Identifying Constraints on Increased Natural Gas Production in Southern West Virginia

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Creating a Statewide Digital Pipeline Map

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Draft Final

January 2009

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Evaluating Drilling and Production Trend Information

Introduction

The West Virginia Geological and Economic Survey (WVGES) oil and gas database was used to construct a series of maps and graphs to examine geographic and temporal trends in gas production in the State. Individual well location, completion and production data were combined for this analysis. Completion and location data are available for wells drilled in the State beginning in 1929, when permitting became required. The first individual annual and monthly production data were reported in 1978, with a small number of records. Production reporting has become more complete over time, as numerous wells drilled prior to 1929 that are still in production have been added to the database. The names of various gas reservoirs and their relative positions to one another are shown in Figure 1.

Historical Overview of Drilling Trends in West Virginia

To document the trends of drilling and production over time, a series of maps and graphs have been prepared. Maps showing gas wells completed by decade (Figures 2) show how the focus of gas well drilling has shifted over time. The pre 1930's wells (Figure 2) were closely associated with the development of oil fields and were concentrated in the northwestern part of the State. The 1930's wells (Figure 3) were also concentrated in the northwestern part of the State, although some wells were drilled in south central and southwestern West Virginia. Development of the giant Elk-Poca (Sissonville) Oriskany gas field began in 1934. In the 1930's, drilling to the Devonian Lower Huron Shale began in the Big Sandy area, adjacent to the Kentucky border. During the 1940's. (Figure 4) drilling was focused on the continuation of development in Elk-Poca (Sissonville) and Big Sandy areas as well as shallow Big Injun development in central West Virginia. Also in this decade, two fields were discovered in the fractured Huntersville Chert-Oriskany Sandstone play in Preston (Terra Alta field) and Tucker (Canaan Valley field) counties. In the 1950's, (Figure 5), drilling was concentrated in southwestern West Virginia to the Lower Huron Shale, and in west central West Virginia where the Big Injun was the main target. Additional drilling in eastern West Virginia included the development of the Glady field in Randolph County and the Augusta field in Hampshire County.

The 1960's saw the introduction of the new completion technique of fracturing. This led to major developments in north central West Virginia (Figure 6) in Upper Devonian sandstones such as the Benson, which previously had been considered too tight (lacking permeability) for gas production. In addition, additional Oriskany fields were discovered in Hampshire and Hardy counties. Also, prolific wells were drilled to the Newburg sand in Jackson and Kanawha counties.

The 1970's (Figure 7) was a period of continued development of the Upper Devonian tight sands, such as the Benson, in north central West Virginia. However, deeper drilling to the Oriskany farther to the east resulted in discovery of the Keyser field in Mineral County in 1978. This discovery touched off interest in the "Eastern Overthrust" belt by a number of large companies. Meanwhile, drilling in southeastern West Virginia to Mississippian reservoirs such as the Big Lime and the Ravencliff began.

The passage of the Natural Gas Policy Act in 1978 stimulated additional drilling to Devonian shales and tight sands (including many below the Benson) that continued through the 1980's. The high prices for oil and gas in the early 1980's coupled with tax credits provided for by the Natural Gas Policy Act led to an explosion in drilling activity for the first half of the decade (Figure 8). New gas wells were drilled in a broad swath across northern West Virginia, and the discovery of oil in the Devonian shales in Ritchie and Pleasants counties, at a time when oil reached record high prices ($30/barrel), sparked much drilling in the vicinity of the Burning Springs anticline. In southern West Virginia, development of tight Mississippian reservoirs such as the Ravencliff continued.

Drilling of deep Oriskany wells in the Eastern Overthrust Belt continued. The Jordan Run field in Grant and Pendleton counties was discovered and developed, and the Headsville field in Mineral County also was developed. Additional deep wells were drilled in the Canaan Valley field, and the Shavers Fork field in Randolph County was discovered.

Drilling in the 1990's (Figure 9) continued, but at a slower pace than in the 1980's, probably due to lower gas prices. Scattered Oriskany wells were drilled in eastern West Virginia. The Thornwood Oriskany field in Pocahontas County (discovered in the 1960s) was put into production and additional wells drilled. The South Burns Chapel Huntersville-Oriskany field on the Monongalia/Preston county line was expanded and an in-fill drilling program provided additional production.

The 1990's also saw the beginning of the State's coal bed methane (CBM) industry, stimulated by passage of legislation (1992) modeled after that of Virginia. In the late 1990's, new technology for drilling CBM wells (multilateral horizontal drilling in a pinnate pattern) was developed by US Steel for their Pinnacle Mine operations in McDowell and Wyoming counties. This technology allows for rapid production of gas from coal seams prior to their underground mining. The 2000's (Figure 10) have seen continuing development of CBM using horizontal as well as vertical wells in southern and to a limited extent northern West Virginia.

Also in the late 1990's, a high-volume, deep discovery well in the Ordovician Trenton-Black River carbonates in Roane County sparked renewed interest in deep drilling. About 300 wells were permitted targeting the Trenton-Black River in the late 1990's and early 2000's, but only about 10% of these wells were actually drilled.

However, drilling to the deep Ordovician carbonate section led to the current drilling trend, because gas was encountered in the lower part of the Devonian shale section in some unsuccessful Trenton-Black River wells. In the mid-2000s, following a large discovery in southwestern Pennsylvania, operators began looking at the oldest and deepest of the Devonian shales, the Marcellus. The application of new technology to drill and stimulate the Marcellus has made this play more appealing to operators from other basins. Horizontal drilling is being used to develop the Marcellus in a number of counties in northern and central West Virginia. Horizontal drilling also is being used with success in the Lower Huron Shale in southwestern West Virginia. High prices throughout much of 2006, 2007 and 2008, coupled with increased demand for energy, also has been a factor, leading to increased interest in gas production throughout the State.

Data Analysis

A closer examination of drilling activity in southeastern West Virginia (Figures 11-19) indicates that drilling was very limited prior to 1930 and through the 1930's. Some drilling began to occur in the 1940's in central Wyoming County, and continued into the 1950's and 1960's, along with drilling in central McDowell County. The 1970's saw development of the Mississippian Weir sand in the Ashland-Clark Gap-Eckman field in eastern McDowell and western Mercer counties. By the 1980's, drilling was more widespread across southeastern West Virginia. In the late 1990's and early 2000's, CBM development occurred at a rapid pace, with high volume, short-lived pinnate wells becoming common.

In northern West Virginia, the closer views show a much different scenario than that of southeastern West Virginia (Figures 20-28). The pre-1930's wells are relatively densely drilled; limited additional drilling to the east (Upshur County) began in the 1930's and continued into the 1940's, expanding into Barbour County. Most of this drilling was pursuing the Benson. The 1950's, 1960's, and 1970's saw a continuation of these drilling trends and the Benson and the deeper Alexander sandstone were developed into western Randolph County. Additional drilling occurred in the 1980's in eastern Taylor County in shallower Upper Devonian sands like the Fourth and Fifth. In the 2000's, interest in CBM and in deeper Marcellus in northern West Virginia was coupled with continued drilling of various Upper Devonian tight sands.

Over time, wells have been drilled deeper and deeper, although the trend is not necessarily as systematic as might be expected. Figure 29 shows average total depth for gas wells by decade. From the pre-1930's wells through the 1940's, the average total depth increased as new development of Devonian shale and Oriskany wells occurred. Average total depth decreased in the 1950's, as operators shifted their focus to shallower targets such as the Big Injun. The advent of fracturing in the 1960's did not forestall a further decrease in the average total depth. In the 1970's and 1980's, average total depth increased as operators drilled new wells to the Devonian shales, Upper Devonian sands such as the Benson and deeper sandstones, and Oriskany wells in eastern West Virginia. The 1970's was also a period of deep exploration in the Rome

Trough of western West Virginia, where several new basement wells were drilled. Average drilling depth decreased slightly in the 1990's and early 2000's, as coal bed methane wells became more common, but should increase again as more Marcellus wells are drilled. The average total depth of gas wells tracks fairly closely with the average total depth of all wells (Figure 30). The deepest total depth of all wells (including dry holes) by decade (Figure 31) reflects more of a trend of deeper drilling over time, with the deepest well drilled in the State to date being drilled in Calhoun County in 1974 to a total depth of 20,222 feet.

Locations of producing gas wells at 5 year intervals were plotted (Figures 32-38). Production data were first reported to the WV Department of Environmental Protection Office of Oil and Gas beginning in 1978. The percentage of producing wells with production reports has increased over time. In 1980, the number of producing gas wells was 8,857 (Figure 32). By 1985, the number of gas wells with production reports had increased to 26,407 (Figure 33). By 2005, the number of gas wells with production reports had increased to 46,328 (Figure 37). This increase in the number of wells is due to more than just new wells being drilled.

In 1980, (Figure 32), the producing gas wells were clustered in north central West Virginia and southwestern West Virginia, reflecting production in the Benson and Devonian shales, respectively. In 1985, (Figure 33), producing wells were more widely distributed in the western two thirds of the State, with some producing wells in the eastern counties. In 1990, (Figure 34), the 34,203 producing gas wells were distributed across an area very similar to that of 1985. By 1995, (Figure 35), some additional producing wells were added in Mason and Cabell counties as well as further east in Mercer, McDowell and Wyoming counties; 38,308 wells had gas production reported in 1995. Reporting problems in 2000 (Figure 36) kept the number of wells with gas production records at 32,218; there were scattered new wells in eastern Randolph, Mercer, McDowell and Wyoming counties. In 2005 (Figure 37), there were 46,328 gas wells with production records, with most production remaining in areas with historic production. Figure 38 shows producing gas wells in 1985 and 2005; areas with production in 2005 and not 1985 are more obvious in the southern counties.

Closer views of southeastern West Virginia (Figures 39-45) show only scattered producing wells in 1980 (Figure 39). In 1985 and 1990, there were more producing wells in McDowell, Wyoming, Mercer and Raleigh counties (Figures 40 and 41). By 1995, the first cbm wells were drilled in Wyoming County (Figure 42). The cbm activity continued through 2000 and 2005 (Figures 43 and 44), along with other drilling programs targeting the Big Lime and Berea. Figure 45 shows just the 2005 producing gas wells; many more wells were producing in 2005 than in 1980.

In northern West Virginia, the closer views (figures 46-52) show a major increase in the number of wells in 1985 (Figure 47) compared to 1980 (Figure 46). This is due largely to improvement in reporting, with some additional drilling especially in northwestern West Virginia. Some additional infill drilling occurred in north central West Virginia, resulting in additional gas production in 1990 and 1995 (Figures 48 and 49).

CBM wells also began producing in Monongalia County in 1992; these are vertical gob wells with relatively small amounts of production compared to the pinnate pattern wells in southern West Virginia. Figures 50 and 51 show only a few additional producing wells for 2000 and 2005. Figure 52 shows only the 2005 producing wells; in the core area of Upshur, Harrison, Doddridge, Lewis, Gilmer and Ritchie counties, the density of wells is much greater than that shown for southern West Virginia in Figure 45.

Annual gas production was summarized by county (figures 53-82) and in Table 1 for the period, 1979 through 2007. In the beginning of this period, 1979 Figure 53), the most productive counties were Harrison, McDowell and Lewis, in that order. In 1980, (Figure 54) gas production in Lincoln County moved ahead of Harrison County, but for most of the decade that followed (Figures 55-61), Harrison County was always at or near the top in terms of production. During this same time, other counties emerged as centers of production, namely Kanawha and Lincoln counties in the south, and Barbour and Gilmer counties to the north. In 1988, Kanawha County established itself as the most productive county in the State, and maintained this position from 1988 through 1998 (Figures 62-72), followed by Harrison County, and eventually Wyoming County. In 1992, (Figure 66) Wyoming County moved up to third place in terms of production by county, and maintained that position until 1996, when its production moved ahead of production in Harrison County to assume the second position. For the first time in the period under analysis, two southern counties ranked first and second in terms of gas production by county.

In 1999, (Figure 73), for the first time Wyoming County had the most production, followed by Kanawha and Harrison counties. In 2000, (Figure 74), Kanawha County briefly regained its status as the State's most productive County, followed by Wyoming and Harrison, and two emerging counties, McDowell and Logan. In 2001, (Figure 75), however, Wyoming once again had the most production, followed by Kanawha, Harrison and McDowell, and has maintained its position as the State's leading gas producing county ever since (Figures 76-81). In 2002, (Figure 76), Kanawha County was still the second most productive County, followed by Harrison and McDowell counties, but in 2003, (Figure 77), production in McDowell County moved ahead of that in Kanawha County, and from 2003 through 2007, the two leading counties in terms of gas production have been Wyoming and McDowell, followed by Kanawha County, all southern counties.

In addition to pointing out the obvious on these maps, it should be noted that the volumes of gas produced per county have increased over the years. In 1979, the largest gas volume for a county was 5.98 Bcf; in 2007, the largest volume for a county was 27.5 Bcf. Overall, from 1979 through 2007, (Figure 82, Table 1), four counties have produced more than 300 Bcf: Kanawha, Harrison, Wyoming and Lewis.

Conclusions

There has been an increase in the amount of gas produced in southern West Virginia from 1979 to 2007. Wyoming County gas production has increased from

2,200,120 Mcf (2.2 Bcf) in 1979 to 27,498,068 (27.5 Bcf) in 2007 (Figure 83), more than an order of magnitude increase. McDowell County production has increased from 4.6 Bcf in 1979 to 20.65 Bcf in 2007 (Figure 84), almost a four-fold increase. Kanawha County has consistently been one of the largest gas-producing counties, as have Lewis and Harrison counties (Figures 85-87) in the north.

Much of the increased production in Wyoming and McDowell counties can be attributed to coalbed methane production. The pinnate pattern, multi-lateral, horizontal wells are designed to degas coal seams rapidly and efficiently. The waiver of the severance tax on the first five years of coalbed methane production, coupled with high gas prices, new drilling technology and the need to degas the coal so underground mining could continue, all led to this dramatic rise in production. At the same time, there was very little increase in pipeline capacity in the State, especially in southern West Virginia.

In the latter half of 2008 and early 2009, gas prices decreased and the global economic slow down began to constrain the availability of credit for drilling, so perhaps demands for additional pipeline capacity will lessen. At the same time, however, interest in Marcellus Shale drilling, primarily focused in northern West Virginia, will most likely increase pipeline capacity demands in the northern part of the State. Dominion Transmission has announced a program to expand its capacity, which should improve the situation. Additionally, MarkWest is constructing a new gas processing plant in southwestern Pennsylvania, which should make marketing “wet” Marcellus gas produced in northern West Virginia easier.

The arrival of the Rockies Express (REX) pipeline in Clarington, Ohio from the western states also may impact gas prices and transportation in West Virginia. New markets for stranded western gas will be opened, removing the market access advantage long enjoyed by Appalachian gas producers. Also, the impact of the reactivation of the Cove Point LNG terminal in eastern Maryland, and construction of a pipeline to move this gas into a storage field in central Pennsylvania may add additional availability of gas to northeastern markets which had previously relied on more local sources of gas. The gas market will most likely become even more competitive in the near future with economic uncertainty and the increased availability of gas from other sources. Having competitively priced pipeline capacity readily available to West Virginia’s gas producers will assist in keeping the gas industry working at or near full capacity, producing a vital domestic energy supply at a reasonable cost.

Opportunities and Barriers

Opportunities exist for developing new gas resources; the Marcellus Shale has attracted interest from far and wide. Companies that do not normally conduct business in the Appalachian Basin have been obtaining leases and evaluating the Marcellus Shale’s potential. Deep potential of the Ordovician and Cambrian rocks in West Virginia has been explored on only a limited basis to date. The number of wells which have tested the Trenton-Black River doubled from 30 prior to 1998 to 60 by 2005, but hundreds more will be required to adequately test the potential of deeper zones.

Constructing new pipelines or increasing capacity or modifying existing pipelines is an expensive and time-consuming process, requiring approval from the Federal Energy Regulatory Commission (FERC). In addition, pipeline construction in West Virginia's largely rugged terrain is costly and requires extensive route planning and evaluation. Acquisition of pipeline rights of ways and dealing with public comment and environmental impacts all are considerations for any proposed pipeline project.

Constructing new pipelines for transporting carbon dioxide (CO_2) would face many challenges similar to those for gas pipeline construction. Some have suggested co-locating CO_2 pipelines along existing gas pipeline rights of way, but problems with heavy equipment operations in close proximity to existing gas pipelines make this not likely to be a viable scenario. Also, the special pipeline material requirements for transporting corrosive CO_2 are an additional consideration.

The proposed locations for CTL and coal gasification plants in Marshall and Mingo counties are in areas with some existing gas pipeline infrastructure which might be used for transportation of pipeline quality gas from a CTL or CTG plant. If CO_2 sequestration is a component of a proposed CTL or CTG plant, new pipelines specifically for CO_2 transportation may need to be constructed.

Creating a Statewide Digital Pipeline Map

Objectives

The main objective of this task was to create a comprehensive, digital oil and gas pipeline map of West Virginia – using easily accessible, non-proprietary data – to show approximate gas transport capacity and distribution capability. This also will allow distribution capability to be quantified for modeling purposes in order to present site data to various industries.

Methods

To create the best possible dataset, two sources needed to be combined. The first of these was the Pipeline Map of West Virginia created by the West Virginia Geological and Economic Survey in 1976. The pipeline network on this map is an updated version of that shown on the Survey's 1970 Oil and Gas Fields map, which was created by the WVGES using proprietary operator data. It is currently the most comprehensive publicly available pipeline dataset, but is only available in paper form.

Second are the layers of the Digital Line Graph data created by the Mineral Lands Mapping Project of the WVGIS Technical Center between 1995 and 2002. This dataset was created by scanning USGS topographic maps for each quadrangle and then digitizing the information into one of four layers. The pipeline data are contained in what the USGS designated as the "miscellaneous" layer, and each pipeline is coded with the USGS code for a gas pipeline.

These datasets have various strength and weaknesses; the purpose of combining the two was to take the strengths of each map and apply them to one comprehensive digital product. Below are descriptions of the strengths and weaknesses of the two datasets, beginning with the WVGES' Pipeline Map.

Figure 1: Example of the Pipeline Map of West Virginia

Strengths:

- Complete dataset as of 1976; this is the most up to date publicly available pipeline data.

- Consists mostly of straight lines between points; this minimizes complication within any pipeline’s given route.

- All lines are attributed with company name (1976 ownership) and pipeline diameter.

Weaknesses:

- Static Product: very limited data have been added to this dataset after the 1976 creation date.

    - No mechanism for adding new data, except for the occasional hand drawn update.

    - Actual data depicts situation prior to 1976. The original base for the map was created in 1970 with revisions taking place using data from 1973.

- Paper Map and more recent digital product both needed for adequate analyses.

- Data depicted are inaccurate

    - On average, pipelines are 500 meters off from actual pipeline locations as shown on 7.5’ topographic maps.

    - Some pipelines are shown on the map as much as 2000 meters from their actual location.

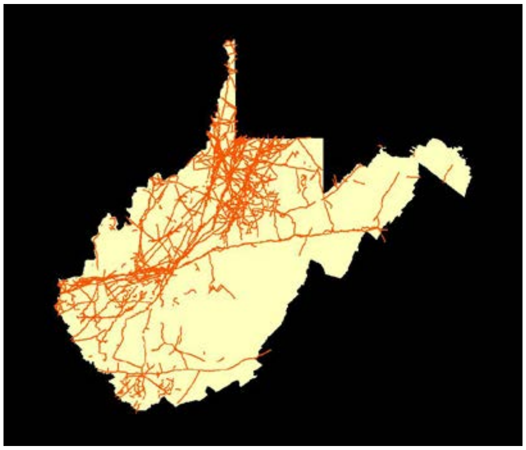

Figure 2: Mineral Lands Mapping Project Raw Pipeline Map

Strengths:

- Fairly Accurate
    - Actual pipeline location as shown on 7.5' quadrangles, occasionally can be inaccurate up to 200 meters.
    - Contains all pipelines that have appeared on topographic maps.

Weaknesses:

- No attributes.
    - The only attribute is the USGS code for a gas/oil pipeline.
- Limited time period:
    - Roughly 50% of the pipelines on the paper pipeline map are in the dataset, this is because the USGS topographic maps rarely get revised.
- Errors.
    - Some lines in the miscellaneous layers have been either miscoded or had no code to determine if they are a gas pipeline or not.

To maintain the strengths and minimize the weaknesses of these datasets a hand evaluation of each pipeline on both maps had to be done. This combined the accuracy of the Mineral Lands Mapping Project with the completeness and attributes of the paper pipeline map. All data in the resulting map had to be attributed by hand, and all conflicts between the two products were resolved. Although this was a long and difficult process the resulting data by far surpassed the quality and completeness of any existing dataset. The original Mineral Lines Mapping project dataset had over 6800 line segments; this has been reduced to fewer than 2800 line segments at the time of this report. 75% of the conflicts between the two datasets have been resolved, and continual resolution between conflicts will continue as long as it is determined that it is cost efficient to continue to do so.

Figure 3: Example of project results overlain on the paper pipeline map.

Other Efforts

There are several inherent weaknesses within the resulting dataset. The most conspicuous of these is the age of the data that have been used to create the dataset. There are efforts in place to obtain more recent data, but these processes have proven to be time consuming.

The first of these efforts is to obtain proprietary pipeline information and location from the operators themselves. This effort has met with varied success and it appears that Columbia Gas (NiSOURCE) is strongly considering providing their dataset to the WVGES. Once one or two of the major operators share their data, the remaining operators might do the same.

The second of these efforts is to obtain data from the National Pipeline Mapping System (NPMS). The National Pipeline Mapping System (NPMS) is a geographic information system created by the US Department of Transportation in order to maintain a geospatial dataset of the nation’s gas distribution system on a national level. Within the past few years, the NPSM has greatly improved the comprehensiveness of their dataset within the boundaries of West Virginia. The main problem in obtaining this dataset is security concerns at the federal and state level and restrictions put on the handling and dissemination of the data.

Conclusions

Great progress has been made to create a comprehensive, digital oil and gas pipeline map. The current dataset is the first improved map of the subject matter created within the last 30 years. The resulting map can easily be used for digital modeling and site selection processes and should give policy makers a general idea of gas distribution capability and transport capacity at the regional level. However, as with all datasets, continual improvements can and should be made. Efforts to obtain more recent data from private and federal government sources should continue until a comprehensive digital product that can be updated on an annual basis is achieved.