National Instrument 51-101 (NI 51-101) Reserves Reconciliation—Part 1

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- Monograph No. 1: Determination of Oil and Gas Reserves, the Petroleum Society;
- Reserves Definitions, the Petroleum Society;
- NI 51-101, Alberta Securities Commission (ASC); and,
- The Canadian Oil and Gas Evaluation Handbook (SPEE).

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Introduction

Because of the uncertainty in estimating oil and gas reserves, the exact quantity of hydrocarbons to be recovered will never be known until production reaches the economic limit and the reservoir is abandoned. It is, however, necessary from time to time to estimate the reserves to be recovered throughout the producing life of a field, and to verify that the reserves are properly estimated and classified according to the definitions and guidelines specified in the Canadian Oil and Gas Evaluation Handbook, "COGEH." The testing procedure that is used is referred to as a "Reserves Reconciliation" and should be performed at least annually or more often if there are material changes to reserves estimates.

A reserves reconciliation is the single most powerful tool in tracking changes in oil and gas reserves estimates. The process keeps track of the flow of reserves into and out of a company's reserves inventory.

Reserves can be added to inventory by:
- Discovery of new reservoirs;
- Extensions of existing reservoirs;
- Installation of improved recovery schemes;
- Infill drilling projects; and,
- Acquisitions of reserves.

Reserves can be deducted from inventory by:
- Dispositions of reserves; and,
- Production of reserves.

Reserves can fluctuate within inventory because of:
- Economic changes; and,
- Technical revisions.

Changing economic conditions may cause either additions or reductions to reserves as economic perceptions of the future change. Technical revisions occur due to estimation procedures, resulting from moving reserves from one classification to another, obtaining new information, and, unfortunately, due to poor geological and engineering reserves estimation practices. Technical revisions form the main focus of this paper.

Basic Concepts of Reserves Definitions

Before a reserves reconciliation can be performed, an evaluator must have a sound knowledge of reserves definitions and their

TABLE 1: Reserves classifications and notations.

Major Classification	Producing Status			Aggregation of Major Classifications	
	Producing (P)	Non-Producing (NP)			
Proved (P_V)	$P_V DP$	$P_V DNP$	$P_V UD$	$1P = P_V$	
Probable (P_B)	$P_B DP$	$P_B DNP$	$P_B UD$	$2P = P_V + P_B$	
Possible (P_S)	$P_S DP$	$P_S DNP$	$P_S UD$	$3P = P_V + P_B + P_S$	
	Developed (D)		Undeveloped (UD)		
	Development Status				

application. As detailed in the COGEH, reserves estimates are classified according to the following criteria:
- Certainty or uncertainty (Proved, Probable, Possible);
- Production status (Producing, Non-Producing); and,
- Development stage (Developed, Undeveloped).

These classifications are summarized in Table 1 along with generally accepted notations for each classification.

The objective of estimating reserves is to establish the "best estimate" of the reserves to be recovered which, according to the COGEH definitions, is the proved + probable (2P) reserves. The proved (1P) and proved + probable + possible (3P) reserves estimates are conservative and optimistic estimates, respectively, which provide a measure of the central tendency about the 2P reserves estimate. When there is a wide range between the 1P and 3P reserves estimates, this indicates a high degree of uncertainty. When the range is very small, there is a low degree of uncertainty. Generally, a high degree of uncertainty exists in the early stages of development of an entity, and this uncertainty decreases (i.e., certainty *increases*) with time as more and more information becomes available, as illustrated in Figure 1.

Production Groups and Product Types

A number of product types are identified in reserves estimates. In conventional oil and gas operations, these product types are produced within three production groups:

Conventional Production Groups	Product Types
Light and Medium Oil (L&M Oil)	Light and Medium Oil, Gas, Natural Gas Liquids, and Sulphur
Heavy Oil (Hvy Oil)	Heavy Oil and very occasionally Solution Gas, Natural Gas Liquids, and Sulphur
Associated and Non-Associated Gas, (A&NA Gas)	Associated and Non-Associated Gas, Natural Gas Liquids, Sulphur, and occasionally other by-products

FIGURE 1: Reserves estimates vs. time.

Other non-conventional production groups and product types are as follows:

Non-Conventional Production Groups	Product Types
In Situ Bitumen Recovery	Bitumen, Synthetic Oil
Oil Sands Mining Projects	Bitumen, Synthetic Oil
Coal Bed Methane Extraction	Natural Gas

This article will focus on conventional oil and gas reserves reconciliation. Non-conventional production groups may be a topic for future articles.

The individual reserves estimates and economic forecasts, which form the evaluation of an entity, are predominantly prepared as part of one of the production groups. Within the evaluations, the individual product type reserves and respective revenues are segregated; however, the capital and operating costs are not. These monetary items pertain to the overall evaluation of the production group and are not split out by product type. Also, some product types may be included in more than one production group. For example, natural gas liquids can be produced within the L&M Oil production group and also within the A&NA Gas production group. It is therefore recommended that reserves reconciliations for conventional production groups be limited to the major production type in each production group such as:
- Light and Medium Oil;
- Heavy Oil; and,
- Associated and Non-Associated Gas.

Reserves Classifications

As a minimum, reserves reconciliation should be calculated for the major reserves classifications of Proved (P_V), Probable (P_B), and Proved + Probable ($P_V + P_B$). Other sub-classifications such as developed and undeveloped, as well as producing and non-producing, may be included for clarification but are usually not required. Likewise, Possible (P_S) reserves may be included but are usually not required.

Reserves Ownership

The reserves to be reconciled for an enterprise should be the "Company Net Reserves." This ownership category of reserves is selected because it identifies the net reserves owned by the company. Detailed discussion on the ownership of reserves is given in the COGEH, Volume 1, Section 7.5.3.

Reserves Reconciliation

Reserves reconciliation should be carried for the period between old and new reserves evaluations—usually at a company's financial year-end. It is desirable to repeat the previous year's reconciliation data for comparison purposes.

Reserves Reconciliation Categories

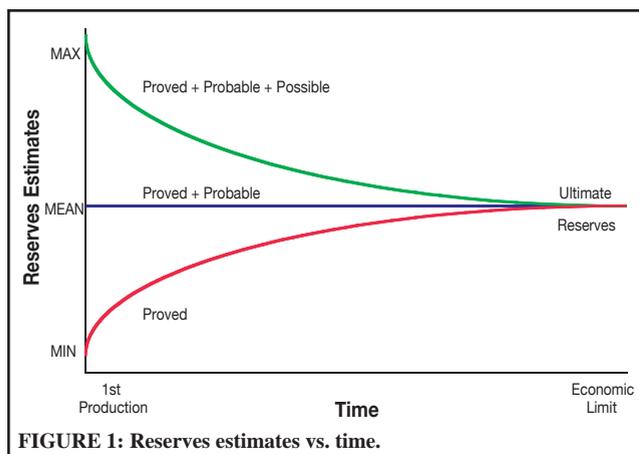In performing a reserves reconciliation, the following categories (as listed in Table 2) should be considered:

TABLE 2: Reconciliation of company net reserves by principal product type.

Factors	Light and Medium Oil			Heavy Oil			Associated and Non-Associated Gas		
	Net P_V (Mbbl)	Net P_B (Mbbl)	Net P_V + P_B (Mbbl)	Net P_V (Mbbl)	Net P_B (Mbbl)	Net P_V + P_B (Mbbl)	Net P_V (MMcf)	Net P_B (MMcf)	Net P_V + P_B (MMcf)
Estimated Reserves at Beginning of Year	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Extensions	xx	xx	xx	xx	xx	xx	xx	xx	xx
Improved Recovery	xx	xx	xx	xx	xx	xx	xx	xx	xx
Discoveries	xx	xx	xx	xx	xx	xx	xx	xx	xx
Acquisitions	xx	xx	xx	xx	xx	xx	xx	xx	xx
Dispositions	xx	xx	xx	xx	xx	xx	xx	xx	xx
Economic Factors	xx	xx	xx	xx	xx	xx	xx	xx	xx
Technical Revisions	xx	xx	xx	xx	xx	xx	xx	xx	xx
Production	xx	xx	xx	xx	xx	xx	xx	xx	xx
Estimated Reserves at End of Year	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

Estimated Reserves at Beginning of Year

These are the reserves which a company has recorded as the closing balance of the previous year's reconciliation.

Extensions

As a result of the development of a pool, new reserves may be added by extending the pool boundaries by drilling new wells and by revising geological and engineering interpretations not known to exist when the opening balance reserves were estimated. Extensions will usually be the result of successful drilling operations requiring significant capital expenditures.

Improved Recovery

The recovery from a pool may be enhanced through:
• The installation of secondary and tertiary recovery mecha-

nisms, such as waterfloods, miscible injection, and in situ combustion;
• The drilling of infill wells; and,
• The installation of field facilities such as compression, line looping, etc.

These improved recovery schemes were not considered as a viable development objective and were not included in the opening balance reserves estimates. Improved recovery will usually be the result of successful applications of improved recovery schemes requiring significant capital expenditures.

Discoveries

The objective of most exploration and development companies is to add reserves through successful exploration drilling operations. In this category, resources are transformed into reserves requiring capital expenditures.

Acquisitions

These are positive revisions to reserves estimates as a result of purchasing oil and gas reserves. Caution must be exercised because the reserves that are purchased may have been estimated by different evaluators than those preparing the current evaluation. Reserves reported for acquisitions should be at the end of the reconciliation period, which will not be the same as at time of acquisition.

Dispositions

These are negative revisions to reserves estimates as a result of selling oil and gas reserves.

Economic Factors

Economic factors such as price forecasts, inflation rates, and operating and capital cost escalation rates can potentially change on a daily basis and can result in reserves estimates changing accordingly. The changes may be positive or negative depending upon the evaluator's perceptions of the future. Economic factors not only change revenues and costs but also affect royalties and income taxes. Conversionary ownership interests may also be affected by changing economic factors.

Technical Revisions

These reserves changes can be either positive or negative indicating different performance predictions than previously anticipated. This item draws the most attention in reviewing reserves reconciliations because it reflects the abilities, judgments, and biases of the evaluator. *Technical revisions are applied only to those carry-forward entities to which reserves were assigned as of the* *opening balance and are still owned by the enterprise as of the closing balance*. No new capital expenditures will be associated with changes in this category. Masking technical revisions by including such items as infill drilling, pool extensions, acquisitions, etc., is not acceptable.

Production

Production is the actual volume produced in the current year of the major product type in the production group reserves that are being reconciled. Natural gas liquids should not be included with light and medium oil or with heavy oil, and solution gas should not be included with associated and non-associated gas.

Estimated Reserves at End of Year

This is the closing volume of reserves, which is equal to the opening volume plus or minus the revisions.

Failure to Report Reserves

Should any personnel of a public issuer, who is aware of reserves not reported to the public by means of a disclosure or press release, trade in the securities of that company they could be charged with insider trading activities.

Reserves and Ultimate Reserves Reconciliation

The above guidelines are provided for the reconciliation of reserves, and reserves are defined in the COGEH (Section 5.4.1) as:

> "Estimated remaining quantities of oil and natural gas and related substances anticipated to be recoverable from known accumulations, from a given date forward."

Another method of reconciliation is based on ultimate reserves, which by definition are:

> "The total quantities of oil and natural gas and related substances to be recoverable from known accumulations and are the sum of the reserves and cumulative production as at a given date."

It is suggested that reserves reconciliation calculations begin with the reconciliation of ultimate reserves. This method is more demonstrative of what is occurring in a reservoir and is not masked by the deduction of production. Qualified reserves evaluators target the ultimate 2P reserves as the expected volume that will be produced from an entity (a well, a group of wells, or a pool). It is desirable to have this volume remain constant and not fluctuate up and down from year to year. The ultimate 1P reserves is a conservative estimate and should increase with time as new data is obtained. Consequently, a corresponding reduction in probable
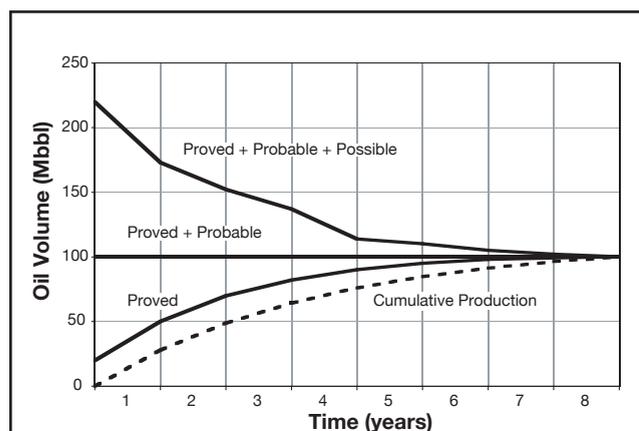

FIGURE 2: Example of oil field production and reserves estimate.

TABLE 3: Example oil field production and reserves estimates.

| Year | Production (as of December 31) | | P_V | | $P_V + P_B$ | | | $P_V + P_B + P_S$ | | |
	Yearly	Cumulative	Ultimate	Remaining	Ultimate	Remaining	Remaining P_B	Ultimate	Remaining	Remaining P_S
Initial	-	-	20.0	20.0	100.0	100.0	80.0	220.0	220.0	120.0
1	27.8	27.8	50.0	22.2	100.0	72.2	50.0	173.0	145.2	73.0
2	20.8	48.6	70.0	21.4	100.0	51.4	30.0	152.0	103.4	52.0
3	15.6	64.2	82.0	17.8	100.0	35.8	18.0	137.0	72.8	37.0
4	11.7	76.0	90.0	14.0	100.0	24.0	10.0	114.0	38.0	14.0
5	8.8	84.7	95.0	10.3	100.0	15.3	5.0	110.0	25.3	10.0
6	6.6	91.3	98.0	6.7	100.0	8.7	2.0	105.0	13.7	5.0
7	4.9	96.3	99.0	2.7	100.0	3.7	1.0	102.0	5.7	2.0
8	3.7	100.0	100.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0

The header "Oil Reserves (as of December 31) (Mbbl)" spans the reserves columns.

reserves will occur if the ultimate 2P reserves estimate is to remain constant.

It is well recognized that this objective is difficult to achieve on an entity-to-entity basis; however, for a group of entities, this criterion must be the target. What seems to be confusing is the fact that the possible reserves for a group of entities should disappear with time. If the 2P reserves are the expected reserves, the 3P reserves estimate will converge to the 2P estimate without any addition to the expected 2P reserves. If possible, reserves (P_S) are realized in the future and the 2P estimate is increased accordingly, then the original estimate of the 2P reserves was conservative.

The following example is included to demonstrate how a reserves reconciliation could be computed for both a reserves reconciliation and for an ultimate reserves reconciliation. In the example, it is assumed that 100 Mbbl of light oil will be produced from a field over an eight-year period. Reserves were calculated annually and categorized as 1P, 2P, and 3P estimates. This data is summarized in Table 3 and also illustrated in Figure 2.

From this data, ultimate reserves and reserves reconciliations have been calculated for the years two and three. It is assumed that this example is for a carry-forward property. The example is for an ideal case where the 2P reserves remain constant and the 1P and 3P reserves converge from their initial conservative and optimistic values, respectively, to the 2P reserves estimate at the economic limit. No other factors are considered other

than the technical revisions due to increasing confidence in the reserves estimates causing the movement of probable reserves to the proved reserves and the reduction of possible reserves.

Table 4 illustrates how these technical revisions are recorded on an ultimate reserves reconciliation. Without production, it is a simple process of revising the 1P reserves to reflect the increasing confidence as time progresses. As noted previously, the 2P reserves estimate remains constant; therefore, the increase in 1P reserves results in an equal decrease in P_B reserves. The reduced 3P reserves estimates can only reflect a reduction in the P_S reserves. As time progresses and the distribution of reserves estimates diminishes as the 1P and the 3P converge to the 2P estimate, the incremental changes also decrease.

Table 5 illustrates the reserves reconciliation, which deducts production in the process. Obviously, similar effects occur, but when production is deducted, the results become obscure. In this case, the annual 1P reserves decrease with time whenever the rate of annual production exceeds the rate of increase in ultimate 1P reserves. Similar results occur in the 2P and 3P reserves estimates. At first glance, it looks like the reserves are being reduced with time; however, this is not the case. Normal, acceptable reserves revisions are being realized, but the production is overriding these positive revisions. Evaluators and users of this information must therefore exercise caution.

TABLE 4: Ultimate reserves reconciliation of company net reserves, light and medium oil carry forward reserves.

Period and Factor	Ultimate Reserves (Mbbl)				
	P_V	P_B	$P_V + P_B$	P_S	$P_V + P_B + P_S$
December 31, Year 1	50.0	50.0	100.0	73.0	173.0
Extensions Improved Recovery Technical Revisions Discoveries Acquisitions Dispositions Economic Factors	20.0	(20.0)	-	(21.0)	(21.0)
December 31, Year 2	70.0	30.0	100.0	52.0	152.0
Extensions Improved Recovery Technical Revisions Discoveries Acquisitions Dispositions Economic Factors	12.0	(12.0)	-	(15.0)	(15.0)
December 31, Year 3	82.0	18.0	100.0	37.0	137.0

DISCUSSION INVITED

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TABLE 5: Reserves reconciliation of company net reserves, light and medium oil, carry forward reserves.

Period and Factor	Reserves (Mbbl)				
	P_V	P_B	$P_V + P_B$	P_S	$P_V + P_B + P_S$
December 31, Year 1	22.2	50.0	72.2	73.0	145.2
Extensions Improved Recovery Technical Revisions Discoveries Acquisitions Dispositions Economic Factors Production	20.0 20.8	(20.0)	- 20.8	(21.0)	(21.0) 20.8
December 31, Year 2	21.4	30.0	51.4	52.0	103.4
Extensions Improved Recovery Technical Revisions Discoveries Acquisitions Dispositions Economic Factors Production	12.0 15.6	(12.0)	- 15.6	(15.0)	(15.0) 15.6
December 31, Year 3	17.8	18.0	35.8	37.0	72.8

TABLE 6: Reserves reconciliation objectives.

Reserve Classification	Entity Level	Reported Level
1P = P_V	Positive Reserves revisions should occur in the vast majority of the entities	Only Positive Reserve revisions should occur at this level unless the reported level is for a small number of entities, less than ten, or for a group of entities dominated by one or two large reserve entities
2P = $P_V + P_B$	Positive Reserves revisions should equal Negative Reserves revisions	Only very minor Positive or Negative revisions should occur at this level
3P = $P_V + P_B + P_S$	Negative Reserves revisions should occur in the vast majority of the entities	Only Negative Reserves revisions should occur at this level unless the reported level is for a small number of entities, less than ten, or for a group of entities dominated by one or two large reserve entities

TABLE 7: Probabilistic aggregation of a constant triangular distribution for each entity.

| Confidence Levels	Min			Mode	Median	Mean			Max
	P_{100}	P_{90}	P_{75}	P_{67}	P_{50}	P_{46}	P_{25}	P_{10}	P_0
Input	100	155	187	200	227	233	278	323	400
Monte Carlo Simulation Number of Entities — 1	103	155	187	199	227	233	277	322	394
2	128	178	200	217	231	233	264	292	368
5	160	199	215	227	233	233	252	269	313
10	172	210	219	232	233	233	246	259	291
20	190	215	223	234	234	233	244	252	271
50	205	223	228	232	233	233	239	244	261
100	214	225	229	233	233	233	237	241	252
200	220	228	231	233	233	233	236	239	248
500	224	230	231	231	233	233	235	237	243
1,000	228	231	232	233	233	233	235	236	239
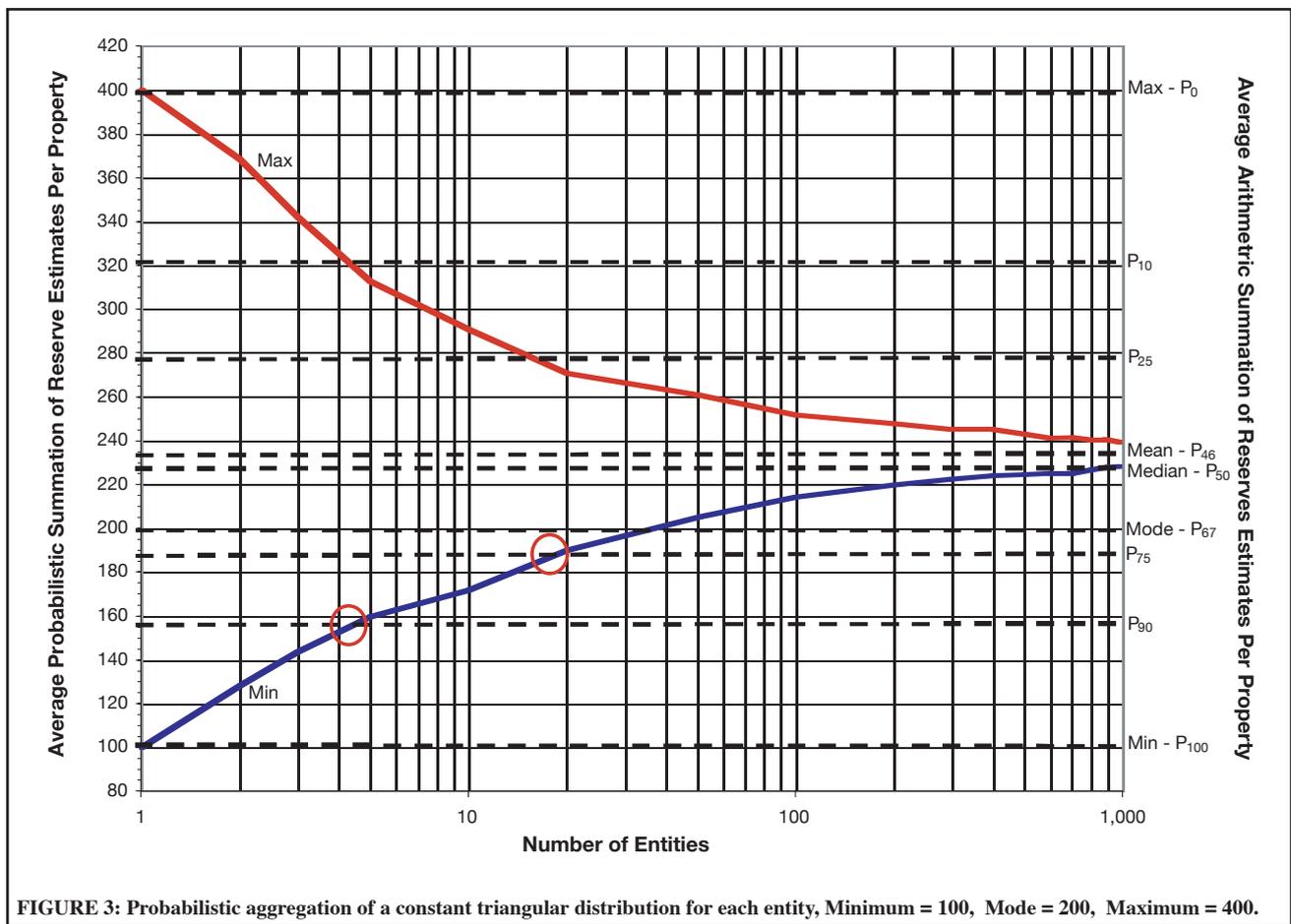
FIGURE 3: Probabilistic aggregation of a constant triangular distribution for each entity, Minimum = 100, Mode = 200, Maximum = 400.

Reserves Reconciliation Objectives

Because of the uncertain nature in estimating reserves, the unexpected occurs, and thus the ideal principles are difficult to follow on an entity-to-entity level. Some reserves estimates, on an entity level, will have positive revisions (increase in estimates), while others will have negative revisions (decrease in estimates). Because the 1P reserves are conservative, there should be a lot more positive than negative revisions and therefore, the objective for an aggregate of 1P reserves should be no negative revisions. Conversely, since the 3P reserves are optimistic, there should be a lot more negative than positive revisions and therefore, the objective for an aggregate of 3P reserves should be no positive revisions. The 2P reserves estimates, which are best estimates, should have equal volumes of both positive and negative revisions between entity estimates, with the effect that, on an aggregate basis, these revisions will average out and the total estimates should remain constant.

These objectives apply to a large number (greater than 10) of entities with equal portions of small, medium, and large reserves entities. For single entity estimates or where one large entity dominates the total estimate, these objectives will be difficult to meet;

however, care must be exercised because negative 1P reserves revisions and changes in 2P reserves are still not desirable. Table 6 summarizes the restraints on 1P, 2P, and 3P reserves reconciliations.

Further clarifications of these objectives can be demonstrated using simple statistical aggregation for various numbers of entities. For the example, it has been assumed that each entity was similar, having a triangular distribution with a minimum value of 100, a mode of 200, and a maximum value of 400. Table 7 illustrates the sum of the statistical values obtained by performing Monte Carlo simulation for various numbers of entities. This data is also plotted on Figure 3.

In this example, if the 1P reserves were estimated at a P_{90} confidence level (155 units) for each entity, only five properties would be required to achieve a minimum average value of 155 units. For a group of entities greater than five, a 1P reserves write-down would not be possible since the arithmetic sum of the P_{90}s for the entities greater than five would be less than the probabilistic minimum values. For a P_{75} confidence level at the entity level, 18 properties would be required to achieve an equivalent minimum average value of 190.