EXECUTIVE SUMMARY

Korean National Oil Corporation, *KNOC*, is looking for an evaluation of enhanced oil recovery technologies, for Alberta Athabasca reservoirs for purposes of bitumen production. In order to have an independent assessment of oil sands recovery technologies in a short time frame and with limited information, *KNOC* has requested the expert opinion of *ARC* on several potential oil production technologies to be deployed in their field developments.

The opinion of a team Heavy Oil and Oil Sands numerical simulation experts is presented. *ARC* has applied our technical know-how to assess four technologies: *SAGD, ES-SAGD, CSS,* and Horizontal Well CSS (H-CSS), as applied to two reservoir types: Wabiskaw reservoirs and McMurray reservoirs.

The results of the assessment with the information generated are summarized for four technology types, SAGD, ES-SAGD, CSS and H-CSS.

3D simulations of selected cases were run to determine the effect of 3D simulations on prediction, and to more accurately predict the effect of shale on performance of the selected processes.

Economics spreadsheets were prepared for selected 3D cases to compare costs of various processes. The results may be used to evaluate the feasibility of various process options.

The main conclusions of this work are:

1. The performance of SAGD improved substantially as formation thickness was increased. The actual minimum economic cutoff thickness will depend on the project economics used by KNOC.

2. ES-SAGD had an advantage over SAGD for all cases tested in terms of oil rate, oil recovery, and steam-oil ratio.

3. There was little sensitivity to Kv/Kh parameter for SAGD and ES-SAGD for thin Athabasca reservoirs.

4. Reduced Initial reservoir pressure decreased oil rate and recovery, and increased SOR for CSS and H-CSS.

5. There was increased oil rate, recovery and reduced SOR with increased permeability for SAGD and ES-SAGD.

6. ES-SAGD is expected to have an economic advantage over SAGD in thicker formations.

7. All ES-SAGD shale cases showed increased oil rate, recovery and lower SOR than equivalent shale SAGD cases.

8. Reduced oil rate and recovery, and increased SOR were observed with increasing shale content for SAGD and ES-SAGD.

9. CSS simulations showed slightly higher cumulative oil than the equivalent SAGD case, but had CSOR values from 36% to 82% higher than the corresponding SAGD SOR.

10. H-CSS simulations are equivalent to CSS simulations in 2D mode. However, economics are different as CSS requires multiple vertical (slant) wells, while H-CSS assumes one long horizontal well.

11. There is some uncertainty in the CSS and H-CSS predictions due to the dependence on dilation-compaction parameters, which had to be estimated

12. SAGD and ES-SAGD were seen as the best processes for the Athabasca reservoirs studied. H-CSS and CSS may have potential, but more data, including mini-frac tests and field tests are needed to verify numerical predictions.

13. 2D and 3D simulations of a uniform reservoir are expected to yield similar results. The lower oil production seen in 3D SAGD is primarily due to the non-uniform initiation of drainage in 3D SAGD, leading to a delayed startup.

14. Low quantities of randomly distributed shale, on the order of 3%, had little effect on SAGD performance, but the performance of CSS was significantly reduced by 9% shale in the reservoir.

15. ES-SAGD may have an advantage over SAGD for certain reservoirs, namely gas cap, bottom water, and low permeability reservoirs.

16. CSS was seen to have advantages for cases of top gas, top gas with bottom water, and thin (7.5 m) reservoirs.