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5 RESERVE ESTIMATES

5.1 Introduction

This section presents the range of hydrocarbon-in-place and recoverable resource estimates for the resources targeted in the initial development phase of the project. In-place and recovery estimates for the remaining resources are provided in Section 6.8 – Contingent Developments.

5.1.1 Original Hydrocarbon In-Place Estimates

Original hydrocarbon in-place best estimate volumes and their associated uncertainty ranges were calculated using both deterministic geologic / earth modeling and stochastic analyses.

The stochastic analysis employed the Monte Carlo method of uncertainty modeling. Each variable in the equation used to determine in-place volumes was assigned a distribution based on interpretation of well and seismic data. The distributions reflect the range of uncertainty for each variable used. The shapes of the different input distributions ranged from uniform to triangular, depending on the variable. For Pools 1 and 3, the @Risk ® software program was used to run multiple realizations of the hydrocarbon in-place volumes and produce an output distribution. Pools 4 and 5 utilized Experimental Design model-based uncertainty analysis, followed by Monte Carlo sampling in Crystal Ball ® software, thus yielding multiple realizations of the hydrocarbon in-place volumes and associated distribution.

For all the pools, the best estimate models were used for the best estimate volumes. The best estimate assessment is determined from the subsurface description represented by the base case reservoir models (static and dynamic). The models are built using available subsurface data, derivatives and / or interpretations of the data (e.g. seismic interpretation, structural framework, petrophysics, facies distribution, core analysis, pressure-volume-temperature analysis, etc). In situations where the required data is unavailable, insufficient or deemed to be of poor quality, the collective experience and judgment of the subsurface technical team is utilized to determine suitable inputs. The result of this process is a favoured deterministic reference case. The upside and downside values were computed probabilistically both for the individual pools and the total resource. The total hydrocarbon in-place volumes for the initial development phase are shown in Table 5.6-1.

5.1.2 Recoverable Resources Estimates

The ranges of recoverable resources were generated by flow simulation modeling of different scenarios. In the assessment, the starting point for each resource was the base case reservoir description, the simulation model inputs described in Section 4, and the base case depletion plans selected for each

of the pools as described in Section 6. Sensitivities to different input parameters were considered and simulated independently for each reservoir. The impact of downtime assumptions, drilling sequence, production constraints associated with the design capacity limits of the production system or economic cut-off criteria for recovery estimation were not considered in the flow simulation modeling. Section 6.6.3 presents the integrated production profiles for the best estimate case that incorporate these considerations while Section 6.6.4 presents upside and downside production scenarios of the resources included in the initial development phase of the project. The Estimated Ultimate Recovery (EUR) numbers quoted in this section are based on a 30-year assumed producing life for each developed resource.

The approach taken for the recovery uncertainty was to begin with deterministic recovery efficiency (RE) for each reservoir compartment. This deterministic RE is obtained directly from the simulation model results of the base case depletion plan. A series of stochastically determined delta recovery efficiencies that account for the uncertainties surrounding the deterministic value was then added to the base value. A spreadsheet model using Excel™ and @RISK™ software was used to generate stochastic estimates of RE and EUR for the individual reservoir compartments. The RE input parameters were allowed to vary stochastically over their prescribed input ranges and correlation coefficients were built into the model for inter-related input parameters.

5.2 Hebron Field Ben Nevis Reservoir (Pool 1)

5.2.1 Hebron Ben Nevis Original Hydrocarbons In-Place

5.2.1.1 In-Place Parameters Considered

The results of the stochastic modeling indicate that the following parameters have the greatest impact on the overall range of in-place volumes uncertainty (listed in descending order of importance):

- Hydrocarbon Saturation
- Porosity
- Seismic Velocity Interpretation
- Oil-Water Contact (OWC) Interpretation
- Shrinkage
- Gas-Oil Contact
- Gross Interval Thickness

5.2.1.2 In-Place Volume Ranges

Table 5.2-1 shows the overall estimated in-place volumes range for the Hebron Ben Nevis reservoir, Pool 1. The total Pool 1 values for the upside and downside cases were computed via a combined stochastic evaluation of the fault blocks, and not from the summation of the stochastic evaluation of the individual fault blocks.

Table 5.2-1: Hebron Ben Nevis (Pool 1) In-Place Volumes Range

Hebron Ben Nevis Oil	Upside Volumes		Best Estimate Volumes		Downside Volumes	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
D-94 Fault Block	1601	255	1328	211	1077	171
I-13 Fault Block	252	40	187	30	141	22
Total Hebron Ben Nevis	1870	297	1515	241	1204	191
Total Hebron Ben Nevis Gas	**Upside Volumes**		**Best Estimate Volumes**		**Downside Volumes**	
	GCF	* GSm^3	GCF	GSm^3	GCF	GSm^3
Solution Gas D-94 Block	112	3.2	145	4.1	189	5.4
Solution Gas I-13 Block	10	0.3	14	0.4	22	0.6
Non-associated Gas	n/a	n/a	n/a	n/a	n/a	n/a
Gas Cap D-94 Block only	0	0	0	0	31	0.9

* $GSm^3 = 10^9$ cubic meters

5.2.2 Hebron Ben Nevis Recoverable Resources Sensitivity Results

5.2.2.1 Reservoir Parameters Considered

The input parameters considered in the Hebron Ben Nevis EUR sensitivity study included the following:

- Aquifer ratio
- Baffle vertical permeability
- Bulk permeability (vertical, Kv and horizontal, Kh) – concurrent increase / decrease in both horizontal and vertical permeabilities, without altering the Kv-to-Kh ratio
- Calcite cement coverage in cement-prone layer
- Fault transmissibility
- Pore Volume compressibility
- Relative permeability
- Skin

- Vertical permeability – increase / decrease in vertical permeability without altering horizontal permeability
- Viscosity
- Zone boundary transmissibility

The results of the sensitivity analysis and stochastic modeling indicate that the following dynamic input parameters (listed in descending order of importance) have the greatest impact on EUR:

- Bulk permeability (vertical, Kv and horizontal, Kh)
- Relative permeability
- Vertical permeability
- Viscosity

5.2.2.2 Recoverable Resources Range

Table 5.2-2 shows the overall EUR range for the Hebron Ben Nevis reservoir, Pool 1. The total Pool 1 values for the upside and downside cases were computed via a combined stochastic evaluation of the fault blocks, and not from the summation of the stochastic evaluation of the individual fault blocks.

Table 5.2-2: Hebron Ben Nevis (Pool 1) EUR Oil Range

	Upside EUR		Best Estimate EUR		Downside EUR	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
D-94 Fault Block	682	109	517	82	410	65
I-13 Fault Block	80	13	46	7	38	6
Total Hebron Ben Nevis	762	121	563	89	443	70

5.3 Hebron Field Hibernia Reservoir (Pool 5)

5.3.1 Hebron Hibernia Original Hydrocarbons In-Place

5.3.1.1 In-Place Parameters Considered

The top six uncertainties impacting in-place volumes were as follows (listed in descending order of importance):

- Porosity
- Swir
- OWC interpretation
- Facies
- Structure

- Permeability

5.3.1.2 In-Place Volume Ranges

Table 5.3-1 shows the overall estimated in-place volumes range for the Hebron Hibernia reservoir, Pool 5.

Table 5.3-1: Hebron Hibernia (Pool 5) In-Place Volume Range

Hebron Hibernia Oil	Upside Volumes		Best Estimate Volumes		Downside Volumes	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
	218	35	148	24	93	15
Hebron Hibernia Gas	**Upside Volumes**		**Best Estimate Volumes**		**Downside Volumes**	
	GCF	GSm^3	GCF	GSm^3	GCF	GSm^3
Solution Gas	122	3.5	85	2.4	53	1.5
Non-associated Gas	n/a	n/a	n/a	n/a	n/a	n/a
Gas Cap	n/a	n/a	n/a	n/a	n/a	n/a

5.3.2 Hebron Hibernia Recoverable Resources Sensitivity Results

5.3.2.1 Reservoir Parameters Considered

The top six uncertainties (listed in descending order of importance) impacting oil recovery were as follows:

- Facies distribution model (static model)
- Porosity
- Permeability
- Water saturation distribution
- OWC interpretation
- Structure

5.3.2.2 Recoverable Resources Range

Table 5.3-2 shows the EUR range for the Hebron Hibernia reservoir, Pool 5.

Table 5.3-2: Hebron Hibernia (Pool 5) EUR Range

	Upside EUR		Best Estimate EUR		Downside EUR	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
Hebron Hibernia	47	7	15	2	6	1

5.4 Hebron Field Jeanne d'Arc Reservoir (Pool 4)

5.4.1 Hebron Jeanne d'Arc Original Hydrocarbons In-Place

5.4.1.1 In-Place Parameters Considered

The top six uncertainties (listed in descending order of importance) impacting in-place volumes were as follows:

- Valley fill configuration (width and thickness)
- Facies distribution model (static model)
- Structural interpretation
- Porosity
- J-function (transition zone interpretation)
- OWC interpretation

5.4.1.2 In-Place Volume Ranges

Table 5.4-1 shows overall in-place volumes range for the Jeanne d'Arc reservoir, Pool 4.

Table 5.4-1: Hebron Jeanne d'Arc (Pool 4) In-Place Volume Range

Hebron Jeanne d'Arc Oil	Upside Volumes		Best Estimate Volumes		Downside Volumes	
	MB	Mm^3	MB	Mm^3	MB	Mm^3
H-Sand North Valley	274	44	204	32	147	23
B Sand	220	35	113	18	57	9
Total Hebron Jeanne d'Arc	464	74	317	50	243	39
Hebron Jeanne d'Arc Gas	**Upside Volumes**		**Best Estimate Volumes**		**Downside Volumes**	
	GCF	GSm^3	GCF	GSm^3	GCF	GSm^3
Solution Gas Pool 4 H	151	4.3	112	3.2	81	2.3
Solution Gas Pool 4 B	353	10.0	181	5.2	92	2.6
Non-associated Gas	n/a	n/a	n/a	n/a	n/a	n/a
Gas Cap	n/a	n/a	n/a	n/a	n/a	n/a
Total	504	14.3	293	8.3	173	4.9

5.4.2 Hebron Jeanne d'Arc Recoverable Resources Sensitivity Results

5.4.2.1 Reservoir Parameters Considered

The top six uncertainties (listed in descending order of importance) impacting EUR were as follows:

- Facies distribution model (static model)
- Valley fill configuration (width and thickness)
- Permeability
- J-function (transition zone interpretation)
- Structural interpretation
- Residual oil saturation

5.4.2.2 Recoverable Resources Range

Table 5.4-2 shows the EUR range for the Jeanne d'Arc reservoir, Pool 4.

Table 5.4-2: Hebron Jeanne d'Arc (Pool 4) EUR Range

	Upside EUR		Best Estimate EUR		Downside EUR	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
H-Sand North Valley	89	14	59	9	33	5
B Sand	60	10	28	4	11	2
Total Hebron Jeanne d'Arc	123	20	87	14	61	10

5.5 Ben Nevis Field Ben Nevis Reservoir (Pool 3)

5.5.1 Ben Nevis Ben Nevis Original Hydrocarbons In-Place

5.5.1.1 In-Place Parameters Considered

The results of the stochastic modeling indicate that the following parameters have the greatest impact on the overall range of in-place volumes uncertainty (listed in descending order of importance):

- Hydrocarbon Saturation
- Porosity
- Seismic Velocity Interpretation
- Degree of cementation
- OWC Interpretation
- Shrinkage
- Gross Interval Thickness
- Gas-Oil Contact

5.5.1.2 In-Place Volume Ranges

Table 5.5-1 shows the overall estimated in-place volumes range for the Ben Nevis Ben Nevis reservoir, Pool 3.

Table 5.5-1: Ben Nevis Field, Ben Nevis (Pool 3) In-Place Volumes Range

Ben Nevis Ben Nevis Oil	Upside Volumes		Best Estimate Volumes		Downside Volumes	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
	925	147	640	102	455	72
Ben Nevis Ben Nevis Gas	**Upside Volumes**		**Best Estimate Volumes**		**Downside Volumes**	
	GCF	GSm^3	GCF	GSm^3	GCF	GSm^3
Solution Gas	211	6.0	159	4.5	122	3.5
Non-associated Gas	n/a	n/a	n/a	n/a	n/a	n/a
Gas Cap	83	2.4	54	1.5	34	1.0
Total	294	8.3	213	6.0	156	4.4

5.5.2 Ben Nevis Ben Nevis Recoverable Resources Sensitivity Results

5.5.2.1 Reservoir Parameters Considered

The input parameters considered in the Ben Nevis Ben Nevis EUR sensitivity study included the following:

- Bulk permeability (vertical, Kv and horizontal, Kh) – concurrent increase / decrease in both horizontal and vertical permeabilities, without altering the Kv-to-Kh ratio
- Fault transmissibility
- Relative permeability
- Skin
- Vertical to horizontal permeability (Kv/Kh) ratio

The results of the sensitivity analysis and stochastic modeling indicate that bulk permeability, skin and relative permeability (listed in descending order of importance) are the dynamic parameters that have the greatest impact on EUR.

5.5.2.2 Recoverable Resources Range

Table 5.2-2 shows the overall EUR range for the Ben Nevis Ben Nevis reservoir, Pool 3. All the gas produced in conjunction with oil production will either be re-injected or used for the GBS facility operation.

Table 5.5-2: Ben Nevis Ben Nevis (Pool 3) EUR Range

	Upside EUR		Best Estimate EUR		Downside EUR	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
Ben Nevis Ben Nevis - Oil	203	32	124	20	75	12

5.6 Hebron Initial Development Summary

5.6.1 Total Resource In-Place Volumes

Table 5.6-1 shows the overall range of in-place volumes calculated for the resources developed in the initial project phase. The total resource values were computed via a combined stochastic evaluation of all the pools, and not from the summation of the stochastic evaluation of the individual Hebron pools.

Table 5.6-1: Hebron Initial Development In-Place Oil Volumes Range

Initial Development Phase	Upside In-Place Volumes		Best Estimate In-Place Volumes		Downside In-Place Volumes	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
Hebron Ben Nevis	1870	297	1515	241	1204	191
Hebron Hibernia	218	35	148	24	93	15
Hebron Jeanne d'Arc	464	74	317	50	243	39
Ben Nevis Ben Nevis	925	147	640	102	455	72
Total Hebron	**3206**	**510**	**2620**	**417**	**2283**	**363**

5.6.2 Total Recoverable Resources

Table 5.6-2 shows the overall range of EUR calculated for the resources developed in the initial project phase. The total resource values were computed via a combined stochastic evaluation of all the pools, and not from the summation of the stochastic evaluation of the individual Hebron pools.

Table 5.6-2: Hebron Initial Development EUR Oil Range

Initial Development Phase	Upside EUR		Best Estimate EUR		Downside EUR	
	MBO	Mm^3	MBO	Mm^3	MBO	Mm^3
Hebron Ben Nevis	762	121	563	90	443	70
Hebron Hibernia	47	7	15	2	6	1
Hebron Jeanne d'Arc	123	20	87	14	61	10
Ben Nevis Ben Nevis	203	32	124	20	75	12
Total Hebron	**1055**	**168**	**789**	**126**	**660**	**105**