Chapter 22

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Analytic Resource Assessment Method for Continuous Petroleum Accumulations—The ACCESS Assessment Method

By Robert A. Crovelli

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Analytic Resource Assessment Method for Continuous Petroleum Accumulations—The ACCESS Assessment Method

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Abstract

The analytic resource assessment method, called ACCESS, was developed to calculate estimates of petroleum resources for the geologic assessment model, called FORSPAN, in continuous petroleum accumulations. The ACCESS method is based upon mathematical equations derived from probability theory in the form of a computer spreadsheet system.

Introduction

This report explains the development of an analytic probabilistic method and spreadsheet software system called Analytic Cell-based Continuous Energy Spreadsheet System (ACCESS), originally published in Crovelli (2000). The ACCESS spreadsheet can be used to calculate estimates of the potential additions to reserves of oil, gas, and NGL (natural gas liquids) in a continuous assessment unit, within a total petroleum system. The ACCESS method is based upon mathematical equations derived from probability theory. It employs a geologic assessment model, an analytic probabilistic method, and finally, the ACCESS spreadsheet.

Geologic Assessment Model

The FORSPAN geologic assessment model is explained in detail in Schmoker (1999). The input-data form to record data required by the FORSPAN assessment model is described in Klett and Schmoker (Chapter 18, this CD–ROM) and illustrated in figure 1. The seven sections of the input-data form, which is completed by the geologist for each assessment unit of a continuous accumulation, are:

- Identification information
- Characteristics of assessment unit [see fig. 1]
- Number of untested cells with potential for additions to reserves in the next 30 years [hereinafter shortened to "number of potential untested cells"]
- Total recovery per cell
- Average coproduct ratios for untested cells, to assess coproducts
- Selected ancillary data for untested cells
- Allocations of potential additions to reserves to land entities.

The geologic assessment model for an assessment unit consists of the following components extracted from the input data provided by the geologist:

A. A set of four assessment-unit probabilities, which are discussed in detail by Schmoker (Chapter 13, this CD–ROM):
   1. Charge
   2. Rocks
   3. Timing
   4. Access

B. A set of nine random variables for an oil assessment unit or a similar set for a gas assessment unit:
   1. Assessment-unit area (acres)
   2. Untested percentage of assessment-unit area (%)
   3. Percentage of untested assessment-unit area having potential for additions to reserves in the next 30 years (hereinafter shortened to "potential percentage of untested assessment-unit area") (%)
   4. Area per cell of untested cells (acres)
   5. Total recovery per cell (MMBO or BCFG)
   6. Ratio of first coproduct
   7. Ratio of second coproduct
   8. Percentage allocation to parcel (or land entity) (%)
   9. Percentage allocation to offshore portion of parcel (%)

The assessment-unit area, untested percentage of assessment-unit area, potential percentage of untested assessment-unit area, and area per cell of untested cells are used to estimate the number of potential untested cells, as explained later.

C. A set of three descriptive parameters provided by the geologist for each of the nine given random variables:
   1. Minimum (F_{100} fractile)
   2. Median (F_{50} fractile)
   3. Maximum (F_0 fractile)

FORSPAN ASSESSMENT MODEL FOR CONTINUOUS ACCUMULATIONS--BASIC INPUT DATA FORM (NOGA, Version 7, 6-30-00)

IDENTIFICATION INFORMATION

Assessment Geologist:… _____ Date: _____
Region:…… _____ Number: _____
Province:…….. _____ Number: _____
Total Petroleum System:. _____ Number: _____
Assessment Unit:……. _____ Number: _____
Based on Data as of:…… _____
Notes from Assessor….. _____

CHARACTERISTICS OF ASSESSMENT UNIT

Assessment-Unit type: Oil (<20,000 cfg/bo) **or Gas** (≥20,000 cfg/bo) _____
What is the minimum total recovery per cell?… _____ (mmbo for oil A.U.; bcfg for gas A.U.)
Number of tested cells:……. _____
Number of tested cells with total recovery per cell ≥ minimum: …….. _____
Established (>24 cells ≥ min.) _____ Frontier (1-24 cells) _____ Hypothetical (no cells) _____
Median total recovery per cell (for cells ≥ min.): (mmbo for oil A.U.; bcfg for gas A.U.)
1st 3rd discovered _____ 2nd 3rd _____ 3rd 3rd _____

Assessment-Unit Probabilities:

Attribute	Probability of occurrence (0-1.0)
1. **CHARGE:** Adequate petroleum charge for an untested cell with total recovery ≥ minimum ……	_____
2. **ROCKS:** Adequate reservoirs, traps, seals for an untested cell with total recovery ≥ minimum.	_____
3. **TIMING:** Favorable geologic timing for an untested cell with total recovery ≥ minimum……..	_____

Assessment-Unit GEOLOGIC Probability (Product of 1, 2, and 3):…….....…… _____

4. **ACCESS:** Adequate location for necessary petroleum-related activities for an untested cell with total recovery ≥ minimum …… _____

NO. OF UNTESTED CELLS WITH POTENTIAL FOR ADDITIONS TO RESERVES IN THE NEXT 30 YEARS

1. Total assessment-unit area (acres): (uncertainty of a fixed value)
   minimum _____ median _____ maximum _____

2. Area per cell of untested cells having potential for additions to reserves in next 30 years (acres): (values are inherently variable)
   calculated mean _____ minimum _____ median _____ maximum _____

3. Percentage of total assessment-unit area that is untested (%): (uncertainty of a fixed value)
   minimum _____ median _____ maximum _____

4. Percentage of untested assessment-unit area that has potential for additions to reserves in next 30 years (%): (a necessary criterion is that total recovery per cell ≥ minimum)
   (uncertainty of a fixed value) minimum _____ median _____ maximum _____

Figure 1. The FORSPAN input-data form.

Assessment Unit (name, no.) _____

TOTAL RECOVERY PER CELL

Total recovery per cell for untested cells having potential for additions to reserves in next 30 years:
(values are inherently variable)
(mmbo for oil A.U.; bcfg for gas A.U.) minimum _____ median _____ maximum _____

AVERAGE COPRODUCT RATIOS FOR UNTESTED CELLS, TO ASSESS COPRODUCTS
(uncertainty of fixed but unknown values)

Oil assessment unit:	minimum	median	maximum
Gas/oil ratio (cfg/bo)……			
NGL/gas ratio (bngl/mmcfg)……			
Gas assessment unit:			
Liquids/gas ratio (bliq/mmcfg)……			

SELECTED ANCILLARY DATA FOR UNTESTED CELLS
(values are inherently variable)

Oil assessment unit:	minimum	median	maximum
API gravity of oil (degrees)……			
Sulfur content of oil (%)……			
Drilling depth (m) ……			
Depth (m) of water (if applicable)……			
Gas assessment unit:			
Inert-gas content (%)……			
CO_2 content (%)……			
Hydrogen-sulfide content (%)……			
Drilling depth (m)……			
Depth (m) of water (if applicable)……			

Figure 1—Continued. The FORSPAN input-data form.

Assessment Unit (name, no.)
Mowry Continuous Gas, Assessment Unit 50370261

ALLOCATIONS OF POTENTIAL ADDITIONS TO RESERVES TO STATES
Surface Allocations (uncertainty of a fixed value)

1. Colorado represents _____ areal % of the assessment unit

Oil in oil assessment unit:	minimum	median	maximum
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			
Gas in gas assessment unit:			
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			

2. Utah represents _____ areal % of the assessment unit

Oil in oil assessment unit:	minimum	median	maximum
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			
Gas in gas assessment unit:			
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			

3. Wyoming represents _____ areal % of the assessment unit

Oil in oil assessment unit:	minimum	median	maximum
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			
Gas in gas assessment unit:			
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			

4. _____ represents _____ areal % of the assessment unit

Oil in oil assessment unit:	minimum	median	maximum
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			
Gas in gas assessment unit:			
Volume % in entity……			
Portion of volume % that is offshore (0-100%)..			

Figure 1—Continued. The FORSPAN input-data form.

Analytic Probabilistic Method

The geologic assessment model FORSPAN is a description of a complex probability problem that needs to be solved for the estimates of potential additions to reserves. The method derived herein, called ACCESS, is a system that solves the problem. That is, the model FORSPAN poses the problem, and the method ACCESS offers a solution. Simply stated, ACCESS is a quantitative solution of the data provided in FORSPAN.

The nine given random variables are assigned probability distributions as probability models that are based on the descriptive parameters (F_{100}, F_{50}, and F_0). That is, each given random variable is assigned a probability distribution with the specified descriptive parameters of minimum, median, and maximum. The ACCESS method does not depend upon the specific assignment of probability distributions in that many assignments could be accommodated by modifications of ACCESS. The assignment of a particular probability distribution is an operational decision. The following probability distributions were assigned to the set of nine given random variables for an oil assessment unit or for a gas assessment unit:

1. Assessment-unit area: Median-based triangular distribution
2. Untested percentage: Median-based triangular distribution
3. Potential percentage of untested area: Median-based triangular distribution
4. Area per cell: Median-based triangular distribution
5. Total recovery per cell: Shifted truncated lognormal distribution
6. Ratio of first coproduct: Median-based triangular distribution
7. Ratio of second coproduct: Median-based triangular distribution
8. Percentage allocation to parcel (or land entity): Median-based triangular distribution
9. Percentage allocation to offshore portion of parcel: Median-based triangular distribution

The mathematical equations for the median-based triangular distribution are derived from probability theory (Crovelli, 1999). The basic probability theory of the triangular distribution can be found in Law and Kelton (1991). The probability theory of the lognormal distribution is given in Aitchison and Brown (1957).

A probabilistic method was derived that combines the given random variables of the geologic assessment model (FORSPAN) to determine parameters (especially, the mean, standard deviation, F_{95}, F_{50}, and F_5) of new random variables of interest, which are functions of the given random variables. The new random variables of interest are the following measures of potential additions to reserves:

- Oil in oil assessment unit
- Gas in oil assessment unit
- NGL in oil assessment unit
- Gas in gas assessment unit
- Total liquids in gas assessment unit

A probabilistic method is required to compute the estimates in the form of parameters (especially, the mean for a point estimate, and fractiles F_{95} and F_5 for an interval estimate) of a probability distribution. An analytic probabilistic method is a probabilistic method that uses mathematical equations from probability theory to obtain the estimates of the potential additions to reserves in an assessment unit. The ACCESS method is an analytic probabilistic method that was developed by deriving the necessary mathematical equations based upon conditional probability theory and laws of expectation and variance. Three key features of ACCESS are the following:

- ACCESS relates the input and output parameters with mathematical equations.
- ACCESS computes the means, standard deviations, minimums, and maximums exactly.
- ACCESS computes the estimates instantaneously.

For example, in the case of gas in a gas assessment unit, the following relationships are developed for the random variables:

N: Number of potential untested cells
X: Total recovery per cell (BCFG)
Y: Gas in gas assessment unit (BCFG)

$$Y = \sum_{i=1}^{N} X_i$$

The random variable *Y* is equal to the sum of a random number *N* of random variables X_i (total recoveries per cell). The mean and standard deviation of *Y* can be derived from the theory of conditional probability and conditional expectation (Ross, 1993). Parameters of particular interest for gas in a gas assessment unit are the mean (μ_Y), standard deviation (σ_Y), minimum [(*Min*(*Y*))], and maximum [(*Max*(*Y*))]:

$$\mu_Y = \mu_N \mu_X$$

$$\sigma_Y = \sqrt{\mu_N \sigma_X^2 + \mu_X^2 \sigma_N^2}$$

$$Min(Y) = Min(N)\, Min(X)$$

$$Max(Y) = Max(N)\, Max(X)$$

Many of the mathematical equations for parameters of the new random variables of interest in the ACCESS method are derived using conditional probability theory (Crovelli, 1992). A simplified flow chart of the analytic probabilistic method for resource assessment of continuous oil and gas accumulations—the ACCESS method—is displayed in figure 2. The number of potential untested cells and the total recovery per cell are combined probabilistically to obtain the estimates of potential additions to reserves in an assessment unit.

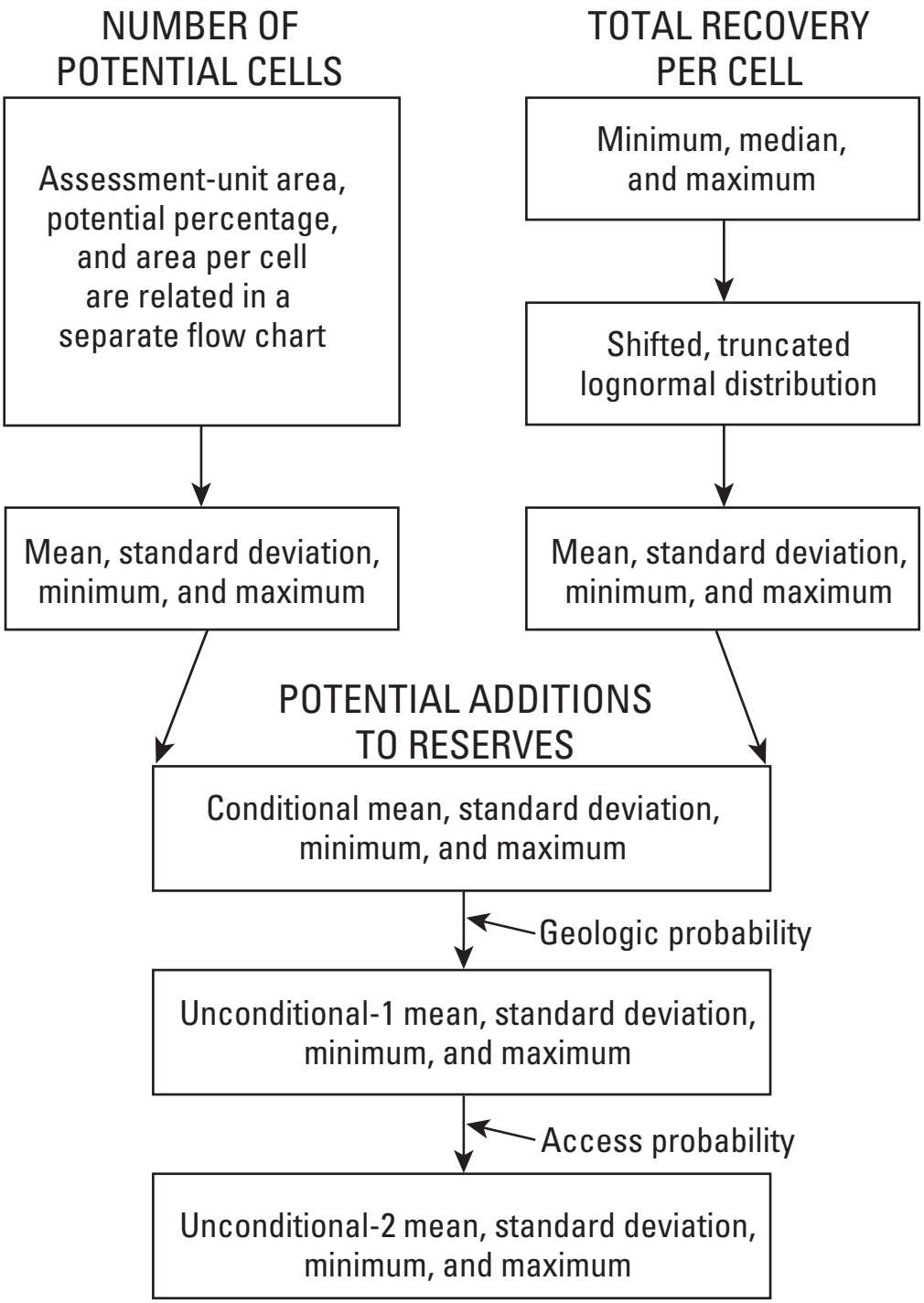

Figure 2. Simplified flow chart of analytic probabilistic method for resource assessment of continuous oil and gas accumulations—the ACCESS method.

Three operations or steps describe how to use the assessment-unit area, untested percentage of assessment-unit area, potential percentage of untested assessment-unit area, and area per cell of untested cells to estimate the number of potential untested cells.

Step 1. The untested percentage of assessment-unit area and potential percentage of untested assessment-unit area are multiplied probabilistically to obtain the potential untested percentage of assessment unit. The following random variables are defined:

R: Untested percentage of assessment-unit area
S: Potential percentage of untested assessment-unit area
T: Potential untested percentage of assessment-unit area

$T = R * S$

The mean (μ_T) and standard deviation (σ_T) of *T* are:

$$\mu_T = \mu_R \mu_S / 100$$

$$\sigma_T = (1/100)\sqrt{\mu_R^2\sigma_S^2 + \mu_S^2\sigma_R^2 + \sigma_R^2\sigma_S^2}$$

Step 2. The potential untested percentage of assessment-unit area (T) and assessment-unit area are multiplied probabilistically to obtain the potential untested area of assessment unit. The following additional random variables are defined:

U: Assessment-unit area
W: Potential untested area of assessment unit
$W = T * U$

The mean (μ_W) and standard deviation (σ_W) of *W* are:

$$\mu_W = \mu_T \mu_U / 100$$

$$\sigma_W = (1/100)\sqrt{\mu_T^2\sigma_U^2 + \mu_U^2\sigma_T^2 + \sigma_T^2\sigma_U^2}$$

Step 3. The potential untested area of the assessment unit (*W*) and area per cell of untested cells are combined to generate the number of potential untested cells. The following additional random variables are defined:

V: Area per cell of untested cells
N: Number of potential untested cells

$$W = \sum_{i=1}^{N} V_i$$

The mean (μ_N) and standard deviation (σ_N) of *N* are:

$$\mu_N = \mu_W / \mu_V$$

$$\sigma_N = \sqrt{(\sigma_W^2 - \mu_N\sigma_V^2) / \mu_V^2}$$

This sequence of calculations for the number of potential untested cells is briefly outlined in the simplified flow chart of figure 3.

Spreadsheet System

Given the geologic assessment model (the FORSPAN model), the analytic probabilistic method is used as the basis for a spreadsheet probability system called Analytic Cell-based Continuous Energy Spreadsheet System (ACCESS). ACCESS consists of a series of 54 panels in the spreadsheet. The individual panel numbers and contents of the spreadsheet ACCESS are given in table 1. A panel is a set of approximately 11 columns of related calculations. Because the total number of columns in ACCESS is 600 columns, ACCESS is constructed as a workbook with four worksheets called Cond (Conditional), Unc1 (Unconditional-1), Unc2 (Unconditional-2), and Numb (Number). Cond contains Panels 1–22; Unc1 contains Panels 23–34; Unc2, Panels 35–46; and Numb, Panels 47–54. Worksheet Cond is linked to the worksheet Numb. Worksheets Unc1 and Unc2 are linked to the worksheet Cond. The topics included in the worksheets Cond, Unc1, Unc2, and Numb are the following:

- Worksheet Cond: Input data from the data form (Panels 1–4), probability distribution calculations (Panels 5–10), and conditional (unrisked) resource estimates (Panels 11–22).
- Worksheet Unc1: Unconditional-1 resource estimates (Panels 23–34), which are risked using the geologic (charge, rocks, and timing) probability of the assessment unit.
- Worksheet Unc2: Unconditional-2 resource estimates (Panels 35–46), which are risked using both the geologic and the access probabilities of the assessment unit. The "geoacc" probability is the product of the geologic probability and the access probability.
- Worksheet Numb: Input data (Panel 47), and probability distribution calculations (Panels 48–54) for the number of potential untested cells.

A probability system is an orderly collection of random variables logically related in terms of their probability distributions and parameters. In the spreadsheet probability system ACCESS, the computed estimates (Panels 11–46) of potential additions to reserves are grouped into nested categories.

The first grouping is by type of risking:

- Conditional (unrisked) estimates
- Unconditional-1 (risked) estimates
- Unconditional-2 (risked) estimates

Each type of risking has various areas:

- Assessment unit
- Parcel (or land entity)
- Offshore portion of parcel

Each area has various commodities:

- Oil in oil assessment unit or gas in gas assessment unit
- Gas in oil assessment unit or liquids in gas assessment unit
- NGL in oil assessment unit or oil in gas assessment unit

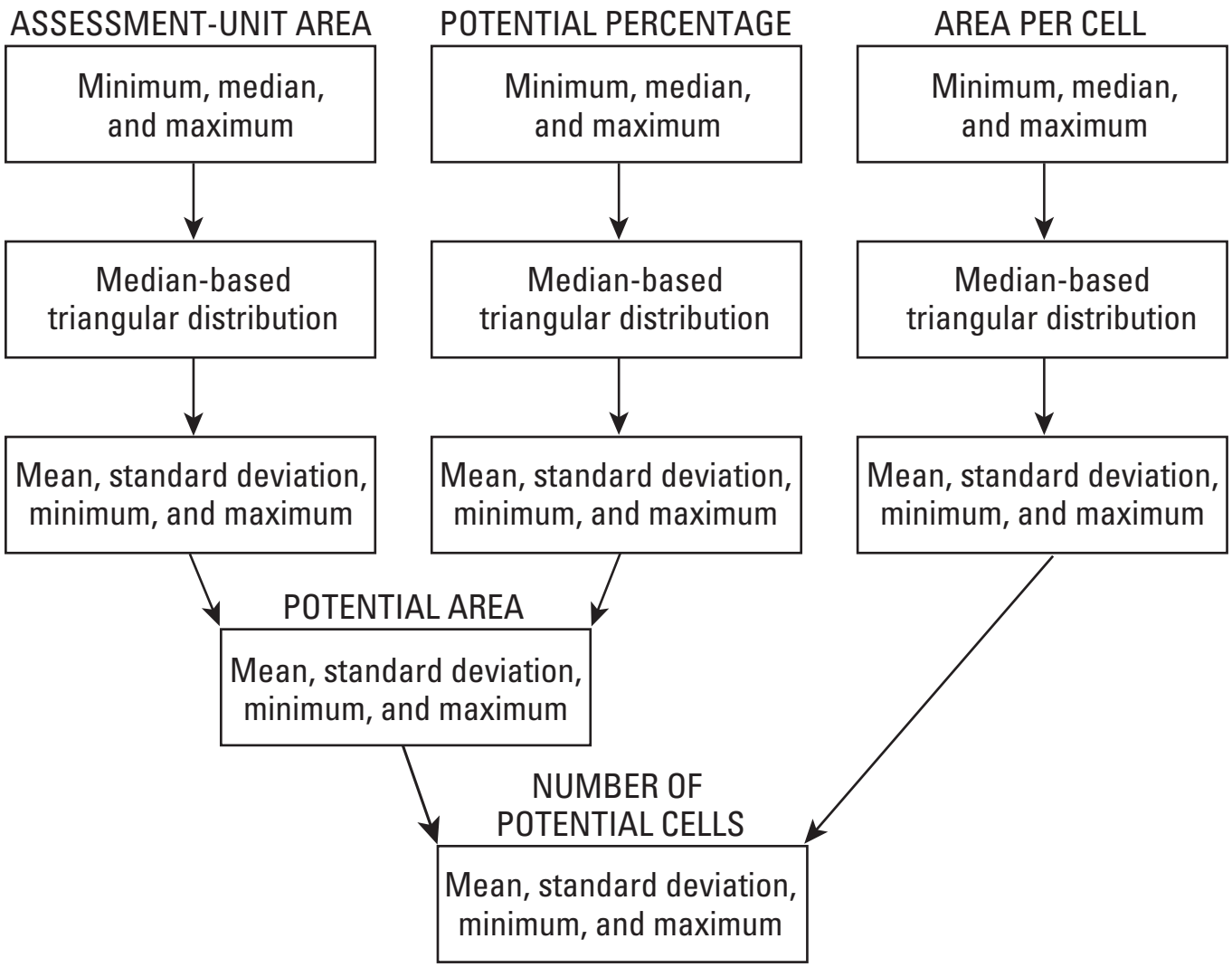

Figure 3. Simplified flow chart of calculations for determining number of potential cells.

- Total in oil assessment unit or total in gas assessment unit

Each commodity has various parameters:

- Mean
- Standard deviation
- Fractiles (F_{100}, F_{95}, F_{75}, F_{50}, F_{25}, F_5, and F_0)

The primary estimates are the mean, median (F_{50}), and fractiles F_{95} and F_5.

Table 1. Spreadsheet ACCESS panel numbers and contents.

1. Input data: Assessment-unit probabilities
2. Input data: Total recovery per cell
3. Input data: Ratios used to assess coproducts
4. Input data: Percent allocation to parcel and offshore portion of parcel
5. Number of potential untested cells: Computed parameters
6. Total recovery per cell: Truncated shifted lognormal distribution
7. Ratios used to assess coproducts: Median-based triangular distribution
8. Ratios used to assess coproducts: Median-based triangular distribution
9. Percent allocation to parcel: Median-based triangular distribution
10. Percent allocation to offshore: Median-based triangular distribution
11. Cond. estimates in assessment unit: Oil in oil A.U. or gas in gas A.U.
12. Cond. estimates in assessment unit: Gas in oil A.U. or liquids in gas A.U.
13. Cond. estimates in assessment unit: NGL in oil A.U. or oil in gas A.U.
14. Cond. estimates in assessment unit: Total in oil A.U. or total in gas A.U.
15. Cond. allocation to parcel: Oil in oil A.U. or gas in gas A.U.
16. Cond. allocation to parcel: Gas in oil A.U. or liquids in gas A.U.
17. Cond. allocation to parcel: NGL in oil A.U. or oil in gas A.U.
18. Cond. allocation to parcel: Total in oil A.U. or total in gas A.U.
19. Cond. allocation to offshore: Oil in oil A.U. or gas in gas A.U.
20. Cond. allocation to offshore: Gas in oil A.U. or liquids in gas A.U.
21. Cond. allocation to offshore: NGL in oil A.U. or oil in gas A.U.
22. Cond. allocation to offshore: Total in oil A.U. or total in gas A.U.
23. Unc1. estimates in assessment unit: Oil in oil A.U. or gas in gas A.U.
24. Unc1. estimates in assessment unit: Gas in oil A.U. or liquids in gas A.U.
25. Unc1. estimates in assessment unit: NGL in oil A.U. or oil in gas A.U.
26. Unc1. estimates in assessment unit: Total in oil A.U. or total in gas A.U.
27. Unc1. allocation to parcel: Oil in oil A.U. or gas in gas A.U.
28. Unc1. allocation to parcel: Gas in oil A.U. or liquids in gas A.U.
29. Unc1. allocation to parcel: NGL in oil A.U. or oil in gas A.U.
30. Unc1. allocation to parcel: Total in oil A.U. or total in gas A.U.
31. Unc1. allocation to offshore: Oil in oil A.U. or gas in gas A.U.
32. Unc1. allocation to offshore: Gas in oil A.U. or liquids in gas A.U.
33. Unc1. allocation to offshore: NGL in oil A.U. or oil in gas A.U.
34. Unc1. allocation to offshore: Total in oil A.U. or total in gas A.U.
35. Unc2. estimates in assessment unit: Oil in oil A.U. or gas in gas A.U.
36. Unc2. estimates in assessment unit: Gas in oil A.U. or liquids in gas A.U.
37. Unc2. estimates in assessment unit: NGL in oil A.U. or oil in gas A.U.
38. Unc2. estimates in assessment unit: Total in oil A.U. or total in gas A.U.
39. Unc2. allocation to parcel: Oil in oil A.U. or gas in gas A.U.
40. Unc2. allocation to parcel: Gas in oil A.U. or liquids in gas A.U.
41. Unc2. allocation to parcel: NGL in oil A.U. or oil in gas A.U.
42. Unc2. allocation to parcel: Total in oil A.U. or total in gas A.U.
43. Unc2. allocation to offshore: Oil in oil A.U. or gas in gas A.U.
44. Unc2. allocation to offshore: Gas in oil A.U. or liquids in gas A.U.
45. Unc2. allocation to offshore: NGL in oil A.U. or oil in gas A.U.
46. Unc2. allocation to offshore: Total in oil A.U. or total in gas A.U.
47. Numb. input data: Assessment-unit area, untested %, potential/untested %, & area/cell
48. Numb. assessment-unit area: Median-based triangular distribution
49. Numb. untested percentage: Median-based triangular distribution
50. Numb. potential/untested percentage: Median-based triangular distribution
51. Numb. area per cell: Median-based triangular distribution

Table 1—Continued. Spreadsheet ACCESS panel numbers and contents.

52. Numb. potential untested percentage: Lognormal distribution
53. Numb. potential untested area: Lognormal distribution
54. Numb. number of potential untested cells: Lognormal distribution

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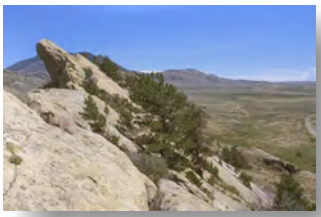

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