Run	Fall 2013*	89.2	Attaining	HQ-CWF
	Browns Run	Spring 2013*	89.7	Attaining	HQ-CWF
	Browns Run	Spring 2012*	92.9	Attaining	HQ-CWF
	Ott Fork	Spring 2014	92.2	Attaining	HQ-CWF
	Ott Fork	Spring 2012*	86.6	Attaining	HQ-CWF

Basin	Stream Name	Season/Year	IBI	Aquatic Life Use	Existing/ Designated Use
Pine Creek	Upper Pine Bottom Run	Spring 2017*	95.1	Attaining	HQ-CWF
	Upper Pine Bottom Run	Fall 2014	81.2	Attaining	HQ-CWF
	Upper Pine Bottom Run	Spring 2012*	96.1	Attaining	HQ-CWF
	Lower Pine Bottom Run	Spring 2016*	90.5	Attaining	HQ-CWF
	Lower Pine Bottom Run	Spring 2014	74.3	Attaining	HQ-CWF
	Lower Pine Bottom Run	Spring 2012*	91.6	Attaining	HQ-CWF
	Bull Run	Spring 2015	94	Attaining	HQ-CWF
	Bull Run	Spring 2012*	88.9	Attaining	HQ-CWF
	Hacket Fork	Fall 2014	93.6	Attaining	EV
	Love Run	Fall 2014	87.4	Attaining	EV
	Love Run	Spring 2010*	96	Attaining	EV
	English Run	Spring 2015	96.8	Attaining	EV
	English Run	Spring 2010*	97.4	Attaining	EV
	Boone Run	Spring 2016	96.8	Attaining	EV
	Boone Run	Fall 2014	97.4	Attaining	EV
	Boone Run	Spring 2010*	94.7	Attaining	EV
	Dam Run	Spring 2016	91.7	Attaining	EV
	Dam Run	Spring 2015	87.6	Attaining	EV
	Dam Run	Spring 2010*	89	Attaining	EV
	Ramsey Run	Spring 2016	86.3	Attaining	HQ-CWF
	Ramsey Run	Spring 2014	80	Attaining	HQ-CWF
	Ramsey Run	Spring 2012*	93.3	Attaining	HQ-CWF
	Bonnell Run	Fall 2014	76.1	Attaining	HQ-CWF
	Bonnell Run	Spring 2012*	90.8	Attaining	HQ-CWF
	Cedar Run	Spring 2016	88	Attaining	EV
	Cedar Run	Spring 2015*	86.3	Attaining	EV
	Gamble Run	Fall 2014	89.3	Attaining	HQ-CWF
	Gamble Run	Spring 2012*	93.5	Attaining	HQ-CWF
Tioga River	Boone Run	Spring 2016	58.7	Attaining	CWF

Streams highlighted in red have fallen out of precision estimates based off previous samples and may require additional follow-up.

An "attaining" aquatic life use indicates the stream is attaining water quality standards for its existing/designated use.

* indicates data collected by DEP

Table 5.13. Benthic macroinvertebrate Index of Biotic Integrity, aquatic life use assessment and existing/designated use for all sampled streams in river basins within shale gas forest districts.

SRBC assessed the macroinvertebrate communities at all ten RWQMN sites located on state forest lands in the month of October between 2012 and 2015. Most of these streams are EV or HQ, and all but one of the 54 calculated macroinvertebrate IBIs scores were higher than the absolute minimum score of 63.0 for HQ and EV streams (Figure 5.12). Macroinvertebrate IBI scores from two of the other three sites that are not EV or HQ consistently scored lower throughout most of the study period. The Little Pine Creek site is a large watershed with the study site located downstream of a reservoir. The Marsh Creek site is impaired from urban runoff and has 12 permitted wastewater treatment plants located upstream. Refer to RWQMN – DCNR Technical Summary (June 2016)[4] for more information.

Bureau staff collected discrete water chemistry field measurements, surface water grab samples, and flow measurements with the 42 macroinvertebrate samples from 2014 and 2015. In addition, eleven sites in the Pine Creek basin were referred to as "screening sites" (Figure 5.13). These collections were made (as described in the BOF CIM section) to complement any future trends observed in the macroinvertebrate samples. The 22 sites from the spring of 2016, as part of the work with USGS, included similar measurements and will be published and posted with their report when completed.

For surface water grab samples, the DEP Bureau of Labs Standard Analysis Code (SAC) 046 was selected for the analysis at 42 macroinvertebrate sites while a SAC

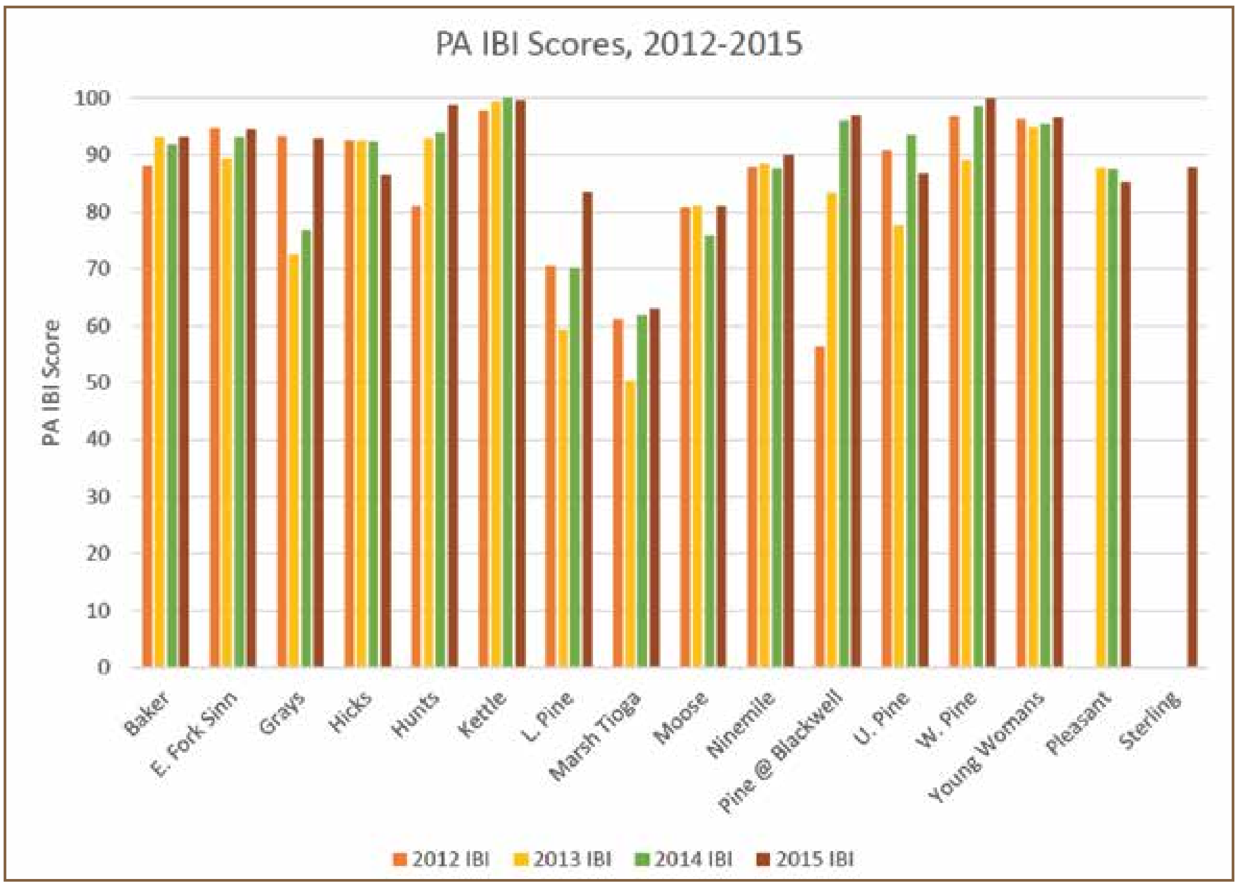


Figure 5.12. Summary of Index of Biotic Integrity scores from the Susquehanna River Basin Commission Remote Water Quality Monitoring Network stations in the shale gas region.

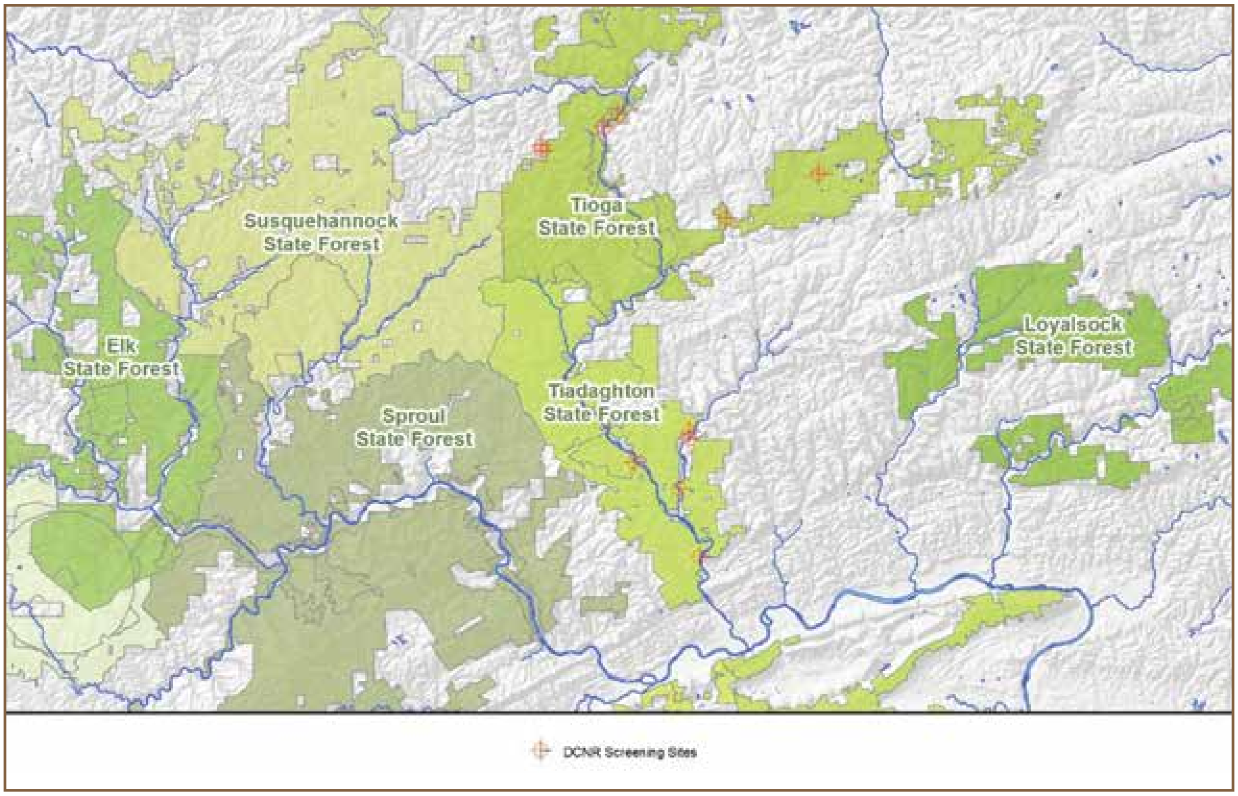
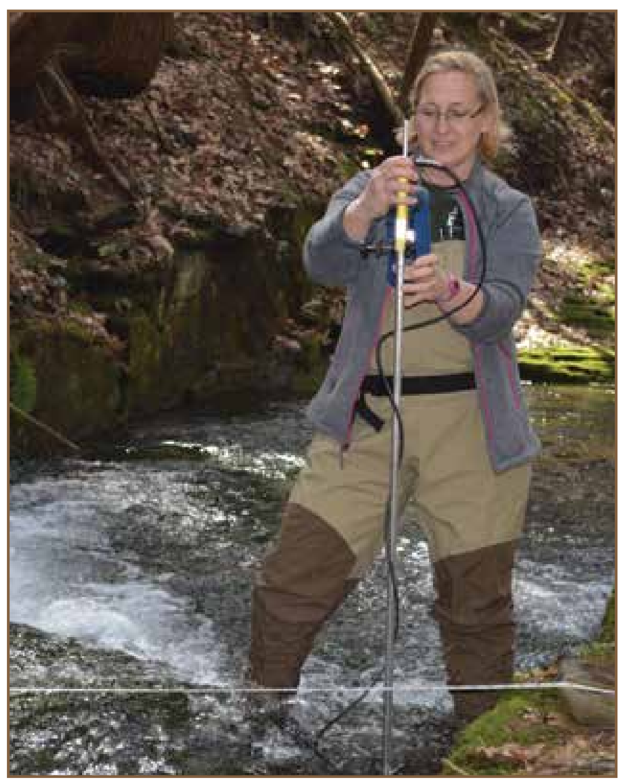


Figure 5.13. Location of screening sites visited by DNCR staff.

972 was selected for the eleven screening sites. These tests were chosen based on recommendations from DEP. A suite of 29 tests within a SAC 046 and twelve tests within a SAC 972 were analyzed and included both inorganic parameters and metals. Included are some parameters consistent with natural gas drilling that have been at the forefront of discussions regarding the potential effects to water quality. Specific conductance (SPC) and total dissolved solids (TDS) are found in flowback water at extremely high levels. Strontium (Sr), Barium (Ba), and Bromide (Br) prove useful to monitor as they are highly specific signatures of flowback and produced waters; whereas other parameters, though useful, can originate from other sources.

Surface water grab samples collected at all 42 macroinvertebrate sites are summarized in Table 5.14. All specific conductance values were found significantly under the bureau's level of concern of 800 µs/cm. Barium, strontium, and bromide levels were all found well below their levels of concern of 2,000 µg/L, 4,000



Measuring flow at a BOF screening site.

µg/L, and 0.5 mg/L, respectively. TDS levels fall well under the 500 mg/L level of concern except for one reading of 920 mg/L found on Pine Island Run, Tioga County. Only one well, which is located on private lands, exists in this basin. A follow-up was completed by DEP Oil & Gas personnel who determined that oil and gas activity associated with this well pad could be ruled out as a reason for this high reading of TDS. The bureau and DEP will continue to monitor this site on Pine Island Run.

Surface water grab samples collected at the eleven screening sites are summarized in Table 5.15. All specific conductance values were found to be less than the level of concern of 800 µS/cm. Most were found well below this level except for one outlier of 673 µS/cm recorded at Basswood Run, Tioga County. This is a stream with historical acid mine drainage (AMD) influence. TDS levels fall well under the 500 mg/L level of concern and the highest reading of 378 mg/L was observed at Basswood Run. Barium, Strontium, and Bromide levels were all found below their levels of concern of 2,000 µg/L, 4,000 µg/L, and 0.5 mg/L, respectively.

Results from discrete water field chemistry and flow measurements recorded at macroinvertebrate sites (Table 5.16) and screening sites (Table 5.17) were found consistent with grab samples for specific conductance and pH, with some outliers being attributed to AMD or agricultural runoff. The remaining measurements are consistent with expected levels in these streams.

Parameter	Units	Min	Max	Count
ALKALINITY	MG/L	0.00	58.40	42
ALUMINUM Total	UG/L	200.00	225.00	42
AMMONIA-Total as Nitrogen	MG/L	0.02	0.03	42
ARSENIC Total	UG/L	3.00	3.00	42
BARIUM Total	UG/L	10.00	55.00	42
BORON Total	UG/L	200.00	200.00	42
BROMIDE	MG/L	0.20	0.20	42
CALCIUM Total	MG/L	0.94	19.80	42
CBOD5 - Biochemical Oxygen Demand	MG/L	0.20	1.70	42
CHLORIDE -IC	MG/L	0.50	10.82	42
HARDNESS Total	MG/L	4.00	69.00	42
IRON Total	UG/L	20.00	239.00	42
LITHIUM Total	UG/L	25.00	25.00	42
MAGNESIUM Total	MG/L	0.35	4.98	42
MANGANESE Total	UG/L	10.00	109.00	42
METHANE	UG/L	1.60	12.00	42
MOLYBDENUM Total	UG/L	70.00	70.00	42
Nitrate & Nitrite Nitrogen	MG/L	0.05	1.96	42
OSMOTIC PRESSURE	MOSM	1.00	4.00	42
pH	pH units	5.00	8.00	42
PHOSPHORUS Total	MG/L	0.01	0.46	42
SELENIUM Total	UG/L	7.00	7.00	42
SODIUM Total	MG/L	0.32	6.43	42
SPECIFIC CONDUCTANCE @ 25.0 C	µS/cm	18.39	173.10	42
STRONTIUM Total	UG/L	10.00	61.00	42
SULFATE - IC	MG/L	4.63	12.01	42
TOTAL SUSPENDED SOLIDS	MG/L	5.00	12.00	42
TOTAL DISSOLVED SOLIDS (@180C -USGS)	MG/L	20.00	920.00	42
ZINC Total	UG/L	10.00	17.00	42

Table 5.14. Results using Standard Analysis Code 046 from grab samples collected at Bureau of Forestry macroinvertebrate sampling sites.

Parameter	Units	Min	Max	Count
ALKALINITY	MG/L	0	43	11
BARIUM Total	UG/L	10	43	11
BROMIDE	MG/L	0.2	0.2	11
CHLORIDE -IC	MG/L	0.5	0.98	11
ETHANE	UG/L	12.4	12.4	11
METHANE	UG/L	1.73	16.5	11
pH	pH units	3	7.8	11
PROPANE	UG/L	14.2	14.2	11
SPECIFIC CONDUCTANCE @ 25.0 C	µS/cm	30	673	11
STRONTIUM Total	UG/L	12	55	11
TOTAL SUSPENDED SOLIDS	MG/L	5	24	11
TOTAL DISSOLVED SOLIDS (@180C -USGS)	MG/L	26	378	11

Table 5.15. Results using Standard Analysis Code 972 from grab samples collected at Bureau of Forestry screening sites.

	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	pH	Turbidity (NTU)	Flow (cfs)
Min	2.10	6.40	19.30	4.11	0.13	0.10
Max	14.30	13.93	221.20	8.33	3.43	25.41
# obs (n)	35	35	35	35	33	30

Table 5.16. Summary of discrete field chemistry measurements collected at Bureau of Forestry macroinvertebrate sampling sites.

	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	pH	Turbidity (NTU)	Flow (cfs)
Min	6.70	10.22	29.30	2.81	0.26	0.20
Max	15.30	13.72	788.00	7.64	14.10	1.67
# obs (n)	11	11	11	11	11	8

Table 5.17. Summary of discrete field chemistry measurements collected at Bureau of Forestry screening sites.

U.S. Geological Survey Toxic Substance Hydrology Program

As part of the bureau's three-tiered approach to monitoring, the bureau partnered with the U.S. Geological Survey (USGS) and its Toxic Substances Hydrology Program (TSHP) to examine the potential for Marcellus shale gas development to impact water quality on state forest lands. This collaborative effort began in the spring of 2016 and is scheduled to continue into the fall of 2018.

The project and methods were introduced and developed by USGS personnel who were interested in partnering with a group who had the technical experience and "on-the-ground" familiarity with state forest lands to help them plan and complete the necessary field work. This provided an opportunity for the bureau's Shale Gas Monitoring Team. Both parties, along with DEP, met early in 2016 to identify the monitoring sites. As part of the selection process, USGS provided a tool (Entrekin et al., 2015) to assign a vulnerability to a HUC (Hydrologic Unit Code) based on variables identified to have the potential for the HUC to be affected by Marcellus shale gas operations. Variables included, but were not limited to: slope, land cover, amount of development, wetlands, and presence/absence of historic mines. For each HUC 12 on state forest lands experiencing gas development, a vulnerability was calculated and the HUCs were ranked and placed into one of five categories (None, Low, Moderate, High, and Highest) with the highest ranked being the most likely to be affected by gas development. Twenty-five locations were selected in which to conduct the study (Figure 5.14).

Sites are currently being visited twice a year in the spring and fall seasons. Spring visits involve water (discrete and grab) and sediment sampling using USGS methodology testing for a suite of parameters (Table 5.18). Additionally, benthic macroinvertebrate collections are conducted using the same DEP methodology used by the Shale Gas Monitoring Team. All macroinvertebrate identification is completed by DEP personnel, complementing their own water quality database. Fall visits involve a repeat of the water and sediment sampling done in the spring, as well as stream flow measurements.

Work is ongoing, and the results of this work must be reviewed and published by USGS prior to distribution. The collaboration between the bureau, DEP, and USGS has proved productive for all agencies. Fostering relationships with individuals and organizations possessing the expertise and experience with specific values has strengthened the bureau's monitoring program. The work completed on this project will provide stakeholders with information on water quality in some of the most developed and least developed watersheds in the shale gas region and can inform the bureau's water monitoring efforts in the future.

Overall, water chemistry analysis from the various continuous water monitoring and the widespread monitoring locations has not provided evidence to suggest that shale gas development has degraded water quality on state forests in the core gas forest districts during the respective data collection periods. A few

Collecting filtered grab samples during USGS TSHP project.

locations did highlight some concerns, but they were not related to shale gas development.

Bureau staff and partners will continue monitoring water quality in the shale gas forest districts to identify any long-term trends. The productive partnerships and extensive sampling locations will be valuable in monitoring water quality into the future.

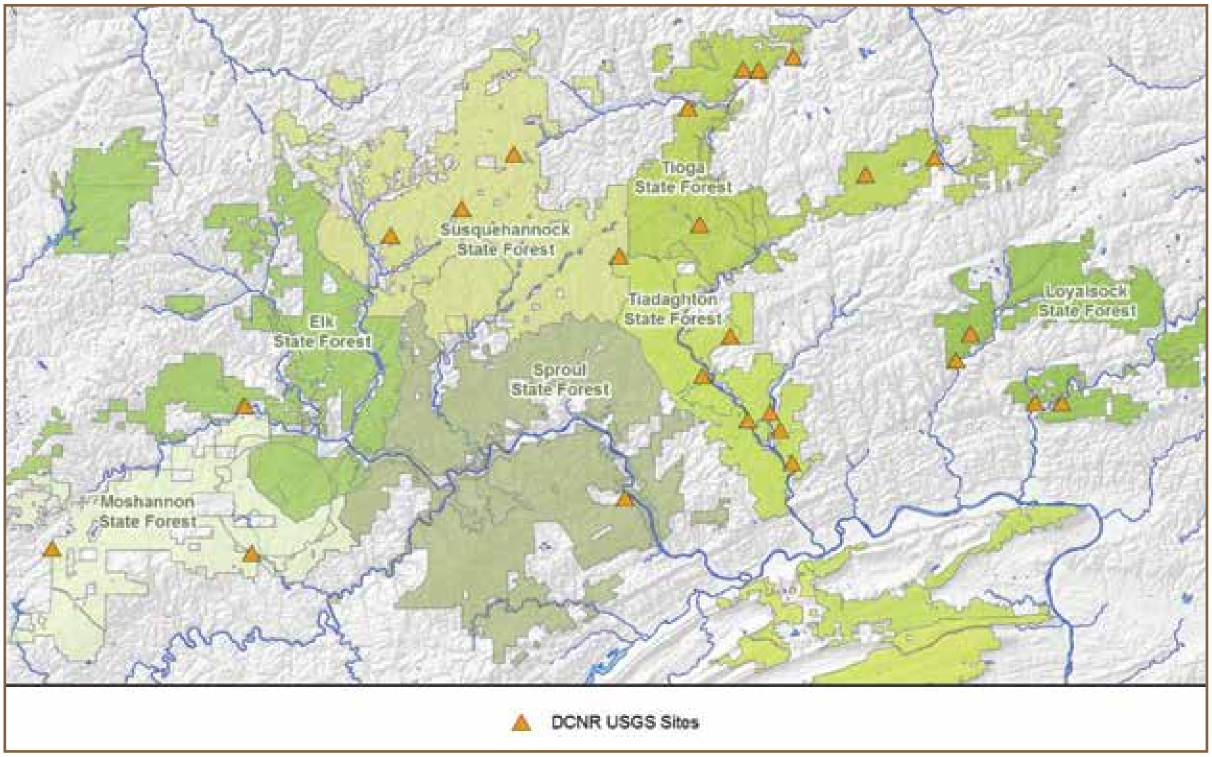


Figure 5.14. Locations of the U.S. Geologic Survey- Bureau of Forestry cooperative project. Sites are shown within boundaries of the shale gas forest districts.

Method/Equipment	Parameter
YSI ProPlus (Field)	pH, Specific Conductance µS/cm, DO mg/L, ORP (mV)
Shimadzu DOC Analyzer	Non-Volatile Dissolved Organic Carbon
Autotitrator	Alkalinity
Ion Chromatography	Cl^-, Br^-, NO_3^-, PO_4^{3-}, SO_4^{2-}
ICP-OES (ICP-OES: Inductively Coupled Plasma-Optical Emission Spectroscopy)	Ca, Mg, Sr, Na, K, Fe, Si, Ba, Cu, Zn, Li, B, Al, Mn
ICP-MS (ICP-MS: Inductively Coupled Plasma-Mass Spectrometry)	Cu, Zn, Li, Be, B, Al, V, Cr, Mn, Co, Ni, Rb, Sr, Mo, Ag, Cd, Sb, Sn, As, Se, Cs, Ba, La, Ce, W, Tl, Pb, Bi, Th, U
HPLC (High Performance Liquid Chromatography)	Lactate, Acetate, Propionate, Formate, Butyrate, Pyruvate, Benzoate
Dichloromethane Extraction followed by Gas Chromatography-Mass Spectrometry (GC-MS)	Non-Volatile Hydrocarbons
Solid Phase Microextraction followed by GC-MS	Semi-Volatile Hydrocarbons
Purge and Trap Gas Chromatography	Trace Light Hydrocarbons (C1-C6, methane to hexane)
Isotope Ratio Mass Spectrometry	Strontium Isotope Composition
16S MiSeq Sequencing	Microbial Community Analysis

Table 5.18. Parameters collected for the U.S. Geologic Survey- Bureau of Forestry cooperative project.

Air

Clean air is a fundamental requirement for the health and well-being of plants, animals, and people. Furthermore, good air quality is an expectation of state forest users. This is true from human health and aesthetic perspectives. Visitors expect to breathe clean, "fresh" air during activities on state forest lands, and they anticipate that the views along state forest roads and trails will not be marred by smog, dust, or other air pollutants.

The mission of DEP is to protect Pennsylvania's air, land, and water from pollution and to provide for the health and safety of its citizens through a cleaner environment. DEP works as partners with individuals, organizations, governments, and businesses to prevent pollution and restore natural resources. DEP's Annual Report[6] summarizes detailed information and trends on Pennsylvania's oil and gas industry.

The bureau works with DEP on issues related to air and water quality, as well as land development related to the oil and gas industry. The bureau relies on DEP (which has jurisdictional authority for air quality) to assess potential effects of air emissions from the shale gas industry and to require applicable air permits for shale gas operations.

DEP Monitoring Efforts/Results

DEP's Bureau of Air Quality[7] is responsible for safeguarding the health of Pennsylvanians by achieving the goals of the federal Clean Air Act and the Pennsylvania Air Pollution Control Act. The Bureau of Air Quality develops air quality regulations, conducts meteorological tracking, and air quality modeling studies and reviews; and develops transportation control measures and other mobile source programs. The Bureau of Air Quality also helps to improve the economic climate for firms to locate and expand in Pennsylvania through programs such as the Small Business Assistance Program.

DEP currently operates and maintains 69 air monitoring sites in 38 counties in the commonwealth. Additionally, the Allegheny and Philadelphia County Health Departments operate air monitoring networks in their jurisdictions consisting of 14 and 11 monitoring sites, respectively.

In response to shale gas development in the commonwealth, DEP has installed air quality monitors at several locations in northern Pennsylvania including Bradford, Clarion, Lycoming, McKean, and Tioga counties. This expansion of the network includes sampling for ozone and nitrogen oxides (NOx), ambient air concentrations, and fine particulate matter in Tioga and Bradford Counties. Volatile organic compound (VOC) monitors are also operating in Susquehanna and Wyoming Counties. In southwestern Pennsylvania, monitoring for fine particulate matter was added to Greene County.

DEP intended to install PM2.5 monitors in Fayette, Indiana, Lycoming, Susquehanna, and Wyoming counties by the end of 2016 and install monitors in Clarion, Jefferson, and McKean counties by the fall of 2017. The original time line has been extended due to challenges in developing the infrastructure to support these sites in very rural portions of the state. Challenges include the hiring and training of additional staff to support and operate the sites, coordinating quality assurance mechanisms to audit the sites and validate these data, and provide supervisory personnel to manage the additional staff. DEP continues to work toward installing these additional samplers.

DEP Air Emissions Related Data from the Shale Gas Industry

i. Long-Term Ambient Air Monitoring Study of Shale Gas Development
**These data are still in the review process by various partners and governmental agencies
ii. 2016 Oil and Gas Report[8]
iii. Overview of the Emission Inventory from 2012-2014 for Unconventional Natural Gas and Other Industries[9]
iv. Ambient Air Quality Update for 2016[10]

v. Commonwealth of Pennsylvania Department of Environmental Protection 2017 Annual Ambient Air Monitoring Network Plan[11]

Air Permitting for Shale Gas Operations (Air Quality Permit Information[12])

The DEP Bureau of Air Quality regulates air emissions through four different mechanisms: permit exemptions, general permits, plan approvals, and operating permits. A permit exemption sets forth detailed emission control and monitoring conditions that a pollution source must meet to be exempt from permitting requirements; this does not exempt the source from compliance with applicable standards. A general permit is a pre-determined permit for a general category of pollution sources that sets forth detailed emissions control and monitoring requirements that must be met for the general permit to be applicable. General permits make the permitting process more efficient for common types of pollution sources, as the general permits must be authorized by the Bureau of Air Quality within 30 days of application. If a general permit does not apply, then an individual plan approval and operating permit must be obtained. The plan approval is the construction permit for the pollution source, and the operating permit is the approval for emissions once the source is operational.

Depending on the details of the pollution source, one or more of these regulatory mechanisms may apply to shale gas operations. For the most part, shale gas drilling and hydraulic fracturing operations will fall under the Category Number 38 Permit Exemption for Oil and Gas Exploration, Development, Production Facilities, and Associated Equipment. Well sites are eligible for the exemption if the operations meet emission control and monitoring criteria. These Pennsylvania requirements are stricter than federal air quality rules for controlling wellhead emissions. The DEP exemption criteria include practices, e.g., a leak detection and repair program for the entire well pad facility rather than just the storage vessels as required by federal rules. Emissions of volatile organic compounds and hazardous air pollutants must also be controlled beyond levels required by the federal rules. Even with the exemption, drilling and hydraulic fracturing operations are subject to federal reporting requirements for volatile organic compounds and they must be included in an operator's annual report for DEP's emissions inventory.

General Permit Revisions

The General Permits establish Best Available Technology (BAT) requirements and other applicable Federal and State requirements including air emission limits, source testing, leak detection and repair, recordkeeping, and reporting requirements for the applicable air contamination sources. DEP has proposed a new General Plan Approval and/or General Operating Permit for Unconventional Natural Gas Well Site Operations (BAQ-GPA/GP-5A or GP-5A). The proposal will revise the existing General Plan Approval and/or General Operating Permit for Natural Gas Compressor Stations, Processing Plants, and Transmission Stations (BAQ-GPA/GP-5 or GP-5) issued in February 2013 (modified January 2015) and the Air Quality Permit Exemptions document (275-2101-003) of February 4, 2017.

The proposed GP-5A was developed under the authority of section 6.1(f) of the Air Pollution Control Act (35 P.S. § 4006.1(f)) and 25 Pa. Code Chapter 127, Subchapter H (relating to general plan approvals and operating permits) and will be applicable to unconventional natural gas well site operations and remote pigging stations. Remote pigging stations are defined as a pigging station not located at an unconventional natural gas well site, natural gas compressor station, natural gas processing plant, or natural gas transmission station that emits more than 200 tons per year (tpy) of methane, 2.7 tpy of volatile organic compounds (VOC), 0.5 tpy of any individual hazardous air pollutant (HAP) or 1.0 tpy of total HAP.

The revised GP-5 was developed under the authority of section 6.1(f) of the Air Pollution Control Act and 25 Pa. Code § Chapter 127, Subchapter H, and will remain applicable to natural gas compressor stations and processing plants and add applicability to natural gas transmission stations. The proposed GP-5A and GP-5 can be accessed at the following link[13].

Comments on both proposed GPs and revised exemption criteria were accepted until June 5, 2017. DEP received more than 10,000 comments from industry, non-government organizations, and the public. After the comments and response document is finalized, both General Permits will be revised.

Additional VOC Regulation

DEP has begun the development of a proposed rulemaking to regulate existing oil and natural gas industry sources. The proposed rulemaking will establish emission limitations and other requirements codified in 25 Pa. Code Chapter 129 consistent with the reasonably available control technology (RACT) recommendations of the Control Techniques Guidelines for the Oil and Natural Gas Industry (CTG) finalized by the United States Environmental Protection Agency (EPA).

The proposed rulemaking will establish RACT requirements for volatile organic compounds (VOC) and other pollutants from existing oil and natural gas production facilities, compressor stations, processing plants, and transmission stations. At a minimum, the proposed rulemaking will address VOC emissions from storage vessels, compressors, pneumatic controllers, pneumatic pumps, fugitive emission components from well sites, compressor stations, and processing plants. The control of VOC emissions will also achieve collateral methane emission reductions. However, in accordance with the Governor's Methane Reduction Strategy, DCNR will examine whether additional reduction of methane emissions from oil and natural gas industry sources can be achieved. The proposed rulemaking, if adopted by the Environmental Quality Board and published in the Pennsylvania Bulletin as a final rulemaking, will be submitted to the EPA for review and approval as a revision to the Commonwealth's State Implementation Plan (SIP).

Additional Methane Regulation

Pennsylvania will reduce methane emissions during development and gas production, processing, and transmission by requiring leak detection and repair (LDAR) measures, efficiency upgrades for equipment, improved processes, implementation of best practices, and more frequent use of leak-sensing technologies.

This includes:

1. To reduce leaks at new unconventional natural gas well pads, DEP will develop a new general permit for oil and gas exploration, development, and production facilities, requiring Best Available Technology (BAT) for equipment and processes, better record-keeping, and quarterly monitoring inspections.
2. To reduce leaks at new compressor stations and processing facilities, DEP will revise its current general permit, updating best-available technology requirements and applying more stringent LDAR, and other requirements to minimize leaks.
3. To reduce leaks at existing oil and natural gas facilities, DEP will develop a regulation for existing sources for consideration by the Environmental Quality Board.
4. To reduce emissions along production, gathering, transmission and distribution lines, DEP will establish best management practices, including leak detection and repair programs.

Short-term studies by DEP have demonstrated that gas-related compounds, particularly odor-causing compounds, are present near shale gas operations. DEP continues to review and update its ability to monitor and regulate air emissions from shale gas operators through the permitting processes and the establishment of additional collection sites near shale gas operations.

Although shale gas development may emit these various pollutants through the various processes involved, the natural gas produced through shale gas development also has the potential to create an overall positive effect on

Category	Year	Carbon Monoxide (TPY)	Nitrogen Oxides (TPY)	PM10 (TPY)	Sulfur Oxides (TPY)	VOCs (TPY)
All Point Sources	2008	117,978	318,134	38,317	924,194	28,675
All Point Sources	2015	77,786	213,650	19,225	259,711	27,991
Difference		40,192	104,485	19,093	664,483	684
Shale Gas Development	2015	8,664	20,063	671	182	6,420
Net Difference		31,527	84,421	18,422	664,301	-5,737

Table 5.19. Statewide pollution inventory data and emissions data from shale gas development, in tons per year (TPY).

air quality in Pennsylvania and the nation. This is mainly because natural gas emits fewer core emissions when compared to coal that is widely used in power generation in Pennsylvania and surrounding states. As of June 2017, DEP released annual air emissions inventory data that demonstrates a decrease in numerous pollutants from 2008 (the time that shale gas development began at a high level) to 2015. Emissions inventory data specific to shale gas development also was presented. These data are shown in Table 5.19. There has been a marked decrease in several major air pollutants, including sulfur oxides, nitrogen oxides, and carbon dioxide. This is due, in part, to the increased use of natural gas for power generation, the shutdown of several major facilities, and the installation of air pollution control equipment.

The bureau will continue to monitor the air quality studies being performed by DEP and make efforts to address identified concerns of state forest users and neighbors. At present time, the bureau does not have plans to initiate its own air quality monitoring program.

Soil

Healthy soils are essential to a healthy forest ecosystem. Forest soils sustain biological activity, diversity, and productivity by providing habitat for plants, animals, and other organisms. Soils regulate water storage and flow; store and cycle nutrients essential for all forest life; and filter, buffer, immobilize, and detoxify potential pollutants. The bureau strives to maintain the highest possible soil quality on all state forests. This is achieved by evaluating the potential effects of management decisions on soil resources and employing best management practices to minimize effects to soils during timber harvesting, road construction, and other forest management activities.

Shale gas development often involves soil disturbing activities that require careful planning and oversight to minimize potential negative effects on soil quality. The construction or improvement of roads increases soil compaction in the road corridors and runoff from roads presents a risk for erosion and sedimentation. Pipelines create similar corridor impacts and often can involve soil disturbance on steep slopes where erosion and stormwater control can be a challenge. Pad construction clears the topsoil (stockpiling it for future use) and causes severe compaction of soils beneath the pad infrastructure, which must be mitigated when pads are no longer in use and site rehabilitation is going to take place. Spills of chemicals or fuels can also threaten soil quality.

DEP regulates all activities that involve soil disturbance within Pennsylvania. Therefore, the bureau collaborates with DEP to manage and monitor soil resources related to shale gas development on state forests. Most soil-disturbing activities involving gas development require an erosion and sediment control plan or permit from

DEP. Disturbances of greater than 5,000 square feet (0.11 acres) require an erosion and sediment control plan, while disturbances greater than five acres require an erosion and sediment control permit. These plans or permits specify the erosion and sediment control best management practices that must be implemented for compliance. The bureau provides DEP input on erosion and sediment control plans and permits with the goal of ensuring that practices are designed appropriately for a forested environment as opposed to practices more suited for an urban or commercial setting.

Gas operators are required to self-monitor their erosion and sediment control practices and make any necessary improvements or corrections. DEP inspectors regularly check active work sites to verify compliance with the plan or permit. The bureau's gas foresters assist by also monitoring for signs of non-compliance and report any potential problems to the operators; and if necessary, DEP.

Shale Gas Infrastructure and Soils

The bureau works with gas companies to place gas infrastructure in areas with the least impact on the forest. Soil characteristics in these areas is one of the important factors that are considered. The key soil attributes include how well the soil drains, surface runoff potential, and erosion hazard. This information is obtained from the Soil Survey Geographic Database (SSURGO) that is maintained by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS).

Soils can be categorized by drainage class, an indicator of the soil's wetness. Most pads, impoundments, and compressors have been constructed on soils that are well drained or moderately well drained (Table 5.20). This demonstrates that wet areas have largely been avoided for placement of infrastructure.

Soils can also be rated based on their suitability for certain land use. One of the ratings available is for erosion hazard from forest road or trail construction. This rating for shale gas roads is shown in Table 5.22.

Over 75 percent of road construction between 2013-2016 was performed along areas with moderate or slight erosion hazard. Sometimes road construction is necessary on steeper slopes or grades where erosion hazard exists to minimize overall forest fragmentation or to avoid sensitive resources, such as wetlands or threatened and endangered species and their requisite habitat.

Table 5.20. Percent of total area disturbed by pads, impoundments, and compressors, and percent of total length disturbed by new pipelines and roads by soil drainage class.

Drainage Class	2008 to 2012				2013 to 2016			
	Percent Total Land Area in Core Gas Forest Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road	Percent Total Land Area in Core Gas Forest Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road
Excessively drained	1.21	0.05	0.21	0.27	1.21	0.00	0.00	0.00
Somewhat excessively drained	2.59	1.70	1.40	0.26	2.59	0.00	0.80	0.00
Well drained	68.65	83.81	74.59	80.24	68.65	77.51	78.33	80.20
Moderately well drained	19.41	11.40	20.35	18.19	19.41	19.73	14.57	12.97
Somewhat poorly drained	3.36	2.15	2.26	1.02	3.36	0.92	0.63	0.00
Poorly drained	3.39	0.84	1.10	0.00	3.39	1.83	5.06	6.83
Very poorly drained	1.39	0.05	0.09	0.02	1.39	0.00	0.60	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

For comparison, the percent of total land area within the core gas forest districts in each runoff class is presented. Analysis based on SSURGO data (Soil Survey Staff 2016).

Table 5.21. Percent of total area disturbed by pads, impoundments, and compressors, and percent of total length disturbed by new pipelines and roads by soil index of surface runoff.

Soil Index of Surface Runoff	2008 to 2012				2013 to 2016			
	Percent Total Land Area in Core Gas Forest Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road	Percent Total Land Area in Core Gas Forest Districts	Percent of Area of Pad Disturbance	Percent Length of Pipeline	Percent Length of Road
Very high	10.75	6.21	7.70	3.37	10.75	3.48	7.91	7.31
High	20.21	14.18	18.67	17.49	20.21	15.79	8.67	14.39
Medium	41.95	29.40	33.32	37.45	41.95	32.85	36.99	27.39
Low	20.62	30.78	28.92	26.37	20.62	40.70	37.10	43.55
Very low	4.14	19.42	11.37	15.32	4.14	7.19	9.33	7.36
Negligible	2.33	0.00	0.02	0.00	2.33	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

For comparison, the percent of total land area within the core gas forest districts in each runoff class is presented. Analysis based on SSURGO data (Soil Survey Staff 2016).

Topsoil Stockpiling on Pads

Well pads and compressor stations require a solid base. To achieve this base, existing vegetation is removed, topsoil is scraped off and stockpiled, and the subsoil is compacted prior to laying gravel on the pad. The topsoil is then stored at the edges of the pad and seeded to prevent erosion. The stockpiles sit undisturbed until the commencement of site rehabilitation activities on the pad.

Stockpiling can alter nutrient cycling, increase the bulk density (compaction), reduce the viable seed bank, and reduce biological activity over time. Oxygen levels can also decrease in the center of the pile. Biological activity rebounds quickly (within three years) once re-spread over the reclaimed area (Idaho Transportation Department 2012, Mason et al. 2011, Natural Resource Conservation Service 2004, Strohmayer 1999, White et al. 2008, and Wick et al. 2008). The current guidelines pertaining to soil stockpiling at development sites are effective in ensuring effective site rehabilitation.

Subgrade Soils Stabilization

In 2010, a three-acre pad was constructed in the Sproul State Forest using subgrade soil stabilization. Subgrade soil stabilization is a method that improves a soil's engineering properties through the incorporation of Portland cement directly into the soil. The resulting surface is referred to as soil cement and is a hard, durable surface that is less prone to heaving from freeze/thaw cycles. Typically, well pads are constructed using a compacted rock base. To construct a rock base pad on this site it was estimated that it would require over 5,000 cubic yards of base material (~450 tri-axle dump truck loads), approximately 4,800 cubic yards of R4 rock base (~400 tri-axle dump truck loads), a geotextile layer, and approximately 2,400 cubic yards of 2A stone (4 to 6-inch topcoat).

The typical subgrade soil stabilization well pad is constructed in a series of steps. First, the site is prepared by removing the topsoil and grading as is typically done with a rock base method. Cement is then spread over

Table 5.22. Percent of newly constructed length of road by erosion hazard from forest road or trail construction.

Erosion Hazard from Forest Road or Trail	Percent of Total Road Miles
Slight	30.6
Moderate	47.8
Severe	21.6
Total	100.0

Analysis based on SSURGO data (Soil Survey Staff 2016).

the entirety of the pad at approximately 80 lb/cubic yard at 1 ft. deep. Water is then added with a reclaimer machine that mixes the cement and soil to a depth of approximately 1-3 ft. depending on the depth to bedrock. The soil cement is then compacted with a roller and allowed to set for 24 hours. The last step involves adding a topcoat of 2A stone to a depth of 4-6 inches.

Completed well pad subject to subgrade stabilization.

Given the novel nature of this construction technique for a well pad, the bureau tested the site to determine if the soil cement proved difficult to reclaim and to see if the incorporated cement had any effect on pH levels of the pad or surrounding forest soils. The pad reclamation began with the removal of the topcoat of 2A stone. Once the top coat was removed, a reclaimer machine pulverized and ripped the soil cement to the depth of the bedrock layer. The well pad site was then graded to the specifications of the pad reclamation plan and the topsoil was spread over the reclaimed pad site. Personnel were on site during the ripping phase of the well pad reclamation to observe and document the progress along with any difficulties associated with preparing the site because of the Portland cement. The removal and ripping of the three-acre site was conducted in one day. From observations, it does not appear that the use of Portland cement impeded the progress in preparing this site for rehabilitation. Portland cement mixed at approximately 80 lbs./cubic yard does not present a detriment to surface ripping for site rehabilitation. However, ripping does require the use of a reclaimer machine to pulverize the soil cement.

Soil samples were taken post site preparation to address the pH questions associated with the use of Portland cement. A total of seven soil samples were collected at different locations in the surrounding forest and on the pad. Samples were collected in the forest at 50 ft. and 100 ft. from the pad edge on three sides of the pad and one sample was collected in the middle of the pad (Figure 5.15). Samples were collected by digging 12 holes spaced 5 to 10 feet apart to a depth of approximately six inches at each sampling location. The soils at the site were then mixed to create a composite sample for each sampling location. Overall, the sample taken within the pad itself did exhibit higher pH, soil magnesium, phosphorus, calcium, and potassium than in the surrounding forest soils (Table 5.23).

The data and experiences gathered from this project indicate that subgrade soil stabilization shows some merit in certain situations. The biggest benefit in subgrade soil stabilization and soil cementing is the reduction in fill and heavy hauling. The quantity of stone and associated truck traffic was greatly reduced by utilizing subgrade soil stabilization over the traditional rock base method. It is estimated that approximately 5,000 cubic yards of base material and 4,800 cubic yards of R4 rock base were not needed in the construction of the pad. This is a savings of approximately 850 tri-axle dump truck trips to the site during construction alone. Additionally, another 850 truck trips would have likely been required to move this material off the site during the rehabilitation process.

Flora

Foresters work to enhance existing vegetation communities, prevent non-native invasive species from overwhelming these communities, and help to

Figure 5.15. Locations of soil samples taken at subsoil stabilization site

	PAD	A1	A2	B1	B2	C1	C2
Soil pH	5.4	4.5	4.6	4.4	4.3	4.4	4.5
Phosphorus (ppm)	13	5	4	3	3	4	6
Potassium (ppm)	94	35	44	38	27	27	37
Magnesium (ppm)	37	9	8	14	11	10	10
Calcium (ppm)	812	54	35	61	40	28	24
Acidity (meq/100g)	6.9	11.1	11.1	12.3	11.1	11.7	12.9
Zinc (ppm)	2.8	3.9	2.5	1.6	1.3	1.2	2.8
Copper (ppm)	0.4	1.1	0.8	0.8	0.7	0.8	0.7
Sulfur (ppm)	25	23.5	37.2	36.1	28.6	19.8	27
CEC (meq/100g)	11.5	11.5	11.5	12.8	11.5	12	13.2
% Saturation of CEC							
K	2.1	0.8	1	0.8	0.6	0.6	0.7
Mg	2.7	0.7	0.6	0.9	0.8	0.7	0.6
Ca	35.3	2.3	1.5	2.4	1.8	1.2	0.9

Table 5.23. Soil chemistry test results at subsoil stabilization project site.

conserve rare plant species on state forest land. Plants serve as keystone species in almost every ecosystem by providing food, habitat, and by shaping site conditions such as temperature, water quality, light, and air quality. Plants also provide valuable economic resources, such as timber, and shape or influence many recreational experiences. Approximately 3,000 plant species have been found in the commonwealth. Approximately 1,900 are native and 1,100 are species not native to Pennsylvania. These species have been further classified into 136 unique plant community types (78 palustrine and 49 terrestrial) by Zimmerman, et al. (2012).

DCNR has listed 228 plant species in Pennsylvania as Endangered, 78 as Threatened, and an additional 41 as Rare. Of these Plant Species of Special Concern, approximately 60 species are known to exist on state forest subject to current shale gas development activities. The bureau oversees the protection of PA Plant Species of Special Concern on state forest lands by reviewing proposed shale gas development projects. Recommendations for avoiding or minimizing effects to Endangered, Threatened or Rare plant species are provided to managers. Biologists and foresters in the bureau work with operators to minimize potential impacts to plant communities and state-listed plant species near development projects early in the planning stages, as well as during construction of shale gas infrastructure. In addition, the bureau has developed periodic monitoring protocols to ensure that infrastructure construction and gas extraction does not have any long-term effects on the viability of populations of Plant Species of Special Concern, along with common native species, on state forest lands.

Since the onset of development and construction of facilities for extraction of natural gas on state forest lands, the bureau has been interested in how these operations could affect native vegetation communities. Shale gas development has converted many areas of mature, interior forest into early-successional communities or forest edge habitat. While this may negatively affect forest interior species, early-successional habitat can often result in a higher diversity of plant species than mature forest. In addition, once utilization of forest acreage by energy companies is complete, opportunities to reclaim or restore these sites may exist to improve or provide unique habitats for plant and wildlife species.

The increase in forest disturbance and traffic on state forest roads increases the potential to spread non-native invasive plant species into interior forest or wetland habitats that were once less likely to be invaded. Barlow (2017) suggest that "[unconventional oil and gas] development predisposes forested landscapes to plant invasion." Before development takes place, the bureau provides information to each lessee providing guidance on pre-construction prevention practices to slow the spread of invasive plants. Following construction, monitoring for invasive plants is conducted by bureau personnel. Furthermore, operators subject to recent leases or surface use agreements are mandated to monitor and control prioritized invasive plant species found within their project limits of disturbance. Collaborative approaches between operators and the bureau have increased the effectiveness of these efforts for both parties.

Shale Gas Infrastructure and Forest Types

Bureau foresters classify each state forest stand by forest community based on on-the-ground conditions and the dominant tree species. Typing data exists for the entire state forest land base, including areas utilized for gas extraction, and can be analyzed to determine which communities have been disturbed most often because of gas infrastructure development on state forest land.

Between 2013-2016, the amount of state forest land cleared for natural gas development fell sharply (Table 5.24). From the onset of gas development on state forest lands, much of the forest disturbance occurred in the dry oak – heath forest type. Between 2013-2016, 103 acres of dry oak – heath forest (the most common type on state forest lands) were converted to natural gas infrastructure, which accounted for approximately 34 percent of the total conversion over that period. The black cherry – northern hardwood forest type had 27.1 acres disturbed between 2013-2016, the second highest total among forest types. The third highest type converted to shale gas infrastructure between 2013-2016 was a non-forested type; the well site type (gas, oil, or water). A total of 61 acres of existing well sites were converted or reconfigured to accommodate shale gas infrastructure. All other forest types had less than 30 acres converted between 2013-2016 (Figure 5.16). The well site and human-made impoundment typing categories are included to indicate locations where new shale gas infrastructure utilized areas of forest that had been previously developed. The "Unknown" typing category is used for newly acquired state forest land or areas that have yet to be thoroughly typed. Evaluating the composition of the forest acres converted for natural gas development allows bureau staff to take a landscape-level approach to siting and placement of infrastructure.

Table 5.24. Acres converted from the top 10 Forest Comminity Types prior to 2013 and from 2013-2016 for shale gas development infrastructure, arranged by forest community type.

Forest Community Type	Percentage of Area in Core Gas Forest Districts	Pre 2013	2013-2016	Total
Dry Oak - Heath Forest	27	555.8	103.4	659.2
Well Site (Gas, Oil, Water)[1]	<1	130.5	60.6	191.1
Dry Oak - Mixed Hardwood Forest	10	145	9.9	154.9
Red Maple Forest	5	135.2	18.1	153.3
Red Oak- Mixed Hardwood Forest	8	115.7	20.8	136.5
Northern Hardwood Forest	25	114.3	10.7	125
Black Cherry - Northern Hardwood Forest	5	45.1	27.1	72.2
Woodland	<1	41.2	7.3	48.5
Unknown	7	20.8	14.2	35
Human-made Impoundment / Pond[2]	<1	12	27	39
Total	**89**	**1315.5**	**299.1**	**1615**

[1]This category includes all sites used for wells of any type on state forest lands, including conventional and unconventional gas development.
[2] This category includes any man-made ponds or impoundments created for any use on state forest lands.

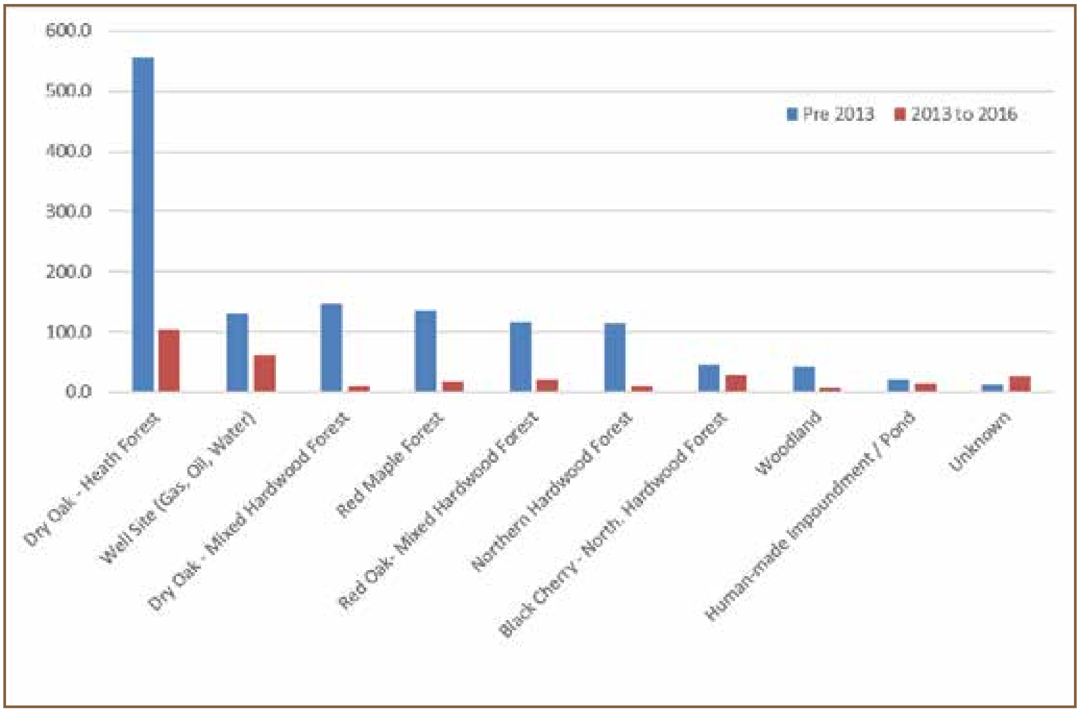


Figure 5.16. Acres cleared prior to 2013 and from 2013-2016 for shale gas development infrastructure, arranged by forest community type.

Monitoring Efforts

The purpose of the plant monitoring program is to recognize any potential effects to vegetation communities within areas utilized for gas extraction, as well as monitoring for observable long-term changes in the composition of these communities. Another focus is reducing the size and number of new infestations of invasive plants near shale gas infrastructure. DCNR defines invasive plants as any plant species that is not native to Pennsylvania, can grow or spread aggressively, and can displace native vegetation. Vegetation data have been used to develop more adaptive management practices that allow for the development of gas resources while protecting and enhancing native plant communities on state forest lands.

The importance placed on native flora and vegetation communities by the bureau is reflected in the vegetation monitoring efforts as part of the shale gas monitoring program. The three components of the plant monitoring program are: 1) evaluating vegetation communities immediately adjacent to shale gas infrastructure, including areas adjacent to well pads, roads, and rights of way; 2) monitoring tracts subject to shale gas development for non-native, invasive plant species; and 3) conducting vegetation inventories in areas of potential future gas extraction to assess the composition of vegetation communities prior to shale gas development. The evaluation of vegetation communities immediately adjacent to shale gas development also includes any communities that contain state-listed rare plant species.

1. <u>Evaluating Vegetation Communities Adjacent to Shale Gas Infrastructure</u>

As gas infrastructure is constructed, forest is cleared and many acres of interior forest habitat are converted to forest edge. As this conversion occurs, it is important for the bureau to monitor how plant communities adjacent to these sites may change over time. Assessment and monitoring of adjacent vegetation communities currently takes place on existing well pads, state forest roads used heavily for gas-related traffic, and pipeline rights-of-way.

Well Pad Vegetation Assessments

The well pad vegetation assessment protocols have been created to provide a means to assess how plant communities at the immediate edge of well pads are changing and how adjacent, undisturbed communities are affected by nearby forest disturbance. The bureau is interested in which, if any, opportunistic weed species that colonize the disturbed edges of the well pads are moving into adjacent interior forest. Similarly, learning which native forest species are first to re-colonize the disturbed well pad edges can guide site rehabilitation and restoration efforts or provide a relative time scale to natural re-forestation efforts at these disturbed forest edges. This careful examination of vegetation at well pad edges also provides an opportunity to understand the establishment success of species typically used in seed mixes. As of December 2016, 179 shale gas well pads have been constructed on state forest lands. In 2012 and 2013, 36 well pads were assessed using this protocol. In 2014, 15 of these pads were chosen for permanent vegetation plots, which are to be surveyed once every three years. An attempt was also made to ensure that the cohort of pads selected were representative of the variety of lessees operating on state forest lands. In addition, some pads were chosen due to their placement near less-frequently affected vegetation community types, or their proximity to adjacent rights-of-way or timber harvests.

The vegetation plot data collected during the well pad assessment protocol categorize plant species into three types of communities found immediately adjacent to a well pad: undisturbed forest, disturbed native vegetation (usually cleared of trees), and disturbed areas planted to erosion and sedimentation seed mixes. Vegetation inventories are taken within milacre (1/1000 acre) plots positioned on three sides of the well pad with two milacre plots inventoried on each side (the side of the pad with the access road is excluded). One milacre is placed 25 feet from the edge of the well pad and another 25 feet into the undisturbed forest. If the first milacre plot on a side is in undisturbed forest, a second plot is not completed. The relative percent cover of all species is recorded within each milacre plot, as well as a tally of all tree regeneration present.

The "undisturbed forest" community type was present on all 15 pads with permanent plots and was found on a total of 46 milacre plots. Hay-scented fern (*Dennstaedtia punctilobula*) had the highest average percent cover, 15.1 percent (Table 5.24). As would be expected, hay-scented fern was found on nearly every well pad in this protocol. This is a very common species in northern Pennsylvania and is widespread throughout the state forest system. In fact, all species listed in Table 5.25 that had the highest mean percent cover across multiple pads were common species that would be expected in most of the forest vegetation communities in northcentral Pennsylvania. These results are all somewhat expected based on historical observations and forest inventory data. These data also indicate that to this point, there is little substantial change in composition of dominant forest plant species in undisturbed forests adjacent to well pad edges.

Species	Number of Pads	Percent Cover
Hay-scented fern (*Dennstaedtia punctilobula*)	13	15.1
Black huckleberry (*Gaylussacia baccata*)	11	10.6
Mountain laurel (*Kalmia latifolia*)	11	5.3
New York fern (*Thelypteris noveboracensis*)	4	3.3
American beech (*Fagus grandifolia*)	8	3.3
Striped maple (*Acer pensylvanicum*)	10	2.7
Swamp dewberry (*Rubus hispidus*)	2	2.4

Table 5.25. Highest mean percent cover values per pad for "undisturbed forest" plots.

Species	Number of Pads	Percent Cover
Hay-scented fern (*Dennstaedtia punctilobula*)	4	16.9
Allegheny blackberry *(Rubus allegheniensis)*	2	8.2
Coltsfoot (*Tussilago farfara*)	1	6.9
Black cherry (*Prunus serotina)*	3	6.3
Rough-stemmed goldenrod (*Solidago rugosa*)	3	5.7
Sweet vernalgrass (*Anthoxanthum odoratum*)	2	4.9
Meadow fescue (*Festuca elatior*)	1	4.8
Redtop (*Agrostis gigantea*)	2	4.2

Table 5.26. Highest mean percent cover values per pad for "disturbed native" vegetation plots.

The "disturbed native" vegetation type was present on six of 15 pads. These areas were typically used for staging of equipment during well pad construction and were cleared of trees. However, the native vegetation was not removed entirely from the site and supplemental plantings were not always necessary. Again, hay-scented fern (*Dennstaedtia punctilobula*) had the highest average percent cover, 16.9 percent (Table 5.26). All species listed in Table 5.25, that had the highest mean percent cover across multiple pads, were common woody species that would be expected in most of the forest edge vegetation communities in northcentral Pennsylvania. Early successional species like Allegheny blackberry and black cherry are not unexpected, as they are typically among the first woody species to re-establish following a disturbance. Species like coltsfoot, rough-stemmed goldenrod, and redtop probably spread to these areas that were cleared of trees by way of gas access roads and state forest road corridors.

The "erosion and sedimentation" vegetation type was present on 13 of 15 pads. Deer-tongue grass had the highest average percent cover, 7.4 percent (Table 5.27). Red fescue (4.3 percent average cover), timothy (4.2 percent), white clover (3.3 percent), and partridge pea (3.3 percent) are species used extensively in reseeding immediately following construction to reduce the potential for soil erosion and sedimentation impacts.

Both sweet-fern and hay-scented fern are common species in northcentral Pennsylvania. Sweet-fern especially prefers dry, open, savannah-like habitat and benefits from the conditions created at well pad edges.

Overall, the species that had the highest percent cover in all three types of communities (undisturbed forest, disturbed native vegetation, and disturbed) were expected. This indicates that in the first five to eight years following construction of the well pads, no unusual shifts have been detected in the vegetation communities adjacent to well pad edges. These early results also indicate that the vegetation communities and forest types in which these 15 pads have been placed are somewhat resilient to rapid changes in species composition following disturbance. However, this does not mean that there have not been areas where invasive plants have colonized following disturbance. It is likely that after the initial colonization by early successional species, both native and non-native, it may be some time before significant vegetation shifts are noticeable. Operationally, this is useful in that at this point, portions of a well pad that can be reclaimed could shift back to the pre-disturbance vegetation community. After the permanent well pad vegetation plots have all been surveyed for a second time, the bureau will be better able to quantify the smaller-scale changes in vegetation that are inevitably taking place on each pad edge.

In addition to permanent milacre vegetation plots, two types of surveys were conducted as part of the larger well pad assessment protocol. One survey focused on non-native, invasive plant species presence. The other survey focused on native and non-native species at the interface of disturbed and undisturbed forest. Monitoring staff walk three sides of the pad at the point in which the non-disturbed forest edge meets the limits of disturbance at the pad. Monitoring staff then observe any native species that are "volunteering" from the forest onto the disturbed pad edge, as well as non-native species that are spreading off the disturbed pad edge into the undisturbed forest. In total, 45 well pad edges (three edges each on 15 well pads) have been subject to this survey.

After comparing the well pad edges, the native species that were found most often volunteering on the disturbed edge (Table 5.28) were hay-scented fern (17 sides), sweetfern (16 sides), and goldenrods (14 sides). The most common native grass was deertongue (13 sides), the most common shrub was Allegheny blackberry (13), and the most common forbs were white snakeroot (10 sides) and common milkweed (8 sides). It is important to note that while population size estimates were taken, these are the average population sizes on sides where the plant was found, not an average of all 45 sides. Many of these species were expected to be found volunteering as they are common on any disturbed site with open light and dry, rocky soils.

Species	Number of Pads	Percent Cover
Deer-tongue grass (*Panicum clandestinum*)	10	7.4
Sweet vernalgrass (*Anthoxanthum odoratum*)	4	4.7
Red fescue (*Festuca rubra*)	3	4.3
Timothy (*Phleum pratense*)	10	4.2
Sweet-fern (*Comptonia peregrina*)	3	3.7
White clover (*Trifolium repens*)	9	3.3
Partridge pea (*Chamaechrista fasciculata*)	5	3.3
Hay-scented fern (*Dennstaedtia punctilobula*)	4	3.1

Table 5.27. Highest mean percent cover values per pad for "erosion and sedimentation" vegetation plots.

Species	Number of Pad Sides	Average Population Size
Hay-scented fern (*Dennstaedtia punctilobula*)	17	674
Sweet-fern (*Comptonia peregrina*)	16	428
Goldenrod species (*Solidago* species)	14	493
Deertongue grass (*Panicum clandestinum*)	13	742
Allegheny blackberry (*Rubus alleghiensis*)	13	534
White snakeroot (*Eupatorium rugosum*)	10	679
Swamp dewberry (*Rubus hispidus*)	8	367
Bracken fern (*Pteridium aquilinum*)	8	102
Woolgrass (*Scirpus cyperinus*)	8	58
Common milkweed (*Asclepias syriaca*)	8	418

Table 5.28. Average population size of native herbaceous and shrub species found volunteering on disturbed well pad edges.

During the surveys, monitoring staff took care to collect data regarding which native tree species were most prevalent as volunteers on disturbed pad edges. As expected, early successional species like black birch, quaking aspen, and fire cherry were prevalent (Table 5.29). Black birch was found the most on pad edges (8 times) and red maple was found on six pad sides. One surprising species that was found on two pad edges was Sycamore, which is a somewhat unusual volunteer given the upper elevation where many of the well pads are found. It may be possible that sycamore seed was present in equipment or fill that was brought up from more bottomland areas along stream corridors.

In addition to recording what native species were volunteering on disturbed well pad edges, the monitoring staff observed several non-native species spreading into the undisturbed forest edge (Table 5.30). Orchardgrass was found on the most edges (8 sides) spreading into the adjacent forest. Invasive species like reed canary grass, bull thistle, and Japanese barberry were all found on six sides spreading into the adjacent forest. One species, Japanese stiltgrass, which was expected to be found in many locations spreading into adjacent forest habitats, was only found spreading into the forest edge on two sides, both on the same well pad. In addition, 18 of the 45 well pad sides included in this protocol were

Species	Number of Pad Sides	Average Population Size
Black birch (*Betula lenta*)	8	86
Red maple (*Acer rubrum*)	6	191
Quaking aspen (*Populus tremulodies)*	3	23
Fire cherry (*Prunus pensylvanica*)	2	250
Black locust (*Robinia psuedoacacia*)	2	16
Sycamore (*Platanus occidentalis*)	2	16
Bigtooth aspen (*Populus grandidentata*)	2	27
Black cherry (*Prunus serotina*)	2	133
Yellow birch (*Betula alleghaniensis*)	1	75
Striped maple (*Acer pennsylvanicum*)	1	38

Table 5.29. Average population size of native tree species found volunteering on disturbed well pad edges.

Species	Number of Pad Sides	Average Population Size
Orchardgrass (*Dactylus glomerata)*	8	189
Reed canary grass (*Phalaris arundinacea*)*	6	161
Timothy (*Phleum pretense*)	6	105
Bull thistle (*Cirsium vulgare*)*	6	23
Japanese barberry (*Berberis thunbergii)**	6	7
Multiflora rose (*Rosa multiflora*) *	5	6
Crown-vetch (*Coronilla varia*) *	4	279
Sweet vernalgrass *(Anthoxanthum odoratum*)	3	692
Queen Anne's lace (*Daucus corota*)	3	94
Free of non-native species	18	

**invasive*

Table 5.30. Average population size of non-native herbaceous and shrub species found volunteering on non-disturbed well pad edges.

found to be free of non-native species spreading into adjacent forested habitats. Or, 27 sites (60 percent) did have invasive plants spreading into adjacent forest. In some pad locations, it appears that species like mountain-laurel and sweet-fern are serving as an effective physical barrier to colonization of adjacent forest by non-native plant species.

By carefully studying the native vegetation volunteering on the disturbed forest edge, the bureau can better guide site reclamation efforts. When armed with the knowledge that on slightly less than half of pad edges, hay-scented fern or sweet fern is likely to begin growing on the disturbed edge, care can be given to choose species in restoration seed mixes that will not be out-competed by these aggressive species. Furthermore, knowing that wildflower species like goldenrod, white snakeroot, and common milkweed can volunteer on disturbed forest sites, allows the bureau to either 1) augment these volunteers with additional seed of these species in the seed mix, or 2) focus on other native forb species in reclamation mixes knowing that one of these three species are likely to volunteer over time. The same type of planning is informed by having observational data about which native tree species are the first to volunteer on disturbed sites. The addition of black birch, red maple, or quaking aspen—three species that seem to volunteer successfully on disturbed sites—to planting plans can help improve planted tree survivorship during site reclamation. Other species that are not found volunteering naturally may be less suited for use on well pad reclamation projects due to growing conditions.

Since gas development often converts interior forest to forest edge or non-forest habitat, it is critical to have an understanding about what species benefit from this conversion are more readily colonizing adjacent interior forest. If non-native species like orchardgrass and timothy are spreading into forest habitats, it is prudent to further restrict their use in reseeding of disturbed sites to meet erosion and sedimentation regulations. Invasive species like Japanese barberry and multiflora rose are aggressively controlled on most state forest lands, supporting the need for continued monitoring and control. The bureau is aware that species like bull thistle and crown-vetch are problematic at these forest edge habitats. Unfortunately, these species are quite widespread and difficult to control efficiently. However, as more high-threat species are eradicated, it may be prudent to focus further invasive control efforts on bull thistle and crown-vetch. Certainly, as site rehabilitation efforts are undertaken, strategies that reduce thistles, knapweeds, and crown-vetch will be a critical component of restoration planning.

Right-of-Way Vegetation Assessments

Within the core gas forest districts, 188 miles of pipelines were constructed because of shale gas development. Of those 188 miles, approximately 22 percent have been co-located within an existing utility ROW. Most shale gas pipelines on state forest lands were installed prior to 2013 (164 miles). Approximately, 696 acres of forest have been cleared for shale gas pipelines, with 572.4 acres cleared prior to 2013 and 124.1 acres were cleared from 2013-2016. The Elk State Forest was the only state forest with more new pipeline miles from 2013-2016 than prior to 2013.

ROW corridors provide ideal habitat conditions for the establishment and spread of not only early successional plant species, but also invasive plant populations to interior forest communities. Due to the limited access and remote locations of some of these corridors, it is important to monitor for invasive plant infestations before they can become established and spread further into adjacent forest habitats. Additionally, areas that intersect these corridors, referred to as "hot-spots," provide an increased likelihood for invasive plants to disperse from the ROW to areas of adjacent forest. These "hot-spots" on state forest land include: stream crossings, timber sales, burned areas, road/trail crossings, and wetland habitats.

In 2015, 26.25 miles of pipeline ROW were surveyed. Of the 105 sections surveyed, only ten segments did not have at least one invasive species present. Based on the analysis of the 2015 section data, the most abundant invasive plant species (based on average percent cover) were Japanese stiltgrass, crown-vetch, and Canada thistle. The most common invasive species (based on number of occurrences) were Japanese stiltgrass (52 sections), bull thistle (50), and Canada thistle (42). In 2016, 27.5 miles of pipeline ROW were surveyed. Of the 110 sections surveyed, all but one had at least one invasive species present. Based on the analysis of the 2016 section data, the most abundant invasive plants (based on average percent cover) were Japanese stiltgrass, crown-vetch, and tall fescue. The most common invasive species (based on number of occurrences) were bull thistle (86 sections), crown-vetch (58), and Japanese stiltgrass (56) (Table 5.31).

In 2015, 112 "hot-spots" were encountered along the 26.25 miles of pipeline ROW surveyed. Within these "hot-spot" areas, the most abundant invasive plant species (based on average percent cover) were Japanese stiltgrass, reed-canary grass, and crown-vetch. The most common invasive plants (based on number of occurrences) were Japanese stiltgrass, Japanese barberry, and bull thistle. In 2016, 79 "hot-spots" were encountered along the 27.5 miles of pipeline ROW surveyed. Within these "hot-spot" areas, the most abundant invasive plant species (based on average percent cover) were Japanese stiltgrass, Oriental lady's thumb, and crown-vetch. The most common invasive plants (based on number of occurrences) were Japanese stiltgrass, bull thistle, and Oriental lady's thumb (Table 5.32).

	2015 Assessment	2016 Assessment
Highest incidence (# of sections)	Japanese stiltgrass (52)	Bull thistle (86)
	Bull thistle (50)	Crown-vetch (58)
	Canada thistle (42)	Japanese stiltgrass (56)

Table 5.31. Most abundant invasive plant species across all right-of-way monitoring sections, 2015 & 2016.

	2015 Assessment	2016 Assessment
Highest incidence (# of hotspots)	Japanese stiltgrass (56)	Japanese stiltgrass (21)
	Japanese barberry (23)	Bull thistle (12)
	Bull thistle (20)	Oriental lady's thumb (11)

Table 5.32. Most abundant invasive plant species across all right-of-way monitoring "hot-spots", 2015 & 2016.

	2015 Assessment	2016 Assessment
Highest incidence (# of occurrences)	White clover (25)	Orchardgrass (14)
	Deertongue grass (15)	Deertongue grass (13)
	Red clover (13)	Bird's foot trefoil (10)

Table 5.33. Most abundant plant species across all right-of-way intensive monitoring swaths, 2015 & 2016.

Within the ROW assessment areas, a subset of 40 sections in 2015 and 35 sections in 2016 were chosen for more intensive vegetation data collection. In 2015, within areas subject to more intensive data collection, the most abundant species (based on average percent cover) were orchardgrass, white clover, and red clover. The most common plant species (based on number of occurrences) were white clover, deertongue grass, and red clover. In 2016, within areas subject to more intensive data collection, the most abundant species (based on average percent cover) were orchardgrass, bird's foot trefoil, and deertongue grass. The most common plant species (based on number of occurrences) were orchardgrass, deertongue grass, and bird's foot trefoil (Table 5.33). The intensive vegetation monitoring data, which were collected to evaluate species composition, seems to indicate that all the most common species were those typically used in reseeding mixes planted to meet erosion and sedimentation regulations.

Most new pipeline ROW corridors are located adjacent to pre-existing state forest roads. This co-location approach helps minimize the creation of new fragmenting features across the forest landscape. Logistically, this approach also allows for utilization of the road surface for temporary workspace during construction, lowers construction costs for operators, and simplifies access for continuing inspections and periodic vegetation maintenance. One of the downsides to this approach is the increased width of these road/ROW corridors. In time, this increased width along state forest roads could provide more habitat for invasive plants to colonize than typical state forest roads. This assessment further demonstrates that the points at which pipeline corridors intersect or parallel state forest roads greatly facilitate the spread of non-native, invasive plants — especially early successional species like bull thistle, Canada thistle, spotted knapweed, and crown-vetch. Some pipeline corridors have been planted with a mix of non-native cool season grasses and native warm season grasses. In these areas, initially only the cool season grasses and white clover were present. However, in the last few years more native warm season grasses have established in these corridors. As this shift continues, some native species may become more abundant along pipeline corridors.

Roadside Vegetation Assessments

With increased truck traffic to facilitate development comes the potential for changes in the composition of the vegetation communities growing on state forest roadsides. Often disturbed corridors like roads and roadside shoulders can be colonized by non-native weed species and invasive plant species. This increases the risk of spread into interior forest habitat.

Acres of roads constructed and modified for gas development declined from 220.5 total miles (2008-2012 to 42.3 total miles (2013-2016). The Elk State Forest was the only forest district where the miles of new roads constructed or modified increased for those periods.

The bureau evaluates the current conditions of roadside vegetation communities on state forest roads utilized for shale gas development and compares them to roadside communities that are not subject to shale gas related traffic, widening, or improvements. Two types of public use roads were identified for evaluation, those with high gas traffic (High Gas roads) and those with no regular gas traffic (Non-Gas roads). Two roads of each type were selected in each core gas forest district. A total of 28 roads were chosen. These are state forest roads that are not maintained by PennDOT or municipalities. Consideration was made to minimize the chance that Non-Gas roads would be utilized by new gas development in the future. Within each three-mile road section, three pairs of milacre (1/1000 acre) vegetation plots were established on both sides of the road at one mile increments (Figure 5.17). In addition, the nearest culvert to the paired plot locations was also monitored for invasive plants species. A version of this protocol was piloted in 2012 and the first round of data collection occurred during the 2013 field season. At that time, only 24 of 28 selected roads were surveyed. The four roads in the Elk State Forest were not included due to the lack of gas development activity during this time. In 2016, all 28 roads were surveyed.

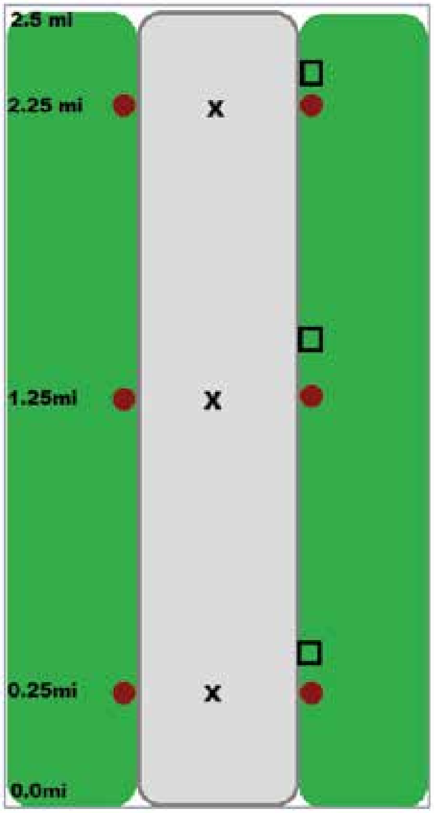


Figure 5.17. Location of roadside vegetation plots (red circles) and closest culverts (squares) within roads targeted for vegetation monitoring.

In 2013, the High Gas roads had less overall plant diversity with a total of 186 species compared to the Non-Gas roads which had 208 species. This may be due to some plots on the High Gas roads which fell in co-located pipeline rights-of-way, which are dominated by species planted after completion of the pipeline construction to meet erosion and sedimentation guidelines. Typically, these seed mixes are similar and contain a mix of native and non-native species. Surprisingly, during the 2016 measurements, this result changed, with more total species (244) found on the High Gas roads, compared to the Non-Gas roads (238). The average number of species per milacre plot on High Gas roads increased from 14.6 to 18.1 species per plot from 2013-2016. However, during the same period the average number of species per plot on Non-Gas roads, 16.6 species, stayed the same. It is possible in the three years since initial measurement of the High Gas roads the seed mixes used on co-located pipelines became fully established. In addition, it is likely that there has been an influx of both native pioneer species and non-native weed species on roadsides. It should be noted that two of the most common species on High Gas roads are non-native: Coltsfoot and dandelion species (Table 5.34). In 2013, 47 of the 186 species (25 percent) found on High Gas roads were non-native, compared to 37 out of 208 species (18 percent) on Non-Gas roads. In 2016, 69 of the 244 species (28 percent) found on High Gas traffic roads were non-native, compared to 52 out of 238 species (22 percent) on Non-Gas roads. From 2013-2016, the increase of non-native plant species on roadside plots was steady for both High Gas and Non-Gas roadsides, which indicates that in the first three-year period between measurements, the amount of gas traffic may not be affecting the proportion of the vegetation community composed of non-native species. In addition, the number of invasive plant species on High Gas roads increased from eight to 13 between 2013-2016, a 63 percent increase. On Non-Gas roads, the total number of invasive species was six in 2013 and increased by 50 percent to nine in 2016 measurements.

Initially, observational findings made clear the physical differences between most High Gas roads and Non-Gas roads. To minimize forest fragmentation, the bureau encouraged the co-location of pipeline corridors along some state forest roads. This created a road with a 20 to 40-foot-wide pipeline corridor immediately adjacent to the running surface, planted with a mix of native and non-native species, such as timothy (*Phleum pratense*), white clover (*Trifolium repens*), orchardgrass (*Dactylis glomerata*), switchgrass (*Panicum virgatum*), and black-eyed susan (*Rudbeckia hirsuta*). This accounts for some of the increased non-native plant species present on High Gas roadsides, as does the increased early successional habitat created by the additional pipeline corridor. Furthermore, roads utilized for High Gas traffic often must be upgraded to accommodate larger trucks and more traffic, which means an increase in limestone road surface material. Over time, this material often gets pushed off the road base onto the vegetated edge. This increases the alkalinity of the soils near the road which can alter the plant composition by creating favorable soil conditions for seed germination. Vegetation communities on Non-Gas roads seem to be more stable and are being invaded by weedy, non-native species or invasive plant species at a slightly slower rate. This is likely due to the lack of widening or additional disturbance.

Over the first two measurements, some differences in the vegetation communities or changes in species composition were slight. However, it is critical to continue this monitoring. Differences in measurements may not have been as great as hypothesized, but certainly the change in habitat between High Gas and Non-Gas roads is notable. The open, early successional habitat found along many state forest roads utilized for gas traffic and pipeline corridors will continue to serve as ideal habitat for additional non-native weeds or invasive species to colonize these areas. Developing a better understanding of potentially vulnerable vegetation communities will yield further insights that will aid in future planning and infrastructure management activities. Furthermore, required routine maintenance activities on pipeline corridors increase the likelihood of new invasions from propagules carried in on equipment. This maintenance also limits the ability of some native, early successional species to establish on roadsides and corridors. By continuing to monitor roadside vegetation, future maintenance activities can be scheduled to avoid flowering and fruiting periods of native species that are found to be establishing on these disturbed corridors. Additionally, the bureau attempts to update recommended native seed mixes based on which native species are be able to successfully recolonize disturbed sites naturally. This may lead to more successful site rehabilitation activities within portions of the state forest subject to natural gas development activities.

State-listed Species Monitoring Efforts

State forest lands provide a protected landscape that harbors many state-listed rare plants, as well as many unique wetland or palustrine forest habitats. These species are listed, or proposed to be listed, as PA Endangered, PA Threatened, and PA Rare. In the past, many of these plant occurrences or wetland habitats were "secure" based on their remote, interior forest location on state forest lands. During the planning stages of placing gas infrastructure on state forest lands, the bureau goes to great lengths to avoid impacts to state-listed plant species and unique habitats. Populations of many Pennsylvania rare plants, such as creeping snowberry (*Gaultheria hispidula,* PA Rare), yellow-fringed orchid (*Platanthera ciliaris,* Proposed PA Threatened), great spurred violet (*Viola*

2013 Assessment **144 plots**	High Gas (HG) Roads *(Species, # of plots)*	Non-Gas (NG) Roads *(Species, # of plots)*
	Coltsfoot (*Tussilago farfara*), 34	Violet species (*Viola spp.*), 44
	Goldenrod species (*Solidago spp.*), 28	Aster spp. (*Symphyotrichum*), 36
2016 Assessment **168 plots**		
	Dandelion species *(Taraxacum spp.*), 40	Violet species (*Viola spp.*), 45
	Coltsfoot (*Tussilago farfara*), 39	Red maple (*Acer rubrum)*, 42
	Violet species (*Viola spp.*), 33	Sedge species (*Carex spp.*), 31

Table 5.34. Most abundant plant species in 2013 and 2016 roadside vegetation assessment plots.

selkirkii, PA Rare), and northeastern bulrush (*Scirpus ancistrochaetus,* PA Threatened, Federally Endangered), are known to exist near shale gas development on state forest lands. Identifying occurrences of these state-listed species and monitoring for threats or declines due to development on state forest land is a high priority.

After conducting a desktop analysis, seven populations of state-listed plants or plant communities were found within 1,000 feet of shale gas infrastructure development projects. Between 2012 and 2015, these seven populations were visited to assess potential threats. Survey methodology was based on Goff et al. (1982) and "Protocols for Conducting Surveys for Plant Species of Special Concern" (PA DCNR, 2011). In all cases, no evident threats to the populations from shale gas development were observed. Again, it should be stressed that these populations are typically not immediately adjacent to any existing infrastructure.

2. <u>Monitoring tracts subject to shale gas development for non-native, invasive plant species</u>

DCNR defines invasive plants as any plant species that is not native to Pennsylvania, can grow or spread aggressively, and displace native vegetation. Invasive plants have the potential to inhibit tree regeneration in young forest stands, exclude native species from plant communities, disrupt wetland habitats, and arrest successional pathways within forests. Forest clearing or disturbance that occurs during the construction of shale gas infrastructure can provide ideal habitat and growing conditions for the establishment of new invasive plant populations. Furthermore, invasive plant material or propagules can be brought onto the state forest on construction vehicles, as well as in fill, quarry material, or mulch used for construction projects. The bureau is committed to controlling the spread of invasive plant species across all state forest lands, which requires adaptive management and landscape-level prioritization based on efficiency, availability of resources, and perceived threat of each species population to ecosystem health. At the landscape level, rarely is it as simple as adopting a strategy of eradicating all known invasive plant populations. Many of these methods require an understanding of the current levels of infestations across a given landscape. Given the distribution of gas infrastructure on state forest lands in northern Pennsylvania, it is necessary to take both a site-level and landscape-level approach to invasive plant species monitoring.

From the onset of natural gas development on state forest lands, it was clear that managing and minimizing the spread of invasive plants would require three main components:

1) A concerted effort to understand how all invasive plants were spreading across natural gas infrastructure.
2) A targeted Early Detection and Rapid Response (EDRR) protocol that efficiently addressed the highest-threat invasive plant species found on state forest lands.
3) Partnerships, both formal and informal, with natural gas operators to treat infestations found to have occurred because of natural gas development.

Pad Invasive Surveys

By surveying the disturbed edges of all pad infrastructure, invasive plant species brought in by construction activities or taking advantage of new forest disturbance have been tracked. The bureau has been able to evaluate and prioritize treatment for all invasive plants based on how species have been found to spread from disturbance-to-disturbance across the landscape. As the spread of certain invasive plants are monitored over time, new insights have been gained into which species are treatment priorities based on their ability to out-compete native species, spread into adjacent forest stands, or limit the success of ecological site rehabilitation efforts.

To date, 265 pads have been constructed on state forest lands for shale gas production. This includes 179 well pads, 38 freshwater impoundments, 17 compressor stations, and 31 additional miscellaneous infrastructure pads. It is also likely that moving forward, additional pads will be constructed. Infrastructure pads on state forest lands are visited on a three-year cycle. During a survey, monitoring staff walk the entire edge of each pad, documenting any invasive plant species present at the site. As of December 2016, 238 infrastructure pads and an additional 66 associated access roads have been surveyed for invasive plant species. Of the 238 surveyed pads, there were 168 well pads, 33 freshwater impoundments, 14 compressor station pads, and another 23 miscellaneous pads that include pads for monitoring, storage wells, and meter stations. Furthermore, of these 238 surveyed pads, 127 have now been visited at least twice since 2011. This allows for a comparison of site invasion by invasive plants over time. If certain pads have active construction taking place, they are not subject to surveys due to safety concerns. Newer pads are not surveyed for the first time until they have had one complete growing season for vegetation to become established. During the survey, the population size for each species present is recorded.

Looking first at the combination of all infrastructure pads (Table 5.35), bull thistle was found on 142 pads - the most by a wide margin. Three other species that typically colonize recently disturbed sites with open growing conditions - crown-vetch, spotted knapweed, and Canada thistle - were also found on a high number of pads. Due to the disturbed nature of these non-forested sites, it is not surprising that these species are those being located on the highest number of pads. Some invasive grass species, like reed canary grass (64 pads), tall fescue (49 pads), and Japanese stiltgrass (47 pads), also easily out-compete most species used for revegetation on disturbed pad edges. This has led to their spread on these sites. While Japanese stiltgrass was not the species found on the most pad edges, it did have the highest mean population size of 749 individuals. An annual grass, this species is extremely difficult to eradicate once well established in populations like those found at many pad edges. Only 29 infrastructure pads out of 238, or 12.1 percent of all pads, were found to be free of invasive plant species.

Species	Number of Pads	Average Population Size
Bull thistle (*Cirsium vulgare*)	142	63
Crown-vetch (*Securigera varia*)	98	409
Spotted knapweed (*Centaurea stoebe*)	91	224
Canada thistle (*Cirsium arvense*)	89	370
Reed canary grass (*Phalaris arundinacea*)	64	273
Tall fescue (*Schedonorus arundinaceus*)	49	292
Japanese stiltgrass (*Microstegium vimineum*)	47	749
Multiflora rose (*Rosa multiflora*)	47	8
Velvetgrass (*Holcus lanatus*)	46	343
Autumn-olive (*Elaegnus umbellata*)	34	11
Oriental ladys-thumb (*Persicaria longiseta*)	33	322
PADS WITH NO INVASIVES	**29**	

Table 5.35. Most common invasive plants found during surveys – all infrastructure pads.

As the infrastructure is broken down by pad type, some trends become apparent. For instance, when well pads are separated from other pad types (Table 5.36) bull thistle again is found on the most well pad edges (114). The same is true when examining data from only the well pad access road edges (Table 5.37). The well pad edges and the well pad access road edges had the same five species found most often: bull thistle, crown-vetch, Canada thistle, spotted knapweed, and reed canary grass. This supports research conducted by Barlow (2017) which found a positive correlation between invasive plants on pad access roads and subsequent presence on the well pads themselves. Of those five, on both pad and road edges, crown-vetch had the largest average population size. The proportion of un-infested well pad edges was the same, 10.7 percent, as the proportion of all infrastructure pads combined.

The same five invasive plant species were found most often on compressor station pads and freshwater impoundment pads (Tables 5.38 and 5.39): bull thistle, Canada thistle, crown-vetch, reed canary grass, and spotted knapweed. While there are far fewer compressors and impoundments, the invasive plant infestations are very similar. In the case of both pad types, crown-vetch had the largest mean population size (279 plants on compressors, 363 plants on impoundments).

Species	Number of Pads	Average Population Size
Bull thistle (*Cirsium vulgare)*	114	69
Crown-vetch (*Securigera varia*)	79	429
Canada thistle (*Cirsium arvense*)	77	409
Spotted knapweed (*Centaurea stoebe*)	75	242
Reed canary grass (*Phalaris arundinacea)*	49	303
PADS WITH NO INVASIVES	**18**	

Table 5.36. Most common invasive plants found during well pad surveys.

Species	Number of Pad Access Roads	Average Population Size
Bull thistle (*Cirsium vulgare)*	87	59
Crown-vetch (*Securigera varia*)	70	478
Canada thistle (*Cirsium arvense*)	58	305
Spotted knapweed (*Centaurea stoebe*)	47	291
Reed canary grass (*Phalaris arundinacea)*	47	163
ACCESS ROADS WITH NO INVASIVES	**16**	

Table 5.37. Most common invasive plants found during well pad access road surveys.

Species	Number of Pads	Average Population Size
Bull thistle (*Cirsium vulgare)*	6	17
Canada thistle (*Cirsium arvense*)	5	233
Reed canary grass (*Phalaris arundinacea)*	5	34
Crown-vetch (*Securigera varia*)	4	279
Spotted knapweed (*Centaurea stoebe*)	4	110
COMPRESSORS WITH NO INVASIVES	**4**	

Table 5.38. Most common invasive plants found during compressor pad surveys.

Species	Number of Pads	Average Population Size
Bull thistle (*Cirsium vulgare)*	16	83
Crown-vetch (*Securigera varia*)	11	363
Spotted knapweed (*Centaurea stoebe*)	10	167
Reed canary grass (*Phalaris arundinacea)*	9	75
Canada thistle (*Cirsium arvense*)	8	152
IMPOUNDMENTS WITH NO INVASIVES	8	

Table 5.39. Most common invasive plants found during freshwater impoundment pad surveys.

Change	Number of Pads
Number of invasives declined	6
Number of invasives remained unchanged	15
Number of invasives increased by 1 or 2 species	44
Number of invasives increased by 3 or 4 species	31
Number of invasives increased by 5-7 species	23
Number of invasives increased by 8-10 species	8

Table 5.40. Change in number of species detected per well pad for 127 well pads surveyed twice between 2011 and 2016.

Many of the infrastructure pads on state forest land have been subject to two surveys between 2011 and 2016, which allows for a comparison regarding the way invasive plants are spreading across the landscape via infrastructure pads. On the 127 well pads that have been subject to two surveys, the number of detected invasive species per pad has increased (Table 5.40) on almost all sites. Only on 21 well pads have the number of invasive species declined or remained constant.

Looking further into the changes in invasive plant species on the 127 well pads subject to two surveys, it is possible to quantify the average change in population size for many of the species (Table 5.41). The species with the greatest change in average population size was velvetgrass, which increased on average by 561 individuals. This is due, at least in part, to the fact that this species was not tracked as an invasive plant in the first two years of monitoring. Rather, it was added in later iterations of pad surveys. Invasive plant species like Canada thistle (average increase of 403 individuals) and Japanese stiltgrass (average increase of 343 individuals) that prefer disturbed, open sites all showed average increases in population size. The species with the highest average decline was brown knapweed (average declined by 110 individuals). Overall, invasive shrub species like multiflora rose (average declined by 26 individuals), autumn-olive (average declined by 20 individuals), Japanese barberry (average declined by 6 individuals), and Japanese knotweed (average declined by 3 individuals) all showed declines, likely due to the prioritization of these species for immediate treatment.

From 2011 to 2016, it is evident from the pad surveys that many invasive plant species populations have spread to new sites on state forest land and populations first found from 2011-2013 have expanded at many sites. This is due primarily to the aggressive nature of invasive plants. However, disturbance associated with the construction of gas infrastructure within state forest land has clearly increased their spread. Invasive plant material and seed can be brought onto a site in

Species	Change in Average Population Size
Velvetgrass (*Holcus lanatus*)	+561
Canada thistle (*Cirsium arvense*)	+403
Japanese stiltgrass (*Microstegium vimineum*)	+343
Tall fescue (*Schedonorus arundinaceus*)	+310
Crown-vetch (*Securigera varia*)	+255
Oriental bittersweet (*Celastrus orbiculatus*)	+250
Oriental lady's-thumb (*Persicaria longiseta*)	+224
Small-flowered willowherb *(Epilobium parviflorum)*	+197
Reed canary grass (*Phalaris arundinaceae)*	+134
Cheatgrass (*Bromus tectorum*)	+121
Brown knapweed (*Centaurea jacea)*	-110
Multiflora rose (*Rosa multiflora*)	-26
Autumn-olive (*Eleagnus umbellata)*	-20
Japanese barberry (*Berberis thunbergii*)	-6
Japanese knotweed (*Fallopia japonica*)	-3
Goat's-rue (*Galega officinalis*)	-3

Table 5.41. Change in invasive plant species average population size for 127 well pads surveyed twice between 2011 and 2016.

contaminated fill or seed, as well as on equipment or vehicles that are not cleaned prior to being driven to a new infrastructure site. Furthermore, wildlife (especially birds) are attracted to forest edges and open, disturbed sites. This helps to further spread invasive seed from one infrastructure site to another. The conditions at most infrastructure pads – disturbed soils, reduced plant competition, and open light – all benefit invasive plant species and aid in their spread across a site. Once populations are established, species like Canada thistle, bull thistle, and spotted knapweed have seeds that are spread passively via wind and move across pad sites or from access roads onto new pad sites.

While several invasive plant species' prevalence on gas infrastructure pads has increased, there are successes to be found in the species not found among the list of most common. Some species, such as mile-a-minute, tree-of-heaven, goat's-rue, poison hemlock, and Japanese knotweed, have been prioritized by the bureau for immediate treatment and eradication. These Early Detection and Rapid Response protocols have led to a steep decline in existing populations of these high-threat species since 2011. Similarly, many invasive shrubs, such as Japanese barberry, autumn-olive, and multiflora-rose, have also been targeted for treatment due to the high threat they pose to forest ecosystems.

Typically, the species that are most prolific on newly disturbed, open sites such as crown-vetch, thistles, and knapweeds cannot spread easily into adjacent forest stands. Because of this, these species have received the lowest priority for treatment in most areas of gas development on state forest lands and have continued to spread across gas infrastructure sites. While these species are not prioritized for treatment and control currently, when site rehabilitation occurs and pads enter the reclamation stage, it will be necessary to treat invasive plants like Canada and bull thistle, spotted knapweed, and crown-vetch prior to planting native species. Furthermore, the proliferation of these species has allowed for the allocation of specialist and equipment resources to test new herbicides and treatment techniques that could prove to be effective in efficiently slowing the spread of these lower-priority invasive plants.

Notes from the Field:

Tract-level Invasive Plant Management

The Elk State Forest is home to 40,802 acres of severed rights gas ownership found in the E. Branch Dam and Clermont Area. Because of the severed rights environment, constant and open communication with the oil and gas companies and their contractors, along with routine inspections, are key in the successful management of shale gas development on state forest land.

This combination of constant communication, routine inspections, and cooperation of the gas operator have been integral to the success in combating invasive plants, specifically goat's rue (*Galega officinalis L.*) in this portion of the Elk State Forest.

Goat's rue was first observed on the edge of a Marcellus well pad in June of 2015 during a routine inspection. Shortly after, it was also found along several road edges and a reclaimed stone pit in the same area of the forest. Immediately, work was conducted in cooperation with the gas and pipeline companies to determine the source and potential vectors of these populations. After many phone calls and e-mails, it was determined that the goat's rue had come from contaminated hay that was used by the pipeline company during their construction of several miles of new pipeline in 2014.

A survey was conducted of the areas associated with the pipeline project and populations were mapped. Once the entire project area was surveyed, the bureau developed a treatment plan. The initial treatment plan was to hand pull the smaller populations that consisted of single plants and small clumps of plants and coordinate with the gas company to treat the larger populations with herbicide.

Once the plan was developed, a meeting was arranged with the gas and pipeline companies to coordinate the herbicide treatment. During the 2015 growing season the larger populations were treated with one round of herbicide in August. This treatment was timed to have the largest effect as possible on the plants as well as prevent any seed from setting. Once the treatment was completed, weekly monitoring was done to determine the effectiveness of the herbicide.

In the spring of 2016, a follow-up plan of treating the plants several times during the growing season was developed based on the 2015 observations. This strategy allowed for the continuous treatment of new germinates that were showing up from the seed bank after the larger plants died out. In addition to the multiple herbicide treatments, hand pulling of any new satellite or single plants that were observed or that germinated in the smaller populations was conducted.

Initial Goats Rue population found in June of 2015 at the edge of a well pad.

Large goat's rue infestation in Elk State Forest.

The 2016 treatments proved to be very effective and it was determined that if properly timed, the number of treatments, man hours, and chemical introduced into the environment, could be reduced to two treatments during the growing season. Therefore, during the 2017 growing season the populations were treated twice with herbicide and several small populations were hand pulled as necessary.

Over the past three years there has been a dramatic reduction in the overall size and health of the populations. Areas that were once infested with goat's rue are now only sparsely populated. The bureau's ability to work closely with the gas and pipeline companies, as well as the bureau's ability to remain flexible and adapt treatment strategies, has proven to be quite effective.

In the end, this process has been successful because of effective, open and timely communication, diligent monitoring, and cooperative efforts. Although goat's rue is still a concern, the bureau is optimistic that eradication of goat's rue on the Elk State Forest is possible.

Early Detection and Rapid Response Efforts

Early Detection and Rapid Response (EDRR) protocols maximize both sampling efficiency and discovery opportunities for new invasive plant species. This protocol was adapted from the approach created by Keefer et al. (2010) for US National Park Service lands. New forest clearing or disturbance due to gas development provides ideal habitat and growing conditions for invasive plant species. Tracking all novel populations and treating them promptly is essential to slowing the spread of invasive plants on state forest lands. The focus of this protocol is on high priority species that are either new or uncommon to a particular state forest; or are currently found outside state forest land, but have the potential to colonize within a state forest. In addition to tracking these species, this strategy also allows for the immediate (based on seasonality) treatment of these populations when found. One main assumption of EDRR is that new occurrences, when found, are relatively small and if immediately treated, could be eradicated with minimal effort, time, and cost. Since these populations will be tracked over time, the effectiveness of treatments can also be evaluated.

EDRR protocols provide a brief (less than 5 minutes) reporting procedure that is carried out by all personnel on the Shale Gas Monitoring Team. Prior to implementation of this protocol, a list of ten high priority invasive species was developed for the core gas forest districts. The list is re-evaluated annually based on the latest survey data.

The following species were considered targets for EDRR from 2013 through 2016:

- Tree-of-heaven (*Ailanthus altissima*)
- Japanese angelica tree (*Aralia elata*)
- Poison hemlock (*Conium maculatum*)
- Glossy buckthorn (*Frangula alnus*)
- Goat's rue (*Galega officinalis*)
- Mile-a-minute (*Persicaria perfoliata*)
- Common reed (*Phragmites australis ssp. australis*)
- Japanese & Giant knotweed (*Polygonum cuspidatum & P. sachalinense*)
- Black swallow-wort (*Vincetoxicum nigrum*)
- Pale swallow-wort (*V. rossicum*)

Having four years of full field implementation of the EDRR protocols allows for many comparisons to be made among the 2013, 2014, 2015, and 2016 data. One interesting result is that the number of new populations found continues to only slightly increase (16 in 2013, 17 in 2014, 18 in 2015, and 20 in 2016). This nearly equivalent result also confirms that the level of survey intensity has remained constant from 2013-2016. It is reasonable to expect that at the current level of survey intensity, approximately 17 high-threat populations per year may be located. During the 2016 field season, an additional 20 populations of high-priority invasive species were located (Table 5.42). This included the first detection of Phragmites in the Elk State Forest and the first detection of poison hemlock in the Tiadaghton State Forest. Tree-of-heaven was the species found most often, with 21 populations in three state forests (Sproul, Tiadaghton, and Loyalsock). To date, 13 populations have been referred to district staff for more intensive treatment. Of those, ten have had treatments conducted by either district staff or gas operator contractors. These EDRR efforts clearly demonstrate to gas operators that the bureau is committed to limiting the spread of these high-threat species. Gas operators have been willing to conduct treatments and have benefitted from the monitoring team's survey data and expertise in controlling these species. Ultimately, this partnership will result in fewer seed sources for new infestations across the entire landscape over time. Since its adoption as a monitoring protocol, some EDRR populations have been found outside gas infrastructure sites, but were treated promptly, further limiting their spread.

As of the 2016 field season, 19 populations of high-priority invasive plant species that were originally detected in 2013 and 2014 have been eradicated (Table 5.43). The bureau considers a population of an invasive plant species eradicated when it has not been detected for two consecutive growing seasons following treatment. In 2016, another eleven populations were found to have no individuals present at the site one growing season following treatment.

Four years of full field implementation allows for a thorough review of the efficacy of initial invasive plant removals and treatments. After four years, monitoring data indicate that all knotweed treatments and nearly all tree-of-heaven treatments have been effective at controlling populations found by EDRR protocols. This is likely due to the small population sizes at all locations, but nevertheless, a positive result. Phragmites treatments have shown mixed results after three years. One population, in the Moshannon State Forest was removed completely. However, other initial populations that have been treated (mostly hand-pulled and dug) needed two years of treatment, but are now appearing to be significantly reduced at each site. Based on these experiences, the treatment technique of cutting stems, then returning eight weeks later and applying herbicide to the re-growth appears to be an effective treatment.

The bureau is continuing treatments of poison hemlock populations, which will likely yield new field observations regarding the most efficient treatments. If a poison hemlock population has had a chance to develop seed, the seed bank may prove difficult to exhaust.

Treatment of goat's rue populations have also shown mixed results, but this is likely due to the large sizes of some populations. Smaller populations seem to be easier to completely remove, while just slightly larger populations (25 plants) are likely to take more than one growing season of treatment. At some sites where goat's rue has been established for several years and a seed bank has developed, four years of treatment has yet to eradicate the population.

Overall, the treatment results to date are promising. In 2013, the focus was on the amount of effective treatment possible only by digging or hand-pulling. In 2014 and 2015, this trend was continued in some cases. However, for a few species targeted and timely herbicide treatment has proven to be the most effective and efficient means to remove these plants. Field treatments in 2016 and 2017 became far more efficient as insight was gained into scheduling the treatments of active cases at the appropriate time during the growing season to maximize results.

District	Species	Closest Road /Location	2016 Pop. Size	2015 Pop. Size	2014 Pop. Size	2013 Pop. Size
Moshannon	Japanese knotweed	US Rt 322 Powerline	16	16		
	Japanese knotweed	US Rt 322 Powerline (Site 2)	20			
	Phragmites	**Bark Camp Road**	**R**	**100+**	**100+**	**100+**
	Phragmites	Quehanna Highway	3	1	100	100
	Phragmites	PA Route 153	100+			
	Poison hemlock	Weiss Grade Road	12	7		
Sproul	**Glossy buckthorn**	**Tract 285 Compressor & ROW**	**R**	**100+**	**100+**	
	Glossy buckthorn	**Dutchmans Road**	**100+**			
	Goat's rue	Old View Road	4			
	Phragmites	**Jews Run Rd / Dominion ROW**	**R**	**500+**	**100+**	**100+**
	Phragmites	Tract 706, Pad 8	40			
	Phragmites	Tract 706, Pad 10	12			
	Phragmites	March Creek Trail	30			
	Poison hemlock	**Jews Run Rd / Dominion ROW**	**R**	**100**		**8**
	Poison hemlock	Young Woman's Creek	100+			
	Tree-of-heaven	Tract 252, Eagleton Rd (Site 1)	0	1		
	Tree-of-heaven	Tract 252, Eagleton Rd (Site 2)	0	1		
	Tree-of-heaven	Tract 252, Eagleton Rd (Site 3)	1			
	Tree-of-heaven	Tract 231A, Kato Orviston Rd	0	1		
Tiadaghton	Mile-a-minute	Bull Run Spur 1 Pipeline		1		
	Mile-a-minute	Tract 289, Pad D	50			
	Phragmites	Tract 728, Pad B	25			
	Poison hemlock	Moore Road Ext	80			
	Poison hemlock	RT 44, Upper Pine Bottom Rd	3			
	Porcelainberry	Railroad St., Cammal	0	2	25	
	Japanese angelica tree	Route 414, Pine Creek Rail Trail		1	25	100
	Pale swallow-wort	**US 220 & PA-44**	**R**	**R**	**100+**	
	Tree-of-heaven	Huntley Road	0	3		
	Tree-of-heaven	Lone Walnut Club Rd (Site 1)	0	1		
	Tree-of-heaven	Lone Walnut Club Rd (Site 2)	0	5		
Elk	**Goat's rue**	**Briggs Hollow Road**	**R**	**12**		
	Goat's rue	**Straight Creek Road**	**R**	**100+**		
	Phragmites	Neverlost Road	25			
Susquehannock	Goat's rue	Horton Run Colony Road	1	11	8	25
	Goat's rue	**Big Fill Hollow Road (Site 1)**	**R**	**1**		
	Goat's rue	**Big Fill Hollow Road (Site 2)**	**R**	**4**		
	Goat's rue	**Big Fill Hollow Road – Monit. Pad**	**R**	**20**		
	Goat's rue	**Big Fill Hollow Road – Pad H**	**R**	**234**		
Tioga	**Glossy buckthorn**	**Landrus Rd & Powerline**		**25**		
	Phragmites	Tract 1040, Pad 822 Acc Rd	75			
Loyalsock	Goat's rue	Chapman Road, Tract 724	0	1	17	25
	Japanese knotweed	Hagerman Run Road	1			
	Mile-a-minute	**T100 Compressor**	**R**	**100+**	**1000+**	
	Mile-a-minute	**T100, Kenney Ridge ROW**	**R**	**100+**	**1000+**	
	Tree-of-heaven	Narrow Mountain Road (Site 1)	1	0	2	
	Tree-of-heaven	Narrow Mountain Road (Site 3)	0	1		
	Tree-of-heaven	Narrow Mountain Road (Site 4)	0	1		
	Tree-of-heaven	Hefner Hollow Trail	15	8	1	

*Populations highlighted in yellow were newly located in 2016.

* Populations in bold are considered too large for Rapid Response treatment. Monitoring and Ecological Services staff are working with District staff and Operators to address these populations referred to the districts.

Table 5.42. 2016 Early Detection Rapid Response Results Summary Table – Active and Referred Cases

District	Species	Closest Road /Location	2016 Pop. Size	2015 Pop. Size	2014 Pop. Size	2013 Pop. Size
Moshannon	Phragmites	COP 323 Pad 2 Impoundment		0	0	25
	Giant knotweed	US Rt 322	0	0	30	
Sproul	Phragmites	Tract 285 Pad C		0	0	5
	Japanese knotweed	Tract 706, Rt 144		0	0	1
	Japanese knotweed	Tract 678 Pad B		0	0	1
Tiadaghton	Glossy buckthorn	Narrow Gauge Road	0	0	1	
	Goat's rue	Huntley Road, Tract 293 ROW		0	0	1
	Phragmites	Tract 289 Pad D	0	0	17	25
	Phragmites	Tract 289, ROW & Lebo Road	0	0	25	
	Phragmites	Tract 322, Bark Cabin Road	0	0	5	
	Phragmites	T 356, Moore Road	0	0	25	
	Japanese knotweed	Tract 685 Compressor	0	0	1	
	Japanese knotweed	Tract 728 Pad D	0	0	0	5
	Tree-of-heaven	Okome Fire Road	0	0	5	
Loyalsock	Tree-of-heaven	Bodine Mtn Road (Site 1), Tract 100		0	0	1
	Tree-of-heaven	Hagermans Run Road, Tract 100		0	0	1
	Tree-of-heaven	Bodine Mtn Road (Site 2)	0	0	2	
	Tree-of-heaven	Brown Road	0	0	2	
	Tree-of-heaven	Narrow Mountain Road (Site 2)	0	0	1	

Table 5.43. Invasive Plant Populations Eradicated as of 2016.

Notes from the Field:

The importance of appropriate timing and diligence required to carry out Early Detection and Rapid Response protocols is well illustrated in this case study from the Tiadaghton State Forest.

This population of poison hemlock was initially located by the gas forester in the early spring of 2016. An existing pipeline ROW had been disturbed with the installation of an additional pipeline the previous year and had been reseeded and mulched with straw during the fall of 2015. Unfortunately, either the equipment used for the work — or more likely the bales of straw themselves — contained seeds of poison hemlock. The gas monitoring foresters were asked to help survey the area and determine the extent of the problem. Due to invasive plant surveys already conducted in the area, the bureau is confident that no poison hemlock was growing in the immediate area prior to this date. Small populations (one to six poison hemlock basal rosettes) were found at six individual locations and one larger population of 50-100 rosettes throughout the pipeline corridor upon additional surveys in 2016. Each plant was treated with a foliar application of glyphosate, which successfully controlled all plants.

Small poison hemlock plants found along Hemlock Road in 2017.

More poison hemlock was found in the spring of 2017. Fortunately, the populations were smaller and three of the 2016 sites showed no new plants. However, monitoring foresters were disappointed to find two new locations with additional plants. They were again sprayed with herbicide at that time, and again a month later when a handful of newly germinated plants were found at the sites.

Cooperation and detailed communication between the monitoring team and the Tiadaghton State Forest gas forester allowed the district to accomplish more with the extra sets of hands and eyes. The cooperation also allowed the gas monitoring field crews to have a better idea where to look for additional infestations, since the gas forester brings insights into where new work was carried out at gas infrastructure sites. In this case, monitoring staff could focus efforts on the entire area that was disturbed and reseeded and not just where initial infestations of poison hemlock were found, preventing staff from potentially missing new plants.

This infestation has taught the bureau that timing is key for any kind of success. This starts with looking for plants when they are easy to observe to prevent missing populations. Timing treatments in early spring for poison hemlock due to its early growth compared to other surrounding vegetation is also critical. Timing the treatment when they are small rosettes requires less effort and uses less herbicide, and most importantly, finding and treating plants before they flower and fruit prevents re-stocking of the seed bank. Diligence is also key, because it is going to take time to eradicate the population. Poison hemlock seeds will not all germinate the next year after they are planted. Treating once and walking away would most certainly end with a large population of poison hemlock that would be nearly impossible to eradicate due to seeds that take time to germinate. Treatments will continue at this site until the existing seeds either germinate or become non-viable. These areas require consistent monitoring not just because of the existing populations, but because new plants can establish anywhere that is subject to disturbance.

Poison hemlock EDRR treatment in Spring 2017.

The bureau's invasive plant management program has benefitted tremendously from the field experience gained conducting EDRR protocols in areas subject to gas development. Since the protocol's pilot in 2013, the same protocols, with unique regional high-priority target species lists, have been initiated in four other state forest districts – Forbes, Gallitzin, Rothrock, and Weiser. Furthermore, recommended treatment protocols for EDRR species have been refined and are now used across all state forest lands. The bureau's identification field guides have also been improved with more "early detection" photos that show immature plants or senesced plants found outside the field season. This addition allows for better identification and detection. Finally, a careful approach to the monitoring and treatment of these species has also provided insights that have led to a revised Invasive Plant Species List for DCNR.

While the bureau has a well-developed invasive plant management and monitoring program, partnerships, both formal and informal, with natural gas operators to treat infestations has been extremely effective. Recent leases, SUAs, and ROWs mandate that operators monitor and control prioritized invasive plant species within applicable limits of disturbance. This has led to a process where the bureau reviews monitoring inventory results, then provides a detailed list of invasive plant populations prioritized for treatment, as well as the most effective treatment protocols for each prioritized species. To further increase the positive impact of these treatments, bureau staff have partnered with operators to treat high-threat species found immediately outside the limits of disturbance in conjunction with the mandated treatments within the limits of disturbance. In a more informal manner, many gas foresters have had success bringing a particular species population to the attention of an operator for immediate treatment. This "rapid response" style treatment is especially useful in areas where high-threat species have been found to be brought in by fill material. The evaluation of operator-sponsored monitoring inventory reports and treatment efforts has further informed the way the bureau prioritizes species for treatment across state forest land and how bureau biologists classify the threat each invasive plant species pose to forest and wetland ecosystems across Pennsylvania.

The proliferation and colonization of invasive plant species is one of the greatest threats to the health and viability of state forest ecosystems. Certainly, natural gas development is not the only forest use which increases the risk of these species spreading onto state forest land. However, the nature of the type of forest disturbance necessary to develop natural gas resources has increased the opportunity for invasive plants to colonize otherwise robust forest habitats. While populations of invasive plants have increased because of gas development, the level of awareness across the bureau has also increased. The lengths the bureau goes to identify novel populations and eradicate existing infestations has increased. While this work will continue, more attention is necessary on private lands subject to gas development, which are unlikely to be subject to the same robust invasive plant detection and treatment programs.

3. <u>Conducting Vegetation Inventories in Undeveloped Tracts.</u>

The majority of recent shale gas development was already underway when the Shale Gas Monitoring Team was organized. To date, only one area has been subject to pre-disturbance vegetation inventories. This pre-development work was conducted on tracts within the Loyalsock State Forest. The area encompasses approximately 26,000 acres of state forest land.

Sample locations consist of a cluster of one primary plot and three secondary plots. Of the 53 clusters initially generated, 33 clusters (132 plots) were completed during the 2013-2014 field seasons. Additionally, 38 Continuous Forest Inventory (CFI) plots that were located within the area were also included in the analysis to increase the rigor of these data. The most common forest community in this tract is the northern hardwood forest type (Table 5.44).

Analysis of these data were limited due to the one-time nature of the data collection. However, detailed forest cover data are available for all clusters. If development does occur on these Loyalsock tracts, these same data will be collected and then compared to the original cluster plot data.

Some noteworthy observations were made over the course of the pre-development data collection. Within the oak-heath stands, no non-native or invasive plant species were encountered on any of the 14 plots. Unique species like trilliums and purple-fringed orchid (*Platanthera grandiflora*) were found in some northern hardwood stand plots. Also noteworthy was the species richness of ferns throughout the tracts. A total of 18 fern species were found during the vegetation analysis. The northern hardwood communities had the highest species richness with nine fern species. A more thorough, tract-level review of on-the-ground conditions near potential development sites has allowed for an updated description of forest types and a careful delineation of potentially sensitive areas.

Sampling of invasive plants along the state forest roads within this tract of the Loyalsock State Forest was also conducted. State forest roads within the tract, as well as several gated haul roads, were surveyed during the 2014 field season for a total of 21 roads (41.6 miles). These included Big Hollow Road, Cascade Road, Hillsgrove Road, John Merrell Road, John Merrell Extension, Lutz Road, Mill Creek Road, and Bodine Mountain Road. The most abundant (by population size) invasive species found along these roadsides was Japanese stiltgrass and the most common species were Japanese stiltgrass, multiflora rose, and oriental lady's thumb. Other invasive shrubs present along these roadways included autumn olive, Japanese barberry, and Amur honeysuckle. These data were then organized spatially into "heat maps" (Figures 5.18 and 5.19) which show infestations from highest densities (red) to lowest densities (green). If development occurs on these tracts, these invasive roadside data can be compared before and after construction. Knowing which invasive plants were present prior to any gas development will aid in developing post-construction treatment guidelines for gas operators. These spatial invasion data can also inform priorities for certain portions of the tract that are less-invaded than others. Since some roads in this study were gated and others were not, the differences in invasion between gated and ungated roads could also be explored if development occurs.

Forest Community Type	# of Monitoring Plots	# of CFI Plots	Total
Northern hardwood (BB)	79	26	105
Woodland (O5)	19	0	19
Oak-heath (AH)	12	2	14
Red maple stands (CC)	12	4	16
Black cherry – Northern hardwood forest (BC)	5	2	7
Emergent Wetland (U4)	4	0	4
Hemlock – white pine forest (FB)	1	1	2
Red oak – mixed hardwood (AR)	0	2	2
Mixed oak – mixed hardwood forest (AD)	0	1	1

Table 5.44. Number of Plots in each Forest Community Type in Loyalsock State Forest BACI study.

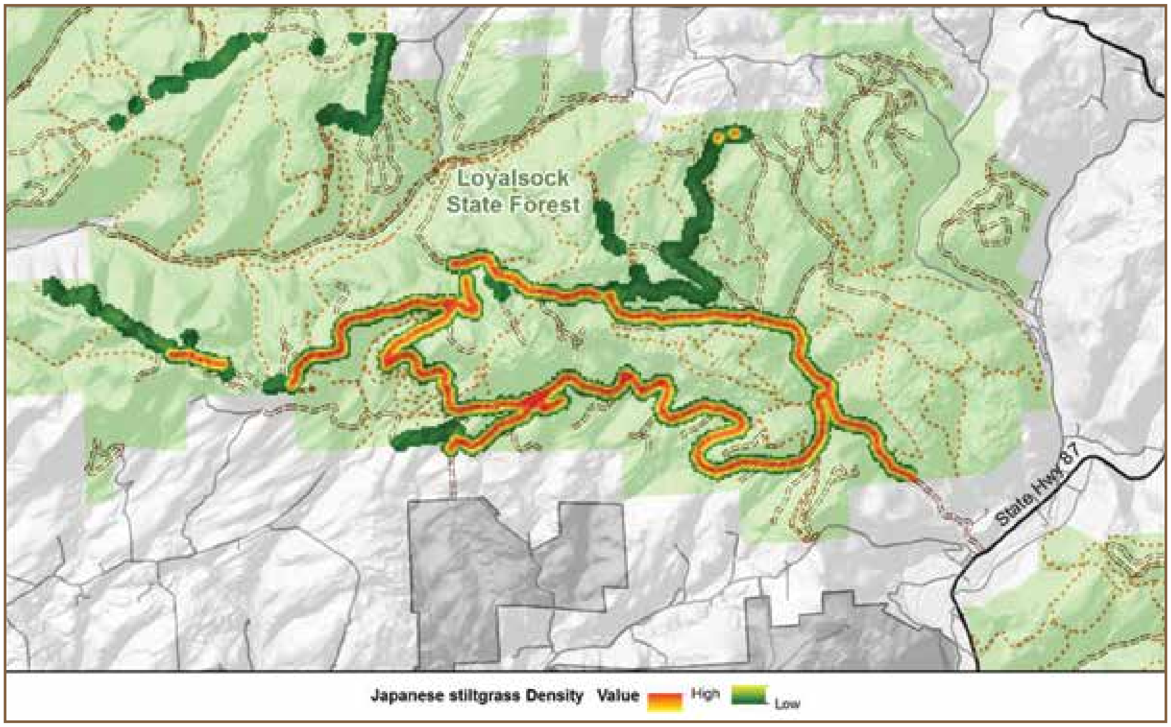


Figure 5.18. "Heat map" showing infestation levels of Japanese stiltgrass along roadsides within Loyalsock State Forest.

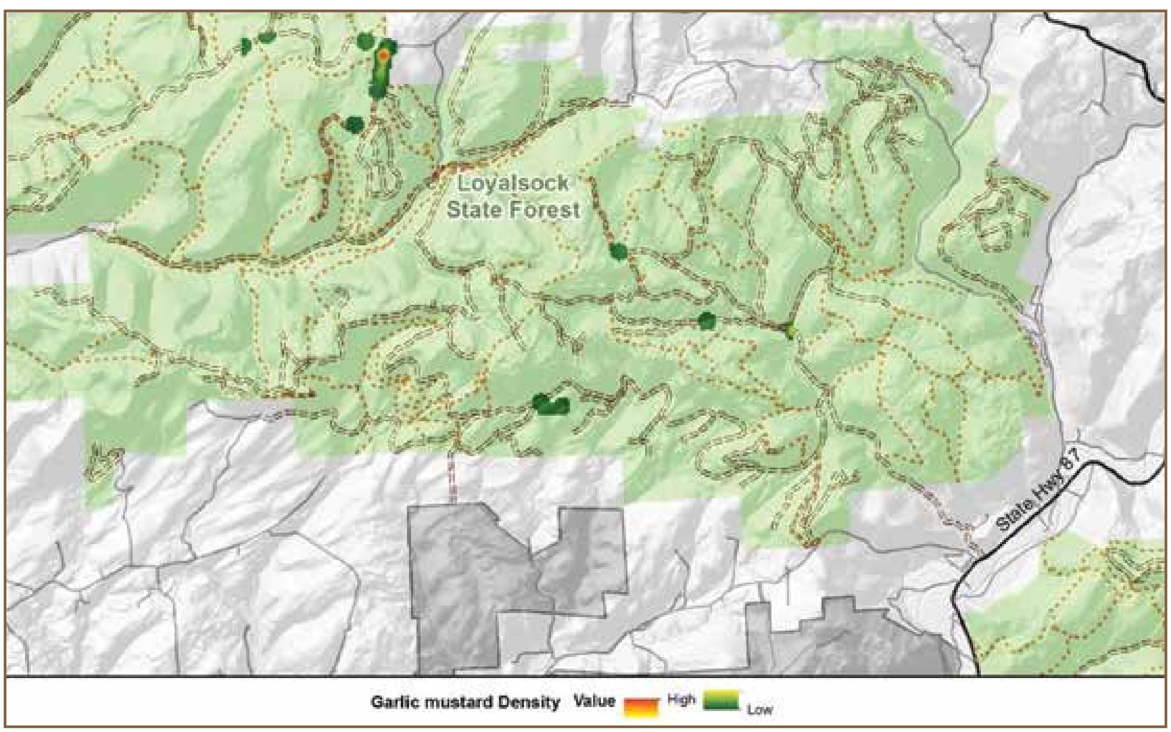


Figure 5.19. "Heat map" showing infestation levels of garlic mustard along roadsides within Loyalsock State Forest.

Fauna

As with any type of development, there is potential for shale gas development on state forest lands to affect wildlife populations and habitats. The disturbance due to gas activity typically sets succession back to an artificial state and can be somewhat permanent. This same disturbance generally leads to a reduction in forest habitat, a reduction in forest interior habitat, and an increase in edge habitat and forest fragmentation. Any alteration of habitat could lead to a shift in wildlife communities such as forest interior species, grassland birds, amphibian, and aquatic organism populations.

Forest Interior Species

Clearing forests for shale gas development increased forest fragmentation and created forest edge habitat. The increased fragmentation and edge can affect the habitat quality for some wildlife species. The bureau collects basic forest wildlife habitat data (i.e., basal area, canopy cover, tree diameter (DBH), species, snags, and tree height) on completed shale gas pads within the state forest using the Habitat Suitability Index (HSI) protocol to better understand the impacts of well pad construction on wildlife. These plots are paired with one being close to infrastructure and the other being 300 feet away from infrastructure. HSI data collected over time will increase understanding of the ecological effects of shale gas development on state forests. Using HSI models for barred owl and downy woodpecker, mean HSI values for interior and edge points were calculated (Allen 1987, Schroeder 1982). An HSI model uses habitat characteristic data to calculate a suitability index which ranges from 0-1, with zero being not suitable and 1 being ideal. Barred owl and downy woodpeckers were selected due to the existence of HSI models for these species that are considered representative forest interior species in Pennsylvania. The interior points averaged HSI values of 0.6 for downy woodpecker and 0.9 for the barred owl. The edge points averaged HSI values of 0.8 for the downy woodpecker and 0.7 for the barred owl. These values are very similar, but this may change over time as the edge effect has time to influence forest development. The interior points had higher average basal area (123 vs. 109), more snags per acre, higher canopy coverage (84 percent vs. 79 percent), and a larger average dbh (14.2 vs. 13.8).

Many of the physical features of the habitat of the interior and edge points are very similar. Some variables such as canopy cover, snags per acre, basal area, and average diameter may change over time between the interior and edge. Other factors such as light, temperature, moisture, and wind are expected to differ between the edge and interior, which may lead to differences in the measured habitat variables over time. The edge effect alone may make otherwise suitable habitat unsuitable for forest interior species. Even though the edge and interior points currently have similar HSI values, interior species will avoid the edge habitat. Greater differences in habitat values over time are expected.

Grassland Nesting Birds

Pipeline rights-of-way require a portion to be maintained as long-term openings. Pipeline corridors are maintained in a manner primarily to ease monitoring and maintenance by the pipeline company. Monitoring the pipeline corridors for the existence of grassland nesting bird nests was conducted to determine if the corridors were being utilized by this group of birds. This included counting grassland bird nests along a transect centered within the pipeline corridor.

No grassland bird nests were detected on the eight monitored pipeline corridors over a two-year period. These transects were located on pipeline corridors in the Moshannon, Sproul, Tiadaghton, Susquehannock, and Loyalsock State Forests. Typically, grassland birds will not utilize grassy pipeline corridors within a forest matrix due to the narrow width and the abundance of neighboring trees. Pipeline corridors are too narrow to function as acceptable nesting habitat for grassland nesting birds despite the presence of grassland habitat. Many scrub-shrub wildlife species can and do use narrow habitat patches. Therefore, the bureau is advocating scrub-shrub habitat where feasible on pipeline corridors to benefit a wider range of wildlife.

Amphibians

Amphibians are good indicators of environmental conditions because they are relatively sensitive to changes. The impact of shale gas development on amphibians at permanent pad monitoring locations and on PCSM features were monitored.

At the permanent pad monitoring locations (the same 15 selected for the permanent vegetation plots), cover boards were used to monitor terrestrial amphibian population trends. Coverboards were placed near the forest edge and the interior forest coincident with the permanent habitat plots. This allows comparisons between the number of species and individuals found between these areas. This protocol was piloted in 2014 and expanded in 2015 and 2016.

The abundance of salamanders detected using coverboards was low for both sites. Edge habitat coverboards yielded three salamanders total, while the interior habitat yielded four salamanders. To get a larger representative sample, the monitoring effort was expanded by increasing the number of coverboards at each location. There is a lag time between coverboard placement and utilization by salamanders. Coverboards are more attractive as refuge after at least two years of weathering to provide the proper moisture and soil characteristics under the boards. Over time, a better comparison of salamanders in edge habitat and interior habitat should be possible. It appears that resilient and adaptable species like the redback salamander utilize both the edge and forest interior habitats.

PCSM features, such as infiltration basins, rain gardens, and infiltration berms are designed to allow water to infiltrate within 72 hours. This short amount of time holding water should be too short for amphibians to find and try to reproduce. Ten structures were monitored to find whether amphibians were utilizing them for breeding purposes. Three of ten PCSM structures contained amphibian eggs. This indicates that water was being held in the structure long enough for amphibians to find and lay eggs. These structures are potential ecological sinks or traps if the water dries up prior to amphibian dispersal. More monitoring will be done to expand the sample size. This information indicates that there is potential to improve the design and construction of PCSM structures to ensure they do not negatively affect amphibians.

Aquatic Organisms

Infiltration Berm PCSM Structure.

Stream habitat is abundant across state forest lands. Aquatic organism passage through connected stream corridors, including intermittent streams, is vital to the health of aquatic communities. Effective habitat management considers all species in the aquatic community, including but not limited to: invertebrates, reptiles, amphibians, and fish. Connectivity is important for dispersal and access to suitable habitat such as spawning areas and colder water refugia.

If installation is not done correctly, culverts have the potential to negatively affect the stream habitat. Improperly placed culverts can lead to excessive erosion, act as barriers to aquatic organism passage, and can cause the stream crossing to fail. Five culverts on gas roads in proximity to the permanent pad monitoring efforts were assessed using the North Atlantic Aquatic Connectivity Collaborative (NAACC) protocol. These culverts were on the gas roads used to access the permanent monitoring pads. This protocol was piloted in 2016 and expanded in 2017. Three of the culverts (60 percent) were rated as allowing limited aquatic organism passage. Two of the culverts (40 percent) were rated as allowing full aquatic organism passage. No assessed culverts blocked all aquatic organism passage. Common problems with culverts are blockages, undersized pipes, and improper installation.

Culvert being assessed on state forest lands.

By monitoring culverts, there is the potential to improve road/stream crossings. Due to the findings that some stream crossings restricted aquatic organism passage, culvert installation BMPs were developed to ensure aquatic organism passage. These BMPs focus on proper sizing of the crossing structure and embedding the structure to prevent perched outlets. The bureau has adopted the NAACC protocol to conduct stream crossing assessments across all state forest land.

Forest Health

The bureau's forest health program is implemented for the protection of all forest land in the state from "fungi, insects, and other enemies." The program is designed to reduce pest-caused economic losses by utilizing integrated forest pest management strategies, providing assistance, and conducting projects aimed at preventing, detecting, evaluating, and suppressing forest pest outbreaks.

Non-native invasive forest pests are a significant threat to forests and considerable effort and resources are expended to detect, monitor, assess, and control non-native invasive forest pests. Some of the major invasive forest insect and disease pests established in Pennsylvania are the gypsy moth, hemlock woolly adelgid, emerald ash borer, thousand cankers disease, walnut twig beetle, Sirex woodwasp, butternut canker, elongate hemlock scale, chestnut blight, Dutch elm disease, and beech bark disease. Other non-native invasive forest pests not yet detected in Pennsylvania, but which would cause considerable tree mortality are the sudden oak death pathogen, Asian longhorned beetle, exotic bark beetles, and winter moth.

Maintaining forest health and the management of destructive insects and disease is a statewide concern. However, there is a focus on the core gas forest districts where shale gas development is the most prevalent. Over time this will allow the bureau to evaluate if any forest health trends are related to shale gas activity.

Annual aerial surveys are conducted across Pennsylvania to detect forest damage and tree mortality. The well pads utilized for the permanent monitoring efforts are monitored for forest health concerns as part of the aerial surveys. Ground-truthing is conducted to confirm unknown causes of the damage. Ground surveys using forest insect and disease reporting procedures are used to determine the presence or absence of forest pests and to document damage when present.

Specialized surveys are also conducted for Asian longhorned beetle, emerald ash borer, hemlock woolly adelgid, elongate hemlock scale, Sirex noctilio woodwasp, exotic bark beetles, sudden oak death, sugar maple decline, butternut canker, ash yellows, beech bark disease, gypsy moth, forest tent caterpillar, winter moth, and thousand cankers disease and the walnut twig beetle vector.

Since most forest insect and disease pests are driven by host condition and climate, there is a great amount of variation in forest pest distribution and abundance any given year.

Due to the stochastic nature of forest pest related damage, the correlation between gas development and forest health is inconclusive. This will only be revealed by continued long-term monitoring.

The principal biotic damage-causing agents from 2013-2016 in this region of Pennsylvania were the forest tent caterpillar and the gypsy moth. The last gypsy moth outbreak in Pennsylvania occurred in 2013, mainly in the northeastern portions of Pennsylvania. During the 2013-2016 period in core gas forest districts, considerable forest damages by gypsy moth were reported.

The spread of oak wilt is a concern for oak forests in Pennsylvania. Due to this risk, it is important that equipment is cleaned when clearing trees for development prior to moving to the next site. Over the last few years, sizeable maple and oak declines were also documented in the same areas. However, the damage-causing agents remain undetermined.

Approximately 3.1 percent of the trees in Pennsylvania's forests are ash, but much of it is concentrated in the northern counties. The emerald ash borer seeks ash trees along forest edges and attacks ash trees that are under stress or are in decline.

Monitoring impacts to forest health is a long-term endeavor. Increased susceptibility to pest attack, especially by non-native invasive species, may occur wherever there is forest disturbance, especially for trees along newly created edges. The bureau will continue to monitor forest edges created by well pads and pipelines for tree dieback, decline, and mortality. Evaluation monitoring projects may be initiated if forest health changes are detected through the bureau's detection monitoring activities.

Website Links

[1] www.srbc.net/programs/projreviewnaturalgas.htm

[2] http://www.dep.pa.gov/Business/Water/CleanWater/WaterQuality/Pages/CIMReports.aspx

[3] http://mdw.srbc.net/remotewaterquality/data_viewer.aspx

[4] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20033428.pdf

[5] https://www.pacode.com/secure/data/025/chapter93/chap93toc.html

[6] http://www.dep.pa.gov/business/energy/oilandgasprograms/oilandgasmgmt/Pages/default.aspx

[7] http://www.dep.pa.gov/Business/Air/BAQ

[8] http://www.depgis.state.pa.us/oilgasannualreport/index.html

[9] http://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Advisory%20Committees/Air%20Quality%20Technical%20Advisory%20Committee/2016/12-8-16/2016_Unconv_Well_and_Compressor_Station_NG_Emission_Inventory_For_2014.pdf

[10] http://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Advisory%20Committees/Air%20Quality%20Technical%20Advisory%20Committee/2017/6-15-17/4_AQTAC_AQ_Summary_170615.pdf

[11] http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-116594/DRAFT_2017-18%20Annual%20Network%20Plan.pdf

[12] http://www.dep.pa.gov/Business/Air/BAQ/Permits/Pages/default.aspx

[13] http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-13330

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Chapter VI. Forest Use: Wild Character, Recreation, and Community Engagement

Key Points

- The Recreation Opportunity Spectrum (ROS) analysis indicates gas development activity shifted 22,423 unique acres to a more developed ROS category since 2008. From 2008-2012, 14,858 unique acres moved to more developed ROS categories and 8,049 acres shifted for the period 2013-2016. However, only 19 acres moved from the primitive (the most undeveloped) ROS category.
- 20.3 miles of non-motorized trails have been directly affected by the placement of shale gas infrastructure (pads, pipelines, and roads) and 52.6 miles have infrastructure within 400 feet.
- Between 2013-2016 there have been 140.5 miles of snowmobile trails closed due to plowing for vehicular gas traffic.
- Compressor station sound monitoring indicates sound levels 300 feet from noise producing feature on the pad are lower than they were in 2015, but most compressors are still above the 55 db(A) Ldn guideline.
- Ambient noise level diversity is greater than at operational compressor stations.
- Well pad sound levels are similar to ambient.
- The Visitor Use Monitoring survey conducted by Penn State indicates that 15.5 percent of respondents reported that shale gas activities have affected their *Use* of state forest land and 18.7 percent reported it affected their *Experience*.
- Forest user feedback regarding gas development through comment cards indicate that traffic, dust, litter, and a general increase in activity in previously isolated/uncrowded places is a concern.

Introduction

Because state forest land has many uses, the bureau strives to balance and manage differing activities, values, and experiences. The bureau recognizes wild character as an important value state forest lands provide to visitors and strives to retain it while managing the forest. Wild character can be defined by both physical factors, such as remoteness and primitiveness, and subjective experiences, such as peace and tranquility. Wild character commonly relates to the quality of experience for state forest visitors regarding scenic beauty, feeling of solitude, sense of remoteness, and the undeveloped and aesthetic nature of the state forest system. Recognizing that shale gas development has the potential to affect wild character, the bureau's shale gas monitoring program uses several metrics to quantify features that can serve as indicators.

Quantitative Metrics: Infrastructure and Activities

Recreation Opportunity Spectrum

Because the perception of wild character can be subjective, direct measurements are difficult. One surrogate measure that is used to approximate the relative wild character of the landscape is the Recreation Opportunity Spectrum (ROS). This is an inventory system developed by the U.S. Forest Service to characterize land by types of recreation experiences. The bureau utilizes ROS to make and communicate management decisions that are transparent, credible, and compatible with other state forest management goals. However, this formulaic approach should be tempered with an awareness of the conditions that can lead to changes in this type of analysis.

ROS builds on the premise that people expect certain types of recreational experiences on public land and that land managers should be able to direct people to appropriate places for these experiences. ROS allows land managers to provide recreational opportunities across a spectrum, or continuum, of five land-use classes so that the user may find satisfying recreational experiences in a variety of recreational activities. The ROS land-use classes follow a continuum from "primitive" to "developed" based on distance from motorized roads/trails (Figure 6.1). The bureau uses acreages associated with each class as a measure of wild character to guide long-term management planning to provide a balance of experiences.

State forests are generally managed to maintain the conditions that define each ROS land-use class or increase the primitive area, but typically not to increase the amount of developed area. Some temporary activities may affect the condition of the forest, but do not change the ROS land-use class, such as temporary roads used in timber harvesting. Permanent impacts can change ROS classes, such as new public use roads or buildings. Closing a road or restoring a developed area can change ROS classes back to a more primitive classification. While remoteness is a consideration of wild character, the primitive classification itself does not define wild character, but does tend to provide experiences that are more of a backcountry nature. However, an area that is not primitive or remote can still offer wild character, depending on the user's perception. For example, some areas that fall into the more developed categories of the ROS analysis may still offer aspects of wild character. Conversely, some areas may be converted to a more developed category when conditions in that area remain unchanged. Two areas with the same ROS zone may also provide

Figure 6.1. ROS classes and characteristics of those classes based on user experience, distance from road, and acreage.

different experiences. For example, a traditional state forest road is not considered primitive or remote, but the narrow shoulders and closed forest canopy offer more wild character than a wide road with no tree canopy, although the ROS category would be the same for both road corridors.

The analysis to calculate and map the distribution of ROS categories on state forest land after the onset of shale gas development was performed in 2012 and findings were shared in the 2014 Shale-Gas Monitoring Report. The analysis was re-run to assess the changes to ROS on state forest land from 2013 through 2016. Since ROS zoning is based on distance to motorized roads, changes in ROS classification can be due to construction of roads or alteration of existing roads. Typically, on state forest land, roads that are gated are considered trails behind the gate because their use is limited to infrequent administrative activity. However, in the case of certain shale gas roads, the road is still considered motorized behind the gate because it still has frequent traffic. In this case, the gate is primarily for public safety and the road is still heavily used by the gas company and its affiliates. Although many activities on state forest land can result in changes to ROS designations, for this report, changes have been filtered to ROS zone acreages to represent those due specifically to shale gas roads since 2012.

Figure 6.2 shows the spatial distribution of changes to categories of ROS due to shale gas activity (roads) in the core gas forest districts between 2008-2016. In general, the changes in ROS designation occurred on scattered parcels of land across these state forests (Figures 6.3 and 6.4; Table 6.1), but with some locally severe alterations at specific locations across the landscape. Overall, gas development activity resulted in 22,423 unique acres shifting to more developed categories since 2008. From 2008-2012, 14,858 unique acres moved to a more developed ROS category and 8,049 acres shifted for the period 2013-2016 (note these are not additive to the total unique acreage shifted, due to some acreage shifting in both time periods). However, of these acres, only 19 acres moved from the primitive (the most undeveloped category).

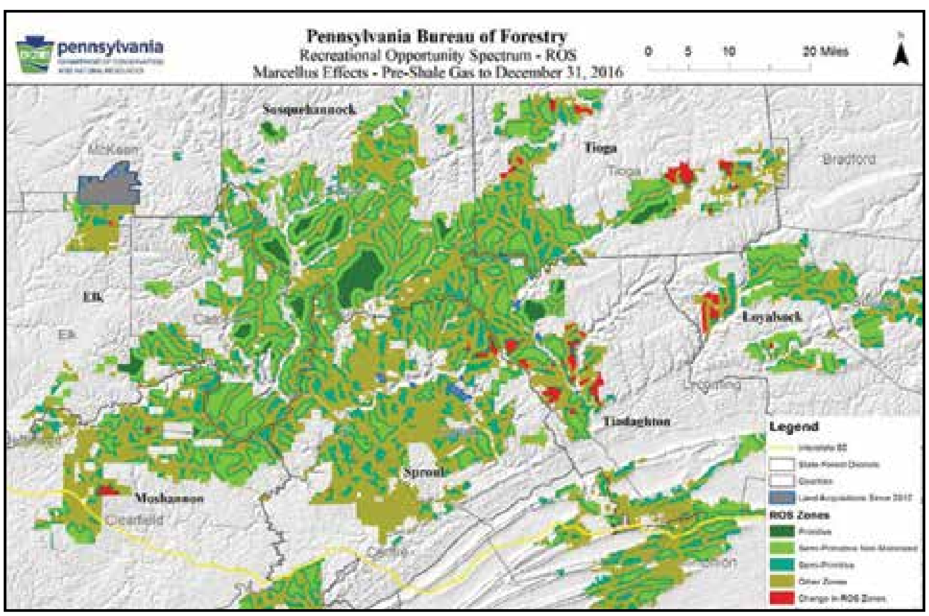


Figure 6.2. Map of the changes in ROS classifications due to shale gas development from 2008-2016 for the core gas forest districts.

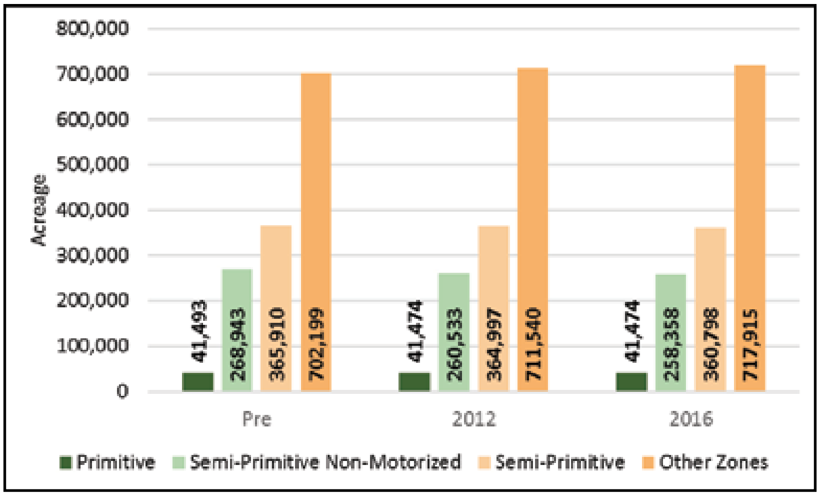


Figure 6.3. Overall acreage in each ROS category within the core gas forest districts for pre-shale gas, in 2012, and in 2016.

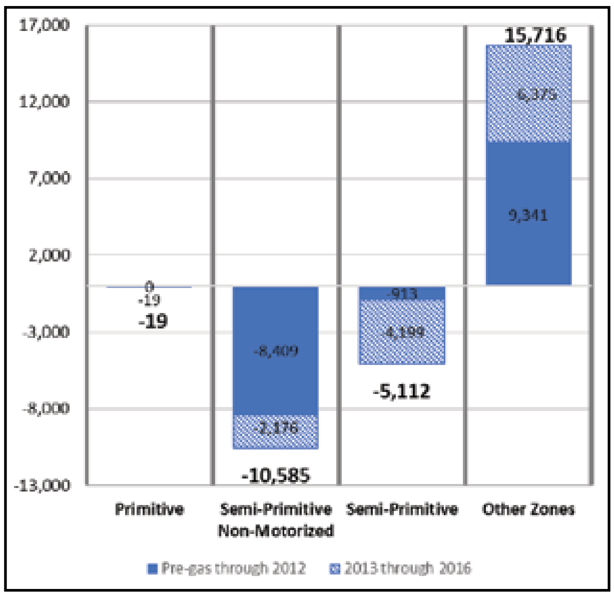


Figure 6.4. Net change in acreage in each ROS category within the core gas forest districts for changes due to gas roads only (pre-shale to 2016). Total net for the entire period in bold.

	ROS Zones			
	Primitive	Semi-Primitive Non-Motorized	Semi-Primitive	Other Zones
Pre-gas to 2012	-19	-8,409	-913	9,341
2013-2016	0	-2,176	-4,199	6,375
Total Net Change Pre-gas through 2016	-19	-10,585	-5,112	15,716

Table 6.1. Net ROS acreage for each ROS category within the core gas forest districts for changes due to gas roads only (pre-shale to 2016).

Changes in overall acreage of ROS were affected by gas road construction and land acquisitions in the core gas forest districts (Figure 6.2). A total of 2.894 acres of state forest land were acquired in the core gas forest districts since 2008. Acquisitions that have occurred since 2012 are shown in the map in gray and outlined in in blue (Figure 6.2).

In general, the overall effects to ROS since the analysis done in 2012 are relatively small. Some areas that were not adequately buffered led to conversion of acreage to a more developed category. In the future, it may be advantageous to create a buffer around certain primitive areas to prevent effects to the ROS zoning, rather than allowing development up to the edge of the primitive zone. Overall, the changes into more developed categories were minimal and these losses were generally offset by the acquisition of new lands on which there was minimal development.

Trails

Much of state forest use occurs on the broad network of designated trails, and so effects to the state forest trail system translates to user effects. Changes near trails due to nearby shale gas infrastructure are easily seen (Figures 6.5, 6.6, and 6.7). However, these changes are difficult to measure. Since trail "impacts" can be subjective and problematic to quantify, several quantitative spatial measures as a proxy for the influence of shale gas infrastructure on a trail and its users were used. Direct effects are defined as those locations where infrastructure crosses or is co-located with trails. Indirect effects were estimated by determining areas where trails were within 400 feet of shale gas infrastructure.

In the 2014 Shale-Gas Monitoring Report, trail effects were reported for designated state forest hiking trails and designated national trails, if there was infrastructure placed within the trails buffer limit. In response to stakeholder feedback and availability of more complete data, all trail categories are included in the summaries below. Trail designations include district specific-use trails (e.g., hiking only trails, snowmobile only trails, etc.), district shared-use trails (open to hiking, biking, horseback riding, and cross-country skiing), and designated state forest hiking trails (hiking only).

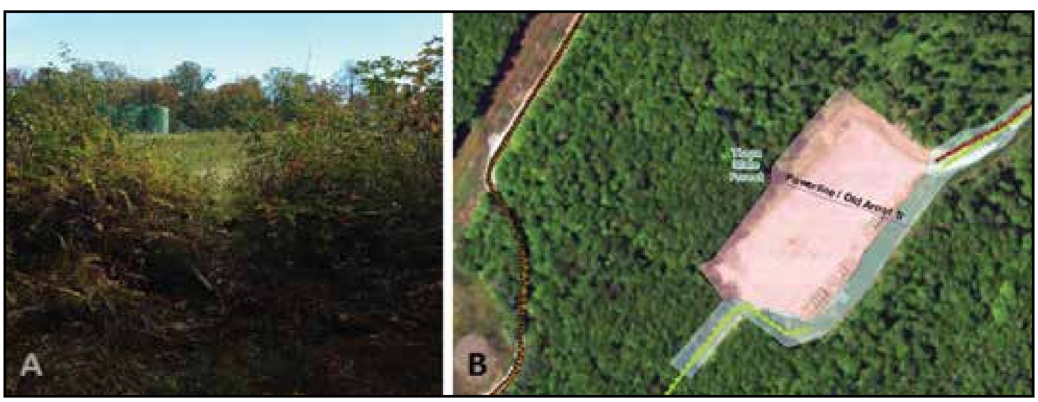


Figure 6.5. Old Arnot Trail (a shared-use trail) traversing a well pad. A) looking east from the intersection of the pad and trail on the west side of the well pad; B) aerial image of Old Arnot Trail (purple) crossing the well pad.

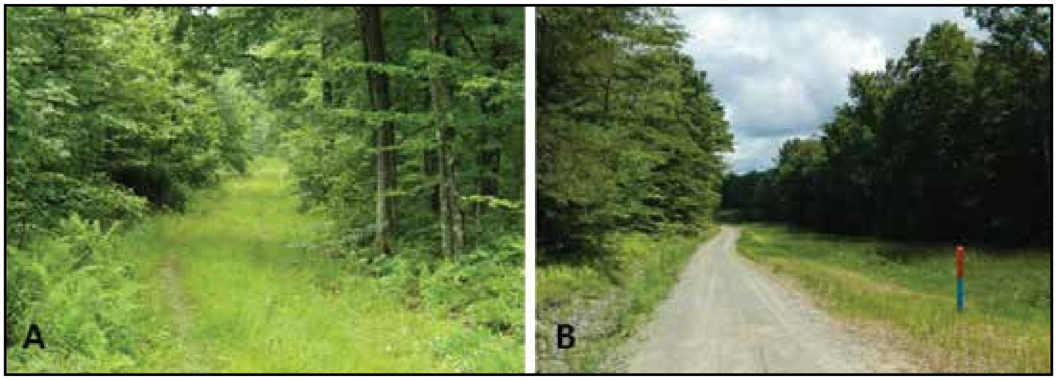


Figure 6.6. Example of an old woods road (gated road serving as a trail); A) before; and B) after improvement and pipeline installation.

Figure 6.7. Shared-use trails crossing access roads and adjacent pipelines. Trail indicated in red.

National scenic and national recreation trails, which are designated by the National Park Service, are also found on some portions of state forest, but are not found on state forest land within the core gas forest districts.

<u>*Non-motorized trails*</u>

A spatial analysis was conducted to determine where non-motorized trails were near, crossed, or were coincident with shale gas infrastructure in the core gas forest districts. First, an intersect analysis was conducted to quantify direct effects to trails (Figure 6.8) by determining the number of times and distance that gas infrastructure directly crossed or coincided with a trail. This information is summarized in Tables 6.2 and 6.3 in the "On Trail" column, which includes existing road crossings that were improved for shale gas traffic access.

In addition, a proximity analysis was completed to identify trails that were within 400 feet of shale gas infrastructure (Figure 6.9; Tables 6.2 and 6.3) to capture indirect effects, such as changes to the aesthetics and wild character. Any trail that starts from a road improved for gas is counted as affected. Snowmobile and ATV trails are reported separately.

Roads are the most abundant form of direct effect, with 13.6 miles of trail coinciding with roads that were created or improved for shale gas development (Table 6.3). At these locations, trail users may be affected by the wider canopy opening and periodic traffic. During the construction phase, traffic is highest, and users will likely hear or see traffic. In some cases, there may be an obstacle, such as an above ground waterline, silt sock, or various debris, during the construction phase (Figure 6.10). After construction is completed, materials are removed, and traffic is usually more limited. However, canopy openings may remain and alter the character of the trail.

Figure 6.8. Example of a direct effect. A) retired timber haul road used as a shared-use trail, showing condition without improvements for shale gas development; B) same trail, altered by construction access road along the trail.

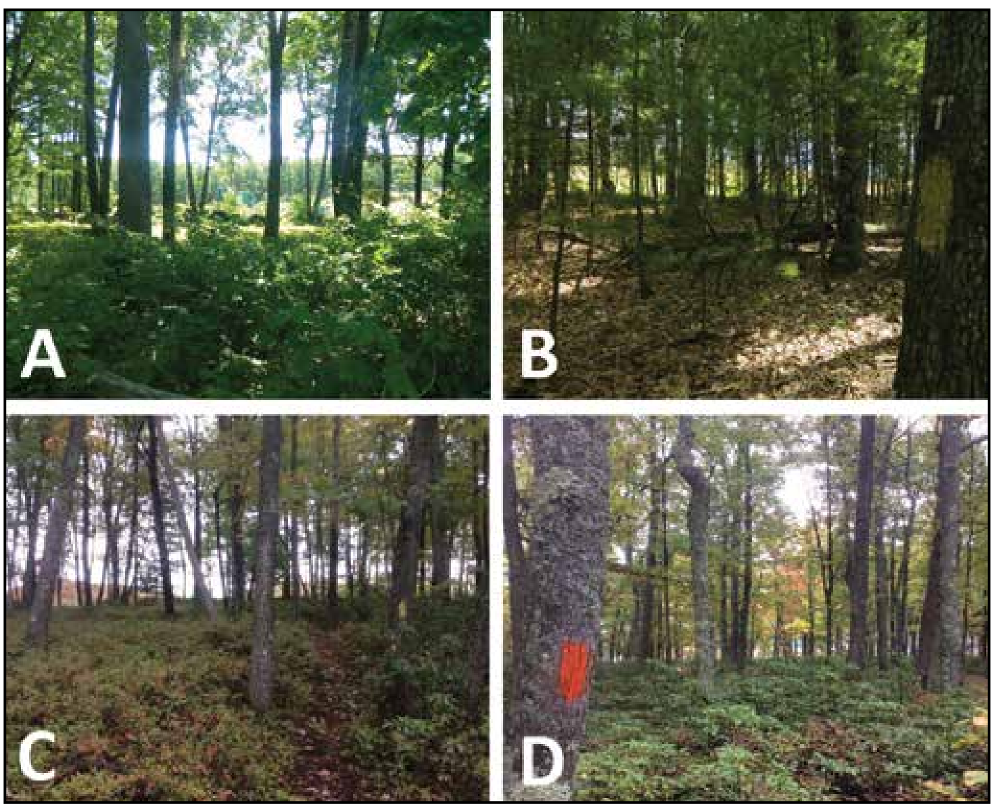


Figure 6.9. Photos from the trail at various distances from infrastructure; A) district shared-use trail within 100 feet of a well pad edge; B) district specific-use trail within 200 feet of a well pad edge with mid-story screen of white pine; C) district specific-use trail within 300 feet of an impoundment, compressor station, and topsoil stockpile; note abundant light levels; compressor was easily heard. D) state forest hiking trail within 400 feet of a well pad; open mid-story allowed pad to be visible and workers audible.

Non-motorized Trails with Adjacent or Coincident Infrastructure										
	Infrastructure Distance from Trail (in feet)									
	On Trail		100		200		300		400	
Trail Class	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail
District Specific-Use	6	2.6	19	3.5	20	4.0	22	5.0	26	5.7
District Shared-Use	34	17.6	121	24.5	132	30.9	141	36.3	163	42.1
State Forest Hiking	1	0.1	13	1.1	13	2.1	14	3.3	16	4.8
Total	41	20.3	153	29.2	165	37.0	177	44.5	205	52.6

Table 6.2 – Number and mileage of non-motorized trails with shale gas infrastructure within 0-400 feet, by proximity category and trail class. For trails in the core gas forest districts. Note: trails are counted within all columns of lesser distances (i.e., the rows are not additive and each column includes the numbers and mileages c contained in columns to their left).

Non-motorized Trails with Adjacent or Coincident Infrastructure										
	Infrastructure Distance from Trail (in feet)									
	On Trail		100		200		300		400	
Infrastructure type	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail
Pads (all types)	10	0.5	11	0.3	16	1.1	21	1.9	28	3.6
Pipelines	20	2.0	85	21.6	89	26.4	90	30.0	91	33.1
Roads	33	17.8	61	7.7	64	10.1	70	13.3	90	16.6

Table 6.3 – Number and mileage of non-motorized trails with shale gas infrastructure within 0-400 feet, by proximity category and infrastructure type. For trails in the core gas forest districts. NOTE: Neither columns nor rows are additive in this table; COLUMNS: the design of this table results in trails counted multiple times in different rows, since a trail may be proximal to a pad, pipeline, and road; ROWS: trails are counted within all columns of lesser distances (i.e., the rows are not additive and each column includes the numbers and mileages contained in columns to their left). Refer to Table 6.2 for totals.

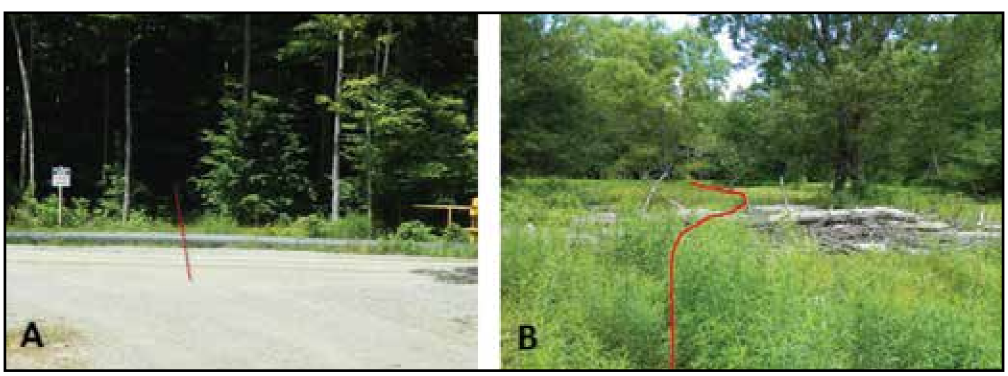


Figure 6.10. Various obstacles near trail intersections during construction activities associated with shale gas development; trail indicated by red line; a) temporary above ground waterline crosses the entrance to a district shared-use trail; b) pile of wood debris from a pipeline project placed across the entrance to a district shared-use trail.

Snowmobile Trails

Snowmobile trails are frequently affected since the infrastructure used for snowmobile trails (joint-use roads, administrative roads, and pipelines) are also used during shale gas development. This may mean interruption of trails for gas construction activity or plowing of roads used as snowmobile trails to provide vehicle access for gas activity. In some cases, the roads are plowed for vehicle access, but are shared by snowmobilers along the edge of the road or on an unplowed strip of snow left along the road per an agreement with the gas companies. When a section of trail must be closed, it will often be relocated onto newly created adjacent trails (Figure 6.11) or pipelines (Figure 6.12) or closed temporarily until construction is concluded. Some trails cannot be re-routed due to topographical constraints, environmental reasons, or connectivity/looping issues.

Closed trails are trails that have been removed from the system. These may be closed without replacement or be re-routed. For re-routes, the closed section is counted in the "closed" column and the re-route accounted for in the "new" mileage. Temporarily closed trails are trails that were closed for a riding season due to short term conflicts. If a trail is temporarily closed for three seasons, it is automatically calculated as a "closed trail" or loss. A "plowed" trail is a trail that was either partially or fully plowed, but the trail has stayed open for riding due to limited vehicle use. "New" trails include re-routed trails, newly created, or newly designated trails. A summary of closed, temporarily closed, plowed, and new trails since the 2012/13 riding season can be found in Table 6.4. New replacement trails are still being planned and focus on establishing trail connectivity and improving trail quality.

Figure 6.11. Snowmobile trail (left red line) shifted from a plowed access road (right red line) onto a new adjacent trail with a forested buffer between the trail and the road.

Figure 6.12. Snowmobile trail shifted from main access road to a parallel pipeline, with vehicular traffic for shale gas development on road surface adjacent to riders.

ATV Trails

As of 2016, no state forest ATV trails have been affected (i.e., shale gas infrastructure within 400 feet or closure or re-routing due to gas activity). Though not managed by the bureau, there is one township road that crosses the Sproul State Forest that received a short duration closure. Kato-Orviston Road is a township road traversing through a section of state forest. The township has the road posted open to ATV use and it serves as a connector to the Bloody Skillet ATV trail. The road was closed from May 2015 to September 2015 and briefly during weekday work hours for the installation of the pipeline in the shoulder of the road (Figure 6.13). No formal complaints were received, although ATV riders were observed to re-route when approaching the construction site.

Viewshed Analysis

Viewsheds are the portion of the landscape that can be viewed from a given location and are key features for all public recreational use. They include the viewable landscape along transportation corridors and areas of visual importance near high-use areas in state forests where visitors congregate and spend time (e.g., a hill in close view of a high-use picnic area or along popular scenic drives). Impact to public use is considered carefully when managing the landscape within heavily visited viewsheds. One factor that can reduce wild character is the presence of visible manmade features or disturbances. Pads, pipelines, and similar infrastructure are manmade disturbances that do not mimic natural forest processes and are undesirable to many visitors in the forest setting.

Snowmobile Season (years)	Newly CLOSED		Newly CREATED		Temporarily closed (by season)		Plowed still open (by season)	
	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail	No. of Trails	Miles of Trail
2013-2014	41	133.5	14	25.1	5	8.4	25	116.2
2014-2015	2	0.8	2	4.4	6	15.4	25	104.7
2015-2016	1	4	19	25.6	25	42.8	56	98.3
2016-2017	2	2.2	1	3.6	25	40.7	28	112.2
Total	46	140.5	36	58.7	n/a	n/a	n/a	n/a

Table 6.4. Number and miles of snowmobile trails in the core gas forest districts that were newly closed, temporarily closed, plowed or newly created by winter riding season. Note that "Temporarily closed" and "Plowed" are recurring year to year and the same trails may be counted year to year.

Figure 6.13. Kato-Orviston township road. A) recreational UTV riding road amid pipeline construction project; B) pipeline welding crew working on pipeline installation.

In 2008, in areas leased for gas development, the bureau identified scenic viewshed "Areas of Special Consideration" along state forest trails, rivers, and major roads to minimize disruption of scenic viewsheds. When considering the effects that shale gas development has had on wild character, an assessment of prominent viewsheds is informative for estimating these effects. Changes in scenic views were examined and roughly quantified based on the infrastructure that was visible in major viewsheds, such as along high use roads and popular vistas.

Road Corridors and Aesthetic Buffers

The narrow roads, minimal traffic, overarching canopies, feeling of solitude, and long relaxing traverses through the forest embody the wild character that so many people seek on state forest land. Scenic driving has been one of the most popular uses of state forest lands for over 50 years. Most recreational users participate in this activity coming to and from the state forest, but for many this is the sole purpose of their visit. Changes to this primitive atmosphere are difficult to quantify, but they are easily seen. Wider built-up roads, increased traffic, pipelines, compressor stations, pads, and other miscellaneous infrastructure detract from the experience of what many visitors come to see in a forest setting (Figure 6.14). In some cases, when areas known for scenic driving could be affected, gas traffic and infrastructure have been relocated or visual mitigation practices have been employed, such as burying pipelines in road shoulders or incorporating buffers. However, perception is highly variable; for example, one person may view an adjacent pipeline as favorable for wildlife viewing (Figure 6.14b) and another may see it as detracting from the forest setting. It is also important to consider that effects will change over time. Many of the linear corridors have not been around long enough for adjacent trees to respond to increased light and fill some of the opened canopy space. Where most closed canopy state forest roads have been in existence for decades. Oak hickory types are more conducive to occupying the void than northern hardwoods, which could be useful in planning future corridors to produce the desired long-term condition of reduced canopy disruption.

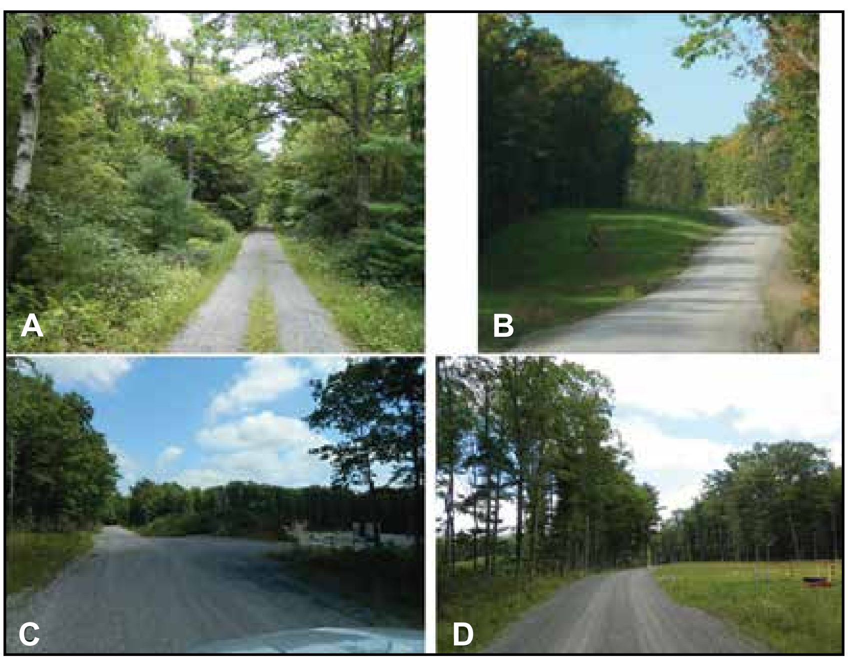


Figure 6.14.

A) Traditional (no gas traffic) low-use state forest road;

B) Post-gas low-use state forest road with adjacent pipeline, note turkeys;

C) Post-gas medium-use state forest road with adjacent well pad and topsoil stockpile with no buffer between the road and infrastructure;

D) Post-gas medium-use state forest road with adjacent well pad with forested buffer (left side of photo) and pipeline co-located within the road corridor (right side of photo).

To quantify effects to road corridors, independent of subjective perception, the number of miles of drivable public use road and drivable trails that have adjacent infrastructure were summarized. Shale gas infrastructure may be visible from 100, 200, 300, 400 feet, or even more depending on the vegetative conditions, so these distance categories were used (Table 6.5).

Because state forests are managed for many uses and values, the bureau maintains various guidelines and recommendations to minimize the effects of one use on another. One example is the incorporation of forested buffers surrounding high-use features during certain disturbance activities, such as gas development or timber harvesting. Some buffers are "no management zones" where the forest is to remain completely undisturbed, and others require that at least a partial canopy be maintained. Buffers not only shield infrastructure from view, but also help to maintain tree canopy connectivity, reduce dust, and maintain the feel of wild character. Roads and trails require a setback that serves as a buffer. Depending on the type of road or trail feature, different restrictions apply, from no cutting or disturbance to minimum overstory basal area retention requirements. These buffers preserve forest aesthetics and wild character in actively managed forests.

However, in balancing the diverse uses and values of state forests, there are times when a project may require a waiver to this requirement so that infrastructure may be placed within the buffer limits. This requires a review of the project and approval to waive the guidelines in favor of other priorities, such as minimizing fragmentation or promoting forest regeneration (Table 6.6). Waivers for this are often the result of discussions and negotiations to consider all the implications of various approaches.

Table 6.5a — Public Use Roads (Z1) With Adjacent Infrastructure

Infrastructure Type	Distance from Road (in feet): 100		200		300		400	
	Miles of Road	Number of Roads	Miles of Road	Number of Roads	Miles of Road	Number of Roads	Miles of Road	Number of Roads
Compressor	0.4	6	1.0	8	1.5	8	2.1	12
Freshwater Impoundment	0.6	9	1.6	12	2.5	14	3.3	15
Gas Well	1.7	15	4.0	23	6.4	29	9.2	33
Meter	0.6	9	1.1	11	1.7	11	2.3	11
Other	0.0	1	0.1	2	0.3	3	0.4	3
Shale Gas Pipeline Corridor	37.9	65	59.4	68	72.5	72	82.0	76

Table 6.5b — Drivable Trails (Z2) With Adjacent Infrastructure

Infrastructure Type	Distance from Road (in feet): 100		200		300		400	
	Miles of Trail	Number of Trails	Miles of Trail	Number of Trails	Miles of Trail	Number of Trails	Miles of Trail	Number of Trails
Compressor	0.1	1	0.2	1	0.2	1	0.2	1
Freshwater Impoundment	0.2	2	0.2	3	0.3	4	0.4	4
Gas Well	0.6	6	1.0	7	1.3	8	1.6	10
Meter	0.1	1	0.1	1	0.1	1	0.2	1
Shale Gas Pipeline Corridor	3.5	24	5.6	28	7.8	29	9.6	29

Table 6.5a-b - Infrastructure within 0-400 feet of roads Note: some roads are counted more than once if a road has an adjacent pipeline, compressor, pads, impoundments and other infrastructure, therefore columns are not additive for total impacts. Additionally, infrastructure is counted within all columns of lesser distances (i.e., the rows are not additive, and each column includes the road mileages contained in columns to their left).

Infrastructure Type	Number within Buffer	Acres Within Buffer
Pipeline	6	72.6
Road Right of Way	6	19.5
Compressor	3	17.5
Freshwater Impoundment	3	12.4
Gas Well	1	6.9
Meter or Valve Tap	3	2.4
Grand Total	**22**	**131.4**

Table 6.6. Projects since 2013 for which a waiver to place infrastructure within the set aesthetic buffer was approved.

Early efforts in shale gas development focused on reducing the number of fragmenting features in the forest by placing shale gas infrastructure in the same corridor as roads or other existing features, such as when pipelines are co-located with roads (Figures 6.14b and 6.14d). Although fragmentation is reduced overall, co-location creates a wider corridor to accommodate both features. The bureau also utilizes the placement of pipelines in road shoulders when appropriate (Figure 6.15), instead of a cleared ROW along the road or a cleared area in the forest behind the forested buffer. The intent for road shoulder pipelines is to reduce both fragmentation and effects to aesthetics, since the corridor can be maintained relatively narrow. Another option that has been useful in certain cases is the creation of a forested buffer between the road and a pipeline corridor to maintain aesthetics, wild character, and a continuous canopy (Figures 6.16 and 6.17). In addition, some linear features that intersect with roads, such as pipeline corridors, have a turn within a short distance from the road (Figure 6.18). In these cases, although the rights-of-way may overlap the buffer area, the wild character perception is still maintained because the bend in the cleared area limits the amount of un-forested area that is visible from a road or trail (Figure 6.18).

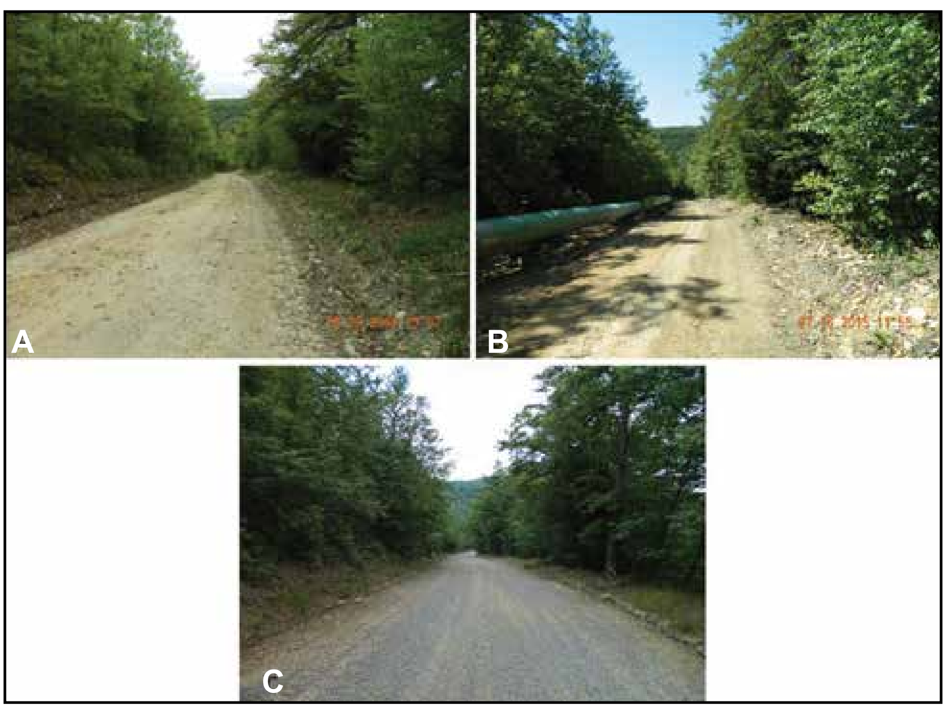


Figure 6.15. Public use road a) before; b) during; c) after gas pipeline installation in road shoulder.

Figure 6.16. Public use road and adjacent pipeline with a 50-foot buffer forested buffer and thick midstory of mountain laurel between the pipeline and road.

A) View of buffer from road corridor, looking toward pipeline ROW;

B) View of forested buffer from the pipeline ROW.

Figure 6.17. Public use roads with adjacent pipelines and a variable forested buffer. Each photo (A & B) shows segments of the road with no buffer (foreground) and the beginning of a forested buffer (background). Note the large canopy gap in the foreground and the increasing connectivity of the canopy across both the pipeline and the road in the area with the forested buffer in the background.

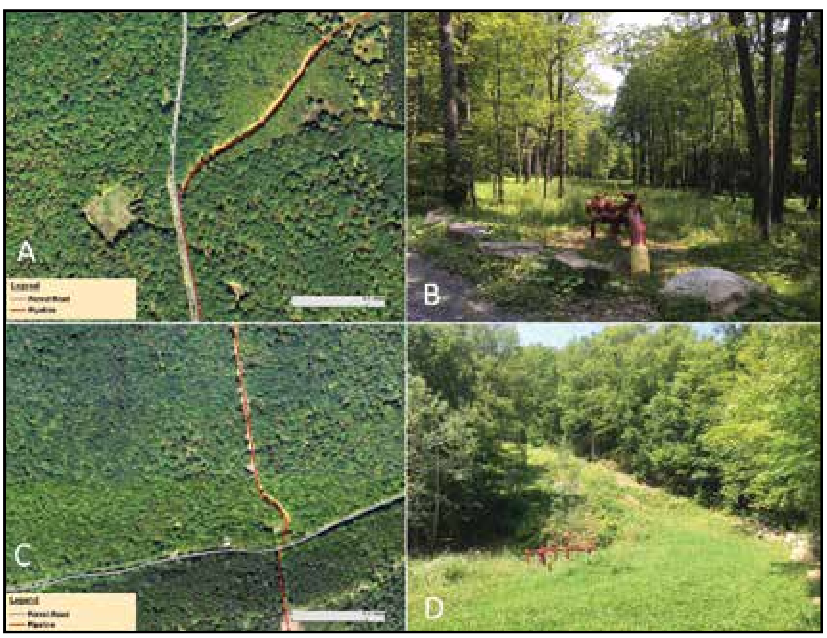


Figure 6.18. Two examples of pipeline rights-of-way with strategic bends to reduce line-of-sight from forest roads. Note how a relatively slight bend (seen in aerial imagery) creates a reduced line-of-sight of non-forested area (seen in photos)

A) looking northeast from the intersection of pipeline #1 right-of-way and the forest road;

B) aerial imagery of pipeline #1 at the same intersection;

C) looking northeast from intersection of pipeline #2 right-of-way and the road;

D) aerial imagery showing pipeline #2 right-of-way at this intersection.

Vistas

Vistas are recreational focal points, with visitors driving or hiking to a specific vista to take in the surrounding landscape (Figure 6.19). Many visitors plan a scenic drive to visit several vistas along a deliberate route. Vistas are established to provide views into or through the forest to unusual or attractive features of the landscape. The size of the vista, parking area, and need for signage and naming are also carefully considered. Because of long sight distances, vistas may be altered by gas infrastructure that traverses through or is placed within the viewshed. In the previous report, vistas were summarized for only those that were affected (disturbance on site). This analysis has been expanded to include visual impacts within the viewsheds of vistas. A viewshed analysis was conducted for all vistas in the core gas forest districts that includes the area in view from the vista to 5 miles (Figure 6.20). The analysis is based on a digital elevation model and predicts what areas can be seen based on topography. However, the analysis does not consider vegetation, such as tree cover. Therefore, the analysis represents a "bare earth" scenario to serve as an approximation for actual line-of-sight from the vista. This may not represent what can actually be seen.

Between 2008 and the end of 2016 in the core gas forest districts, gas infrastructure has been placed within the 5-mile radius viewshed of 46 vistas (of 190 vistas total). This infrastructure consists of 3.9 miles of pipeline corridors across 12 pipelines, 20.9 miles of road from 124 roads, and 193 pads totaling almost 296 acres.

Changes to vista visitation are not as quantifiable as a simple viewshed analysis. Nearby infrastructure can have a negative effect on the visit to the vista. Even if a view is preserved, the approach to the vista may be altered due to gas infrastructure. The Ramsey Point vista is an example of an affected vista because of the infrastructure that was placed nearby (Figures 6.21 and 6.22). However, it is also important to consider the negative scenic changes that were avoided in the placement of the well pad. For example, this vista approach was affected because the choice was made to avoid major changes to the viewshed of the Pine Creek Rail Trail and to the major roads through the Pine Creek Valley. To achieve this, the only feasible alternative was to site the infrastructure on the ridgetops based on the topography and desire to minimize the disturbance. This example illustrates the complexity of the decision-making for differing forest uses and tradeoffs that are made at a local level to prioritize and minimize effects in a holistic way.

Figure 6.19. Typical state forest vista.

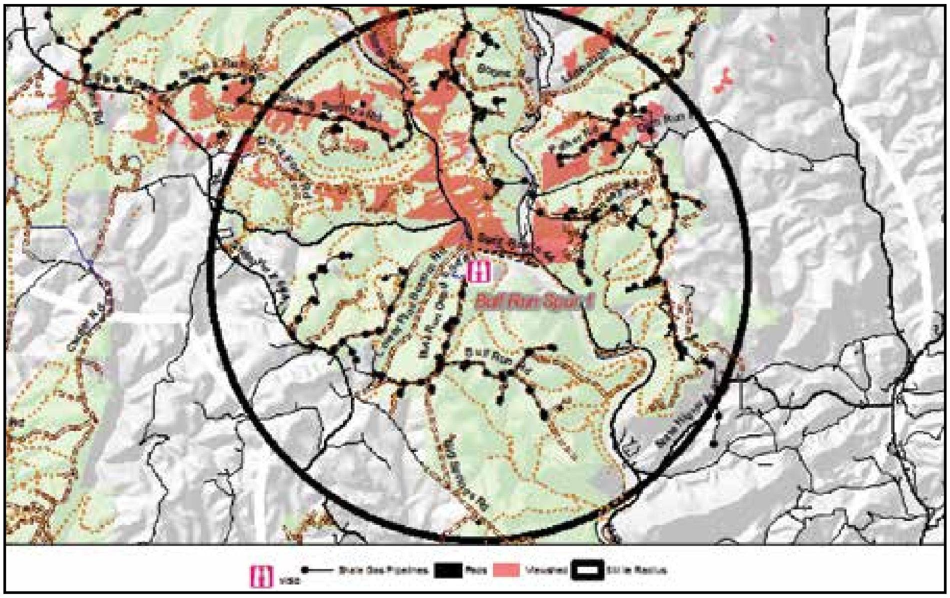


Figure 6.20. Example of a 5-mile radius viewshed. Magenta denotes area seen from the vista in the absence of vegetation.

Figure 6.21. Ramsey Point Vista a) view from vista; b) approach to vista.

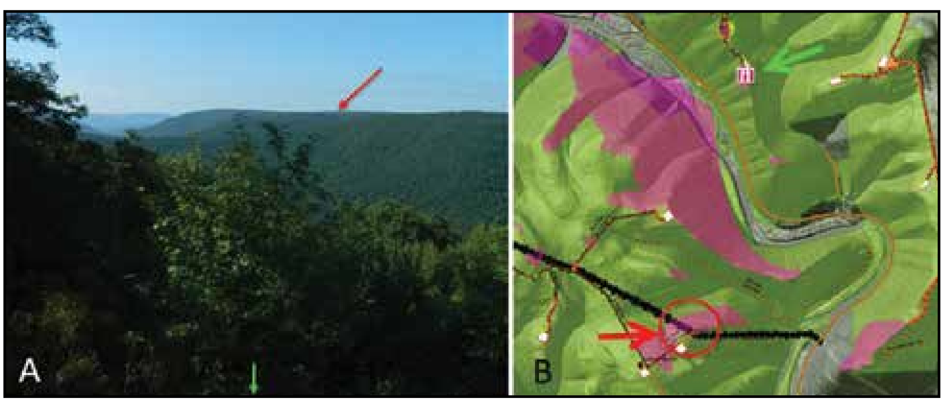


Figure 6.22. A) View from Ramsey Point Vista looking south;
B) viewshed analysis (magenta overlay). Green arrow denotes vista location, red arrow denotes pipeline cutting through the viewshed boundary. Note: this pipeline was created prior to shale gas development and would not be counted as new infrastructure in the viewshed analysis. The approach to the vista; however, was impacted by the creation of the shale gas well pad seen in Figure 6.21.

Sound Monitoring

Soundscape is another component of wild character and shale gas development introduces novel sounds to the forest landscape. This is in the form of heavy equipment traffic, drilling, compressor stations, equipment on well pads, and others. To quantify the potential effects to visitors (and wildlife), sound levels at gas infrastructure pads are monitored as part of the monitoring efforts on state forest land.

The sound level is reported in db(A) Ldn which is the unit of measure for the bureau's sound guideline. The guideline reads: ***When no suitable alternatives exist, and a compressor station must be sited on state forest lands, the operating noise level of the compressor station should not exceed an Ldn of 55 db(A) at any distance greater than 300 feet from the compressor building.*** The Ldn metric is the average sound level over a 24-hour period, with a penalty added for noise during the nighttime hours of 10:00 p.m. and 7:00 a.m. This is a standard metric for use in reporting noise magnitude.

Compressor Stations

Since 2013, the shale gas monitoring program has measured operating sound levels at 14 compressor station sites, each of which has a unique configuration and specifications (Figure 6.23). The monitoring program collects ambient sound data at approved compressor sites before compressors are built (Figure 6.24). The bureau also collects operating sound data twice a year at each operating station, once with leaves on the trees, and once with leaves off (Figure 6.25). The guidelines include a threshold for sound levels at compressor stations, which is an average of 55 db(A) Ldn at 300 feet from anything on the compressor pad capable of producing noise. Ambient sound has been measured at six approved compressor locations. Three compressor stations, which had such ambient sound level data, have been built and become operational since the ambient data were collected. Two others have not yet been built. The final station was operational at the onset of monitoring, but has since gone offline. Each site is uniquely configured and situated among the native vegetation (Figures 6.23 and 6.25). Such site-specific details can make generalization about conditions surrounding compressor stations difficult.

Figure 6.23. Examples of different configurations and types of compressor stations.

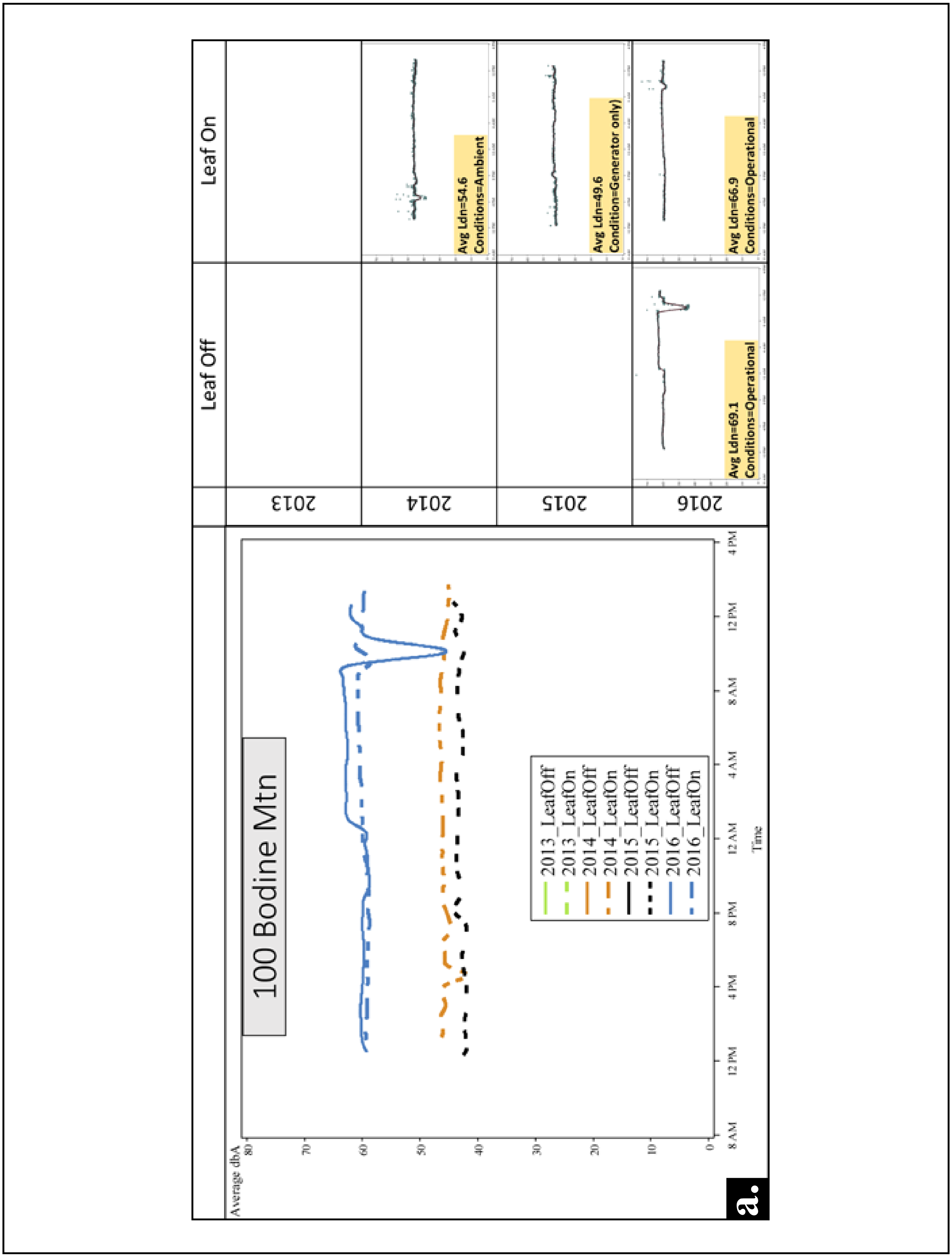
Figure 6.24. Top photos show conditions when ambient reading was taken at a proposed compressor site in 2013. Lower photos show conditions at compressor site in 2015 after station was constructed.

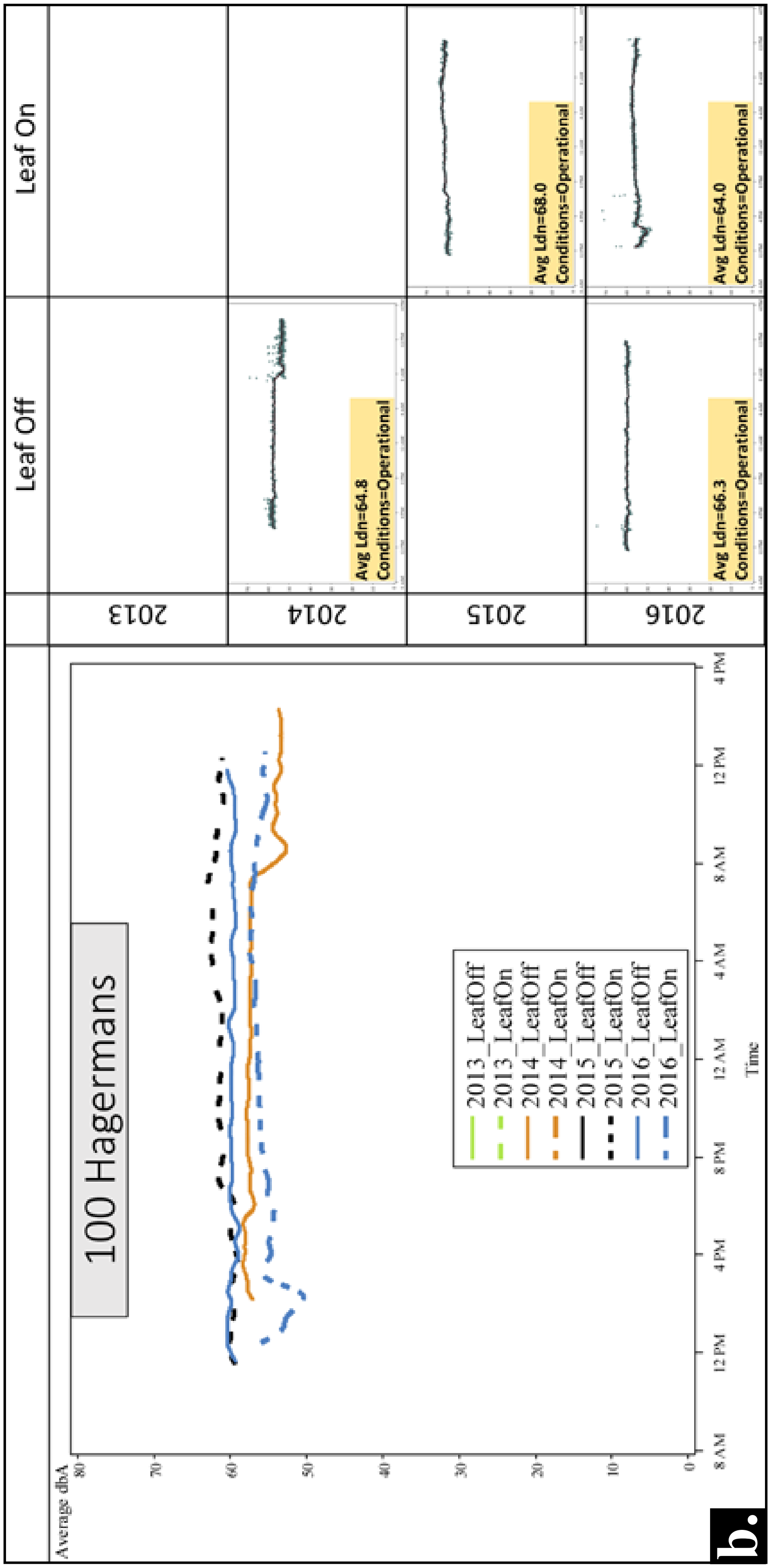
Figure 6.25. Top row shows the varying conditions of "leaf off" measurements and the bottom row shows '"leaf on" conditions across various compressor sites.

In general, each compressor station has a unique signature and it is difficult to generalize across these infrastructure units. There were no differences between leaf off and leaf on conditions at 300 feet from the compressor station (Table 6.7 and Figure 6.26). There were no discernable differences in sound levels at night versus daytime, although a few measurements of ambient conditions reveal a variation throughout the 24-hour period which could be explained by a suite of natural conditions, from dawn chorus to thunderstorms, as well as traffic or forest visitors. Despite the wide variation in sound signatures at each station, Figure 6.26 reveals a few key points. First, readings at ambient conditions have much more diversity of levels, although the ambient average is typically lower than when the compressor station is operational (Figures 6.26c, 6.26g and 6.26m). For example, Compressor 729 has ambient sound levels around 10-20 db(A) lower than the average operating sound levels (Figure 6.26m). The electric compressor station generally had a lower average operational sound level, ranging from 45.1-50.4 average db(A) Ldn under operational conditions in visits to this compressor (Figure 6.26i).

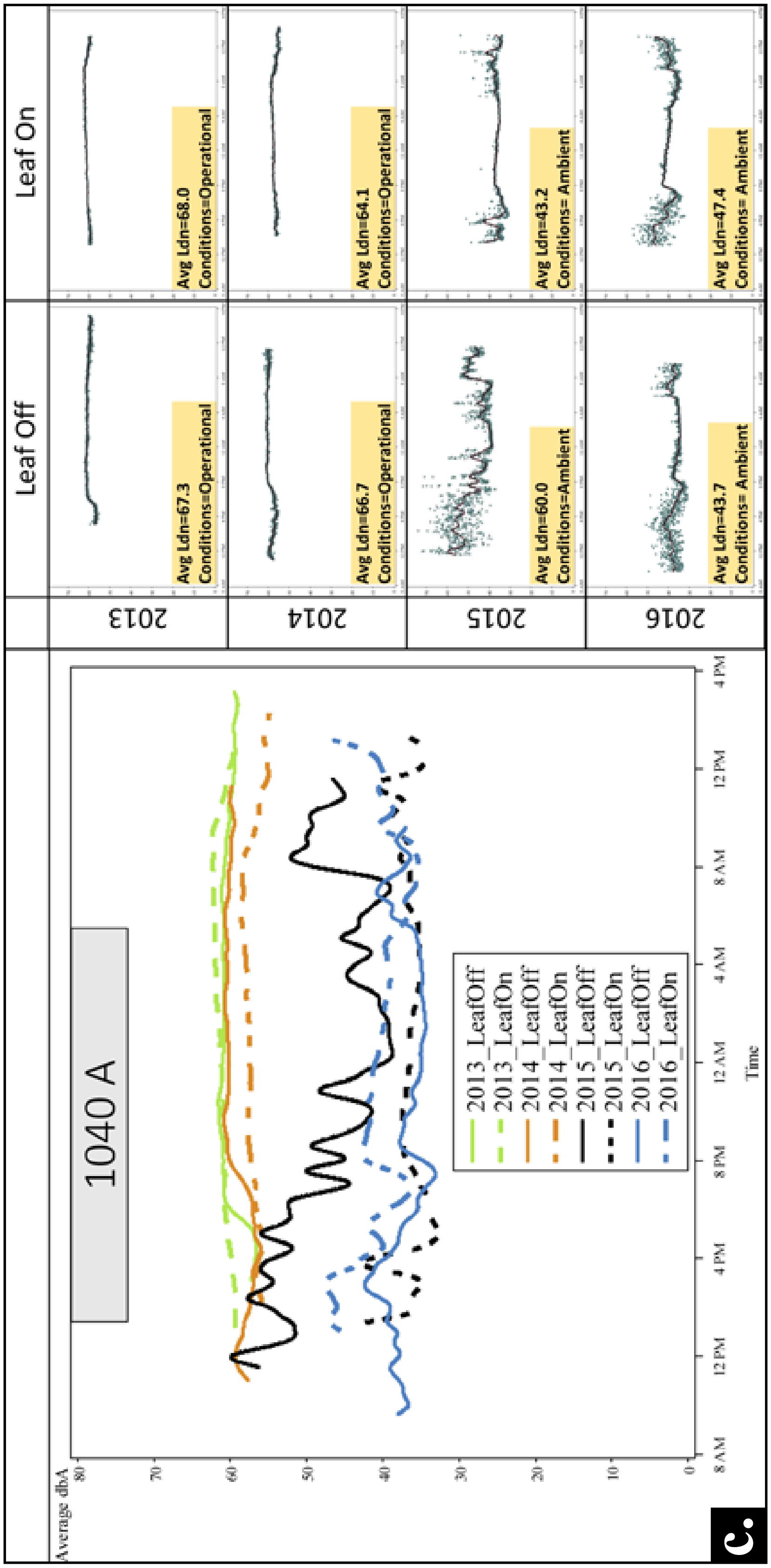
Compressor	Year	2013		2014		2015		2016	
		Leaf Off	Leaf On	Leaf Off	Leaf On	Leaf Off	Leaf On	Leaf Off	Leaf On
100- Bodine Mtn	Avg Ldn	--	--	--	54.6	--	49.6	69.1	66.9
	Condition	--	--	--	*Amb*	--	*Ope***	*Ope*	*Ope*
100-Hagermans	Avg Ldn	--	--	64.8	--	--	68	66.3	64
	Condition	--	--	*Ope*	--	--	*Ope*	*Ope*	*Ope*
1040A	Avg Ldn	67.3	68.0	66.7	64.1	60.0	43.2	43.7	47.4
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Amb*	*Amb*	*Amb*	*Amb*
231A	Avg Ldn	46.2	58.2	--	--	--	--	--	--
	Condition	*Amb*	*Amb*	--	--	--	--	--	--
285A	Avg Ldn	76.9	69.0	70.5	71.2	58.2	54.0	52.0	57.2
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*
289A	Avg Ldn	61.7	62.9	64.4	64.7	58.7	59.6	56.8	55.9
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*
293A	Avg Ldn	--	--	--	--	--	48.7	63.9	67.0
	Condition	--	--	--	--	--	*Amb*	*Ope*	*Ope*
322A	Avg Ldn	--	65.0	--	--	--	52.6	--	--
	Condition	--	*Amb*	--	--	--	*Amb*	--	--
324-Electric	Avg Ldn	--	--	48.0	--	--	50.4	45.1	45.5
	Condition	--	--	*Ope*	--	--	*Ope*	*Ope*	*Ope*
587A	Avg Ldn	68.3	74.3	64.6	62.8	62.5	65.6	61.8	62.5
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*
595A	Avg Ldn	66.0	72.7	69.9	66.6	67.0	58.5	64.8	67.4
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*
685A	Avg Ldn	66.5	59.1	71.9	62.3	55.1	50.5	54.4	56.2
	Condition	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*
729A	Avg Ldn	53.5	50.0	--	--	70.6	65.0	65.8	68.3
	Condition	*Amb*	*Amb*	--	--	*Ope*	*Ope*	*Ope*	*Ope*
997A	Avg Ldn	--	67.3	--	67.1	67.1	63.2	66.3	64.7
	Condition	--	*Ope*	--	*Ope*	*Ope*	*Ope*	*Ope*	*Ope*

Table 6.7. Average db(A) Ldn and operational condition (ope=operational; amb=ambient) for every compressor station measurement taken since 2012. Measurements below 55db(A) are marked in green. **The compressor station at 100-Bodine Mtn was operational for the Leaf On-2015 measurement, but only a generator was running (no compressors).

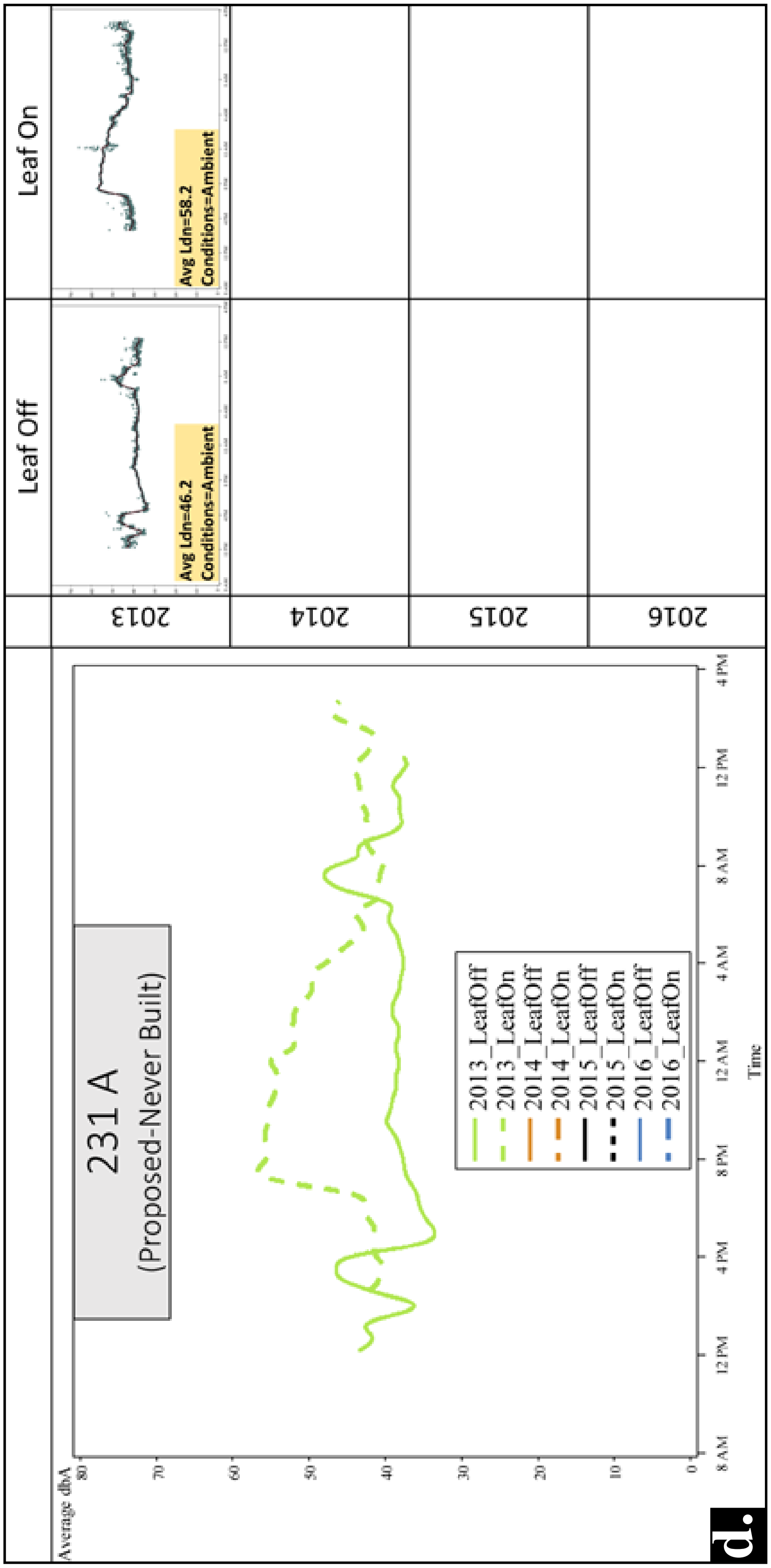

Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=54.6
Conditions=Ambient
Avg Ldn=49.6
Condition=Generator only)
Avg Ldn=69.1
Conditions=Operational
Avg Ldn=66.9
Conditions=Operational
a.
100 Bodine Mtn
Average dbA
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Time

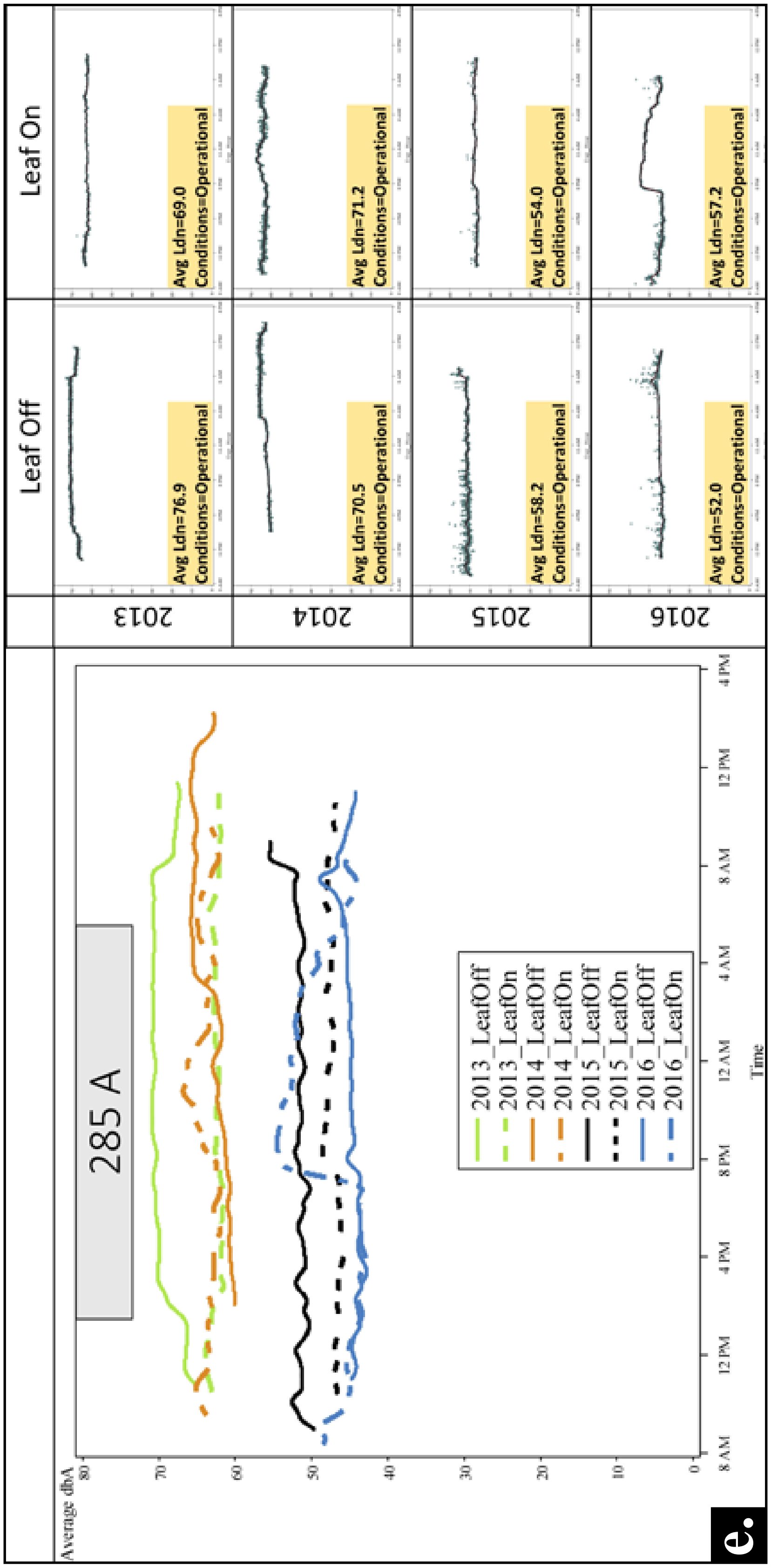


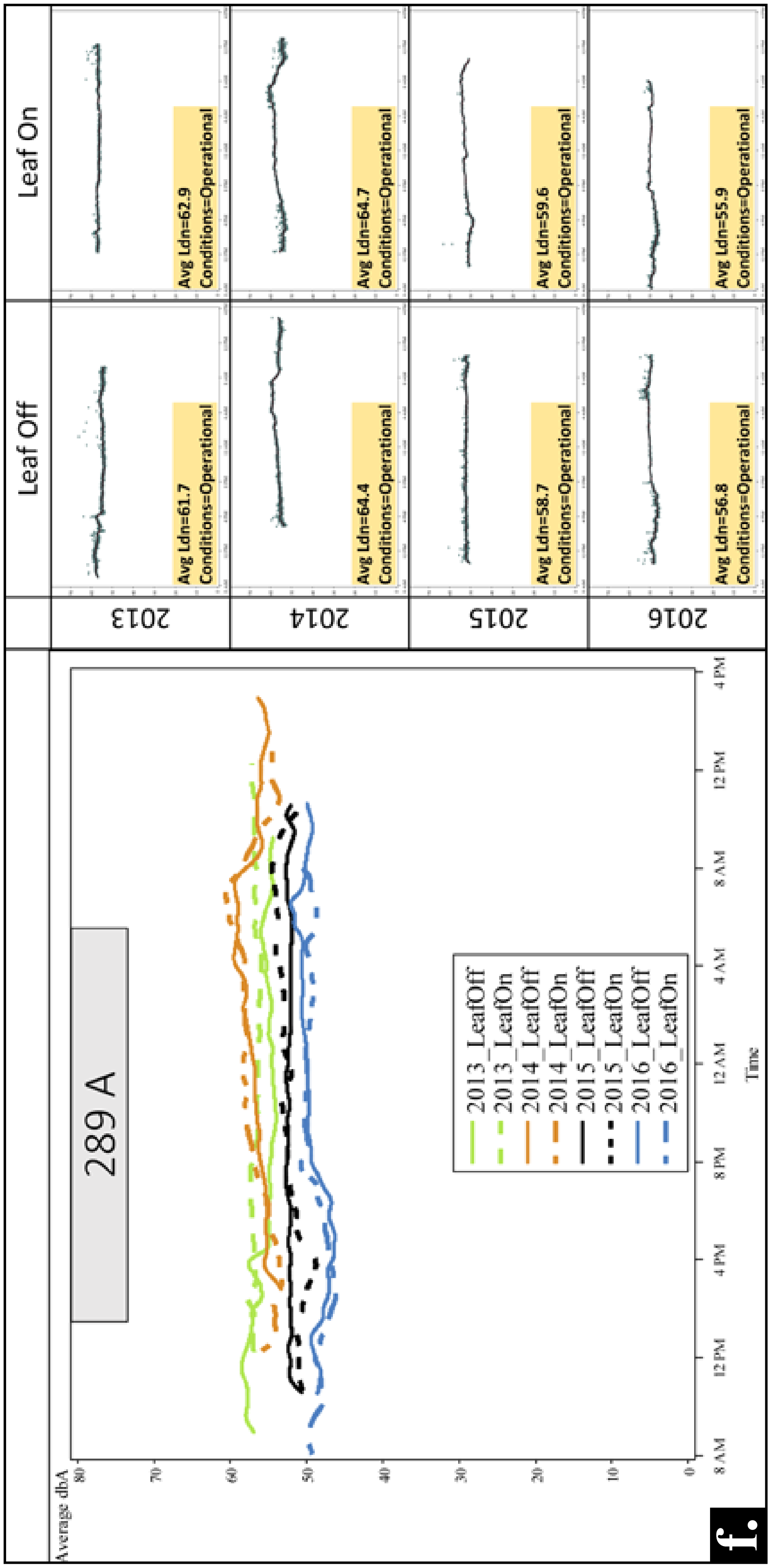
b.
100 Hagermans
Average dbA
Time
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=64.8
Conditions=Operational
Avg Ldn=68.0
Conditions=Operational
Avg Ldn=66.3
Conditions=Operational
Avg Ldn=64.0
Conditions=Operational

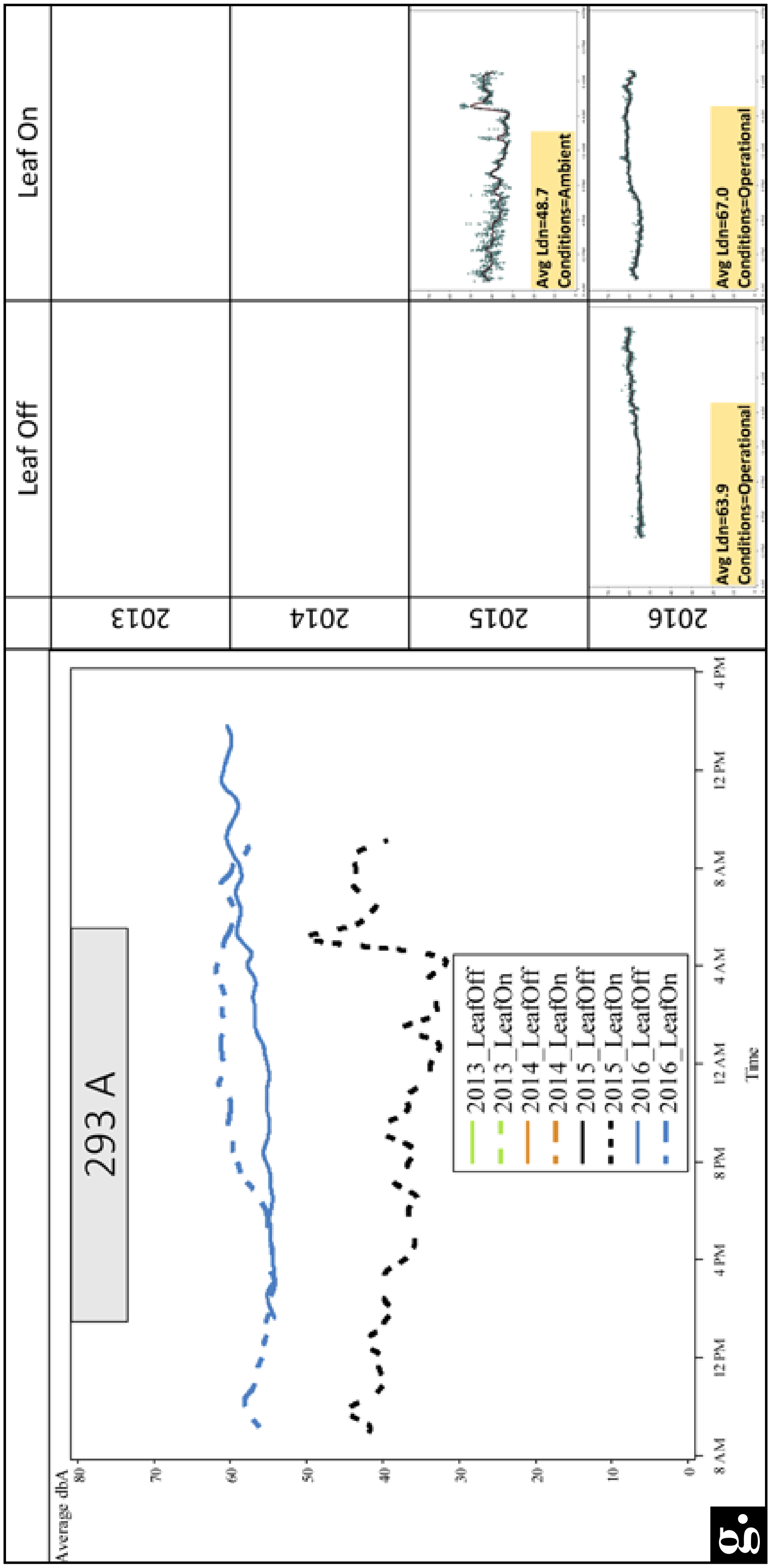


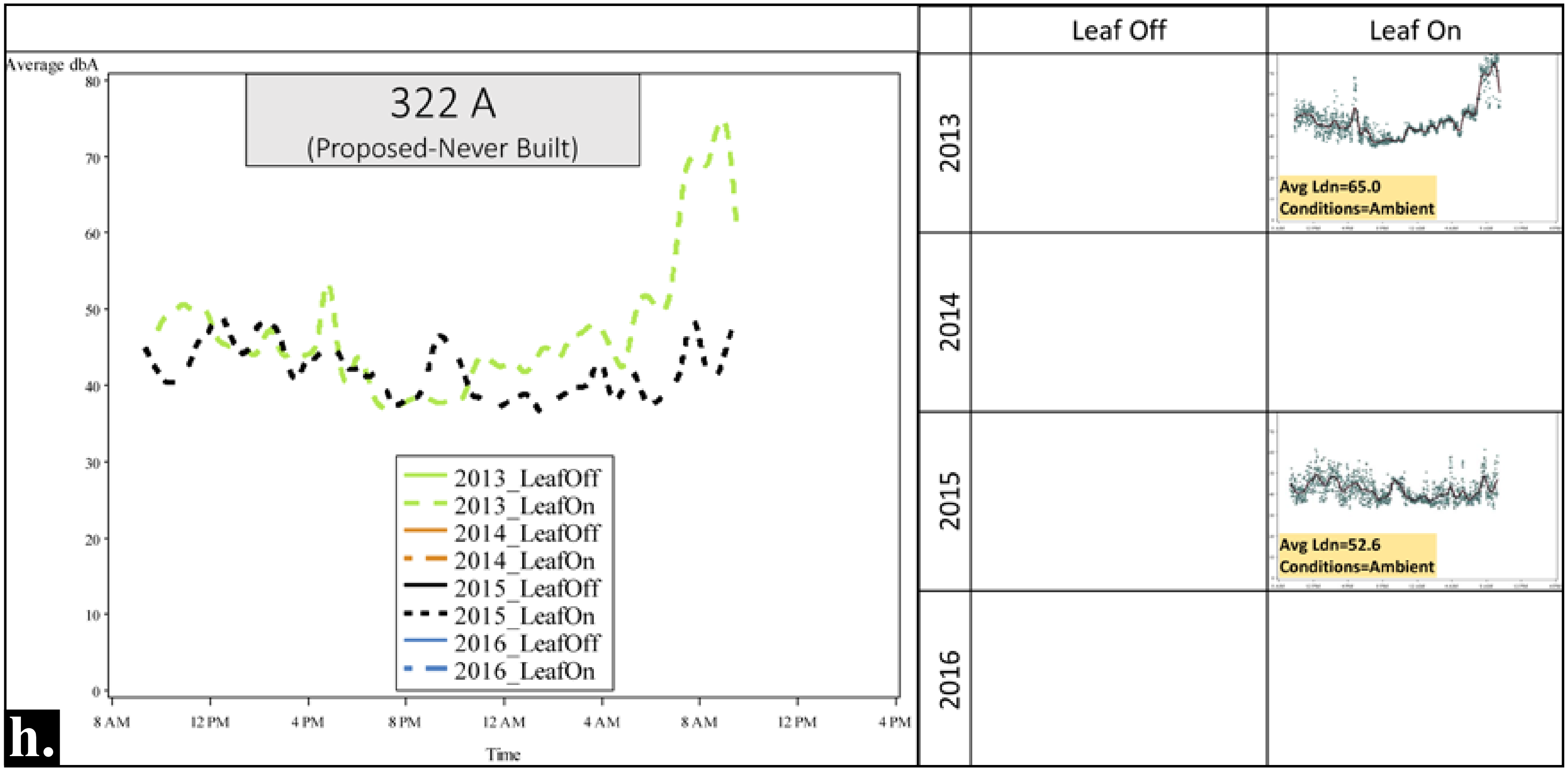
c.
1040 A
Average dbA
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=67.3 Conditions=Operational
Avg Ldn=68.0 Conditions=Operational
Avg Ldn=66.7 Conditions=Operational
Avg Ldn=64.1 Conditions=Operational
Avg Ldn=60.0 Conditions=Ambient
Avg Ldn=43.2 Conditions= Ambient
Avg Ldn=43.7 Conditions= Ambient
Avg Ldn=47.4 Conditions= Ambient


d.
231 A
(Proposed-Never Built)
Average dbA
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=46.2
Conditions=Ambient
Avg Ldn=58.2
Conditions=Ambient

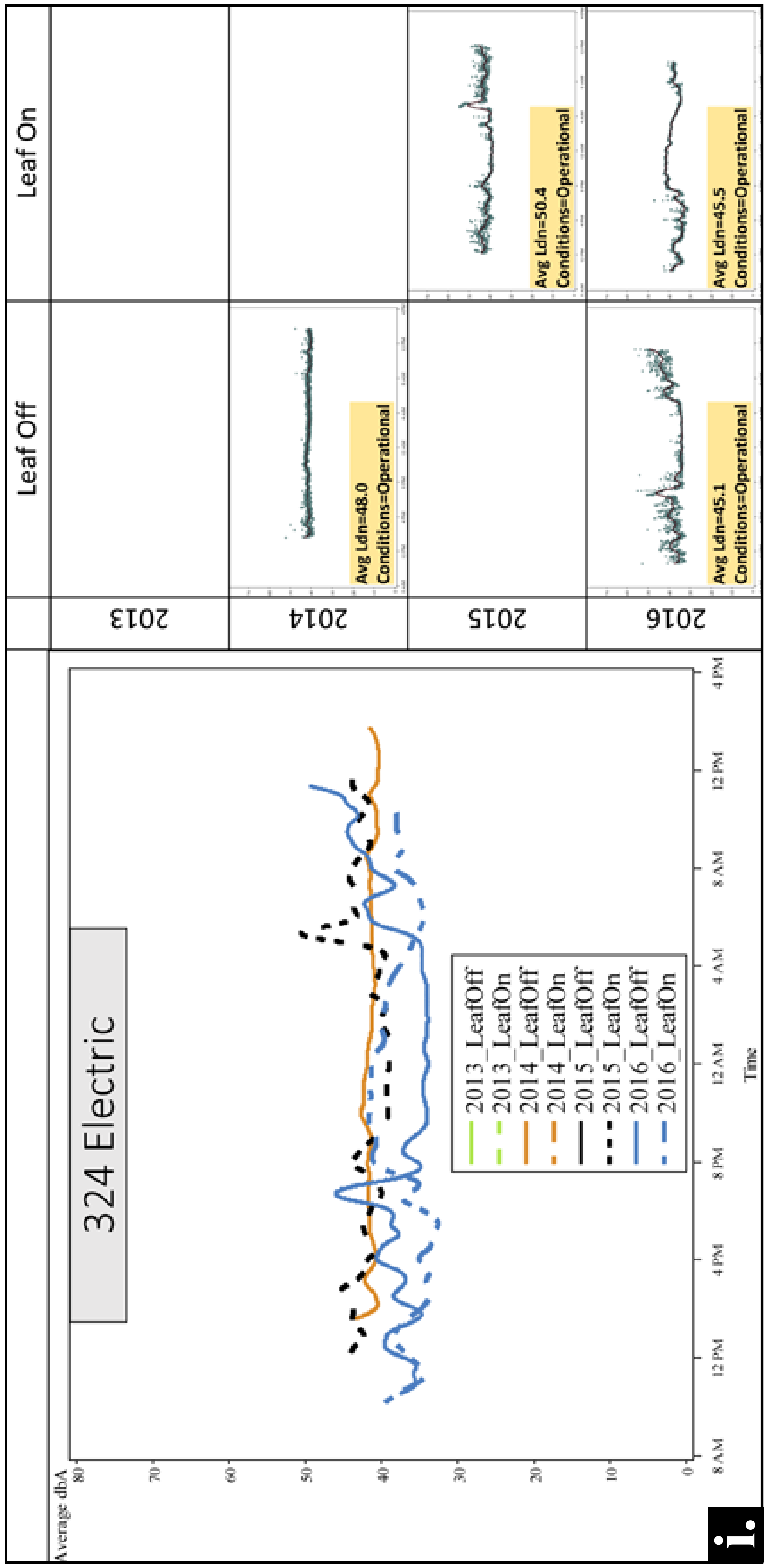

e.
285 A
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=76.9
Conditions=Operational
Avg Ldn=69.0
Conditions=Operational
Avg Ldn=70.5
Conditions=Operational
Avg Ldn=71.2
Conditions=Operational
Avg Ldn=58.2
Conditions=Operational
Avg Ldn=54.0
Conditions=Operational
Avg Ldn=52.0
Conditions=Operational
Avg Ldn=57.2
Conditions=Operational
Average dbA
Time
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn


Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=61.7
Conditions=Operational
Avg Ldn=62.9
Conditions=Operational
Avg Ldn=64.4
Conditions=Operational
Avg Ldn=64.7
Conditions=Operational
Avg Ldn=58.7
Conditions=Operational
Avg Ldn=59.6
Conditions=Operational
Avg Ldn=56.8
Conditions=Operational
Avg Ldn=55.9
Conditions=Operational
f.
289 A
Average dbA
0
10
20
30
40
50
60
70
80
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn

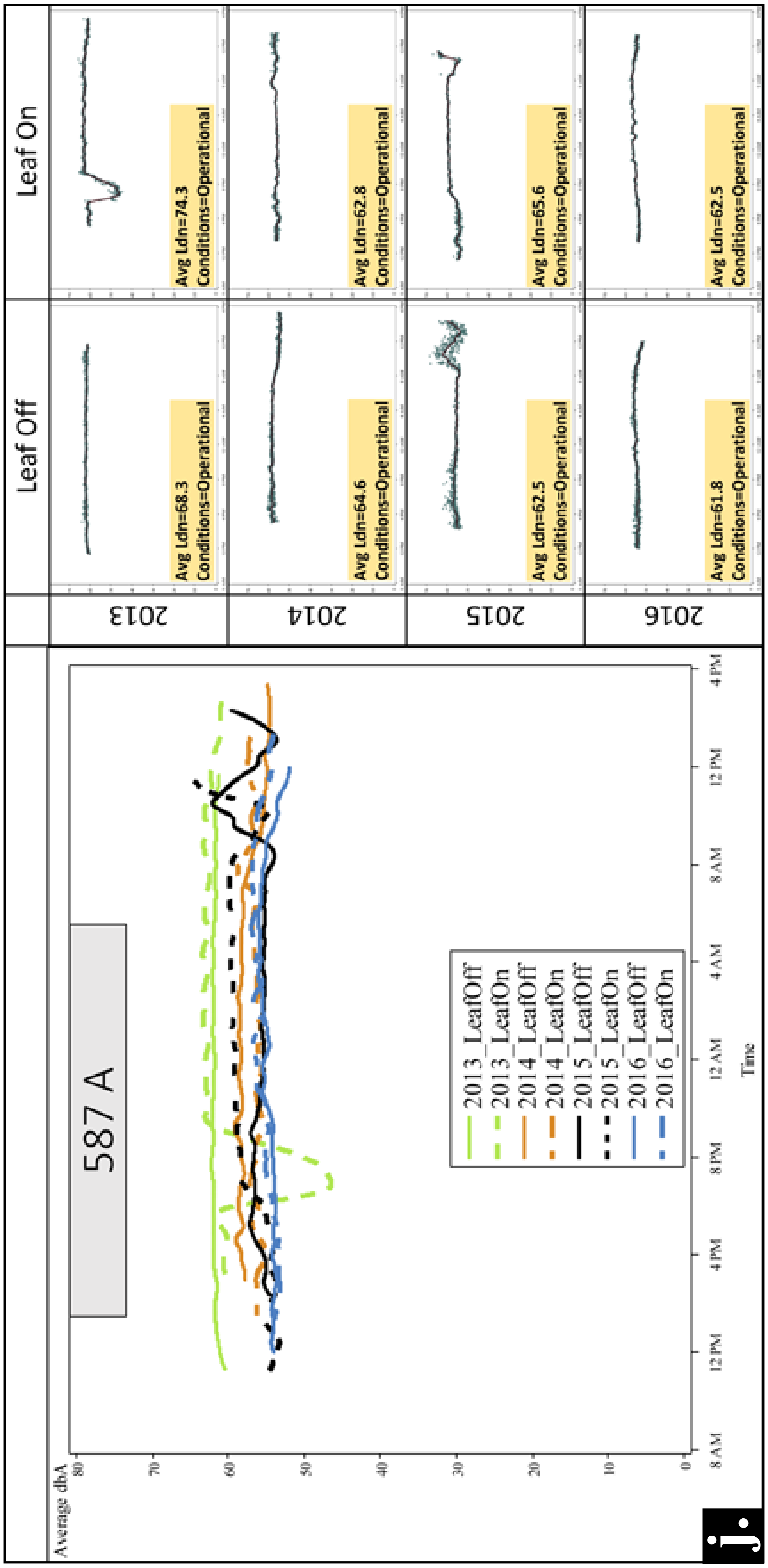

Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=48.7
Conditions=Ambient
Avg Ldn=63.9
Conditions=Operational
Avg Ldn=67.0
Conditions=Operational
293 A
Average dbA
0
10
20
30
40
50
60
70
80
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn

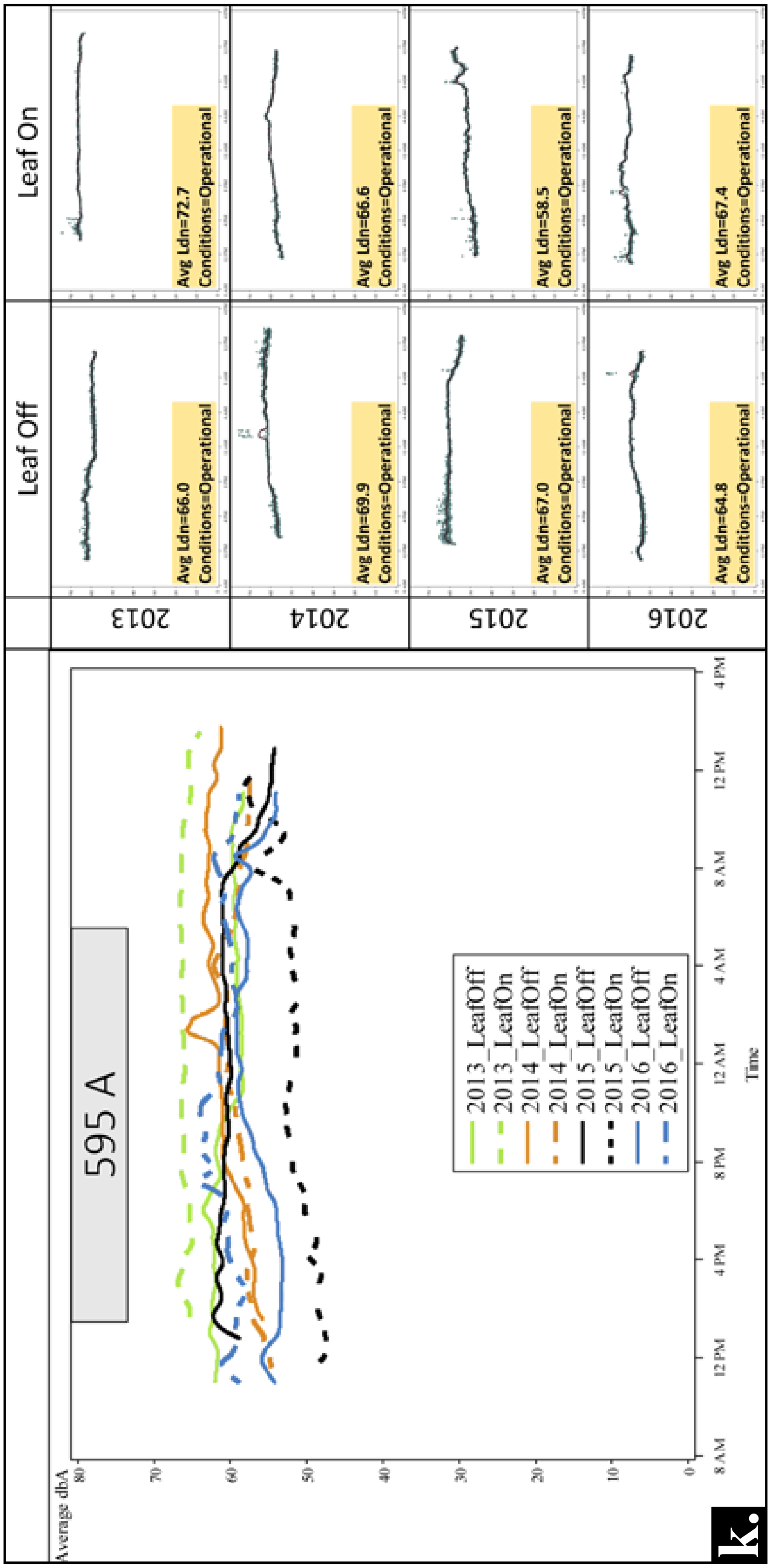


h.
322 A
(Proposed-Never Built)
Average dbA
80
70
60
50
40
30
20
10
0
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=65.0
Conditions=Ambient
Avg Ldn=52.6
Conditions=Ambient



324 Electric
Average dbA
0
10
20
30
40
50
60
70
80
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=48.0
Conditions=Operational
Avg Ldn=50.4
Conditions=Operational
Avg Ldn=45.1
Conditions=Operational
Avg Ldn=45.5
Conditions=Operational
i.


587 A
Average dbA
80
70
60
50
40
30
20
10
0
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
Avg Ldn=68.3
Conditions=Operational
Avg Ldn=74.3
Conditions=Operational
2014
Avg Ldn=64.6
Conditions=Operational
Avg Ldn=62.8
Conditions=Operational
2015
Avg Ldn=62.5
Conditions=Operational
Avg Ldn=65.6
Conditions=Operational
2016
Avg Ldn=61.8
Conditions=Operational
Avg Ldn=62.5
Conditions=Operational


595 A
Average dbA
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
Leaf Off
Leaf On
2013
2014
2015
2016
Avg Ldn=66.0
Conditions=Operational
Avg Ldn=72.7
Conditions=Operational
Avg Ldn=69.9
Conditions=Operational
Avg Ldn=66.6
Conditions=Operational
Avg Ldn=67.0
Conditions=Operational
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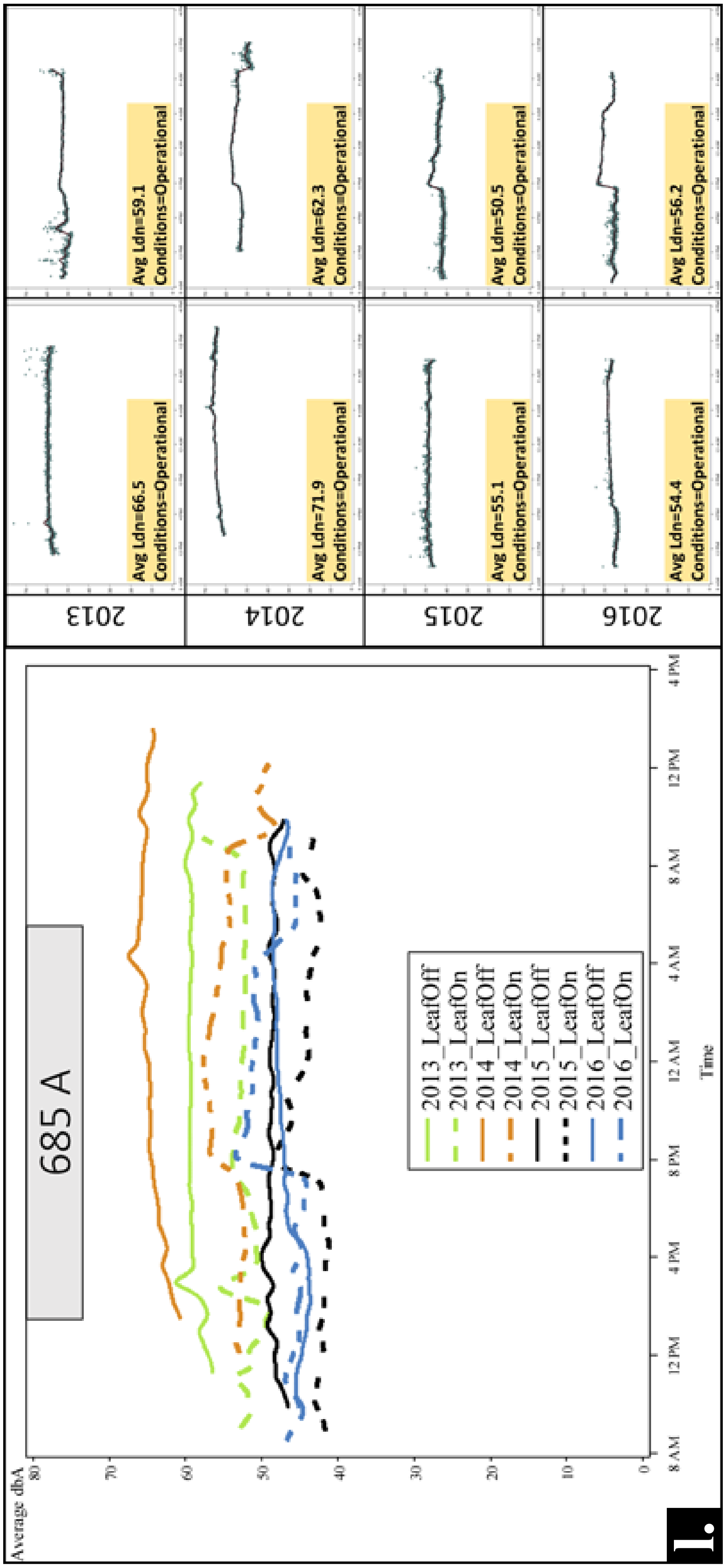
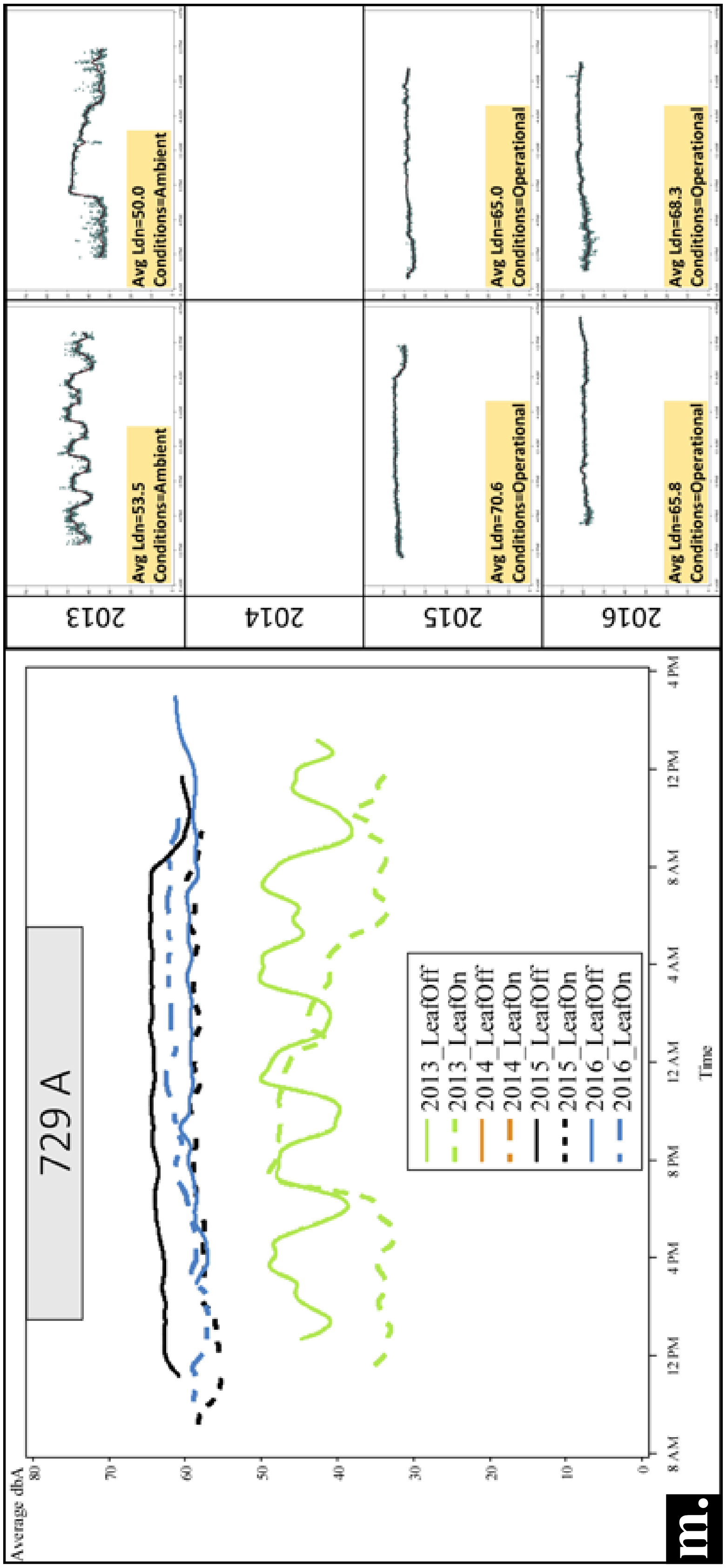
Conditions=Operational
Avg Ldn=64.8
Conditions=Operational
Avg Ldn=67.4
Conditions=Operational



1.
685 A
Average dbA
Time
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
2013
2014
2015
2016
Avg Ldn=66.5 Conditions=Operational
Avg Ldn=59.1 Conditions=Operational
Avg Ldn=71.9 Conditions=Operational
Avg Ldn=62.3 Conditions=Operational
Avg Ldn=55.1 Conditions=Operational
Avg Ldn=50.5 Conditions=Operational
Avg Ldn=54.4 Conditions=Operational
Avg Ldn=56.2 Conditions=Operational


729 A
Average dbA
Time
8 AM
12 PM
4 PM
8 PM
12 AM
4 AM
8 AM
12 PM
4 PM
2013_LeafOff
2013_LeafOn
2014_LeafOff
2014_LeafOn
2015_LeafOff
2015_LeafOn
2016_LeafOff
2016_LeafOn
2013
2014
2015
2016
Avg Ldn=53.5
Conditions=Ambient
Avg Ldn=50.0
Conditions=Ambient
Avg Ldn=70.6
Conditions=Operational
Avg Ldn=65.0
Conditions=Operational
Avg Ldn=65.8
Conditions=Operational
Avg Ldn=68.3
Conditions=Operational
m.

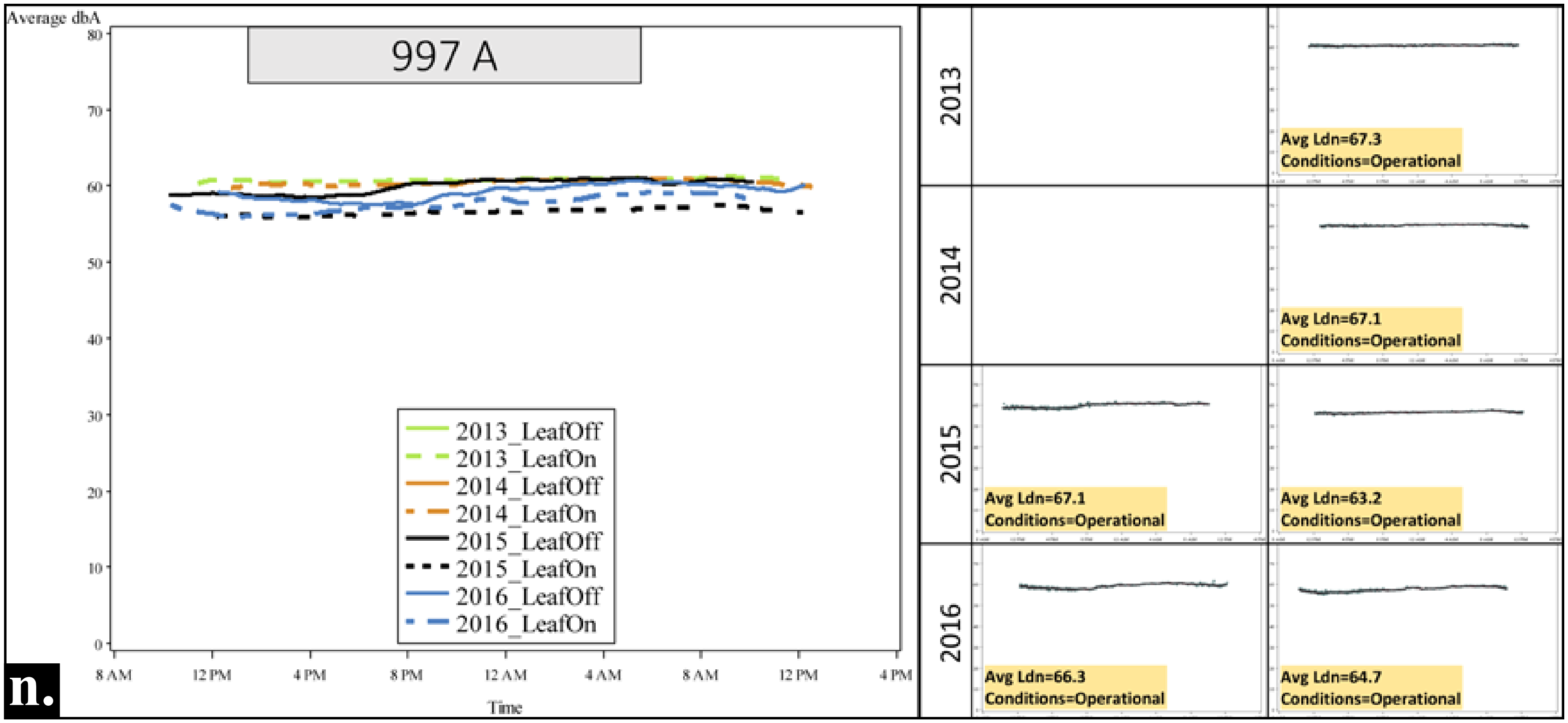


Figure 6.26 A-N. Compressor monitoring graphs for each of the 14 compressor sites.

Several compressors that have been online since 2013 show lower operational 24-hour averages starting in 2015 (Figures 6.26e, 6.26f and 6.26l). The compressor station sound levels may have decreased due to noise attenuation modifications, decreased production, or compressor station shut down. Operators communicate with the bureau regarding noise attenuation efforts and subsequent measurements have shown decreases in sound levels. Attenuation methods include things such as tree plantings or enclosing noisy equipment in insulated structures. Decreased natural gas production may also lead to changes in compression needs, which may affect sound levels. In some cases, when compressor engines and fans have been observed to be off, sound levels dropped substantially.

Well pads

Well pads with permanent vegetation monitoring sites are also measured for sound at 300 feet from the nearest sound source while collecting vegetation data. Five sound measurements were recorded at well pads in 2014, four in 2015, and five pads in 2016. Because these data are not collected over a 24-hour period, the sound levels are reported in average db(A), which does not include the nighttime adjustment associated with Ldn.

Table 6.8 shows the average value for sound meter data collected every five seconds over a short period (several hours). Measurements show that well pads have sound levels similar to ambient conditions (Table 6.8 and Figure 6.27).

While the bureau has only measured sound levels at 14 well pads, the sound levels measured and observed have been relatively quiet. The sound guideline was not written specifically for well pads, but well pads often have various equipment needed for gas production, which has the potential to generate sound. Because well pad sound levels can be efficiently measured while collecting other monitoring data, the bureau will continue to monitor these to examine trends and expand

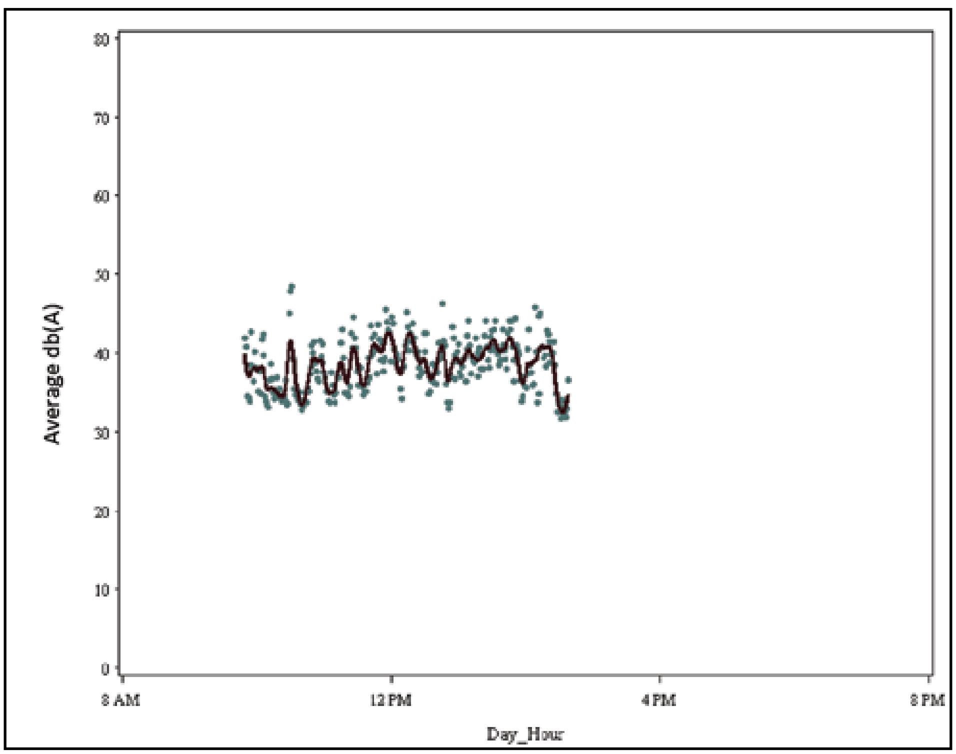


Figure 6.27. Well pad sound monitoring graph for one of the 14 well pad sites. Other well pad graphs show similar trends.

Well Pad ID	Min	Max	Average
1006-Turkey Pad	35	53	39
100-Pad M	36	53	42
154-Pad A	35	63	38
285-Pad F	32	56	38
289-Pad B	32	51	34
324-Pad A	34	48	36
356-Pad J	34	69	37
587-Pad 3	35	54	37
595-Pad E	32	58	34
678-Pad B	32	55	36
706-Pad 10	32	64	36
720-Pad A	33	56	38
724-Pad A	30	64	35
729-Pad E	32	55	34

Table 6.8. Minimum, maximum, and average db(A) readings for well pads recorded for several hours during the day for each site.

the baseline dataset of 'typical' sound levels at well pads across state forest land.

<u>*Sound Summary and Future Direction*</u>

Sound levels have been measured at 12 operating compressor stations, two approved compressor station sites (yet to be built), and 14 well pads. Several compressor stations show a general trend since 2013 of decreasing average sound level. Four of 12 compressor stations monitored in 2016 had at least one of the two readings of the 24-hour average below the bureau's guideline for sound level. This is due to several factors, including mitigation practices, decreased volumes being processed at the compressors, and some compressors fully or partially going offline during decreased demand and production. The bureau is working cooperatively with operators to address compressor sound and to meet recommended guideline thresholds. Well pads have average sound levels like ambient conditions, both in the level (db(A)) and the variability over time (diversity of sound magnitude).

The bureau's monitoring protocols examine the magnitude of sound near infrastructure, but level is only one component of noise. These measures provide a gauge to detect trends and a relatively simple metric to establish thresholds and guidelines. However, the true effects are more complex than solely the magnitude of the sound. To understand the biological effect and the disruption caused by a sound, it is necessary to look at the character of the sound and delve into the complexities of perception. More information is needed to determine what soundscapes are acceptable or disruptive beyond just the magnitude. Frequency, persistence, and context of the sounds are essential to get at the true effects to the soundscape and wild character. To address this complex question, a research project is underway in conjunction with researchers at Penn State University. The following description from the research proposal submitted to the bureau in 2016 describes the goals of the study:

> *The sounds emanating from these natural gas compressor stations are constant, and may interfere with the experiences visitors seek while recreating within these forests. Furthermore, sound levels vary, not only with topography and vegetation density, but also by individual compressor stations. Anthropogenic sounds in protected area settings not only impact ecological systems and processes, but they also impact visitor experiences, and have been found to negatively influence aesthetic evaluations of protected area settings (Weinzimmer et al., 2014) and mood state (Benfield et al., 2014). To date, it is unknown how current or future natural gas compressor station sounds influence visitor experiences, and research is needed to inform visitor management in these Pennsylvania State Forest areas.*
>
> *The proposed project serves to examine Pennsylvania State Forest visitor thresholds for experiencing natural gas compressor station sounds. Specifically, this study will serve to gain an understanding of the sounds/noise (both natural and anthropogenic) that PA State Forest visitors are experiencing, and how they influence the visitor experience. Moreover, this study will examine the sound/noise levels (masking of natural sounds) in which natural gas*

compressor station sounds become: a) annoying and b) unacceptable; thus informing thresholds.

Recreation Activity

Trends and effects to forest use can be quantified by examining changes in recreational use of the forest. Without formal user inventories across every location on state forest, the 'actual' recreational use cannot be determined. Therefore, documentation that exists for recreation, such as agreements and permits, is examined to discern trends.

Recreational Agreements

Each year the bureau has vendors, groups, and individuals who request permission to hold events or conduct services on state forest land. Permission for these activities are carried out through either a Special Activities Agreement (SAA) or Commercial Activities Agreement (CAA). These agreements allow the bureau to define the constraints and conditions under which the activity must take place to minimize conflicts and ensure appropriate use of state forest land. A special questionnaire attachment is included with the agreement to capture changes in use or displacement due to shale gas activities on these recreation events (Figure 6.28).

Since 2013, the bureau has instituted 193 new agreements across all forest districts. Of those agreements, 17 respondents (8.8 percent overall) indicated that shale gas activity has affected their use or experience of the state forest (Figure 6.29 a, c). For core gas forest districts only, the number of agreements indicating that they were affected is nine (12.5 percent) (Figure 29 b, d). No events reported being relocated due to gas, but six respondents indicated that they did have to re-route the course of their event due to gas activities. For those affected, the explanation was attributed to unfavorable experiences, snowmobile trail inaccessibility (due to closed or plowed roads or gas traffic on groomed trails), or natural conditions that were less peaceful (loss of wild character).

Camping Permits

Permits are only required for motorized camping or for designated sites. Backcountry/hike-in campers do not need a permit unless camping at a site for more than one consecutive night. The bureau has recently begun to track campsite reservations issued statewide, but some forest districts have maintained records of their permitting at a local level. Starting in 2014, the bureau began compiling the number of permits issued yearly based on the district records. Although this dataset is somewhat inconsistent across the state, it is apparent that the number of permits issued fluctuates through time and it does not appear that core gas forest districts have a clear pattern or a trend that is unlike all other districts (Figure 6.30). It is important to note that major camping facilities are typically not located near major gas infrastructure. Well pads and compressor stations tend to occur on ridgetops while campgrounds are often found along streams.

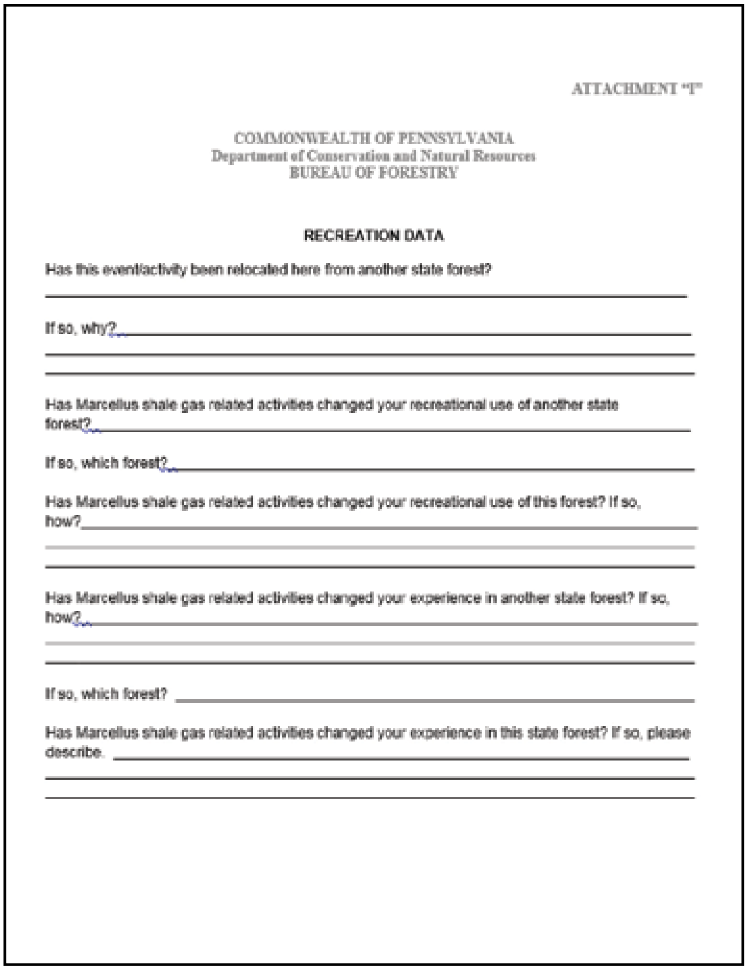
Qualitative Metrics: Social Perception and Coummunity Engagement

Community engagement in various forums is a way to solicit feedback and quantify effects on forest use.

Visitor Use Monitoring

In 2011, the bureau began a partnership with the Pennsylvania State University to adapt the National Visitor Use Monitoring (VUM) program to measure ten state forest districts and 30 state parks over a five-year period. The objectives of the study are:

1. To conduct surveys of visitors to selected Pennsylvania state forest and state park areas and develop a visitor profile, including information on the origin of visitors (e.g., local, non-local resident, out of state), trip context and purpose (e.g., day versus overnight visitor, primary purpose versus casual visitor), length of stay



ATTACHMENT "I"

COMMONWEALTH OF PENNSYLVANIA
Department of Conservation and Natural Resources
BUREAU OF FORESTRY

RECREATION DATA

Has this event/activity been relocated here from another state forest?

If so, why?

Has Marcellus shale gas related activities changed your recreational use of another state forest?

If so, which forest?

Has Marcellus shale gas related activities changed your recreational use of this forest? If so, how?

Has Marcellus shale gas related activities changed your experience in another state forest? If so, how?

If so, which forest?

Has Marcellus shale gas related activities changed your experience in this state forest? If so, please describe.

Figure 6.28. Attachment that is included in group activity agreements (commercial activities agreements and special activities agreements).

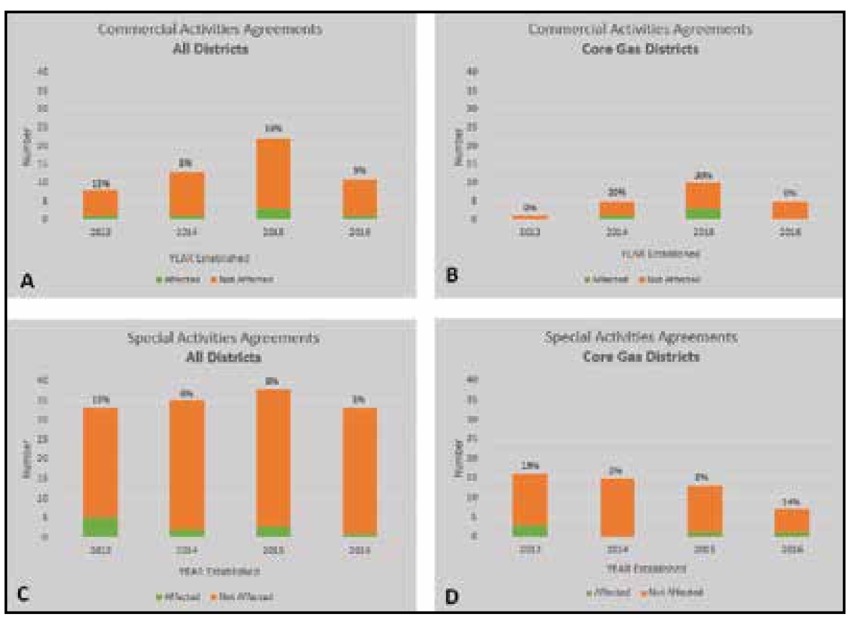


Figure 6.29. Number of commercial and special activities agreements reporting impacts from gas development by year for:

A) Commercial Activities Agreements across all forest districts;

B) Commercial Activities Agreements within core gas forest districts only;

C) Special Activities Agreements across all forest districts;

D) Special Activities Agreements within core gas forest districts only.

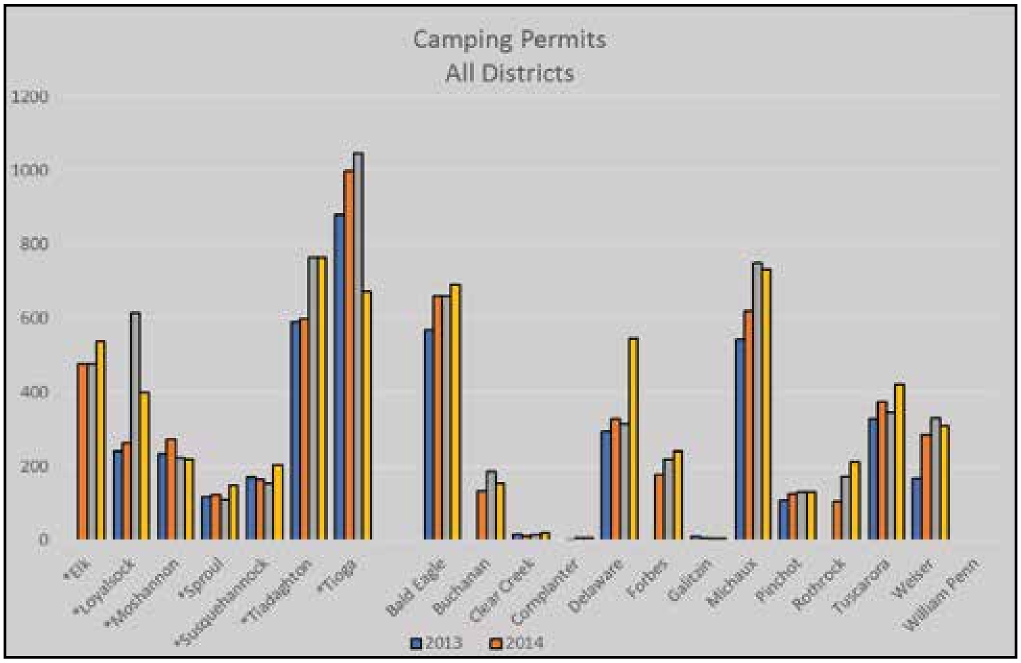


Figure 6.30. Number of camping permits issued each year by forest district. Core gas forest districts are show on left.

in the area, spending patterns, size and type of visiting groups, previous visitation history, activities pursued, and different patterns of visitation across seasons.

2. To measure overall recreational use and specific visitation patterns within the selected state forests and state parks, including the number of visitors per vehicle and the distribution of use across different types of sites within the area.
3. To develop a demographic profile of visitors at the designated state forests/parks.
4. To identify visitor expectations and levels of satisfaction with various aspects of their visit.
5. To examine visitor opinions about probable future state forest and state park management and facility development decisions.
6. To examine visitor reactions to oil and gas activities and the impacts of these activities on recreational visitation patterns and experiences.
7. To measure visitor expenditures and levels of economic impact on surrounding communities.

As part of these surveys, visitors were asked questions related to their use and experience related to shale gas activities. Six of the ten forest districts surveyed are core gas forest districts (Figure 6.31). Districts surveyed are as follows; Sproul and Susquehannock (2011-12), Forbes and Delaware (2012-13), Tioga and Tiadaghton (2013-14), Elk and Moshannon (2014-15), and Michaux and Buchanan (2015-16). At the time of this report data were not yet compiled for year five (Michaux and Buchanan), so these estimates do not contain these data. For the first four years across eight surveyed districts, 15.5 percent of respondents reported that shale gas activities had affected their *Use* of the state forest and 18.7 percent reported that it had affected their *Experience* (Figure 6.31). Districts with most affected responses came from the Sproul, Susquehannock, Tiadaghton, and Tioga State Forests (Figure 6.31). All these state forests have high numbers of recreational users and active gas construction at the time of the survey. Road and traffic issues, displacement/closed areas, and general environmental concerns were the most common reasons cited as impacts (Figure

6.32). However, most users did not report that shale gas activity had changed their use or their experience of state forest land. Completed reports with additional detailed information can be found in the reports on the bureau's **website**[1].

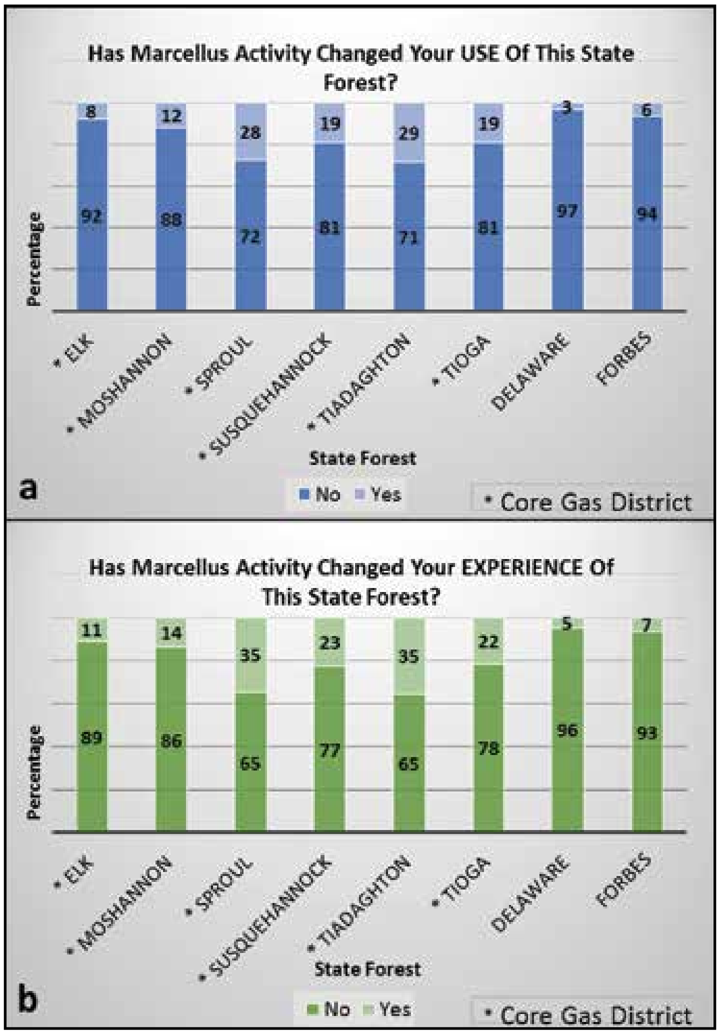


Figure 6.31. Visitor Use Monitoring (VUM) survey results.

a) percentage of surveyed visitors whose USE of specific state forests was affected;

b) percentage of surveyed visitors whose EXPERIENCE of specific state forests was affected.

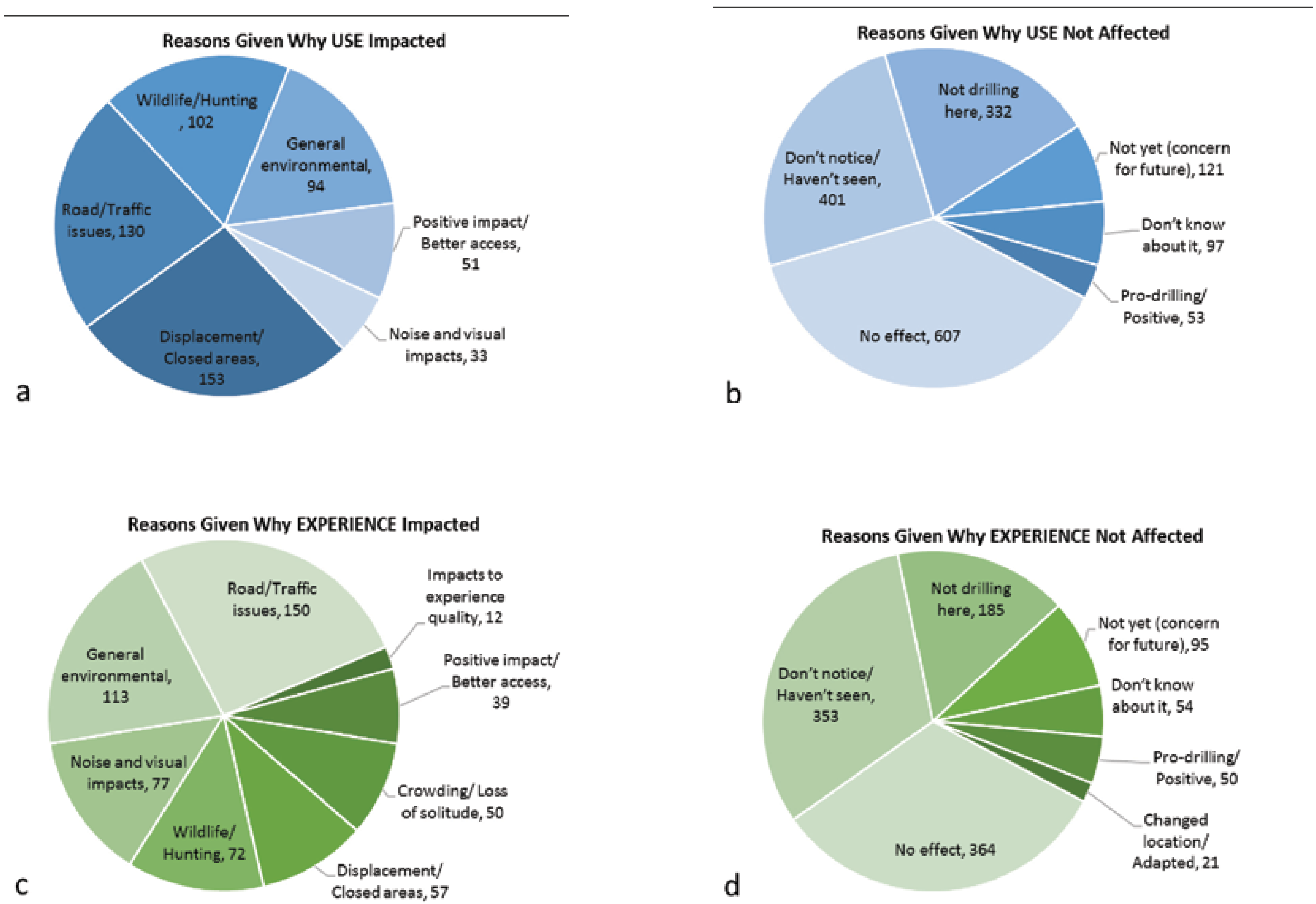


Figure 6.32. Reasons given for why a) state forest USE was impacted; b) state forest USE was NOT affected; c) state forest EXPERIENCE was impacted; D) state forest EXPERIENCE was NOT affected by shale gas development activity.

Comment Cards

In addition to the formal study of visitor use with Penn State University, the bureau has also incorporated a comment card system that continually monitors visitor needs, use, and experience. Postage paid comment cards (Figure 6.33) are placed at high recreation areas such as trail heads, parking lots, boat launches, and forest district offices. The comment card responses primarily come from state forest visitors that obtain the comment cards at these various locations across state forests. In addition, comment cards have been used to garner feedback from special events or targeted groups. For example, the cards were handed out to participants at a forest district open house event that featured an educational drive-through; 107 responses from 2015 are from this event (Table 6.9 for numbers of responses by year). In 2016, cards were mailed to all leased camps across state forest land and 529 cards came from this effort. Although not designed to be statistically analyzed, summaries of the comment card responses are useful in providing periodic evaluation of user issues and evaluating broad trends in visitor concerns, attitudes, and emerging issues.

Comment cards are reviewed when they are received, and any immediate concerns are relayed to the forest districts. A summary of the cards received is compiled quarterly and sent to the forest districts and program managers. Typical requests for action are related to trail maintenance issues, signage, littering or vandalism, need for ranger patrol, water sources, restrooms, or unsuitable activities. Typical comments regarding shale gas activity remark on dissatisfaction with increased traffic or express the visitor's overall opinion of shale gas development on state forest land.

In 2016, a new question regarding shale gas activity was added to help capture displacement of visitors. The question asks, "Has shale gas activity at another location prompted you to use this location (if so, where)?" This will help to discern where users have abandoned an area to take up their recreation at another location to avoid the shale gas activity. Of the 602 users that responded to this question, 26 respondents (4 percent) reported that they did change location due to shale gas activity at another location. (In addition, prior to the addition of this question, many users indicated through written

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pennsylvania DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
BUREAU OF FORESTRY

DC: ____________

COMMENT CARD

Please give us a minute of your time to help us serve you better on this state forest. How would you rate our facilities and services in

State Forest Name: ____________ at Location: ____________ Date of Visit: ________ Your Home Zip: ______

What is the primary reason or activity that brings you to this state forest (please circle): scenic driving, camping, backpacking, hiking, biking, hunting, fishing, boating, horseback riding, ATV riding, snowmobiling, wildlife viewing, relaxation, picnicking, other (please specify)? ____________

Please circle one for each item:	Poor	Fair	Avg.	Good	Very Good
Scenery	1	2	3	4	5
Condition of the natural environment	1	2	3	4	5
Condition of Forest roads	1	2	3	4	5
Condition of Forest trails	1	2	3	4	5
Parking lot\Trailhead condition\Appearance	1	2	3	4	5
Condition of developed recreation facilities (latrines, picnic tables, fire rings, campsites, pavilions, etc.)	1	2	3	4	5
Feeling of safety and security	1	2	3	4	5
Adequacy of signage	1	2	3	4	5
Availability of recreation information: (maps, website, etc.)	1	2	3	4	5

Has Marcellus activity at another location prompted you to use this location? (if so, where) ____________

Has Marcellus activity changed your recreational use of this state forest? (if so, how) ____________

Has Marcellus activity changed your experience on this state forest? (if so, how) ____________

What do you like or what are we doing right? ____________

What improvements would you like to see? ____________

Figure 6.33. Bureau of Forestry comment card that is placed at high use locations to collect feedback from forest users.

comments that they had adjusted the location of their recreation on state forest land; see section below on written comments and Figure 6.36).

Of the 2,101 cards that have been received since the system was implemented in 2012, 430 users (20 percent) indicated that shale gas development has affected their recreational use, experience, or location of state forest visitation (Table 6.9). A response was characterized as "affected" if the user answers yes to any of the questions regarding gas development: 1) Has shale gas activity at another location prompted you to use this location?; or 2) Has shale gas activity changed your recreational use of this state forest?; or 3) Has shale gas activity changed your experience on this state forest?

The proportion of visitors that indicated affected use and experience has dropped steadily since the beginning of the card's use in 2012 (Figures 6.34 and 6.35). In 2012, 24 percent of respondents indicated their *Use* was affected by gas activities; this decreased to only 12 percent in 2016 (Figure 6.34). A similar decrease can be seen from 2012-2016 (35 to 14 percent) when these data are filtered by visitors to core gas forest districts only (Figure 6.34, hatched area). The same trend of decreasing reported effects shows for visitor *Experience* (Figure 6.35). However, the decrease in percentage was not as marked (2012=26 percent; 2016=19 percent) as with recreation *Use* effects, suggesting that perhaps visitor *Experience* continues to be somewhat disrupted while *Use* effects have tapered off with decreasing activity and development (Figure 6.35). Again, a similar decrease is seen when these data are filtered by visitors to core gas forest districts only (Figure 6.35, hatched area; 37 to 23 percent).

Additionally, many respondents indicated they had not been affected by shale gas development, but still provided comment on gas activity. Responses for all written comments regarding shale gas development are summarized in Figure 6.36.

The most common recreational activity in which comment card respondents took part was hiking (Figure 6.37). The number of users that indicated they were affected (Use, Experience, or Location) by shale gas development varied across categories. For most categories, the percentages of users in each group that indicated an effect (right axis, line graph Figure 6.36) fell between 20 and 35%, with only ATV and horseback riders showing a lower percentage of users affected. These are not exhaustive surveys, but responses received via voluntary acquisition and submission of the cards.

Examining the proportion of respondents who indicated they were affected by gas activity shows a pattern of declining effect over time for both core gas forest districts and other forest districts (Figure 6.38). However, the percentage of users that indicated an effect is consistently much lower in the non-core gas forest districts, as is expected.

The average rating for each evaluation criterion from 2012-2016 was calculated separately according to whether the visitor was or was not affected by shale gas activity (Figure 6.39). In all nine categories, the average rating was lower in the respondents who were affected by gas development. When the data are filtered

Comment Cards: Recreation affected by shale gas development?	Year 2012	2013	2014	2015	2016	Grand Total
No	151	416	245	280	581	1673
Yes	61	130	45	25	167	428
Grand Total of Responses	212	546	290	305	748	2101
Percentage Affected	29%	24%	16%	8%	22%	20%

Table 6.9. Number of comment cards received each year and the number of responses that indicated gas development had affected their use, experience, or location of recreation on state forest land.

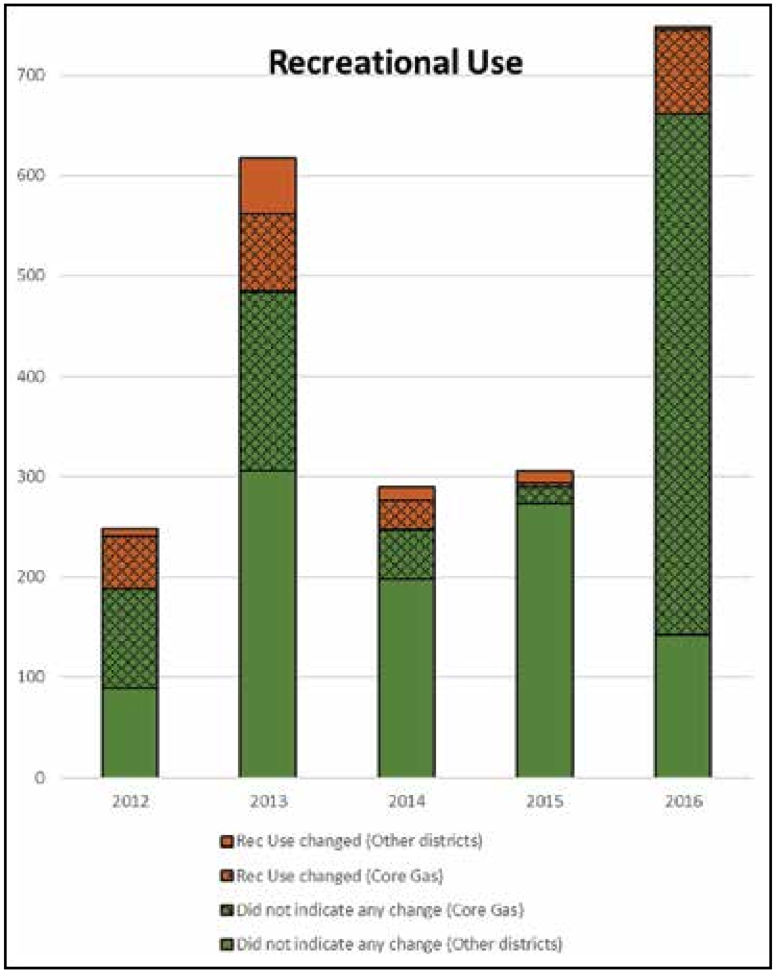


Figure 6.34. Number of comment card respondents that indicated their USE of state forest land was affected by shale gas activities by year for ALL FOREST DISTRICTS (solid bar) and for CORE GAS FOREST DISTRICTS (hatched bar).

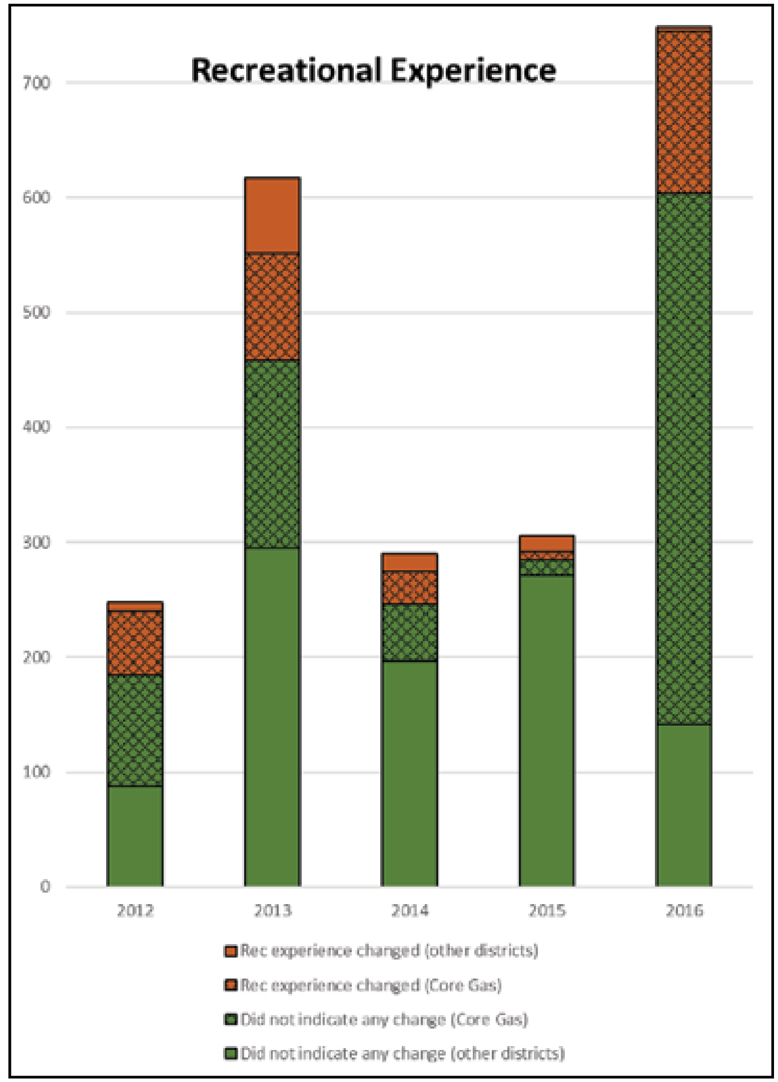


Figure 6.35. Number of comment card respondents that indicated their EXPERIENCE of state forest land was affected by gas activities by year for ALL FOREST DISTRICTS (solid bar) and for CORE GAS FOREST DISTRICTS (hatched bar).

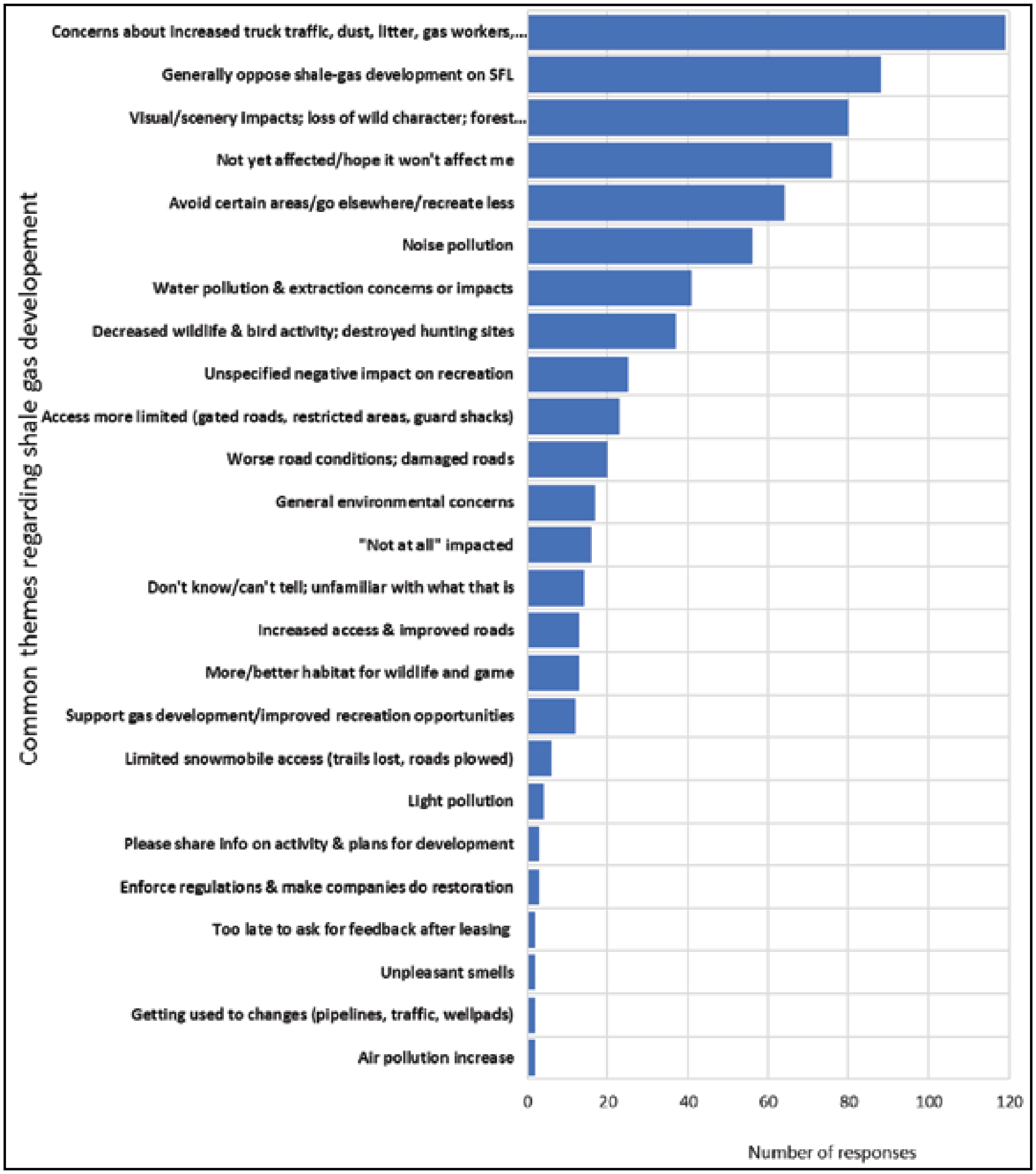


Figure 6.36. Summary of common and recurring themes of written remarks on comment cards regarding gas activities. Note: some cards may be counted in more than one category if the individual addressed several of themes on one card.

by core gas forest districts only, the discrepancy between those who indicated gas effects and those who did not is slightly more pronounced. On average, those affected gave ratings 6.9 percent lower than users who were not affected; in core gas forest districts, the average ratings were 9.2 percent lower than users who indicated no effect.

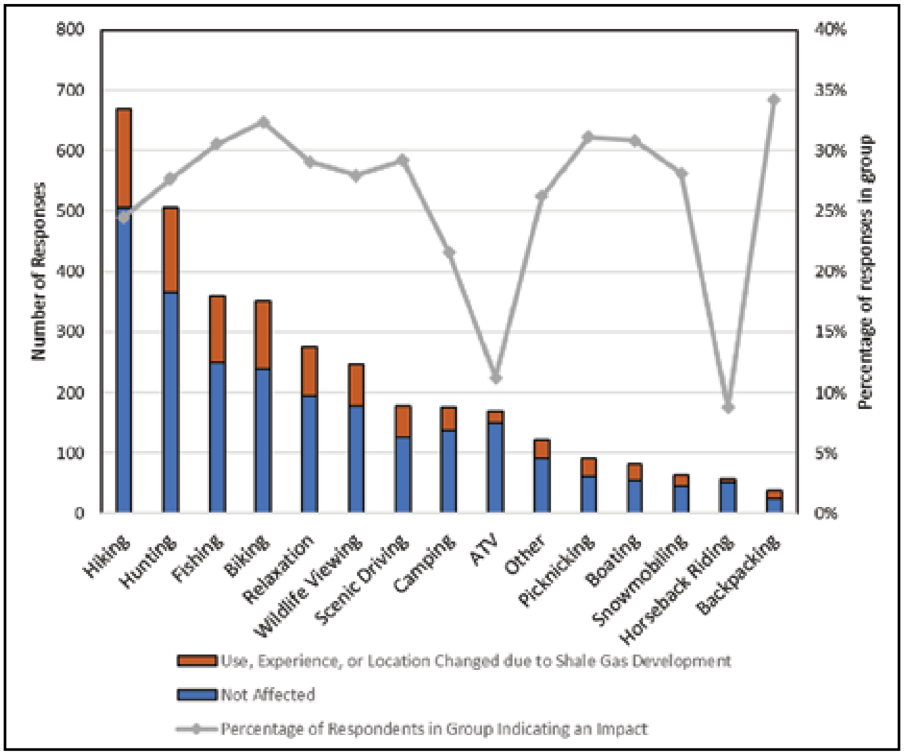


Figure 6.37. Number of comment card responses and percentage impacted by shale gas development on state forest land for each user group. Note that cards may be counted in more than on category if the user indicated more than one activity.

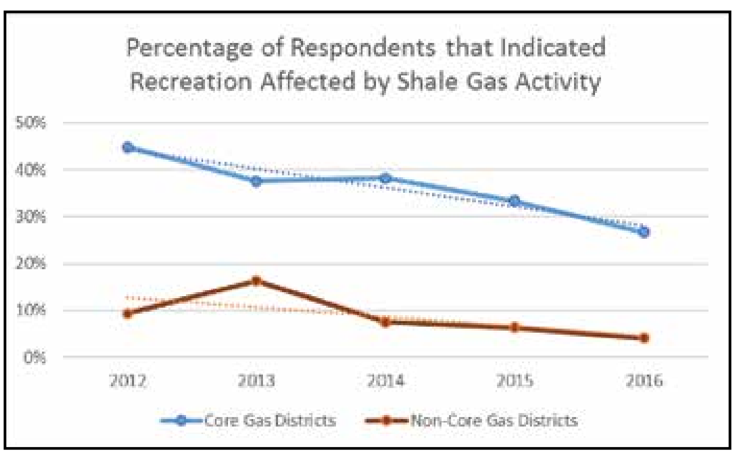


Figure 6.38. Percentage of respondents that indicated their recreation was affected by shale gas activity through time for core gas forest districts vs. other forest districts. Dotted line represents general linear trendline of percentage of respondents through time.

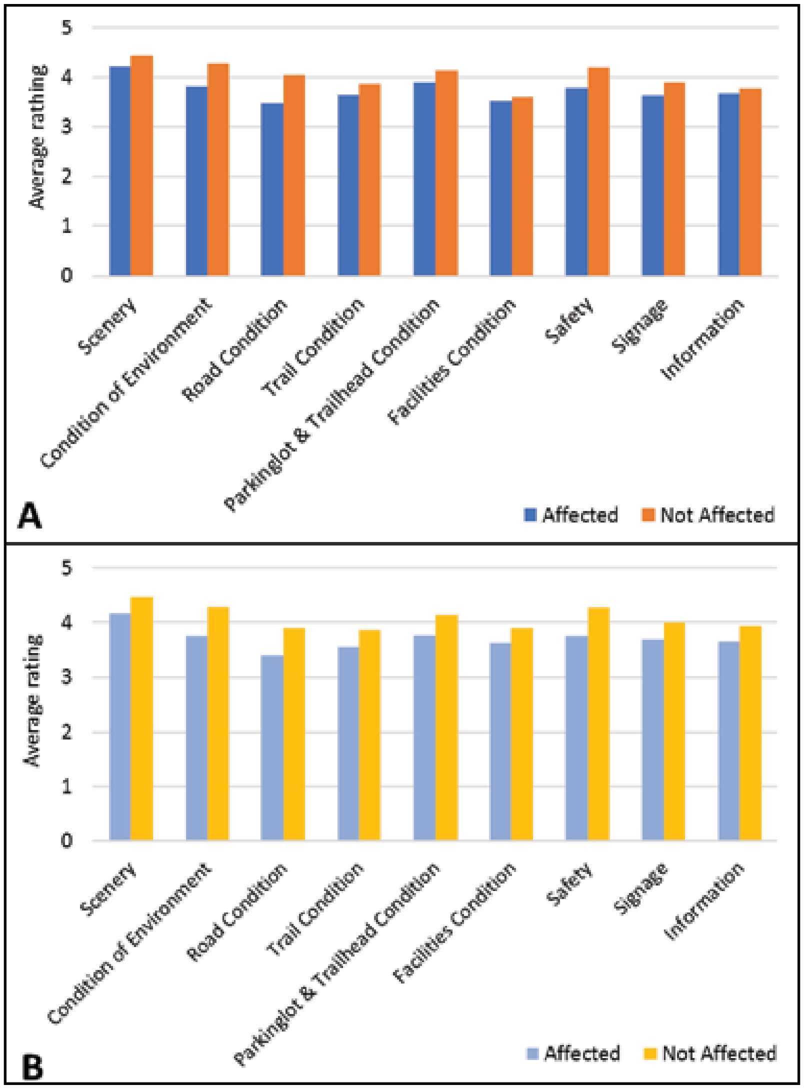


Figure 6.39. Bar graph of condition ratings by affected vs not affected

a) across all forest districts and

b) filtered by core gas forest districts only.

SFRMP Comments

As part of its 2016 revision of the State Forest Resource Management Plan (SFRMP) the bureau conducted several efforts to obtain public input and feedback. The SFRMP is the primary instrument that the bureau uses to plan, coordinate, and communicate its management of the state forest system.

2013 Online Survey

In 2013, the bureau conducted an online survey to gauge public sentiment about state forest management prior to embarking on revision of the SFRMP. The following results relate in some way to shale gas development.

The results of the question "How important to you are the following considerations in the management of state forest lands?" demonstrate that economic issues are thought to be the least important consideration in the management of state forest lands (Figure 6.40). Economic considerations might be inferred to include revenue from leasing for gas development or from timber harvesting operations.

Another question in the online survey asked users to rank the importance of different values on state forest land. From the responses in Figure 6.41, energy development was ranked as the least important value on state forest land by survey respondents.

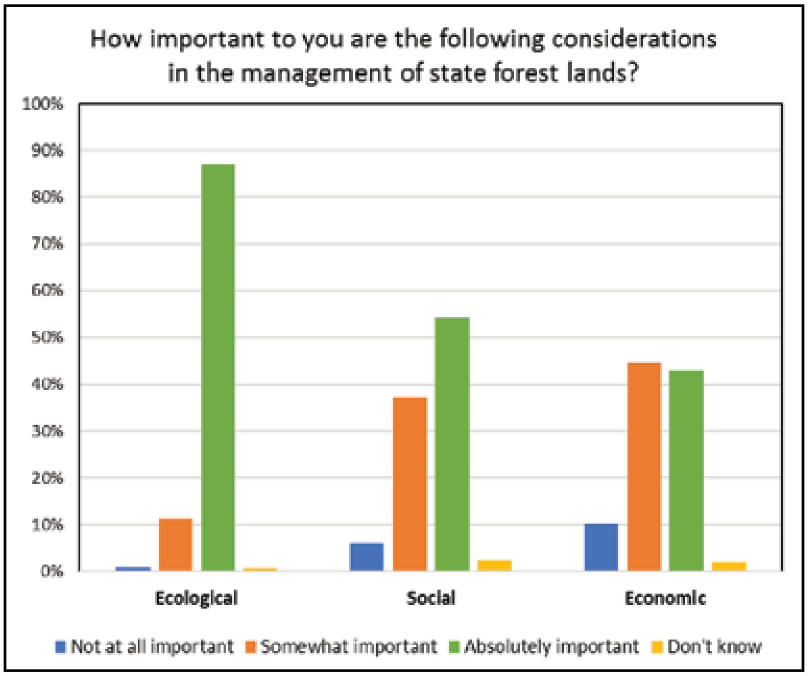


Figure 6.40. Results of survey question: "How important to you are the following considerations in management of state forest lands?". There were 3,228 responses to this question; 27 respondents skipped this question.

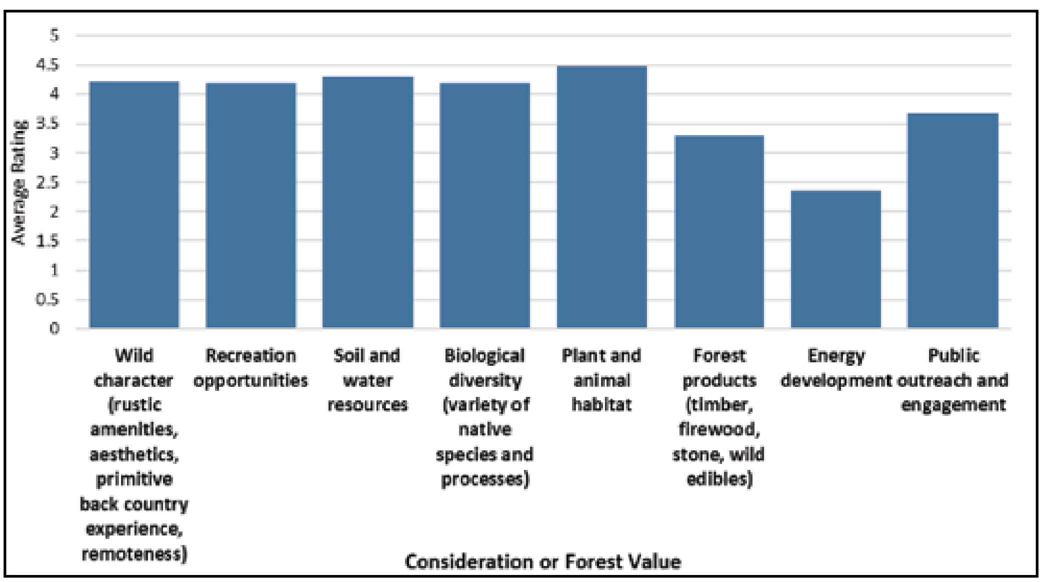


Figure 6.41. Results of survey question: "Rate the importance of each value on state forest land (1 is the least important and 5 is the most)." There were 3,241 responses to this question; 14 respondents skipped this question.

In response to the question, "How well are the following managed on state forest land?", most respondents said that energy development was managed neither poorly or well, poorly, or very poorly (Figure 6.42).

Although this survey was not designed to answer questions specifically about shale gas development, it is useful in gleaning relative importance, values, and perception held by state forest stakeholders and the general public. These responses may indicate that shale gas development may differ from traditional views of the use and purpose of state forests by the public. Follow-up questions would be needed to identify more in-depth trends, sentiments, and causal relationships.

2015-16 Public Comment Phase

In late 2015 and early 2016, the bureau held a public comment period on the draft SFRMP, in which feedback was submitted via public meetings, emails, letters, and an online survey. The bureau received many comments on shale gas development during the public comment phase. Gas development was the most frequently commented upon issue. A summary of the comments is provided below, which was posted to the bureau's website when the 2016 SFRMP was finalized. More information can be found on the bureau's **website**[2].

- Many people expressed concern over the effects of fragmentation, mainly due to gas development, but also related to other forms of development.
- The bureau had a large number of people and organizations provide comments that were generally against the development of natural gas on state forest land, citing various concerns, such as fragmentation, loss of wild character, and potential impacts on wildlife and water resources.
- The bureau also heard from a few individuals that supported gas development on state forest land.
- A number of people and organizations suggested that the Oil and Gas Lease Fund Act requires that all rents and royalties from oil and gas leases of commonwealth state forest land be placed in a special fund to be used exclusively for conservation, recreation, dams, and flood control.
- A large number of commenters called for the bureau to halt all drilling activities within state forests for companies who have violations.
- The bureau had a large number of comments expressing support for the Governor's Executive Order that placed a conditional moratorium on additional gas leasing in state forests. Many other commenters suggested that the bureau ban leasing entirely in the SFRMP.

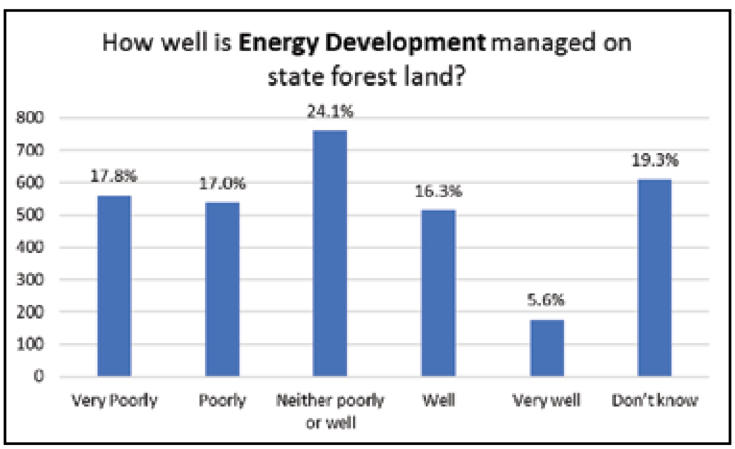


Figure 6.42. Results of survey question: "How well is energy development managed on state forest land?". There were 3,154 responses to this question; 56 respondents skipped this question.

- Several organizations and individuals requested more detail on how the bureau will evaluate decisions for new leasing or what the bureau should do before allowing new leasing.
- The bureau received a large number of comments asking us to prohibit drilling at the surface within the boundaries of state forests to minimize direct environmental impacts to these special places whenever possible.
- The bureau also received a large number of comments asking it to prohibit surface impacts where mineral rights are not owned by the commonwealth.
- A large number of commenters asked the bureau to make operators use horizontal drilling beneath severed rights land.
- The bureau received comments suggesting that there be training for DCNR staff by DEP on how to spot violations.
- The bureau heard a number of comments generally calling for it to assess the financial need of managing gas development.
- A number of commenters expressed concerns regarding the impacts of pipeline construction on state forest lands. Some of these comments came with recommendations for dealing with such impacts, such as co-location of pipelines
- Numerous commenters expressed questions or concerns about how the bureau is dealing with the existing impacts of gas development, such as what the buffers and restrictions are.
- A large number of commenters called for the bureau to require compressor stations to comply with noise limits and to shut them down if they fail to do so.
- Commenters also specified that the bureau should site compressor stations away from recreation sites.
- The bureau received a number of comments calling for the bureau to establish a contingency fund or escrow account to ensure the reclamation of lands affected by shale gas development.
- The bureau received multiple comments from individuals and organizations that were against potential development of Clarence Moore lands in Loyalsock State Forest.

Advisory Committees

The bureau and department coordinate many advisory committees to provide input and guidance on matters relevant to the agencies. Each of the advisory committees have been consulted on matters regarding shale gas development. Summaries of the committees and their activity related to shale gas development are provided below.

Natural Gas Advisory Committee

The Natural Gas Advisory Committee (NGAC) is a department-level committee comprised of members selected by the Secretary. NGAC advises DCNR on the environmentally sound extraction of gas resources. The Governor's Shale Gas Advisory Commission Report from July 22nd, 2011 recommended that "DCNR should establish a Natural Gas Advisory Committee to enhance communications among stakeholders regarding natural gas development on state forest and park land." (Recommendation 9.2.34). The report also recommends, "DEP and DCNR – along with industry – should continually review and examine the range of best management practices utilized during construction and operation of the well site, and consider incorporating these types of practices into regulatory and operator guidance…" (Recommendation 9.2.23). NGAC provides valuable insight and expertise concerning the complex nature of natural gas management. The stated purpose of NGAC is:

> The purpose of NGAC will be to advise and provide recommendations for implementing natural gas management in a manner which is consistent with the mission of DCNR and its bureaus. There are several program areas involved with implementing new strategies dealing with natural gas management in DCNR, notably the Bureaus of Forestry, State Parks, and Topographic and Geologic Survey.

The primary work of NGAC will focus on state forest lands and the work of the bureau, whose mission includes managing state forests under sound ecosystem management, to retain wild character, and to maintain biological diversity while providing pure water, opportunities for low density recreation, habitats for forest plants and animals, sustained yields of quality timber, and environmentally sound utilization of mineral resources. NGAC will provide recommendations for implementing the bureau's ecosystem management and resource sustainability approach to natural gas management.

The NGAC will work with DCNR to help identify natural gas management concepts and principles, and assist in integrating them into DCNR's natural gas management efforts on state forest and park lands.

Since its inception in the fall of 2013, the bureau has engaged NGAC regarding numerous topics, such as:

- the Bureau of Forestry Guidelines for Administering Oil and Gas Activity on State Forest Lands,
- the Bureau of Forestry shale gas monitoring program, including specifically the 2014 Shale-Gas Monitoring Report,
- the Bureau of Forestry State Forest Resource Management Plan,
- the Bureau of Topographic and Geologic Resources – Exploration and Development Well Information Network (EDWIN),
- Land and Water Conservation Fund and other grant-funded protected lands,
- compressor noise,
- non-surface disturbance leasing,
- air monitoring,
- site restoration,
- wastewater / produced water management, and
- pipelines.

Conservation and Natural Resources Advisory Council

The Conservation and Natural Resources Advisory Council (CNRAC) is the department's only legislatively mandated council, comprised of 18 members (six members each) appointed by the Senate, House, and Governor. The mission of CNRAC is:

To provide the Department of Conservation and Natural Resources, Governor, General Assembly, and public, advice regarding the conservation and stewardship of the commonwealth's natural resources.

CNRAC strives to be the foremost source of quality advice to the Department on sustaining the natural environment for all Pennsylvanians to enjoy and appreciate.

Ecosystem Management Advisory Committee

The Ecosystem Management Advisory Committee (EMAC) is a bureau-level committee comprised of members selected by the State Forester. The purpose of EMAC is to advise the bureau concerning its ecological approach to resource management. EMAC will work with the bureau to help identify ecosystem management concepts and principles, integrate these concepts into the updating of the state forest resource plans, and evaluate the implementation of these concepts and principles.

EMAC was engaged in 2010, at the start of the shale gas monitoring program, on what shale gas impacts might be and what monitoring priorities should be, both short-term and long-term. They have also provided feedback on various aspects of the monitoring program from time to time in the intervening years. EMAC was consulted on the 2016 revision of the State Forest Resource Management Plan, which included shale gas related goals and objectives, and on the establishment of Core Forest Focus Areas, which will prohibit conversion of forest land, such as by natural gas development.

Recreation Advisory Committee

The Recreation Advisory Committee (RAC) is a department-level committee comprised of members selected by the Secretary of DCNR. This committee provides valuable insight and expertise concerning the complex nature of large-scale natural resource-based recreation planning and management. The committee's input will be an important component in the recreation planning process used by the Bureaus of Forestry and State Parks. Other factors that are included in this process include the linkages between the publics' wants and needs, the Department's fiscal and physical limitations, legal mandates, and the capacity of ecosystems to tolerate human impacts. RAC will also review current and proposed operating guidelines and procedures. The stated purpose of RAC is:

> The purpose of RAC will be to advise the DCNR, Bureaus of Forestry and State Parks on natural resource-based recreation planning and management. The committee will also advise the Bureaus of Forestry and State Parks in planning, and implementation of their natural resource-based recreation operations and help identify recreational needs, opportunities, and directions that could be pursued.

RAC has been consulted on the follow topics related to shale gas development:

- the Bureau of Forestry shale gas monitoring program,
- the Bureau of Forestry State Forest Resource Management Plan,
- the Pipeline Infrastructure Task Force,
- activity on the Clarence Moore lands of Loyalsock State Forest, and
- Land and Water Conservation Fund conversion issues.

Silviculture and Timber Advisory Committee

The Silviculture and Timber Advisory Committee (STAC) is a bureau-level committee comprised of members selected by the State Forester. The stated purpose of STAC is:

> The purpose of STAC will be to advise the bureau on natural resource management related to silviculture and timber harvesting. The committee will also help identify silviculture and timber needs, opportunities, and directions for the bureau to pursue.

STAC has been consulted on road bonding issues regarding shared use of roads by timber and natural gas companies.

Pipeline Infrastructure Task Force

Led by the Secretary of DEP, the Pipeline Infrastructure Task Force (PITF) was formed in 2015 and tasked with developing polices, guidelines, and tools to assist in pipeline development (including planning, permitting, and construction) as well as long-term operation and maintenance. Bureau staff played an integral role in the PITF. The top recommendations of the PITF, delivered in a final report to the Governor in February 2016 were as follows:

- Establish early coordination with local landowners and lessors;
- Educate landowners on pipeline development issues;
- Train emergency responders;
- Enhance emergency response training for responder agencies;
- Minimize impacts of stream crossings;
- Use anti-degradation best available combination of technologies to protect exceptional value and high-quality waters;
- Ensure adequate staffing for reviewing pipeline infrastructure projects;
- Implement electronic permit submissions for Chapters 102 and 105;
- Expand PA1Call for all classes of pipelines;
- Identify barriers to sharing rights-of-way
- Attract military veterans to the energy workforce; and

- Enhance science, technology, engineering, and math (STEM) education.

Several of these recommendations have direct relevance to the bureau and to pipeline projects on state forest lands.

In addition, the Conservation and Natural Resources Workgroup of the PITF developed the following recommendations:

1. Communicate Pipeline Development Conservation Practices to the Public
2. Develop Public Access to Pipeline GIS Information
3. Use a Landscape Approach for Planning and Siting Right-of-Way Corridors
4. Give Special Consideration to Protected / Designated Lands in Pipeline Siting
5. Mitigate the Loss of Public Use of Public Lands Resulting from Pipeline Development
6. Avoid Geological Hazards During Planning
7. Implement Full-Time Environmental Inspections During Pipeline Construction
8. Monitor Water Quality During Construction
9. Implement Post-Construction Monitoring for an Appropriate Period
10. Tie Permitting Standards to the Duration of Impact
11. Implement a Mitigation Bank to Improve Water Quality
12. Reduce Forest Fragmentation in Pipeline Development
13. Promote Biodiversity in Pipeline Development
14. Develop Rare Species Work Windows to Avoid Impacts
15. Minimize Impacts to Riparian Areas at Stream Crossings
16. Promote Wildlife Habitat Opportunities Along Pipeline Corridors
17. Restore and Maintain a Boarder Zone in Forested Areas
18. Minimize Aesthetic Impacts in Pipeline Development
19. Minimize Recreational Impacts in Pipeline Development
20. Provide Recreational Opportunities in Pipeline Development
21. Reseed Rights-of-Way Using Native Plants
22. Use Pennsylvania-Sources Plant and Seed Vendors and Landscape Services
23. Require Performance-Based Metrics for Long Term Maintenance of Rights-of-Way
24. Prevent Invasive Plant Species Establishment
25. Finalize Functional Protocols for Impacts and Offsets
26. DEP Should Follow the 2008 Final Mitigation Rule for all Mitigation Sites

Many of these recommendations were based on the bureau's existing approach to pipeline management and others may be incorporated into that approach moving forward.

Bureau of Forestry Website

The bureau is committed to being transparent in its monitoring and providing access to monitoring related information. It was in this spirit the bureau created a Shale Gas Monitoring section of its public webpage. The webpage provided the 2014 Shale-Gas Monitoring Report, links to the raw data that were used in generating the 2014 Shale-Gas Monitoring Report, updates to sections of the report, lease tract summaries, and the interactive shale gas infrastructure map.

The website served as a mechanism for distributing information to stakeholders. Table 6.10 shows usage statics of the pages from 2013-2016. Several of the pages in the table were not created until the release of the 2014 Shale-Gas Monitoring Report in April of 2014, so statistics for those periods reflect a time-frame shorter than 4 years. The greatest volume of views occurred immediately following the release of the 2014 report.

The bureau will continue to utilize its webpage for the dissemination of information regarding shale gas monitoring.

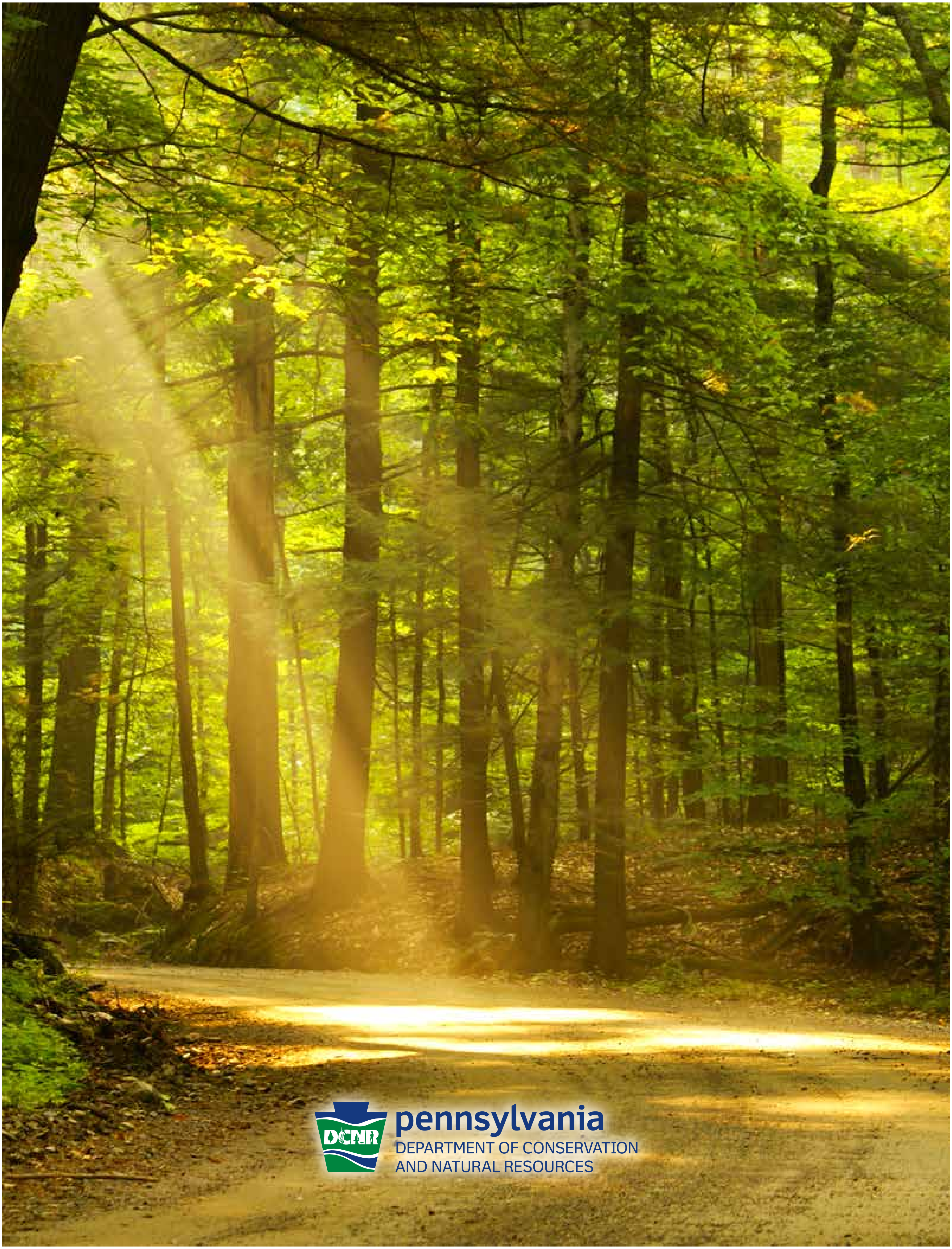
Page	Views	Unique Views	Average Time
Forestry Index	518,813	364,713	2:28
Natural Gas Index	16,145	10,058	1:33
Monitoring Report Index	4,388	2,919	2:17
Monitoring Data Files Index	1,043	507	0:46
Water	253	145	2:05
Infrastructure	155	116	1:46
Incidents	136	65	1:33
Air	123	68	1:07
Recreation	75	54	2:17
Flora	68	53	2:13
Soils	66	49	0:57
Forest Health	65	42	1:08
Forest Landscape	44	38	2:14
Timber	44	31	1:29

Table 6.10. Usage statistics for monitoring related pages on DCNR Bureau of Forestry webpage.

Website Links

[1] http://www.docs.dcnr.pa.gov/forestry/recreation/index.htm

[2] http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20032040.pdf


DCNR
pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES