

### *6.11.7 Impacts on Rail and Air Travel*

The development of high-volume hydraulic fracturing natural gas would require the movement of large quantities of pipe, drilling equipment, and other large items from other locations and from manufacturing sites that are likely far away from the well sites. Rail provides an inexpensive and efficient means of moving such material. The final movement, from rail depots to the well sites, would be accomplished with large trucks. The extent of rail and the choice of unloading locations depends on the well sites and cannot be predicted at this time. However, the use of rail to transport materials would have several predictable results:

- Total truck traffic would decrease;
- Truck traffic near the rail terminals would increase,
- Truck traffic on the arterials between the terminals and well fields would increase.

These positive and negative impacts would likely alleviate some impacts but might exacerbate impacts in neighborhoods along the routes to and from the rail centers. These impacts would require examination as part of road use agreements.

The heavy, bulky, equipment utilized for horizontal drilling would not likely be transported by air. However, the large numbers of temporary workers that the industry would employ would likely utilize the network of small airports and commuter airlines that service New York State. This would increase the traffic to and from these airports. None of the regional airports in New York State are at capacity, so the air travel is not expected to be a significant impact. In fact, the extra economic activity would be positive. However, residents that are along approach and departure corridors would experience more noise from increased service by airplanes.

## **6.12 Community Character Impacts<sup>408</sup>**

High-volume hydraulic fracturing operations could potentially have a significant impact on the character of communities where drilling and production activities would occur. Both short-term and long-term, impacts could result if this potentially large-scale industry were to start operations. Experiences in Pennsylvania and West Virginia show that wholesale development of

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<sup>408</sup> Section 6.12, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011, and was adapted by the Department.

the low-permeable shale reserves could lead to changes in the economic, demographic, and social characteristics of the affected communities.

While some of these impacts are expected to be significant, the determination of whether these impacts are positive or negative cannot be made. Change would occur in the affected communities, but how this change is viewed is subjective and would vary from individual to individual. This section, therefore, seeks to identify expected changes that could occur to the economic and social makeup of the impacted communities, but it does not attempt to make a judgment on whether such change is beneficial or harmful to the local community character.

The amount of the change in community character that is expected to occur would be impacted by several factors. However, the most important factors would be the speed at which high-volume hydraulic fracturing activities would occur and the overall level of the natural gas activities. Slow, moderate growth of the industry, if it were spread over several years, would generate much less acute impacts than rapid expansion over a limited time. Community character is constantly in a state of flux; a community's sense of place is constantly revised and adapts as social, demographic, and economic conditions change. When these changes are gradual, residents are given time to adapt and accommodate to the new conditions and typically do not view them as negative. When these changes are abrupt and dramatic, residents typically find them more adverse.

If the high-volume hydraulic fracturing operations reach some of the more optimistic development levels described in previous sections, the size and structure of the regional economies could be influenced by this new industry. Local communities that have experienced declining employment and population levels for decades could quickly become some of the fastest growing communities in the state. Traditional employment sectors could decline in importance while new employment sectors, such as the natural gas extraction industry and its suppliers, could expand in importance. Employment opportunities would increase in the communities and the types of jobs offered would change.

Total population would increase in the communities and the demographic makeup of these populations would change. In-migration resulting from the high-volume hydraulic fracturing

operations would bring a racially and ethnically diverse workforce into the area. Most of the new population would be working age or their dependents. In addition, most of the employment opportunities created would be for skilled blue collar jobs.

In addition to employment and demographic impacts, the proposed high-volume hydraulic fracturing would greatly increase income and earnings throughout affected communities. Royalty payments to local landowners, increased payroll earnings from the natural gas industry, added profits to firms that supply the natural gas industry, and added earnings from all of the induced economic activity that would occur in the communities would all add to the affluence of the region. While total income in the communities would increase, this added income and wealth would not be evenly distributed. Landowners that lease out their subsurface mineral rights would benefit financially from the high-volume hydraulic fracturing operations; however, those residents that do not own the subsurface mineral rights or chose not to exploit these rights would not see the same financial benefits. Some entrepreneurs and property owners would see large financial gains from the increase in economic activity, other residents may experience a rise in living expenses without enjoying any corresponding financial gains.

In some areas, the housing market would experience an increase in value and price if there is not sufficient outstanding supply to meet the increased demand. Existing property owners would most likely benefit; residents not already property owners could experience price rises and difficulties entering the market. Additional housing would most likely be constructed in response to increased demand, and in certain instances such development could occur on currently undeveloped land. Activities that achieve lower financial returns on property, such as agriculture, may be considered less desirable compared to housing developments. While at the same time, farmers who own large tracts of land could also benefit greatly from the royalty payments on the new natural gas wells.

Local governments would see a rapid expansion in the amount of sales tax and property tax generated by gas drilling and would now have the funding to complete a wide range of community projects. At the same time, the large influx of population would demand additional community services and facilities. Existing facilities would likely become overcrowded, and additional new facilities would have to be built to accommodate this new population.

Commuting patterns in the affected communities would also change. An increase in traffic both from the added truck transportation and from the additional population would likely increase traffic on certain areas roadways and, as further explained in the Transportation subchapter, would likely lead to the need for road improvements, reconstruction and repairs.

Ambient noise levels in the communities would likely increase as a direct result of drilling and additional traffic at the well pads, and as a result of increased development in the region (see Section 2.3.13). Aesthetic resources and viewsheds could be at least temporarily impacted and changed during well pad construction and development (see Section 2.3.12).

### **6.13 Seismicity<sup>409</sup>**

Economic development of natural gas from low permeability formations requires the target formation to be hydraulically fractured to increase the rock permeability and expose more rock surface to release the gas trapped within the rock. The hydraulic fracturing process fractures the rock by controlled application of hydraulic pressure in the wellbore. The direction and length of the fractures are managed by carefully controlling the applied pressure during the hydraulic fracturing process.

The release of energy during hydraulic fracturing produces seismic pressure waves in the subsurface. Microseismic monitoring commonly is performed to evaluate the progress of hydraulic fracturing and adjust the process, if necessary, to limit the direction and length of the induced fractures. Chapter 4 of this SGEIS presents background seismic information for New York. Concerns associated with the seismic events produced during hydraulic fracturing are discussed below.

#### *6.13.1 Hydraulic Fracturing-Induced Seismicity*

Seismic events that occur as a result of injecting fluids into the ground are termed “induced.” There are two types of induced seismic events that may be triggered as a result of hydraulic fracturing. The first is energy released by the physical process of fracturing the rock which creates microseismic events that are detectable only with very sensitive monitoring equipment.

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<sup>409</sup> Alpha, 2009, Section 7; discussion was provided for NYSEDA by Alpha Environmental, Inc., and Alpha’s references are included for informational purposes.

Information collected during the microseismic events is used to evaluate the extent of fracturing and to guide the hydraulic fracturing process. This type of microseismic event is a normal part of the hydraulic fracturing process used in the development of both horizontal and vertical oil and gas wells, and by the water well industry.

The second type of induced seismicity is fluid injection of any kind, including hydraulic fracturing, which can trigger seismic events ranging from imperceptible microseismic, to small-scale, “felt” events, if the injected fluid reaches an existing geologic fault. A “felt” seismic event is when earth movement associated with the event is discernable by humans at the ground surface. Hydraulic fracturing produces microseismic events, but different injection processes, such as waste disposal injection or long term injection for enhanced geothermal, may induce events that can be felt, as discussed in the following section. Induced seismic events can be reduced by engineering design and by avoiding existing fault zones.

#### *6.13.1.1 Background*

Hydraulic fracturing consists of injecting fluid into a wellbore at a pressure sufficient to fracture the rock within a designed distance from the wellbore. Other processes where fluid is injected into the ground include deep well fluid disposal, fracturing for enhanced geothermal wells, solution mining and hydraulic fracturing to improve the yield of a water supply well. The similar aspect of these methods is that fluid is injected into the ground to fracture the rock; however, each method also has distinct and important differences.

There are ongoing and past studies that have investigated small, felt, seismic events that may have been induced by injection of fluids in deep disposal wells. These small seismic events are not the same as the microseismic events triggered by hydraulic fracturing that can only be detected with the most sensitive monitoring equipment. The processes that induce seismicity in both cases are very different.

Deep well injection is a disposal technology which involves liquid waste being pumped under moderate to high pressure, several thousand feet into the subsurface, into highly saline, permeable injection zones that are confined by more shallow, impermeable strata (FRTR, August

12, 2009). The goal of deep well injection is to store the liquids in the confined formation(s) permanently.

Carbon sequestration is also a type of deep well injection, but the carbon dioxide emissions from a large source are compressed to a near liquid state. Both carbon sequestration and liquid waste injection can induce seismic activity. Induced seismic events caused by deep well fluid injection are typically less than a magnitude 3.0 and are too small to be felt or to cause damage. Rarely, fluid injection induces seismic events with moderate magnitudes, between 3.5 and 5.5, that can be felt and may cause damage. Most of these events have been investigated in detail and have been shown to be connected to circumstances that can be avoided through proper site selection (avoiding fault zones) and injection design (Foxall and Friedmann, 2008).

Hydraulic fracturing also has been used in association with enhanced geothermal wells to increase the permeability of the host rock. Enhanced geothermal wells are drilled to depths of many thousands of feet where water is injected and heated naturally by the earth. The rock at the target depth is fractured to allow a greater volume of water to be re-circulated and heated. Recent geothermal drilling for commercial energy-producing geothermal projects have focused on hot, dry, rocks as the source of geothermal energy (Duffield, 2003). The geologic conditions and rock types for these geothermal projects are in contrast to the shallower sedimentary rocks targeted for natural gas development. The methods used to fracture the igneous rock for geothermal projects involve high pressure applied over a period of many days or weeks (Florentin 2007 and Geoscience Australia, 2009). These methods differ substantially from the lower pressures and short durations used for natural gas well hydraulic fracturing.

Hydraulic fracturing is a different process that involves injecting fluid under higher pressure for shorter periods than the pressure level maintained in a fluid disposal well. A horizontal well is fractured in stages so that the pressure is repeatedly increased and released over a short period of time necessary to fracture the rock. The subsurface pressures for hydraulic fracturing are sustained typically for one or two days to stimulate a single well, or for approximately two weeks at a multi-well pad. The seismic activity induced by hydraulic fracturing is only detectable at the surface by very sensitive equipment.

Avoiding pre-existing fault zones minimizes the possibility of triggering movement along a fault through hydraulic fracturing. It is important to avoid injecting fluids into known, significant, mapped faults when hydraulic fracturing. Generally, operators would avoid faults because they disrupt the pressure and stress field and the hydraulic fracturing process. The presence of faults also potentially reduces the optimal recovery of gas and the economic viability of a well or wells.

Injecting fluid into the subsurface can trigger shear slip on bedding planes or natural fractures resulting in microseismic events. Fluid injection can temporarily increase the stress and pore pressure within a geologic formation. Tensile stresses are formed at each fracture tip, creating shear stress (Pinnacle; “FracSeis;” August 11, 2009). The increases in pressure and stress reduce the normal effective stress acting on existing fault, bedding, or fracture planes. Shear stress then overcomes frictional resistance along the planes, causing the slippage (Bou-Rabee and Nur, 2002). The way in which these microseismic events are generated is different than the way in which microseisms occur from the energy release when rock is fractured during hydraulic fracturing.

The amount of displacement along a plane that is caused by hydraulic fracturing determines the resultant microseism’s amplitude. The energy of one of these events is several orders of magnitude less than that of the smallest earthquake that a human can feel (Pinnacle; “Microseismic;” August 11, 2009). The smallest measurable seismic events are typically between 1.0 and 2.0 magnitude. In contrast, seismic events with magnitude 3.0 are typically large enough to be felt by people. Many induced microseisms have a negative value on the MMS. Pinnacle Technologies, Inc. has determined that the characteristic frequencies of microseisms are between 200 and 2,000 Hertz; these are high-frequency events relative to typical seismic data. These small magnitude events are monitored using extremely sensitive instruments that are positioned at the fracture depth in an offset wellbore or in the treatment well (Pinnacle; “Microseismic;” August 11, 2009). The microseisms from hydraulic fracturing can barely be measured at ground surface by the most sensitive instruments (Sharma, personal communication, August 7, 2009).

There are no seismic monitoring protocols or criteria established by regulatory agencies that are specific to high volume hydraulic fracturing. Nonetheless, operators monitor the hydraulic

fracturing process to optimize the results for successful gas recovery. It is in the operator's best interest to closely control the hydraulic fracturing process to ensure that fractures are propagated in the desired direction and distance and to minimize the materials and costs associated with the process.

The routine microseismic monitoring that is performed during hydraulic fracturing serves to evaluate, guide, and control the process and is important in optimizing well treatments. Multiple receivers on a wireline array are placed in one or more offset borings (new, unperforated well(s) or older well(s) with production isolated) or in the treatment well to detect microseisms and to monitor the hydraulic fracturing process. The microseism locations are triangulated using the arrival times of the various p- and s-waves with the receivers in several wells, and using the formation velocities to determine the location of the microseisms. A multi-level vertical array of receivers is used if only one offset observation well is available. The induced fracture is interpreted to lie within the envelope of mapped microseisms (Pinnacle; "FracSeis;" August 11, 2009).

Data requirements for seismic monitoring of a hydraulic fracturing treatment include formation velocities (from a dipole sonic log or cross-well tomogram), well surface and deviation surveys, and a source shot in the treatment well to check receiver orientations, formation velocities and test capabilities. Receiver spacing is selected so that the total aperture of the array is about half the distance between the two wells. At least one receiver should be in the treatment zone, with another located above and one below this zone. Maximum observation distances for microseisms should be within approximately 2,500 feet of the treatment well; the distance is dependent upon formation properties and background noise level (Pinnacle; "FracSeis;" August 11, 2009).

#### *6.13.1.2 Recent Investigations and Studies*

Hydraulic fracturing has been used by oil and gas companies to stimulate production of vertical wells in New York State since the 1950s. Despite this long history, there are no records of induced seismicity caused by hydraulic fracturing in New York State. The only induced seismicity studies that have taken place in New York State are related to seismicity suspected to have been caused by waste fluid disposal by injection and a mine collapse, as identified in



Section 4.5.4. The seismic events induced at the Dale Brine Field (Section 4.5.4) were the result of the injection of fluids for extended periods of time at high pressure for the purpose of salt solution mining. This process is significantly different from the hydraulic fracturing process that would be undertaken for developing the Marcellus and other low-permeability shales in New York.

Gas producers in Texas have been using horizontal drilling and high-volume hydraulic fracturing to stimulate gas production in the Barnett Shale for the last decade. The Barnett is geologically similar to the Marcellus, but is found at a greater depth; it is a deep shale with gas stored in unconnected pore spaces and adsorbed to the shale matrix. High-volume hydraulic fracturing allows recovery of the gas from the Barnett to be economically feasible. The horizontal drilling and high-volume hydraulic fracturing methods used for the Barnett Shale play are similar to those that would be used in New York State to develop the Marcellus, Utica, and other gas bearing shales.

Alpha contacted several researchers and geologists who are knowledgeable about seismic activity in New York and Texas, including:

- Mr. John Armbruster, Staff Associate, Lamont-Doherty Earth Observatory, Columbia University;
- Dr. Cliff Frohlich, Associate Director of the Texas Institute for Geophysics, The University of Texas at Austin;
- Dr. Won-Young Kim, Doherty Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University;
- Mr. Eric Potter, Associate Director of the Texas Bureau of Economic Geology, The University of Texas at Austin;
- Mr. Leonardo Seeber, Doherty Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University;
- Dr. Mukul Sharma, Professor of Petroleum and Geosystems Engineering, The University of Texas at Austin; and
- Dr. Brian Stump, Albritton Professor, Southern Methodist University.

None of these researchers have knowledge of any seismic events that could be explicitly related to hydraulic fracturing in a shale gas well. Mr. Eric Potter stated that approximately 12,500 wells in the Barnett play and several thousand wells in the East Texas Basin (which target tight gas sands) have been stimulated using hydraulic fracturing in the last decade, and there have been no documented connections between wells being fractured hydraulically and felt quakes (personal communication, August 9, 2009). Dr. Mukul Sharma confirmed that microseismic events associated with hydraulic fracturing can only be detected using very sensitive instruments (personal communication, August 7, 2009).

The Bureau of Geology, the University of Texas' Institute of Geophysics, and Southern Methodist University (SMU) are planning to study earthquakes measured in the vicinity of the Dallas - Fort Worth (DFW) area, and Cleburne, Texas, that appear to be associated with salt water disposal wells, and oil and gas wells. The largest quakes in both areas were magnitudes of 3.3, and more than 100 earthquakes with magnitudes greater than 1.5 have been recorded in the DFW area in 2008 and 2009. There is considerable oil and gas drilling and deep brine disposal wells in the area and a small fault extends beneath the DFW area. Dr. Frohlich recently stated that "[i]t's always hard to attribute a cause to an earthquake with absolute certainty." Dr. Frohlich has two manuscripts in preparation with SMU describing the analysis of the DFW activity and the relationship with gas production activities (personal communication, August 4 and 10, 2009). Neither of these manuscripts was available before this document was completed. Nonetheless, information posted online by SMU (2009) states that the research suggests that the earthquakes seem to have been caused by injections associated with a deep production brine disposal well, and not with hydraulic fracturing operations.

#### *6.13.1.3 Correlations between New York and Texas*

The gas plays of interest, the Marcellus and Utica Shales in New York and the Barnett Shale in Texas, are relatively deep, low-permeability, gas shales deposited during the Paleozoic Era. Horizontal drilling and high-volume hydraulic fracturing methods are required for successful, economical gas production. The Marcellus Shale was deposited during the early Devonian, and the slightly younger Barnett was deposited during the late Mississippian. The depth of the Marcellus in New York ranges from exposure at the ground surface in some locations in the northern Finger Lakes area to 7,000 feet or more below the ground surface at the Pennsylvania

border in the Delaware River valley. The depth of the Utica Shale in New York ranges from exposure at the ground surface along the southern Adirondacks to more than 10,000 feet along the New York Pennsylvania border.

Conditions for economic gas recovery likely are present only in portions of the Marcellus and Utica members, as described in Chapter 4. The thickness of the Marcellus and Utica in New York ranges from less than 50 feet in the southwestern portion of the state to approximately 250 feet at the south-central border. The Barnett Shale is 5,000 to 8,000 feet below the ground surface and 100 to 500 feet thick (Halliburton; August 12, 2009). It has been estimated that the entire Marcellus Shale may hold between 168 and 516 trillion cubic feet of gas; in contrast, the Barnett has in-place gas reserves of approximately 26.2 trillion cubic feet (USGS, 2009A) and covers approximately 4 million acres.

The only known induced seismicity associated with the stimulation of the Barnett wells are microseisms that are monitored with downhole transducers. These small-magnitude events triggered by the fluid pressure provide data to the operators to monitor and improve the fracturing operation and maximize gas production. The hydraulic fracturing and monitoring operations in the Barnett have provided operators with considerable experience with conditions similar to those that would be encountered in New York State. Based on the similarity of conditions, similar results are anticipated for New York State; that is, the microseismic events would be unfelt at the surface and no damage would result from the induced microseisms. Operators are likely to monitor the seismic activity in New York, as in Texas, to optimize the hydraulic fracturing methods and results.

#### *6.13.1.4 Affects of Seismicity on Wellbore Integrity*

Wells are designed to withstand deformation from seismic activity. The steel casings used in modern wells are flexible and are designed to deform to prevent rupture. The casings can withstand distortions much larger than those caused by earthquakes, except for those very close to an earthquake epicenter. The magnitude 6.8 earthquake event in 1983 that occurred in Coalinga, California, damaged only 14 of the 1,725 nearby active oilfield wells, and the energy released by this event was thousands of times greater than the microseismic events resulting from hydraulic fracturing. Earthquake-damaged wells can often be re-completed. Wells that cannot

be repaired are plugged and abandoned (Foxall and Friedmann, 2008). Induced seismicity from hydraulic fracturing is of such small magnitude that it is not expected to have any effect on wellbore integrity.

#### *6.13.2 Summary of Potential Seismicity Impacts*

The issues associated with seismicity related to hydraulic fracturing addressed herein include seismic events generated from the physical fracturing of the rock, and possible seismic events produced when fluids are injected into existing faults.

The possibility of fluids injected during hydraulic fracturing the Marcellus or Utica Shales reaching a nearby fault and triggering a seismic event are remote for several reasons. The locations of major faults in New York have been mapped (Figure 4.13) and few major or seismically active faults exist within the fairways for the Marcellus and Utica Shales. Similarly, the paucity of historic seismic events and the low seismic risk level in the fairways for these shales indicates that geologic conditions generally are stable in these areas. By definition, faults are planes or zones of broken or fractured rock in the subsurface. The geologic conditions associated with a fault generally are unfavorable for hydraulic fracturing and economical production of natural gas. As a result, operators typically endeavor to avoid faults for both practical and economic considerations. It is prudent for an applicant for a drilling permit to evaluate and identify known, significant, mapped, faults within the area of effect of hydraulic fracturing and to present such information in the drilling permit application. It is Alpha's opinion that an independent pre-drilling seismic survey probably is unnecessary in most cases because of the relatively low level of seismic risk in the fairways of the Marcellus and Utica Shales. Additional evaluation or monitoring may be necessary if hydraulic fracturing fluids might reach a known, significant, mapped fault, such as the Clarendon-Linden fault system.

Recent research has been performed to investigate induced seismicity in an area of active hydraulic fracturing for natural gas development near Fort Worth, Texas. Studies also were performed to evaluate the cause of the earthquakes associated with the solution mining activity near the Clarendon-Linden fault system near Dale, NY in 1971. The studies indicated that the likely cause of the earthquakes was the injection of fluid for production brine disposal for the incidents in Texas, and the injection of fluid for solution mining for the incidents in Dale, NY

The studies in Texas also indicate that hydraulic fracturing is not likely the source of the earthquakes.

The hydraulic fracturing methods used for enhanced geothermal energy projects are appreciably different than those used for natural gas hydraulic fracturing. Induced seismicity associated with geothermal energy projects occurs because the hydraulic fracturing is performed at greater depths, within different geologic conditions, at higher pressures, and for substantially longer durations compared with the methods used for natural gas hydraulic fracturing.

There is a reasonable base of knowledge and experience related to seismicity induced by hydraulic fracturing. Information reviewed in preparing this discussion indicates that there is essentially no increased risk to the public, infrastructure, or natural resources from induced seismicity related to hydraulic fracturing. The microseisms created by hydraulic fracturing are too small to be felt, or to cause damage at the ground surface or to nearby wells.

Seismic monitoring by the operators is performed to evaluate, adjust, and optimize the hydraulic fracturing process. Monitoring beyond that which is typical for hydraulic fracturing does not appear to be warranted, based on the negligible risk posed by the process and very low seismic magnitude. The existing and well-established seismic monitoring network in New York is sufficient to document the locations of larger-scale seismic events and would continue to provide additional data to monitor and evaluate the likely sources of seismic events that are felt.

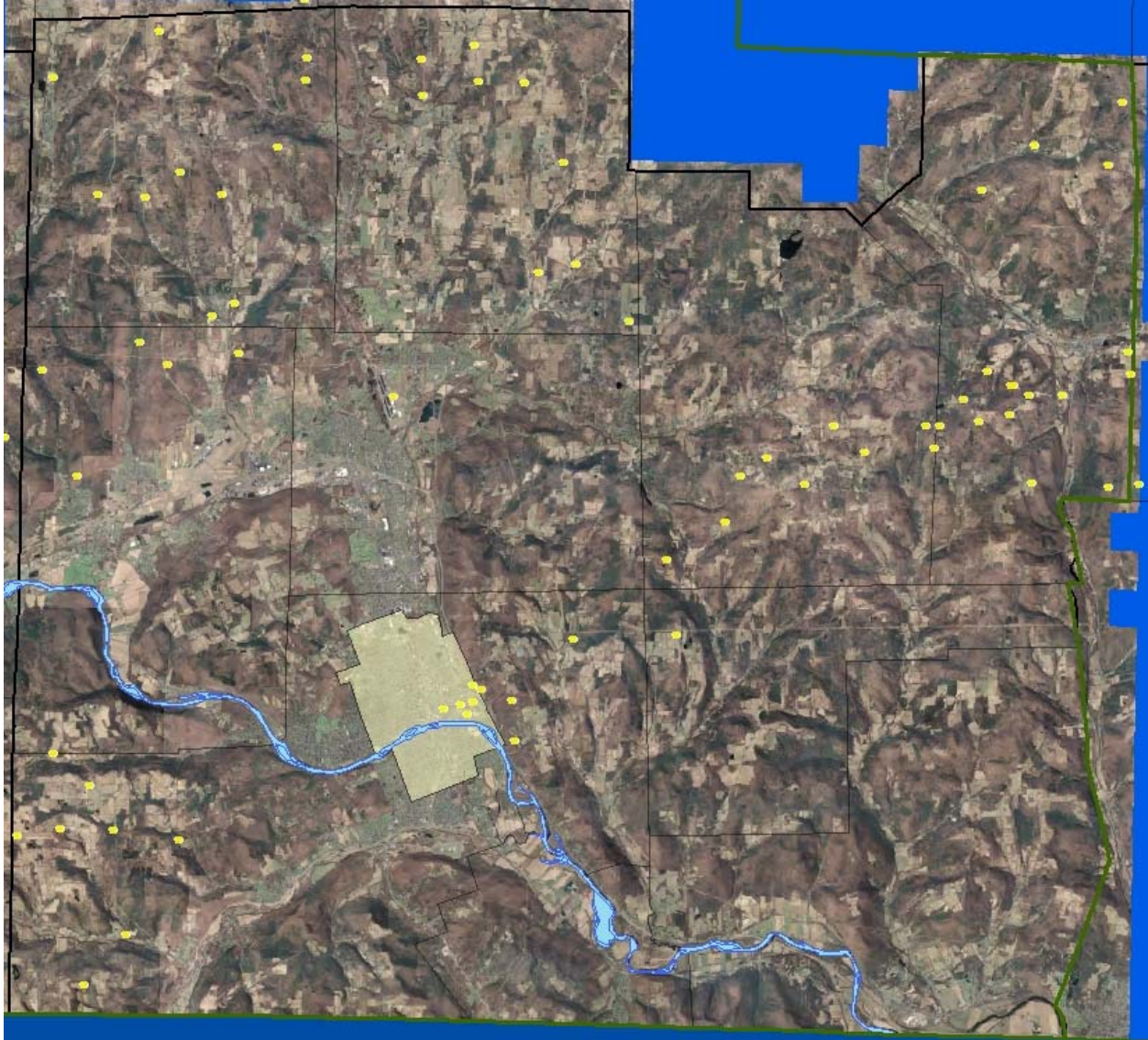
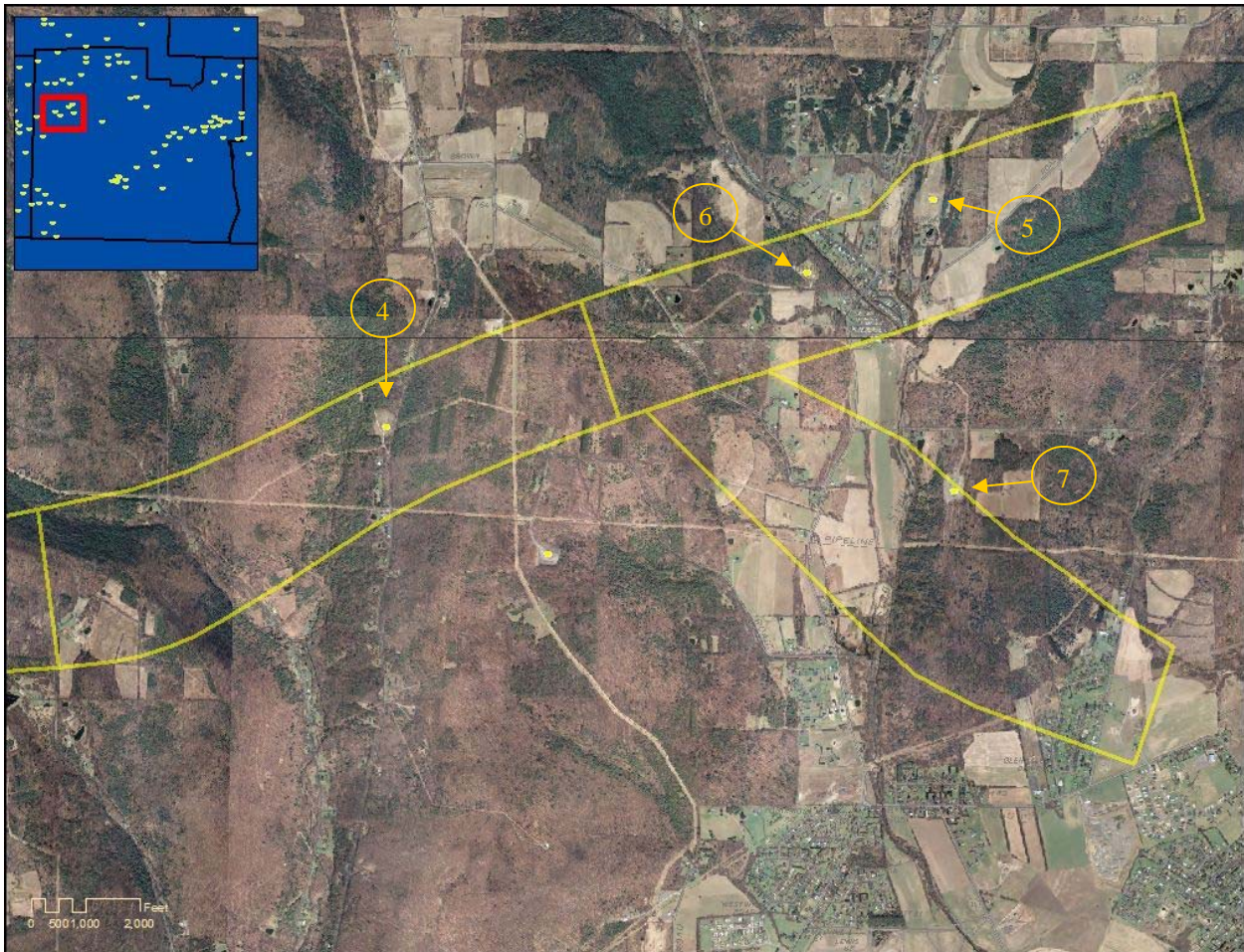


Photo 6.9 The following series of photos shows Trenton-Black River wells in Chemung County. These wells are substantially deeper than Medina wells, and are typically drilled on 640 acre units. Although the units and well pads typically contain one well, the size of the well units and pads is closer to that expected for multi-well Marcellus pads. Unlike expected Marcellus wells, Trenton-Black River wells target geologic features that are typically narrow and long. Nevertheless, photos of sections of Trenton-Black River fields provide an idea of the area of well pads within producing units.

The above photo of Chemung County shows Trenton-Black River wells and also historical wells that targeted other formations. Most of the clearings visible in this photo are agricultural fields.



Photo 6.10 The Quackenbush Hill Field is a Trenton-Black River field that runs from eastern Steuben County to north-west Chemung County. The discovery well for the field was drilled in 2000. The map below shows wells in the eastern end of the field. Note the relative proportion of well pads to area of entire well units. The unit sizes shown are approximately 640 acres, similar to expected Marcellus Shale multi-well pad units.



Photos 6.11 Well #4 (Hole number 22853) was a vertical completed in February 2001 at a true vertical depth of 9,682 feet. The drill site disturbed area was approximately 3.5 acres. The site was subsequently reclaimed to a fenced area of approximately 0.35 acres for production equipment. Because this is a single-well unit, it contains fewer tanks and other equipment than a Marcellus multi-well pad. The surface within a Trenton-Black River well fenced area is typically covered with gravel.



Rhodes 1322 11/13/2001



Rhodes 1322 5/6/2009



Photos 6.12 Well #5 (Hole number 22916) was completed as a directional well in 2002. Unit size is 636 acres. Total drill pad disturbed area was approximately 3 acres, which has been reclaimed to a fenced area of approximately 0.4 acres.



Gregory #1446A 12/27/2001



Gregory #1446A 5/6/2009

Photo 6.13 Well #6 (Hole number 23820) was drilled as a horizontal infill well in 2006 in the same unit as Well #6. Total drill pad disturbed area was approximately 3.1 acres, which has been reclaimed to a fenced area of approximately 0.4 acres.



Schwingel #2 5/6/2009



Photos 6.14 Well #7 (Hole number 23134) was completed as a horizontal well in 2004 to a true vertical depth of 9,695 and a true measured depth of 12,050 feet Well unit size is 624 acres. The drill pad disturbed area was approximately 4.2 acres which has been reclaimed to a gravel pad of approximately 1.3 acres of which approximately 0.5 acres is fenced for equipment.



Soderblom #1 8/19/2004



Soderblom #1 8/19/2004



Soderblom #1 5/6/2009

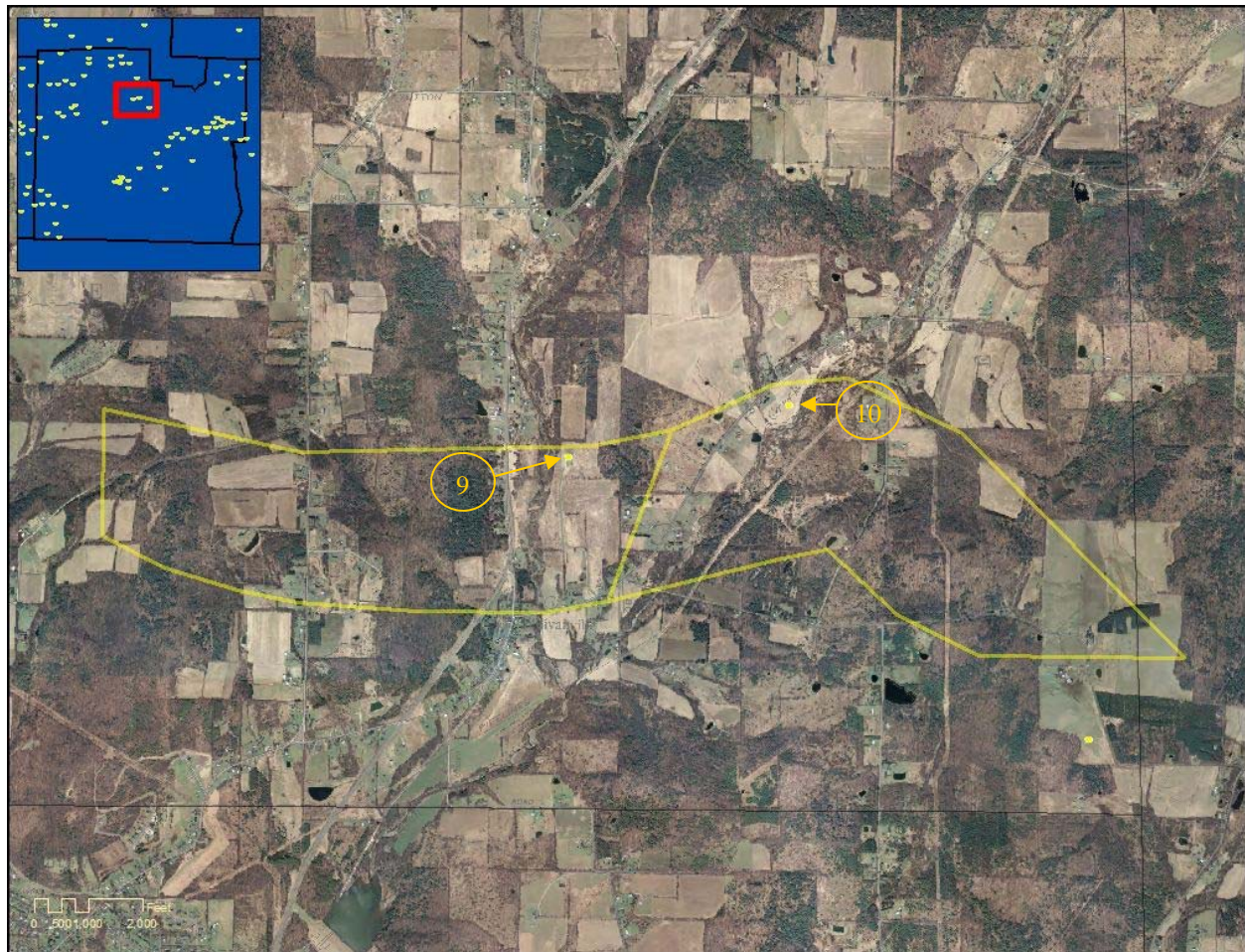


Soderblom #1 5/6/2009



Soderblom #1 5/6/2009

Photo 6.15 This photo shows two Trenton-Black River wells in north-central Chemung County. The two units were established as separate natural gas fields, the Veteran Hill Field and the Brick House Field.





Photos 6.16 Well #9 (Hole number 23228) was drilled as a horizontal Trenton-Black River well and completed in 2006. The well was drilled to a true vertical depth of 9,461 and a true measured depth of 12,550 feet. The well unit is approximately 622 acres.



Little 1 10/6/2005



Little 1 11/3/2005

Photos 6.17 Well #10 (Hole number 23827) was drilled as a horizontal Trenton-Black River well and completed in 2006. The well was drilled to a true vertical depth of 9,062 and a true measured depth of 13,360 feet. The production unit is approximately 650 acres.

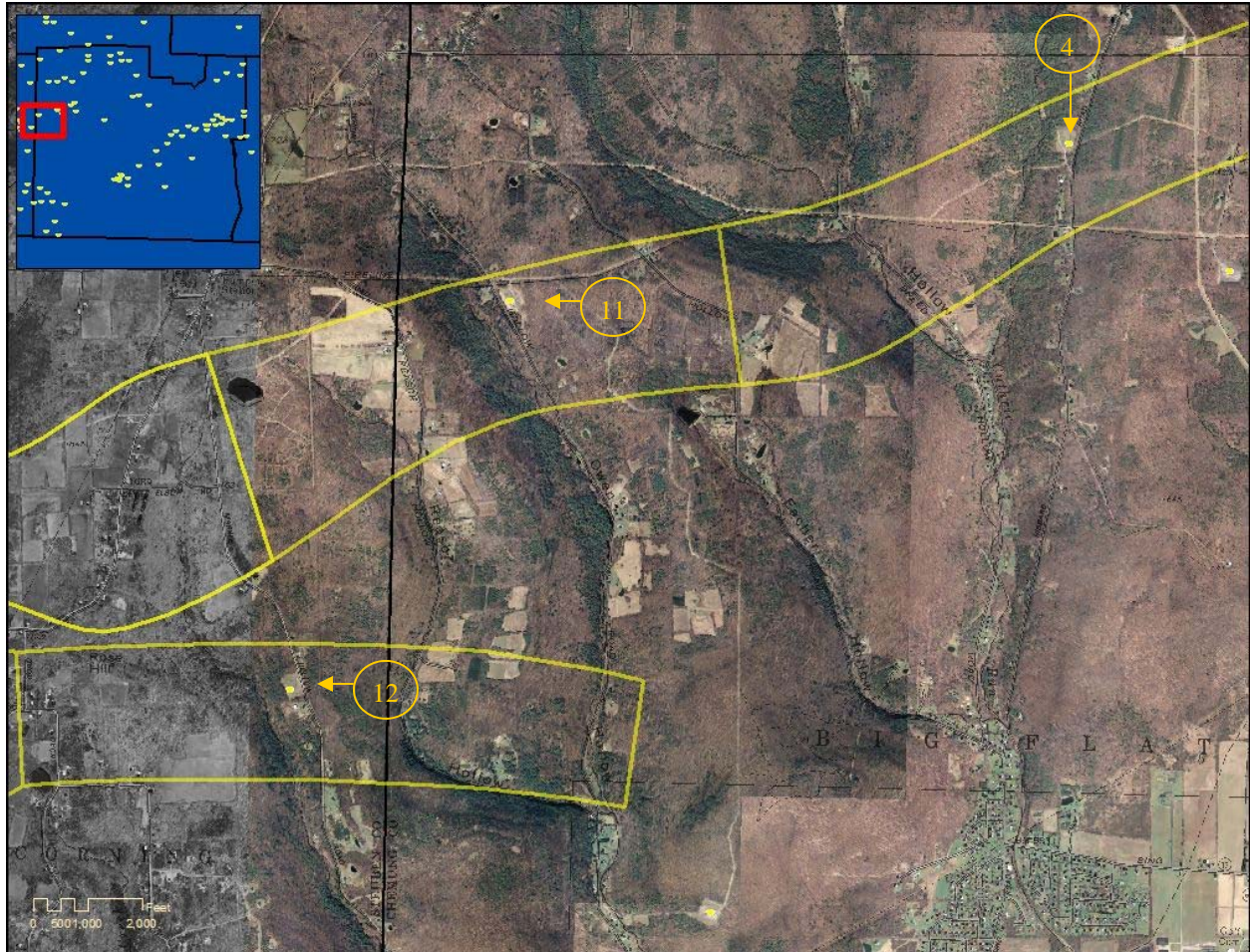


Hulett #1 10/5/2006



Hulett #1 5/6/2009

Photo 6.18 This photo shows another portion of the Quackenbush Hill Field in western Chemung County and eastern Steuben County. As with other portions of Quackenbush Hill Field, production unit sizes are approximately 640 acres each.





Photos 6.19 Well #11 (Hole number 22831) was completed in 2000 as a directional well to a total vertical depth of 9,824 feet. The drill site disturbed area was approximately 3.6 acres which has been reclaimed to a fenced area of 0.5 acres.



Lovell 11/13/2001



Lovell 5/6/2009

Photos 6.20 Well #12 (Hole number 22871) was completed in 2002 as a horizontal well to a true vertical depth of 9,955 feet and a true measured depth of 12,325 feet. The drill site disturbed area was approximately 3.2 acres which has been reclaimed to a fenced area of 0.45 acres.



Henkel 10/22/2002



Henkel 5/6/2009

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