

APPENDIX 6

U.S. GEOLOGICAL SURVEY METHODOLOGY FOR THE ASSESSMENT OF UNDISCOVERED OIL AND GAS RESOURCES

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A6.1 INTRODUCTION

The USGS conducts assessments of technically recoverable undiscovered oil and gas resources of the onshore and state waters of the United States. The last comprehensive USGS oil and gas assessment was completed in 1995, and comprises the onshore and state waters portion of 71 geologic provinces (Gautier and others, 1996). In 1999, the USGS launched a new initiative to produce incremental assessments of the most significant U.S. oil and gas provinces.

To meet the requirements of Section 604 of EPCA, the USGS reorganized the priority list for the new assessments. For the Phase I Inventory (released 2003), new assessments were conducted for the Uinta-Piceance Basin, San Juan Basin, Montana Thrust Belt, Powder River Basin, and Greater Green River Basin. The 1995 assessment results were used for the Paradox Basin. For the Phase II Inventory, new assessments were conducted for Northern Alaska (NPRA and ANWR-1002), Wyoming Thrust Belt, Denver Basin, Florida Peninsula, Black Warrior Basin, and Appalachian Basin. For the Phase III Inventory, new assessments were conducted for Yukon Flats, Eastern Oregon-Washington and Eastern Great Basin. Inventories for Southern Alaska, Ventura Basin and the Williston Basin were conducted using the 1995 resource assessment results. Updated resource assessments were also conducted for the San Joaquin Basin, Hanna Basin, Wind River Basin, Raton Basin, Bend Arch-Fort Worth Basin, Western Gulf, East Texas Basin, and LA-MS Salt Basins, and the Michigan Basin which were included in the extrapolated areas.

The general assessment methodology has not changed from the 1995 assessments; however, some refinements have been made to accommodate increased geologic understanding of the occurrence of resources and more sophisticated means of capturing the range of uncertainty inherent in these variables. For example, the assessment model for continuous resources in the 1995 assessment assumed a homogenous distribution of oil and gas resources in a play. For the new assessments, that model has been replaced with an analysis of geologically controlled sweet spots of production, which demonstrate the geologic heterogeneity common to continuous oil or gas accumulations. The recognition of production sweet spots is a major advancement

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in the assessment of continuous resources.²

A6.2 TERMINOLOGY

Terminology used in this report reflects standard definitions and usage of the oil and natural gas industry and the petroleum resource assessment community. Several terms have been developed by the USGS for oil and gas assessment purposes (see Glossary in Appendix 2). The 1995 USGS assessment focused on the definition and assessment of geologic *plays*. In the latest USGS assessments, the focus is on understanding total petroleum systems and defining *assessment units* within total petroleum systems. The total petroleum system approach is designed to focus the geologic studies on the hydrocarbon source rocks, processes that create hydrocarbons, migration pathways, reservoirs, and trapping mechanisms. For discussion purposes in this report, the term *play* will be used throughout to represent both *assessment units* and *plays*.

The USGS assesses two main categories of hydrocarbon occurrence: conventional and continuous (Figure A6-1). Conventional oil and gas accumulations are defined as discrete fields with well-defined hydrocarbon-water contacts, where the hydrocarbons are buoyant on a column of water. Conventional accumulations commonly have relatively high matrix permeabilities, have obvious seals and traps, and have high recovery factors. In contrast, continuous accumulations (also called unconventional accumulations) commonly are regional in extent, have diffuse boundaries, and are not buoyant on a column of water. Continuous accumulations have very low matrix permeabilities, do not have obvious seals and traps, are in close proximity to source rocks, are abnormally pressured, and have low recovery factors. Included in the category of continuous accumulations are hydrocarbons that occur in tight reservoirs, shale reservoirs, unconventional reservoirs, basin-centered reservoirs, fractured reservoirs, and coal beds.

Figure A6-1. Conventional vs. Continuous Accumulations

A6.3 OVERVIEW OF THE OIL AND GAS ASSESSMENT PROCEDURE

The assessment process is based on the characterization of the petroleum geology of each province. The geologists define the geologic elements of the total petroleum systems, and, in conjunction with an analysis of historic oil and gas production and exploration/discovery data, define the oil and gas plays within the provinces. The geologists then develop probability distributions for sizes and numbers of undiscovered conventional accumulations, or numbers of cells and EUR for continuous accumulations, using all available geologic information and historic oil and gas data. These distributions are then used to generate probability distributions for undiscovered oil and gas resources.

² The production sweet spots were not used in creation of the study areas and resource estimates for the EPCA Inventory. Although the USGS has done significant work in defining these areas, the EPCA Steering Committee decided that the uncertainty associated with the sweet spots is too great for use in the Inventory.

A6.4 ROLE OF GEOLOGIC INFORMATION IN THE ASSESSMENT

The strength of the USGS oil and gas resource assessments is the province geologists' understanding of the petroleum geology of the provinces being assessed. These fundamental geologic studies allow new concepts and hypothetical plays to be incorporated into the assessment of undiscovered resources. A purely statistical approach to an assessment such as discovery process modeling that uses only historical data will overlook any new geologic concepts, models, or hypothetical plays.

The team of geologists develops an understanding of the province petroleum geology using published, proprietary, and original research and data. Studying the total petroleum systems within a province includes: (1) identification and mapping the extent of the major hydrocarbon source rocks; (2) understanding the thermal evolution of each source rock, the extent of mature source rock, and the timing of hydrocarbon generation, expulsion, and migration; (3) estimating migration pathways and all forms of hydrocarbon trapping; (4) modeling the timing of structural development and the timing of trap formation relative to hydrocarbon migration; (5) determining the sequence stratigraphic evolution of reservoirs, and the presence of conventional or continuous reservoirs, or both; and (6) modeling the burial history of the basin and the effect burial and uplift has had on the preservation of conventional and continuous hydrocarbons.

Once the total petroleum systems of the province are known in satisfactory detail, the team of geologists defines oil and gas plays, which represent a synthesis of all geologic information, including production and exploration data. The key component of this analysis is a geologic model for the assessment of each play. The geologic model encompasses all elements of the total petroleum system, and is commonly summarized by a total petroleum system events chart.

A6.5 SOURCES OF OIL AND GAS DATA

Data for domestic oil and gas fields, reservoirs, and wells are derived from commercial databases purchased annually by the USGS. With more than 2.5 million domestic oil and gas wells and 40,000 oil and gas fields, the USGS has opted to purchase the data from commercial vendors rather than attempt to generate a comprehensive database. The oil and gas wells and production databases are now purchased from the IHS Energy Group (IHS) (2000 a, b). Previous assessments used the predecessors to IHS: PetroROM Production Data (Petroleum Information/Dwights LLC, 1999a) and the Well History Control System (Petroleum Information/Dwights LLC, 1999b). The USGS also relies on the NRG Associates, Inc. Significant Oil and Gas Fields of the United States (NRG Associates, 2001). Data from these commercial databases are subject to proprietary constraints, and the USGS cannot publish, share, or serve any data from these databases. However, derivative representations in the form of graphs and summary statistics can be prepared and presented for each play. The USGS, however, cannot verify the accuracy, completeness, or currency of data reported in commercial databases.

The IHS production database provides oil and gas production data for wells, leases, or

producing units (collectively called “entities” in these databases). The IHS oil and gas wells database provides individual well data (including data for dry holes) that include well identification, locations, and information on penetrated and producing formations. Oil and gas field databases provide location, geologic characterization, and oil and gas production data for domestic oil and gas fields and reservoirs.

Additional oil and gas data are obtained, where available, from operators, state agencies, and other government sources, such as the U.S. Department of Energy’s Energy Information Administration proprietary files, publications from the former Bureau of Mines, and other sources.

A6.6 ASSIGNING ACCUMULATIONS AND WELLS TO PLAYS

Digital maps of plays are created using a GIS.³ Digital play maps are used to assign oil and gas wells and accumulations to their respective plays, and these assignments are entered into the databases. Oil and gas accumulations are assigned to only one play. Wells, however, can be assigned to more than one play if they penetrate vertically stacked plays. Oil and gas accumulations and well assignments are reviewed to ensure proper assignments, identify inconsistent data, and examine the need for minor revisions of play boundaries.

Historic production and exploration/discovery data are collected for each play using oil and gas accumulations or well assignments. Types of data retrieved include: (1) known volumes (sum of cumulative production and remaining reserves) of recoverable oil, gas, and natural gas liquids (NGLs) of accumulations; (2) discovery dates of accumulations (the year the first reservoir in the accumulation was discovered); (3) monthly production and cumulative production of wells; (4) initial classification and final classification of wells (for example, new-field wildcat, development, producing, abandoned, etc.) of wells; and (5) completion dates of wells.

A6.7 OIL AND GAS PRODUCTION DATA

The historic oil and gas production data are compiled for each play so that the data from discovered accumulations can be used as a guide for potential undiscovered accumulations. For conventional plays, these data include: (1) field name, (2) field discovery year or date of completion of the discovery well, (3) known volumes of oil, gas (non-associated and associated-dissolved), and NGLs, and (4) depth to the top of each reservoir. All of the production data for conventional assessment units are arranged in terms of oil accumulations and gas accumulations and sorted by size and discovery date for statistical calculations and plotting. A list of new-field wildcat wells and their completion dates is compiled and organized into the number of wells drilled per year for conventional plays. (A new-field wildcat well is an exploratory well drilled at least two miles from a producing field to test a separate trap). Once organized, the number of wells drilled in a given year is used as a measure of exploration effort. These data are then combined with the production data using the discovery dates of the accumulations

³ The oil and gas play boundaries are available at <http://energy.cr.usgs.gov/oilgas/noga>.

and the completion dates of the wells.

Oil and gas production data compiled for each producing well in continuous-type plays include past monthly production of liquids (oil and NGL) and gas (non-associated and associated-dissolved), from which EURs are estimated using well decline-curve analysis, the date of first production, and depth to the topmost perforation. A list of all wells and completion dates are compiled and organized. However, the number of wells drilled in a given year is not combined with production data, but analyzed separately.

Co-product ratios (GOR; NGLs to gas ratio; and LGR) are calculated and major commodities (oil or gas) are identified for each conventional accumulation. Co-product ratios are based on accumulation-level oil, gas, and NGL volumes. Oil and gas accumulations are treated separately; an oil accumulation is defined as one having a GOR less than 20,000 cubic feet/barrel whereas a gas accumulation has a GOR equal to or greater than 20,000 cubic feet/barrel.

Supplemental data from individual reservoirs within the accumulations include thickness (net and gross), average porosity, average permeability, temperature, pressure, fluid properties (for example, sulfur content of oil, API gravity of oil, non-hydrocarbon gas contents), trap type, drive type, and well spacing. These data are combined with the data from the commercial databases to help refine the geologic interpretations and assessment process.

A6.8 GRAPHS AND STATISTICS FOR CONVENTIONAL PLAYS

Two sets of graphs and statistics are generated for conventional plays—one set using known accumulation sizes as of the effective date of the assessment and one set using accumulation sizes that are corrected for anticipated reserve growth (grown accumulation size) within the forecast span of the assessment.

The set of graphs and statistics generated for conventional plays includes sizes and number of accumulations with respect to discovery date and exploration effort, exploration effort through time, size distributions of accumulations, reservoir depth versus discovery date and exploration effort, co-product ratios versus reservoir depth, and a histogram of the API gravity. Accumulations containing less than a specified minimum volume of oil or gas (that is, the smallest accumulation size that is considered in the assessment process) are not included in these graphs or statistics. Counts of new-field wildcat wells are used as a measure of exploration effort for finding new accumulations.

A6.9 ASSESSMENT INPUT FOR CONVENTIONAL PLAYS

Critical input data for conventional plays are probability distributions for sizes and numbers of undiscovered oil and gas accumulations and co-product ratios. The geologists develop these distributions by synthesizing all petroleum systems information and historic oil and gas data. For hypothetical plays, the geologist may utilize an analog data set for sizes and numbers of discovered fields as a guide to the distributions of

sizes and numbers of undiscovered fields in the play or assessment unit being assessed. Geologists provide information on oil and gas quality, range of drilling depths, and range of water depths for future economic analyses.

A6.10 GRAPHS AND STATISTICS FOR CONTINUOUS-TYPE PLAYS

A set of graphs and statistics comparable to that for conventional plays is generated for continuous-type plays, but the EUR per cell and numbers of tested cells are used rather than accumulation sizes and number of discovered accumulations. Tested cells of less than the specified minimum EUR per cell are not included in these graphs or statistics, and reserve-growth adjustments for cells are not incorporated.

The set of graphs and statistics generated for continuous-type plays includes number of wells drilled through time (all wells as opposed to new-field wildcat wells), probability distributions of EUR, EUR versus production-start year and number of all wells drilled, cumulative EUR versus production-start year and number of wells drilled, cumulative EUR versus depth of the topmost perforation, and GOR versus ranked EUR. All of this information is provided to the assessor as a guide to generating distributions for the assessment of undiscovered resources.

A6.11 ASSESSMENT INPUT FOR CONTINUOUS PLAYS

Critical input data for the continuous play assessment model include numbers of cells that have potential to be added to reserves, the EUR distribution for these cells, and the co-product ratios. For hypothetical plays, the geologist may utilize an analog data set for distribution of cell size and for the EUR distribution as guides to the distributions of cell sizes and EUR's of undiscovered area in the play being assessed. The geologist provides information on oil and gas quality, range of drilling depths, and range of water depths for future economic analyses.

A6.12 USGS ASSESSMENT REVIEW

The province geologist must present the geology of the play and the input data to a team of USGS personnel for a formal review. The team consists of geologists, geophysicists, and assessment methodologists with broad expertise in petroleum geology, which together promotes a consistent geological and methodological approach to the assessment. Every aspect of the geology and input data are reviewed, and any changes are incorporated into the input data at this time. Once the input data have been finalized, the input data are ready for quantitative analysis.

A6.13 CALCULATION OF UNDISCOVERED CONVENTIONAL AND CONTINUOUS RESOURCES

The final reviewed assessment input forms are the basis of the quantitative calculations of undiscovered oil and gas resources. For conventional plays, the probability distributions for sizes and numbers of undiscovered accumulations and the co-product

ratios provided by the assessor are entered into a Monte Carlo simulator and run for a specified number of iterations to provide distributions of undiscovered oil, gas, and NGL resources. In the 1995 assessment, a Truncated Shifted Pareto Distribution (Gautier and Dolton, 1996) was used for the shape of the curve for the distribution of sizes of oil and gas fields. For the present assessment, a Truncated Shifted Lognormal Distribution is used for this purpose (Charpentier and Klett, 2000).

For continuous plays, the distributions for assessment-unit area, untested percentage of assessment unit area, potential percentage of untested area, and area per cell of untested cells are combined analytically to determine the distribution for number of potential untested cells. The distribution for numbers of potential untested cells EUR per cell, and the co-product ratios are combined using an Analytic Probability Method (Crovelli, 2000) to directly calculate the probability distribution of undiscovered oil and gas resources.

A6.14 ASSESSMENT RESULTS

The results and maps of the resource assessment of the oil and gas plays from the USGS are available on the internet and can be downloaded at <http://energy.cr.usgs.gov/oilgas/noga>.

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Appendix 6
USGS Methodology for the Assessment
of Undiscovered Oil and Gas Resources

Denver Basin Assessment: Higley, Debra, Charpentier, Ronald R., Cook, Troy, Klett, T. R., Pollastro, Richard, Schmoker, James W., and Schenk, Christopher J.

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