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REVIEW OF DEPARTMENT OF INTERIOR METHODOLOGY FOR ASSESSMENT OF UNDISCOVERED OIL AND GAS RESOURCES INCLUDING ADDENDUM, NRC COMMENTS, AND CNWRA RESPONSE TO COMMENTS

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NRC COMMENTS AND CNWRA RESPONSE TO NRC COMMENTS

OG1.0 INTRODUCTION

This report presents the results of a review of the National Assessment of Undiscovered Conventional Oil and Gas Resources, USGS-MMS Working Paper, Open File Report 88-373, 1988. The working paper is a joint product of the U.S. Geological Survey (USGS) and the Minerals Management Service (MMS). Both are agencies of the U.S. Department of Interior (DOI). Hereafter, the working paper is referred to as OFR 88-373 or the Report.

The purpose of this review is: (1) to analyze the methodology of the national assessment; and (2) to consider application of the methodology to the assessment of natural resources that is required, by 10 CFR Part 60, in a license application for a repository to isolate high-level radioactive waste (HLW). With the emphasis on methodology, the review focuses on the first part of OFR 88-373, the part through page 203. Little attention is paid to the following part, pages 204 through 511k, which discusses the petroleum regions of the United States and presents tables of resources.

Two earlier documents were also reviewed for background information. These are Dolton (1981) and Miller (1975), which discuss national oil and gas assessments conducted in 1980 and 1975, respectively, by the USGS.

OG2.0 BACKGROUND

The Report presents the results of the most recent in a series of national assessments, by DOI, of undiscovered oil and gas resources. It is more sophisticated and comprehensive than the earlier efforts, due to on-going improvements in methodology and expansion of the data base. The Report presents estimates of undiscovered, conventionally recoverable oil and natural gas resources as of January 1, 1987.

For the assessment, the 48 states and Alaska are divided into 9 onshore regions, with 80 geologic provinces, and 4 offshore regions, with 35 geologic provinces. Hawaii is excluded, due to its negligible potential for oil and gas.

The work is done by two agencies within DOI: the U.S. Geological Survey (USGS) and the Minerals Management Service (MMS). The USGS handles the onshore area and the offshore areas under State-controlled waters. The MMS handles the offshore areas under Federal jurisdiction, including the Outer Continental Shelf Exclusive Economic Zone adjacent to the lower 48 states and Alaska.

Earlier, the USGS published Estimates of Undiscovered Recoverable Conventional Resources of Oil and Gas in the United States, Dolton (1981). The estimates were made in mid-1980, as of December 31, 1979. They represent an update of the estimates published in Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States, Miller (1975). Offshore resources were last reported in Estimates of Undiscovered, Economically Recoverable Oil and Gas Resources for the Outer Continental Shelf as of July 1984, OCS Report MMS 85-0012, 1985.

The USGS and MMS released OFR 88-373 in early 1988 and invited public review and comment on the procedures, assumptions, and preliminary results.

Review is also expected by such groups as the National Academy of Sciences, National Petroleum Council and Association of American State Geologists.

OG3.0 GENERAL CONSIDERATIONS

OG3.1 Commodities

The assessment covers undiscovered conventional sources of recoverable crude oil, natural gas, and natural gas liquids.

The assessment does not cover heavy oil deposits, tar deposits, oil shale, gas from tight sandstones or gas from tight fractured shales. However, the text discusses these kinds of resources and provides estimates where possible.

OG3.2 Compatible Estimates

As mentioned in Background, the assessment is a joint effort of the USGS and MMS. Each agency had made earlier assessments, by differing methods. For the joint effort, the agencies standardized certain elements of the task, such as economic assumptions, geologic definitions and formats for the results. As a result, although the individual Agency methodologies differed in procedural approach and the type and level of detailed data, the estimates presented in this report for the various resource categories are compatible. (OFR 88-373, page 14.)

The next two sections of this report cover the specifics of the two assessments.

OG3.3 Explanation of Terms

The terminology of the Report is intended to be representative of the standard definitions and usage practiced by the oil and gas industry and the resource estimation community. (OFR 88-373, page 4).

Some key terms are explained below.

A field is a single pool or multiple pools of hydrocarbon accumulations grouped on, or related to, a single structural or stratigraphic feature. (OFR 88-373, page 7).

A play is a group of geologically-related prospects with similar hydrocarbon sources, reservoirs, and traps. (OFR 88-373, page 9).

A prospect, or geologic prospect, is a geologic feature which could potentially trap commercial quantities of hydrocarbons. (OFR 88,373, page 118).

Undiscovered resources are resources estimated to exist from broad geologic knowledge and theory outside of known fields. (OFR 88-373, page 5).

Undiscovered recoverable resources are economically recoverable under conditions of current technology and imposed economic assumptions. (OFR 88-373, page 5).

OG3.4 Economic Assumptions

Several economic assumptions are applied to determine the resources that are economically recoverable. The assumptions relate to future oil and gas prices and future costs of extraction and transportation, including inflation rates, discount factors, acceptable investment rate of return and timing of development activity. Future oil and gas prices are projected from the January 1, 1987 date of the estimates, using a starting price of $18/barrel of oil and $1.80/thousand cubic feet of natural gas. Future costs of development activities and transportation are based on the 1985-1986 period. Assumptions on the timing of development are made for each province based on experience. No provision is made for leasehold and exploration costs; these are considered to be previously expended.

OG4.0 ONSHORE AND STATE OFFSHORE ASSESSMENT BY USGS

OG4.1 Scope

The USGS assessment of onshore areas and offshore areas under State regulation covers 80 petroleum provinces.

OG4.2 Data Base

Most of the assessment information is collected from the public domain, either in published form or by purchase from commercial sources. Some data are from unpublished USGS work now in progress. A principal source of well data is the Well History Control System (Petroleum Information, Denver, CO) which contains computerized information on more than 1.8 million wells. Production data comes from the Petroleum Data System (Petroleum Information, Denver, CO) and from R.G. Nebring and Associates, Colorado Springs, CO.

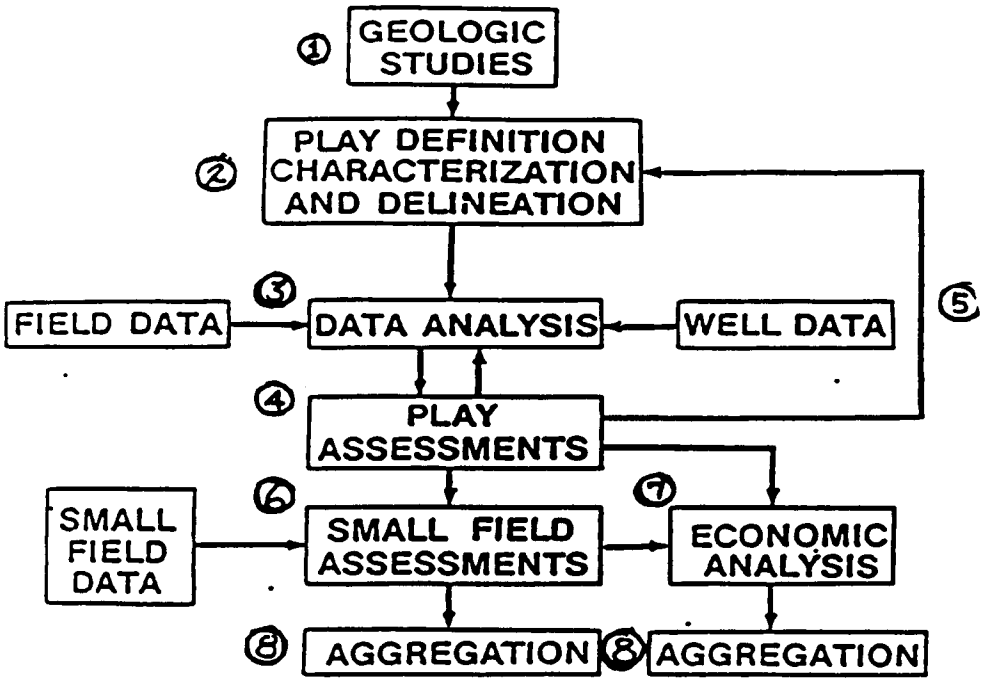
OG4.3 Elements in the USGS Methodology

The USGS approach is based on play analysis: an assessment area is divided into plays; the individual plays are analyzed; resources are estimated for each play by the computer program FASPFS (Fast Appraisal System for Petroleum - Field Size); finally, the resources are aggregated by the computer program FASPAG.

Some plays are not suited to the FASPFS approach, for example, plays for which data from analogous fields are lacking, and small fields, estimated to contain less than 1 million barrels of oil and 6 billion cubic feet of gas. Plays without adequate data are assessed directly by eliciting expert judgement by a modified Delphi method. Estimates of small fields are based on log-geometric extrapolations of numbers of fields and associated resources.

A flow chart for assessment by play analysis is reproduced in Figure 1. The elements in Figure 1 are numbered to key to the descriptions below.

1) Geologic Studies. Province geologists assemble, review and analyze the available geological and geophysical data, including data and analyses from previous assessments.



FLOW CHART FOR ESTIMATION OF UNDISCOVERED RESOURCES

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FIGURE 1

(from OFR 88-373, Figure II.A.1, page 20-a)

2) Play Definition Characterization and Definitions. Using input from element 1, the province geologists identify and characterize possible plays. An assessment panel reviews this work to refine the identity of plays. During the assessment, about 250 plays were identified.

3) Data Analysis. Each province geologist develops further studies to carefully describe and analyze the selected plays, incorporating production and other exploration data. Each province geologist presents the results to an assessment panel of 3 to 6 members. The panel prepares a comprehensive data summary for each play, consisting of maps, cross sections, charts and graphs. The data summary is based largely on information from surface and subsurface studies of the play area, and information from contiguous or analogue areas. Geophysical data are available for some areas.

The next step is to prepare a numerical model of the key geological characteristics of each play, suitable for computer processing. Judgements of the assessment team are elicited by consensus concerning: a) the four play attributes, which are regional characteristics that describe a given play -hydrocarbon source, timing, migration, potential reservoir facies; b) the accumulation attribute - probability that at least one undiscovered accumulation above threshold size exists in the play; c) reservoir size - the possible range for the size of accumulations in the play; d) reservoir number - the conditional number of undiscovered accumulations in the play. The four play attributes and the accumulation attribute are estimated by probability (0-1) of being favorable or present in the play. 0 represents total certainty that the attribute is absent, and 1 represents total certainty that the attribute is present. Reservoir size and reservoir number are estimated by probability distributions using 7 fractiles. The fractiles represent seven probability levels ranging from 100 percent (total certainty that at least this value will be attained) to 0 percent (total certainty that this value will not be exceeded). The probabilities arising from the expert judgements are entered into the appraisal data form, which is reproduced as Figure 2.

4) Play Assessments. After completion of the appraisal data form for a given play, the information is entered into computer data files as the input for the play-analysis program FASPFS. The play-analysis program is a preferred alternative to the Monte Carlo simulation, considered to be less efficient and time-consuming. The method was developed by the USGS from a play analysis technique of the Geological Survey of Canada. It systematically goes through the geologic probability model; computes the means and variances of the variables, i.e. the estimates in element 3; calculates all the probabilities of hydrocarbon occurrence; and generates estimates of undiscovered hydrocarbons in the play. Because of its speed, FASPFS provides quick turn-around of results for use by assessment teams. A further advantage is that it produces mathematical equations of probabilistic relations, which can be used for later review.

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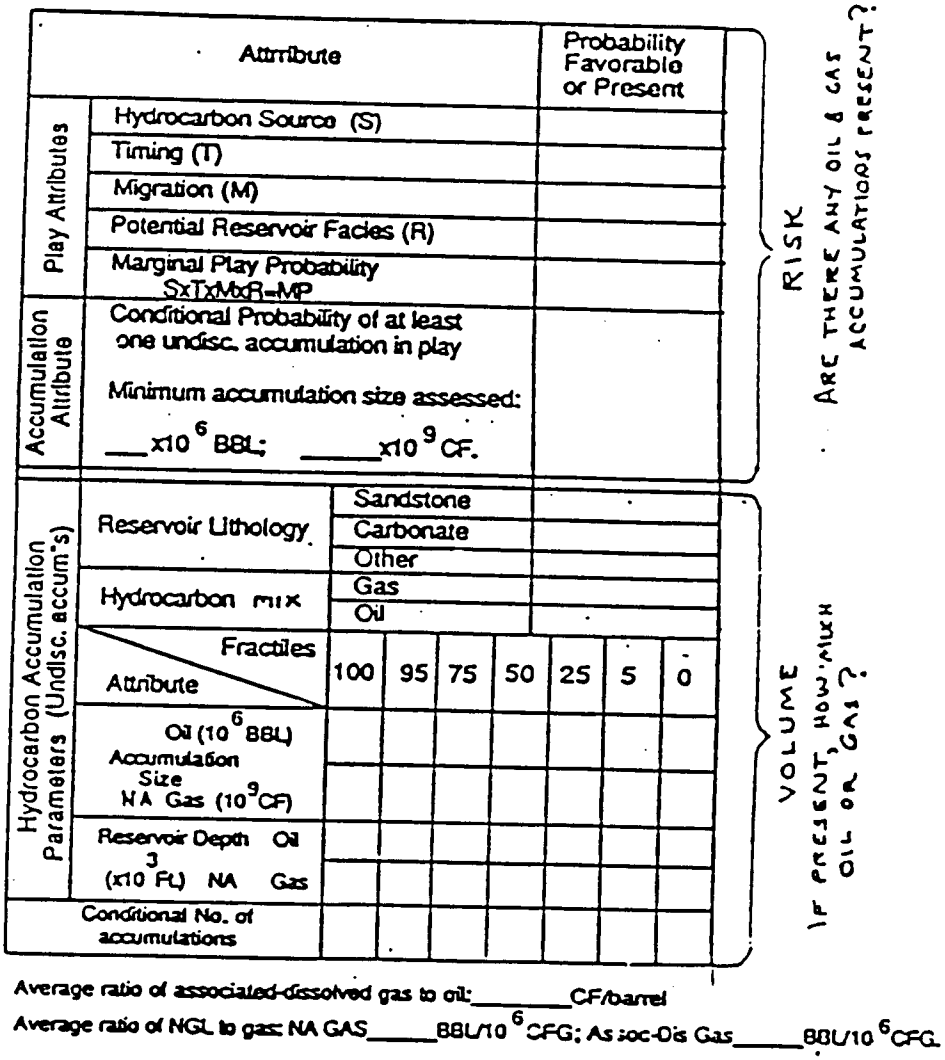

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FIGURE 2

(from OFR 88-373, Figure II.C.1, page 26-a)

Oil and Gas Appraisal Data Form used in the National Assessment

5) Review of Assessments. The initial resource assessments are reviewed by the province geologists and the assessment panel. The geologic input is checked for validity. The assessments are reviewed to ensure that they properly represent the geologic conditions. Comparisons are made among the plays. The review cycle is completed several times for some plays.

6) Small Field Assessments. After play analysis, the assessment panel estimates resources in small fields, those estimated to contain less than 1 million barrels of oil or 6 million cubic feet of gas. Small fields are numerous, but the information about them is too limited to permit the play analysis approach. Hence, a statistically-based approach is followed, using the observed distribution of sizes of known fields. Estimates of small field resources are made for each province as a whole.

7) Economic Analysis. Upon completion of the resource assessment, an economic screen is applied to determine the minimum size of field that can be economically developed in each province. The minimum economic field size is estimated based on an acceptable after-tax return on investment, taking into account discounted future revenues and costs. Fields that fail to meet the minimum size test are excluded from economically recoverable resources.

8) Aggregation. Final resource estimates are aggregated into totals for provinces, regions and the nation by FASPAG (Fast Appraisal System for Petroleum Aggregation). FASPAG is based on probability theory. It interfaces directly with FASPFS.

OG5.0 FEDERAL OFFSHORE ASSESSMENT BY MMS

OG5.1 Scope

The MMS assessment of offshore areas under Federal regulation covers 35 petroleum provinces.

OG5.2 Data Base

In contrast to the data base for the USGS assessment, which is taken largely from the public domain, the data base for the MMS assessment is largely proprietary. It comes from industry activities under permits and leases on offshore areas. About 4 million miles of seismic lines have been run on the permits and leases, and more than 25,000 wells have been bored. MMS has an extensive body of data, including more than 1 million miles of seismic records, numerous well logs and other geologic data. For provinces with limited data, commercially-available information is obtained for geologically similar provinces in the United States and abroad. Also, information is obtained from the USGS on geologically-similar plays in the onshore and State waters.

OG5.3 Elements in the MMS Methodology

In general, the elements of the MMS approach are similar to those of the USGS, but the procedures are different. The main elements of the methodology are discussed below.

1. Data acquisition and Interpretation. Most of the geological, geophysical and engineering information comes from industry activities under Federal leases and permits. Under lease terms, MMS inspects and selectively acquires proprietary information. The information is in the form of reflection seismic surveys, well logs and information from cores and cuttings. The seismic data are used in developing the regional geologic framework. For the assessment, MMS collected about 1 million line miles of seismic data. Geologic information comes from thousands of exploration wells and exploratory wells, as well as from a limited number of COST wells, joint ventures financed by the industry in unexplored areas.

2. Identification of Hydrocarbon Traps and Prospects. With all available information at hand, potential hydrocarbon traps are identified. The regional geological framework is developed through interpretation of the geophysical data. Broad regional plays are characterized. Then, the focus narrows to analysis of smaller scale geologic features and the identification of an individual geologic prospect, which is the basic unit for the assessment. A prospect may contain one stratigraphic zone that is prospective for hydrocarbons, or more than one zone.

3. Evaluation of Geologic Risks and Zone Variables. The next step is to translate geologic characteristics of each prospect (and zone within a multi-zone prospect) into numerical representations that can be used as input into the PRESTO (Probabilistic Risk Estimates Offshore) program. PRESTO calls for geologic factors related to: 1) risk - the geologic risk that a prospect, or zone, does not contain hydrocarbons and 2) reservoir size - how much resources are present in a prospect, or zone, that is simulated to contain hydrocarbons.

Four risk factors are evaluated by the specialists and the range of probabilities is set for each:

Presence of an adequate hydrocarbon source
Presence of open migration paths
Presence of a reservoir rock
Presence of a cap rock

The 9 factors in reservoir size are referred to as zone variables, or reservoir attributes. For each attribute, each evaluator uses best judgement to estimate the range of values and to select the proper distribution type for the values. The available distribution options are fixed point, normal, lognormal, uniform, loguniform, and triangular. The attributes are:

Probability of oil only
Probability of gas only
Proportion of the reservoir that is gas-bearing
Areal extent
Zone pay thickness
Oil recovery factor
Gas recovery factor
Solution oil-to-gas ratio
Condensate yield

4. Risk Analysis by PRESTO. The goal of risk analysis is to identify the likelihood that an individual geologic prospect, as modeled, does not contain hydrocarbons. PRESTO is built on a heirarchial structure, based on size, and it first deals with a petroleum area (the largest unit), then on down through a basin, a prospect, and, finally, a zone (the smallest unit). In analyzing risks, PRESTO goes through a number of simulations (trials) each governed by a different random number, to determine, first, whether a basin contains hydrocarbons. The outcome of any trial is that the basin is dry or that the basin is considered to have hydrocarbons in at least one prospect. The simulation continues until 1,000 trials have been run with at least one hit (presence of hydrocarbons). The hit history is saved. Based on the basic hit history, the program continues with the prospects in each basin and develops a hit history for each. Then, zones within a prospect are treated in the same way.

PRESTO is considered to mimic the approach of industry in drilling a basin for undiscovered resources. It uses statistical techniques to compute the outcome of the simulated drilling. On each PRESTO trial, each identified prospect is drilled and is found to be dry or hydrocarbon-bearing, according to risk analysis. If hydrocarbons are present, the quantity of resources is calculated by PRESTO, as described below in Evaluation of Resources. A file is created that stores the resources for each prospect for each trial. Next, an economic field size is determined, as described below in Application of Economic Test. If economic resources are discovered, the successful prospect is considered a field, and the resources are entered into the assessment.

5. Evaluation of Resources. Resources are computed by PRESTO for each prospect that is simulated to contain hydrocarbons. For prospects with more than one zone, resources are estimated for each zone and then aggregated for the prospect. The hit history for each prospect or zone determines the number of trials. For each trial, random numbers are used to select the values for each reservoir attribute. These values are used in the resource volume equations to yield possible solutions for the amount of resources.

6. Application of Economic Test. After PRESTO has simulated the prospect and computed the amount of resources simulated to be present, an economic test is applied to determine whether the resources are commercially recoverable. The test is a comparison of the prospect resources for a given trial, with a minimum field economic size, the smallest field size that will yield a prescribed rate of return under

the economic conditions of the prospect. The PRESTO program compares the resources computed for a trial to the minimum field economic size estimated by the MONTCAR (Monte Carlo Range-of-values) program. MONTCAR is a discounted cash flow model that includes economic conditions and costs specific to the prospect. If the resources exceed the minimum of economic field size, the resources are stored for later aggregation; if not, the resources are considered to be zero for that trial.

7. Estimation of Resources in Marginal Situations. In addition to estimating undiscovered economically recoverable resources, the assessment also considers smaller prospects and high-cost areas which would not be economic at current prices. The program for this task is DIST (DISTributions of possible field sizes). Generally speaking, the data base is adequate to define the prospects above minimum field economic size that are in the PRESTO prospect inventory. However, information is less complete at the lower end of prospect size range. DIST is based on the relationship, described in the literature, between the size of fields and the rank of fields, from largest to smallest. DIST generates a field size distribution for each PRESTO trial. DIST provides resources for the small fields.

OG6.0 ASSESSMENT METHODS FOR OIL AND GAS

OG6.1 General Discussion

Many methods have been used in assessing undiscovered oil and gas resources. The differences are mainly due to 1) the objective of the assessment and 2) the amount and type of information that is available.

Dolton (1981) discusses five major categories of methods. The categories are listed below along with remarks taken from pages 12 and 14 of Dolton (1981).

Category	Remarks
Extrapolation of historical trends	Uses past performances to predict future discoveries.
Areal- or volumetric-yield	Calculations are based on discovered oil and gas per unit area or volume of rock in well-explored districts.
Geochemical material balance	Estimates are made of the equations for the amount of oil and gas generated, migrated and trapped.
Play analysis	Resources are generated by combining geologic risk factors with reservoir engineering factors. Input for each variable is in the

	form of a known or estimated probability function.
Direct subjective assessment	Geologic information and, generally, the results of analyses by one or more of the other four methods are reviewed. Resources are estimated directly, on a subjective basis, by an expert or a team of experts.

The method of direct subjective assessment was used in the national assessments reported in Dolton (1981) and Miller (1975). The 1988 assessment, in OFR 88-373 was mainly done by play analysis, supplemented by direct subjective assessment.

OG7.0 APPLICATION TO RESOURCE ASSESSMENT FOR A HLW REPOSITORY

OG7.1 General Considerations

From several standpoints, the assessment technology in OFR 88-373 provides a useful model for considering a methodology appropriate to the assessment of undiscovered resources required in 10 CFR Part 60:

1) The assessment is the latest in a series, each showing technical improvement and greater sophistication.

2) The work is by a Federal agency, for national purposes.

3) The methodology is under broad review and comment.

4) With modifications, elements of the methodology can be used for resources other than oil and gas. The same general logic can be applied.

As with other assessments, the assessment for a HLW repository needs to satisfy a particular set of requirements. Among these are the following:

1) All types of resources are considered: metals, non-metallics, hydrocarbons, ground water.

2) Both discovered and undiscovered resources are considered.

3) The appraisal areas consist of the repository site, of some 30 sq mi, together with several comparison areas of similar size, all within a common geologic setting.

4) The estimated resources are evaluated for gross and present value, in current market terms.

OG7.2 Elements of a Methodology for Undiscovered Resources

Some elements of a possible methodology for a HLW repository are proposed below. The elements are based on the oil and gas methodology in OFR 88-373, modified to accommodate the requirements of 10 CFR Part 60. The methodology is limited to undiscovered resources.

1) Determine commodities for assessment. Appraise the areas to establish the types of commodities that can be present - metals, non-metallics, hydrocarbons, ground water. A separate assessment is carried out for each of the selected commodities.

NOTE: The rest of this outline deals with a single commodity.

2) Select control area. Select an area that (a) contains one or more known deposits of the selected commodity; (b) is similar, geologically, to the geologic setting of the site; and (c) can provide diagnostic geologic and economic factors.

3) Determine appraisal criteria. By study of the control area, develop the three kinds of appraisal criteria:

(a) Recognition criteria - the general features of the geologic environment that are necessary for a deposit of the commodity to be present.

(b) Appraisal criteria - the specific geological and spatial factors of the geologic environment that relate to the size and grade of the deposit.

(c) Economic criteria - the economic and engineering factors that determine the cost of an extractive operation and the market value of the product.

4) Identify the presence of prospects. Analyze all applicable data and, by comparison with the control area, identify geologic environments that are present and are favorable for the presence of a deposit. Consider each favorable geologic environment as a prospect.

5) Characterize each prospect. For each prospect, prepare a comprehensive data summary with maps, cross sections, charts and graphs. Evaluate the recognition criteria (from 3a) and the appraisal criteria (from 3b).

6) Estimate the probability of a deposit within the prospect. Elicit expert judgement on the probability that a deposit is present within the prospect, using the recognition criteria in 3a.

7) Estimate the appraisal factors. Elicit expert judgement on the probable ranges of values for the appraisal factors in 3b.

8) Assess the resources. By computer simulation, using a resource equation that combines the probabilities from 6 and 7, develop a probabilistic estimate of the resources.

9) Calculate gross and net value. Apply the economic criteria, from 3c, to the estimated resources, from 8, to obtain estimated gross and net values for the undiscovered resources.

OG8.0 REFERENCES

Dolton, G.L., Carlson, K.H., Charbentier, R.R., Coury, A.B., Crovelli, R.A., Frezon, S.E., Khan, A.S., Lister, J.H., McMullins, R.H., Pike, R.S., Powers, R.B., Scott, E.W., and Varnes, K.L. (1981). Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: Circular 860, U.S. Geological Survey, 87 p.

Miller, B.M., Thomsen, H.L., Dolton, G.L., Coury, A.B., Hendricks, T.A., Lennartz, F.F., Powers, R.B., Sable, E.G., and Varnes, K.L. (1975). Geological estimates of undiscovered oil and gas resources of the United States: Circular 725, U.S. Geological Survey, 78 p.

U.S. Department of Energy (1980). An assessment report on uranium in the United States of America: GJO-111(80), U.S. Department of Energy, 150 p.

ADDENDUM

OGA1.0 INTRODUCTION

This addendum to the review of the DOI Methodology for Assessment of Undiscovered Oil and Gas Resources report presents additional comments on the methodology of the national oil and gas assessment by the Department of Interior. The addendum is based on analysis of three independent reviews of the assessment and on direct discussions with persons involved in the assessment.

The Department of Interior (DOI) encouraged wide review of, and comment on, its preliminary assessment report, Geological Survey Open-File Report 88-373. DOI requested formal reviews from the Association of American State Geologists (AASG) and the National Academy of Sciences (NAS). The AASG review was issued in December 1988, and the NAS review is expected in April 1990. Independently, the Energy Information Administration (EIA) of the Department of Energy prepared a review that was released in February 1989. In addition, responding to a request by then-Secretary of the Interior, Don Hodel, the American Petroleum Institute (API) commented on the Open-File Report.

Each of the three reviews released to date covers somewhat different ground. As requested by DOI, AASG solicited comments about the geologic data, from the technical community, through a series of regional workshops. These were held in Anchorage, Denver, Los Angeles and New Orleans, with a follow-up meeting in Jackson, MI. Whereas the AASG was expected to concentrate on the geologic input into the assessment, the published review ranges widely over the entire process. The API critique covers, in 15 pages of text, both methods and results. The EIA report presents detailed analyses and comments, in 162 pages of text, with emphasis on natural gas.

The next section of this addendum presents selected points taken from the 3 reviews. Center comments are attached to some.

The final section of this addendum contains some notes of clarification on the USGS methodology.

OGA2.0 SELECTED POINTS TAKEN FROM THREE REVIEWS OF DOI ASSESSMENT

OGA2.1 Background

The national assessment was performed by two agencies within DOI. The U.S. Geological Survey (USGS) estimated resources onshore and in offshore, state-controlled lands. The Minerals Management Service (MMS) covered the offshore, federal lands. In some respects the methods are similar: for example, each uses play analysis and applies economic screens to the estimated endowment in order to identify recoverable resources. In other respects the methods are different. MMS relies primarily on proprietary seismic and borehole data. The computations are done by PRESTO, which is Monte Carlo in nature. USGS uses borehole and geologic data from the public domain with less emphasis on seismic information. It computes by FASPFS, which uses an analytic method of computation.

OGA2.2 Selected Points

The following statements cover some of the main points expressed in the AASG, API and EIA reviews. The author's comments are attached to some of the statements.

Review Statement 1. All the oil and gas estimates contain great uncertainty.

Comment 1. This is true of every appraisal of undiscovered resources.

Review Statement 2: The play approach is sound.

Comment 2. The DOI assessment is the first governmental application to apply play analysis on a nation-wide basis. Industry has been doing both on national and worldwide bases.

Review Statement 3a. The quality of the assessment depends, in great measure, on the quality and experience of the experts whose judgement is being solicited. Some of the assessors appeared to be unqualified.

Review Statement 3b. The USGS should make greater use of knowledge in the private sector.

Review Statement 3c. The USGS should release all input data, including the National Assessment Oil and Gas Appraisal Data Form that was prepared for each of the 250 plays.

Comment 3. This appears to be a matter of timing, rather than intent, on the part of the USGS. The original plan was to release the data after all reviews were released. Release was advanced, at the urging of the AASG. Because MMS uses proprietary data, it escapes the matter of data release.

Review Statement 4. In elicitation of judgement from the experts, the Delphi approach is preferred to the discussion-consensus approach of the USGS.

Comment 4. A main concern about the discussion-consensus approach is that the assessment can be dominated by strong individuals. The USGS believes that its approach yields better estimates, because there is opportunity for more complete exchange of views, and that the dominance problem can be handled by proper structuring and direction of the interactions among the assessors.

Review Statement 5. In aggregation of the probabilistic estimates, the Monte Carlo method of PRESTO, used by MMS, appears better than the analytic method of FASPFS, used by USGS.

Comment 5. The preference for Monte Carlo is understandable because it is time-tested and well-known. USGS defends its analytic approach as being faster and cheaper and providing results quickly to the assessors in meeting. The slight error, perhaps 4% as compared with Monte Carlo and mostly in the tails of the distribution function, is lost among the many uncertainties within the process.

Review Statement 6. MMS and USGS should adopt a common methodology. PRESTO is preferred to FASPFS.

Comment 6. Adoption of a common methodology faces several technical, historical, and institutional problems. FASPFS is an USGS innovation, used for the first time. PRESTO has been used for some time by MMS in evaluating offshore federal leases and now has a certain standing in the industry.

OGA3.0 CLARIFICATION NOTES ON THE USGS METHODOLOGY

OGA3.1 Resource Equation

In its basic form, the equation by which FASPFS computes the endowment within a play can be expressed thus --

> The estimated, probabilistic risk of a hydrocarbon occurrence, within the play, times the estimated, probabilistic size and number of hydrocarbon occurrences (if present) equals the estimated, probabilistic quantity of endowment of oil and gas.

To complete the assessment, an economic screen is applied to the quantity of endowment to identify the portion that is recoverable. This is the quantity of recoverable oil and gas resources, i.e. the resource estimate. The input into FASPFS comes from the Appraisal Data Form, which is reproduced as Attachment A. The input consists of four probability factors, which are numbered below and on Attachment A.

Factor 1 - Play attributes
Factor 2 - Hydrocarbon accumulation
Factor 3 - Accumulation size
Factor 4 - Number of accumulations

Risk is accommodated by factors 1 and 2. Hydrocarbon accumulation is accommodated by factors 3 and 4. Factor 1 is, itself, the product of 4 sub-factors, which are estimated separately.

OGA3.2 Elicitation of Expert Judgements

The elicitation of expert judgements takes place in two stages: 1) play definition and 2) reaching consensus on estimates.

In the first stage, play definition, through a series of interactive meetings with province geologists and others, the five-person play review panel accepts or modifies the definition of plays provided by province geologists. The province geologists then reassemble and re-analyze the background information on each of the defined plays.

The second stage, reaching consensus, is more involved because of the large number of estimates needed to assess each play. The five-person resource appraisal committee met with province geologists and others over a period

ATTACHMENT A

CODE: _____

NATIONAL ASSESSMENT
OIL AND GAS APPRAISAL DATA FORM
(FASPFS)

Evaluator_____ Play Name:_____
Date _____ Province _____ No. _____

	Attribute	Probability Favorable or Present	Comments
Play Attributes	Hydrocarbon Source (S)		
(1)	Timing (T)		
(1)	Migration (M)		
	Potential Reservoir Facies (R)		
	Marginal Play Probability SxTxMxR=MP		
(2) Accumulation Attribute	Conditional Probability of at least one undisc. accumulation in play.		
	Minimum accumulation size assessed: ___ x10^{6}BBL: ___ x10^9 CF.		

Hydrocarbon Accumulation Parameters (Undisc. accum's)			100	95	75	50	25	5	0
	Reservoir Lithology	Sandstone							
		Carbonate							
		Other							
	Hydrocarbon type	Gas							
		Oil							
(3)	Accumulation Size (Fractiles)	Oil (10^6 BBL)							
(3)		Gas (10^9 CF)							
	Reservoir Depth (x10^3 Ft.)	Oil							
		NA Gas							
(4)	Conditional No. of accumulations								

Average ratio of associated-dissolved gas to oil:_____CF/barrel

Average ratio of NGL to gas: NA GAS_____BBL/10^6 CFG; Assoc-Dis Gas_____BBL/10^6 CFG.

Est. % resource on: Federal land___%; Indian (native) land___%; Non-Federal offshore___%

Play area_____mi^2

Discovered resources:

	OIL (10^{6}BBL)	GAS (10^9 CF)	NGL (10^6 BBL)
IN ACCUM'S > CUT-OFF	_____	_____	_____
TOTAL	_____	_____	_____

Minimum economic field size:	Onshore	Offshore
Oil (10^3 bbls)	____	____
Gas (10^9 cu. ft.)	____	____

Fraction economic onshore____%

Proportion onshore ____%

of about 18 months. Consensus was reached on each estimate through discussion by all participants. For each estimate, a standardized elicitation procedure was followed.

A flow chart that portrays the elements in the USGS methodology, prepared by EIA, is reproduced in Attachment B.

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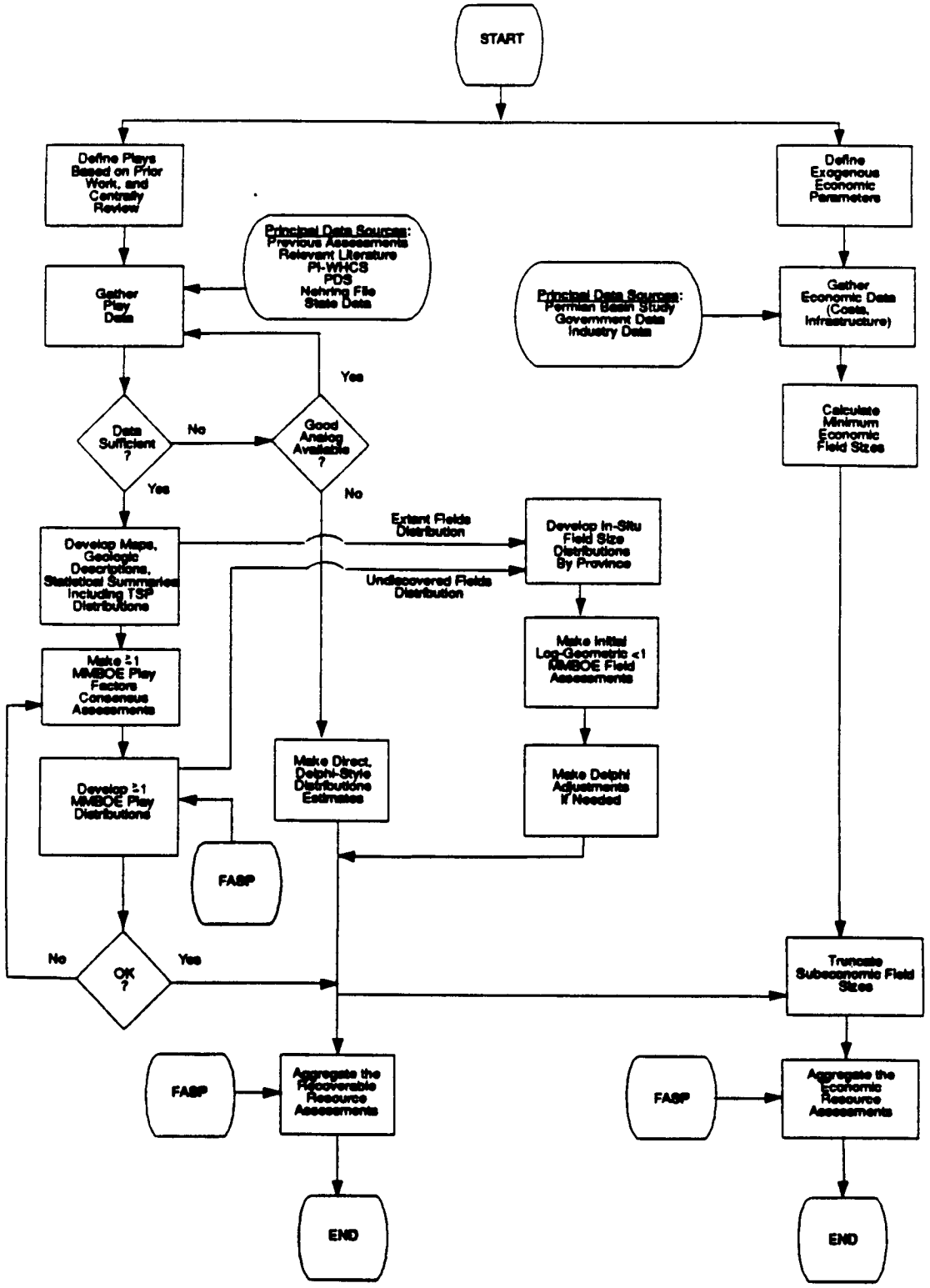
ATTACHMENT B

Figure 2.1. United States Geological Survey Undiscovered Oil and Gas Resource Assessment Procedure as Applied to Data as of 1/1/87



RESPONSE TO NRC COMMENTS

OGC1.0 INTRODUCTION

Under date of January 25, 1990, the NRC submitted to the Center for Nuclear Waste Regulatory Analyses a note entitled:

> NRC Comments on Center Report - "Review of Department of Interior Methodology for Assessment of Undiscovered Oil and Gas Resources", by Dr. Robert J. Wright.

The CNWRA report, which is referred to above, comprises Task Activity 3702-002-305-303 and consists of two parts as follows:

> Review of Department of Interior Methodology for Assessment of Undiscovered Oil and Gas Resources.
>
> Addendum to Review of Department of Interior Methodology for Assessment of Undiscovered Oil and Gas Resources.

In the following pages, the NRC comments of January 25 are listed and the CNWRA provides responses to the NRC comments. As in the NRC note of January 25, the comments are organized by author, in alphabetic order, and by number. Where an NRC comment bears no number, a number is inserted and bracketed in parentheses. Each comment is presented in original form, in quotes, or abbreviated form. Each response is keyed by number to the relevant comment.

OGC2.0 CNWRA RESPONSE TO COMMENTS BY T. CARDONE

Comment (1). "The proposed modified assessment methodology on pages 9 and 10...appears to be appropriate but rather general." "What are the appraisal criteria and control areas that will be applied to establish the types of commodities that may exist around Yucca Mountain?"

Response 1. As explained on page 9 of the original document, the intent in pages 9 and 10 is to analyze the oil and gas methodology and to identify the elements appropriate for a general methodology that could be used for all commodities. No real methodology is proposed here. The development of a general methodology would draw on the oil and gas experience and, also, the experience of other past assessments.

In a general methodology, an early step would be to identify the commodities to be assessed, based on the geology of the target area and the kinds of minerals that can be found in that specific geologic environment. Then, the appraisal criteria and a control area would be established for each mineral commodity that is to be assessed.

OGC3.0 CNWRA RESPONSE TO COMMENTS BY HAROLD LEFEVRE

On this and the following pages are responses to the Lefevre comments that deal with methodology and with the treatment of the Yucca Mountain area in the oil and gas assessment of the United States. The page numbers refer to

the pages in the original review, and in the addendum, which together comprise the submittal for Task Activity CNWRA 3702-002-305-303.

OGC3.1 CNWRA response to comments on the original report

Page 1 Comment (1). As a follow-up of the original report for Task Activity 3702-002-305-303, the oil and gas resources, developed by the USGS, should be examined for application to Yucca Mountain.

Page 1 Response 1. This has been done. See Page 2, Response 1, following.

Page 2 Comment (1) "Discuss the impact of the given estimates on the Yucca Mt. site. Is it in a favorable area so far as the USGS is concerned? Does the report give the impression that the prospects look good for hydrocarbon exploration and discovery?"

Page 2 Response 1. As part of the national appraisal, the USGS published a number of open-file reports that give the particulars on various areas. The one that covers the Yucca Mountain area is James A. Peterson, Eastern Great Basin and Snake River Downwarp, Geology and Petroleum Resources, Open-File Report 88-450-H, 1988. Appendix A to this report provides the cover page and pages 2 and 42 of the text.

In Nevada, the USGS identified 2 plays among the 250 in the U.S. Both plays are in the eastern Great Basin: Play I, Tertiary unconformity and Play II, upper Paleozoic. Figure 1 in Attachment A provides the outlines of each play. The border of play II passes about 10 miles northeast of Yucca Mountain; thus, Yucca mountain is close to, but outside, the play.

The eastern Great Basin is probably the most complex of the oil provinces recognized by the USGS, and the geologic control for the boundaries of Play I and Play II is sparse. This is reflected in the straight-line outlines of the plays, which are drawn, in part, along county and township lines. Nevertheless, it is believed that the plays cover all the area that is potential for oil and gas.

Even if Yucca mountain were within a play, no resources would be assigned to it (or any other locality), because an essential characteristic of undiscovered resources is that the location is not known. Table 2 (Attachment A) says that the mean value of the estimates for undiscovered resources, located somewhere in Play II, is: 49.0 million barrels of oil and 67.0 billion cubic feet of natural gas in fields greater than 1 million barrels of oil or 6 billion cubic feet of gas.

The USGS work is too broad brush to provide definitive answers to the favorability/unfavorability of Yucca Mountain for exploration. However, a preliminary impression is that the paleotemperature of the rocks may have been too high for gas or oil occurrences, due to the depth of burial and the volcanism.

Page 2 Comment 2. "Ask the Center to acquire and provide to the NRC the USGS's final report and follow on comments relevant to the Yucca project."

Page 2 Response 2. The Center has reviewed the USGS final report, which was released on August 17, 1989. It presents the big picture: estimates of petroleum resources in provinces, regions and the nation. It is not helpful for small areas like Yucca Mountain, and the discussion of methodology is limited.

A copy of the final report will be provided to the NRC.

Page 4 Comment 1. Does the USGS report say anything about economic assumptions that is applicable to Yucca Mountain?

Page 4 Response 1. No.

Page 4 Comment 2a. Is there "Any statement regarding the extent of time frame of future projections, eg. how many years estimate is possible (advisable) with any degree of certitude?"

Page 4 Response 2a. The USGS does not directly address the length of time for reliable predictions. However, the method of economic analysis that is used by the USGS has an indirect, built-in limitation on the time period for meaningful predictions.

The overall objective of the USGS project is to estimate undiscovered petroleum resources that are commercially viable. A field is considered to be commercially viable if a discounted cash-flow analysis shows that an after-tax return of 8 percent can be achieved. The cash-flow method of analysis is standard practice in evaluating a potential extractive operation for minerals. It adjusts costs and income, over the life of the operation, to a common point in time, which typically is the start-up of production.

Economic analysis, as described on page 9 of CNWRA 89-3, is applied in an early stage of the USGS method to determine the minimum size of field that can be economically developed in each province. Only the fields that survive the economic test are assessed and are included in the national estimate. The costs in each province are gathered from historical records and are updated to 1986, the year of the analysis. The price of oil is considered to be $18 per barrel in 1986, declining 2 percent per year, in real terms, from 1987 to 1989 and increasing at 4 percent per year, in real terms, thereafter.

Cash-flow analysis effectively places an upper limit on the length of time to be considered, because income to be received well into the future has negligible present value. For example, at an 8 percent discount rate, one dollar of income, that is received 50 years after today is worth about 3 cents today. This means that present value -- such as the net value of resources required in 60.122(c) (17 (ii) -- is little affected by what happens after a few decades. Hence, the certitude of a projection is unimportant after a few decades into the future.

Page 4 Comment 2b. "Can we ask the USGS (or any economist) what constitutes the 'foreseeable future'? Was it the Commission's intent to project 'foreseeable future' as 10,000 years?"

Page 4 Response 2b. In the minerals industry, the time span for "foreseeable future" is no longer than a few decades, at most. This would be for long-lived operations where the quantity of the ore reserves exceeds all foreseeable needs for production. Examples are certain operations for iron ore in Australia, lime-stone in the United States and beach sand in India.

Further, "foreseeable future" is effectively limited to a few decades by the negligible present value of income to be received in the distant future, as explained in Response 1a.

It appears unlikely that the Commission intends to project "foreseeable future" as 10,000 years.

Page 5 Comment 1. "Yucca Mountain is within which province?"

Page 5 Response 1. Yucca Mountain is within Province 082, Eastern Basin and Range, of Region 3, Colorado Plateau and Basin and Range. Region 3 includes all of Idaho, Nevada, Utah and Arizona, as well as the west half (roughly) of Colorado and New Mexico.

Page 5 Comment 3. "Are any plays identified in the Yucca area?"

Page 5 Response 3. Yucca Mountain is about 10 miles outside the boundary of Play II, lower Paleozoic and about 30 miles outside the boundary of Play I, Tertiary unconformity (Appendix A, p.2).

Page 5 Comment 4. "Will elements of the report be revised based on ...interview with the USGS in Denver?"

Page 5 Response 4. The addendum, CNWRA 89-3A, contains the results of the interview.

Page 5 Comment 5a. Are there only 250 plays for the entire U.S.?

Response 5a. Yes.

Comment 5b. "How many plays are in the Yucca region?"

Response 5b. See Response 3, above.

Page 9 Comment 6. Has an economic analysis been done to determine minimum field size for Yucca Mountain?

Page 9 Response 6. Presumably not, because Yucca Mountain is not within a play.

Page 15 Comment 1. "Are there any other elements not proposed? If so, what are they? Do you mean to say 'the elements are proposed' not 'some'?"

Page 15 Response 1. "Elements" refers to the elements in a possible methodology for a HLW repository.

"Some elements" is, perhaps, an unfortunate choice of words. It does not mean that some elements are proposed and others are withheld. It intends to mean that the proposal of elements is tentative, based only on reflection during review of the oil and gas documents, not on thorough study.

Page 16 Comment 1. "Given the lack of any petroleum (commercial) within 180 miles (?) of the site how can we make an appraisal? Do you just assume it would be present and drill lacking any viable geophysical data?"

Page 16 Response 1. A general methodology, suited to repository needs, is independent of the distance from known production. Drilling is not a part of this form of appraisal.

OGC3.2 CNWRA response to comments on the addendum

Addendum Page 1 Comment 1a. "Did the DOE (Waste Part) contribute to the review" of the DOI work?

Addendum Page 1 Response 1a. No, but an important review was published by the Energy Information Administration, which is part of the DOE.

Addendum Page 1 Comment 1b. "Is it possible to obtain copies of the comments - as well as those by the other contributors?"

Addendum Page 1 Response 1b. Important reviews have been released by three organizations, and copies can be obtained from them. The following are the references to the three reviews:

Review of Geologic Information Utilized by the U.S. Geological Survey and Minerals Management Service in Their Assessment of U. S. Undiscovered, Conventionally Recoverable Oil and Gas Resources, December 1988, by Association of American State Geologists. Write to Director, U. S. Geological Survey, 12201 Sunrise Valley Road, Mail Stop 101, Reston, VA 22090.

Critique of USGS/MMS National Assessment of Undiscovered Conventional Oil and Gas Resources, 1989, American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.

An Examination of Domestic Natural Gas Resource Estimates, February 1989. Energy Information Administration, U. S. Department of Energy, Washington, DC 20585. Title notwithstanding, this report covers estimation of both gas and oil.

OGC4.0 CNWRA RESPONSE TO COMMENTS BY KEITH MCCONNELL

Comment 1. "I have doubts that using a methodology derived from an assessment of undiscovered oil and gas resources is particularly effective when considering metallic and non-metallic mineral resources."

Response 1. The intent of pages 9 and 10 of the original report is to analyze the USGS oil and gas methodology and identify the elements that are

appropriate for a general methodology. The development of a general methodology would also draw on other past assessments, such as NURE for uranium, the assessment of Alaskan lands between 1974 and 1978 and the 1987 mineral resource assessment of the Republic of Costa Rica.

One conclusion drawn from the Center's reviews of the oil and gas and the uranium assessments is that:

> The NURE uranium method and the USGS oil and gas method are generally parallel in logic and procedure. (CNWRA 89-4B, p.3).

Comment 2a. "I have thought through the methodology outlined on pages 9 and 10 and found it to be too broad and general to be effective in assessing mineral resources at a high-level waste repository."

Response 2a. The ideas on pages 9 and 10 are not intended to represent a methodology. That would be premature. Rather, as indicated on page 9, the intent is to disaggregate the USGS method and identify the elements that might be used in a general methodology.

Comment 2b. "Specifically, with respect to the second step in the methodology, 'Select control area,' I have to question what a similar geologic setting for gold at Yucca Mountain would encompass. Would this similar geologic setting include Paleozoic host rocks as well as volcanic host rocks; also, would detachment and normal fault zones be considered as separate geologic settings? Under these circumstances, one could conceive of hundreds of 'prospects' at the Yucca Mountain site."

Response 2b. In selecting control areas, the first step is to identify the types of gold deposits that are permissive within the specific geologic environment of Yucca Mountain. The second step is to seek a control area for each type of gold deposit that can be expected in that specific environment.

Also, see Response 4.

Comment 3a. "Step 3a appears to be another iteration of Step 1."

Response 3a. In one sense, element 1 and element 3a do the same thing but with different degrees of rigor and for different purposes. ("Element" is preferred to "step", because "step" implies a greater degree of firmness in thinking than is now present). Element 1 is a first cut, designed to identify commodities that can be present; these are then treated under element 2 an element 3a. The control area supplies detailed information that serves, in 3a, as the basis for a rigorous comparison with Yucca Mountain and an estimate of the probability that a deposit is present.

Comment 3b. "I am unclear on how the approach in Step 3b can be followed on undiscovered deposits without data collection activities."

Response 3b. In element 3b, the appraisal criteria are derived by study of the control area: what combinations of geological features in and around a deposit (whether a cause of, or a result of, mineral deposition) are characteristic of this type of deposit? In other studies,

"favorability attributes", "favorability criteria" and "mineralization criteria" are used with similar meaning. Data collection activities are not proscribed but are not required.

Comment 3c. "Step 3c brings into effect factors that may not be applicable in the postclosure of any repository."

Response 3c. The engineering and economic factors that determine cost are expected to be those of the time of the assessment and are unrelated to postclosure.

Comment 4. "As mentioned in (Comment) #2 above, Step 5 would seem to be unworkable in that if fault zones are considered to be favorable geologic environments, then hundreds of gold prospects of nearly unlimited spatial continuity could be conjured up for the Yucca Mountain area."

Response 4. The term "geologic environment" is used here in both a comprehensive and a specific sense. It refers to the combination of all geologic features that are shown, in the control area, to be distinctive for a certain type of deposit, including structure, rock, type, mineralogy, rock alteration, geochemistry, etc.; together with the spatial relations between them. It is true that Yucca Mountain has many faults and that gold occurs in faults, but structure is only one of many features needed to define the specific geologic environment for a given type of gold deposit.

Comment 5. "Where does collection of data come into the methodology? Step 5 seems mainly to be a synthesis step with no new data collection activities. The activities as listed without collection of new data would do little to resolve the uncertainty of whether a mineral deposit was present."

Response 5. This comment raises a critical question about the objective of an assessment under Part 60: is it intended "to resolve the uncertainty of whether a mineral deposit was present"?

Part 60 appears to pose a quite different question: do the resources at the site "have greater gross value or net value than the average for other areas" (60.122(c)(17)(ii)), such other areas being "areas of similar size that are representative of and are within the geologic setting" (60.21(c)(13)). A general methodology to address this question is not expected to require the collection of new data, but complete analysis of existing data is essential.

Comment 6. "Any use of expert judgement would need to assure that the experts were well schooled in the requirements of Part 60 to be sure the probabilities were meaningful."

Response 6. The quality of an assessment will depend largely on the expertness of the experts. It may not be necessary for them to be experts in Part 60, although that would be useful. Perhaps more important is expertness in 1) the geology of Yucca Mountain and 2) the geologic environment and favorability attributes for each deposit type under assessment. This calls for several groups of experts.

OGC5.0 CNWRA RESPONSE TO COMMENTS BY J. TRAPP

Comment 1. "Terminology needs to be consistent with 10 CFR Part 60 (i.e., control area)."

Response 1. The two meanings attached to "control area" are real, unavoidable and unfortunate. The use in mineral assessment predates Part 60. There is some relief in the fact that the Part 60 usage rarely bumps into the usage for resources.

Comment 2. "Proposed elements of a possible methodology for a HLW repository. If proposed Element No. 3 can be done to satisfaction, then Elements 1, 2 and 4 through 9 are not needed."

Response 2. In a sense, element 3a covers the same ground as element 1 but with greater rigor and for a different purpose. See McConnell Response 3a. Each element is seen as necessary.

Comment 3. "Without much more in the way of specifics can not provide additional comments. The elements presented are standard methods with the exception of 'new' computer code which may or may not be applicable to minerals."

Response 3. Agreed.

APPENDIX A

DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Eastern Great Basin and Snake River Downwarp, Geology and Petroleum Resources

By James A. Peterson[1]

U.S. Geological Survey Open-File Report 88-450-H

This report is preliminary and has not been revieved for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1]Missoula, Montana 59812

1988

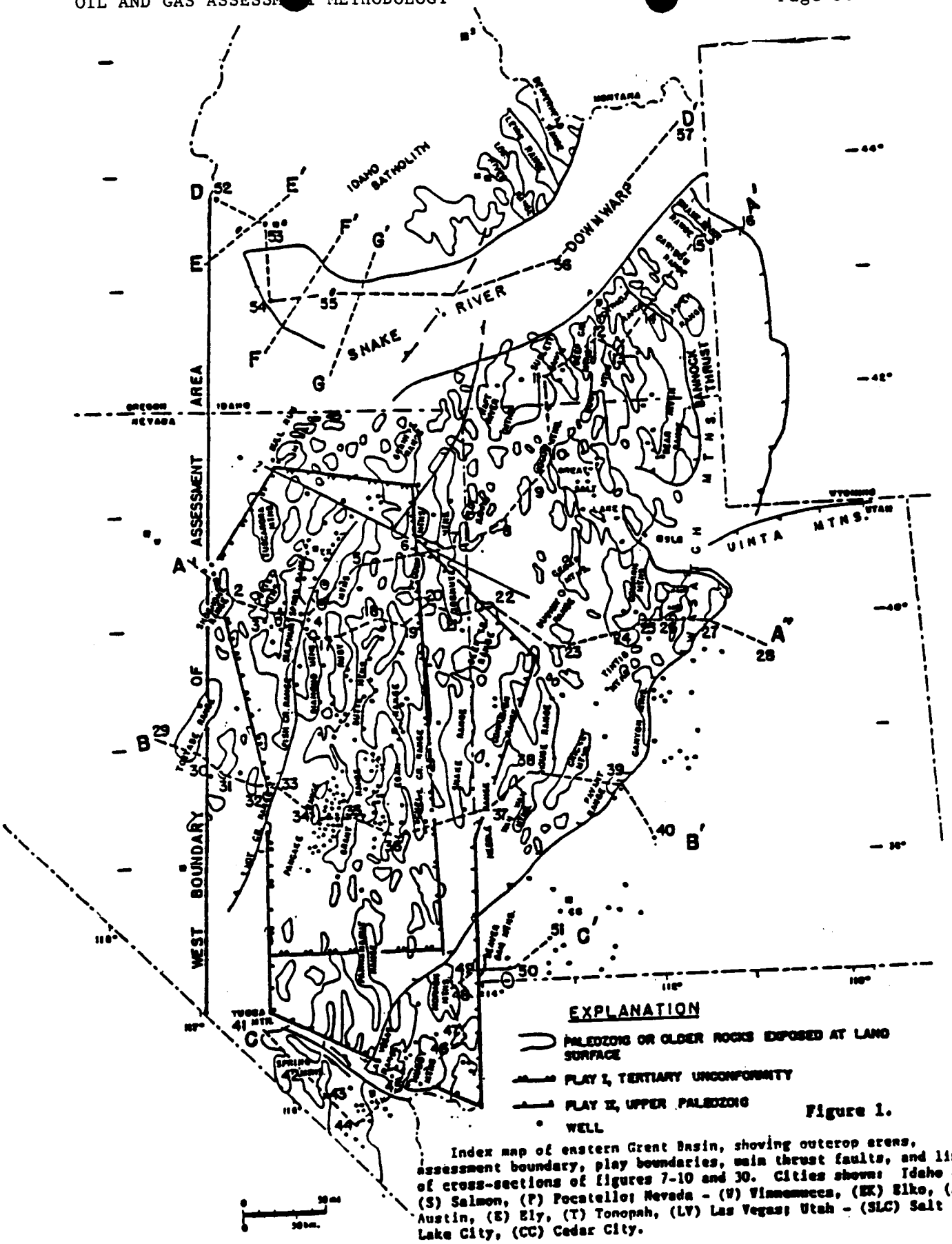


Figure 1.

Index map of eastern Great Basin, showing outcrop areas, assessment boundary, play boundaries, main thrust faults, and lines of cross-sections of figures 7-10 and 30. Cities shown: Idaho - (S) Salmon, (P) Pocatello; Nevada - (W) Winnemucca, (EK) Elko, (A) Austin, (E) Ely, (T) Tonopah, (LV) Las Vegas; Utah - (SLC) Salt Lake City, (CC) Cedar City.

Table 2.—Statistical estimates of undiscovered petroleum resources

Play	Mean	F95	F50	F5
Fields greater than 1 MMBO or 6 BCF gas:				
Tertiary unconformity	220.0 MMBO 102.0 BCF	66.0 MMBO 20.0 BCF	182.0 MMBO 75.0 BCF	503.0 MMBO 276.0 BCF
Late Paleozoic	49.0 MMBO 67.0 BCF	14.0 MMBO 10.0 BCF	40.0 MMBO 45.0 BCF	112.0 MMBO 194.0 BCF
Small fields (less than 1 MMBO or 6 BCF gas):				
Oil	42.0 MMBO	31.0 MMBO	41.0 MMBO	54.0 MMBO
Gas.	33.0 BCF	22.0 BCF	32.0 BCF	45.0 BCF
Total for province:				
Oil	311.0 MMBO	111.0 MMBO	263.0 MMBO	669.0 MMBO
Gas	202.0 BCF	52.0 BCF	152.0 BCF	515.0 BCF