Petroleum GIS Perspectives

Esri • Fall 2011 GIS for Petroleum

Subsurface Modeling of Directional Well Bores at Fidelity Exploration & Production Company

Barbara Shields, Esri Writer

Petroleum geologists have honed skills and technology to understand oil production and subsurface relationships such as formation properties, sources of petroleum, and how well bores are engineered. They study how a rock formation is fractured to create fissures that allow petroleum to seep through the formation to the well bore. John Farrell, GIS manager at Fidelity Exploration & Production Company, has been studying one such factor—rock units. By using geographic information system (GIS) technology to model rock layer data, he created visualizations that suggest relationships between rock units and well bore productivity. Looking at what happened in the past adds to the exploration department's understanding of where to drill in the future.

Rock data collected at the time a well was drilled is a history of a subsurface event that can be visualized on a map. After running this data through a model in ArcGIS, one can create 3D maps that show where well bores corkscrew their way down through the earth's crust (figure 1). This phenomenon is difficult to see on a two-dimensional map or cross-section view. The 3D map is more intuitive to people in exploration and production who are accustomed to thinking in three dimensions. Farrell and his team of GIS specialists created subsurface modeling of directional well bores in the Bakken Formation, Mountrail County, North Dakota.

"It is useful to see which rock unit was penetrated by which well bore and the oil production rates," said Farrell. "This type of model is interesting to potential drillers because it shows that a well bore went down this way and intersected a particular rock unit. By knowing that the well was a good producer, geologists might infer that this combination of engineering factors and well bore path through the rock unit are probably related."

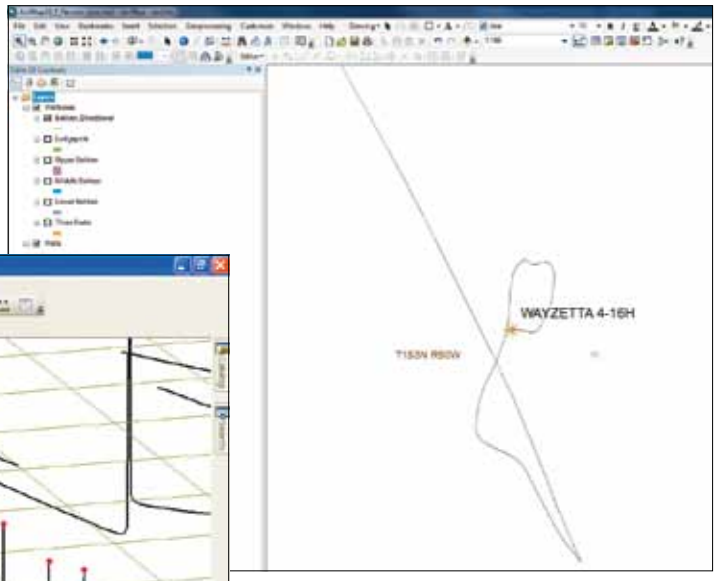

Figure 1—A zoomed-in view shows a well bore corkscrew effect. The sharp turn northwest corresponds to the horizontal kickoff.

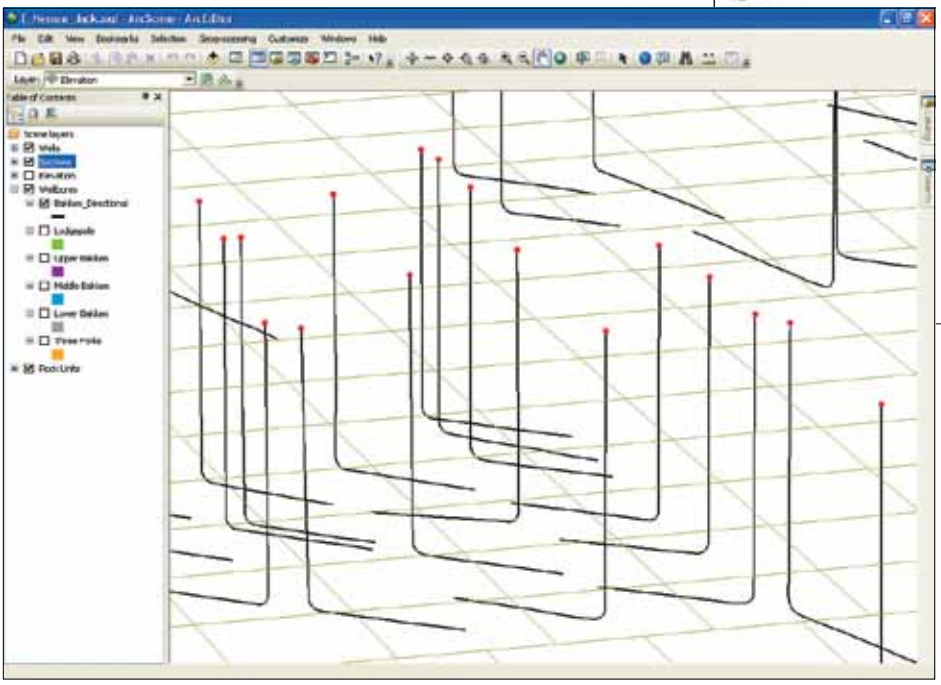

Figure 2—An Oblique View of Several Digital Well Bores

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Save the Date for Esri's Petroleum User Group Conference

Esri's Petroleum User Group (PUG) Conference is essential for oil, gas, and pipeline companies looking to improve their field management operations. We invite you to mark your calendar for the PUG Conference, to be held April 30–May 2, 2012, in Houston, Texas. Learn how new advances in ArcGIS integrate systems, making them accessible by all.

Participate by submitting to the Map Gallery, Lightning Talks, or paper sessions via the event website. Watch for website updates about speakers, sponsors, exhibits, and PUG socials. Learn more and register at esri.com/pug.

Petroleum GIS Users Meet at the Esri International User Conference

Petroleum GIS users were well represented at the Esri International User Conference (Esri UC) in San Diego, California, July 11–15, 2011. Of the more than 13,000 attendees, 450 work or plan to work in the petroleum and pipeline industries including geologists, information technologists, engineers, corporate analysts, and university students.

Offering nearly 300 technical sessions, the Esri UC was a sea of knowledge and experience where attendees were immersed in ideas about geospatial technology, applications, software integrations, and innovations applicable to their needs regardless of the size of their systems or organizations. Many petroleum/pipeline-relevant technical sessions were offered such as ArcGIS 3D Analyst—Working with Terrain Datasets, ArcGIS for Land Management, Image Processing, Managing Imagery and Raster Data Using Mosaic Datasets, and Managing Your Mobile Workforce.

"The Esri UC is the one mandatory event I need to go to every year. If I don't go, I don't know how to plan for the year. It helps me decide what we need to do and how to spend our resources," said J. B. Akin, GIS technology manager, SandRidge Energy.

Successful petroleum-specific case studies and applications were presented and demonstrated. Exploration and production topic titles included 20 Years of GIS in YPF, Argentinean Oil; Creating a Safe Zone for Locating a Subsalt Well Location; Marcellus Shale: Pioneering the Terrain and History within Appalachia; and Profiling Lake Ice Using GIS, GPS, and Ground Penetrating Radar—A Model Behavior That Could Be Used in Modeling the Behavior of Petroleum Products. Some paper and technical sessions have been posted on esri.com and are accessible via the Search the UC Proceedings tool.

Oil and pipeline maps were displayed in the Map Gallery such as the McGraw-Hill, Platts *Gulf of Mexico Oil Transportation* map and the Department of the Interior's *Science Supporting Gulf of Mexico Oil-Spill Response, Mitigation, and Restoration Activities: Assessment, Monitoring, Mapping, and Coordination* map.

Networking and developing professional ties are always invaluable Esri UC take-aways. On Tuesday night, the Petroleum User Group (PUG) met at a partner-supported event for dinner, music, and roundtable discussion. Sponsors for the PUG socials were Coler & Colantonio, Critigen, Idea Integration, IHS Energy, Spatial Dimension, and Trimble.

Sponsors also participated in the Esri UC EXPO, a bazaar of hundreds of GIS-related vendors, consultants, and experts. Here, users had questions answered, tried out hardware and software applications, and met with people who advised them about ways to improve their systems and become more efficient.

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Subsurface Modeling of Directional Well Bores at Fidelity Exploration & Production Company

The most difficult component of this project was gathering data from various data sources and ensuring that quality assurance steps were followed to clean the data. The structure surfaces of rock units used in the study are the product of well-by-well identification and correlations of wire line log data or mud log samples by the corporation's geologists as well as GPS surveys of as-built well locations. Other data resources included commercial data sources; proprietary data sources such as PETRA projects; and North Dakota Industrial Commission (NDIC)/ Department of Mineral Resources survey plats, directional survey records, and planning reports. Pulling this data together and categorizing it was a meticulous process that accounted for at least half the project's time. Geotechnical specialists copied the data to the Directional Survey Data table in PETRA, making it convenient to export it to other applications.

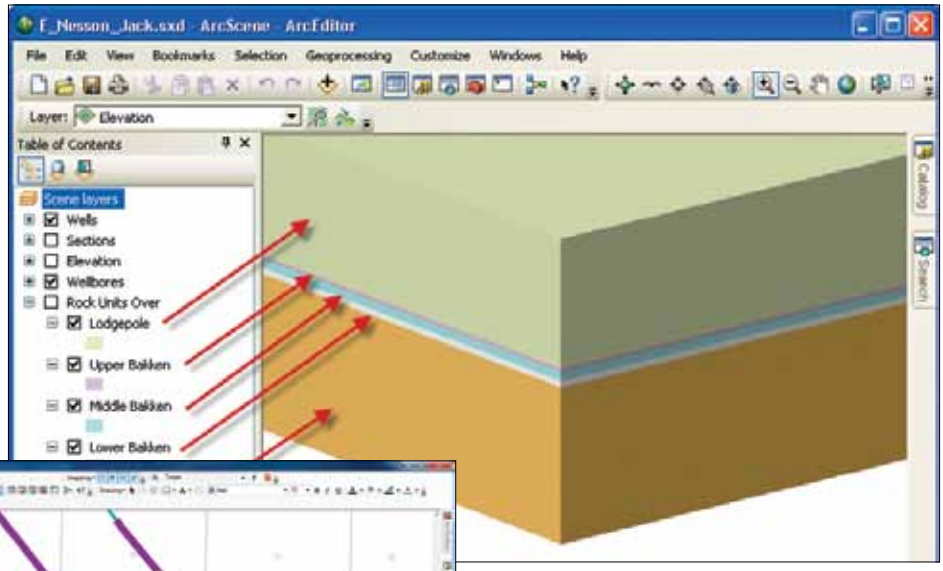

Figure 3—Multipatch Features Representing Rock Units

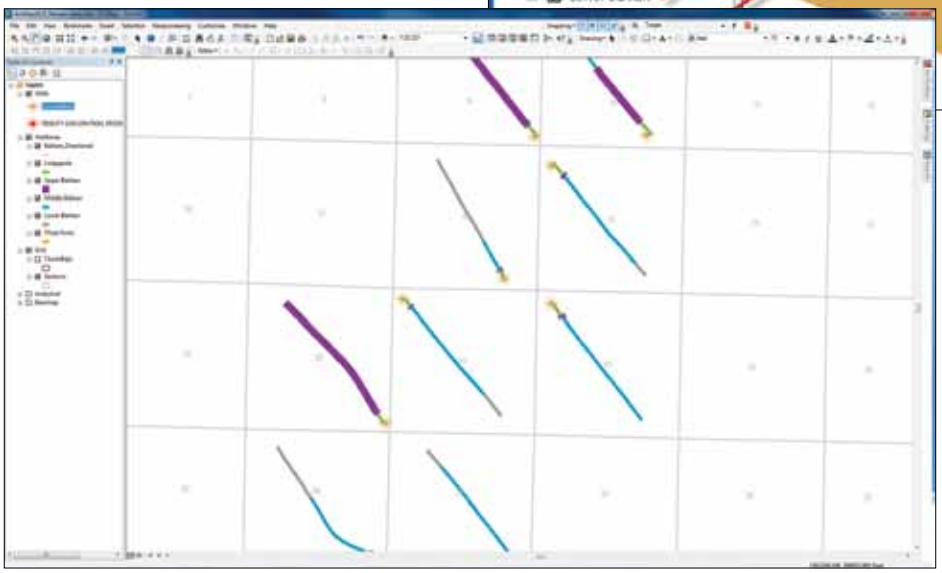

Figure 4—Map of Well Bores Penetrating Specific Rock Units

The project team customized an application to normalize the coordinate reference systems for all the spatial data. The team exported data from PETRA to ArcGIS to hang well bore points for each well vertically from the well's location. These locations are recorded in the XML file exported from the well location feature class. The vertices of each well bore are positioned relative to the surface location of the well. Custom software written by Fidelity Exploration & Production Company is used to construct the spatial representation of the well bores.

The resultant polyline feature class includes one polyline per well and is z aware to render it in 3D using ArcGIS 3D Analyst extension. The team also used this 3D tool to view a solid model of the rock units and see which solids are penetrated by the digital well bores.

Based on wire line and mud log data, the company's geologists interpreted the subsea depths of the structure tops of rock units. From these interpretations, the team created triangulated irregular network (TIN) datasets and used them as the starting point to construct a 3D solid model of the rock units in the Bakken Formation.

PETRA software made it possible for the geographic coordinates and subsea depth of grid values representing each structure top to be exported to an ASCII file. Grid cell attributes, including longitude-latitude and z options, were loaded into dBASE files via Microsoft Access and then conveniently loaded into ArcGIS tables for processing.

The Make Feature Layer and Create TIN tools in ArcMap were used to create georeferenced points with z-values for each member of the Bakken Formation. The Extrude Between tool in ArcGIS 3D Analyst specified stratigraphically adjacent TINs as the input values to create solid volumes for rock units. Using ArcGIS modeling tools, the team produced maps showing which well bores intersect or terminate in specific rock units (figures 3 and 4).

"The use of ArcGIS for subsurface geologic modeling is demonstrated with this project," said Farrell. "Given the advancement of the solid modeling tools introduced with ArcGIS 10, the possibilities for additional analyses are attractive to both geologists and GIS specialists."

For more information and to get the white paper *Use of ArcScene 10 for Subsurface Modeling of Directional Well Bores in the Bakken Formation, Mountrail County, North Dakota*, contact John Farrell, Fidelity Exploration & Production Company, Denver, Colorado, at John.Farrell @fidelityepco.com.

Learn more about ArcGIS 3D Analyst at esri.com/3danalyst.

Wind Farm GIS Optimization Model Improves Design Process

By Meagan Krawczyk, Contract Wind Energy Analyst, Shell Wind

Effective wind farm layout design is critical to the success of any wind project. Currently, the most common practice is to design a layout that achieves maximum energy production, quantified as a capacity factor (the ratio of actual output of energy over a period of time and its output if it had operated at full capacity). However, it is more efficient if the wind farm modeler also includes an analysis of the economic tradeoffs between more efficient wind capture and increased project construction and operating costs. GIS can be used to meet the complexities of including cost optimization in the wind farm design process.

The traditional design process is to study site and wind conditions, calculate energy optimization, and finally create the wind farm layout. This approach does not consider project costs related to roads, cables, construction, and other factors until after a layout has been created. Some wind farm engineers choose to perform optimization analysis separately. The wind farm design would be more efficient if engineers and modelers would employ the alternate model, cost of energy optimization, that includes project cost metrics in the layout design phase and uses this information, along with wind and site data, to guide turbine placement.

AWS Truepower, LLC, developed openWind, a software program for designing, optimizing, and assessing wind farm projects. By using it in tandem with ArcGIS, wind farm modelers can include optimizations of grid, energy, and cost for energy analysis to determine the cost of energy associated with a given wind farm layout.

A wind resource grid, turbine specifications, site constraints, turbine spacing, and defined site-specific characteristics are needed to complete an optimization analysis.

Wind Resource Grid (WRG): This file defines the wind regime based on wind frequency and direction. Input a digital elevation model (DEM), a land-cover/roughness file, and meteorological data in the form of a .tab file to define wind frequency and direction.

Turbine Specifications: Input the attributes that define the height of the turbine, the turbine blade length, how much power the tur-

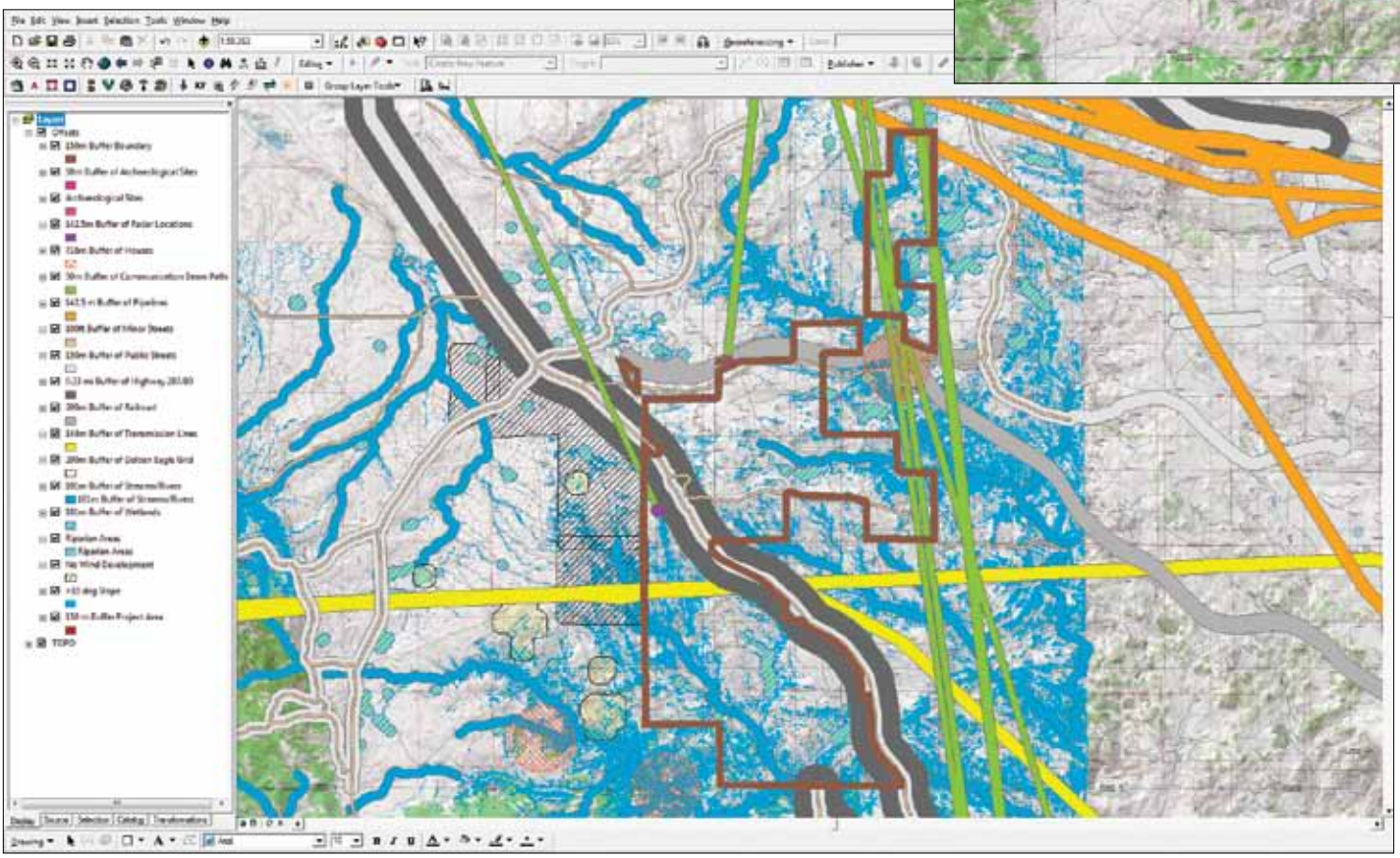

Figure 1—Federal Site Constraints

bine will put out related to wind speed, and so forth.

Site Constraints: These are areas where turbines cannot be sited. Shell Wind's procedure is to input shapefiles representing various site characteristics,

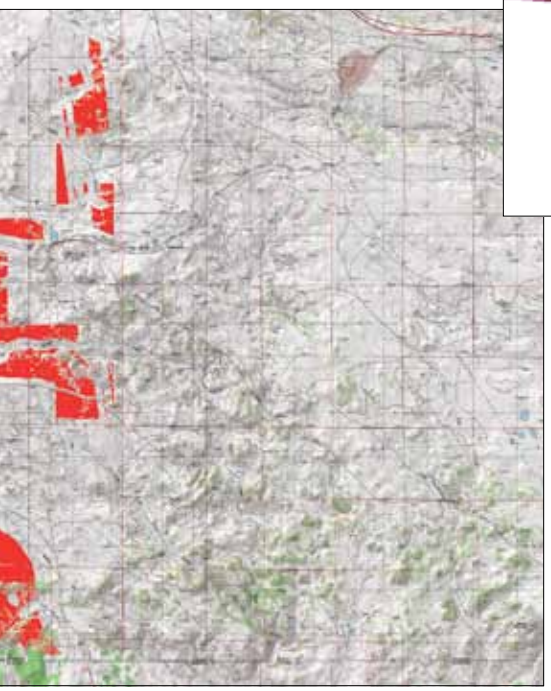

Figure 2—Buildable Area

such as roads, water bodies, transmission lines, pipelines, and steep terrain, into the GIS and create buffers for them that meet site-specific setback requirements (figure 1). Shell Wind uses ArcGIS to merge, dissolve, and invert buffers to show a buildable area where turbines can be placed (figure 2).

Turbine Spacing: How far apart to space turbines is defined by the characteristics of the wind for the site. The modeler will define a minimum and maximum turbine spacing based on the wind rose. For example, the wind rose in figure 3 indicates that wind is dominant out of the west, and little to no wind is coming out of the north or south sectors. The spacing would therefore be higher in the west–east direction than in the north–south direction. Defining how far apart turbines are spaced is important, because if turbines are placed too closely together, they begin to affect each other with turbulence and

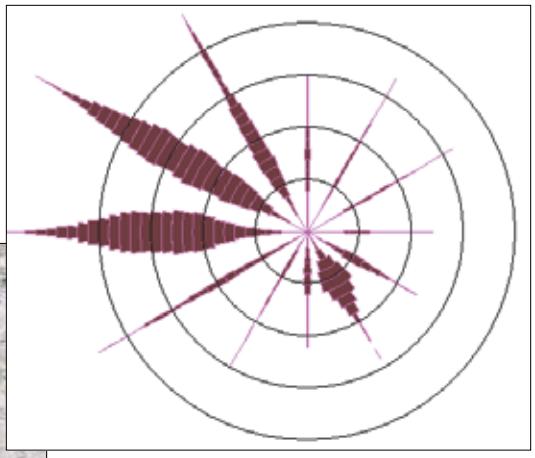

Figure 3—This wind rose indicates that wind is dominant in the west.

a slowing and diversion of the wind—this is the wake effect. Turbulence is caused by spinning blades that create the wake that affects turbines downwind from the front of the layout. High turbulence can damage turbines and decrease their energy production.

Once all necessary files have been entered and characteristics defined, the layout is ready to be optimized. There are three options for designing a layout in openWind: gridded, optimized for energy, and optimized for cost of energy.

The gridded layout tool produces compact layouts that fit into a defined area. This tool is well suited to layouts for offshore wind farms where there is a fairly uniform wind resource and few natural obstacles.

The energy optimizer uses the WRG to design a layout that should, in theory, capture the most energy. This optimizer can create layouts that are widely distributed and not designed very well from a construction point of view.

The cost of energy (COE) optimizer integrates the cost of construction and operation and allows those costs to be offset by the turbine energy production. Part of this calculation includes looking for the best wind resource and lowest wake effects. To run this optimizer model, additional files must be input and cost characteristics defined such as cable, road, and turbine costs as well as financial assumptions.

Cable costs include cost/km of cable, running cables along roads, and substations. Road costs include cost/km of building new and using existing roads, steep terrain definitions, and cut-and-fill definitions. The turbine cost mostly includes the foundation, the turbine, and periodic turbine component costs, which can be defined as a function of the site suitability assessment. Financial assumptions include the total life of the wind farm, the debt ratio, and annual costs.

COE results also require shapefiles or rasters for roads, cables, and water bodies as well as information that should be considered as a cost-multiplier layer. For example, the costs for crossing rivers can be applied per geometry object. This methodology truly leverages the ability of ArcGIS to integrate site survey information into shapefiles. In a similar manner, the modeler can include cost savings such as existing roads, with each road segment having its own upgrade cost. The modeler defines a start node for the collection system (substation) and for the road network. All this information is used to assess the cost of energy associated with a given layout.

The output for all three of these optimizers is a turbine layout, which Shell Wind uses to produce energy estimates for a specific site and layout. In addition, the COE optimizer also produces a collection system and road network in the form of polylines and includes costs and lengths for roads and collection systems in the energy estimate.

When comparing the estimated energy of the energy optimized layout to the COE layout, the observation is that the layout plan that includes COE will generally have lower gross energy and capacity factors than the energy optimized layout. This seems logical, as the energy optimized layout focuses on producing the optimal layout for the wind resource on-site, and the COE optimizer focuses primarily on lowering the cost per megawatt-hour of the layout. This then leads to the COE layout's estimated cost generally being lower than the energy optimized layout's cost. Figures 4 and 5 display the COE layout versus the energy optimized layout. Note how condensed and linear the COE layout is compared to the more distributed energy optimized layout.

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Wind Farm GIS Optimization Model Improves Design Process

The COE layout appears to have greater impact for sites that have a low ratio of turbines to land. If the site is highly constrained (too little available land) and the turbines are packed in tightly, the COE layout will turn out to be very similar to the energy optimized layout.

Using the highest-resolution DEM available is important because it supports more accurate road and cable design when the program is calculating steep terrain and cut-and-fill costs, for example. Additionally, testing a few different locations for the road and cable nodes could be beneficial, as shifting these nodes can create varying layouts and, in turn, alter the estimated costs.

The openWind compatibility with ArcGIS allows users to take advantage of the advanced functionality and wealth of data associated with ArcGIS programs to collect and prepare input data for project design. Additionally, incorporating GIS resources into wind farm layout design has helped mature the layout optimization process. This enables Shell Wind's engineers and wind farm modelers to work together more dynamically on cable and road design and create a more efficient wind farm plan.

For more information about wind energy projects, visit the American Wind Energy Association website (www.awea.org). For more information on openWind and for a free download of the software, visit www.awsopenwind.org.

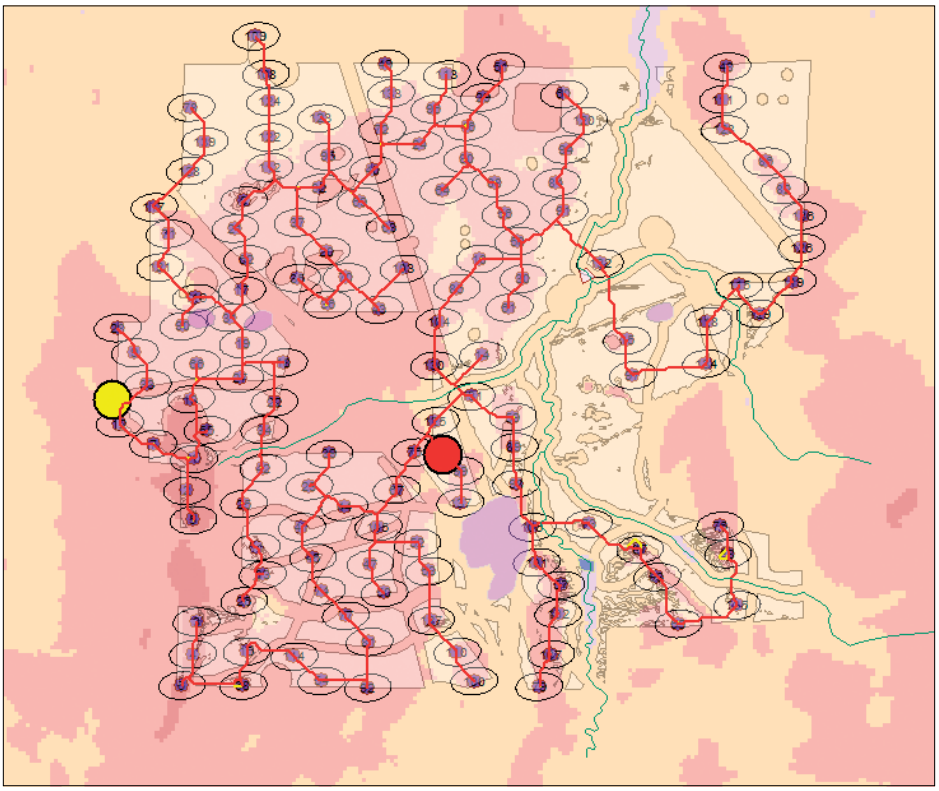

Figure 4—Cost of Energy Optimized Layout

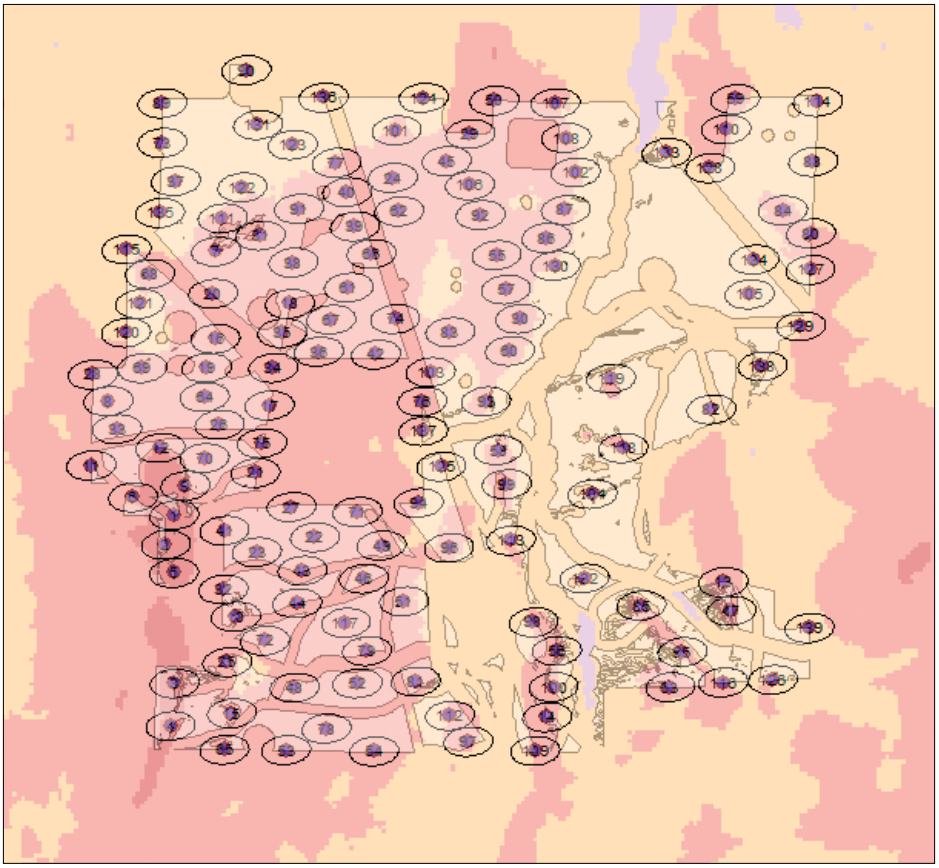

Figure 5—Energy Optimized Layout

About the Author

Meagan Krawczyk is a contract wind energy analyst with Shell Wind in Houston, Texas. She has been part of the Wind Resource Team at Shell since October 2010; some of her work includes designing layouts and defining constraints for Shell's business development sites, performing due diligence on acquisition projects, and benchmarking Shell Wind's projects against competitor projects.

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