Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems

Final Management Progress Report

Reporting Period: October 1, 2006 through May 31, 2009

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DISCLAIMER

Acknowledgement

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Abstract

This report describes work performed during the initial period of the project "Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems." The specific region that is within the scope of this study is the Fayetteville Shale Play. This is an unconventional, tight formation, natural gas play that currently has approximately 1.5 million acres under lease, primarily to Southwestern Energy Incorporated and Chesapeake Energy Incorporated. The currently active play encompasses a region from approximately Fort Smith, AR east to Little Rock, AR approximately 50 miles wide (from North to South). The initial estimates for this field put it almost on par with the Barnett Shale play in Texas. It is anticipated that thousands of wells will be drilled during the next several years; this will entail installation of massive support infrastructure of roads and pipelines, as well as drilling fluid disposal pits and infrastructure to handle millions of gallons of fracturing fluids. This project focuses on gas production in Arkansas as the test bed for application of proactive risk management decision support system for natural gas exploration and production.

The activities covered in this report include meetings with representative stakeholders, development of initial content and design for an educational web site, and development and preliminary testing of an interactive mapping utility designed to provide users with information that will allow avoidance of sensitive areas during the development of the Fayetteville Shale Play. These tools have been presented to both regulatory and industrial stakeholder groups, and their feedback has been incorporated into the project.

Executive Summary

Exploitation of a large natural gas reserve in central Arkansas, the Fayetteville Shale Play, will necessarily require development of significant infrastructure. Thousands of wells and hundreds of miles of gathering lines and roads will be constructed, as well as reserve pits and disposal options for fracture fluids. The project, "Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems," was proposed to develop modules for a web-based decision support tool that can be used by oil and gas exploration and production companies as well as governmental regulators and other stakeholders to proactively minimize adverse ecosystem impacts associated with the recovery of gas reserves in sensitive areas in the Fayetteville Shale Play in central Arkansas. An additional goal of this project is to provide a mechanism that will help to streamline the process of acquiring the necessary permits for drilling in the play.

The first year of the project resulted in identification of and contact with stakeholders involved in the Fayetteville Shale Play (FSP). Stakeholder meeting discussions were positive and indicated a willingness of the industrial and regulatory parties to collaborate with each other and the project team. The major themes that emerged as areas where the greatest benefit to the stakeholders would be felt were public education and data integration. As a result of the stakeholder input to the project, we have deployed an educational website found at the following URL: http://lingo.cast.uark.edu/LINGOPUBLIC/. In addition we have developed a web-based mapping decision support tool, known as the Infrastructure Placement Analysis System, that will allow better planning for development in sensitive locations by providing a map of the intersection of proposed features such as drilling pads, roads, or gathering lines with sensitive locations, as well as the ability to share proposed developments directly with regulatory agencies so that they receive early warning of potential issues prior too official permit application. Recent data layer additions include the Extraordinary Resource Water designation and the SSURGO soils data layer. A unique feature of the IPAS is the inclusion of uncertainty estimates associated with spatial boundaries and features. Geospatial data is not precise, and the system provides the user an understanding of the likelihood of intersection of

proposed development with an environmentally sensitive or important feature. For example, system boundaries of highly erodible soils are uncertain, and the system will report that it is likely, moderately likely, or unlikely that a specific feature intersects that soil type. The IPAS a web site is located at the following URL: http://lingo.cast.uark.edu/ipas/.

Conclusions

Feedback from the stakeholders has been very positive. The system has been constructed with expansion in mind, meaning that additional data layers that provide further guidance on sensitive locations can be acquired and incorporated into the web based mapping utility. We have worked with the Arkansas Natural Heritage Commission to add available data layers considered important for inclusion in decisions regarding environmentally friendly development. We have incorporated modules for habitat prediction, reserve pit failure, and sediment run off as compliments of decision support. The infrastructure placement analysis system is a restricted access site with full features available only for industry and regulatory agencies; however, guest access with restricted functionality is available to the public through application for a user account.

Operators can use the software in the planning process to better evaluate alternative sites, identify sensitive areas, and minimize environmental impacts by diverting projects away from sensitive areas. By implementing the software, operators can streamline the process for permitting well placement and infrastructure development. We estimate that the software can reduce the time required to locate infrastructure elements by a day or more for at least 10% of wellsites. Cost savings could approach $2.25 million/year with a drilling rig day rate of up to $45,000 based on the current estimated rate of 500 new wells per year; as gas prices recover from the current (2009) lows, the drilling rate may increase to previous levels of over 1000 per year, with potentially increased savings.

Regulatory stakeholders have indicated they felt these tools would be valuable for field inspections where it is not always easy to gather all the needed information in a single convenient place. Other regulators have indicated that the ability to screen for potential impacts is a tool they would like to use to provide developers with advance warning to exercise

care at specific sites. Industrial representatives were uniformly complimentary of the educational website; public understanding of their industry and perceptions are important to their operations, and they have promoted our work in their public forums and meetings. Finally, non-regulatory stakeholders, with strong interest in environmental protection, view these tools as awareness heightening opportunities to engage shale gas developers earlier in the development process to allow for proactive protection rather than relying on the more common reactive approach once an impact has occurred.

In summary, through early and regular stakeholder involvement during the course of this project, we have provided valuable and relevant tools and information that will, over time, simultaneously streamline production and enhance protection of the environment during the development of the Fayetteville Shale Gas Play.

Probabilistic Risk Based Decision Support for Oil and Gas Exploration and Production Facilities in Sensitive Ecosystems

INTRODUCTION

The Fayetteville Shale play is an unconventional natural gas play across central Arkansas. It is a tight shale formation and requires fracturing to produce economic quantities of gas. Initial estimates suggest that it may rival the Barnett Shale play in Texas. Currently there are about 1.5 million acres under lease. It is anticipated that thousands of wells will be drilled during the next decade; this will entail installation of massive support infrastructure of roads and pipelines, as well as drilling fluid disposal pits and infrastructure to handle millions of gallons of fracturing fluids. This project focused on gas production in Arkansas as the test bed for application of proactive risk management decision support system for natural gas exploration and production.

The project produced web-based application modules that allow mid- and small-sized exploration and production companies to generate development plans for resource extraction in sensitive ecosystems in a manner that will meet regulatory requirements and proactively minimize risks to the ecosystem through implementation of best management or development practices implemented on a site specific basis. The principal objective of this project was development of tools that allow rapid evaluation of alternative leases through a GIS-based information system so that location-specific environmental concerns can be identified early in the permitting process.

Earlier work on risk reduction in E&P has been built on probabilistic reliability analysis of field equipment to predict the probability of a failure-related release of produced fluids (DE-FC26-01BC15332). This analysis was coupled with a GIS-based fate and effects model linked to a natural resources damage assessment and remediation model to generate a ranked risk index map of the lease as a decision support tool for allocation of maintenance resources and provided a tool to predict environmental risk, thereby allowing for proactive risk management. This general framework was extended and adapted to the Infrastructure Placement Analysis System (IPAS) through the exploration and production lifecycle in the Fayetteville Shale Play.

Exploring for gas involves subsurface seismic mapping which can result in surface disturbance. When potential oil or gas deposits are identified, exploratory drilling begins. This phase requires constructing, operating, and maintaining a system of access roads and local pipelines to connect well sites to storage facilities and dispose of drilling wastes, and gravel pads for wells and to house equipment. In addition, the production phase normally requires storage tanks, separating facilities, and gas compressors. Finally, gathering lines and compressors are needed to transport gas to cross country transmission pipelines and ultimately to users. Impacts in the drilling stage include disturbed land, which can be significant depending on the length of roads, size of equipment, and other factors. The movement of heavy vehicles and drilling can create continuous noise potentially disturbing wildlife behavior patterns.

The Infrastructure Placement Analysis System provides planners, engineers, developers, cultural resource managers, and researchers with web-based map-enabled tools capable of presenting information and maps from a variety of geospatial data, for any proposed site or corridor location within the Fayetteville Shale Play. The system is available for use in the planning process to evaluate the potential of alternatives, to highlight sensitive areas and features, and to enable minimization of adverse environmental impacts through diversion of development projects away from sensitive areas – an opportunity that was not readily available prior to the advent of horizontal and directional drilling technology. Implementation of the tools assembled for this project should lead to a streamlined permitting process for well placement and infrastructure development.

In this report, we summarize the development and deployment of stakeholder-identified priority activities, specifically an educational publicly available website and the controlled-access IPAS website which provides tools to aid screening for potential infringement on sensitive or protected environmental systems.

Stakeholder involvement

On October 11, 2006 we held the first stakeholder meeting. A summary of participants is presented in Table 1 below. Three areas were identified where this project could have a significant impact. These were education, integration, and data sharing. A follow-up meeting

with the regulatory/governmental agencies was held on December 18, 2006 at the ADEQ offices in Little Rock, Arkansas. At this meeting, additional stakeholders who had been identified during the October meeting were included. The primary outcomes of this meeting were identification of specific agencies roles and an understanding of the interaction between these agencies. The details of this meeting have been summarized in a previous report.

Table 1. Fayetteville Shale Play Stakeholders		
Regulatory/Governmental Stakeholders		Role
Larry Bengal	Arkansas Oil and Gas Commission	Primary regulatory body for exploration, drilling and production
Mo Shafii	Arkansas Department of Environmental Quality	Regulates reserve pits
Ed Ratchford	Arkansas Geological Commission	Repository of geological data
Todd Fuggit Chris Kelly	Arkansas Natural Resources Commission	Well head and water well protection
Bill Holiman Cindy Osborne Chris Colclasure	Arkansas Natural Heritage Commission	Maintains database of endangered species
Ken Adams	Bureau of Land Management	Oversees resource extraction on all federal lands
Wayne King	US Forest Service	Defines allowable surface impacts on federal land
Chris Davidson	US Fish and Wildlife Service	Enforcement of Threatened and Endangered Species Act
Sara Usdrowski Marc Fossett Elaine Edwards	US Army Corps of Engineers	Enforces section 404 of the Clean Water Act
Industrial Stakeholders		
John Thaeler Mike McAllister	Southwestern Energy	Resource extraction
Paul Hagemeier John Satterfield	Chesapeake Energy	Resource extraction

On March 16, 2007 a third stakeholder meeting with representatives from Chesapeake Energy and Southwestern Energy was held. There was support of the concept of pooling of existing permits into a single easily accessed location, which has been implemented in the public website through an interactive mapping utility. However, there was concern regarding the recommendation via the decision-making algorithm of specific BMP's at specific proposed drill sites. The specific concern was that voluntary BMPs might be stipulated in permits (for

which regulatory authority does not currently exist), which would remove operational flexibility from the developer in implementing site specific best practices. Based on this input from the industrial stakeholders, the development of the IPAS focused on creation of a screening tool rather than an automated system designed to recommend specific designs for the infrastructure development.

IPAS provides the capability to identify the intersection of proposed features such as drilling pads, gathering lines, or access roads with sensitive locations. The data layers currently used for this intersection demonstration were obtained from the ANHC. We have also worked with ANHC to map habitats in the FSP. These layers will aid developers in assessment of the likelihood of finding a sensitive species near proposed sites. SSURGO soils layers and extraordinary resource waters (Figure 1) are also available.

On June 12, 2009 the final stakeholder meeting was held in Little Rock Arkansas. At this meeting, the IPAS website was presented to government and industry stakeholders, and they

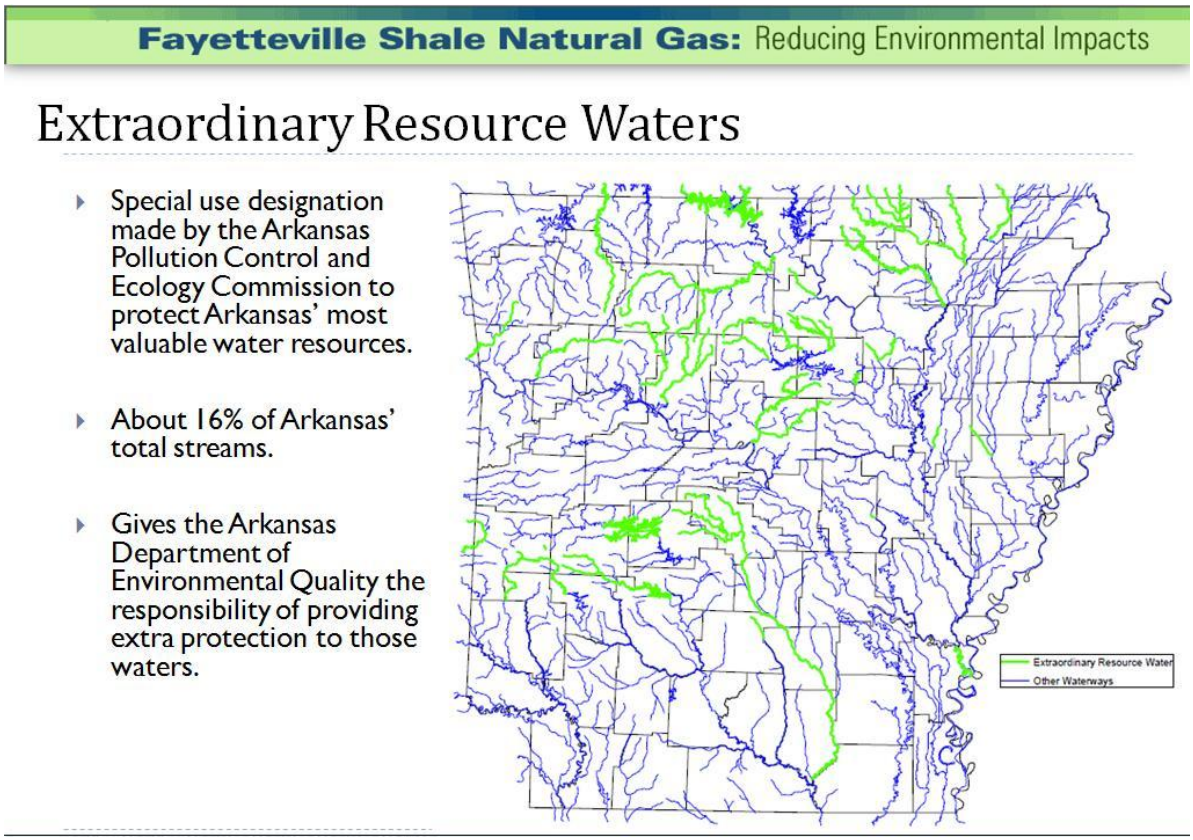

Figure 1. Map of Arkansas ERW

were provided information to allow them to request a logon ID and password.

Project tasks:

Phase 1: Development of Environmentally Friendly Technologies Database

Identify and establish contact with stakeholders.

Education: We have created website as a central location where interested parties can access information about development in the Fayetteville Shale Play, including maps of production data as well as current and pending permits from the Arkansas Oil &Gas Commission (AOGC) and the Arkansas Dept of Environmental Quality (ADEQ). We have received educational information from some of the industrial participants that has been included in the final website. An important aspect of this site is to provide a forum where questions regarding the development of the Fayetteville Shale Play can be answered. The website describes current use of minimally damaging modern technologies in a straightforward manner. Screenshots from the website are provided in Appendix A.

Integration: Improving inter-agency communication during the permitting process would result in a more streamlined mechanism for the cooperation of the agencies involved in the regulation of the FSP. We have agreement with the Arkansas Oil & Gas Commission and the Arkansas Dept of Environmental Quality to mine their data sites for current information regarding permits that can be integrated to an interactive online mapping utility. The information can be screened for active or inactive status as well as the current well status at a particular location. In addition, active permits and production levels can be shown for individual wells or groups of wells.

Data sharing: We have an agreement with the Arkansas Natural Heritage Commission (ANHC) to provide information regarding the location of sensitive species in the Fayetteville Shale Play. This information will be made available through an interactive web mapping service, which will allow users to determine the intersection of, for example, a drill pad with a sensitive location in the play area. Users of the system can create views which can be easily emailed to other system users, in particular developers can send the use to regulatory agencies to prescreen for potential problems at specific sites.

Technology Evaluation

Subtask 1.1 Analysis of existing practices

In June and July, 2007 we visited both SEECO sites in Conway County and Chesapeake sites in White County. The Chesapeake report available in previous project reports, and the SEECO report is available at: http://www.ead.anl.gov/pub/doc/ANL-EVS_R07-4TripReport.pdf

Subtask 1.2: Identification of best practices

The US Fish and Wildlife Service (USFWS) finalized a BMP document for the Fayetteville Shale Play; it is available at the following URL: http://www.fws.gov/arkansas-es/wn.htm. We participated on the panel and reviewed the BMP document during its preparation. This USFWS document forms the basis for the work on this task. We have analyzed the USFWS BMP document and incorporated the GIS data layers that will allow users to identify appropriate BMP information. The IPAS does not make specific BMP recommendations.

Delineate regulatory and environmental concerns in the region and database development

This task is closely linked with the USFWS BMP. We currently have a data sharing agreement in place with the Arkansas Natural Heritage Commission allowing a "red flag" identification of sensitive locations. This level of warning will provide developers the option to avoid environmentally sensitive locations by placement of the feature in a new location, or contact ANHC directly for more detailed species information to allow establishment of save appropriate protective measures in advance of development.

Through extensive discussions with regulatory agencies, we have a clear understanding of the regulatory concerns in the Fayetteville Shale Play. As indicated in the previous reports, Arkansas Oil & Gas Commission has primary governing authority regarding the development of natural gas resources in the Fayetteville Shale Play, beginning with seismic exploration and ending with well closure. The Arkansas Dept of Environmental Quality has jurisdiction over construction, operation, and closure of reserve pits. This authority derives from its responsibility for maintaining the quality of surface waters in the state of Arkansas. The other major regulatory activity in the Fayetteville Shale Play is associated with the U.S. Army Corps of Engineers enforcement of section 404 of the Clean Water Act relating to the construction of

small reservoirs for collection of surface water necessary for fracture jobs, and for other infrastructure development that has the potential to generate sediment loading in streams.

Through discussion with regulators and industry representatives, we have identified the major concerns that are associated with the development of the Fayetteville Shale Play: water supply and water quality both for surface waters and groundwater. Residents in the area are concerned about potential impacts to drinking water wells, while others are concerned about adverse impacts to fishing streams. According to the USFWS, the most significant environmental impacts are associated with sediment runoff into local streams that affects aquatic species.

Adapt fate and effects and ecosystem effects models

A significant environmental concern is sediment runoff, and models designed to predict levels of runoff will be useful in managing ecosystem risk during development. Figure 2 shows the preliminary influence model based on a flow partitioning steepest descent topography analysis (Tarboton, 1997). The potential placement of the reserve pit on different sides of the pad affects the region most likely to be impacted by a spill. The black squares are potential reserve pit failure locations.

Habitat mapping in the FSP was conducted in collaboration with the USFWS and ANHC. While it is not possible to predict the location of sensitive species, it is possible to make recommendations that cautious development occur in specific habitats. These warnings have a "yellow flag" level. Manual collection of habitat distribution data throughout 1.5 million acres (approximately under lease) of the Fayetteville Shale Play would be cost prohibitive. Therefore, it is desirable to develop a modeling strategy which can predict areas most likely to contain sensitive species. Development of a habitat distribution model would require following information:

- Important habitat characteristic data

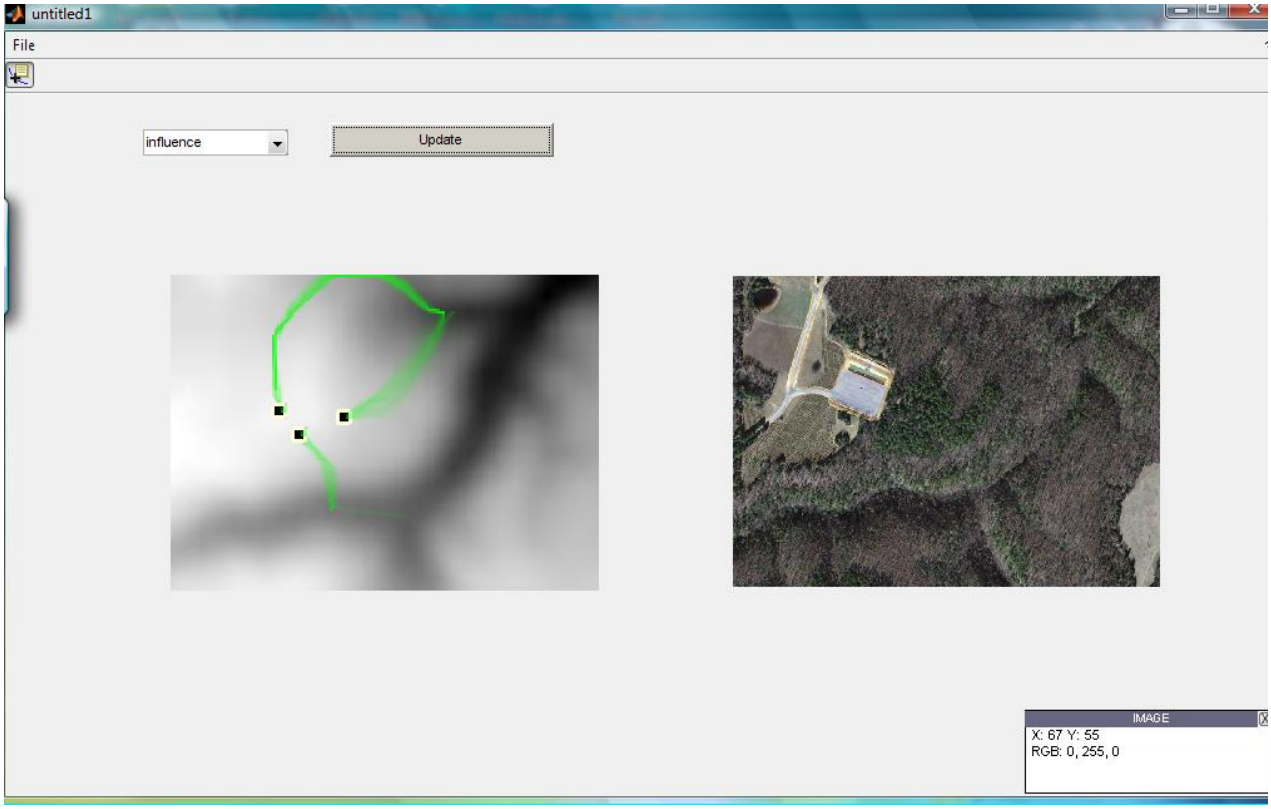

Figure 2. Influence zone of a spill depicted as green highlight. The computational algorithm identifies the direction of steepest descent and partitions flow to adjacent grid elements based on the direction. This algorithm allows for flow spreading where earlier steepest descent approaches send all flow into the lowest adjacent element

- spatial distribution of the characteristics on the study site

The important habitat characteristics may include all or some of the following factors: vegetation type, distance from water body, soil type, availability of nesting spots, topography, population density, etc. The characteristics of a field site in question are compared with the characteristics of the habitats known to have target specie(s).

Phase 2: Preparation of decision support tools –Infrastructure Placement Analysis System

The Infrastructure Placement Analysis System provides regulators and gas producers operating in the Fayetteville Shale Play with a platform to assess potential environmental impacts of proposed well pad, reserve pit, compressor station, gathering line, and road placements. The system is web-based and provides access to current geospatial data layers from a variety of sources. A screenshot of the interface is shown in Figure3 and additional screenshots are given in Appendix B. A list of available data layers is provided in Table 2.

A graphical user interface has been created in which standard map navigation tools as well as special icons are available to activate a Feature Placement Tool. This tool allows users to propose a location for well pad (with associated reserve pit), gathering line, or road using all available layers as a guide. After placement, the system will report potential environmental impacts.

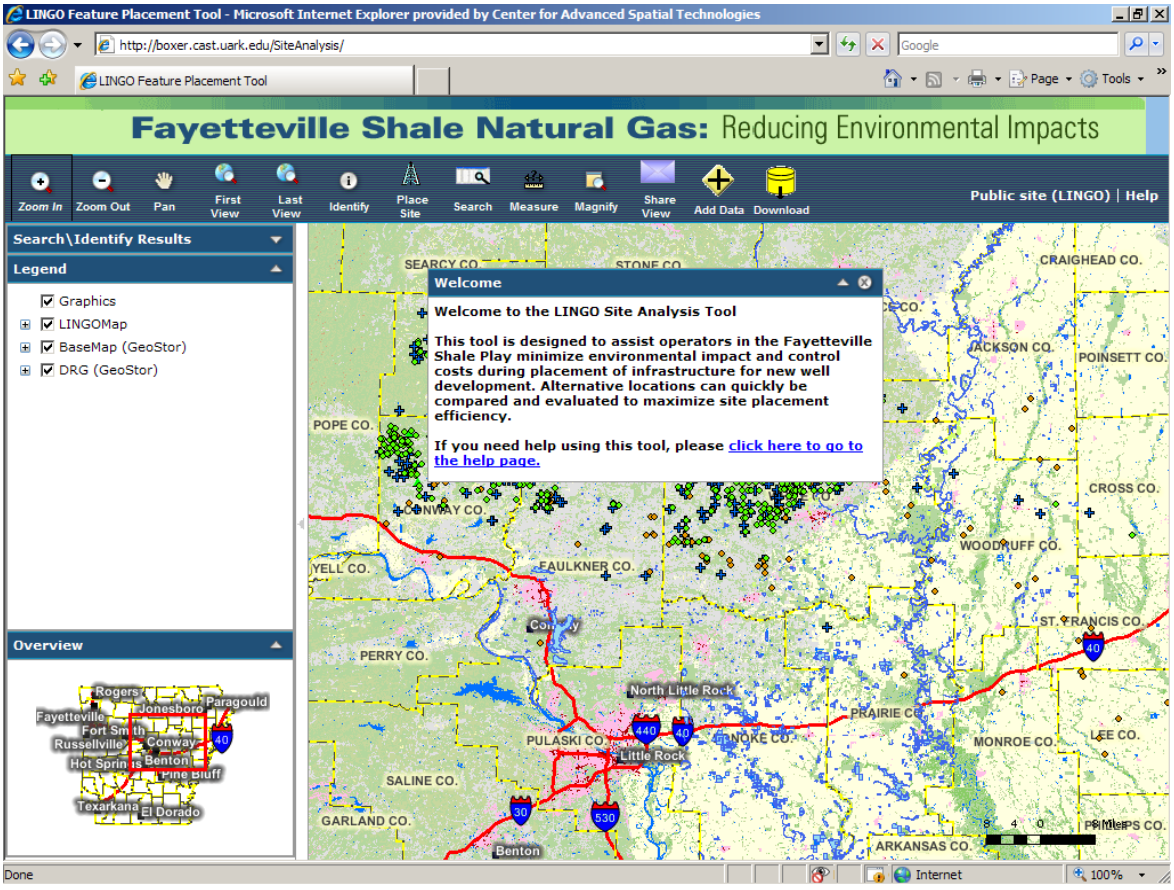

Figure 3. Fayetteville Shale Infrastructure Placement Analysis System. IPAS allows users to place features on the map and provides information regarding proximity of areas sensitive to impact.

Table 1 Partial list of data layers available in the Fayetteville Shale Natural Gas GDSS

Source	Layer
US Geological Survey	National Elevation Dataset (NED will serve as the basis for all terrain based decisions such as slope, aspect and flow)
US Geological Survey and US Environmental Protection Agency	National Hydrology Dataset (1:24,000 scale)
Arkansas Geographic Information Office	Arkansas Road Centerlines
Arkansas Geographic Information Office	Public Land Survey System (Township, Range and Section corners)
Arkansas Geographic Information Office	2006 Orthophoto Image Base (0.33 – 1.0 meter GSD)
Arkansas Geographic Information Office	Arkansas political boundaries (county, city)
Arkansas Natural Heritage Commission	Threatened and Endangered Species (Red Flag version)
Arkansas Natural Resources Commission	Location of known wetlands
Arkansas Natural Resources Commission	Watershed boundaries
US Forest Service	Public forest boundaries
US Census Bureau	TIGER Road Features
Bureau of Land Management	Public land boundaries
Arkansas Oil and Natural Gas Commission	Existing drill pad and well locations (permit status and production history)
Arkansas Oil and Natural Gas Commission	Locations of major gas transmission lines
Arkansas Department of Environmental Quality	Locations of reserve pit locations and permit status
Arkansas Natural Resources Commission	2006 Land Cover
Natural Resources Conservation Service (US Department of Agriculture)	Soil Survey Geographic Data (SSURGO)

Two primary users are envisioned: 1) regulators at AOGC, ADEQ, and ANRC who will have easy access to complex geospatial analysis to inform permitting decisions, and 2) producers who wish to vet infrastructure placement proposals and expedite permitting by efficiently communicating with regulators. After several meetings with both regulators and producers, it

is clear that the data layers underlying the system must be recognized by all parties as current and accurate. Therefore, we have placed a high priority and expended significant effort to develop technical relationships with AOGC, ADEQ, ANHC, and ANRC to ensure the currency of geospatial layers available to the IPAS.

The layers which are not developed by these agencies are recognized components of the Arkansas State and US Federal infrastructure and are accompanied by Federal Geographic Data Committee (FGDC) metadata. The system complements existing Fayetteville Shale Play informational websites, such as the Arkansas Oil and Gas Commission (AOGC) map service which provides access to well permit and production status. It will complement the Arkansas Department of Environmental Quality (ADEQ) site at which users can search for NPDES Permits by county, organization or permit number. ADEQ issues permits related to reserve pit construction and removal.

Another component of the IPAS is an integrated view of the permit status of wells.

In addition to providing a contextual view of proposed infrastructure placement, the system provides quantitative assessments including, but not limited to:

Proximity to threatened and endangered species habitats,

Delination of potential run-off areas based on local terrain, soil type and land cover,

Proximity to bodies of water and a traces from that body up the watershed, and

Infiltration potential.

Potential environmental impacts identified by the IPAS can be electronically forwarded to a variety of agencies or individuals for review. Impact information will include detailed reasons behind the assessment, an estimate of the likelihood of the impact and a URL which will direct the recipient to the same map view (including active layers) used to generate the report. Producers and regulatory officials with whom we've met all agree that this immediate electronic exchange of detailed information will increase the speed with which various permits can be submitted, reviewed, and issued. Producers of natural gas in the Fayetteville Shale Play will be able to better plan drilling activities, reducing costs caused, for example, by equipment scheduling delays. Regulators can likewise better manage environmental impacts by immediately having access to a analysis of impacts within the scope of their authority.

Despite the scope and sophistication of the IPAS, it is clearly designed to be a planning tool and is not intended to replace on-site surveys, which are required to establish applicable best management practices. As an example of the limits of the tool, consider proximity of a placement to a local water body. Proximity to down-slope surface water is a major limiting factor in road construction but existing hydrographic layers only locate streams to within 100 feet. Likewise, knowledge of local elevation is limited to heights at 30 meter intervals. Aerial imagery can, in some cases, be used to reduce error in relative distance measurement but only an on-site survey can accurately establish proximity. In addition, terrain relief and soil type used to assess run-off can only be accurately surveyed on site. However, because the system takes into account imprecision and uncertainty in the underlying geospatial data layers it provides enough information to filter for potential for environmental impact the full set of possible infrastructure locations and thus limit the number of required on-site surveys. The GIS layers listed in Table 2 also reflect information required to recommend a BMP based on the US Fish and Wildlife document mentioned as part of Tasks 1.2 and 2.

Finally, because many of the geospatial layers listed in Table 2 are from national datasets or layers readily available in most states, the IPAS can be exported to other regions of the country where the environment impact of drilling activities is a concern.

Integrate map products with risk analysis modules

The geospatial decision support system described above represents the current use of map products in the project. As indicated previously, we have included spatial uncertainty analysis based on buffer zones that are related to the defined spatial uncertainty of the data layers that are used in the decision making process. A risk assessment would include both the likelihood of occurrence and the cost consequences of a specific event. In the current context a traditional risk analysis is not necessary to provide adequate decision support. This arises from the fact that, for example, the likelihood of erosion associated placement of a pad or access road is essentially certain. Therefore the risk can be directly correlated with the consequences. These in turn are directly related to the geospatial characteristics of the site being developed, and these data are represented by the GIS data layers available in the project.

Web deployment

The educational/outreach site and the IPAS are hosted at: http://lingo.cast.uark.edu.

Testing and technology transfer

We sponsored a session at the International Petroleum Environmental Conference in November 2008 where the modules were demonstrated. In addition, the IPAS tool was demonstrated to regulators and industry representatives in a day workshop held in Little Rock, AR on June 11,2009.

Conclusions

Funding

This project was selected under DOE's Low Impact Natural Gas and Oil solicitation, February 2006.

Anticipated DOE Contribution: $499,582

Performer Contribution: $136,832 (30% of total)

Contact Information

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Appendix A:

Screen shots of the educational website.

Http://lingo.cast.uark.edu

Figure A1. Introductory page for the public educational website

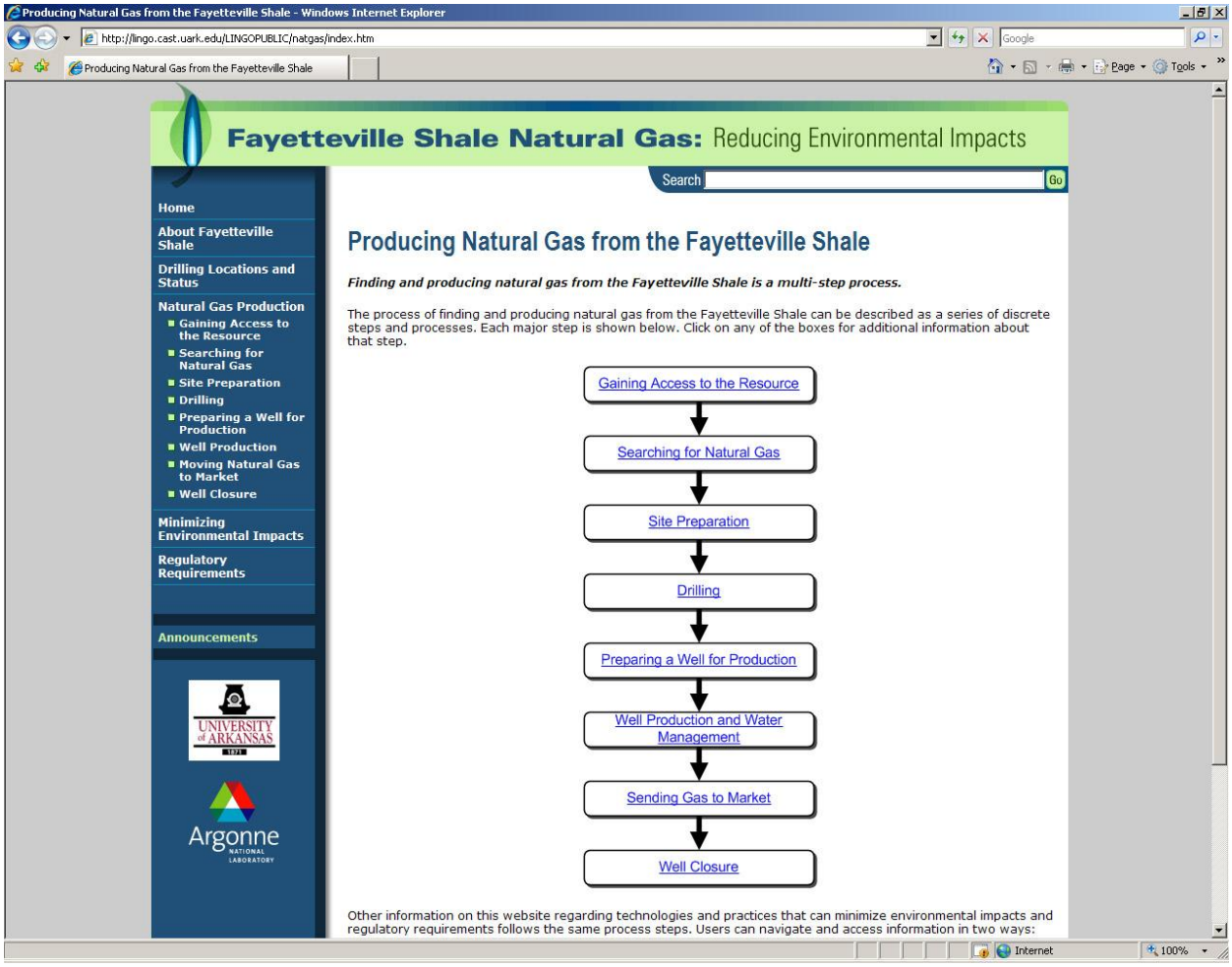

Figure A2. Screenshot showing the structure of the website, based on the life cycle of natural gas production in the Fayetteville Shale Play.

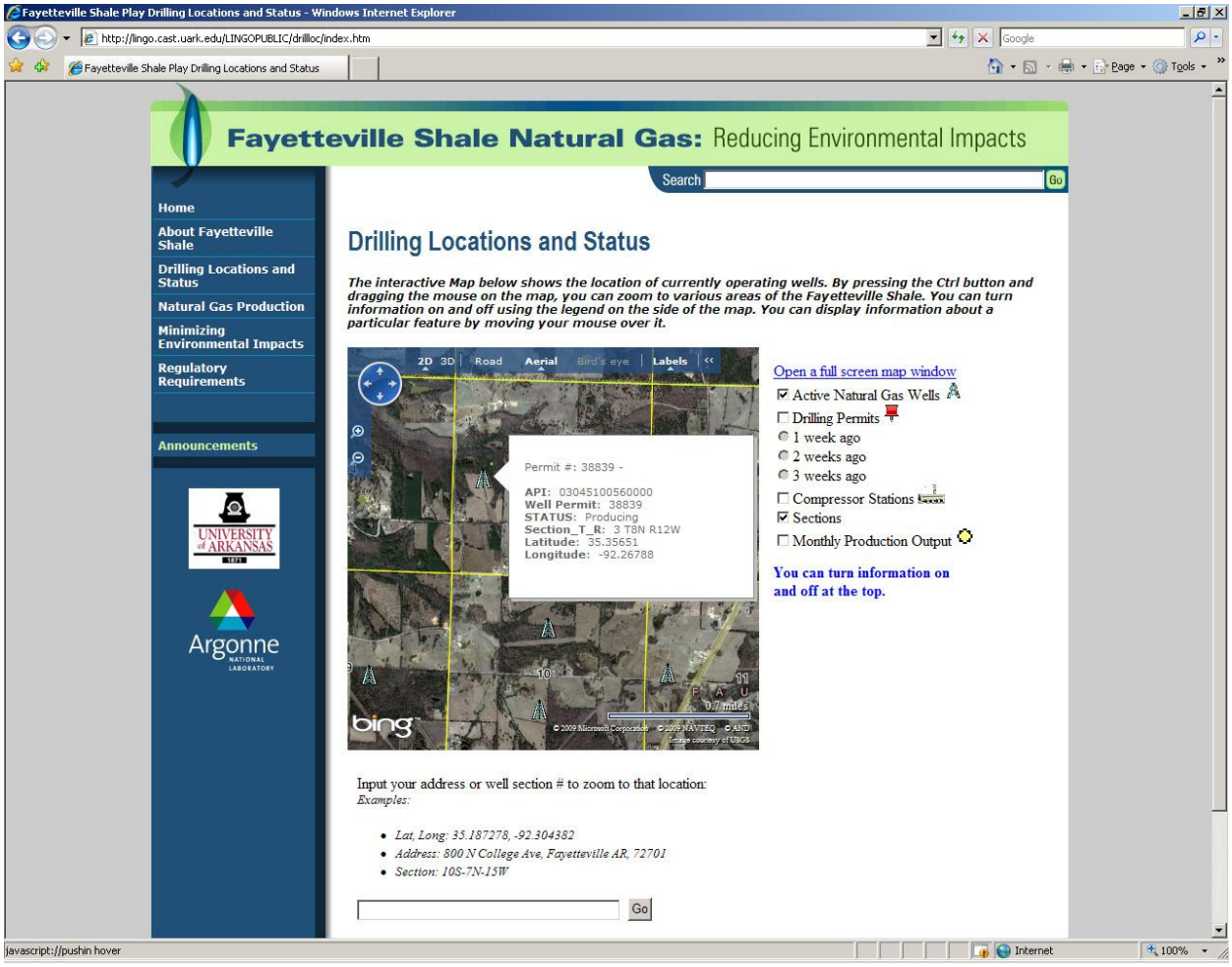

Figure A3. The educational website has an interactive mapping feature, that will allow users to find information about individual wells, as well as information regarding well permits.

Appendix B:

Screen shots of the IPAS website.

Http://lingo.cast.uark.edu

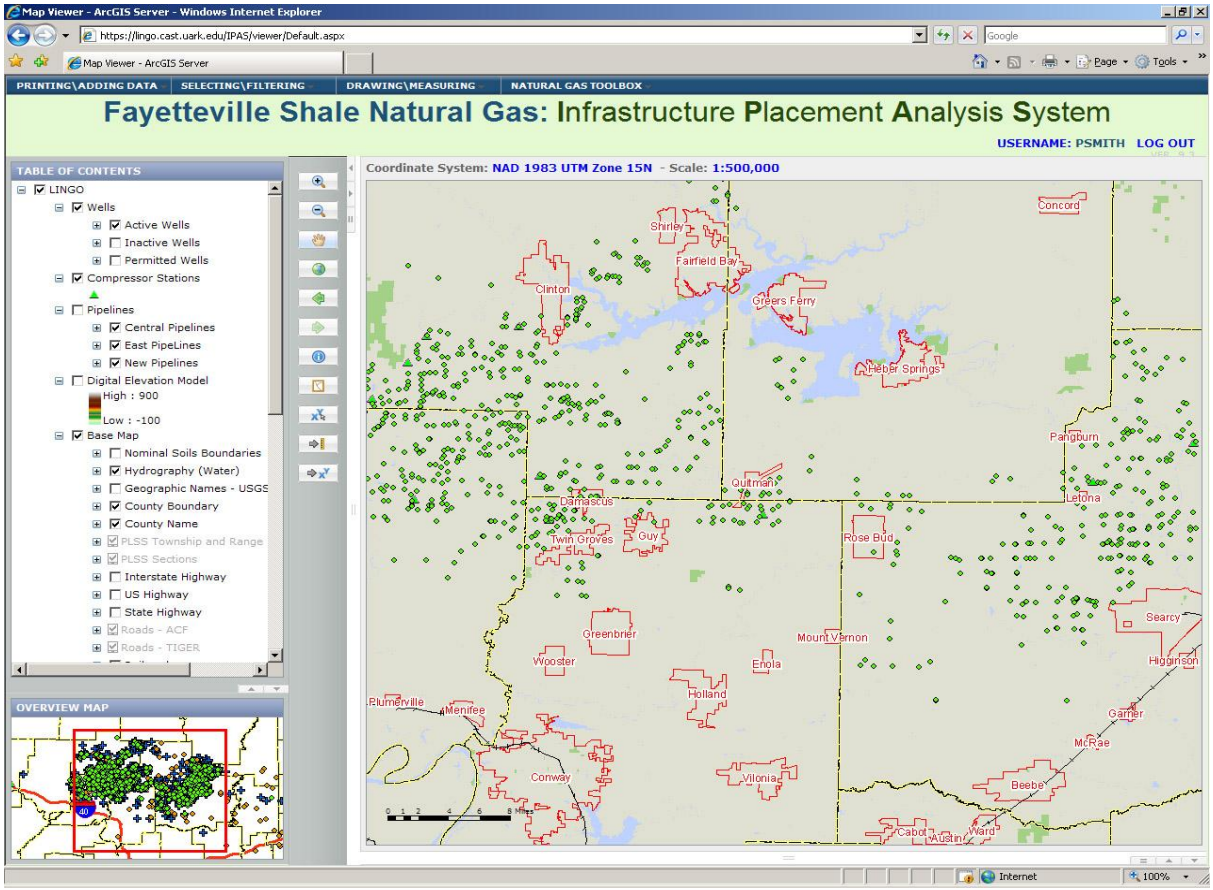

Figure B1. The IPAS viewer displays wells and infrastructure against a background of standard map layers.

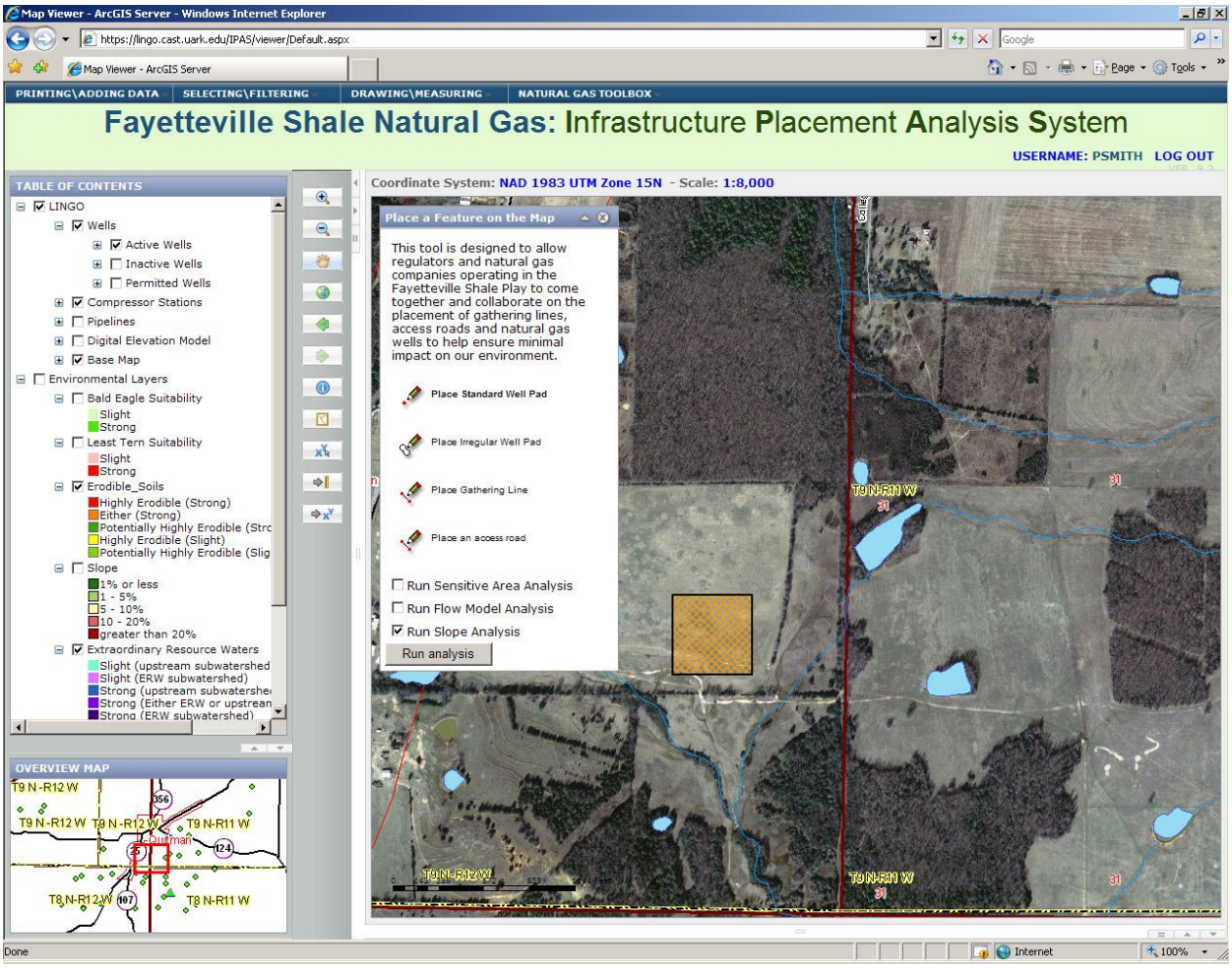

Figure B2. The Place a Feature tool allows a producer to propose a location for a well pad, gathering line, or access road and then run one of three different analyses.

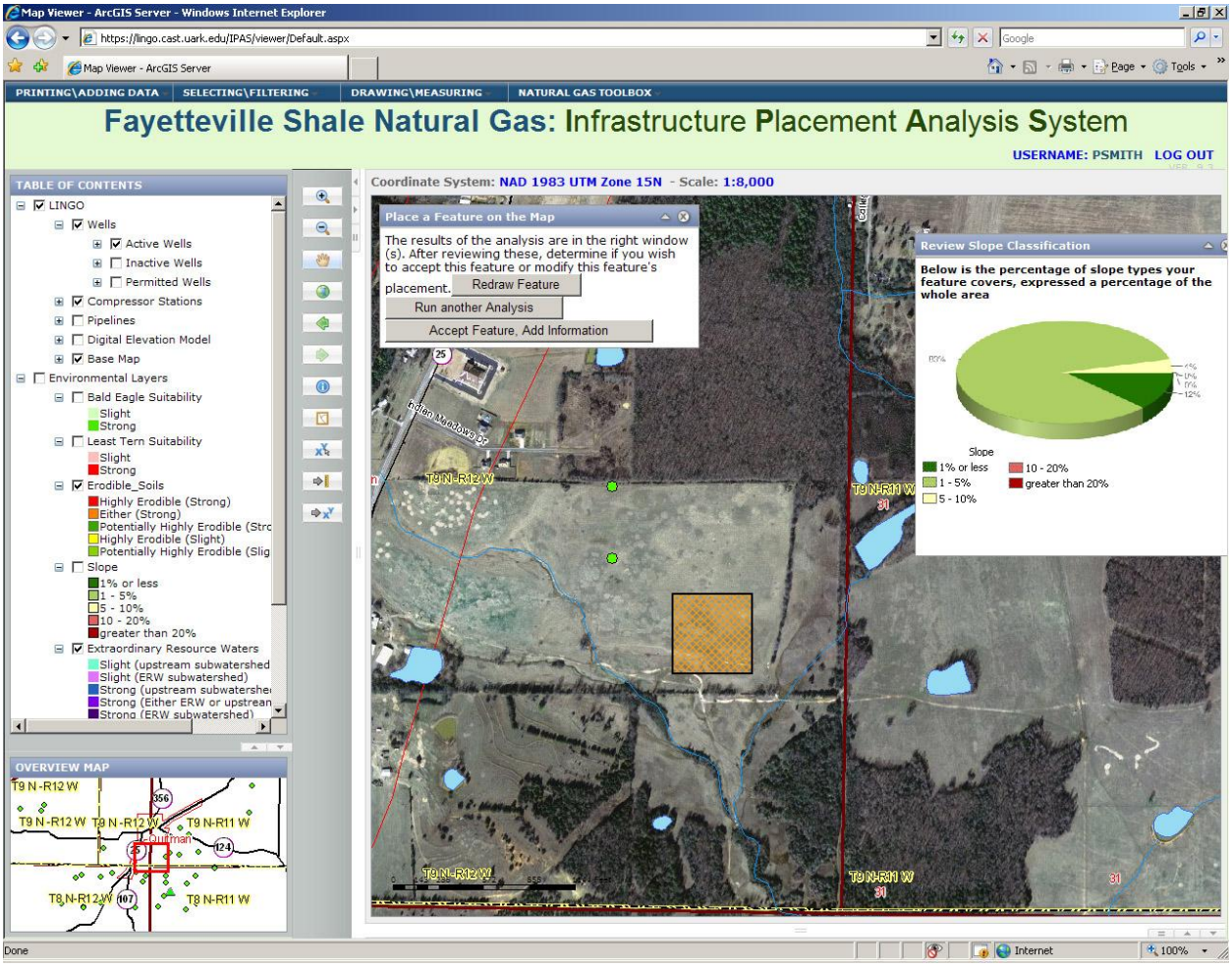

Figure B3. In this example, a standard well pad feature has been proposed, and the Slope Analysis has been run. Reviewing the graph, it appears that most of this pad is found on 1 to 5% slope.

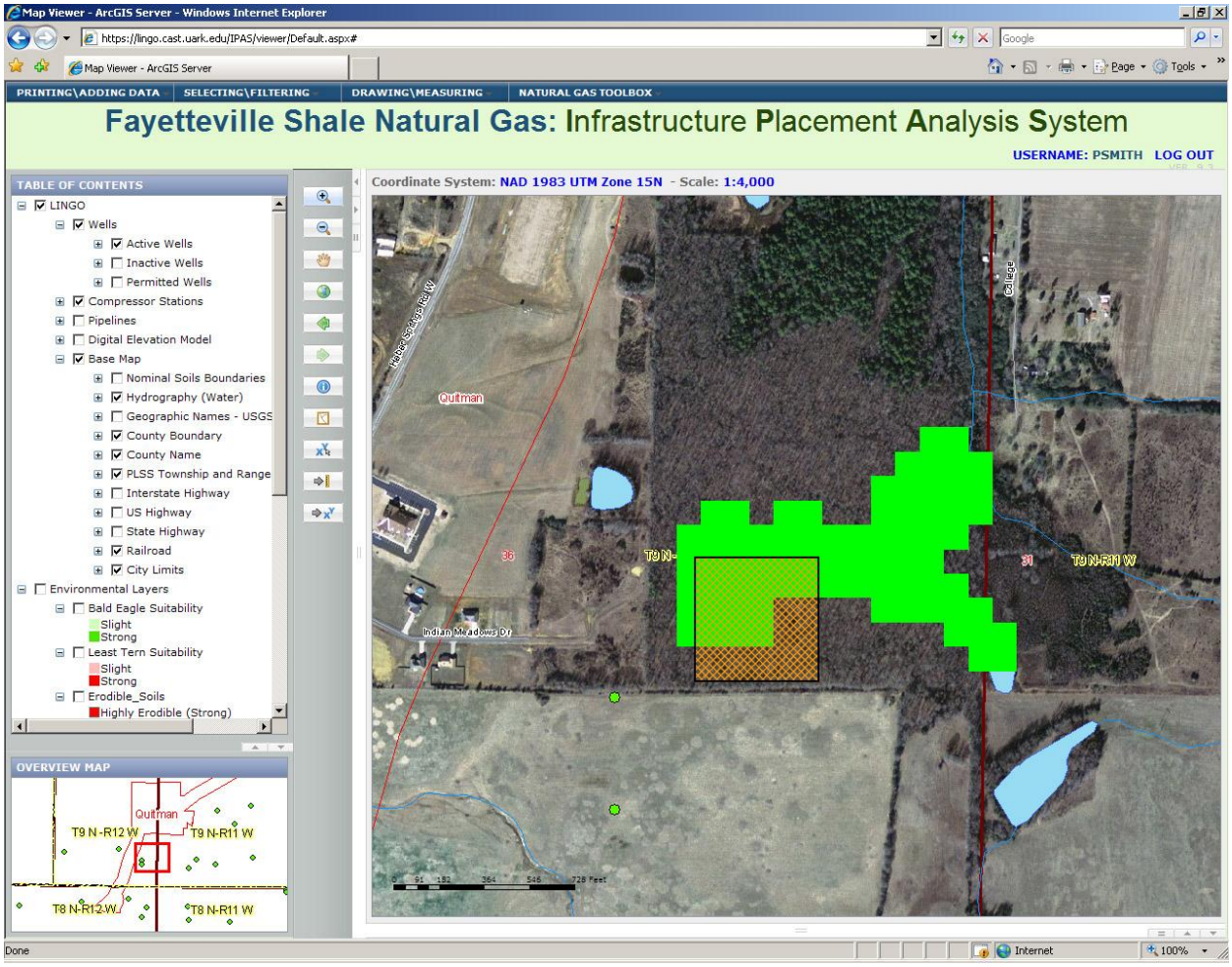

Figure B4. The spill model shows the flow path from all locations within the propose well pad until flow reaches the closest water body or bodies.

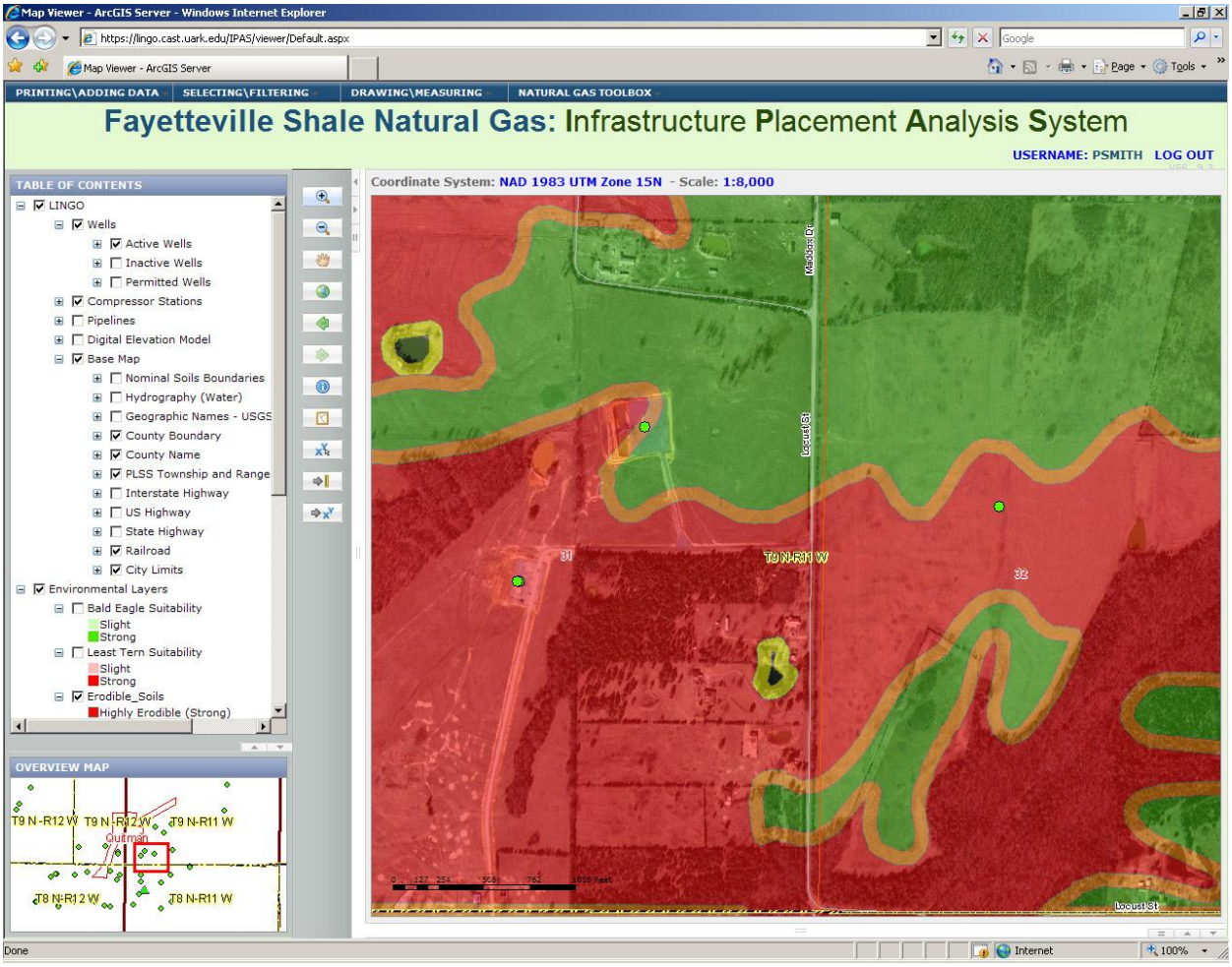

Figure B5. Soil data is classified by erodibility – note the orange zone between the red and green areas, representing the uncertainty in the spatial location of the boundary between categories.

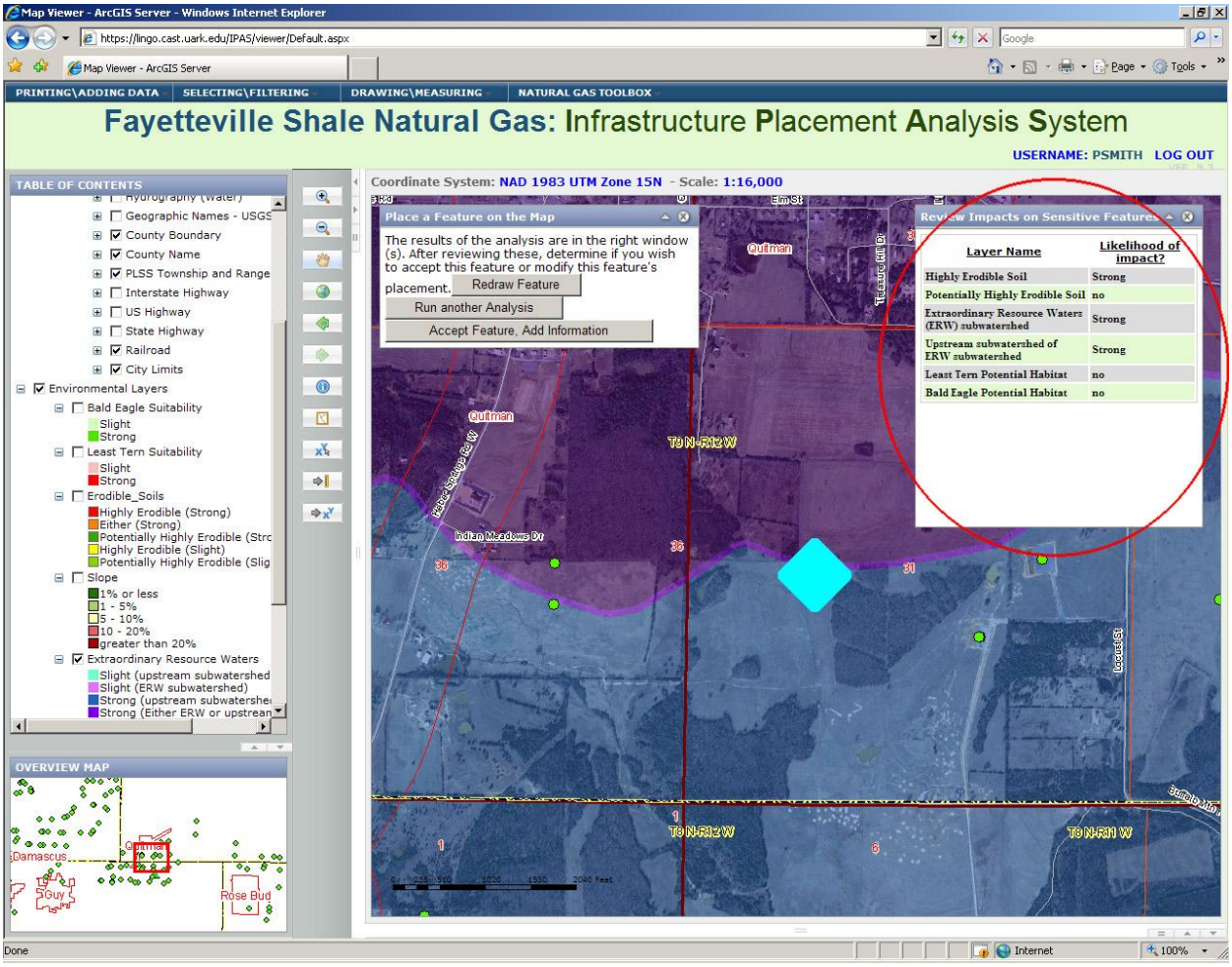

Figure B6. The results of the Sensitive Areas Analysis indicate that this proposed well pad has a high likelihood of impacting highly erodible soils and Extraordinary Resource Waters.

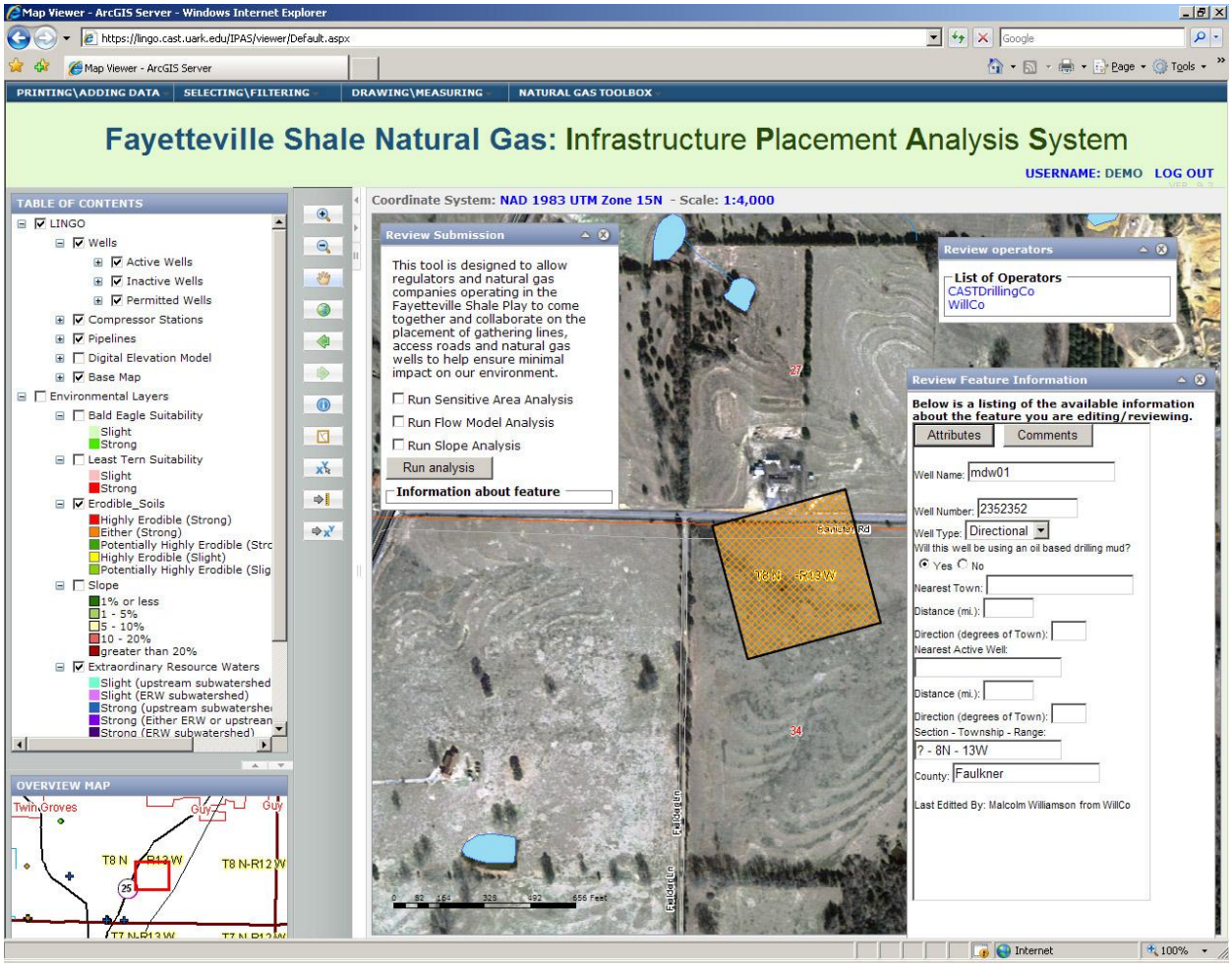

Figure B7. After running the desired analyses, the proposed well pad has been submitted by the producer and may be reviewed by a regulator.

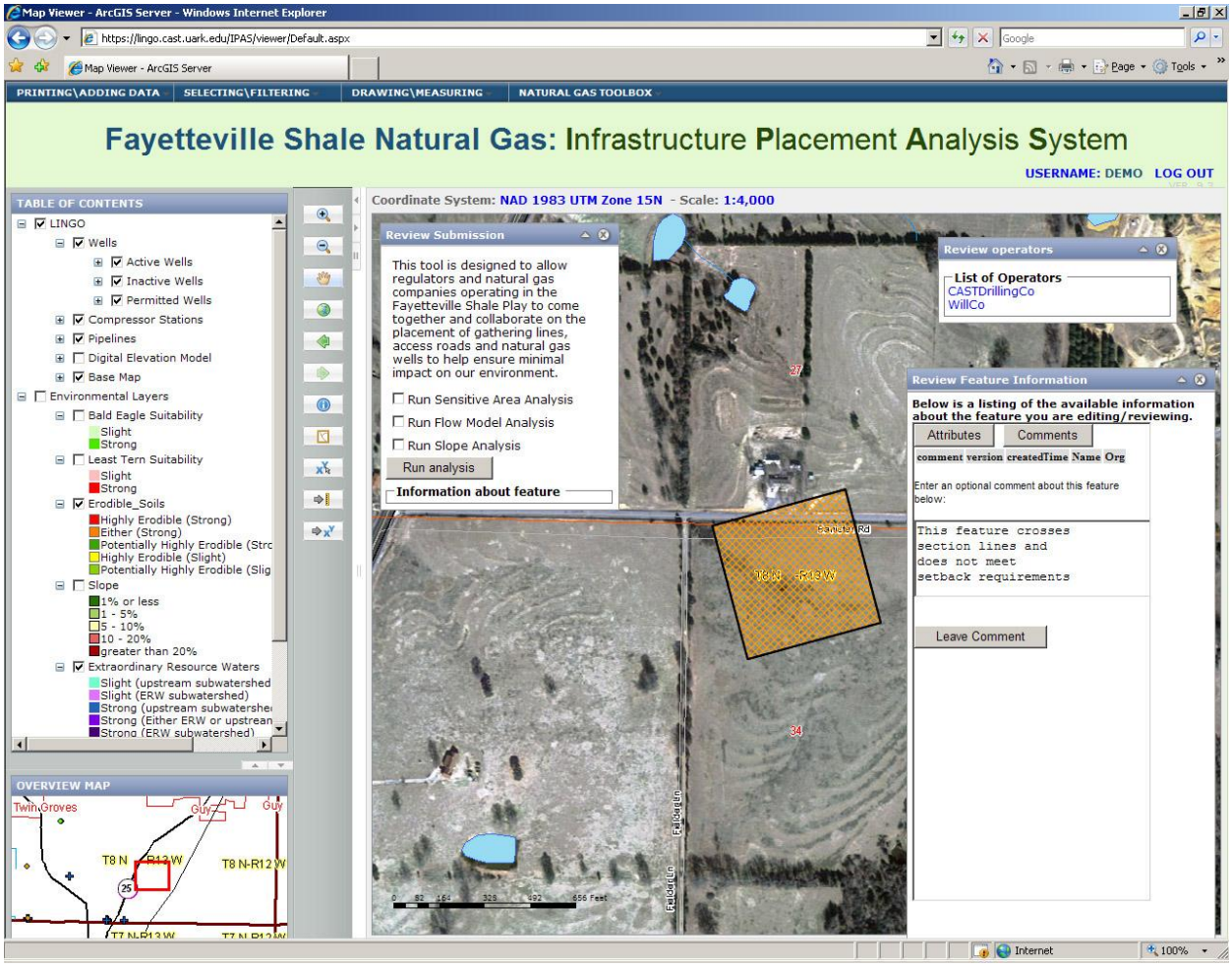

Figure B8. The regulatory reviewer can provide feedback on the proposed feature and return it electronically to the producer, streamlining the permitting process.