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Landscape Changes: Assessing Pennsylvania State Park Viewsheds Across the Marcellus Shale Region

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Abstract

The Marcellus Shale industry has impacted Pennsylvania since 2005 and has been a major driver of land use change ever since. The Pennsylvania state park system has been facing encroachment from this industry ever since the first Pennsylvania wellpad was drilled in 2008. Previous research conducted overviews the impacts associated with this industry in regards to environmental quality, but there is limited research associated with the social impacts. The conducted research overviews the Marcellus Shale industry in regards to encroachment on Pennsylvania state parks through a GIS analysis. The purpose of the research is to evaluate how the viewsheds (areas of vision from a given point) of Pennsylvania state park land has been impaired by the Marcellus Shale industry. The results of the research show how the landscape of state parks have change due to the Marcellus Shale industry, and also a focus will be placed on scenic vistas (areas that highlight spectacular views within state parks) of selected parks to see to what extent that pristine landscape has been altered. The results of the research will help provide an idea of landscape change utilizing a GIS analysis and hopefully help to guide future growth.

Keywords: GIS, Viewshed, Pennsylvania, Fracking, Landscape

INTRODUCTION

The Pennsylvania state park system has been facing encroachment by the Marcellus Shale industry. Currently, there are only a few gas leases that are permitted on Pennsylvania state park land, and currently these leases have yet to be utilized for natural gas extraction. These areas which encroach on state park land may not necessarily impact the state park system directly, but visibility on the landscape has not been previously considered. The landscape changes can be modeled by conducting a viewshed analysis utilizing a GIS (Llobera 2003).

The Marcellus Shale industry in Pennsylvania has been a major driver in land use change in recent years. It is estimated that about 500 trillion cubic feet of natural gas is trapped in the

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Marcellus Shale formation below Pennsylvania in the northern and western regions of the state (Engelder and Lash 2008). Since the first natural gas producing well in Pennsylvania in 2008, to three years later in 2011, Pennsylvania has become one of the top five gas producing states within the United States of America (Considine et al. 2009).

Pennsylvania state parks are sites with great cultural, environmental, and economic significance. The first state park in Pennsylvania was established as Valley Forge State Park in 1893 (Pennsylvania State Parks 2016). The DCNR reports when all of the 120 state parks within Pennsylvania are combined there are more than 115,000 hectares of state park land (Pennsylvania State Parks 2016). With a total of about 38 million visitors annually, spending about $40 million on-site and $818 million off-site, Pennsylvania state parks are a major tourist attraction and economic driver within the state of Pennsylvania (Mowen et al. 2012). Since many of these state parks are situated over the Marcellus Shale formation, there is a potential for impacts from the gas extraction industry.

In order to assess how the landscapes surrounding state parks has been altered or has the potential for alteration, a viewshed analysis can be conducted. A viewshed from a point is the collection of areas visible from that point (Bolstad 2012). Views from any area that is not flat are blocked by existing landscape terrain; elevations will hide points if the elevation of the terrain is higher than the line of sight between the viewing points (Bolstad 2012). This analysis can be utilized to show how the existing landscape surrounding and within Pennsylvania state parks is altered by the Marcellus Shale industry.

PURPOSE AND SCOPE

Based on data distributed by the Pennsylvania State GIS data clearinghouse (PASDA) on Marcellus Shale leases and Pennsylvania state park land, it is possible to conduct various analyses and interpret results based on those analyses. The purpose of this research project is to evaluate to what extent the viewsheds (areas of vision from a given point) of Pennsylvania state park land have been impaired by the Marcellus Shale Industry of Pennsylvania.

The proposed research will address the following elements: Calculate the maximum distance an individual 5’ 5” tall with 20/20 vision is capable of viewing a 30’ wide wellpad; and calculate how many wellpads are within the vieswheds of selected Pennsylvania state park vistas.

LITERATURE REVIEW

The Marcellus Shale region extends through most of the Appalachian Region of the United States. This area includes northern and western Pennsylvania, the New York Southern Tier, eastern Ohio, and western New Jersey, along with most of West Virginia, western Virginia, and western Maryland. The region also extends into portions of Kentucky and Tennessee (McKay et al. 2011). Figure1 shows the extent of the Marcellus Shale formation through the Appalachian Mountains.

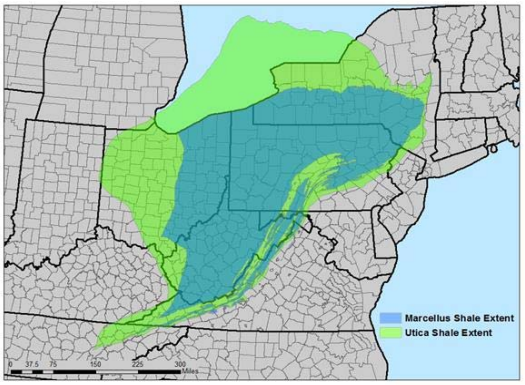

Figure 1. Extent of the Marcellus shale and Utica shale formations (USGS 2016)

The most common process used to extract natural gas from the Marcellus Shale is a process called hydraulic fracturing (fracking) (Clark et al. 2012). Fracking is a process by which water, sand, and various chemicals are pumped into a wellbore at very high pressures to create cracks in the shale (Upadhyay and Bu 2010). When the cracks in the shale are created, natural gas can then be extracted (Upadhyay and Bu 2010).

The Pennsylvania state park system was established in 1893, with the establishment of Valley Forge State Park. As of 2012, there are 120 state parks located in Pennsylvania. The state parks within Pennsylvania are overseen by the Pennsylvania Bureau of State Parks, which is a division of the Pennsylvania Department of Conservation and Natural Resources (DCNR).

The state park system within Pennsylvania plays as a major economic driver within the state of Pennsylvania. Direct visitor spending in Pennsylvania state parks generates about $40 million annually (Mowen et al. 2012). The off-site spending associated with visits in general, such as restaurants/bars, transportation, and other associated uses, Pennsylvania state parks generate about $818 million dollars annually (Mowen et al. 2012). When combining the revenue generated on-site and off-site, the general tourist spending for Pennsylvania state parks is about $858 million annually (Mowen et al. 2012).

A total of 32 state parks in Pennsylvania have at least one scenic vista (Pennsylvania State Parks 2016). Vistas are scenic overlooks that have a pristine view of the local landscapes. There are a total of 43 scenic vistas that are located in Pennsylvania state parks (Pennsylvania State Parks 2016). These vistas create an identity for an area and draw a large number of park visitors (Pennsylvania State Parks 2016).

Viewsheds can be thought of as the spatial representation of any visual property associated with, or generated by, a spatial configuration (Llobera 2003). Spatial representation can be thought of as the way in which a visual property at a location is represented and stored (Llobera 2003). A visual property refers to the measure of any "visual-related characteristic" that is associated with a location in a given area (Llobera 2003). Finally spatial configuration can be thought of as when we as people can vary the scope, scale and intent of the visual analysis (Llobera 2003). The analytical potential of the viewshed is not only linked to the choice of what constitutes the spatial configuration but also to the way in which it is represented and stored (Maloy and Denls 2001). Viewsheds are an important concept to grasp in the spatial world. This analysis is commonly used for landscape features that are averse to viewing,

such as communication towers and large industrial complexes (Bolstad 2012). Historically, many parks and scenic areas across the world have utilized the capabilities of creating viewsheds to assess landscape entity visibility (Bolstad 2012).

When assessing a viewshed in terms of a GIS, it can be thought of as a spatial data model to represent terrain based off of Digital Elevation Models (DEMs), which are raster data files (Bolstad 2012). Raster data files are a type of GIS data that use a system of cells in gridded form that store spatial data, in the case of DEMs, elevation is stored as data (Bolstad 2012). A viewshed as defined in terms of a GIS, is the collection of areas visible from that point (Bolstad 2012). The view from any terrain that is not flat will be blocked by terrain (Llobera 2003). Elevations will tend to hide points if the elevations are higher than the line of sight between the target point and the viewing point (Bolstad 2012). Viewsheds are calculated based on cell-to-cell intervisibility (Brody et al. 2006). A line will be drawn between the potentially visible cell and the view cell; elevation is then calculated for every cell that falls within the line of sight (Bolstad 2012). If the slope to a target cell is less than the slope to a cell that is closer to a viewpoint along the specified line of sight, then the target cell is not visible from the viewpoint (Bolstad 2012).

There are two factors to be considered when conceptualizing the idea of sight: 20/20 vision and the curvature of the Earth. Since all objects are not uniform in size, a smaller object will not be as visible as a large object at great distance (Holladay 1997). Since the size of large objects is considered,

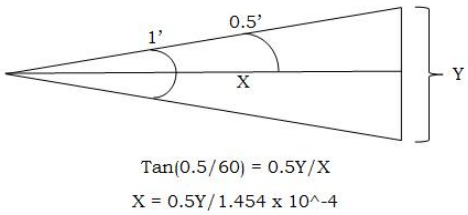

Figure 2. Mathematical theoretical designation of sight

the curvature of the Earth must be considered to represent objects that disappear past the horizon (Lee et al. 2009). The smaller of the two distances will be used to represent the maximum viewing distance of the object, a limiting factor.

The concept of 20/20 vision can be thought of as the ability to see an object within one second of arc (Holladay 1997). If the size of the object being viewed is known we can derive human sight utilizing trigonometry (Figure 2) (Holladay 1997). The Y input will be represented in feet and the result (X) will be represented in feet. This mathematical function allows us to conceptualize the maximum viewing distance of objects of a specified size assuming a viewer has 20/20 vision (Holladay 1997).

The delineation of the Earth's curvature can provide an idea of another limiting factor in sight. This can be thought of as the distance to the horizon that separates the sky and the Earth (Lee et al. 2009). Objects that are past the viewing distance of the horizon will remain hidden from sight (Bolstad 2012). This input will be used to show the maximum viewing distance based on the curvature of the Earth and can be calculated when inputting parameters into the actual viewshed analysis (Bolstad 2012).

When considering the size of an object, we must consider height and width together to get an accurate representation of an abject for a viewshed analysis. If an object has dimensions where it is more narrow than tall, the object will tend to fade out of sight because it is too narrow. Considerations must be made to represent both height and width of an object to determine the actual maximum size of the object (Drzyzga 2015). Along with the size of a wellpad, we must also consider the average height of a human as a viewing standard. The Center for Disease Control states that the average American height is 5'7" for men and 5'3" for women (CDC 2016). To account for both men and women, an average height can be utilized at 5'5" so no gender-size bias is present.

There are three broad impacts that are necessary to cover when considering viewshed impairments and the impact to state parks; these include visual impacts, economic loss, and loss of place.

Actual direct impacts are the major visual impacts associated with the Marcellus Shale industry and fracking. The average height of a wellpad varies depending on different factors, such as topography, regulations, drilling depths, and other factors, but an average height of wellpads will be assumed 120 feet with a width of 30 feet (Anonymous Source from Anonymous Gas Company, 2015). Utilizing the concept of 20/20 vision stated above, a maximum viewing distance of 31.46 km can be derived (Woodson et al. 1992). Regional atmospheric conditions may vary due to atmospheric haze, clouds, and other atmospheric limiting factors (Meitner and Daniel 1997).

When an area loses its aesthetic value, the tourism rate for that area decreases. The value of Pennsylvania's state park system was placed with the following values in 2008 by the Pennsylvania State University (Mowen et al. 2010). State parks in Pennsylvania received 33.6 million visitors, who directly spend $858 million annually on their trips (Mowen et al. 2012). The in-park spending supports a total of 9,453 full-time and part-time employees that contributed $291.4 million in labor income (Mowen et al. 2012). When these areas lose their aesthetic values, the tourism for that area decreases and the generated revenue can be lost (Sheridan 2013).

Rumbach (2011) has already shown the effects of a loss of tourism in a three county study area in the southern region of Virginia due to natural gas extraction; the loss of tourism caused in this region of America can also happen in Pennsylvania if the Marcellus Shale industry continues to grow at an exponential rate.

The loss of place is a social issue when considering the impacts to state parks. When an area is tied to

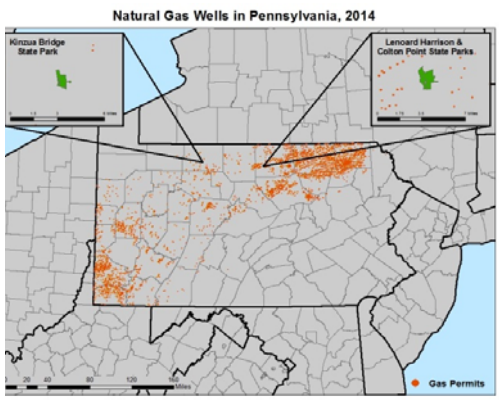

Figure 3. Locations of natural gas permits issued in Pennsylvania along with the selected Pennsylvania state parks (PASDA 2016)

a certain thought or object, it creates what people feel as “place.” The sense of place comes from three psychological processes: identity, familiarity, and attachment (Fullilove, 1996). Communities can also be impacted when a sense of place is lost. A lost sense of place can have social and economic impacts within that community. A lost sense of place within a community can have major impacts on the quality of life within a community (Muehlenbachs et al. 2012).

Research conducted by Fisher (1996) has shown the capabilities of viewshed analyses and how landscape can be manipulated in natural landscapes due to development. Germino et al. (2001) have also shown the capabilities of viewshed analyses by modeling the viewshed of sections of the Rocky Mountains. These are just some examples of the capabilities of viewshed analyses. These previous works support how we can use a viewshed analysis to see the landscape manipulation development causes within the Pennsylvania state park system. The research conducted by Rumbach (2011) has shown the social and economic importance of tourism and the preservation of recreational space. This presents a necessary reasoning as to why Pennsylvania state parks should be a consideration for this analysis. When the necessary data to run the viewshed analysis are acquired, the analysis can be applied to Pennsylvania state parks.

GAPS IN LITERATURE

There are data available for the Marcellus Shale industry in Pennsylvania, along with writings on the value of state parks within Pennsylvania, but there have been no previous analyses run on the viewsheds of state parks in Pennsylvania. Little exists on how viewsheds can be impacted due to natural gas extraction, along with the effects of these actions. Even though there are writings on environmental issues associated with the Marcellus Shale industry, there is no research on the social impacts that the Marcellus Shale industry places on state parks in Pennsylvania.

The viewsheds of state parks in Pennsylvania have major effects on the actual utilization of the parks. The actual aesthetic issues associated with the Marcellus Shale industry can be great at times, which can lead to heavy alteration of a landscape. Additionally, there can be a major economic loss for Pennsylvania if the natural gas industry is allowed to alter the landscape of scenic vistas in Pennsylvania state parks. There will also be a sense of place loss if the landscape of a specific and meaningful area is altered.

STUDY AREA

There are two broad study areas that need to be considered for this analysis. The first is the locations of wellpads, which are underlain by the Marcellus Shale formation. Pennsylvania will be the main focus of the study, but surrounding states will be considered, since many parks are close to state borders. As stated by Jacquet (2012), gas permits may not necessarily mean the site has undergone the fracking process but gas leases are the most common data available and can be utilized at almost any given time (PASDA 2016).

The locations of three Pennsylvania state parks with scenic vistas will be the second input study area for the viewshed analysis. The three state parks selected will include Kinzua Bridge State Park located in McKean County and Colton Point State Park along with Leonard Harrison State Park located in Tioga County. (Figure 3 shows the locations of the selected state parks in Pennsylvania with natural gas wells). Both state parks are underlain by the Marcellus Shale formation. Kinzua Bridge State Park will help to give a representation of the northwest region of Pennsylvania, and Colton Point State Park along with Leonard Harrison State Park will help to give a representation of the northeast region of Pennsylvania. Both Colton Point State Park and Leonard Harrison State Park cover areas of the Pennsylvania Grand Canyon. The counties considered for the study area include the Pennsylvania Counties of Bradford, Cameron, Clinton, Elk, Lycoming, McKean, Potter, Tioga, and Warren Counties, as well as Cattaraugus County in New York due to close proximity to the New York border.

METHODS

Methods to complete this project are outlined below. All the methods to complete this project are known and can be done utilizing a GIS.

The necessary data to run this analysis can be acquired through PASDA (PASDA 2016). To run analyses on the impacts of the Marcellus Shale industry, data were acquired. The data needed to complete a viewshed analysis are DEMs for Pennsylvania Counties and one New York County due to close proximity to the New York border. The required Pennsylvania county DEMs include the counties of Bradford, Cameron, Clinton, Elk, Lycoming, McKean, Potter, Tioga, and Warren Counties, as well as Cattaraugus County in New York. These datasets will provide the necessary terrain information for Pennsylvania surfaces. Also required for the viewshed analysis will be points of wellpads, in this case, gas permits that represent sites in the Marcellus shale region that already has been utilized, currently is utilized, or has future potential for utilization. These data are freely available and are very accurate and up-to-date. For the Pennsylvania state park system analysis, a polygon feature will need to be acquired. One feature that will need to be difficult to acquire are the points of the scenic vistas within Pennsylvania state parks. These data are not freely available through the DCNR, and would

Table 1. GIS data providers

Data Name	Data Description	Data Provider
PA County DEM	Digital Elevation Model which is available for each county in Pennsylvania	United States Geological Survey
PA State Park Boundary	Polygon feature of Pennsylvania state park areas	Pennsylvania Spatial Data Access
PA State Park Vistas	Point feature of Pennsylvania state park scenic vista locations	Manual Collection
Marcellus Shale Lease Locations	Point feature of fracking lease locations in Pennsylvania	Pennsylvania Spatial Data Access

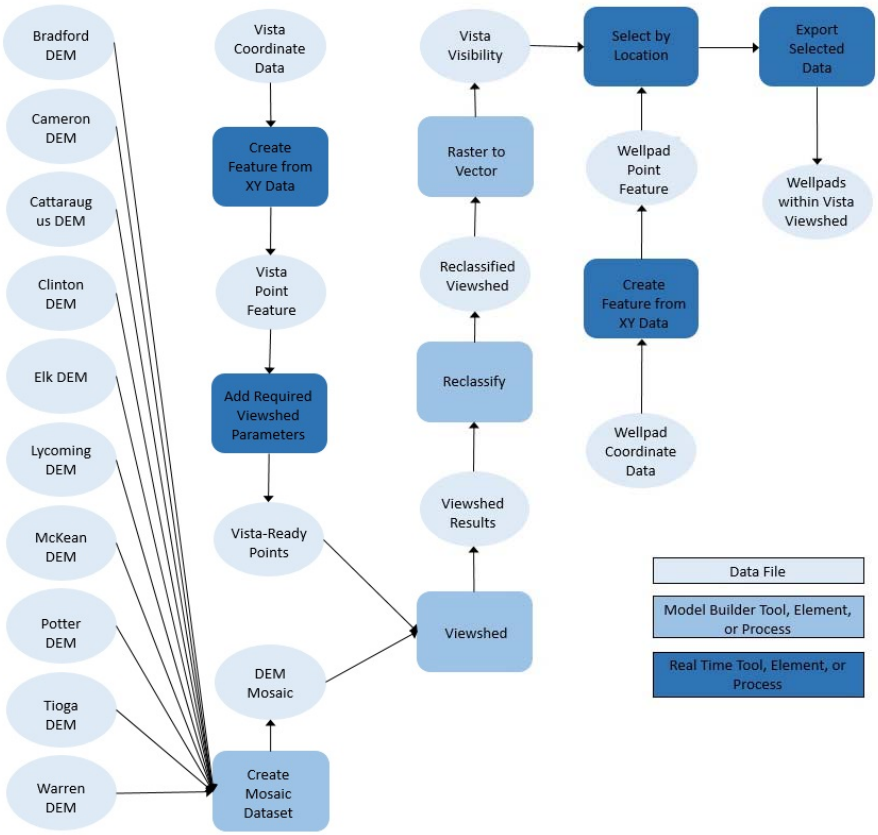

Figure 4. Complete GIS workflow for the Pennsylvania State Park viewshed analysis

be most useful if they are represented as point data. Table 1 shows the various data that will need to be acquired and utilized for the proposed research, a brief description of the data, and the provider of the data

The results will be determined utilizing a GIS, specifically, ArcGIS. The GIS analysis will be broken into the following parts: Calculate the. maximum distance an individual 5' 5" tall with 20/20 vision is capable of viewing a 30' wide wellpad; and calculate how many wellpads are within the vieswheds of selected Pennsylvania state park vistas.

In order to complete the viewshed analysis, a mosaic dataset will need to be created containing all county DEMs. A raster mosaic is a combination of multiple raster files into one raster file (Bolstad 2012). This will all be done via the model builder feature in ArcGIS, which allows the user to build a set of tools to run an analysis easier when the analysis needs to be run multiple times. This saves time and places less emphasis on the user segment. The main tool that will need to be utilized is the Viewshed Tool. The Viewshed Tool is a Spatial Analyst Tool so this extension will have to be activated in ArcGIS. There will need to

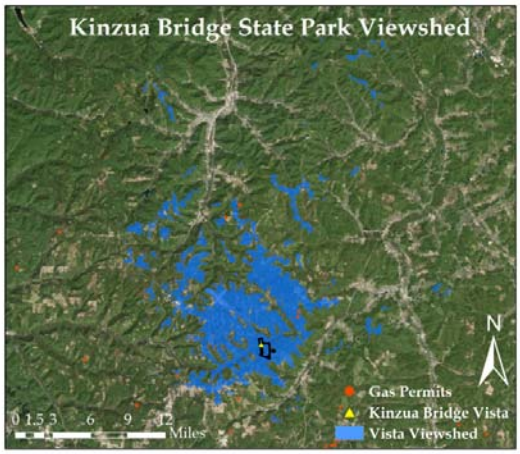

Figure 5. Kinzua Bridge State Park viewshed results

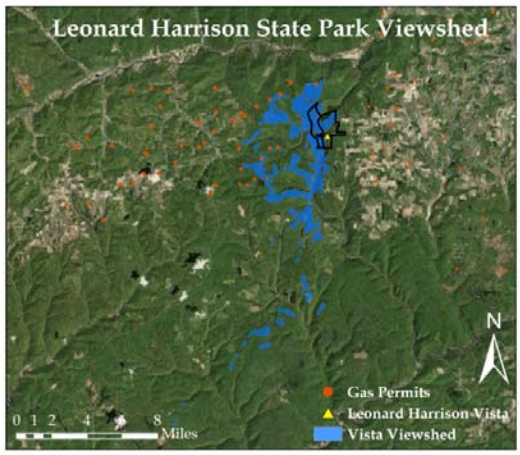

Figure 6. Leonard Harrison State Park viewshed results

be three new fields created in the attribute table of the points. OFFSETA, OFFSETB, and RADIUS2. OFFSETA describes the height of the points being observed, which will be set at 30' to accommodate for the width of a tower which is the minimum visualization value. OFFSETB describes the height of the viewer, which will be set at 5' 5" to represent the average height of an American human (CDC 2016). RADIUS2 is the distance the viewshed extends converted to the units the data are represented in (Bolstad 2012). The concept of theoretical distance states that the 20/20 vision limiting factor for the size of an average wellpad is 31.46 km. This will be the input distance for OFFSETB. The curvature of the Earth can be directly accounted for in ArcGIS utilizing an input option for the viewshed analysis.

When analyzing the data associated with the Pennsylvania state park system, it seems relevant to assess the areas that draw visitors, such as scenic vistas that may have an impaired view based on the results of the viewshed analysis. In this analysis, the viewing point of the analysis will be the Pennsylvania state park scenic vistas, the target point will be all wellpads within the theoretical area of sight from the state park scenic vistas, and the line of sight will be the connecting line between the state park vistas and the fracking rig. The state park scenic vistas that intersect the viewshed can then be selected to determine the scenic vistas that have wellpads visible within the viewshed (Bolstad 2012). This can all be done utilizing the model builder tool of ArcGIS. This analysis will be the main focus of the research. Since scenic vistas emphasize on existing landscape, the alteration of this landscape will show what is happening to the landscape the DCNR emphasizes as scenic. The final result of this analysis will show the scenic vistas that have some sort of viewshed impairment. Figure 4 shows the entire GIS workflow for the viewshed analysis.

RESULTS

The results of the conducted research show the

number of wellpads permitted within the viewshed of Kinzua Bridge State Park and Leonard Harrison State Park. The vistas at Colton Point State Park were not assessed due to unexpected site conditions. Upon visiting this sight, it became evident that the viewshed would be almost contained within the park due to the mountainside of Leonard Harrison State Park blocking the majority of the view from Colton Point State Park.

Data were collected with a Trimble GeoXH GPS field receiver and were later processed utilizing Trimble Pathfinder Office software. To assure accuracy, a total of 300 points were collected with a minimum of six satellites to control accuracy. Another measure taken to help control accuracy was the utilization of two Trimble units. The same input parameters were utilized to help assure accuracy.

The input of the observer points from each state park study area allows the calculation of the viewsheds. These viewsheds were then utilized to obtain a count of natural gas permits within the viewsheds of the state park vistas.

Kinzua Bridge is famous for its utilization of a former railroad bridge as an observation deck for recreational use. This is the most popular vista at Kinzua Bridge so this will be the vista assessed at this site (Pennsylvania State Parks 2016). Upon visiting the site, the number of park patrons at the studied vista were recorded within the 30 minutes spent at the site. A total of 15 other park vista patrons were observed at the Kinzua Bridge study site. The final analysis revealed seven gas permits within the viewshed of the Kinzua Bridge observation deck vista. Figure 5 represents the final viewshed analysis for the Kinzua Bridge State Park scenic overlook.

Leonard Harrison sits along the eastern side of the Pennsylvania Grand Canyon. This site is easily accessible via roads, parking lots, and hiking trails. The vista chosen at Leonard Harrison was near the visitor center, one of the more traveled areas of the park. This vista is located near the trailhead to access the bottom of the Pennsylvania Grand Canyon. Upon visiting the site, the pre-determined vista seemed to be the site with highest accessibility and the highest observation point as well. A total of five other park vista patrons were observed at the Leonard Harrison study site within the 30 minutes spent at the site. The final analysis revealed 42 gas permits within the viewshed of the Leonard Harrison observation point. Figure 6 represents the final viewshed analysis for the Leonard Harrison State Park scenic overlook.

When combining the two study area sites, the analysis revealed 20 park patrons over the two viewing sites during the combined hour used for data collection time. The analysis also revealed 49 gas permits over the two combined viewsheds from both state park observation point viewsheds.

DISCUSSION

The research conducted reveals how many natural gas extraction sites are present throughout the most current permitted data available through April, 2015. As data becomes available, the analysis can be re-run to get the most up-to-date count of natural gas permits as the natural gas extraction industry in Pennsylvania continues to grow.

The low number of natural gas permits at the sites could be representative of the landscape. All of the sites assessed are near very natural areas and other areas of conservation. The areas themselves were difficult to access at places. This could be another factor determining the number of natural gas permits near the study sites.

One aspect of the results that must be noted is the clustering of the permitted wellpads. Many of the natural gas permits were within close proximity to each other. This could be a factor of the division of land where natural gas extraction is leased.

Since the visitor counts were noted, the low number of visitors must be discussed. The data were collected on March 28th, 2015. The areas assessed still had snow and ice on the ground. This could be a factor that influenced the lower number of fellow park patrons on the day of data collection.

As the natural gas industry throughout the Marcellus Shale region continues to grow, the associated impacts must be considered. The associated social impacts are difficult to assess due to different views and ideas on what constitutes an issue and how to assess these issues. This analysis can help guide future growth and assess possible social impacts created by this industry in the future.

CONCLUSION

The encroachment of the Marcellus Shale industry upon Pennsylvania state parks will be an issue in current times and will be in future years. These areas that are encroaching on state park land may not necessarily impact the state park system directly, but one area that is not always considered when assessing associated impacts is visibility on the landscape.

Research conducted by Allen (2012) estimates 500 trillion cubic feet of natural gas is trapped in the Marcellus Shale formation below Pennsylvania in the northern and western region of the state; even if just 10% of this natural gas was extracted, it would be enough natural gas to satisfy the needs of America for the next two years (Allen 2012). Recent fracking activity in Pennsylvania has made the state one of the top five gas producing states within the United States of America (Considine et al. 2009).

The visual impacts, economic losses, and loss of place will all be major issues that face the Pennsylvania state park system. If the Marcellus Shale industry continues to encroach on these areas they will face all of these issues. The proposed research will help provide an idea of landscape change utilizing a GIS analysis and hopefully help to guide growth in the future.

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