Decision **99-22**

Imperial Oil Resources Limited Cold Lake Production Project Mahkeses Development

September 1999

Alberta Energy and Utilities Board

ALBERTA ENERGY AND UTILITIES BOARD
Decision 99-22: Imperial Oil Resources Limited Cold Lake Production Project Mahkeses Development

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640 – 5 Avenue SW
Calgary, Alberta
T2P 3G4

Telephone: (403) 297-8311
Fax: (403) 297-7040

Web site: www.eub.gov.ab.ca

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ALBERTA ENERGY AND UTILITIES BOARD
Calgary Alberta

APPLICATION TO AMEND APPROVAL NO. 3950
IMPERIAL OIL RESOURCES LIMITED
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MAHKESES DEVELOPMENT **Application No. 970163**

1 INTRODUCTION

1.1 Application

Imperial Oil Resources Limited (Imperial) applied to the Alberta Energy and Utilities Board (Board/EUB) under Section 14 of the Oil Sands Conservation Act to amend Approval No. 3950 to allow for an expansion of its Cold Lake commercial project and under Section 9 of the Hydro and Electric Energy Act to construct and operate an electrical power plant. The Board granted Approval No. 3950, which allows for the commercial development of the Clearwater oil sands deposit using cyclic steam stimulation (CSS) in the Cold Lake Production Project (CLPP), to Imperial in September 1983. As shown in Figure 1 (attached), the existing approval area covers development phases 1-10. The details of the applied-for expansion project are as follows:

- a new three-phase (phases 11-13) development known as Mahkeses, which would be located adjacent to Imperial's existing Cold Lake operation, as shown in Figure 1 — The Mahkeses project would use CSS technology to recover bitumen from the Clearwater Formation; a combination of directional and horizontal wells would be drilled into the Clearwater Formation on an average well spacing of 3.2 hectares (ha);

- a central plant in the north half of Section 33-64-3 W4M for processing bitumen and produced water;

- a cogeneration power plant located in the north half of Section 33-64-3 W4M capable of generating 220 megawatts of electricity;

- expansion of the approved phases 1-10 development areas and the drilling of additional wells to sustain operations at the existing central plants.

As part of this application, Imperial also submitted an environmental impact assessment (EIA) report to the Director of Environmental Assessment, Alberta Environment (AENV; formerly Alberta Environmental Protection).

1.2 Interventions

Interventions opposing the application were filed by the following: Stop and Tell Our Politicians (STOP), Ron and Carol Pernarowski, Marie Lake Landowners Association (MLLA), Cold Lake First Nations (CLFN), and the Alberta Government, represented by Alberta Environment (AENV), Alberta Health (Health), and the Lakeland Regional Health Authority (LRHA).

STOP is a society comprising some 63 concerned residents from the Crane, Hilda, Ethel, and Marie Lakes area and the Riverhurst Community. Ron and Carol Pernarowski are landowners of the southeast quarter of Section 6-64-3 W4M. The MLLA is a group of residents and property owners located at and around Marie Lake. The CLFN comprises three reserves, namely, Cold Lake Reserve No. 149B (English Bay), situated directly east of the Imperial lease; Cold Lake Reserve No. 149 (Le Goff), located directly south of the town of Cold Lake; and the Cold Lake Reserve No. 149A (Cold Lake), located on the south shore of Cold Lake.

Although he did not file an intervention, Mr. Bob Dodds, a landowner in the southwest quarter of Section 3-64-3 W4M, appeared at the hearing to express his views on the expansion project. The locations of the landowners are shown on Figure 1.

Letters in support of the application were filed by the Cold Lake Regional Chamber of Commerce, Klinger's Oilfield Services Ltd., Municipal District of Bonnyville No. 87, Reid's Welding Inc., Council of Town of Cold Lake, and the Town of Bonnyville. There were no representatives present at the hearing to speak to these submissions.

1.3 Hearing

The application was considered at a public hearing conducted 30 November - 3 December, 7–11 December, and 14-16 December 1998 and 5 January 1999 at Cold Lake South, Alberta, before Board Members F. J. Mink, P.Eng., G. J. Miller, and J. D. Dilay, P.Eng.

The following table lists the participants in the hearing and the abbreviations used in this report.

THOSE WHO APPEARED AT THE HEARING

Principals and Representatives (Abbreviations Used in Report)	Witnesses
Imperial Oil Resources Limited (Imperial)	
D. G. Davies	H. B. Dingle, P.Eng.
P. L. Miller	R. J. Ottenbreit, P.Eng.
	W. R. Costello, Ph.D., P.Geol.
	B. S. Carey, Ph.D.
	D. N. Butchko, P.Eng.
	J. T. Sampson, C.E.T.
	A. J. Kennedy, Ph.D., P.Biol.
	P. R. Kry, Ph.D.
	K. M. Hale
	G. D. Willson, of AGRA Earth & Environmental
	J. E. Green, P.Biol., of AXYS Environmental Consulting Limited
	W. C. Edwards, P.Eng., of Levelton Engineering Limited
	W. M. Veldman, P.Eng., of Hydroconsult
	D. M. Trotter, Ph.D., of AGRA Earth & Environmental
	G. R. Ash, P.Biol., of RL&L Environmental Services
	T. L. Dabrowski, Ph.D., P.Geol., of Komex International Limited
	J. W. Fennell, P.Geol., of Komex International Limited
	J. T. Dance, P.Geol., of EBA Engineering Consultants Limited
	S. Talebi, Ph.D., of Canada Centre for Mineral and Energy Technology
	E. Detournay, Ph.D., of University of Minnesota

THOSE WHO APPEARED AT THE HEARING (cont'd)

Principals and Representatives (Abbreviations Used in Report)	Witnesses
Stop and Tell Our Politicians (STOP) R. C. Secord	S. A. Ulfsten E. Nyland, Ph.D., P.Geoph. R. Wilde J. O. Nriagu, Ph.D. of University of Michigan at Ann Arbor C. Axell E. Reddecliff U. Weyer, Ph.D., P.Geol., of WDA Consultants Inc.
Ron and Carol Pernarowski (the Pernarowskis) J. W. Bodnar, P.Ag.	R. Pernarowski C. Pernarowski
Marie Lake Landowners Association (MLLA) R. M. Kruhlak S. W. Chambers	D. Savard B. Gibeault H. Martin
Cold Lake First Nations (CLFN) L. Mandamin	Chief Scannie M. Francis M. Piche
Government of Alberta S. H. Rutwind C. Graham G. P. Van Ness	R. George, P.Geol., of Alberta Environment M. Klebek, P.Geol., of Alberta Environment J. Nagendran, P.Eng., of Alberta Environment D. Wong, P.Eng., of Alberta Environment B. Black, of Alberta Environment B. Levitt, C.E.T., of Alberta Environment A. Mackenzie, CPHI (C) of Alberta Health and Wellness L. Skjonsby, CPHI (C) of Lakeland Regional Health Authority J. Kupper, Ph.D., of Thurber Environmental Consultants Ltd.

THOSE WHO APPEARED AT THE HEARING (cont'd)

Principals and Representatives (Abbreviations Used in Report)	Witnesses
Alberta Energy and Utilities Board staff D. Larder, Board Counsel K. Sadler, P.Eng. B. Austin, P.Geol. H. Nychkalo R. Stein, P.Geol. L. Andriashek, P. Geol. N. Barnes	

2 ISSUES

The Board believes the issues relating to the application to be

- the need for the proposed project
- technical issues
- environmental issues
- consultation process
- socioeconomic issues

3 THE NEED FOR THE PROPOSED PROJECT

3.1 Views of Imperial

Imperial submitted that there was a need for the proposed expansion project. Commercial bitumen production has occurred in a phased development on Imperial's oil sands leases in the Cold Lake region since 1983. Currently ten phases are in operation. The next integral step in Imperial's phased development approach is called Mahkeses, which constitutes phases 11-13. Mahkeses extends Imperial's development of the Clearwater main valley trend to its southeastern limit. Significant recoverable bitumen reserves, estimated to be 46 million cubic metres (m^3), are present in this development area.

Imperial indicated that the economic viability of the Mahkeses development was not tied to current oil prices but projected over the 35-year life of the project. The drilling of additional wells and construction of additional field facilities in the K-trunk, lower E-trunk, and the current northeast trunk areas would optimize bitumen production and steam utilization in the current production area. The cogeneration facility would also allow Imperial's Cold Lake operation to be self-sufficient in electricity.

Imperial stated that it has no intention at this time to upgrade the products. It suggested that it is currently cheaper and therefore more desirable to add incremental capacity to an existing operation than to build an upgrader.

In summary, Imperial maintained that it holds valid oil sands leases and should be provided the opportunity to develop them in an orderly manner.

The proposed expansion project would recover some 46 million m^3 of bitumen at a rate of 4800 cubic metres per day (m^3/d) over a 35-year period. Bitumen produced at Cold Lake requires blending with diluent, otherwise known as hydrocarbon condensate or pentanes plus, in order to meet pipeline viscosity and density specifications. The blended bitumen from the Mahkeses project would be transported to markets in Canada and the United States. Imperial did not anticipate any shortage of pipeline capacity and assumed a steady increase in demand for the bitumen within the U.S. markets. With research ongoing in the area of partial upgrading and the fact that diluent can be manufactured, Imperial had no concerns about the supply of diluent.

Imperial pointed out that its bitumen production during the first half of 1998 averaged 21 000 m^3/d, which is about 6 per cent of Canada's total daily crude oil production. Imperial stated that its Cold Lake operation is Canada's second largest single source of crude oil supply.

Imperial proposed the construction of a facility to cogenerate steam and electrical power at a generating capacity of about 220 megawatts (MW). In order to optimize the use of steam and make the project more cost effective, given that only about 45 per cent of the 220 MW would be required on the project site, it provided for backup production in case of equipment failure. Imperial expected to make all surplus power available for sale to the Alberta Power Pool.

3.2 Views of the Interveners

STOP said that, when Imperial's megaproject was being reviewed by the Board in 1979, Canada was in the midst of a national oil supply crisis. Therefore, project approval was granted notwithstanding environmental concerns. STOP pointed out that the oil supply climate has changed in that there is no longer a shortage in Canada. In fact, oil produced at Cold Lake is exported in its unrefined state. Furthermore, environmental protection is presently a greater public concern.

STOP suggested that to address the question of need, one must consider whether there is a broader public purpose in addition to providing economic gain. STOP also suggested that the need for the project based on the CSS technology should be considered.

STOP stated that although it was asking that the expanded bitumen operation application be denied, it was not opposed to construction of the cogeneration facility, provided it does not draw groundwater from Quaternary aquifers.

3.3 Views of the Board

The Board notes that a large part of the proposed expansion area is contained within the existing area of Approval No. 3950 and would result in an improved development plan for previously-approved areas. Also, Imperial is the holder of the oil sands lease in the application area.

The Board agrees that the requested approval amendment is needed in order to fully develop and optimize recovery of the bitumen resources in the Cold Lake area. Furthermore, as noted in Section 4.1.3, the Board believes that the proposed expansion area represents the best remaining Clearwater resources. Subject to other concerns and requirements, the Board is satisfied that there is a need for the expanded operation.

The Board is satisfied that there is a market for the additional bitumen that would be produced by the proposed expansion project and that pipeline capacity is not expected to be a problem. From the supply and demand perspective, the Board finds the project to be in the public interest of the province. The Board notes that most, but not all, bitumen produced at Imperial's Cold Lake project is exported. Approximately 7 per cent is upgraded and consumed in Alberta. Although diluent supply shortages may occur in the future, the Board believes substitutes should be available with ongoing research to address the problem.

The Board does not agree with STOP that previous decisions by the Board related to Imperial's project did not give adequate consideration to environmental concerns.

The Board believes the proposed cogeneration facility, which would optimize the Imperial operation at Cold Lake and provide surplus electric energy to the Alberta system, is in the public interest.[1]

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1 EUB Decision 99-4 approved Imperial's request to designate the proposed electrical generation, transmission, and distribution system as an industrial system pursuant to Section 2.2 of the Hydro and Electric Energy Act.

4 TECHNICAL ISSUES

4.1 Project Boundaries and Limits

4.1.1 Views of Imperial

Imperial indicated that the reservoir in the Mahkeses area is the highest quality resource remaining within the Clearwater Formation, with a gross thickness of more than 40 m and a net pay thickness of more than 25 m. The net pay was characterized by a bitumen saturation of more than 8 weight per cent.

Imperial noted that, although there are other areas with high-quality net pay adjacent to existing developed pads, these areas would be used to maintain the production to satisfy the existing plants of Maskwa, Mahikan, and Leming.

Imperial divided the bitumen resource in the area within the extended lease limit into two categories on the basis of reservoir quality:

- an initial development, primarily composed of a high-quality, low-risk resource, supporting reliable predictions of CSS performance, and
- a surrounding development, which contains a lower quality resource and therefore has a greater recovery risk associated with it.

Imperial estimated that the original bitumen-in-place (OBIP) for the Clearwater Formation in the total Mahkeses project area is 305 million m^3. Of this amount, 200 million m^3 is in the proposed initial development area (29 pads) and 105 million m^3 is in the surrounding area.

The 105 million m^3 OBIP in the surrounding area is in a generally lower quality reservoir. Either there is thick bottom water in direct contact with the net pay (south and east) or the sand quality and bitumen saturation are significantly lower (north). Imperial considered this surrounding area to be the long-term limit to development for the proposed Mahkeses plant and that it would provide future development opportunities. The bitumen recovery of 46 x 10^6 m^3 suggested by Imperial was from the initial development area only.

Future development of the surrounding area at Mahkeses would require additional pads and steam generation capacity in addition to the requirements of the initial 29 pads. As many as 33 additional pad locations have development potential.

Imperial said that it would test well spacing of additional pads to ensure that each pad's expected reserves were produced within the remaining plant life. As a result, well spacing on these pads will range between 1.6 and 3.2 ha to match the pad's life with the remaining plant life. Imperial developed pads at phases 1 - 10 on 1.6-ha well spacing, based on the performance history and technology of the day. Since then, it gained additional experience on the relationship between well spacing and recovery. It selected a well spacing of 3.2 ha for Mahkeses based on an analysis of 2.4-ha pad performance at the Leming pilot, the lack of operating experience and performance data for spacing in excess of 2.9 ha, and selecting well spacing with a pad life similar to the plant's life, thereby reducing development costs. Using 3.2-ha spacing would result in half the number of wells drilled over the plant's life and reduce field capital costs by 40 per cent, compared to development on 1.6-ha spacing.

Through delineation drilling outside the approved CLPP development, Imperial has identified three areas that can provide additional development pad locations for the existing Maskwa and Mahikan plants: the K-trunk, lower E-trunk, and northeast-trunk.

Imperial proposed that the K-trunk and the northeast-trunk would be based on 3.2-ha well spacing and that the lower E-trunk would use 1.6-ha spacing. The development plan for each trunk encompasses areas both within and outside of the current CLPP development area. The assessment of environmental impacts includes development inside and outside the approved area.

Imperial expected the percentage of bitumen recovered at Mahkeses to match those from phases 1-10 even though well spacing would be increased. As well, Imperial did not see a need to increase steam injection pressures or other operating parameters to accommodate the larger spacing.

4.1.2 Views of the Interveners

With respect to the development options, STOP questioned the need for the project to develop to the south end of the lease at this time, particularly in view of the uncertainty with respect to arsenic contamination. STOP suggested that, given that many of the residents are clustered to the south of the Mahkeses project, it may have been better for Imperial to have pursued the northern area of its lease or areas where there were fewer people nearby.

Similarly, the CLFN indicated that the proposed project would be advancing closer to its reserve lands, while environmental monitoring on these lands from existing operations had ceased. As a result, environmental impacts or changes to the environment were no longer monitored. In its view, development closer to the English Bay Reserve would almost certainly result in increased impacts on the reserve lands.

4.1.3 Views of the Board

The Board accepts that from a resource development perspective, development of the resources in the Mahkeses lands represents the next logical step toward the overall development of the Imperial lease. Similarly, the Board is satisfied that the areas proposed for pads to sustain production in existing areas of operation represent logical development areas to access the best available resources. Accordingly, the Board agrees with the proposed project limits.

The Board also notes that developments beyond the proposed project limits will be subject to separate applications in the future. Further comments on the environmental issues related to the project limits are provided in Section 5.5.

4.2 Bitumen Recovery

4.2.1 Views of Imperial

Imperial proposed to use CSS at Mahkeses to recover bitumen from the Clearwater Formation. High-pressure and high-temperature steam would be injected into the reservoir above the formation-fracture pressure (between 9 and 10 megapascals [MPa]) of the bitumen-bearing sands. Initially, the injection phase would last between four to six weeks. A soak period of four to eight weeks would follow. The same well would then be converted into a production well and the bitumen would be produced for three to six months. This injection-production cycle would be repeated a number of times over the life of the well. The time to steam and produce the wells would vary with each cycle.

According to Imperial, CSS should be used to recover bitumen at Mahkeses, as it is the only commercially-proven recovery process for the Clearwater Formation at Cold Lake. Additionally, the CSS process has demonstrated its performance from equivalent reservoirs at May, Leming, Mahikan, and Maskwa. This leads to reliable expectations for performance and recovery levels at Mahkeses.

Imperial noted that the selection of an appropriate bitumen recovery process is affected by the properties of the reservoir fluids and the unique characteristics of the reservoir in the Cold Lake area. Consequently, over the last 30 years, Imperial has piloted various recovery processes at Cold Lake. The investigation of most of these recovery processes has been supplemented through direct participation in off-site pilots or by applying available third-party performance data to the Cold Lake resource through modelling and interpretation. Currently, the most notable investigation of recovery processes other than CSS is the company's participation in evaluating the steam assisted gravity drainage (SAGD) process at the underground test facility (UTF) pilot in the Athabasca oil sands.

In the 1970s, Imperial conducted the initial SAGD pilots and subsequently received the first patent for the SAGD process. Horizontal wells with vertical injection wells were piloted in both constant-pressure SAGD and cyclic-pressure modes and a detailed assessment of SAGD was conducted in 1995. Imperial developed a SAGD simulation model, initially calibrated to UTF data, using Cold Lake reservoir properties. The results indicated that SAGD at Cold Lake would be expected to achieve an ultimate recovery of 25 per cent OBIP at a cumulative oil-steam ratio of 0.2. In comparison, CSS performance in an equivalent reservoir is expected to recover 23 per cent OBIP at a cumulative oil-steam ratio of 0.3.

A recent update of Imperial's simulation study of the SAGD process suggested bitumen recoveries of 40 per cent. However, Imperial believed that if actual reservoir properties were applied, recoveries would be lower. Futhermore, Imperial noted that, even with the 40-per cent recovery, the process would not be economic due to increased steam requirements. In fact, a 50-per cent increase in steam injection volumes would be required to achieve the same bitumen recovery as CSS during the project life.

Imperial believed that the recovery and performance estimates for SAGD at Cold Lake are optimistic, given the sensitivity of SAGD to vertical permeability differences and the effects of large non-condensable gas accumulations on the constant-pressure recovery process. The Athabasca and Cold Lake resources differ significantly in both of these respects, leading to better performance characteristics for SAGD in the Athabasca area.

Consequently, Imperial's position was that, while the SAGD process may be applicable in other areas, such as the proposed SAGD commercial projects at Christina Lake and Foster Creek, it is not commercially feasible at Imperial's Cold Lake reservoir. It maintained that if it were required to use the SAGD process at Mahkeses, the proposed expansion would not proceed.

4.2.2 Views of the Interveners

STOP noted that SAGD appears to be the process of choice for many new projects, particularly in the Cold Lake and Athabasca areas. Specifically, it referred to the Christina Lake project and others, where bitumen recoveries of 50 per cent and higher were anticipated. In fact, STOP pointed out that Imperial's application referenced a recovery of 40 per cent for SAGD versus 23 per cent for CSS at the Mahkeses project.

STOP maintained that SAGD should be used by Imperial if the project proceeds. In STOP's view, the SAGD process would result in fewer wellbores within the reservoir, which would result in fewer areas of elevated temperatures from wellbore heating. This in turn would lower the potential of environmental effects, such as arsenic mobilization, in the associated formations and aquifers.

In addition, STOP noted that the SAGD process typically operates at pressures below the reservoir fracture pressure and well below the pressures currently used in conjunction with the CSS process at phases 1 to 10. Therefore, STOP's view was that the number of casing failures and the potential effects of those failures would be greatly reduced if the Board required the SAGD process to be used. In fact, STOP requested that a decision on the application be deferred until a better technology was available to exploit the resource.

STOP also pointed out that the details around Imperial's latest economic analysis for the SAGD process had not been filed and, as a result, the applicability of SAGD to the Mahkeses area could not be determined. Furthermore, STOP was of the view that the adverse environmental implications of the CSS process had not been considered adequately in Imperial's evaluations.

4.2.3 Views of the Board

Regarding the proposed use of the CSS process for Mahkeses, the Board notes the many years of experience that Imperial has devoted to understanding the process and its applicability to this specific reservoir. The Board accepts that understanding the particular reservoir characteristics is fundamental to managing operational efficiencies and recoveries. At the same time, the Board is aware that the CSS process represents additional risks for impacts to the reservoir and surrounding formations that must be carefully managed. In this regard, the Board notes that Imperial's efforts, particularly subsequent to the T-Pad incident, aimed at identifying and mitigating wellbore failures appear to have reduced failures significantly.

Consequently, at this time the Board accepts the use of the CSS process in the Mahkeses area. While other projects in other areas are anticipated to have very promising recoveries, they have not been substantiated through field operations. The Board notes that while some field trials (e.g., Suncor-Burnt Lake and Blackrock Resources-Hilda Lake) using SAGD are currently under way in the vicinity of the Imperial project, these developments are at a very early stage. Although initial results look very promising, the Board cannot be certain that ultimate recoveries will match those anticipated from simulations. However, the Board sees great potential for the SAGD process in terms of increased recoveries and reduced environmental impacts where it is suitable for the particular reservoir. Furthermore, if it becomes clear that the CSS process is not being managed in an acceptable fashion at the existing project or at Mahkeses, the Board will require Imperial to further justify continued application of the CSS process.

The Board acknowledges that, generally speaking, the high-pressure steam injection process has inherent risks related to operational integrity and sustainability from an environmental standpoint. Consequently, it is imperative that proponents design these projects in such a way that these risks are manageable. Furthermore, the Board expects operators to fully evaluate lower-risk recovery methods as part of future development plans.

4.3 Formation Integrity

4.3.1 Gas Pools as Indicators of Formation Integrity

4.3.1.1 Views of Imperial

Imperial pointed out that high-pressure steaming causes fractures only in the Clearwater Formation. It stated that its operation had not induced or enhanced fractures through the overlying Grand Rapids Formation and Colorado Group shale, which would permit Clearwater fluids to enter the Quaternary aquifers. The geology of the region is illustrated in Figure 2. On the basis of many years of operating data, Imperial maintained that the integrity of the formations above the Clearwater production zone had not been and would not be compromised by the CSS recovery process. Imperial indicated that beneath the Quaternary sediments are up to 180 m of Colorado Group shale, which acts as a high-quality reservoir seal, capping bitumen and gas in the underlying Mannville Group. Imperial believed that the effectiveness of the Colorado Group shale as a seal is demonstrated by the presence of as many as 20 Colony natural gas pools in the upper portions of the Grand Rapids Formation within its lease area.

The presence of these gas pools constituted Imperial’s prime argument illustrating the integrity of the overlying Colorado Group shale. Imperial argued empirically that because natural gas is a highly mobile fluid, it could not have been contained for millions of years unless an effective, impermeable seal were present. Further support for Imperial’s argument is the presence of six to seven different sand units within the Grand Rapids Formation. Different bitumen-water contact levels from one sand reservoir to the next within the Grand Rapids Formation demonstrate that these sand units function as separate, isolated reservoirs, sealed by intervening shale beds.

Imperial further argued that formation integrity is maintained between the Grand Rapids Formation and the underlying Clearwater Formation. About 5-15 m of shale effectively separate and seal the thick Clearwater Formation oil sands from the multiple and separate bitumen and water sand units in the overlying Grand Rapids Formation.

Imperial stated that this multiple stacked sequence of different reservoirs and fluid systems could not be possible without highly effective reservoir seals throughout the geological sequence. Any vertical connection or hydraulic pathway from the production zone in the Clearwater Formation to the Quaternary sequence would have to connect all of the separate sand units in the Grand Rapids Formation. The resulting drainage of gas and transmission of pressures from the reservoirs had not been detected by Imperial to date. To illustrate, Imperial provided pressure histories of a number of Colony gas pools within the lease, each of which showed continual decline in pressure as they were produced. Had there been an influx of water as a result of steaming, a pressure increase would be expected in the pools as gas was compressed, and the wells would have watered out prematurely. Imperial offered as proof the fact that neither event had been observed and that there had not been an influx of high pressure fluids from the Clearwater production zone. Imperial further stated that, even if there had been a significant influx of fluids, the gas pools would act as pressure sinks, which would prevent pressures from being transmitted any higher. Imperial presented evidence of pressures in the Lloydminster sand that have constantly remained at levels significantly lower than the steam injection pressure within the Clearwater bitumen, some 5-15 m deeper. Finally, of 191 wells drilled throughout Imperial's property, none showed pressures above normal or any uphole pockets of higher pressures.

4.3.1.2 Views of the Interveners

STOP accepted Imperial's argument that the presence of gas pools suggests that the formation directly above them demonstrates integrity, but it argued that the gas pools are localized, not continuous, and that the potential exists for hydraulic communication between the Clearwater Formation and the Quaternary along fractures in those locations where the pools are absent. In its view, the presence of discontinuous gas pools did not provide conclusive evidence of integrity of the entire overlying formations.

STOP argued that constant pressure recordings in the Colony gas pools did not constitute definitive evidence that the pools are not leaking. Rather, STOP suggested that a possible explanation for the lack of any pressure decline observed in the Colony gas pools could be attributed to a gradual leakage of gas from the pool that is subsequently replenished with gas produced by the steaming process in the underlying Clearwater bitumen.

AENV's view was that the gas pool pressure plots presented by Imperial as proof of formation integrity are inconclusive. AENV submitted that the two pressure measurements available for the 14-25-64-4 W4M gas well located near the D- and E-trunk oil-in-shale anomaly[2] did not provide sufficient information to conclude that the gas cap had not been affected by the anomaly.

[2] The term refers to the anomalous occurrence of bitumen and water (in form of an emulsion) found within the Colorado Group shale, which has a chemical composition indicative of deeper formation fluids from either the Grand Rapids or Clearwater formations. The bitumen, or oil-in-shale, occurs at pressures in excess of the natural formation reservoir pressure, which indicates that the source is likely from the Clearwater formation production zone during the high-pressure steaming component of the CSS cycle.

4.3.1.3 Views of the Board

The Board finds the Grand Rapids gas pressure plots submitted by Imperial to support its position that there has not been any influx of pressure or fluids from the Clearwater Formation into the Grand Rapids gas pools (which overly the Cold Lake Production Project) to be inconclusive. The Board notes that, of the eight Grand Rapids gas wells represented, only three directly overlie steaming operations in the Clearwater Formation and pressures for one of those three wells predate underlying Clearwater steam injection. Furthermore, the Board suggests that in the absence of a discussion by Imperial on the original Grand Rapids gas volumes in place and subsequent gas production volumes (material balance analysis), the pressure data are not conclusive. The Board expects Imperial to enhance its Grand Rapids gas well pressure data collection in the expansion area.

4.3.2 Geological, Hydrogeological, and Geotechnical Evaluation of Formation Integrity

4.3.2.1 Views of Imperial

Imperial argued that, with the exception of the Viking Formation, the Colorado Group consists primarily of shale deposited in a very uniform depositional environment and is lithologically homogeneous. Imperial thus assumed the geotechnical properties to be consistent and laterally uniform as well. Consequently, Imperial argued that stress results from one site can be applied to the unit on a regional basis. To evaluate the potential for formation shear induced by steaming, Imperial conducted a detailed profile of stresses at various intervals in one borehole to determine the maximum and minimum stress states in shale of the Colorado Group and in the Grand Rapids Formation. The results of that experiment showed that formation failure can occur only if there is a pre-existing natural fracture that is oriented in the optimal direction. In these cases, increases in the stress field have the potential to reactivate that fracture and cause shear along that single fracture.

Imperial stated that it had studied the issue of stress transfer for many years, using computer models to predict stress, pressures, and formation movements. The analyses showed that steaming in the Clearwater Formation causes a maximum change in horizontal, vertical, and shear stress in the Colorado Group from about 100-500 kPa. Imperial took the position that this stress transfer was within the elastic limits of the rock and that shear would not occur.

Imperial presented interpretations of fracture mapping and modelling, combined with the empirical observation of sealed gas pools in both the Clearwater and Grand Rapids formations, as evidence that there were no natural connected vertical pathways through the full thickness of the Grand Rapids Formation and Colorado Group shale and into the Quaternary. Imperial acknowledged that natural fractures exist in the formations above the Clearwater, specifically in the shale of the Colorado Group. These fractures are found at different intervals and were described as being discontinuous, small, circular to elliptical tension fractures calculated to be 30-60 cm long. Imperial stated that in order for a connected vertical pathway and hydraulic connection to exist along fractures through the entire Colorado Group sequence, two conditions would have to be met. First, the small fractures would have to have a sufficiently high density to allow for interconnection, referred to as the threshold density, and second, the rock would have to have fracture densities above the threshold density through the entire thickness of the Colorado Group shale.

To address the potential for the integrity of the Colorado Group shale to be compromised by connected fractures, Imperial examined fracture sizes, dip angles, and densities in 20 wells drilled through the Colorado Group shale and into the Grand Rapids Formation. Imperial applied a simulation program to demonstrate that in order for a single connected fracture to occur in a 40-m thickness of Colorado shale, a minimum constant fracture density of 2.5-3 m^2/m^3 would be required. For a single fracture to extend through the entire 180 m of Colorado Group shale, the density would have to be increased to 6 m^2/m^3. Imperial's examination of fracture density logs from these wells indicated that, in an average well, less than 20 per cent of the Colorado Group shale thickness has a fracture density equal to or greater than the 2.5-m^2/m^3 threshold. Approximately 80 per cent of the Colorado Group shale was either unfractured or had a density of about 1 m^2/m^3 and did not satisfy the minimum requirements for fracture connection over just a 40-m interval, as opposed to the full 180-m interval thickness of the Colorado Group shale.

Imperial acknowledged that certain geological zones within the Colorado Group shale were more prone to being fractured. For example, the upper 20-30 m of the Lea Park Formation was found to be highly fractured. At depth, however, there were thick (20-m) zones, such as in the Second White Specks and Belle Fourche, with very low fracture densities across the whole area, where the fracture frequency was about one for every 3-m depth. A similar analysis of the fracture data over the Grand Rapids interval indicated that less than 5 per cent of the formation had a fracture density above the minimum 2.5-m^2/m^3 density threshold. Given these fracture density distributions, Imperial constructed a statistical model to estimate that the probability of having one connected pathway through the Colorado Group shale was less than one in a trillion.

In addressing the question of whether high-pressure steaming in the Clearwater Formation can create vertical fractures that extend into the Quaternary, Imperial stated that for depths less than 350 m from surface, hydraulically-induced tensile fractures will develop only in the horizontal direction, not vertically. As background to this statement, Imperial explained that fractures open up or push against the minimum in situ stress. If the minimum in situ stress is in the vertical direction, the fracture moves horizontally; if the minimum stress is in the horizontal direction, the fracture will be vertical. Fracture propagation can be more easily attained in low-permeability zones, such as shale or low-mobility bitumen, but is exceedingly more difficult if the fracture is in a porous, permeable zone in which fluid, and pressure, can leak off.

Imperial's view was that prior to steaming, the horizontal and vertical stress states within the Clearwater Formation are initially similar, so that during the first steaming cycle vertical fractures could be propagated. However, during successive steaming cycles, the preferential fracture propagation is horizontal. Imperial postulated that in the event that a vertical fracture did develop during the first steaming cycle, the fracture would be terminated by higher horizontal stresses in the shale at the base of the overlying Grand Rapids Formation. If this vertical fracture were to somehow continue propagating upward, it would encounter the highly permeable Lloydminster water sand and the leak-off of fluids would halt the fracture propagation. In the event that the fracture could continue vertically through the water sand, the fracture would begin to propagate horizontally as it encounters lower vertical stresses in the upper parts of the Grand Rapids Formation.

To validate this model of fracture development, Imperial conducted a field test in one well to determine the in situ stresses in the formations overlying the Clearwater Formation. The results of that test indicated that, for depths less than 350 m, the minimum stress is in the vertical direction and, therefore, only horizontal fractures would develop. This depth occurs essentially at, or very near, the base of the Colorado Group shale. When questioned whether stress tests from only one well are representative of the Colorado shale as a whole, Imperial argued that, because the shale was deposited in a marine environment, the unit is widespread and has uniform lithologic properties. Imperial's view was that there is a reasonably good correlation between rock strengths and mineralogical and lithological properties, and therefore it concluded that the geotechnical properties and stress fields in the Colorado Group sediments are likely to be similarly uniform.

Imperial's discussion of pressure transfer from the production zone upward into the Quaternary focused on poroelasticity, permeability, and what Imperial referred to as the "diffusivity consolidation coefficient." That is, the questions Imperial addressed were how long would it take for a pressure pulse in the Clearwater Formation fluids to be expressed in the Quaternary aquifers and was the transmission of pressure diffusive or elastic. From a theoretical basis, it was Imperial's view that for very low-permeability units, such as the Colorado Shale, the diffusivity coefficient is very small and the corresponding response time is very long.

Imperial stated that it is difficult to determine the diffusivity coefficient for low-permeability materials such as shale. Values measured in the field may differ from values derived in the laboratory because of the presence of fractures and joints, which increase the permeability. Because of the great length of time required to conduct a field experiment, Imperial did not perform permeability measurements of the Colorado shales at the lease site. Imperial relied on information derived from previous studies conducted elsewhere, such as permeability values derived for the Pierre shales in North Dakota and the Joli Fou Formation at Cold Lake. In addition, it presented other indirect evidence, such as the presence of gas traps that are below hydrostatic pressure, to demonstrate that the diffusivity coefficient is very small.

With respect to the mode of pressure transmission, Imperial concluded that in order for elastic wave propagation to occur, the mechanical boundary conditions would have to be changed. This would involve changing the stress in the rock, and the amount of stress generated in the Colorado by steaming in the Clearwater is very small (0.1-0.5 MPa), well within the elastic limits of the rock. Imperial maintained that only the pore pressure is being increased in the Clearwater and, therefore, only the hydraulic boundary condition is being affected. Therefore, Imperial asserted that the mechanism of pressure transmission is dominantly diffusive, not elastic. On the basis of the estimated permeability and diffusivity coefficients of the Colorado, Imperial stated that, assuming the shale is not fractured, it would take about 50,000 years for a pressure increase in the Clearwater to propagate upward and be expressed in the Quaternary aquifers. As evidence, Imperial cited observations of pressure that showed that elevated pressures were confined almost entirely to the Clearwater Formation and only in a few cases occurred in the lower Grand Rapids Formation. Numerous wells completed in the water sands and gas pools demonstrated to Imperial that pressures were not being transmitted from the Clearwater production zone. Imperial asserted that STOP made serious errors in calculations regarding the generation of fracture and strain, which have led to erroneous determinations of stress changes in the Colorado, as much as two orders of magnitude higher than exist.

In response to the question whether ground heave during the steaming cycle can induce fractures or enhance hydraulic connections between the Clearwater and the Quaternary, Imperial stated that heave is insufficient to create new fractures. Imperial had observed casing-shear failures at the Clearwater-Grand Rapids interface as a result of pressurizing the Clearwater Formation and noted that because of a pressure discontinuity at the boundary, horizontal shear develops.

However, the effect of this stress propagates only through the Clearwater shale and a short distance into the Grand Rapids before dissipating. Imperial's numerical modelling of formation movements due to steaming operations in the Clearwater Formation showed that the changes in the stress and strain in the overlying formations become subdued moving upward into the Colorado Group shale and are insufficient to overcome the native strength of the formations and to create a shear fracture in either the shale or the casing. Imperial validated the model by observing surface heave equal to the amount predicted by the model, as well as predicted pressure fluctuations and shear movement causing casing failure at the Clearwater-Grand Rapids interface. Imperial did not present any mitigative measures, as this type of failure occurs below the confining shale of the Colorado Group and is considered by Imperial to have no impact on the Quaternary aquifers.

In response to STOP's assertion that the major cause of intermediate casing failures is formation shear, not corrosion, Imperial said that the cause-code reported on the casing failure sheets is based on judgement and at times is not reliable. Casing failure can only be determined from detailed examinations involving analysis of samples of casing, detection of embrittlement, and the use of a borehole camera to examine casing connections. Imperial did not accept STOP's position that the rate of casing failures had not decreased. Further discussion of casing failures is in Section 4.4.

4.3.2.2 Views of the Interveners

STOP argued that there are lateral differences in the lithology of the Colorado Group, such as siltstone beds of the Viking Formation, in which the stress states and geotechnical properties may differ from those in the shale. STOP indicated that in order to determine whether the mechanism of rock failure is tensile or shear, it is critical to know the difference between the maximum (horizontal) and minimum (vertical) stresses. STOP believed that Imperial did not have sufficient data to be able to determine the differences between the maximum and minimum stress states within shale of the Colorado Group in the lease area. STOP's assessment of the difference in dynamic and static moduli values of the Colorado Group indicated that the values derived by Imperial's laboratory experiments are about 10 times higher than the difference derived from the seismic data. STOP believed that this order of magnitude can be explained if the rock is weakened by joints and fractures. STOP suggested that Imperial's stress-test results from a single well are not representative of, and therefore do not adequately characterize, the Colorado Group shale over the entire lease area.

STOP maintained that steaming in the Clearwater Formation increases the stress state sufficiently to cause shear within the overlying formations, resulting in well-casing failure. As evidence, it cited a Canadian Association of Petroleum Producer's (CAPP) report assessing thermal well-casing failure risks, which stated that lateral shear in the production zone could produce horizontal displacements as great as 20 cm, leading to complete shear and separation of the production casing. STOP's assessment indicated that pressure generated in the Clearwater Formation could create stresses in the Clearwater and the Grand Rapids that develop into shear fractures. This was supported by STOP's analysis of the well-failure data, which show that shear occurs in the Grand Rapids. STOP concluded that shear force would also be applied to the base of the Colorado Group shale. STOP presented the apparent large number of casing failures near the base of the Colorado as evidence that this shear process was occurring. STOP supported this view further by assessing Imperial's report into T-pad failure, which analyzed 83 uphole primary failures. Evaluation of this casing failure data indicated to STOP that the major cause of failure was injection pressure or formation shift. STOP also noted that there are specific horizons within the Colorado Group in which wells appear to be more susceptible to failure. The section from depth 180 to 259 m is particularly prone to shear and hydration after being disturbed by fluid invasion. STOP's assessment showed that 65 per cent of the intermediate casing failures have occurred at the Second White Specks interval, and STOP believed that the reasons for this have not been fully investigated.

AENV suggested that there is a potential for hydraulic connection between the Clearwater production zone and the Quaternary aquifers along natural fractures. Following examination of 20 fracture density logs, AENV concluded that fractures exist in all geologic units, from the Lower Grand Rapids Formation to the uppermost Lea Park Formation. Although an individual log may show intervals that are without fractures, AENV demonstrated that taken collectively, the logs show that no segment of the bedrock sequence is free of fractures. Some intervals, such as the Westgate, Joli Fou, and Second White Specks, show significantly more fractures than others. More significantly, in terms of vertical connection and groundwater pathways, AENV identified high-angle fractures at intervals where horizontal fractures are present and in some cases where horizontal fractures are absent (e.g., the Westgate interval). In places the density of high-angle fractures exceeded that of horizontal fractures. AENV believed that the number of vertical fractures recorded may be underrepresented, as vertical fractures cannot be logged in vertical wells. AENV argued that, although the fracture density at depth may be considerably less than the density of the upper 20-30 m of the Colorado, only one connected fracture system is required to establish hydraulic communication. AENV stressed that this connection may comprise an interconnected, climbing network of vertical and lateral fractures, not just vertical ones.

AENV also believed that the assumptions made by Imperial in determining that the probability of a connected fracture through the entire Colorado Group at one in a trillion are flawed, particularly assumptions regarding uniform distributions of fracture orientations and size.

STOP argued that steaming in the Clearwater generates fractures in the Colorado through the process of both pressure transmission and stress transfer. STOP believed that the boundary conditions of the fluid and solid used by Imperial are wrong and that both a mechanical and a hydraulic boundary condition prevail. By way of example, STOP presented the argument that fractures cannot be opened solely by an increase in hydrostatic pressure; there must also be a change in mechanical state of the rock. In addition, STOP stated that formation heave, which was as much as a 0.5-m rise in ground surface elevation, is a clear example of the physical movement occurring during steaming, and that this is a strong argument for applying a mechanical boundary condition.

STOP argued that the permeability values Imperial applied to determine the diffusivity coefficient are not representative of the Colorado Group shale but are more typical of values for granite or metamorphic rock. STOP believed that the permeability of the Colorado shale is much higher than that used by Imperial and, therefore, the diffusivity coefficient is significantly larger.

STOP presented the argument that if there are units in which the deviatoric stress (difference between maximum principle stress and minimum vertical stress) is large, then cohesion is reduced and a small pressure will induce shear failure. Once shearing has occurred, then pressure transmission becomes much easier. STOP suggested that a range of pressure of slightly more than 0.1-0.2 MPa is sufficient to induce shear failure.

4.3.2.3 Views of the Board

The Board agrees with Imperial's assertion that shale of the Colorado Group is an effective, if not one of the most effective, caprock and aquitard unit to prevent production fluid and pressure from escaping from the Clearwater Formation production zone. The Board also agrees with the interpretation that the depositional environment of the Colorado Group shale is generally uniform and that, correspondingly, on a regional scale the mineralogical, lithological, and geotechnical properties of the shale are likely very similar. However, the Board agrees with AENV's and STOP's arguments that stress tests from a single test hole are not representative of the geotechnical properties of the rock within the entire lease area and that more tests are required for characterization. The Board found no evidence presented by Imperial to validate its statement that prior to steaming, the horizontal and vertical stress states within the Clearwater Formation are initially similar.

The Board accepts that the probability of a single connected fracture from the Clearwater production zone through the Grand Rapids Formation and the Colorado Group into the Quaternary aquifers is likely very low. However, AENV made a convincing argument that, on the basis of its interpretation of the fracture density logs, the potential for a connected network of vertical and horizontal fractures is higher than that determined by Imperial. With respect to the issue of poroelasticity, pressure diffusion, and formation permeability, the Board agrees with Imperial's assessment that the shale of the Colorado Group has a very low permeability, but it is unconvinced that the low permeability value assigned to the shale by Imperial is representative of the rock unit. The Board believes that the value used by Imperial, derived from studies on the Pierre shales of the United States, is at the extreme end of a spectrum of values for shale in Alberta and may be too low.

The Board believes that there is need for additional information regarding the natural properties of the local caprock above the Clearwater production zone. Supplemental baseline geological information is needed, such as permeability, lithological discontinuities, natural fracture distributions, and geochemical properties, which can influence groundwater flow, water quality, and corrosion of casing and degradation of cement. More quantitative, site-specific information on these parameters is needed. Similarly, there is very little information regarding the nature of the sediments within the Quaternary, particularly the lower part of the sequence. Therefore, the Board will require additional monitoring, sampling, and testing. In addition, much of the hydrostratigraphic framework defined by the applicant is based on rudimentary information, some of it collected by suboptimal sampling methods. As well, in some cases the applicant has relied heavily on results from previous regional studies of the area and has applied those regional results to the local lease area without validating the appropriateness of those data to site-specific investigations.

The Board believes that the applicant needs to further evaluate the geological and geotechnical properties of the Colorado Group, including mineralogy, permeability, poroelasticity, diffusion coefficients, and rates of groundwater flow through the shale. The Board believes that in situ permeability values need to be measured for the shale of the Colorado Group at the applicant's lease.

Similarly, although there has been extensive modelling of the theoretical fracture size and distribution within the shale of the Colorado Group, additional information is needed, such as core analysis and additional logging, to confirm the modelling. The applicant argued that the probability of a connected fracture from the Clearwater to the Quaternary is almost zero, less than one in a trillion. However, AENV provided a convincing argument that, in aggregate, the fracture density logs from the 20 wells show that no horizon within the Colorado Group is free of fractures. There are significant differences in the estimation of fracture density, and these have implications with respect to permeability, pressure and fluid propagation, and susceptibility of the formation to seismic shear failure. The Board believes that a more comprehensive overview of fracture density logs from a more widespread, regional study is required to confirm the potential of natural fractures to be connected throughout the entire sequence from the Clearwater to the Quaternary.

Therefore, as part of the enhanced monitoring program, the Board requires that more detailed and comprehensive information be provided on the geological and geotechnical properties of the sediments above the Clearwater Formation. This would include at least the following:

- sampling, examination, and analysis of core from both the Quaternary and bedrock units to determine lithological discontinuities and variations, fracture densities, evidence of fluid flow along fractures, and geochemical analyses to determine potential for sulphide corrosion and heavy metal concentrations (including arsenic)—the Second White Specks zone in particular appears to have anomalous properties compared to the rest of the Colorado Group units;

- an expanded regional-scale examination of fracture densities, from examination of both core and fracture density logs, as a means to assess the potential for enhanced hydraulic communication between the Clearwater Formation and the Quaternary;

- implementation of a regional monitoring network at existing operations and in the proposed expansion area to determine in situ hydraulic parameters of the Colorado Group shale, such as permeability and groundwater chemistry—permeability data will validate the values used by the applicant to determine the diffusivity coefficients;

- validation of the stress state of the Colorado Group shale with data collected at varied depth intervals from a number of wells—in the Board's view, it is problematic to apply values from just one well site to the lease area, given the injection history of production wells over a 20- to 30-year period, local heave at the pad scale, and local heterogeneities in the lithology of the Colorado shale.

4.3.3 Fluid and Pressure Transmission

4.3.3.1 Views of Imperial

Imperial indicated that as a result of differential thermal expansion of the production casing and the surrounding cement, a micro-annulus (less than 1 mm wide) could develop along the length of the wellbore as the well cools and the casing contracts. Creation of this micro-annulus may be responsible for the uphole migration of fluids and pressure, such as the oil-in-shale anomaly. Cement bond logs indicated that this micro-annulus is likely larger across the Grand Rapids Formation than in other formations. Attempts to seal this gap by applying 21 MPa pressure to the cold casing were successful for all but the Grand Rapids interval. Imperial was confident that, although the cement has been pushed out further than normal, the integrity of the cement sheath had not been affected by excessive thermal expansion. However, Imperial also stated that the presence of a micro-annulus may be sufficient to increase the potential for localized crinkling (buckling) to occur. Imperial acknowledged that incomplete or poor cementing of casing, particularly in deviated wells, can result in small zones where drilling fluid is still present. In these intervals the casing has the potential to crinkle (buckle) and fail as it expands in response to steaming.

In the course of its operations, Imperial encountered two anomalous occurrences of Clearwater Formation bitumen within the Colorado Group shale sequence (oil-in-shale), one in the M- and P-trunk and another in the D- and E-trunk area covering more than 1 km^2. Imperial found bitumen in the D- and E-trunk in a horizontally-fractured interval at a depth of about 300 m from surface at pressures of about 5 MPa, essentially the fracture pressure for shale at that depth, and about 2 MPa above natural reservoir pressures. Bitumen migrated approximately 1 km horizontally from the source inferred by Imperial. Imperial stated that it examined the integrity of well casings at the pad and was able to rule out casing failure as the cause. Imperial's interpretation of the in situ stresses indicated that any vertical fracture created by steaming would turn horizontal before reaching the Colorado Group, and therefore it discarded that mechanism. Similarly, an evaluation by Imperial of the fracture density logs indicated insufficient connectivity to establish a vertical pathway.

Imperial believed that the most probable cause was the upward migration of Clearwater bitumen along a near-wellbore path, and not along vertical fractures. It believed that inadequate cementing of casing in a single well at the steaming pad was the most likely cause. Imperial admitted that an attempt to locate the precise wellbore by subsequent steaming of pads within this trunk failed to reactivate the conduit. Imperial believed that the conduit may have plugged off because of collapse of detrital shale surrounding the hole, increased viscosity of the bitumen as it cools, or precipitation of salt within the conduit. Imperial asserted that such wellbore conduits are rare, as only two oil-in-shale anomalies have been located.

When questioned about the potential for vertical fractures to have developed and propagated vertically from the anomaly into the Quaternary (as a result of shear displacement along the horizontal fracture), Imperial argued that this is not possible because the stresses favour the development of horizontal fractures, not vertical ones. Imperial said that Clearwater Formation fluid (water) was not detected in Quaternary aquifers uphole, evidence that upward movement of production fluids terminated within horizontal fractures induced in the Colorado shale. Further, Imperial argued that the high fluid pressure currently measured in the fracture could not be retained if fluids had leaked through vertical fractures to the Quaternary formations.

Imperial responded to AENV's and STOP's suggestions that abrupt rises of water levels in groundwater monitoring wells can be attributed to pressure increases propagated through fractures from steaming events in the Clearwater Formation. Imperial indicated that this is not possible because the absence of pressure decline in the fluids in the oil-in-shale anomaly below the D- and E-trunk indicates that hydraulic connection has not occurred. In response to the observations that water-level fluctuations at TH1 well appear to correlate closely with steaming events in the Clearwater at D55 pads, Imperial argued that steaming cannot be affecting well levels. Imperial noted that the water level in monitoring well D55-6, located directly above the D55 steaming pad, is as much as 20 m lower than in TH1 and that it has remained relatively constant over time. Imperial presented this as evidence that there is no hydraulic connection between the two.

In response to AENV's argument that the D55-6 monitoring well was improperly completed or not completed in the same stratigraphic horizon as TH1, Imperial countered that when perforated, the water level in D55-6 dropped 15 m, indicating good communication with the aquifer. Imperial also maintained that even if the well were completed in a lower stratigraphic unit than at TH1, it should still respond to a pressure increase from the Clearwater Formation below. The constant water levels at D55-6 illustrated that was not occurring.

With respect to upward vertical gradients and rapidly rising water levels as indicators of hydraulic communication with steaming in the Clearwater, Imperial attributed upward gradients in the lower Quaternary units to natural groundwater flow from adjacent bedrock uplands. Imperial stated that rising water levels in some wells were due to equilibration of the well completed in a low-permeability unit, and not to the effects of steaming pressure.

4.3.3.2 Views of the Interveners

AENV and STOP both argued that near-wellbore pathways, such as a micro-annulus created by differential thermal expansion or incomplete cementing, could provide the vertical pathway for the migration of pressures and fluids from the Clearwater production zone. In addition, STOP suggested that buckling and shear due to poor cementing or a wellbore micro-annulus may be the cause of the intermediate casing failures, and not environmental stress cracking, as stated by Imperial.

AENV challenged Imperial's assertion that a near-wellbore pathway was the cause for the migration of Clearwater bitumen into the Colorado Group shale. While agreeing that a near-wellbore path is plausible, AENV believed that the existing pressure differentials and natural fractures in the formation are another reasonable explanation. AENV also expressed the view that destabilization of the shales as a result of steam injection from the failed casing and/or leaking connections may cause shear displacement along the horizontally-induced fractures and that this may induce multiple hydraulic fractures that deviate upward into the Quaternary. These vertical fractures may connect fluids in the anomaly with Quaternary aquifers above. AENV expressed concern that the well pad responsible for creating the conduit had not been identified by Imperial. AENV stated that no information was presented in the outstanding Environmental Protection Order (EPO) 95-07 to indicate that test holes were drilled to confirm that D62 pad was the source of the anomaly.

AENV and STOP both argued that unusual behaviours of water levels in Quaternary groundwater monitoring wells can be attributed to localized pressure increases as a result of pressure leaks from the Clearwater Formation through fractures. AENV and STOP shared the view that Imperial's steam injection has affected water levels in wells located at the south end of the D- and E-trunk developments and possibly farther. To illustrate, AENV and STOP showed that sharp rises in water levels in monitoring well TH1 showed a strong correlation with rises in Clearwater pressures at steaming pads D55. AENV indicated that the D55-6 well may still have been affected by steam pressure increases from below but did not record the increases because the well was improperly completed (plugged perforated interval), which could explain nearly constant water levels; or the well may be completed in a lower stratigraphic interval (possibly Empress unit 3) with poor hydraulic communication with units above. This would account for the 20-m difference in water level between TH1 and D55-6. AENV postulated that steaming at pad D55 could be causing the water level fluctuations at TH1, even though these are not recorded at the D55-6 well. Possibly, increased pressure resulting from steaming at D55 migrates upward along a wellbore in a nearby pad (e.g., D-62). AENV further supported this argument by noting that there was a strong correlation between increases in pressure and water levels in the Quaternary aquifers in response to pressure changes related to the casing failure event at T-pad.

As an additional argument, AENV noted that the vertical hydraulic gradients in the lower parts of the Quaternary sequence in a number of water wells located along the periphery of the Marie Highlands are determined by Imperial to be in an upward direction. In some cases where gradients have been observed over time to be downward, there have been sudden reversals upward, accompanied by significant increases in water levels (as much as 12 m). AENV argued that these rapid increases in water levels were too great to be attributed to local recharge events to the groundwater system. Instead, AENV believed that a possible mechanism for these upward gradients and increased water levels was increased pressurization from steaming in the Clearwater Formation.

4.3.3.3 Views of the Board

The Board is satisfied that extensive hydraulic communication is not occurring, but notes that at specific locations the occurrence of oil-in-shale, along with water well responses and apparent correlation with steam injection pressure increases, needs to be further evaluated. Rapid rises in water levels just prior to the T-pad failure indicate that in past cases there has been direct response of Quaternary water wells to steaming pressure increases in the Clearwater Formation. The correlation implies a cause-and-effect relationship between steaming and well response, and additional information on geochemistry, pressure values, and temperature levels is required to adequately assess the potential for the existence of vertical pathways to transmit pressures and fluids to the Quaternary. In this regard, the Board requires that an enhanced groundwater-monitoring network be implemented at the existing facility to provide information on water level responses to steam injection. The area of most immediate concern is in D- and E-pads, in which the oil-in-shale anomaly and anomalous water levels have been recorded. Information about stratigraphic horizon, water level fluctuations, and groundwater temperature and chemistry will provide baseline information so that the performance and integrity of the Colorado Group and Grand Rapids Formation in the proposed expansion areas can be compared.

4.3.4 Hydrochemical Evidence of Formation Integrity

4.3.4.1 Views of Imperial

Imperial evaluated boron-to-chloride versus strontium-to-chloride ratios for groundwater in the bedrock units (Colorado, Grand Rapids, Clearwater) to demonstrate that there are chemical dissimilarities between fluids in the Colorado Group and Grand Rapids Formation, as opposed to fluid in the Clearwater Formation. The isotopic chemical fingerprinting analysis showed that the source of the high chloride in the Quaternary aquifers shows mixing with water from either the Colorado Group or Grand Rapids Formation, and that they are not a result of mixing with production water from the Clearwater Formation. Imperial argued that the source of the elevated chloride is from the Colorado Group shale, directly beneath the Quaternary aquifers, and could not be from the Grand Rapids Formation because of a lack of pressure drive from below.

In response to AENV's assertion that the low amount of sulphate in deep Quaternary aquifers indicated an influence of deeper bedrock water on deep Quaternary aquifers through fractures or other pathways in bedrock, Imperial argued that sulphate is a nonconservative ion, which can be influenced by sulphate reduction and attenuation processes. Therefore, variability in sulphate concentrations cannot be used to characterize the source.

Imperial stated that its analysis of 39 dissolved gas samples extracted from Quaternary aquifers indicated predominantly a Colorado source of dissolved gas in the Quaternary groundwater. This supported its argument that the upper 30 m or so of the Colorado Group is highly fractured and much more permeable. One exception was an anomalous result at Maskwa well 97-10, which contains gas with a stable-carbon isotopic signature indicative of a source from the Clearwater Formation. In response to STOP's suggestion that the gas migrated upward along a continuous fracture network from the Clearwater into the Quaternary, Imperial argued that the source of this gas was the result of small-volume gas emissions up the annular space between the casing cement and the formation. Imperial believed that these emissions occurred either before or after abandonment of a nearby abandoned gas-producing well (Esso 2-78), and not within fractures in the bedrock.

4.3.4.2 Views of the Interveners

AENV agreed with the applicant's interpretation that the source of chlorides in Quaternary aquifers was most likely not from Clearwater Formation or production water but rather from bedrock units above that horizon. However, AENV contended that because the isotopic signatures are essentially the same for the Colorado Group and Grand Rapids Formation water, the source of chlorides could be from either unit, and not solely the Colorado Group, as Imperial stated. AENV's position was that if the source of the chlorides was the Grand Rapids Formation, it would indicate movement of groundwater along a vertical pathway.

AENV adopted the view that the relatively high chloride values, combined with very low levels of sulphate concentrations in the lowermost Quaternary aquifer in a number of water wells, are atypical of values expected for Quaternary units. This would be true if diffusion of chloride ions was occurring from the upper part of the underlying Colorado Group shale (high chloride-high sulphate) into the Quaternary aquifers, as postulated by Imperial. AENV suggested that the high chloride-low sulphate values in the lowermost aquifers indicated an influx and mixing with groundwater moving upward along fractures or other pathways from formations deeper than the Colorado shale, possibly the Grand Rapids or Clearwater formations. Water from these units was shown to have high chloride, but very low sulphate values.

Citing the results from the Maskwa well 97-10, AENV asserted that the results of the dissolved gas analyses indicated that there are hydraulic connections, either fractures or other pathways, between the Clearwater production zone, the Colorado Group shale, and the Quaternary aquifers. Arguing on the basis that the upper 20-30 m of the upper Colorado Group likely has vertically-connected fractures, AENV concluded that the gas analyses demonstrated that there are vertically-connected fractures extending from the Clearwater Formation to the Quaternary aquifers.

4.3.4.3 Views of the Board

The Board is satisfied with the applicant's conclusion that the chemical fingerprinting data showed that the chloride in the Quaternary aquifers is not derived from the Clearwater Formation but is from a source higher in the bedrock sequence. However, the isotope analysis was not able to differentiate between water from the Colorado Group or the Grand Rapids Formation. The Board believes that the arguments favour the most likely source to be the upper part of the Colorado Group shale, which is fractured, more permeable, and in direct contact with Quaternary aquifers.

4.3.5 Seismicity and Effect on Formation Integrity

4.3.5.1 Views of Imperial

From its seismic monitoring network, Imperial observed Type A[3] seismic events in the Colorado Group shale of a magnitude of minus one to minus two. Imperial interpreted Type A seismic events at its leases to correspond to slight shifts or shear along existing fractures that are about one-half metre in diameter. Imperial found no evidence of large seismic events in the Colorado Group shale.

Imperial indicated that its experiments involving the injection of water into the formation to evaluate the potential to produce seismic events showed that S waves, or shear waves, could be generated by casing failures in the Colorado Group shale. However, with respect to past Type A seismic events, Imperial noted that the quality of the data gathered by earlier monitoring station observations (Kapotas's 1980s work) was insufficient to permit an accurate location of the source depth, magnitude, and focal mechanism of the events recorded at its lease. Specifically, Imperial argued that, although the data may be used to argue a likelihood of seismic events occurring in the Colorado, the quality was not sufficient to reach a definite conclusion that Type A events have occurred within the Colorado Group shale. Imperial argued that Kapotas and Kanasewich determined the depth location of the Type A events to have an uncertainty of about 1 km, which means that the data was not accurate enough to assign the event to a specific formation (i.e., Colorado Group versus Clearwater Formation).

4.3.5.2 Views of the Interveners

With respect to seismicity, STOP's main argument was that sufficient information from Kapotas's and Kanasewich's work in the 1980s was available to conclude that some of the past Type A seismic events at the applicant's lease likely occurred within the Colorado Group shale. STOP argued that these events may have been responsible for shear waves that caused formation and casing failure. Although acknowledging that the past seismic data were poor, STOP maintained that the depth of the 34 Type A seismic events could be determined and that a number of these events occurred in the Colorado interval.

STOP's assertion was that if there were sufficient pressure and stress to generate shear failure, then the hydraulic connectivity of existing joints and fractures and the transfer of pressure from the production zone to the Quaternary would be increased. Imperial's chemical-fingerprint data

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[3] Type A events are defined as measured seismic events that have no obvious (or nonobvious) source or cause but are located within the volume being evaluated.

indicated to STOP that increased fracture and joint connectivity may not necessarily result in increased mass transport of fluid, but rather only in increased propagation of fluid pressure.

STOP expressed concern that the applicant's current passive seismic monitoring installations may be focused on a frequency range higher than the frequency range measured in the 1980s network and higher than the natural frequency of the low-strength rocks in the Colorado Group.

4.3.5.3 Views of the Board

The Board agrees with both Imperial and the interveners' assessments that the quality of the historic seismic data is poor. The Board believes that Imperial's implementation of a regional passive seismic monitoring system, designed to detect events related to formation and casing shear, may provide the baseline data to determine if high-pressure steam injection in the Clearwater Formation is causing formation shear in the Colorado Group. Furthermore, the Board views the risks associated with seismic events as manageable. Notwithstanding that position, the Board notes the ongoing public concern on this matter. The Board expects Imperial to expand its monitoring program by designing and implementing a lease-wide investigation to assess seismicity within the Colorado Group and to submit the results of the study to the Board and to brief the public on the results.

4.3.6 Formation Integrity: Summary of Board Views

The Board acknowledges that the potential for Imperial's CSS process to compromise the integrity of the geologic formations is a complex issue. There is some uncertainty regarding the degree, if any, of impact that high-pressure steaming in the Clearwater Formation has had on the capability of the shale of the Colorado Group to isolate production fluid and pressure from potable groundwater in the overlying Quaternary aquifers. To some extent, this uncertainty stems from a lack of background information and knowledge regarding the natural properties of the rock units in the stratigraphic sequence and the response of those units to high-pressure steaming in the Clearwater bitumen zone. Furthermore, some statements and conclusions made by the applicant regarding the local and regional-scale properties of the rock units appear to be based on results from other past studies in the region or on work elsewhere, outside of the Alberta Sedimentary Basin, and may not be appropriate for the applicant's geological setting.

However, the Board believes that, based on the depositional environment, lithological properties, and regional distribution, the shale of the Colorado Group is, in principle, an effective aquitard to prevent CSS production fluids from mixing with near-surface Quaternary aquifers and a suitable caprock to maintain the integrity of the steam chambers within the underlying Clearwater Formation. Accordingly, the Board agrees with the applicant's position that direct communication is not occurring on a large scale.

Notwithstanding that position, the Board believes that the nature and scale of operation at the site require a comprehensive and systematic validation of assumptions made to reach that conclusion. The operation also requires a detailed monitoring program to detect any serious change of circumstance and provide early remedial action if necessary. If the application is otherwise satisfactory and can be approved, the Board will condition the approval to require that such a program be implemented at the earliest convenience, with input from all appropriate parties.

The Board also acknowledges that the applicant has made significant improvements to the integrity of the production casing and its ability to prevent casing failures, and hence to the integrity of the formation as a whole. However, the Board believes there that are some outstanding issues regarding the integrity of the production-well infrastructure that require additional examination. These include the issue of integrity of wellbore cementing, the development of micro-annuli, the ability of casing to withstand shear, and the integrity of the casing connections. These issues are discussed further in Section 4.4.

4.4 Wellbore Integrity/Monitoring

4.4.1 Views of Imperial

Imperial indicated that it is confident in the integrity of its well casings and does not expect casing failures to occur in the proposed expansion area. In response to historic casing failures, it implemented design improvements to prevent future failures and stated that it has the operating experience to prove the effectiveness of these improvements.

Imperial indicated that it identified near-surface production casing failures at (0-25 m) as being caused generally by exterior corrosion that occurs between the production casing and conductor pipe. In response, it implemented a cementing program to ensure cement tops on production casing are at surface to eliminate the potential for future corrosion for existing and new wells.

Imperial identified intermediate casing failures (from 25 m down to the base of the Grand Rapids) as being caused either by sulphide-stress cracking or stress-corrosion cracking. To prevent such future failures, Imperial initiated injection of nitrogen into the annulus between the tubing and casing during the soak phase for each of the production wells. To prevent stress-corrosion-cracking failures at casing connections, Imperial made changes to the design of its casing connections. Imperial stated that it now uses metal-to-metal seal connections to improve connection sealability and reduce seepage rates through connection threads.

Imperial indicated that since 1995 it had made significant enhancements to its casing inspection program, including casing integrity checks. Each producing well was inspected sometime during cycles 5-7 before steaming, a process that was repeated in each well at every cycle from cycle 8 and later. Wells in cycle 8 and later also had a corrosion assessment log performed. Imperial conducted additional casing integrity checks on wells with known impairments and on wells adjacent to failures.

Imperial also upgraded its casing monitoring program. It stated that a system was in place to monitor steam pressures and rates in each well. Any change in trends related to steam pressure or steam injection rate triggers an alarm and an immediate investigation by Imperial. The system is sensitive enough to detect pinhole leaks.

Since 1995 there have also been improvements to well control capabilities, enabling Imperial to control wells more quickly and to higher pressures (up to 10 MPa) than previously. The number of near-surface and intermediate-depth failures had decreased as a result of improvements to the design of casing and couplings, and monitoring programs. Damaged wells can be identified before they fail and be repaired or taken out of service. Imperial indicated that failures, when they do occur, would be identified quickly, minimizing the effect of any fluid releases. All of the improvements and changes made by Imperial in recent years related to detection and remediation programs would be applied at the proposed expansion project.

Imperial maintained that intermediate-depth casing failures were not caused primarily by formation shifting within the Colorado shale. From its investigation of the retrieval and analysis of casing samples from several failed wells, completion of an embrittlement detection project, and the use of borehole camera information of failed casing connections, it confirmed environmental cracking to be the cause of intermediate-depth casing failures.

Imperial also stated that it had conducted an extensive cement bond log study from 1995 to 1997, which confirmed that the existing cementing practices provided adequate cement integrity and that the steaming of the wells did not adversely affect the cement bond in providing hydraulic isolation. In light of those results, Imperial indicated that it would not be conducting any additional routine cement evaluation programs for the expansion project. Imperial would continue to run cement bond logs as required by EUB regulations when cement returns to surface were not achieved. Imperial would be staying abreast of any advances in logging technologies. It stated that cement integrity would remain intact for at least 25 years, based on cement bond log studies conducted from 1995 to 1997. Imperial stated that these studies confirmed that, although there may be a micro-annulus between the production casing and cement in the casing annulus, existing cementing practices provided adequate cement integrity and the steaming of the wells did not adversely affect the cement bond in providing hydraulic isolation.

Imperial maintained that changes to an alternative wellbore design, such as the setting of surface casing or dual casing design across the Colorado shale, need not be considered because it believed it had already made the necessary improvements to resolve the concern about casing failures. It pointed out that the installation of additional casing would significantly increase costs and make operations more difficult. Imperial also believed that a reduction of the wellbore operating pressure is not necessary, since it would impair resource recovery and probably make the expansion project uneconomical.

4.4.2 Views of the Interveners

STOP stated that changes implemented to casing and coupling design after the casing failures at AA- and T-pads in 1994 and 1995 had not significantly improved casing failure rates. It also indicated that failure mechanisms and their primary causes are still not adequately understood. It believed formation heave during steaming at pressures above fracture pressure caused the Colorado shale to shift, resulting in shearing of casing strings in the Colorado shale. STOP requested that approvals for above-fracture-pressure steam injection be rescinded to prevent such failures. It also requested that the applicant be required to set surface casing to help prevent casing failures which, the interveners believed, resulted in groundwater contamination from failures within the Colorado shale. STOP indicated that Imperial's monitoring program to detect failures was not effective in minimizing environmental damage. STOP believed that environmental damage has occurred as a result of inadequately identifying well casing impairments, which would lead to future casing failures. It also believed that Imperial's inability to detect failures during the steam injection cycle and its inability to immediately control failed wells where pressures are in excess of 10.3 MPa would contribute to environmental damage.

STOP also stated that Imperial's reporting of casing failures had not been accurate in terms of numbers, causes, and types of failures that were occurring. STOP indicated that Imperial's casing strings could have a micro-annulus and/or fractured cement in the wellbores between the casing and the formation when the wells were subjected to steaming operations. This would allow a pathway for fluid migration and contamination of groundwater. In addition to the presence of micro-annuli, STOP believed that there would be uncemented portions of casing in the wellbores, particularly in deviated wells, which would result in casing failure due to buckling or crimping of unsupported casing strings. STOP expressed concern about the degradation of cement over time in producing and abandoned wells and cement integrity up to and beyond the 25-year projected life of the project.

4.4.3 Views of the Board

The Board believes that, directionally, the current wellbore design is acceptable due to ongoing improvements to the casing and connection design. These improvements have come about through operational changes and continued research and development. Notwithstanding, the Board expects Imperial to continue its efforts in these areas with a view to further reducing the number of casing failures. The Board notes improvements to Imperial's monitoring, detection, and operational practices. The Board also expects continued improvements to monitoring, failure detection, and remediation programs. While casing failures continue to pose a risk, the Board believes improvements made in recent years, particularly since the T-pad incident, reduce those risks to acceptable levels. Any future changes Imperial proposes to implement are to be reviewed and approved in consultation with Board staff. Additionally, the Board expects Imperial to submit an annual report on wellbore integrity and remediation efforts conducted to further satisfy the Board that improvements implemented by Imperial continue to be effective.

The Board notes Imperial's view that steaming of the wells does not adversely affect cement bond and hydraulic isolation. The Board believes that near-wellbore flow pathways may exist locally but are not occurring on a project-wide scale. The Board notes such supporting evidence as the oil-in-shale anomaly, Clearwater gas in Quaternary aquifers at Maskwa 97-10, and the apparent responses in Quaternary water wells to steaming in the Clearwater Formation.

The Board notes the significant number of previous casing failures, in particular the shear failures reported at the interface of the Grand Rapids and Clearwater formations and other up-hole shear failures. However, it remains unclear what relationship, if any, these types of failures have to hydraulic isolation and wellbore integrity at points in the wellbore other than the actual failure site. Imperial stated that there are micro-annuli in the casing annulus above the producing Clearwater Formation and that the largest of the micro-annuli are across the overlying Grand Rapids Formation, which may provide a pathway for steam migration to upper zones.

Regarding the suggestion by STOP that surface casing be added to all project wells, at this time the Board will continue to monitor the effectiveness of setting surface casing in the prevention of casing failures. In its Leming Lake hearing decision report (*Decision 96-3*), the Board required Imperial to set and evaluate surface casing at its near-shore pads. The Board is of the view that an insufficient amount of time has lapsed to complete its assessment for the requirement to set surface casing.

The Board also notes that Imperial proposes both directional and horizontal wellbores for the Mahkeses project. The Board believes that achieving proper hydraulic isolation is essential to ensure wellbore integrity and notes that deviated wells, as well as the thermal environment, will pose additional challenges in this regard. Therefore the Board emphasizes that Imperial is required to comply with the hydraulic logging requirements of EUB *Guide G-51: Injection and Disposal Wells* that apply to all newly drilled wells prior to placing the well on injection. The Board expects this initial evaluation to identify any potentially problematic wells, confirm that proper hydraulic isolation of wellbores has been achieved, and provide a future reference for any subsequent hydraulic isolation evaluation. The Board recognizes that certain evaluation logs may pose some challenges when conducted within elevated thermal environments. The details of these evaluation logs, including the type and number of logs and the frequency of any subsequent logging, are to be discussed with Board staff.

The Board also notes that Imperial has acknowledged that there are some anomalies in the reports on casing failures submitted to the EUB. The Board appreciates the difficulties operators have in determining the exact type and cause of casing failures because of limitations in the recovery of failed casing for analysis to identify the failure mechanisms. The Board acknowledges that *IL 89-19: Casing Failure Reporting* allows for discretionary reporting of casing failures when details regarding the failure are unclear or unknown. However, the Board intends to take the necessary steps to ensure that the EUB database is as complete and accurate as practical for this and other projects.

With respect to STOP's concern about cement integrity, the Board notes that Imperial will have responsibility for the integrity of the wells for the long term.

5 ENVIRONMENTAL ISSUES

5.1 Arsenic

5.1.1 Origin of Arsenic in Groundwater

5.1.1.1 Views of Imperial

Imperial acknowledged that, in the course of its groundwater investigations, elevated levels of arsenic were found in private water wells, piezometers, and monitoring wells installed in and around the Cold Lake operations. Imperial maintained, however, that its analysis showed the presence of arsenic is not related to its operations. It argued that arsenic-bearing minerals are present as natural constituents of the sediments of the region and that arsenic concentrations in the Cold Lake region are therefore natural in origin.

Imperial asserted that there are differences in the natural level of arsenic in the tills of the area and that arsenic content increases with depth at some locations. Similarly, there are differences in arsenic concentrations in groundwater, and deep wells tend to have higher arsenic levels than shallow ones.

Imperial noted that elevated arsenic concentrations had been found as early as 1978 in groundwater near the Cold Lake operations in advance of its commercial project, and more recently at locations up-gradient from the lease. Imperial's position was that concentrations of arsenic found in groundwater of the Cold Lake area are consistent with levels found elsewhere in Alberta and that the occurrence of arsenic is a natural, province-wide phenomenon.

Furthermore, Imperial argued that arsenic is not used in any part of the operation and that arsenic concentrations in bitumen and produced water from the Clearwater Formation are too low to elevate arsenic concentrations in regional aquifers.

Imperial also noted that its comparison of arsenic concentrations in off-lease well water to the wells' proximity to company facilities, to locations of previous casing failures, to the aquifers in which the wells are completed, and the presence of parameters such as chloride, iron, and organic compounds are further confirmation that the occurrences of arsenic in groundwater does not correlate with its operations.

Imperial stated that differences in arsenic concentrations in groundwaters within its lease and those found off lease were not significant. Imperial concluded that there had not been an impact on arsenic concentrations as a result of its operations.

5.1.1.2 Views of the Interveners

STOP sampled water from 51 private water wells located in the vicinity, primarily south, of the Imperial Cold Lake project. Concentrations of total arsenic found in these water samples ranged from less than 3 micrograms per litre (µg/L) to more than 40 µg/L. Twenty-one samples contained arsenic in excess of the World Health Organization guideline of 10 µg/L for drinking water. STOP found that higher arsenic levels were generally associated with deeper wells (greater than 30 m) and that the highest concentrations were found in the Crane Lake area.

STOP stated that arsenic in groundwater exists predominantly in two inorganic forms, namely arsenite and arsenate. Furthermore, STOP stated that arsenate is thermodynamically stable under aerobic conditions, whereas arsenite is stable in anaerobic, or reducing, environments. STOP concurred with Imperial that the dominant form of arsenic in the Cold Lake area is arsenite. STOP further stated that, unlike arsenate, arsenite occurs primarily as a neutral, uncharged species; it is not bonded to soil components and is therefore not retarded with respect to groundwater flow.

STOP said there is evidence to suggest that high pressure fluid injection for oil extraction and the operation of salt water extraction wells can mobilize arsenic from minerals in the rocks. STOP's evidence took the form of

- one reported analysis of produced water from the Leming Plant containing 50-64 μg/L arsenic;

- elevated levels of arsenic as great as 53 μg/L in a number of wells around casing failures;

- arsenic levels above the Canadian Drinking Water Quality (CDWQ) guideline interim maximum acceptable limit of 25 μg/L in a number of monitoring wells around the extraction facilities;

- a lack of correlation between chloride and arsenic concentrations in water from privately-owned water wells near the Cold Lake project; STOP's position was that the lack of correlation implied either a decoupling of the two ions as they moved through the rocks or that they have been derived from two separate sources; STOP was further of the opinion that interaction with iron could provide a mechanism for decoupling the arsenic flux from a marker ion such as chloride;

- a plot of dissolved organic carbon (DOC) versus arsenic for water from the same privately-owned water wells; STOP's position was that this plot showed that, in general, high concentrations of arsenic are associated with elevated levels of DOC and that this suggests that the generation of the two parameters may be related, presumably through a biological pathway.

STOP indicated that Imperial's operations may be responsible for increased arsenic concentrations in groundwater by a number of indirect mechanisms:

- The patchy occurrence and large temporal and spatial variation in arsenic concentrations could be the result of destabilization of the natural geochemical cycle of arsenic.

- Exchange of matter and energy between the Clearwater Formation and the Quaternary aquifers can affect the mobility and levels of arsenic in groundwater.

- Changes in temperature and pressure and migration of fluids and gases along fractures may enhance the dissolution and transport of arsenic from the Colorado shale to the overlying aquifers. STOP cited elevated levels of arsenic in the lowermost aquifers in a number of piezometers as potentially having been affected in this manner.

Upon learning of the elevated arsenic values from Imperial's sampling of residents' water wells, AENV conducted a thorough review of all available data. These included Imperial's data from domestic water wells and other data on file with AENV. Additionally, AENV has six monitoring sites in the vicinity of the Cold Lake project, with one or more wells completed at different depths at each site. AENV found that arsenic concentrations exceeded the CDWQ guideline in some samples from all of the sites. One of the monitoring sites is located at Bonnyville, about 50 km from Imperial's Cold Lake project, and had an arsenic concentration of 91 μg/L. Also, a well near Bourque Lake, located hydraulically up-gradient of Imperial's project, contained elevated arsenic.

AENV also indicated that it examined the province-wide data on arsenic from farmstead water supplies and found that there are other places in the province where levels of arsenic were in excess of 50 μg/L.

AENV also examined a report of arsenic content of tills, clays, and Colorado shale from boreholes near the Cold Lake project, based on Alberta Geological Survey drill samples collected in 1976 and 1977. The results indicated that the silt and clay fractions of the till, clay, and Colorado shale units of the area all have a natural arsenic content, ranging from 8 to 20 parts per million (ppm), the average being 16 ppm.

After examining all of these data, AENV stated that it was not possible to relate arsenic concentrations found in water from domestic wells to the Imperial Cold Lake project. AENV also maintained that there did not appear to be a correlation with arsenic occurrences on and off the area of the Cold Lake project. AENV stated that data on the spatial distribution of arsenic in well water presented in the EPO report indicated that the arsenic is randomly distributed and high arsenic concentrations are not correlatable to Imperial's site. There are wells with high and low concentrations both on and off the site.

5.1.1.3 Views of the Board

Based on the evidence, the Board cannot conclude that the source of elevated arsenic in local water wells in the Cold Lake region can be attributed to the Imperial project.

The Board notes the evidence that arsenic occurs naturally in both the sediments and in the groundwater in the Cold Lake area and elsewhere in the province. The Board also notes that elevated arsenic levels were found in some area well water before Imperial's operations began.

While the Board accepts Imperial's assertion that arsenic is not used in any part of its operations, the Board notes that some evidence suggests that arsenic concentrations as great as 100 μg/L are present both in the bitumen and in produced water from the Clearwater Formation. The Board is, therefore, of the view that any release of production fluids will introduce additional arsenic, over and above the natural concentrations, into the groundwater system in the vicinity of such releases. These releases would then be carried away from the release site by natural groundwater flow in any aquifers that are impacted.

Regarding the fate of such arsenic, the Board believes that it is reasonable to expect that the natural attenuation processes of mixing and dispersion would dilute the arsenic concentrations to near natural concentrations as it travels through the aquifers by naturally occurring groundwater flow. No evidence as to the rate of such attenuation was presented. However, the Board believes that, having regard to the relative volumes, reduction of arsenic concentrations to near-background values would occur over a distance of a few hundred metres. The Board therefore believes that arsenic concentrations arising from this mechanism would not materially impact water in aquifers more than a few hundred metres from any production sites.

The Board notes that concentrations of arsenic found in groundwater on lease are not noticeably different from arsenic concentrations found in groundwater off lease. High and low concentrations of arsenic are present in groundwater both on lease and off lease.

5.1.2 Increased Arsenic Caused by Pumping-Induced Lowering of the Water Table

5.1.2.1 Views of Imperial

Imperial acknowledged that changes in the position of the water table have occurred at some distance from the wells where it withdrew water from Quaternary aquifers. The magnitude of such pumping-induced changes were, however, in the order of a few millimetres and were insignificant when compared with natural annual fluctuations in the water table of 1-2 m. Imperial further indicated that its water withdrawal from Quaternary aquifers was at no time great enough, or sustained enough, to cause water levels to drop below the top of the pumped aquifers. Thus, air was never introduced into the aquifers and mobilization of arsenic in the aquifers by the introduction of oxygen could not have occurred as a consequence of its activities.

5.1.2.2 Views of the Interveners

STOP claimed that pumping of Quaternary aquifers by Imperial had caused declines in water levels of up to 60 m in Imperial's pumping wells and lesser declines in water levels of the pumped aquifer at great distances from the pumping wells. STOP presented evidence that in the early 1990s water levels in a domestic water well located about 17 km south of Imperial's pumping centre declined by about 15 m as a result of pumping by Imperial. STOP also stated that the declines of water levels in the aquifers would have caused declines in the level of the water table near the ground surface in affected areas.

STOP claimed that pumping-induced declines in the water table would, in turn, have caused reduced minerals such as arsenopyrite in upper strata near the water table to be oxidized to more soluble arsenite as the result of the water table decline. A subsequent rise in the water table could then dissolve the arsenite. STOP recognized that there are natural, climate-induced changes or fluctuations in the water table but contended that pumping of water by Imperial from the Quaternary aquifers could have increased the effect. STOP's position was that even a very small decline, if taken over a very large area, could represent a large volume from which to leach arsenic.

AENV agreed that water levels in Quaternary aquifers had been affected over large areas as a result of past pumping from the aquifers by Imperial. AENV agreed with Imperial, however, that any changes that such pumping would have caused to the position of the water table near the ground surface would be in the order of a few millimetres, an insignificant amount when compared to the natural fluctuations in the water table.

5.1.2.3 Views of the Board

The Board agrees with the positions that the past pumping of deep Quaternary aquifers has caused declines in water levels as great as 60 m in the pumped wells, and that these declines translate to lower water levels, changes in magnitude and direction of hydraulic gradients, and, eventually, lowering of the water table at locations that may be tens of kilometres away from the pumping centres. The Board further agrees that these effects were transmitted beyond Imperial's lease and into areas occupied by private residents, including the area south of Crane Lake.

The Board notes that STOP presented evidence that this deep drawdown will translate into a reduction in the level of the water table and that lowering of the water table can cause an increase in oxygen flux to the water table. This increased oxygen flux would oxidize reduced arsenic minerals to a more soluble form, which would then be mobilized by subsequent water table increases. The Board believes that the past changes in the depth to the water table resulting from Imperial's groundwater pumping would not likely be greater than a few millimetres and would be negligible compared with the natural annual fluctuations in depth of the water table, which are known to be in the order of 1-2 m. The Board also agrees with the evidence that at no time were water levels in pumped aquifers drawn below the tops of the respective aquifers. Introduction of oxygen and subsequent mobilization of arsenic in the aquifers due to increased oxygen flux therefore could not have occurred.

5.1.3 Mobilization of Arsenic Due to Elevated Temperature

5.1.3.1 Views of Imperial

Imperial acknowledged that ground temperature increases by more than 20°C over distances of 15-20 m from production wells. However, Imperial stated that it had conducted groundwater monitoring near past casing failures where hot steam and fluids at temperatures greater than 200°C had entered an aquifer. Imperial stated that it found no correlation between these high-temperature releases and concentrations of arsenic in the groundwater.

5.1.3.2 Views of the Interveners

STOP stated that increased temperatures in the bedrock and Quaternary sequence could increase arsenic mobilization because both the oxidation rate of arsenopyrite and the solubility of arsenite increase with increasing temperature.

STOP maintained that the past steaming of several thousand production wells to a temperature of 300°C would have heated the rock and materials surrounding the wellbores, including the Quaternary aquifers. This would constitute a mechanism to raise the temperatures of aquifers and enhance the dissolution of arsenic-bearing minerals around the production wells. Further, STOP submitted that the arsenic that was liberated in this manner would stay in solution and would not precipitate out as it migrated with the groundwater to areas of colder temperature.

AENV stated that the mobility of arsenic would be greatly affected by temperature increases. However, it believed that more information about arsenic reaction and dissolution rates was needed.

5.1.3.3 View of the Board

The Board agrees with STOP's position that past steaming of production wells has heated the formation around the wellbores, including the Quaternary units. The Board also agrees that this would constitute a mechanism to enhance the solubility of naturally-occurring arsenic minerals in the heated portion surrounding the wellbores and could result in an increase of dissolved arsenic concentrations above the naturally-occurring background values. The Board notes that no evidence as to the magnitude of the change of arsenic solubility relative to rock-temperature changes was available. Therefore, the magnitude of the potential increase in arsenic concentrations attributable to this method remains unresolved. Notwithstanding the unresolved nature of this issue, the Board considers the issue to be of some concern and will direct Imperial to investigate the matter in follow-up studies and monitoring programs.

5.1.4 Increase of Arsenic in Domestic Water Wells over Time

5.1.4.1 Views of Imperial

Imperial made no direct statement regarding changes in arsenic concentrations in groundwater over time. It did, however, report that concentrations greater than the 25 μg/L recommended maximum limit of the CDWQ guideline came to light in a 1979 report on a survey of domestic water wells it conducted prior to starting operations in the area.

5.1.4.2 Views of the Interveners

STOP indicated that there is a possibility that arsenic concentrations in groundwater in private wells located south of Imperial's project have increased over time. This was based on a comparison of arsenic concentrations reported in 1979 with data collected in 1998. The comparison indicated that about three-quarters of the 1979 water samples had arsenic concentrations of less than 5 μg/L, whereas only about half of the 1998 samples had arsenic levels of less than 5 μg/L.

STOP presented the individual views of three residents of the area. The residents maintained that because of concentrations of arsenic and other trace elements, the quality of their water had deteriorated to the point where the local health authority had recommended it not be used for drinking, cooking, or washing. They believed that arsenic levels had risen dramatically in the past few years and that the past and present water quality survey supported this view. The residents supported STOP's views that past high rates of groundwater withdrawals by Imperial have caused arsenic to be released in greater quantities to the groundwater system.

5.1.4.3 Views of the Board

The Board does not agree with STOP's position that comparison of results of a well-water quality survey conducted for Imperial prior to the start of operations with results presented by STOP indicates that arsenic concentrations in the area are increasing over time. The Board notes that concentrations as great as 30 μg/L were found in the Imperial survey and that these are comparable to those found in the STOP survey. The Board further notes that whereas STOP maintained arsenic values were generally found in wells deeper than 30 m, wells with elevated levels sampled by Imperial were generally less than 20 m deep, because only a few deeper wells existed in 1978. In contrast, 29 of 50 wells sampled by STOP exceeded 20 m in depth and

12 exceeded 30 m. The Board's view, therefore, is that the evidence does not support increased arsenic concentrations in domestic well water over time. The greater percentage of wells with arsenic levels above 5 µg/L in the STOP survey reflects the fact that a greater number of deep wells were sampled in the STOP survey.

5.1.5 Water Sampling and Analytical Protocols

5.1.5.1 Views of Imperial

Imperial reported that its initial testing for arsenic in water samples was for total arsenic: that is, water samples were not filtered before being treated with acid and shipped for analysis. Imperial stated that its arsenic determinations were changed in 1997 from total arsenic to dissolved arsenic, and later samples were filtered prior to acid treatment. Imperial indicated that the change in procedure was made after discussion and agreement with AENV.

Imperial maintained that analysis for total arsenic gave arsenic values for not only the water but any other arsenic that may have been present on sediment included in the water sample. Imperial stated that inclusions of sediment can be especially problematic in water sampled from monitoring wells and piezometers that are completed in fine-grained sediment and which are difficult to develop and clean rigorously. Imperial maintained that for purposes of comparison and to be representative of transport of arsenic in the groundwater, analysis for dissolved arsenic is the proper procedure.

Imperial also presented its protocol for transport of water samples to the analytical laboratory: that water samples were to be maintained at a temperature of 4°C before arrival at the laboratory.

5.1.5.2 Views of the Interveners

STOP pointed out that there were changes and irregularities in Imperial's sampling and analytical protocols over time. In particular, STOP noted that analyses for arsenic performed prior to June 1997 were for total arsenic, whereas later analyses were for dissolved arsenic. STOP also pointed out that results for total arsenic were generally higher than those for dissolved arsenic. STOP argued that sampling protocols state that samples should be kept at a temperature of 4°C after collection and prior to delivery to the analytical laboratory. Given that laboratory reports from Imperial showed several instances where the submitted sample temperature was above the recommended holding temperature of 4°C upon arrival at the laboratory, STOP inferred that Imperial's analytical results were flawed. Finally, STOP referred to sample D-97 with an arsenic determination of 8780 µg/L indicated for "fresh water" and questioned the meaning of this concentration.

AENV confirmed Imperial's statement that it requested Imperial to change its sampling protocol from sampling for total arsenic to sampling for dissolved arsenic.

5.1.5.3 Views of the Board

The Board does not agree with STOP's position that Imperial's sampling and analytical protocols for arsenic were compromised over time. The Board notes that AENV required Imperial to change its sampling protocols for sampling water from its piezometers and monitoring wells from testing for total arsenic in unfiltered samples to testing for dissolved arsenic in filtered samples. The change occurred in June 1997.

The Board believes that sampling protocols for water from piezometers and monitoring wells should include filtering through 0.45 micron or smaller filter to exclude fine sediment or completion fluids, which may contain sorbed arsenic, before acidizing the sample to maintain dissolved arsenic in solution. The Board also maintains that filtering of water from domestic water wells, while preferable, is less important because initial well development and, especially, later prolonged use of the domestic water wells would have effectively removed fine-grained sediment from the producing interval of the wellbore. Conversely, piezometers and monitoring wells would not have benefited from the prolonged use and removal of fine-grained sediment from the zones of completion. Such sediment would be much less likely to enter water sampled from domestic water wells. The Board, therefore, agrees with Imperial and AENV that a comparison of dissolved arsenic concentrations determined from filtered water from Imperial's piezometers and monitoring wells after June 1997 to total arsenic in domestic well water is preferable to comparison with total arsenic in Imperial's piezometer and monitoring wells as determined before June 1997.

Regarding STOP's position that several water samples submitted by Imperial arrived at the analytical laboratories at temperatures above the stated 4°C protocol, the Board's view is that the deviation was not great enough to have affected dissolved arsenic determinations from acidified samples. The slight deviation in sample temperature would not have caused arsenic to precipitate from the water sample or caused it to be lost to the analysis.

Lastly, in regard to STOP's concern regarding the extremely high arsenic concentration of 8780 µg/L, which was reported for the sample designated D-97, the Board notes that the sample was not collected from a piezometer, monitoring well, or private well. The sample represents a control sample in which Imperial added a known amount of arsenic to fresh water as a check on the analytical laboratory and therefore has no relevance to local conditions.

5.1.6 Concern for the Health of Local Residents

5.1.6.1 Views of Imperial

Imperial reported that when it found arsenic concentrations in water above the CDWQ guidelines in water from some domestic water wells located in the vicinity of its project, it recognized this as a potential health hazard. Consequently, Imperial stated that it notified both the well owners and the local health authority of the findings. Imperial also notified the deputy minister of Alberta Health and met with senior officials of Health and AENV to inform them of the well owners' concerns and the need for a follow-up study.

5.1.6.2 Views of the Interveners

STOP presented the views of local residents regarding arsenic content in groundwater, based on its survey of households near the area of Imperial's Cold Lake project. Residents indicated high arsenic levels in groundwater to be one of their major concerns related to water quality. In particular, they expressed concern about the effects of long-term exposure to arsenic. They expressed further concern about the cost of removal of arsenic from their water supply, and most indicated that they believed industry and government should be financially responsible for the treatment and restoration of domestic water sources.

The Pernarowskis noted that tests conducted on their water well indicated arsenic levels ranging from 10 to 45 μg/L, which are above the World Health Organization guidelines of 10 μg/L. Their position was that any amount of arsenic in their water was too much. They also expressed concern over the change in their lifestyle that was required because of arsenic in their water and the possible health effects on their grandchildren.

Health concluded that, based on Imperial's EIA, the project holds no significant adverse health impacts for the population. Health noted that concerns about arsenic in groundwater and well water used for human consumption were raised external to the Imperial application. It further noted that the concerns were first brought to the attention of Lakeland Regional Health Authority (LRHA) by Imperial in February 1998.

Health reported that, in response to Imperial's disclosure of the information, it established a working group with membership from LRHA, Health, AENV, the Department of Public Health of the University of Alberta, and the University of Alberta Trace Metals and Environmental Toxicology Laboratory. The group's purpose was to assess any potential public health risk associated with arsenic and groundwater and to develop recommendations for addressing the issue.

The group developed a strategy that included

- providing the test results to local residents,
- providing information about arsenic and human health, including water treatment methodologies, to local residents, and
- developing a reliable sampling protocol and laboratory testing that would yield reliable results.

Health reported that part of developing the sampling methodology would be a program in which water samples would be collected in the Cold Lake area by the LHRA and analyzed for trace elements and for different arsenic species.

Health further indicated that more extensive sampling and testing for arsenic were scheduled for 1999 for a larger area in Alberta, and that as many as 60 locations were chosen for monthly sampling for 12 months. The purpose of this sampling was to provide a high-quality data set that could be interpreted from a perspective of risk to human health.

Health reported that in the years 1994-1997 it participated in an Alberta-wide survey of farmstead water quality. The survey sampled water from 857 sites across Alberta and showed that significant geographic variation in arsenic and other contaminants exists in the province.

LRHA acknowledged that it was advised of the results of Imperial's regional well survey, which indicated that total arsenic levels ranged from 9.9 to 45.2 μg/L and that some of the locations tested exceeded the CDWQ recommended maximum standard of 25 μg/L. LRHA indicated that it responded to numerous questions about the effects of arsenic after the affected residents were informed about the situation by Imperial.

LHRA further reported that its subsequent arsenic speciation testing in the Cold Lake area was performed on water from two Imperial wells, one Husky Oil well, one Blackrock Resources well, and seven residential wells. The total arsenic concentration ranged from 1.05 to 39.9 µg/L, and the 25 µg/L maximum standard was exceeded at two locations. The speciation testing showed that 88 per cent of the arsenic was present as arsenite and 12 per cent as arsenate. LHRA said that between February and June 1998, additional analyses were performed at ten residences and nine water wells at an unspecified number of residences. Arsenic concentrations ranged from 0.14 to 38 µg/L, with water from five wells exceeding the 25 µg/L maximum standard.

In total, LHRA analyzed one or more samples from 28 locations during 1997 and 1998. The 25 µg/L maximum standard was exceeded by at least one sample at 11 of these locations. LHRA concluded that the levels of arsenic found suggested no immediate or acute health risk based on the Guidelines for Canadian Drinking Water Quality. However, it also indicated that the reported arsenic levels were identified as having a possible long-term chronic impact if the well water was consumed daily as their primary water source.

5.1.6.3 Views of the Board

The Board is of the view that Imperial demonstrated due diligence in reporting the initial findings on arsenic in a timely fashion to the appropriate regulatory authorities, as well as to the local landowners.

Notwithstanding the Board's findings that Imperial's operations are not related to elevated arsenic concentrations in private water wells, the Board shares the concerns of the citizens about arsenic in their domestic water and expects these concerns to be addressed. The Board fully supports the initiatives under way by Health, LRHA, and AENV.

5.2 Aquifer Protection — Elevated Chlorides, Phenols, and Dissolved Organic Carbon

5.2.1 Views of Imperial

Imperial indicated that as a condition of EPO 95-07, it was required to install a regional groundwater monitoring network to monitor water quality in deep Quaternary aquifers down gradient of its operations. The geology of the area is shown in Figure 2 and the locations of the regional monitoring wells in Figure 3. It further indicated that groundwater analyses at these regional monitoring wells identified elevated levels of chloride, phenols, and DOC in some of the deeper aquifers. Imperial noted that the detected levels of these parameters do not represent a health hazard but were initially suspected to be an indication of oilfield contamination. Upon investigating the matter, Imperial concluded that the impacts of its operations are localized and remediable and that the higher-than-expected levels of chloride, phenols, and DOC south of its operations are naturally occurring. The chloride and phenols originate from the Colorado shale underlying the aquifers, and the elevated DOC results from naturally-occurring organic material in the aquifer sediments.

As indicated in Section 4.3.4.1, Imperial maintained that the source of elevated chloride in the Quaternary aquifer results from the mixing of Colorado and Quaternary waters where Quaternary aquifers rest directly on the fractured Colorado bedrock.

Imperial committed to obtaining background groundwater monitoring data prior to start-up operations at Mahkeses.

5.2.2 Views of the Interveners

STOP, Mr. Pernarowski, MLLA, and CLFN all expressed concern with the conclusions of Imperial's investigation into elevated chemical parameters in deeper aquifers. They suggested that Imperial had not gathered sufficient evidence to conclusively state that its operations were not impacting groundwater to the south of its operations.

As discussed in Section 4.3.4.2, AENV agreed with Imperial's interpretation that the source of chloride in Quaternary aquifers is not likely produced water or natural Clearwater Formation water but rather water from bedrock units above that horizon. However, AENV contended that because the isotopic signatures are essentially the same for the Colorado Group and the Grand Rapids Formation water, the source of chloride could be either unit, not just the Colorado, as stated by Imperial. AENV noted that a Grand Rapids source would indicate movement of groundwater along a vertical bedrock pathway or near-wellbore feature.

AENV adopted the view that the relatively high chloride values combined with very low sulphate concentrations in the lowermost Quaternary aquifer, as found in a number of groundwater monitoring wells are atypical of values expected for Quaternary units. It stated that this is especially true if diffusive flow from the Colorado bedrock (high chloride and sulphate) into the Quaternary aquifers were occurring, as postulated by Imperial. AENV suggested that the high chloride-low sulphate values in the lowermost aquifers indicate an influx and mixing with groundwater moving upward along fractures or other pathways from deeper formations, such as the Grand Rapids or Clearwater, both characterized by high chloride-low sulphate water.

5.2.3 Views of the Board

The Board notes that Imperial is responsible for localized groundwater impacts resulting from casing failures and seepage from pits, ponds, and landfills at its Cold Lake operation. The Board expects that these impacts will be remediated and monitored.

With respect to deep Quaternary aquifers, the Board heard a great deal of evidence related to the presence of elevated chlorides, phenols, and DOC in some of the deep aquifers south of the Imperial operations. This evidence suggests that Imperial is not responsible for these off-site impacts in the area of Crane Lake. The Board agrees with Imperial's conclusion that chemical fingerprinting data show the chloride in the Quaternary aquifers is not derived from the Clearwater formation, but from the Colorado Group or Grand Rapids Formation. However, the Board believes that there are still some unanswered questions regarding elevated chemical parameters within the project area and at the regional monitoring wells around the perimeter of the project. Therefore, the Board believes that continued monitoring of existing regional monitoring wells will provide valuable information that will more clearly define the source of these elevated parameters.

With regard to the proposed Mahkeses project area, the Board accepts Imperial's commitment to obtain background groundwater monitoring data prior to project operations should this application be approved. The Board notes that it expects Imperial to consult with AENV and EUB staff prior to installation of the monitoring system.

5.3 Water Management

5.3.1 Views of Imperial

Imperial stated that it has developed a water management strategy for the Mahkeses project that will

- maximize produced water recycling,
- minimize the utility need for fresh water,
- expand brackish water use,
- use the existing surface water withdrawal permit for start-up, and
- implement contingency measures in the event of low water levels in Cold Lake.

Imperial noted that it has developed technology that maximizes the volume of produced water it can treat and recycle into steam. This, plus the expanded use of brackish water for make-up water (voidage replacement) and start-up water, would greatly reduce Imperial's freshwater usage for the Mahkeses project.

Imperial noted that the older steam generators at the Leming plant use fresh water only. However, to minimize freshwater use during the Mahkeses start-up phase, the volume of steam generated at Leming could be decreased.

Imperial indicated that the need for make-up water for the Mahkeses project would be met by increasing the use of brackish water obtained from the McMurray Formation. As a result, it maintained that an increase to the currently-permitted surface water withdrawal from Cold Lake was not necessary.

Imperial described the McMurray Formation as laterally extensive. It indicated that the optimum location for additional water source wells would be along the eastern edge of the project area in a thick, water-saturated McMurray section. Imperial modelled a minimum long-term sustained flow rate per well of 15 000 m^3/d, with a potential to exceed 30 000 m^3/d per well. Imperial indicated that these withdrawal rates would not impact underlying Devonian or overlying Cretaceous and Quaternary aquifers. Imperial also noted that the extraction of brackish water does not require AENV approval.

Imperial stated that the Mahkeses project would not increase its current use of fresh water. Imperial stated that water required for Mahkeses start-up would come from Cold Lake under its existing surface water withdrawal permit. However, the low water level in Cold Lake caused Imperial to file an application under the Water Act (previously the Water Resources Act) with AENV for a six-month temporary groundwater withdrawal permit for up to 7000 m^3/d. As this application was under review by AENV at the time of the hearing, Imperial filed a second request for a three-month contingency groundwater withdrawal permit. Imperial indicated that this permit allows for groundwater withdrawals from the Empress I aquifer only. Imperial evaluated freshwater withdrawal from either surface or groundwater sources as having manageable or negligible impacts on surface or groundwater levels. Imperial did not anticipate adverse impacts on domestic water wells associated with groundwater extraction.

Imperial emphasized that its operations are not responsible for the lowered lake level in Cold Lake. It stated that the levels of Cold Lake are governed by natural processes and that Imperial uses approximately only 0.2 per cent of the total volume of water entering the lake.

In response to intervener requests that water from the North Saskatchewan River be used as a source of fresh water, Imperial noted that under the Water Act, which prohibits interbasin transfer, access to fresh water from the North Saskatchewan River would not be permitted by AENV.

Imperial committed to filing applications for all licences required under the Alberta Environmental Protection and Enhancement Act (AEPEA) by August 1999.

5.3.2 Views of the Interveners

AENV confirmed that Imperial has filed an application under the Water Act for a six-month temporary groundwater withdrawal permit for up to 7000 m^3/d. In addition, it has also filed other licence applications, including contingency water supply. AENV said that its decision on these applications will have regard for the EUB's comments regarding water management specifically, as well as the general matter of how the Mahkeses application meets the public interest test. Imperial's application to AENV will be subject to public review and comments.

AENV's view was that Imperial's proposal to withdraw start-up water from the Empress I aquifer was technically feasible. However, given that previous pumping affected three domestic wells, AENV would require mitigative measures to offset adverse impacts.

With respect to contingency water supplies in the event of low water levels at Cold Lake, AENV indicated that Imperial has applied for groundwater withdrawal if surface water sources are suspended. This creates a potential problem for Imperial in that the long-term requirement may conflict with the start-up water withdrawal requirement, because the same aquifer is proposed as the water source. AENV's position was that these wells could not satisfy both requirements. Other wells could be used, but this would require a subsequent approval under AEPEA.

AENV indicated that this potential situation demonstrates the need for a long-term regional study, including consideration of cumulative impacts related to water withdrawal.

With respect to the use of brackish water, AENV stated that while this option was environmentally preferable, it had concerns as to the sustainability of the brackish water supply, and it requested that the EUB consider this issue, bearing in mind that there may not be a freshwater alternative if the brackish water supplies are interrupted.

STOP reiterated AENV's request that the EUB consider the appropriateness of brackish water use and its concern for long-term supply. STOP also confirmed that domestic water wells had, in fact, been impacted by Imperial's groundwater withdrawal program in the past and that these impacts had been documented over many kilometres. STOP also said that while AENV has a regional water plan, it does not have a long-term plan for Imperial.

Variations in lake water levels and the decrease of flow in Marie Creek concerned several interveners, who were skeptical of Imperial's position that these variations are natural. The concerns of the other interveners were related more to the issue of groundwater quality and monitoring.

5.3.3 Views of the Board

The Board supports the priorities adopted by Imperial for its water management strategy to supply the Mahkeses plant.

The Board notes Imperial's plans to optimize water management by integrating water handling at the Mahkeses plant with existing plants. The Board also expects Imperial to reduce freshwater use at Leming if the availability of fresh water for Mahkeses becomes an issue.

While Imperial appears confident it will be able to meet its needs, the Board is concerned that the applicant's long-term water management plan is somewhat uncertain. Further, the Board notes that Imperial chose not to file its AEPEA licence applications concurrently with its application for a major project to the EUB, as required in *IL 96-7: EUB/AEP Memorandum of Understanding on the Regulation of Oil Sands Development*. The Board notes that Imperial has committed to limiting its use of fresh surface or groundwater, turning instead to a greater reliance on brackish water extracted from the McMurray Formation.

The Board notes that AENV has jurisdiction over water resources. With respect to brackish water, the Board recognizes that a water diversion permit is not required under the Water Act for extraction of brackish water. However, the Board expects that Imperial would satisfy local residents' concerns regarding the impact of water withdrawal from the McMurray Formation on overlying aquifers.

The Board agrees that there is no evidence to suggest that Imperial's operations are impacting surface water levels. However, the Board notes that there have been impacts to domestic water wells from Imperial's groundwater extraction practices in the past. The Board agrees with intervener statements that impacts to domestic wells resulting from groundwater withdrawal by Imperial are not acceptable. The Board recognizes that AENV requires Imperial to manage its groundwater extraction such that impacts are minimized.

5.4 Waste Storage and Containment

5.4.1 Views of Imperial

Imperial submitted that it monitors and addresses all environmental concerns surrounding waste storage facilities. It noted that the material underlying lime-sludge ponds and oilfield landfill is a fine-grained till; therefore, seepage rates are low and natural attenuation processes reduce the concentration of the leachate to acceptable levels within a few hundred metres of these waste containment features. Imperial said that it has a network of shallow groundwater monitoring wells around the perimeter of all its waste containment facilities in order to monitor water quality. Imperial confirmed that seepage was occurring from the May lime-sludge pond and noted that groundwater monitoring is continuing, even though this pond has been decommissioned.

Imperial noted that all dangerous oilfield wastes (DOWs) were stored in a special DOW trailer on site, conforming to the requirements of EUB *Guide 55: Storage Requirements for the Upstream Petroleum Industry.*

5.4.2 Views of the Interveners

STOP and Mr. Pernarowski raised concerns regarding storage of waste in unlined earthen ponds and the potential impact of this practice on groundwater.

Mr. Pernarowski also expressed concern about the design, length of use, and capacity of multiwell drilling sumps. His concern was directed toward possible seepage from these large sumps into the groundwater system and concentration of metals, specifically arsenic, from reuse of drilling fluid. Mr. Pernarowski was also concerned about the EUB's ability to provide adequate surveillance in this area.

5.4.3 Views of the Board

The Board notes that seepage from lime-sludge ponds is occurring and that Imperial is addressing this issue. The Board expects that the lime-sludge containment structures associated with the proposed Mahkeses expansion will be designed in a manner to avoid seepage and will include perimeter groundwater monitoring wells to assess groundwater quality and to detect any escape of material. The Board notes that the design and surveillance of lime-sludge ponds is under AENV jurisdiction. The Board is satisfied that Imperial is meeting regulatory guidelines in its waste-handling operations.

5.5 Air and Surface Water Issues

5.5.1 Views of Imperial

Imperial maintained that its current air and surface water monitoring practices are in keeping with provincial guidelines. It believed that the levels of emissions from its project are low and that current monitoring practices are adequate to address concerns.

Imperial indicated that the maximum ambient concentration of sulphur dioxide, nitrogen dioxide (NO_2), hydrogen sulphide, particulate matter, and volatile organic carbon (VOCs) from the project would not have a significant adverse impact on the environment. Predicted sulphur dioxide emissions of 1.1 tonnes per day from the Mahkeses project would not require sulphur recovery under EUB *Informational Letter* (*IL) 88-13: Sulphur Recovery Guidelines — Gas Processing Operations.* Imperial also indicated that, given the low emission levels, the acid deposition rate from the project would not cause significant impacts to soil or surface water.

Imperial noted that reduced flows in Marie Creek may be associated with a weir at the south end of Ethel Lake. The weir was constructed and operated by Imperial but now belongs to AENV. Imperial stated that it no longer uses water from Ethel Lake and that the pump house has been dismantled.

Regarding development setbacks, plans call for a 300-m setback from all lakes and rivers within the project area for environmental protection reasons. Resource recovery would not be compromised under this configuration, as deviated wells would be able to access all parts of the reservoir.

5.5.2 Views of the Interveners

CLFN and Mr. Pernarowski expressed concern regarding the increasing incidences of swimmer's itch at Cold Lake and implied that it could be related to Imperial's operation. CLFN also expressed concern about the presence of a yellow substance along the shores of Cold Lake, the absence of water in Marie Creek, and associated dead or stressed vegetation. CLFN requested that Imperial re-establish air and water monitoring adjacent to Marie Lake and on the English Bay Reserve.

MLLA expressed concern with variations in the level of Marie Lake and the decrease in flow in Marie Creek. MLLA was skeptical of Imperial's position that these variations are natural.

STOP, Mr. Pernarowski, MLLA, and CLFN indicated that the EUB and AENV should require regional environmental monitoring, similar to that required in the Fort McMurray area. Imperial should be required to participate in such a regional monitoring program with other area operators.

AENV requested and received a commitment from Imperial that it would adopt the Canadian Council of Ministers of the Environment guidelines or codes of practice regarding nitrogen dioxide and volatile organic compound emissions.

5.5.3 Views of the Board

The Board agrees that Imperial's current air and surface water monitoring practices meet provincial guidelines. However, the Board notes concerns raised by interveners regarding the lack of off-site air and surface water monitoring. The Board expects Imperial to be proactive in addressing area residents' concerns. Accordingly, the Board expects Imperial to work with AENV and all concerned parties to ensure that an appropriate and effective monitoring system is implemented.

The Board notes intervener concerns regarding the Ethel Lake weir and the possible association with diminished flows in Marie Creek. The Board notes that AENV has taken ownership of the weir and will be dealing with it.

With respect to the proposed 300-m setback from surface water bodies, including Marie Creek and Jackfish Creek, the Board considers this to be an adequate distance given past operational experience at the project. However, given the potential effects in the case of a surface release in these areas, the Board expects Imperial to ensure that impacts do not occur in these environmentally sensitive areas. Should operational issues over the life of this project cause the Board to become concerned with the proposed setbacks, the Board will require increased setbacks and may subject wells within the enlarged setbacks to operational constraints.

Furthermore, the Board accepts the views of the interveners that development closer to existing landowners has the potential to affect more local residents. Therefore, the Board expects the applicant to be vigilant in preventing and monitoring for impacts. The monitoring program for this project has taken into account the need for early detection and immediate mitigation of impacts related to the relative proximity of the proposed project development.

6 CONSULTATION PROCESS

6.1 Public Consultation

6.1.1 Views of Imperial

Imperial submitted that it had conducted an extensive communications and consultation process throughout the development of the application. Its public consultation program began in 1996 when the expansion project was announced through public disclosure documents, news releases, and the issuing of background documents to local landowners, residents, and interested parties. Three open houses were held in 1996, in addition to numerous group and one-on-one meetings. Where applicable, concerns raised by the public were incorporated in Imperial's EIA. Upon filing this application with the EUB in February 1997, Imperial held open houses to describe the application, placed newspaper advertisements to notify readers about the availability of the application, and distributed copies of the application to interested parties. Imperial met with concerned parties and noted that, of the twelve parties originally expressing concern, only four interveners remained as active hearing participants. Imperial pointed out that the agreement reached with the MLLA is evidence of the success of its public consultation program. Imperial stated that it is committed to ongoing consultation through the life of the project and that the expansion project would become part of the community awareness program in place for the existing operations.

Imperial stated that it had a number of concerns about how STOP's householder survey was conducted. Furthermore, the issues raised by those surveyed had previously been expressed to Imperial in 1996 as a result of its public consultation program and subsequently addressed in Imperial's EIA.

6.1.2 Views of the Interveners

STOP expressed the view that Imperial was not effective in its efforts to communicate with or have a link with the Cold Lake community.

MLLA acknowledged that Imperial had many meetings with it on the proposed expansion project. However, it maintained that Imperial's public consultation program on events prior to the expansion project was not effective. In MLLA's opinion, Imperial provided little direct information to the neighbouring residents following the T-pad failure, was not forthcoming with EPO information, and did not address recurring odour problems at Marie Lake until the expansion proceedings commenced. In MLLA's view, Imperial and the regulators have not demonstrated concern about the lack of effort placed on issues such as arsenic in the lake water. As a result, MLLA suggested that there appears to be a sense of fear and mistrust among the area residents. MLLA recommended that Imperial

1) have annual contact with landowners directly affected and others indirectly affected by operations, clearly reporting any occurrences and remedial actions;

2) collect information relating to air and water quality and changes in water level, as a minimum; these data should be collected, summarized, independently reviewed, and considered by a regional committee and then submitted to the Board.

MLLA submitted that Imperial should be required to develop an effective public consultation plan and report annually on the effectiveness of the plan. Failure to comply with this requirement should result in the approval being rescinded.

Mr. Pernarowski acknowledged that an Imperial landman had visited his house twice and suggested that if there were any problems he should notify Imperial. However, Mr. Pernarowski stated that he was not aware of the issues at that time and would have appreciated an Imperial representative identifying and discussing potential issues and concerns. He said that he and others had to initiate discussions of their concerns, although the initiative should have come from Imperial.

Regarding the STOP household survey, Mr. Pernarowski found it to be very well planned, objective, and unbiased. He stated he did not understand why Imperial did not conduct a survey for its purposes.

CLFN recalled that in the early 1980s Imperial would consult with the Band on issues of joint interest; however, such ongoing consultation was no longer taking place. CLFN also stated that when it identified events or issues that were of concern to the Band, there was no mechanism in place to raise these concerns with Imperial.

6.1.3 Views of the Board

The Board believes that the public consultation conducted by Imperial for this proposed expansion project was generally acceptable in that it gave interested parties opportunities to express their concerns on the application. The Board has a greater concern about opportunities for ongoing dialogue between residents and Imperial about its operation. It is evident that some concerns raised by the community related to the lack of information about existing operations or the impacts associated with past incidents. The Board believes that a permanent forum where concerns about the industry can be raised by the public serves a useful purpose for dealing with ongoing issues and cumulative effects of development in the area. The Board requests Imperial to explore the possibility of establishing such a forum with other operators in the area and advise the Board of the results. The Board will make its staff available to participate as necessary.

Regarding STOP's householder survey, the Board acknowledges that it identified a number of concerns held by the local residents. However, the Board notes that these issues were previously identified through other means.

6.2 Cumulative Impacts on Region

6.2.1 Views of Imperial

Regarding the matter of regional environmental monitoring, Imperial's view was that although benefits of a regional approach to environmental and conservation issues were recognized for the oil sands developments around Fort McMurray, it did not support the need for a similar approach for the Cold Lake area. Imperial maintained that the extent of the development at Cold Lake is not comparable to that in the Fort McMurray area. Although it recognized that there were a number of potential projects announced for the Cold Lake area, it was yet to be seen if these would materialize over the short term.

Imperial also noted that the EIA for the Mahkeses project identified very few impacts from different oil sands operations that overlap or accumulate. This suggested that it may be more appropriate to monitor around individual projects (point source monitoring) rather than monitor cumulative effects across the region. However, Imperial stated that it intends to monitor the effects of its own operations, to share information with other operators, and to coordinate activities where appropriate to do so.

6.2.2 Views of the Interveners

MLLA's view was that some form of regional coordination should take place among the various companies to coordinate and assess, on a cumulative basis, the effects of these operations in the Cold Lake area. Specifically, MLLA recommended that a regional management program be developed to monitor and manage environmental and socioeconomic effects of this project on the other heavy oil developments in the Cold Lake area. Its view was that the evidence indicated there was a degree of overlap among the various operators in monitoring certain factors, such as lake levels, wildlife access, and transportation. Therefore, it seemed sensible that there should be some coordination among operators to get a better product and share it with the community. MLLA pointed out that AENV has devised a terms of reference for such a process to be used in the Fort McMurray area, and while there are differences in the development, these terms of reference could be used as a guideline.

MLLA also pointed out that the many substantial heavy oil operations in the Cold Lake area have had a significant impact on air quality, water quality and quantity, wildlife, fisheries, local roads, and infrastructure. It stated that Imperial's EIA did not appreciate the full impact of the projects currently announced in the area when considering cumulative impacts. It further stated that the information Imperial presented was at least two years old.

MLLA maintained that implementing a regional monitoring system was not premature but was being proactive. It also suggested that the EUB and AENV cooperate to develop such a monitoring system for the area and that this requirement should be incorporated in any approval issued.

The other interveners concurred with MLLA that the matter of cumulative impacts for this project and others in the region needs to be considered.

6.2.3 Views of the Board

The Board recognizes that the extent of development in the Cold Lake area is not as great as that contemplated for the Athabasca oil sands area. However, given the current level of development in the Cold Lake area and having regard for those projects approved for development or in the planning stage, the Board sees merit in the establishment of a committee to monitor regional development in the Cold Lake area.

While the Board would not suggest the final make-up of such a committee, it seems reasonable to have participation from groups including the EUB, industry, government, municipalities, and the public. The Board suggests further that the need and scope for such a review be discussed with other operators in the area in consultation with municipal officials and the public.

The Board cautions that the purpose of the committee should not be to focus on particular operators or projects. Rather, it should be a forum to review regional issues, such as infrastructure requirements (roads, services, etc.) and regional studies, with an aim to reduce the burden on industry through the sharing of data, resources, and costs. The results would benefit the public and would be more extensive than individual groups or companies would otherwise have produced.

The Board will follow up on the establishment of such a committee with the relevant parties.

7 SOCIOECONOMIC ISSUES

7.1 Views of Imperial

Imperial submitted that significant economic benefits would occur as a result of the proposed expansion project without causing adverse social impacts. The economic benefits at the local and provincial level included

- direct, indirect, and induced employment impacts, which would result in almost 2700 person-years of work in the province during the project development—Albertans employed directly for the project development would total about 1150 full-time equivalent workers, of which half would be from the local area;

- employment of 270 full-time equivalent positions during the ongoing project operation and pad development—about 185 of these would be created directly;

- generation of $15 million (1996 dollars) in annual labour income to workers in the Cold Lake area;

- generation of $800 000 in annual municipal tax revenues to the Municipal District of Bonnyville;

- revenue collected by the federal and provincial governments in the form of royalties, income taxes, and corporate taxes totals more than half of the project’s undiscounted net social benefit, which is expected to be $2.45 billion;

- two-thirds of construction and more than 90 per cent of operating expenditures for the project would occur in Alberta;

- the total direct, indirect, and induced impacts of the construction phase on Alberta, expressed in gross domestic product terms, is estimated at $362 million;

- about $300 million (1996 dollars discounted at 8 per cent) to be realized by local and provincial governments as a result of social benefits.

On the basis of the foregoing, Imperial suggested that the proposed Cold Lake expansion project is desirable from an economic perspective for the local region, the province, and the country.

Imperial suggested that the current levels of community services and infrastructure could accommodate the social impacts of the proposed project. Imperial conducted a study of the impact the project would have on social areas, including population, education, health, social services, protective services, recreational services, community planning, community infrastructure, transportation, and housing. Imperial found that generally impacts would be neutral during the construction phase with two exceptions: a positive impact associated with housing as vacancy rates declined with the influx of out-of-town workers, and a negative impact identified for transportation and protective services as the volume of traffic increased. Imperial suggested that with the increased traffic occurring at regular times during the day, the police would have the opportunity to manage the traffic. During the operation phase of the project the introduction of more families to the community would result in positive impacts in the areas of education and housing and neutral to positive impacts for population and recreational services. There would continue to be a negative impact on transportation in the operation phase as a result of a slight increase in traffic and subsequent degradation of local roads. Imperial noted that as part of the socioeconomic impacts study, potential issues were identified during discussions with local officials and the general public. Imperial assessed the impact of the issues for both the construction and operation stages of the proposed expansion and recommended mitigation and monitoring measures where appropriate. Imperial stated that it was committed to implementing the recommended measures.

Imperial pointed out that the Municipal District of Bonnyville and the towns of Cold Lake and Bonnyville submitted letters of support for the proposed expansion.

7.2 Views of the Interveners

STOP submitted that the proposed project would not generate new employment. The construction phase would use union members transferred from completed jobs. During the operational phase, only an additional 10 full-time employees would be required.

With respect to population growth and local infrastructure, STOP suggested that local taxpayers are still paying off the long-term debt incurred by local governments to build the infrastructure for growth predicted by Imperial in its 1979 social impact study.

Regarding social issues, STOP pointed out that arsenic in the water had become a social cost to local residents in terms of having to acquire water for domestic use, reducing the value of their land, and affecting the range of economic and recreational life choices associated with the major water bodies.

STOP submitted that a historical resources impact assessment cannot be conducted during a snow-covered period of the year, as was done by Imperial.

MLLA pointed out that the level of Marie Lake has fluctuated significantly in recent years and that the lake, which at one time supported a tremendous fishery, now requires a stocking program.

Mr. Pernarowski suggested that he is bothered by the *carte blanche* approvals or supports given Imperial by the towns of Bonnyville, Cold Lake, and the MD of Bonnyville. He questioned whether they are looking at the economic benefits only. Mr. Pernarowski suggested that the health of the people of the Lakeland area is poorer than in the rest of the province.
Mrs. Pernarowski is of the view that due to the contamination of their water they would not be able to sell their property if they chose to leave at this time.

CLFN pointed out that it is the nearest, most impacted First Nations community to Imperial's Cold Lake project and yet does not benefit from this project. A socioeconomic impact study conducted by Imperial at the time of the megaproject (late 1970s, early 1980s) proposed action to ensure that negative social and cultural impacts of the project, anticipated by First Nations people, were mitigated. The most important of the proposed actions was to minimize the environmental impacts of the project and provide supportive services to the First Nations people employed by Imperial and its contractors. During the initial construction phases, CLFN people performed a significant amount of work for Imperial. However, CLFN did not know of any members currently employed by Imperial. CLFN acknowledged that Imperial had made some strong statements in this hearing regarding its willingness to identify measures that would ensure that CLFN benefited from this project. CLFN asked that if the Board approved the project, it support its decision by citing Imperial's statements respecting socioeconomic opportunity for the CLFN people.

With respect to the historical resources impact assessment that Imperial conducted for the proposed expansion, CLFN suggested that it was reduced to a limited survey (614 shovel tests) of snow-covered terrain. CLFN noted that the 614 shovel tests equate to about 98 m^2 of exposed area spread over the entire Imperial lease.

CLFN observed that Imperial's project site is on their traditional land and that they are permanent people. They have seen their livelihood (trapping, fishing, and logging) eroded during the last few decades, and as a result CLFN people now rely on government for support.

As part of its review of the proposed project, AENV contacted Alberta Community Development (ACD), which is responsible for the Historical Resources Act. ACD had no concern about the historical resource impact assessment conducted on behalf of Imperial. A field assessment conducted on the Imperial site did not encounter any archaeological resources or historical sites.

7.3 Views of the Board

The Board accepts that most of the negative social impacts resulting from the proposed expansion would occur during the construction period. The community infrastructure needed to support the construction and operation phases of this expansion project are for the most part already in place. Given the evidence, the Board believes that the Mahkeses expansion would result in significant and sustained economic growth in the area, as well as in the province in general. On balance, the Board finds the project to be of significant public benefit.

The Board acknowledges that Imperial made commitments to CLFN respecting socioeconomic opportunity for its people. The Board encourages Imperial to act on its commitments. However, it does not find it appropriate to include them as conditions to the scheme approval.

The Board is somewhat concerned with the commitments made by Imperial to CLFN and the extent to which these have been met. The Board considers such commitments to be binding on the company as a matter of ongoing public trust by the industry. The Board recommends that Imperial review its past and current commitments with the community and re-establish a dialogue at the earliest date.

8 DECISION

Having carefully considered all of the evidence, the Board has determined that Application No. 970163 is in the public interest and is prepared to recommend approval of the application to the Lieutenant Governor in Council. The Board believes that, while there are operational and environmental risks associated with the proposed development, these risks are manageable and the project can proceed in an environmentally and socially acceptable manner. Given the potential risks, the Board also believes that some additional measures are required to ensure that potentially adverse impacts from the project are minimized. Therefore, the Board will impose the following requirements and conditions as part of its approval.

1. Imperial must implement an enhanced regional monitoring network at its existing operations and in the proposed expansion area to monitor groundwater flow directions and groundwater chemistry.

2. Imperial must set up an enhanced groundwater-monitoring network to provide information on any water level responses to steam injection.

3. Imperial must conduct additional sampling, testing, and studies to help assess formation integrity and to provide baseline geological and geotechnical information and further knowledge on properties that can influence groundwater flow, water quality, and corrosion of casing and degradation of cement.

4. Imperial must design and implement monitoring programs to specifically address the potential that its operations may have on liberating or introducing arsenic into the groundwater.

5. The Board expects Imperial to expand its research in the matter of seismicity within the Colorado Group in the project area, provide the results to the Board, and brief the public.

6. Imperial must comply with the hydraulic logging requirements of EUB *Guide G-51* for all newly drilled wells prior to their being place on steam injection.

7. Imperial must explore the possibility of establishing a forum with other operators where concerns about the industry can be raised for the purpose of dealing with ongoing issues. Imperial shall report back to the Board on the results of its investigations.

8. Imperial must conduct pressure surveys prior to the commencement of steaming and thereafter in any Grand Rapids gas wells that it operates within the expansion area.

9. Imperial must submit an annual summary report on casing integrity and remediation efforts.

Prior to implementation of the above conditions, Imperial must consult as required with the Board and AENV regarding scope and timing.

Dated at Calgary, Alberta, on 16 September 1999.

ALBERTA ENERGY AND UTILITIES BOARD

[Original signed by]

F. J. Mink, P.Eng.
Board Member

[Original signed by]

J. D. Dilay, P.Eng.
Board Member

[Original signed by]

G. J. Miller
Board Member

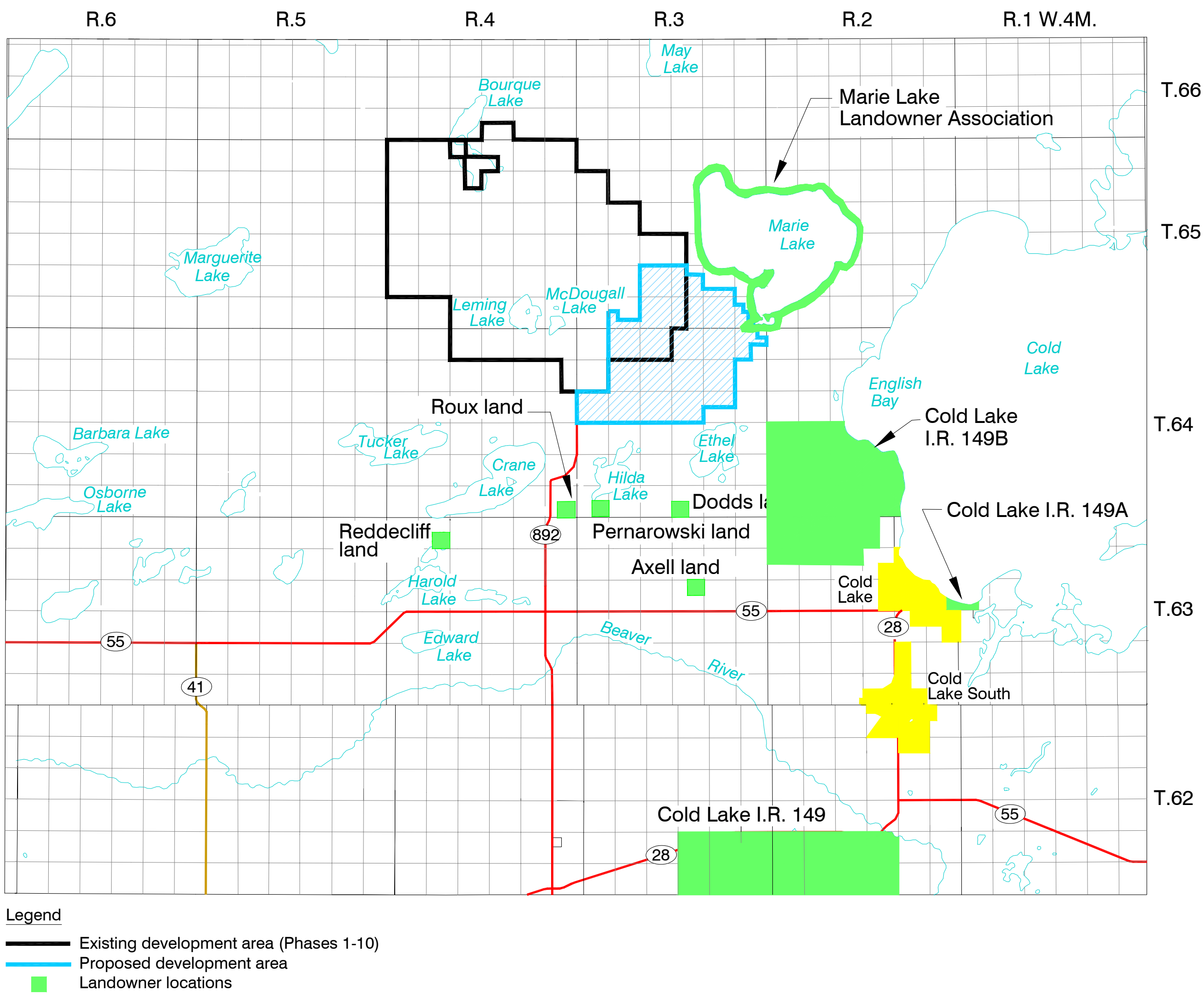

Figure 1. Cold Lake Expansion Project and Surrounding Area (Imperial Oil Resources Limited, Application No. 970163)

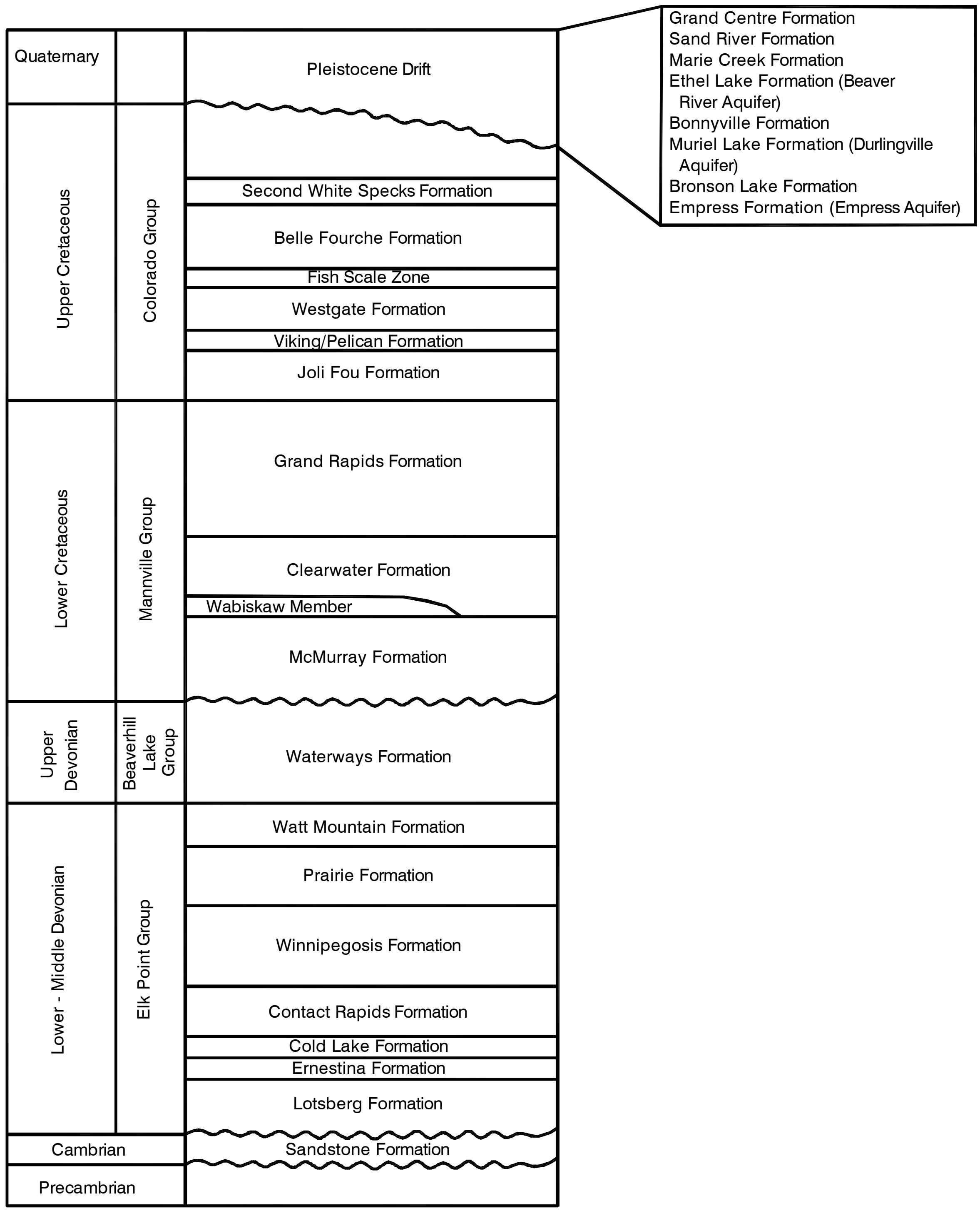

Figure 2. Cold Lake Expansion Project - Stratigraphy of the Cold Lake Area (Imperial Oil Resources Limited, Application No. 970163) (modified from Imperial Application, Volume 1, Figure 2-1)

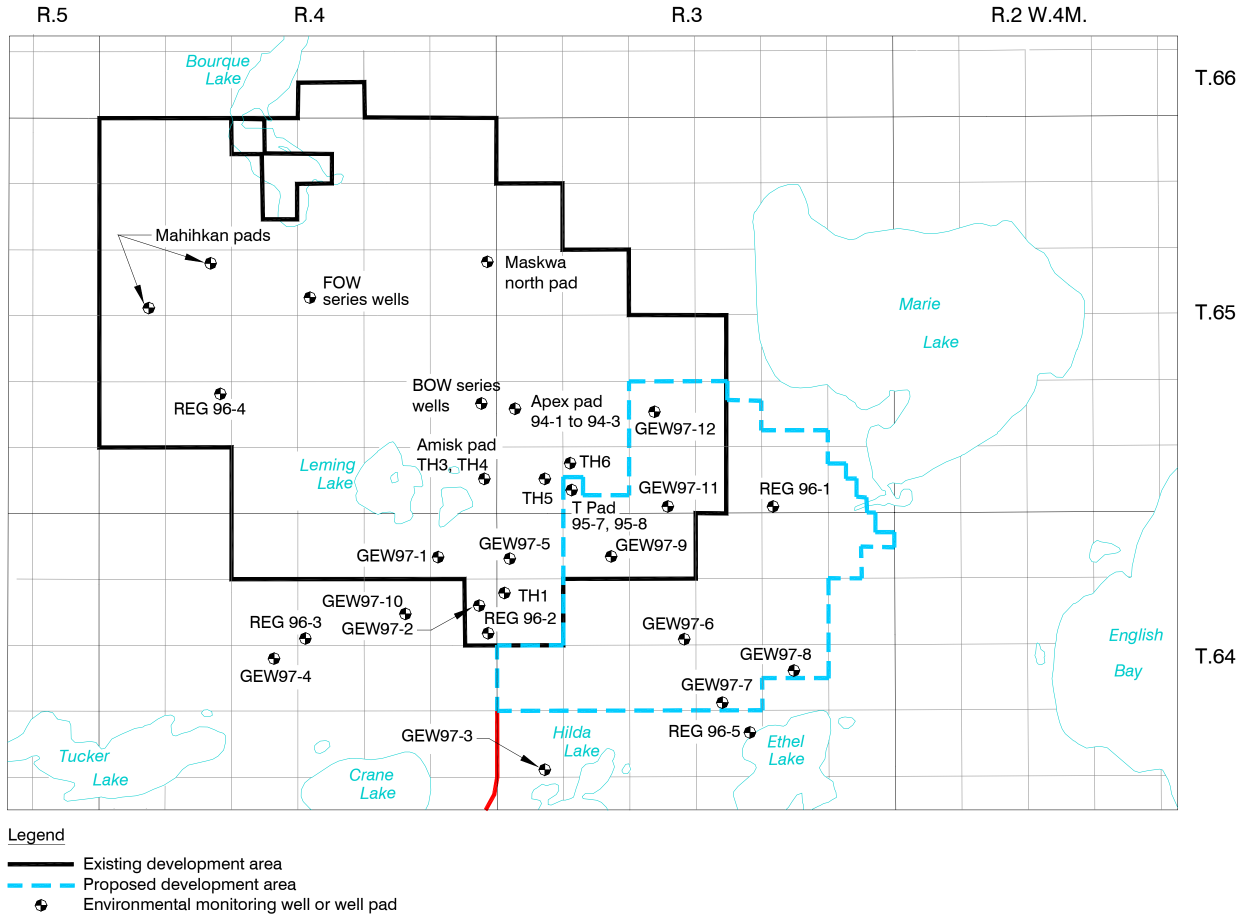

Figure 3. Cold Lake Expansion Project - Regional Monitoring Wells (Imperial Oil Resources Limited, Application No. 970163)