Part 2: Monitoring Values »Infrastructure

I. Key Points:

- Approximately 1,486 acres of forest have been converted to facilitate gas development in the core gas districts, including roads, infrastructure, well pads, and pipelines.
- 161 total miles of road have been improved or constructed for shale-gas development in the core gas districts. Of these, 131 miles of state forest roads that existed prior to the shale-gas development have been improved or upgraded for gas development activities, and 30 miles of new roads have been constructed for gas development activities. This road work involved the conversion of approximately 242 acres of forest.
- 191 infrastructure pads have been constructed to facilitate shale-gas development in the core gas districts. This involved the conversion of approximately 786 acres of forest.
- 104 miles of pipeline corridor have been constructed or widened in the core gas districts. This involved the conversion of approximately 459 acres of forest.
- Six new bridges and six large culvert stream crossings have been either replaced or installed by gas companies in the core gas districts.
- 83 percent of all dust control activities on state forest lands related to shale-gas development have used non-potable water rather than chemical dust suppressants.
- Extensive amounts of heavy truck traffic have been reduced on state forest roads through the use of water transport systems.
- Waivers are typically granted to reduce overall impact to the forest. The most common lease-term waivers are related to buffers on wetlands and roads.

II. Introduction

State forest lands located within the shale-gas region are experiencing significant activity associated with the development of the shale-gas resource. Natural gas exploration and development can cause short-term or long-term conversion of existing natural habitats to gas infrastructure. The footprint of shale-gas infrastructure is a necessary part of shale-gas development; however, the bureau attempts to manage this infrastructure to reduce surface disturbance and minimize impacts to other state forest uses and values.

In addition, the existing transportation infrastructure on state forest lands, such as roads and bridges, is experiencing a considerable increase in use due to shale-gas development. The bureau strives to design and maintain its infrastructure to efficiently serve its intended purpose and ensure the safety of its staff and state forest users, while providing opportunities for quality outdoor experiences.

This chapter focuses on the infrastructure required for shale-gas development as well as the effect of shale-gas development on existing state forest roads. State forest infrastructure that is generally associated with recreation, such as hiking and ATV trails, is covered in greater detail in the Recreation section of this report.

Roads

The right of ingress and egress to private subsurface estates is provided for by law. This may include the right to construct new roads as necessary. Similarly, lessees are permitted to construct new roads to develop their leased lands. The bureau works with private subsurface owners and lessees to use existing roads whenever feasible, reducing the need for additional clearing and new road construction. The use of state forest roads by private subsurface operators is mandated by a road use agreement. A road use agreement is required for lessees using state forest roads outside of their lease boundaries. Road use agreements set limitations on road use and establish conditions for road improvements and maintenance. Some state forest districts have also successfully used road use agreements to coordinate the construction of recreational infrastructure, such as alternative snowmobile trails, where the operators have affected traditional recreational use of state forest roads and trails.

Most state forest roads are improved dirt roads surfaced with shale, gravel, or limestone and designed to accommodate travel by licensed motor vehicles at maximum speeds of 25 miles per hour. Historically, the majority of traffic on state forest roads has been attributed to the following:

- Recreational users of state forests in passenger vehicles
- Bureau personnel in light duty and occasional heavy duty vehicles for administration of state forest lands
- Bureau maintenance staff and equipment to maintain and rehabilitate roads
- Commercial timber operators utilizing tri-axle log trucks or tractor-trailers to haul timber purchased from the bureau to lumber mills (averaging two to four trips per day)

These types of traffic are considered the traditional uses of state forest roads, and the roads were constructed and are maintained to accommodate such uses.

On average over the past few years, the bureau has annually administered the construction of approximately 12 miles of new road and 100 miles of road improvements as part of its statewide timber management program. These timber haul roads are built to the specifications in the Silviculture Manual. This new construction is typically considered temporary in that the majority of these roads are retired at the conclusion of the timber sale operation. Roads that are improved as part of a timber sale include both public use roads and previously retired haul roads that are reopened. Improvements to these types of roads as part of a timber sale are implemented to bring the road condition up to the minimum standard necessary to accommodate the sale.

The minimum road standards required to facilitate shale-gas development on state forest land exceed the minimum requirements necessary to accommodate the traditional uses of state forest roads. Shale-gas development requires extensive truck traffic (hundreds of trips per day during periods of peak activity) by vehicles larger than those typically using state forest roads. As a result, existing roads that are utilized by the shale-gas industry must be upgraded to meet different standards. Commonly, the road's base material must be increased to accommodate frequent trips of heavier equipment, and road widths must be increased to accommodate wider trucks and two-lane travel. Similar road characteristics are necessary when new roads are constructed for this activity.

Although temporary in nature, the volume and frequency of shale-gas truck traffic is in stark contrast to the public's expectations and typical experiences on state forest lands. Heavy truck traffic increases social and environmental concerns related to noise, dust, access limitations, public safety, and user experience, as well as operational concerns associated with road conditions, maintenance, and rehabilitation. One primary attribute of the state forest roads being affected by shale-gas development is the "wild character" of the road. State forest roads, in general, have a traditionally rustic and aesthetically pleasing value and wild character. Scenic or pleasure driving is the largest motorized recreational use of state forest lands. Even when other recreational activities are the primary reason for forest visits, most of the visiting public appreciates and values what they see on their way to their ultimate destination. It is important that the wild character of state forest roads be preserved to the greatest extent possible during and following use by gas companies.

The bureau has adapted to this non-traditional forest road use by shale-gas operators by developing updated standards applying to road construction and road improvements for shale-gas development. Implementation of these new standards is required before use of state forest roads commences. This ensures that any road suitability issues are addressed prior to handling the increased truck traffic.

In addition, heavy-hauling restriction guidance has been given to gas operators to avoid conflict with traditional forest users. On days with heavy-hauling restrictions, operators are asked not to operate heavy-hauling trucks (e.g., water trucks, drill rigs) on state forest roads. The heavy-hauling restriction dates are adapted from year to year, but the general timeframes are found in Figure 2.1.

State Forest Heavy Hauling Restrictions

Holidays

- Memorial Day weekend
- Fourth of July holiday and weekend (if applicable)
- Labor Day weekend

Hunting and Fishing Seasons

- Opening weekend of trout season
- Opening weekend of youth spring gobbler season
- Opening weekend of regular spring gobbler season
- Regular bear season
- Portion of regular firearms deer season, including opening day

Heavy hauling and seismic activity may be restricted during the following dates at the discretion of the district forester:

- Seismic activity may be restricted during the morning hours of spring turkey season.
- Special activities or events on state forest or adjacent state park lands as identified by district. Restricted roads and hours of operation will be determined by the district.
- Opening day of deer archery season
- Opening day of youth/special use hunting
- Opening day of early muzzleloader season

Operators should be advised that the list of restricted dates has been minimized to the greatest extent possible and that potential visitor use conflict may be encountered beyond the specified dates.

The bureau will permit minor truck traffic between the hours of 10 p.m. and 4 a.m. for daily or essential needs only (e.g., cutting removal, drinking water delivery, sanitation, cement).

Figure 2.1

There are distinct benefits associated with the use of state forest infrastructure by shale-gas operators for their development operations. With regard to cost, it is of benefit to the bureau that the roads needed for gas operations are improved or constructed at the cost of the gas companies. Forest managers ensure that that these roads meet or will meet the standards needed by the bureau and forest users while also being suitable for the gas industry. In most cases, roads used by gas companies will not need large scale maintenance investments by the bureau for many years. This allows the bureau's limited road maintenance budget to be utilized on other roads.

Not only are roads improved, but also bridges and large culverts. These stream crossing improvements have also been completed by gas companies at no cost to the bureau. In some cases, crossings have been installed in areas where it may have been cost prohibitive for the bureau to otherwise provide access for traditional forest activities such as timber management and recreation. In such cases, construction by the gas companies has opened new areas for access by other forest users.

Another distinct benefit of working with the gas companies on infrastructure construction has been an increased knowledge of new technologies for infrastructure construction and maintenance. This new knowledge has and will continue to benefit the bureau through cost savings and durability improvements related to construction and maintenance techniques.

Well Pads

A well pad is the area where shale-gas well drilling and hydraulic fracturing occurs. A typical shale-gas well pad is approximately 3.5 to 7 acres. On state forest land, the number of wells per pad ranges from one to 10, with approximately four to eight wells being the average. A typical well drains approximately 100 acres, but that

figure can vary depending on a number of factors. Well pads are typically constructed of crushed limestone or other rock, compacted to form a stable operating surface. Modern drilling rigs weigh several thousand tons and require construction of a solid pad that can adequately support their weight and maneuverability needs.

Compressor Pads and Compression Systems

Compressor stations are commonly used in association with gas production and pipelines. Gas well pressures and volumes steadily decline over the life of production. Similarly, gas moving through steel pipelines creates friction, causing pressure loss. Compressor stations use turbines, motors, or engines powered by electricity, diesel fuel, or natural gas to increase the pressure of the gas within the pipelines to overcome friction and move the gas from one location to another. During production, compressors draw gas from the well bore as production volumes decrease and discharge it at higher pressure through the gathering pipeline. Secondary compression may be necessary, depending on the length of the gathering line, to increase pressure as the gas enters larger marketing or transmission lines.

The footprint of a compressor station is variable. Compressors are specifically engineered for a given compression need. Compressors are generally housed within a structure and under roof. These sites may also include gas-related infrastructure such as separators, which capture undesirable particles or liquids, that may condense out of the gas stream as it flows through the pipeline. Chemicals necessary to aid production during cold temperatures can also be stored at a compression site.

There are currently two strategies for providing the compression necessary for successful gas production:

- Distributed – The compressors are co-located on the established well pad and service all the producing wells within that pad. Distributed compressors are smaller, produce less horsepower, and are more numerous than those associated with centralized compression. The configuration is dynamic, and compression is moved and adjusted as necessary.
- Centralized – The compression is strategically located within the development field to service gas produced from multiple well pads and dozens of individual wells. Centralized compression often requires several large units that produce considerable horsepower. These facilities typically require the development of an additional pad site to accommodate the necessary infrastructure.

A negative aspect of gas compression is the noise created by the engines. Noise from compressors can dramatically affect a state forest user's recreational experience and generate conflict. The undeveloped wild character of state forests offers peace, solitude, and a feeling of remoteness for many users. Unlike compressors, most sources of potential noise on state forest land are temporary in nature. Thus, the continuous noise from compressor stations makes them predominantly incompatible with other state forest resources, uses, and values. As such, alternatives that avoid siting compressors on state forest lands are pursued where possible; however, a certain amount of compression will be necessary on state forest lands for efficient gas transportation and production. The bureau's objective is to maintain and perpetuate a visitor's anticipated recreational experience on state forest lands. Additional information regarding compressor noise and monitoring of compressor noise is presented in the Recreation section of this report.

Fresh Water Storage and Water Conveyance Systems

The water-intensive nature of shale-gas development requires extensive advance planning. DEP and corresponding interstate river basin commissions have jurisdictional responsibility for surface water resources and associated withdrawal requests. However, when the surface or groundwater withdrawal point is located within state forest lands and the commonwealth owns the surface and subsurface rights, the terms for

When reviewing requests for water acquisition, the bureau takes into consideration potential impacts to watersheds, headwater streams, wetlands, and adjacent ecological resources.

Whenever feasible, freshwater is moved from centralized storage facilities to the active location(s) via pipeline, significantly reducing heavy hauling, minimizing vehicular conflicts, and decreasing air and dust pollution. These pipelines may be above-ground or buried water pipeline networks, or a combination of both. When feasible, buried pipelines are installed to minimize additional earth disturbances by being co-located with existing gas pipelines, buried in the ditchline or vegetated berm, or trenched and buried beneath the running surface of the road.

accessing the water withdrawal site are set forth in the lease agreement. On the other hand, when the surface or groundwater withdrawal point is located within state forest lands and the commonwealth owns the surface rights and a private party owns the subsurface rights, the terms for accessing the water withdrawal site are customarily contained in a surface use agreement.

The development of a single shale-gas well requires an average of 5 million gallons of water for the completion process (i.e., hydraulic fracturing). This quantity of water must be readily available and in close proximity to the well site throughout this process. Centralized fresh water storage facilities and temporary pipelines for transporting water are preferred over the traditional method of housing multiple storage tanks on the well pad and filling them via truck. Centralized freshwater facilities reduce truck traffic and in some cases can decrease total acreage disturbed because an impoundment is not needed at each pad.

Typically, water needed for shale-gas development can be acquired through:

- Surface water withdrawals
- A third-party supplier who trucks the water on site
- Groundwater well withdrawals.

There are several options for water storage, depending on the specific needs of the project:

- Earthen impoundments – non-portable, open pits that may involve significant construction operations; typically five to 14 acres in size and can serve many well pads, thereby reducing the overall disturbance. Constructed dam breasts over 15 feet high must be permitted. These water impoundments are tracked as a type of pad by the bureau.
- PortaDams – semi-portable, above-ground impoundments consisting of heavy-duty liners on a steel framework; perimeter can be lined with hydraulic fracturing tanks for additional storage capacity; typically three to five acres in size and can serve multiple well pads.
- Above-ground storage tanks – semi-portable, bolted together, cylindrical tanks that are often set on concrete.

Other Types of Infrastructure and Pads

Other types of infrastructure are occasionally required to facilitate shale-gas development. These include storage pads, meter stations, valve stations, tap stations, and stone pits.

- Storage pads – facilities that provide for the temporary storage of equipment and stockpiling of materials used in the development of shale-gas infrastructure. Not to be confused with gas storage fields.
- Meter stations – facilities that measure the amount of natural gas being supplied by a given source to a gas transmission pipeline (receipt meter station) or the amount of natural gas being withdrawn from a gas transmission pipeline by a customer (sales meter station).
- Valve stations – facilities used to isolate a segment of the main pipeline on a gas transmission pipeline. These stations are typically located at distances of 15 to 50 miles along each line to limit the amount of pipeline that may need to be depressurized for tie-ins and maintenance. These facilities also aid in reducing the amount of gas that would be lost in the event of a pipeline break.
- Tap stations – facilities that direct gas from a gathering system to a transmission pipeline to other locations. These facilities typically have only pressure regulating equipment.
- Stone pits – facilities where stone is extracted to support shale-gas development activities.

For reporting, these types of infrastructure have been grouped together and referred to as "other" infrastructure pads.

Pipelines

The development of oil and gas resources requires pipelines for delivering the product to market. Moving produced gas from the well to the marketplace requires significant planning, engineering, and infrastructure development. Gathering pipelines move natural gas from multiple well pads to centralized marketing pipelines. Marketing pipelines flow to transmission pipelines, which transport large volumes of gas over long distances to distribution centers or storage facilities.

Existing pipeline infrastructure and capacity may be inadequate for current and anticipated gas production needs. When compared to other aspects of gas development, pipeline construction has the greatest potential to cause forest conversion and fragmentation due to the length and quantity of pipelines required. Therefore, careful pipeline planning occurs early in the development process to address production needs while minimizing impacts and implementing ecosystem management. Midstream pipelines accommodate multiple operators, thereby reducing additional right-of-way needs, costs, and unnecessary impacts and improving efficiency.

Lessees or subsurface owners have the right to construct pipelines to transport oil and gas produced on state forest land. To construct a pipeline on state forest lands, lessees must obtain a license for right-of-way. The bureau has developed a formal process to administer such requests. The bureau works with all operators to coordinate the location and establish the conditions for pipeline construction.

Infrastructure Approvals and Waivers

The bureau conducts an extensive review of all gas activities and infrastructure proposed by operators. To facilitate these reviews, the bureau is typically provided with the operator's unconstrained conceptual site plan as early in the development process as possible. The bureau then evaluates the plan for known areas of concern or potential conflicts and coordinates with the operator to develop an infrastructure layout that minimizes impacts to state forest land while facilitating efficient extraction of gas.

Bureau staff confirm that all approvals, permits, and review requirements have been satisfied for the proposed activity and provide final approval. Final approval letters are issued to lessees for all proposed infrastructure. Commencement of construction and installation of proposed infrastructure is authorized upon receipt of final approval from the bureau.

The recent *DCNR Oil and Gas Leases* and also the *Guidelines for Administering Oil and Gas Activity on State Forest Land* contain a number of provisions intended to prevent gas development operations from interfering with other state forest uses and values. For example, the recent vintage of leases prohibits well drilling and site clearing within the following distances from certain features:

- 200 feet from any building
- 200 feet from any stream or body of water
- 300 feet from any stream or body of water designated as exceptional value by DEP
- 300 feet from any trail or road
- 300 feet from the boundary line of leased premises
- 600 feet from the boundary line of a state park or a state forest Wild or Natural Area.

These restrictions are in place to minimize the impact of development when it occurs near valued resources. For instance, the buffer for streams helps prevent erosion and sedimentation impacts, and the buffer for trails and roads helps preserve the wild character of these travel corridors.

Any deviation from conditions specified in leases or agreements with the bureau requires an approved waiver.

The bureau grants waivers when the proposed deviation from lease terms is the most effective way to resolve conflicts between competing resource uses and values, minimizes overall impact to the forest, and is in the best interest of the commonwealth. The waiver process is a mechanism to resolve complex, on-the-ground resource management challenges and to monitor the effectiveness of management practices and guidelines. Each waiver request is reviewed on a case-by-case basis.

To request a waiver, the operator submits the following to the bureau:

- Identification of the specific lease term for which a waiver is sought
- Description of the proposed deviation
- Justification of the need to deviate from the identified lease term
- Identification of alternatives considered and investigated
- Any necessary mapping, including GIS data where applicable

The waiver request is reviewed by bureau staff to determine if it is sufficiently documented, justified, and consistent with local management objectives. Modifications to the project or additional alternatives may be suggested to the operator during this review process. Often a compromise can be reached that balances the objectives of the operator and the protection of high-value resources.

The state forester reviews the waiver request and provides an approval or denial. If it is determined that the requested waiver does not minimize overall impact to state forest resources, uses, or values and is not in the best interest of the commonwealth, the waiver request will be denied. Waiver approvals may be subject to additional conditions that require the operator to provide reasonable protection or mitigation measures.

Through 2012, the bureau approved 35 waivers of lease terms for well drilling and site clearing. The breakdown of waivers by type is shown in Table 2.1. The most commonly waived lease term was the buffer on wetlands. At times, the development plans for gas extraction necessitate impacts in the vicinity of wetlands. In such cases, the goal is to minimize impacts to the wetlands themselves and allow impacts in the wetland buffers only when absolutely necessary.

The justification for waiving wetland buffers was typically that doing so minimized impacts on the wetlands themselves. In several instances, wetlands occurred in previously disturbed areas (e.g., clear cut, strip mine), and these disturbed/low-quality wetlands were preferentially developed instead of impacting undisturbed forest. See the Flora chapter for more information about wetland buffer waivers.

Type of Waiver	Number of Waivers
Wetland Buffer	15
Road Buffer	9
Lease Boundary Buffer	5
Trail Buffer	2
Natural Area Buffer	1
Stream Buffer	0
Other	3

Table 2.1

The second most common waiver of lease terms was for buffers of existing roads. The justification for road waivers was typically that the waiver eliminated the need to construct a new access road, thereby reducing forest fragmentation.

Justification for other types of waivers of lease terms followed these same themes. Waivers were often granted to take advantage of existing disturbance. The decision to grant a waiver typically balanced one type of impact against another, such as allowing a lease boundary buffer to be encroached upon to maximize the distance from a water supply watershed. For pad placement, waivers were sometimes granted to minimize the number of pads necessary to drain the gas from a leased tract. Pad location was preferentially given to flat areas in order to limit the amount of cut and fill necessary and to reduce erosion risks.

Overall, the waiver of lease terms approval process is viewed as successful adaptation that gives operators access to gas resources while minimizing impacts to state forest resources, uses, and values. The waiver approval process is a collaborative effort in which the concerns of the operator and the bureau are all balanced to achieve an outcome that is in the best interest of the commonwealth.

III. Monitoring Efforts/Results

Several practices have been designed to monitor the development of new shale-gas infrastructure and the impacts on existing state forest infrastructure:

- Spatial data assessment – GIS analysis of data collected on the construction of shale-gas infrastructure and the effects on the state forest road system
- Infrastructure and recreation field visits – a periodic review of issues, new methods, products, and benefits of shale-gas development with district personnel and the bureau's infrastructure monitoring specialist
- Forest road survey - designed to monitor the structural and material aspects of forest roads that are newly constructed or improved for utilization by shale-gas development
- Road shutdown, reroute, and general traffic control monitoring – within each of the core shale-gas districts
- Bridge and crossing inspection – the evaluation and entry into the bureau bridge inspection database of new and replacement bridges and culverts greater than 36 inches
- Dust control notification - implementation of the dust control notification form and database for all chemical dust control applications for state forest roads

Each of these monitoring efforts is discussed in greater detail in the sections that follow.

Spatial Data Assessment

The bureau monitors the state forest and shale-gas infrastructure spatially, through the use of GPS and GIS systems, and in tabular form through numerous database applications. This spatial data comes from both submittals by the gas companies and data gathered by bureau field staff. The analysis that follows provides a spatial assessment of the state forest road system, as affected by shale-gas development, and the infrastructure constructed specifically for shale-gas development.

Roads

An inventory of state forest roads has been used since the late 1960s in the form of straight-line diagrams. These documents describe the road condition, length, width, materials, and drainage infrastructure. Over time, as technology has advanced, so has the bureau's methodology for inventorying and monitoring road infrastructure. Presently, the bureau incorporates the use of GIS technology as the primary data capturing and analysis tool.

The linear distance of new road construction and existing road miles that were widened to facilitate gas development can be expressed in acres by estimating the final right-of-way width that will be maintained in a non-forested condition. It is estimated that approximately 242 acres of forest were cleared to construct new roads and widen existing roads (Table 2.3). Final right-of-way (ROW) widths that will be maintained in a non-forested condition for some roads have not yet been determined, and some of this acreage could be returned to a forested condition over time.

In the core gas state forest districts, a total of 161 miles of roads have been constructed or modified to facilitate shale-gas development (see Table 2.2). The Tiadaghton State Forest has seen the greatest mileage of new road construction and existing road modifications to accommodate this activity (see Figure 2.2).

State Forest District	Miles of New Road Construction	Miles of Existing Road Modified	Total
Moshannon	4.7	11.5	16.2
Sproul	4.0	39.1	43.1
Tiadaghton	13.5	44.4	57.9
Elk	0.3	0.0	0.3
Susquehannock	0.1	8.3	8.4
Tioga	6.0	15.8	21.8
Loyalsock	1.6	11.8	13.4
Total	**30.2**	**130.9**	**161.1**

Table 2.2 Miles of road construction and modification for 2008-2012 by state forest in the core gas region.

Overall, the increase in road miles on developed tracts resulting from new construction to support shale-gas activities ranged from 0.1 percent in the Susquehannock State Forest to 9.7 percent in the Tiadaghton State Forest (see Figure 2.3).

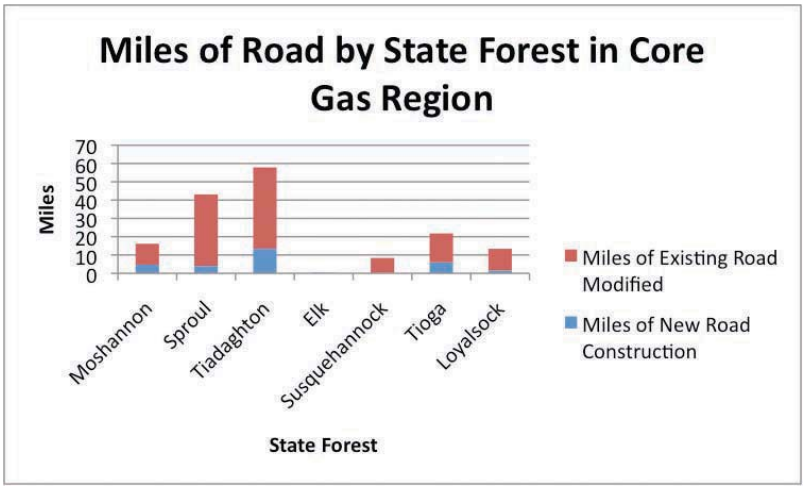


Figure 2.2 Miles of road construction and modification for 2008-2012 by state forest in the core gas forest districts.

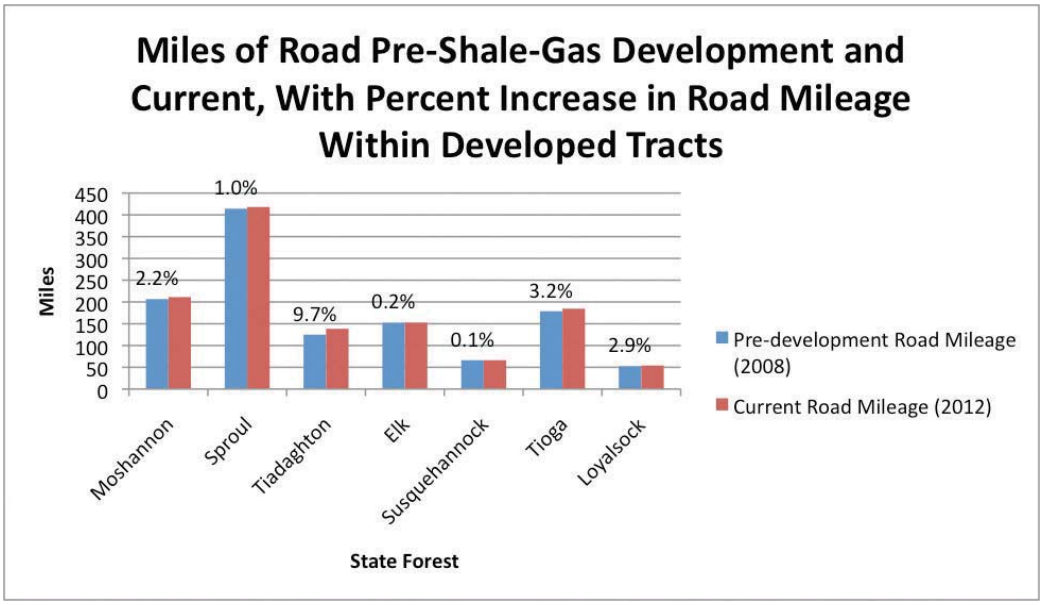


Figure 2.3 Percent increase in total district road mileage on developed tracts attributed to gas development from 2008 to 2012.

State Forest District	Acres Converted to Road ROW
Moshannon	31.7
Sproul	20.8
Tiadaghton	68.1
Elk	1.2
Susquehannock	4.1
Tioga	47.5
Loyalsock	68.2
Total	**241.6**

Table 2.3 Acres converted from forest to road ROW from 2008 to 2012.

The density of roads can be expressed as an average of the miles of roads in relation to the area of each state forest tract. As would be expected, given the mileage data presented above, an increase in road density has also resulted between pre-development (2008) and 2012 (Table 2.4).

Each state forest in the core gas region has experienced an increase in road density (Figure 2.4). The greatest percentage change in road density has occurred on the Tiadaghton State Forest, followed by the Tioga State Forest.

State Forest District	Pre-Development Average Tract Road Density (miles/square mile)	Current (2012) Average Tract Road Density (miles/square mile)	Change in Road Density (miles/square mile)	Percent Change in Road Density
Moshannon	1.8	2.0	0.2	9.5
Sproul	1.0	1.1	0.1	12.7
Tiadaghton	1.0	1.5	0.4	38.9
Elk	0.9	0.9	0.0	2.7
Susquehannock	1.2	1.2	0.1	7.5
Tioga	1.1	1.3	0.2	21.0
Loyalsock	0.7	0.8	0.1	19.1

Table 2.4 Road density on tracts with shale-gas development from 2008 to 2012.

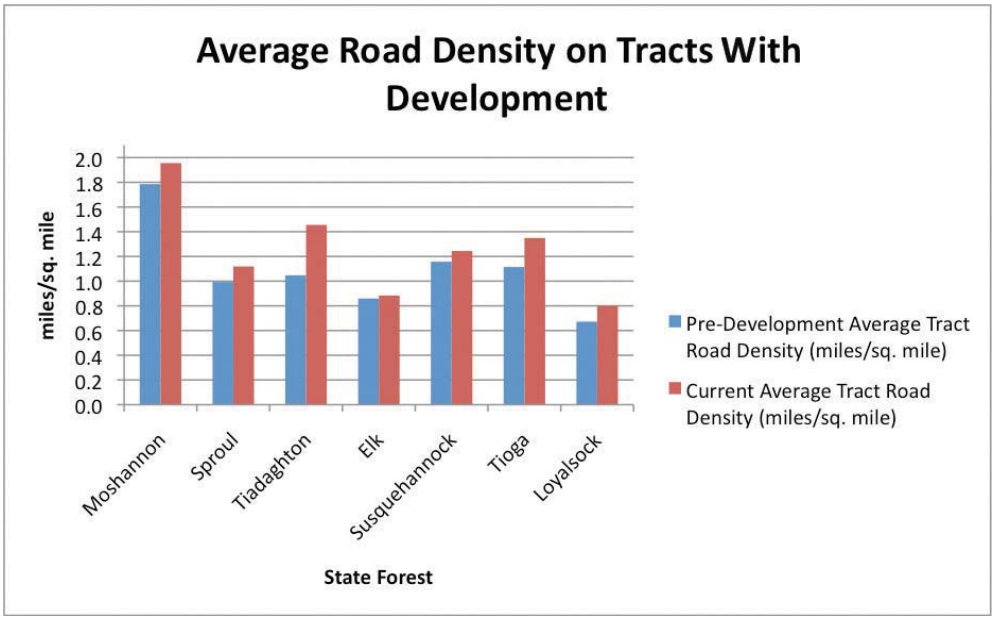


Figure 2.4 Average road density on tracts with development from 2008 to 2012.

Pads

The term "pad" is used to reference infrastructure sites that include well pads, compressor stations, freshwater impoundments, storage pads, stone pits, and meter, valve, or tap stations. Associated with each pad is a limit of clearance (LOC). The LOC is a bureau designation that is negotiated between the district and gas company where actual removal of predominant vegetation cover – including overstory, midcanopy, or understory vegetation, and/or original soil substrate – will occur. The LOC includes the as-built operational area of the infrastructure plus the area that was cleared around it to facilitate the construction of that infrastructure.

In the core gas state forest districts, there are a total of 191 infrastructure pads (all types) covering approximately 786 acres and requiring a limit of clearance of approximately 1,087 acres (see Table 2.5).

State Forest District	Number of Infrastructure Pads	Actual Pad Acres	LOC Acres
Moshannon	12	63.3	96.7
Sproul	42	156.5	196.0
Tiadaghton	69	318.3	389.2
Elk	4	6.5	19.3
Susquehannock	11	32.2	37.3
Tioga	39	135.7	252.6
Loyalsock	14	73.1	95.6
Total	**191**	**785.6**	**1,086.7**

Table 2.5 Number and acreage of all infrastructure pads by state forest district from 2008 to 2012.

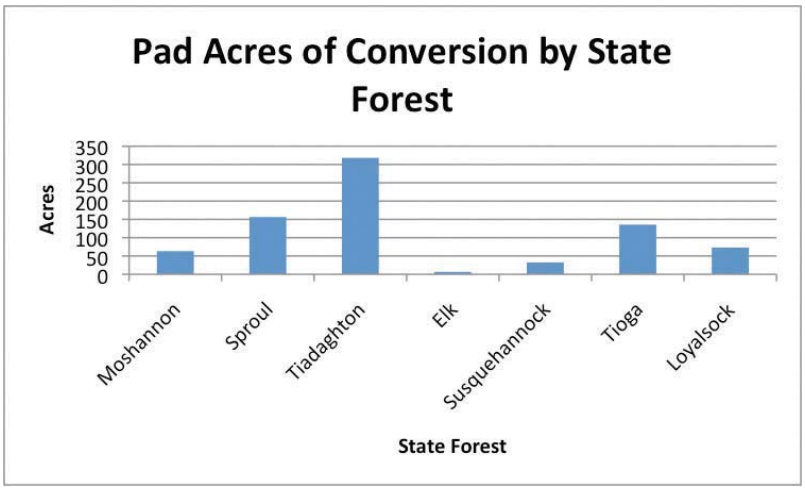


Figure 2.5 Acres converted to infrastructure pads by state forest district from 2008 to 2012.

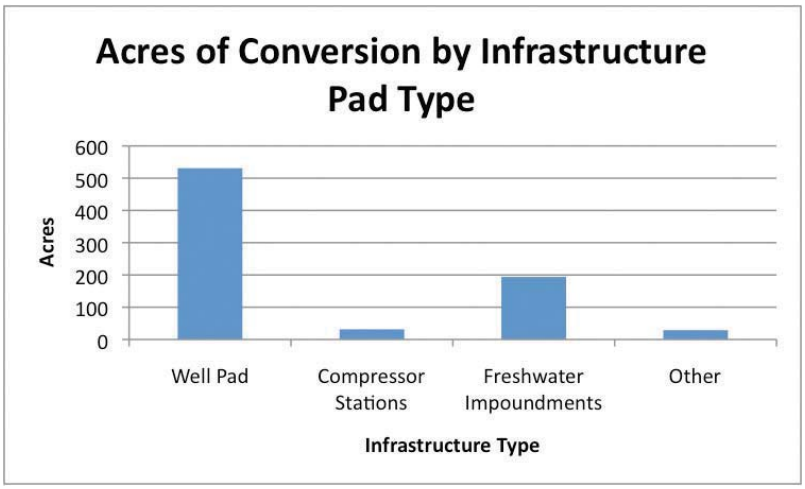


Figure 2.6 Acres converted by infrastructure type from 2008 to 2012.

State Forest District	Number of Well Pads	Well Pad Acres	LOC Acres
Moshannon	11	47.6	85.9
Sproul	35	115.9	150.8
Tiadaghton	51	189.2	235.3
Elk	4	6.5	19.3
Susquehannock	5	20.8	22.0
Tioga	27	103.1	193.3
Loyalsock	10	47.9	66.4
Total	**143**	**531.1**	**773**

Table 2.6 Number and acreage of well pads by state forest district from 2008 to 2012.

The Tiadaghton State Forest has the greatest number of pads and the greatest number of acres converted to infrastructure pads (Figure 2.5).

Figure 2.6 shows that the majority of acres converted were for well pad infrastructure (531), followed by freshwater impoundments (194). A synopsis of impacts related to each pad type is provided in the paragraphs and tables below.

In the core gas state forest districts, there are 143 individual gas well pads covering approximately 531 acres and requiring a limit of clearance of approximately 773 acres (see Table 2.6). The well pad acreage presented is the as-built footprint of the operational areas of the well pads. The Tiadaghton State Forest has the greatest number of well pads and acres converted to this infrastructure.

In the core gas state forest districts, there are nine individual compressor pads covering approximately 32 acres and requiring a limit of clearance of approximately 40 acres (see Table 2.7). The compressor pad acreage presented is the as-built footprint of the operational areas of the compressor stations. The Tiadaghton and Tioga state forests have the greatest number of compressor pads, but the Loyalsock State Forest has the greatest number of acres converted to this infrastructure.

State Forest District	Number of Compressor Pads	Compressor Pad Acres	LOC Acres
Sproul	1	1.7	2.6
Tiadaghton	3	5.7	6.1
Susquehannock	1	0.03	1.0
Tioga	3	9.4	15.0
Loyalsock	1	15.0	15.0
Total	**9**	**31.7**	**39.5**

Table 2.7 Number and acreage of compressor pads by state forest district from 2008 to 2012.

In the core gas state forest districts, there are 26 freshwater impoundment pads covering approximately 194 acres and requiring a limit of clearance of approximately 229 acres (see Table 2.8). The freshwater impoundment acreage is the as-built footprint of the operational areas of the impoundments. The Tiadaghton State Forest has the greatest number of freshwater impoundments and the greatest number of acres converted to this infrastructure.

Approximately 70 percent of the impoundments on state forest lands employ a freshwater conveyance system to pump water from a surface water source to the impoundment. This has led to a significant reduction in the amount of trucks using the state forest road system. As a result, this has alleviated some of the forest visitor concerns related to the frequency of encountering trucks on state forest roads, the amount of dust and noise, and the overall condition of state forest roads. Table 2.9 provides data from Pennsylvania General Energy and Anadarko Petroleum Corporation regarding the benefits of using water conveyance systems over the use of conventional trucking in Tiadaghton State Forest.

State Forest District	Number of Freshwater Impoundments	Freshwater Impoundment Acres	LOC Acres
Moshannon	1	15.6	15.6
Sproul	3	36.7	40.4
Tiadaghton	12	108.4	133.6
Susquehannock	3	9.0	10.7
Tioga	5	17.5	29.7
Loyalsock	2	6.5	6.5
Total	**26**	**193.8**	**229.1**

Table 2.8 Number and acreage of freshwater impoundments by state forest from 2008 to 2012.

Operator	Million Gallons Pumped in 2012	Truck Round Trips Eliminated Due to Pumping in 2012
Pennsylvania General Energy	190.9	41,300
Anadarko Petroleum Corporation*	100.8	22,000

Table 2.9 Statistics on water use and truck trips saved due to the use of water conveyance systems. Data provided by operators.

*Anadarko utilized its water conveyance system for both commonwealth and private land development. The data presented cover both.

State Forest District	Number of Other Infrastructure	Other Infrastructure Acres	LOC Acres
Moshannon	0	0.0	2.7
Sproul	3	2.2	2.2
Tiadaghton	3	14.9	14.9
Susquehannock	2	2.4	3.6
Tioga	4	5.7	14.6
Loyalsock	1	3.8	8.5
Total	**13**	**29.0**	**45.7**

Table 2.10 Number and acreage of other infrastructure pads by state forest district from 2008 to 2012.

In the core shale-gas state forest districts, there are 13 other types of infrastructure pads covering approximately 29 acres and requiring a limit of clearance of approximately 46 acres (see Table 2.10). The other infrastructure acreage is the as-built footprint of the operational areas of the other types of infrastructure. The Tioga State Forest has the greatest number of these types of pads, but the Tiadaghton State Forest has the greatest number of acres converted to these types of infrastructure.

Throughout the state forest system, primary land use and land capability are dictated by the bureau's management zoning designations. Management practices are applied to these zones to protect and enhance the values for which the land was zoned. The different land management zones are described below.

- Multiple Resource Management Zone is the least restrictive management zone and applies to areas managed for many resources, such as timber, water, recreation, fauna, flora, and minerals.
- Aesthetic/Buffer Management Zone applies to areas where connectivity, aesthetics, and water quality conservation are the primary values. These areas are associated with linear features such as roads, trails, and streams, or encompass a significant feature of state forest land.
- Limited Resource Management Zone is applied to areas where management alternatives are limited due to site quality or topographic constraints. Recreation, aesthetics, water, and soil protection are the primary values.
- Natural Area Management Zone applies to areas that have been designated as or are pending designation as State Forest Natural Areas. Natural areas are defined as areas of unique scenic, historic, geologic, or ecological value, that will be maintained in a natural condition, usually without direct human intervention.
- Wild Area Management Zone applies to areas that have been designated or are pending designation as State Forest Wild Areas. Wild areas are defined as extensive areas that the general public will be permitted to see, use, and enjoy through such activities as hiking, hunting, fishing, and the pursuit of peace and solitude. No development of a permanent nature will be permitted so as to retain the undeveloped character of the area and conserve ecological resources.
- Special Resource Management Zone applies to areas that will be managed for specific values, such as public wild plant sanctuaries, special wildlife management areas, certain recreation sites, vistas, and reservoirs.
- Anthropogenic Site Management Zone applies to human-made structures or facilities such as roads, ROWs, mineral sites, tower sites, buildings, and so forth. The primary value for this zone is human amenities.

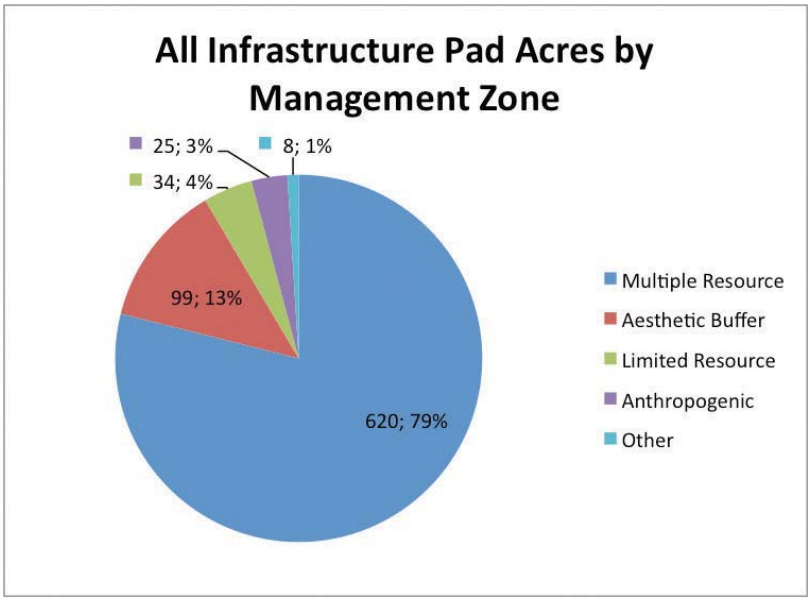


Figure 2.7 Acres converted to infrastructure pads by management zone from 2008 to 2012.

The pie chart above (Figure 2.7) shows the impact of infrastructure pads by management zone. The majority of acres (620) converted to support shale-gas infrastructure are in the Multiple Resource Management Zone designation. It should be noted that no pad infrastructure has been allowed in the Natural Area and Wild Area management zones, as surface development is incompatible with these zones. To the extent possible, impacts to the Aesthetic/Buffer Management Zone have been minimized, but occasionally infrastructure is sited in such zones to take advantage of proximity to existing road corridors and thus limit new forest clearing.

Pipelines

In the core gas forest districts, approximately 104 miles of pipeline corridor have been constructed as a result of shale-gas development. Twenty-one miles of these corridors are coincident with previously existing pipeline corridors. Co-locating pipelines was done to utilize existing corridors rather than create new corridors. This has resulted in a total of 843 miles of pipeline corridor within the gas state forest districts. Approximately 760 miles of pipeline corridor existed prior to the commencement of shale-gas development. These pre-existing corridors are covered by right-of-way agreements. Sproul State Forest has the greatest number of miles of pipeline corridor, with approximately 215 miles, and the Moshannon and Susquehannock state forests following closely behind, with approximately 191 miles and 177 miles respectively (see Table 2.11 and Figure 2.8).

State Forest District	Pipeline Corridor Type		Miles of Shale-Gas Lease ROWs Coincident with Existing ROWs	Total
	Existing	Shale-Gas Lease		
Moshannon	188.5	5.9	3.6	190.8
Sproul	207.3	14.5	7.0	214.7
Tiadaghton	25.4	52.4	7.1	70.7
Elk	110.8	2.0	0.0	112.9
Susquehannock	173.7	3.9	0.2	177.4
Tioga	44.7	18.5	2.7	60.5
Loyalsock	9.2	6.5	0.0	15.6
Total	**759.5**	**103.7**	**20.6**	**842.7**

Table 2.11 Miles of pipeline corridor by type, 2012.

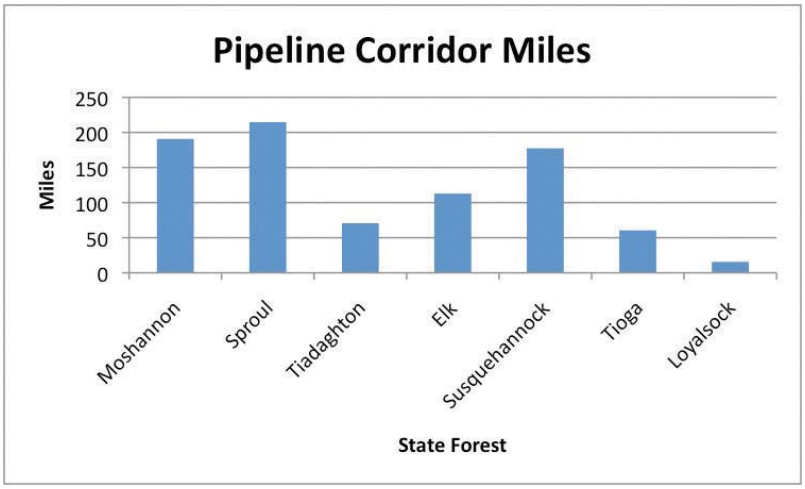


Figure 2.8 Miles of pipeline corridor by state forest district 2012.

The linear distance of new pipeline construction and existing pipeline miles that were widened to facilitate gas development can be expressed in acres by estimating the final ROW width that will be maintained in a non-forested condition. It is estimated that approximately 459 acres of forest have been cleared to construct new pipelines and widen existing pipelines (Table 2.12). Final ROW widths that will be maintained in a non-forested condition for some pipelines have not yet been determined, and some of this acreage could be returned to a forested condition over time.

State Forest District	Acres Converted to Pipeline ROW
Moshannon	39.2
Sproul	78.2
Tiadaghton	144.2
Elk	9.1
Susquehannock	29.4
Tioga	94.4
Loyalsock	64.3
Total	**458.8**

Table 2.12 Acres converted from forest to pipeline ROW from 2008 to 2012.

The density of pipeline corridor can be expressed as an average of the miles of pipeline corridor in relation to the area of each state forest district. Table 2.13 shows the density of existing and shale-gas lease pipeline corridor types for each state forest district. The Moshannon State Forest has the highest density of existing pipeline corridors, with approximately 0.6 miles of pipeline corridor per square mile, and the Tiadaghton State Forest has the highest density of shale-gas lease pipeline corridors, with 0.23 miles per square mile.

Pipeline corridors at times must cross streams. Pipeline crossings represent a potentially significant impact on streams and rivers in state forests. Pipeline crossings are typically constructed by an open-cut trench across the stream or by horizontal directional drilling (HDD) beneath the stream. The open-cut trench represents a direct impact on the riparian vegetation, stream bed, and water. The HDD can affect riparian vegetation, depending on the details of the operation, and can affect nearby water bodies through an inadvertent return – a release of high-pressure drilling mud outside the drilling hole. Following construction, riparian areas must be revegetated (at least with herbaceous vegetation), which may have varying degrees of success, leading to potential erosion and sedimentation control issues. The number of stream crossings and the DEP Chapter 93 stream designations for lease agreement crossings are found in Table 2.14 and Figure 2.9. A total of 35 lease agreement pipeline corridor stream crossings occur in the core gas districts, with the highest number occurring in the Tioga State Forest. A protocol has been developed to examine the condition of pipeline stream crossings, and it is presented in the Water chapter of this report.

State Forest District	Pipeline Corridor Type		Total Density
	Existing	Shale-Gas Lease	
Moshannon	0.6	0.02	0.6
Sproul	0.4	0.03	0.4
Tiadaghton	0.3	0.23	0.3
Elk	0.4	0.01	0.4
Susquehannock	0.4	0.01	0.4
Tioga	0.2	0.07	0.2
Loyalsock	0.1	0.04	0.1
Total Avg. Density (mi./sq. mi.)	**0.3**	**0.1**	**0.4**

Table 2.13 Density of pipeline corridors per square mile by state forest district 2012.

State Forest District	Stream Classification				Total
	EV	HQ	CWF	Not Classified	
Moshannon		2			**2**
Sproul		1	2		**3**
Tiadaghton	1	7			**8**
Susquehannock		2			**2**
Tioga			16	1	**17**
Loyalsock	1	2			**3**
Total	**2**	**14**	**18**	**1**	**35**

Table 2.14 Number of stream crossing by DEP Chapter 93 stream classification from 2008 to 2012.
EV = Exceptional Value, HQ = High Quality, and CWF = Cold Water Fishes

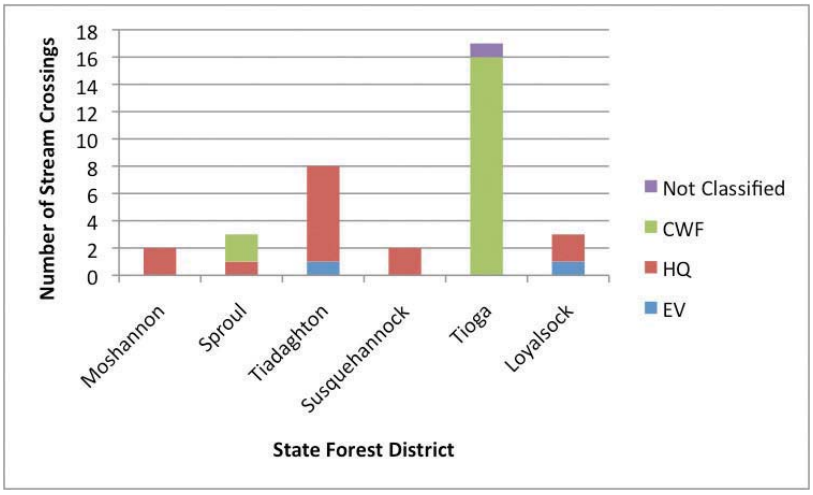


Figure 2.9 Number of stream crossings by DEP Chapter 93 stream classification from 2008 to 2012.
EV = Exceptional Value, HQ = High Quality, and CWF = Cold Water Fishes

Extracted gas must be transported from well pads through gathering pipelines to connect with marketing pipelines that lead to storage or distribution centers. Gathering pipelines are constructed to reach marketing pipelines in the most efficient and ecologically sensitive way possible. Many pipelines follow existing road or ROW corridors to minimize forest conversion. In most cases, this results in pipelines that follow gentle slopes. However, there are times when the most efficient method is to cross a mountain ridge perpendicular to the slope. This results in pipeline segments that fall on relatively steep slopes. Slopes of the lease agreement pipeline corridors for the core gas districts are found in Table 2.15 and Figure 2.10. The majority of pipeline corridors on lease agreements are on slopes less than 20 percent. However, there are approximately three miles of pipeline that were constructed on slopes in excess of 20 percent. Gas companies are required to install erosion and sedimentation control measures for all pipeline construction, but particular attention is paid to these measures when building on steep slopes. The effectiveness of erosion and sediment control practices is monitored by both DEP and bureau gas foresters on a regular basis.

State Forest District	Slope Category						Total
	0 to 10%	11 to 20%	21 to 30%	31 to 40%	41 to 50%	> 50%	
Moshannon	5.70	0.23					**5.9**
Sproul	13.59	0.84	0.02	0.07			**14.5**
Tiadaghton	47.32	3.21	0.86	0.37	0.40	0.23	**52.4**
Elk	2.00	0.01					**2.0**
Susquehannock	2.52	0.95	0.30		0.10		**3.9**
Tioga	17.56	0.80	0.09	0.10			**18.5**
Loyalsock	4.24	1.43	0.46	0.25	0.04	0.05	**6.5**
Total	**92.9**	**7.5**	**1.7**	**0.8**	**0.5**	**0.3**	**104**

Table 2.15 Miles of lease agreement pipeline corridor by slope class and state forest from 2008 to 2012.

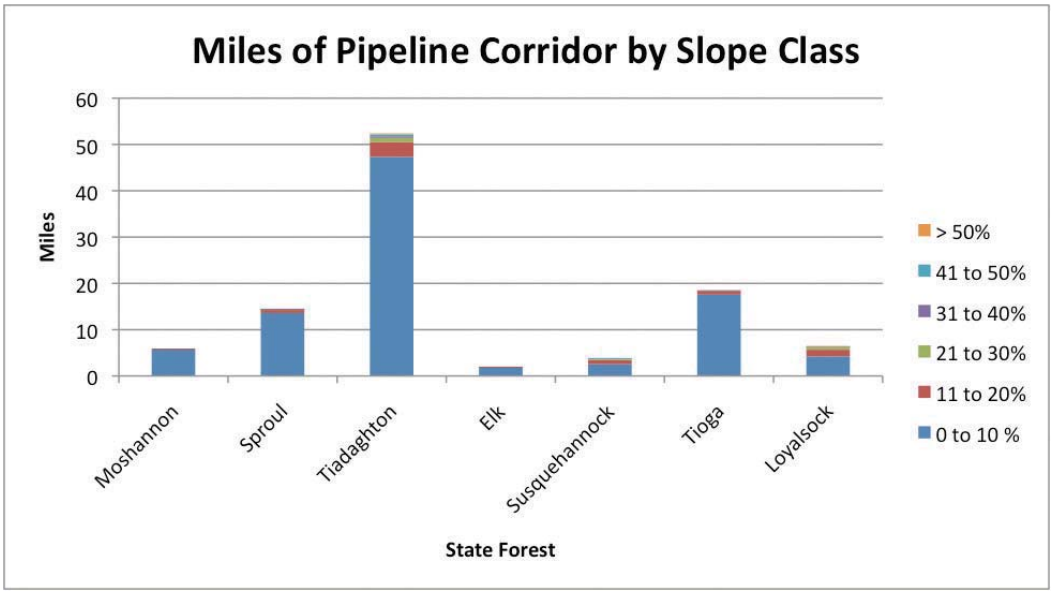


Figure 2.10 Miles of lease agreement pipeline corridor by slope class and state forest from 2008 to 2012.

Total Conversion

From 2008 to 2012, approximately 1,486 acres of state forest land were converted from a forested condition to facilitate gas development activities (Table 2.16 and Figure 2.11). This figure could change with time because some edges of pads, roads, and pipelines may not be maintained and could revert to a forested condition in the future.

State Forest District	Pad Acreage	Road Acreage	Pipeline Acreage	Total Acreage
Moshannon	63.3	31.7	39.2	**134.2**
Sproul	156.5	20.8	78.2	**255.5**
Tiadaghton	318.3	68.1	144.2	**530.6**
Elk	6.5	1.2	9.1	**16.8**
Susquehannock	32.2	4.1	29.4	**65.7**
Tioga	135.7	47.5	94.4	**277.6**
Loyalsock	73.1	68.2	64.3	**205.6**
Total Acreage	**785.6**	**241.6**	**458.8**	**1,486.0**

Table 2.16 Total acreage converted to non-forest by infrastructure type from 2008 to 2012.

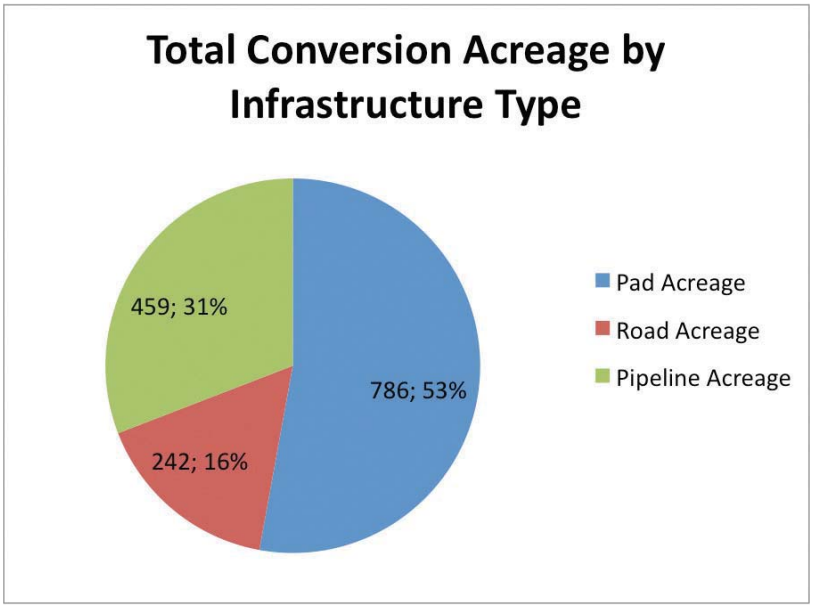


Figure 2.11 Total acreage converted to non-forest by infrastructure type from 2008 to 2012.

Seismic Surveys

Seismic data facilitates the successful exploration and development of conventional and unconventional oil and natural gas reservoirs in Pennsylvania. Seismic data is acquired when an energy wave travels through the subsurface and is reflected off of the various layers of rock at depth to a data recording device at the earth's surface called a geophone. Each layer of rock acts as its own reflective surface, where the reflectivity of any given surface is dependent on its density and the velocity at which the energy wave can travel through the medium.

Figure 2.12

These energy waves are most commonly generated on land from an explosive charge buried within a previously drilled borehole, or from a heavy truck-mounted vibrating plate (commonly referred to as vibroseis). The energy reflection from the layers of rock (the signal) is gathered and recorded on the surface by geophones and is processed to produce an image, which may be interpreted and used to guide the exploration and development process. The images produced are representative of a cross-section through the earth and show the various layers of rock encountered at the subsurface (Figure 2.12). The acquisition of seismic data is considered integral to interpreting subsurface structure and effectively developing oil and natural gas reservoirs.

Seismic data is acquired in two-dimensional (2-D) or three-dimensional (3-D) form as indicated by the image produced of the subsurface.

2-D surveys: require an energy source that is in line with the receiver to produce a vertical profile of the subsurface. 2-D surveys consist of one or more seismic lines acquired individually. Each line will produce an image in a single vertical plane.

3-D surveys: require a multitude of geophones placed in an array, which collect the reflection signals from points outside the plane of the energy source to produce a "cube-like" profile of the subsurface. Multiple seismic lines collecting data simultaneously are required to produce a three-dimensional image. 3-D surveys are more complex and labor intensive and require more land-base.

Two methods of seismic surveys commonly occur on state forest lands:

Explosive surveys: utilized for cross-country surveys where road access is limited; drill buggies, heli-portable drills, or tracked machines drill a 20-foot "shot-hole" every 220 feet along a linear survey route; data collection receivers (or geophones) are placed at fixed intervals and data is collected.

Vibroseis surveys: utilized when a sufficient road network exists; large weighted trucks strike the road surface and collect data in a similar fashion to that described above.

Seismic operators are highly encouraged to employ the least intrusive technologies available for gathering seismic survey data. Exclusion areas containing sensitive resources are clearly delineated by the operator in the field and seismic crews are informed of operational restrictions and/or avoidance measures.

The bureau has developed guidelines to help manage seismic activity on state forest lands. See *Guidelines of Administering Oil and Gas Activity on State Forest Land* for more information.

Field management and inspections are used to document compliance with the operating specifications set forth in the seismic permit and the pre-activity meeting. Examples of incidents documented during past field inspections include damage to trees, debris or trash found, unauthorized use of trails, damage to gates, illegal parking, vandalism, and unauthorized shot-hole locations.

Between 2007 and 2012, the bureau approved 26 individual seismic surveys to take place on state forest lands. As a result of these 26 seismic survey permits, over 643,000 acres of 3-D seismic data and 49 line miles of 2-D seismic data have been acquired. A vegetation monitoring protocol has been designed to monitor vegetation impacts. Impacts to vegetation from seismic operations should be temporary (Figure 2.13), as vegetation will restore itself naturally. Additional monitoring protocols may be developed to account for additional potential impacts as a result of seismic data acquisition activities.

Figure 2.13 Seismic activity on state forest lands.

Infrastructure and Recreation Field Visits

The bureau implements on-site forest infrastructure monitoring and recreation field visits. Staff from the core gas forest districts and the infrastructure specialist in the Recreation Section periodically meet to review shale-gas development. They discuss, document, and review issues, new methods, products, and benefits that stem from shale-gas development. Several of the findings and lessons learned from these visits are reviewed here.

Traditional state forest roads typically have a closed or nearly closed canopy over the top of the road and are barely wide enough for two passenger vehicles to safely pass each other. Such roads exhibit the wild character and back-country experience that state forest users have come to expect. Conversely, some roads used by the shale-gas industry are considerably wider, enough for two hauling trucks to pass each other safely, and often the tree canopy has been opened over the top of the road.

Based on the traditional traffic use of state forest roads, minimal road sub-base construction was typical. However, the original state forest roads were not adequate for the volume of traffic or the increased vehicle weights that came with shale-gas development. Changes were necessary to modify and create roads in the forest that could withstand this new type of traffic. The challenge is to balance the needs of gas operators with the traditional needs of other forest users. The roads also need to be constructed in a manner that would be compatible with bureau road maintenance operations after gas companies finish using the roads. In some cases, existing state forest roads that were improved or new forest roads that were constructed during the first two years of shale-gas development began to take on industrialized characteristics, such as heavily fortified sub-base, undesirable drop-offs along the sides, and excessively wide running surfaces. In response to these changes, the roads section of the bureau's *Guidelines for Administering Oil and Gas Activity on State Forest Lands* was updated to offer clarification and guidance to both bureau staff who were implementing the gas program and also the gas companies that were operating on state forest lands.

The updated guidelines described a clearer vision for how state forest roads were to be constructed to meet traditional forest visitor expectations, the bureau's long-term maintenance capabilities, and gas companies' operational needs. The changes primarily deal with the creation of a stable road sub-base using geo-textiles, such as geo-fabrics, geo-grids, and geo-cells, in conjunction with the traditional sub-base stone. Another successful method has been the use of soil cementing to create the road sub-base (described in more detail below). These approaches have greatly reduced the height and width of the road profile, enhancing the appearance of the forest road while still providing the capabilities needed to handle large volumes of heavy truck traffic.

Figure 2.14 Traditional state forest road in Loyalsock State Forest. Note the closed canopy and narrow road base.

Figure 2.15 State forest road in Tiadaghton State Forest that has minimal wild character value after it was improved for shale-gas development. Note the break in the tree canopy, wide base, and heavily armored edges.

Figure 2.16 Constructed forest road, with adjacent pipeline ROW, used for shale-gas development access. This demonstrates reduced wild character value due to wide road surface and long, straight profile.

Figure 2.17 State forest road in Tioga State Forest that is utilized for shale-gas development that demonstrates reduced wild character value due to overwidening.

Figure 2.18 State forest road in Moshannon State Forest that was improved for shale-gas development but retained significant wild character value. A gas line ROW is adjacent to the road.

Figure 2.19 State forest road in Moshannon State Forest that was improved for shale-gas development but retained wild character value. Note that the canopy is still closed over the top of the road.

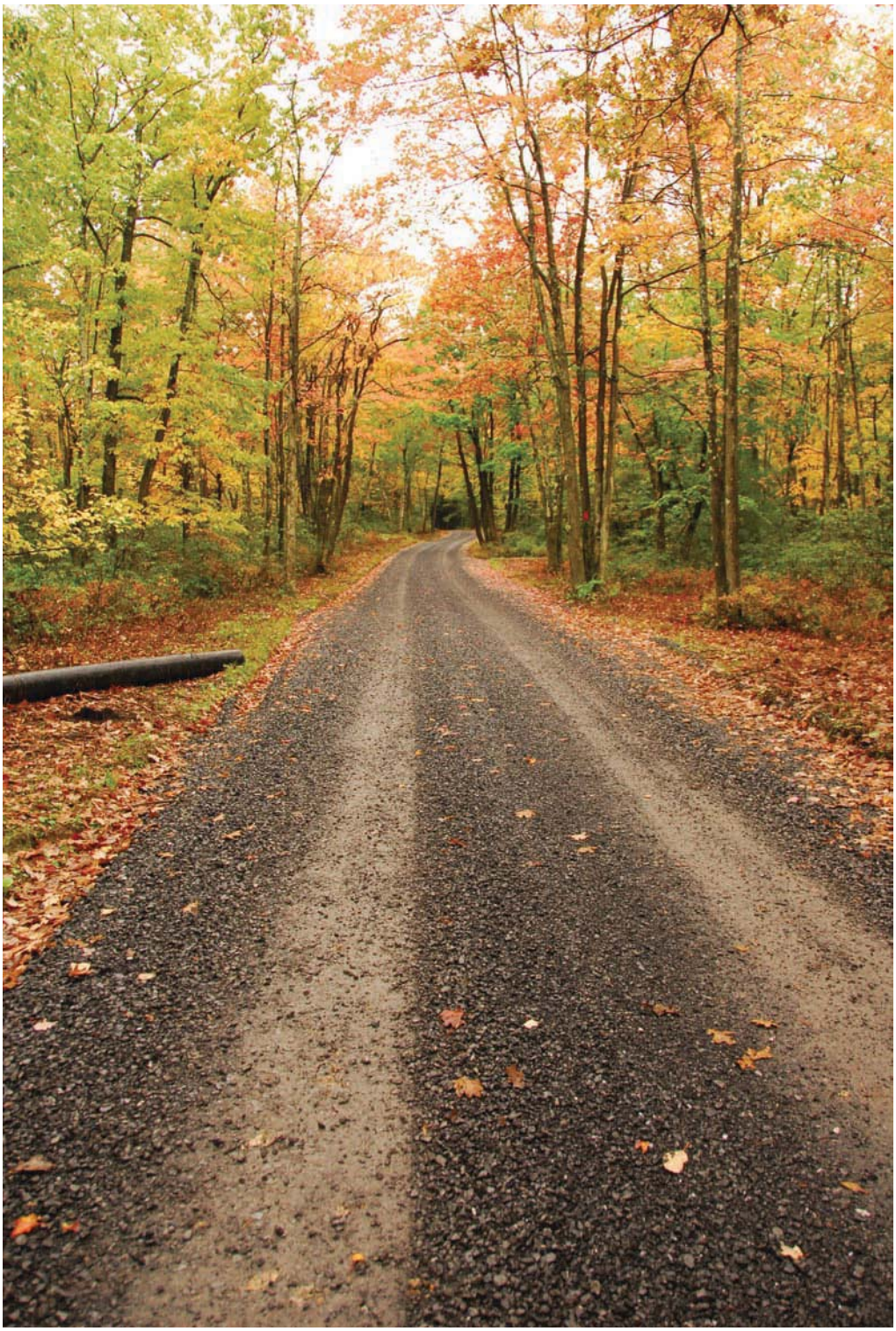


Figure 2.20 State forest road in Tiadaghton State Forest that was improved for shale-gas development but retained wild character value. Note that the canopy is still closed over the top of the road.

A recent technology for improving some state forest roads is the use of soil cementing. Soil cementing limits the increased height of the road profile by eliminating the need for a large amount of stone to be placed as the sub-base. Soil cementing, or stabilizing the road sub-base with cement, has been shown to be effective in stabilizing the road sub-base. This technology involves adding cement to the road surface in a 7 percent concentration, sometimes adding additional stone, and then mixing the conglomerate together. The new material is then graded with a proper crown and rolled. This new road sub-base is then covered with a running surface of six to 12 inches of crushed limestone or driving surface aggregate.

Although proven to be stable, an initial concern with this new sub-base was how it would impact future road maintenance activities by the bureau. It was unclear whether typical equipment operated by bureau maintenance staff could manage the soil cementing sub-base. The technique was tested on a short section of road in the Sproul State Forest (Figure 2.21), and it was found that the treated sub-base could be maintained through existing bureau procedures and would not pose maintenance problems like a standard concrete material would. Presently, 5.6 miles of state forest road have received a soil cement treatment to the sub-base. While this road sub-base treatment is not appropriate for use on all state forest roads, it does have applicability in some cases without negatively impacting future maintenance activities by the bureau.

An innovative method to preserve the wild character of a state forest road has been implemented at several large pipeline crossings. Traditionally, the intersections of pipelines and roads have created long, linear views of the cleared and maintained pipeline ROW. In the Tiadaghton State Forest, the district staff and gas company personnel collaborated to develop a layout for a large pipeline project that would minimize this negative visual effect (Figures 2.22 and 2.23). They minimized the width of

Figure 2.21 State forest road in Sproul State Forest that was improved for shale-gas development and received a soil cement treatment to the sub-base.

the permanently maintained ROW, allowing for 60 to 70 percent of the initial clearing to be replanted as a forested site. Conifer plantings are planned for the site because conifer trees grow at a faster pace and hold their foliage year round to further reduce the visual impacts. In addition, the ROW layout incorporated the use of a crescent shape as the ROW climbed the slope and also embedded "doglegs" to further break up the linear visibility of the ROW. These layout modifications limit the distance that the ROW is visible from the road.

In considering whether to place pipeline ROWs along existing state forest roads, the bureau is confronted with the conflicting goals of maintaining the wild character of forest roads and limiting forest fragmentation due to new pipelines. The addition of a pipeline ROW along a road corridor can detract from the wild character of the road, but it minimizes the amount of new forest fragmentation by taking advantage of the existing disturbance corridor. Conversely, placing the ROW at a distance or setback from the road creates an additional disturbance corridor but preserves the wild character of the road. In some cases, the road and/or pipeline corridor can be kept narrow enough that there is still a closed canopy over the disturbance corridor. The bureau is implementing both approaches and is evaluating their outcome and effectiveness.

Figure 2.22 View of pipeline in Tiadaghton State Forest discussed here. Note dogleg on opposite side of stream to minimize long, linear view of pipeline.

Figure 2.23 View of pipeline in Tiadaghton State Forest discussed here. Note dogleg at top of hill to minimize long, linear view of pipeline.

Forest Road Surveys

Forest roads are the primary means of access for nearly every forest user group. Forest roads also represent a significant investment to infrastructure that requires continual long-term monetary and manpower investments by the Bureau of Forestry. Shale-gas development represents a considerable increase in the amount of traffic and types of vehicles using forest roads. These changes are not compatible with traditional forest road construction, and major road improvements are necessary to accommodate gas development. Since the 2008 state forest lease, impacts to the forest road system and associated corrective measures have greatly changed the structure and character of the state forest road system. The purpose of this survey work is to document and quantify the condition of state forest roads and how they change over time in relation to how the roads were constructed or improved and what materials were used to accommodate shale-gas development traffic.

In addition, a comparison of required maintenance for roads that were improved for shale-gas development versus traditional state forest roads will also be evaluated. Experience has shown that the increase in traffic and heavy hauling will result in road failure if the road profile and materials are not improved and that, over time, the improved roads will require less maintenance and remain in better condition following shale-gas development activities.

Roads that have received or will receive heavy shale-gas related traffic since 2008 are considered for this survey. The road to be surveyed is divided into quarter-mile sections. Data collection points are established at the beginning of the road and at quarter-mile intervals to the end of the road or to the point where gas-related traffic terminates. If the road extends beyond the termination point, an additional point is established one quarter-mile past where gas-related traffic ends.

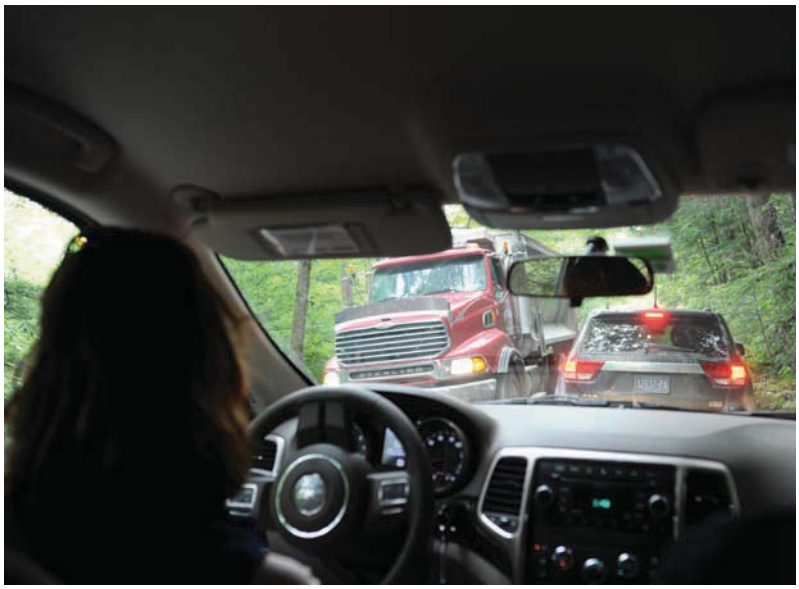
GPS coordinates are collected at the starting location, at every data collection point, at every road or trail intersection, and at the end of the road survey. The points are collected at the center of the running surface. An assessment and site evaluation is performed at each point. The running surface width, cross-sectional width, limit of clearance width, and ditch widths are measured. In addition, a visual determination of road feature assessments is made at each collection point. These assessments include the ditch type and condition, road profile, road surface aggregate material, condition of the road, road sub-base material, and dust conditions related to the road.

All state forest roads in each state forest district that are used for shale-gas development are scheduled to be surveyed. This survey work began with the testing of the Road Survey Monitoring Protocol in May 2012. Following field testing of the protocol and associated edits, the survey began on roads in the core gas forest districts.

Initial survey results show that the average running surface width of roads used for gas development is 14.5 feet, and the average road cross-sectional width is 34.5 feet. The primary road profile is of a "crowned" shape for nearly 95 percent of the road survey points. The most common road running surface material found in the road surveys is 2A limestone, followed by 2RC limestone and driving surface aggregate (DSA). The road sub-base improvement materials include the use of geo-textiles (geo-grid, geo-fabric, and geo-cell) in conjunction with the use of native stone materials and imported #3 and #4 stone, which is most commonly a limestone base material. Soil cementing was also used in a limited number of situations and has been found to be very effective. Road drainage methods include sheetflow and ditch. This road drainage method was indicated on 55 percent of the road survey points.

In addition to these findings, the survey protocol was also conducted, when possible, on the portions of roads not used for shale-gas development. Surveys

were also conducted on some roads in anticipation of future shale-gas development. Results from these data sets indicate that the average running surface is 9.4 feet and the average road cross-sectional width is 25.6 feet. The primary running surface material is native materials on 50 percent of the points. 2A and 2RC limestone represent the remaining running surface material, with 31 percent and 18 percent, respectively. This shows an average of 5.1 feet increase in running surface width and 8.9 feet increase in road cross-sectional width due to shale-gas development. The running surface materials typically changed from primarily native materials to limestone- based road surfacing products.



Future efforts include the surveying of all of the remaining roads that have been used or are likely to be used in the Moshannon, Sproul, Elk, and Loyalsock state forests. The return interval for resurveying these road plots will be determined based on periodic surveys of certain roads to gauge measureable change in road conditions. The road data collected will continue to guide the bureau in road construction methods, materials, and maintenance intervals for roads utilized in shale-gas development. The data will also assist in guiding the bureau in improving other forest roads that are not used for shale-gas development due to lessons learned on shale-gas used roads. The bureau will track the useable life of the various road materials to determine the best products to be used in traditional state forest road maintenance and construction. Based on what is learned from the roads utilized for shale-gas development, it is anticipated that the bureau will find cost-saving measures in its maintenance and improvement of traditional state forest roads.

Road Shutdown, Reroute, and General Traffic Control Monitoring

The Bureau of Forestry strives to keep all public use roads open to the public during shale-gas development, but there are exceptions when roads must be closed. In a few instances, there have been long-term closures of roads due to public safety concerns. More typically, however, road closures are temporary, usually from a few minutes to a few hours, for operational reasons such as road improvement projects, pipeline crossing construction, bridge or culvert replacement, drilling rig moves, and oversized loads. Although not closed to public travel, there have been roads within the Sproul and Loyalsock state forests that have had long-term reroutes implemented on them that resulted in different traffic patterns than the public has traditionally experienced. These reroutes consist of changing a road from two-way to one-way traffic flows.

In addition to road closures and traffic pattern reroutes, many users have experienced sign-in/sign-out procedures when accessing certain areas by vehicle. Manned security stations are located in some areas where all persons passing must stop and sign in/sign out. This is required so that, in the event of an accident at or near a well pad that is being developed, the company will

have a roster of all persons and vehicles for which they need to account. These security practices are common in all of the state forests that have active gas development activities during the drilling and hydraulic fracturing stages.

Below is a summary of altered traffic patterns and road closures by state forest district:

Tiadaghton State Forest
There have been two roads with long-term closures. Moore Road has been closed for its entirety since 2009, and a quarter-mile section of Ramsey Road has been closed since 2010. Each of these road closures is anticipated to be opened when the wells along these roads go into the production stage (i.e., when drilling and hydraulic fracturing are completed).

Sproul State Forest
There has been a reroute of Penrose Road to Coon Run Road for one-way traffic. This was in place from 2010 until 2012. The road is now open for two-way traffic, since gas development activity has slowed in the district. It is anticipated that this road will return to a one-way traffic pattern when gas development activity increases. The one-way traffic pattern was a solution that the district implemented due to the very steep topography and the narrow roadway. These conditions resulted in limited places for vehicles to pass one another safely. In addition, a section of the road passes a former Civilian Conservation Corps camp location. To preserve this cultural resource, road widening was not permitted.

Loyalsock State Forest
There is a reroute affecting Hagerman Run, Brown, Long Run, and Gray's Run roads for one-way traffic. This has been in place since 2011 and will likely continue until shale-gas development is completed in this area. The one-way traffic pattern was a solution that the district implemented due to the very steep topography. This condition resulted in limited places for vehicles to pass one another safely. In addition, Hagerman Run Road's proximity to the stream doesn't allow for the widening of the road. A further consideration in this traffic solution was the impact of heavy truck traffic passing through the village of Gray's Run. The one-way traffic plan reduces the amount of traffic affecting the residents of Gray's Run.

Bridge and Crossing Inspection
Various gas companies have made significant additions and repairs to bridges and other large stream crossings as part of their use of state forest roads. There have been five new bridges and one bridge deck replacement in the state forests since shale-gas development began in 2008. The bridges have been primarily prefabricated metal bridges that are constructed off site and then transported and installed. Also, six stream crossings have been completed by the installation of large, greater than 36-inch culverts. The culverts are either corrugated metal or smooth-bore plastic construction.

The bridge crossings are added into the Pennsylvania Department of Transportation's Bridge Database System. Each of these crossings is then scheduled for periodic field inspections for safety and structural analysis. These inspections take place on average every five years and are performed by DCNR inspectors or through a certified contractor.

Figure 2.24 New bridge installed in Tiadaghton State Forest.

Figure 2.25 New bridge installed in Tioga State Forest.

Dust Control Notification

State forest roads consist of a soil and aggregate material that can lead to potential issues with dust caused by vehicle traffic. Road dust is created as vehicle tires pulverize the surface aggregate, releasing small particles of dust referred to as fines. These fines from the pulverized material can then become airborne and are known as fugitive dust. Fugitive dust has the potential to be a detriment to forest users' safety, impact personal property, and cause environmental concerns.

The nature of gas development on state forest lands requires access across state forest roads by a multitude of vehicle types and sizes. The frequency of traffic is a factor that contributes to releasing fugitive dust. The trips made by these vehicles carry the potential to create fugitive dust to various extents based on weather conditions. While all stages of gas development require many more vehicles per day than a traditional state forest road typically experiences, of greatest concern is the period of time when a well is being hydraulically fractured. This generally requires the greatest concentration of heavy vehicular traffic.

The primary dust control method recommended by forest district management and utilized by natural gas companies is the use of non-potable water as a suppressant. Eighty-three percent of the roads that have had some type of dust suppressant applied used non-potable water. Non-potable water (water drafted from a source such as a stream or river and not treated to drinking water standards) is preferred over potable water, as potable water can retain chemicals that injure plant and aquatic life. Among other concerns, chemical dust suppressants have been known to change the chemical properties of dirt and gravel roads to the extent that the road itself hardens and becomes impossible to maintain using the bureau's standard maintenance practices. When the road reaches this condition, the only alternative is to completely rehabilitate the road through full-depth reclamation. However, chemical dust suppressants have been used on some state forest roads, and their usage is summarized below.

Sproul State Forest

- Chemical dust control treatments on segments of five roads, totaling 3.5 miles.
- Road segments have been treated since August 2010, and they have been approved for reoccurring treatment as conditions require.
- Justifications for the usage of chemical dust control have been: 1) for safety – traffic visibility, and 2) to control fugitive dust that impacts both private and state forest leased camps.
- Products used have been "Dustless" and "Aggrabond."

Tioga State Forest

- Chemical dust control treatments on segments of seven roads, totaling 12.5 miles.
- Most road segments have been treated since May 2011, and they have been approved for reoccurring treatment as conditions require.
- Justification for the usage of chemical dust control has been for safety related to traffic visibility.
- Products used have been "Ultrabond 2000" and "Dustless." Feedback from the company that used Dustless was "the application was not as effective as marketed" and, following the initial application, all further dust control was by water only. Companies using Ultrabond 2000 were satisfied with the results.

Loyalsock State Forest

- Chemical dust control treatments on segments of five roads, totaling 12.1 miles.
- Road segments have been treated since July 2011, and they have been approved for reoccurring treatment as conditions require.
- The justifications for the utilization of chemical dust control have been: 1) for safety – traffic visibility, and 2) to control fugitive dust that impacts a private camp within the forest. There have been complaints received from private residents and the public due to fugitive dust on state forest roads.
- Product utilized has been "Ultrabond 2000."

IV. Conclusion/Discussion

State forest lands located in the shale-gas region have seen changes in infrastructure due to the development and extraction of this resource. Overall, approximately 1,486 acres of forest have been converted to facilitate shale-gas development. This included 161 miles of new or improved roads, 191 pads (of all types), and 104 miles of new or widened pipelines. Road surveys have demonstrated an average of 5.1 feet increase in running surface width and 8.9 feet increase in road cross-sectional width due to shale-gas development, as well as a change from primarily native road bed materials to limestone-based road surfacing products. To help minimize these effects on ecology, aesthetics, and wild character, the bureau is encouraging the implementation of best management practices for road, pad, and pipeline construction.

While there are physical changes in new or modified infrastructure that can be measured and compared relatively easily, it has been difficult to measure the visual changes and changes in experience that result from infrastructure development. Each forest visitor is likely to have a different perception and expectation of the forested environment, which leads to challenges in quantifying and describing those effects. The bureau will continue to explore avenues for assessing such impacts.

There are plans for a formal dust monitoring study of state forest roads in the core gas forest districts. The Bureau of Forestry will be working with the Penn State Center for Dirt and Gravel Road Studies for this monitoring effort. The bureau will also be working on methods for monitoring the reclamation of forest roads that have been impacted by shale-gas development through natural or man-made processes.