Using water wisely – water conservation and enhanced oil recovery in Alberta

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ABSTRACT
In Alberta water resources and oil production are fundamentally intertwined. Enhanced oil recovery methods use water to extend declining conventional production and to expand development of the oilsands. Water is needed for waterflood and tertiary recovery methods in oil pools, and for steam injection to produce bitumen from the deeper oilsands deposits that underlie much of northeast Alberta.

The government of Alberta has developed a water conservation policy to reduce the use of fresh water in enhanced oil recovery throughout the province. The effectiveness of the new policy will be measured in 2009 based on quantitative and qualitative measures of four essential outcomes established in the policy.

RÉSUMÉ
Dans Alberta des ressources en eau et la production de pétrole sont fondamentalement entrelacées. Les méthodes augmentées de rétablissement d'huile emploient l'eau pour prolonger la production conventionnelle en baisse et pour augmenter le développement des oilsands. L'eau est nécessaire pour le waterflood et les méthodes tertiaires de rétablissement dans des gisements de pétrole, et pour que l'injection de vapeur produise le bitume à partir des dépôts plus profonds d'oilsands qui sont à la base de beaucoup d'Alberta du nord-est.

Le gouvernement d'Alberta a développé une politique de conservation de l'eau pour réduire l'utilisation de l'eau doux dans le rétablissement augmenté d'huile dans toute la province. L'efficacité de la nouvelle politique sera mesurée dans 2009 basés sur des mesures quantitatives et qualitatives de quatre résultats essentiels établis dans la politique.

1. INTRODUCTION

Primary oil production from conventional oil pools requires small quantities of fresh water for drilling and fracture fluids to enhance the permeability of the reservoir. However the total water needs throughout the production lifetime of a conventional low-viscosity oil reservoir are much larger. Total water use varies from 0.5 to 5 times the volume of oil produced over the full production life of an oil reservoir. On average the water consumed approximates the volume of oil produced (1:1 voidage ratios).

The injection of steam into oilsands deposits to recover bitumen is another important and growing application of enhanced recovery “tertiary’ methods that decreases the viscosity of the bitumen to enable in-situ recovery (without open pit mining). Water volumes are large, with 3-5 m^3 of water injected for each cubic metre of bitumen recovered. Recycling of the injected steam reduces the water/oil ratio to less than 1:1 (with 90% recycling of the produced water). Steam injection water use was 27 million m^3 in 2007, more than the total used for recovery of conventional oil.

Schematic diagrams illustrating fundamental concepts of enhanced recovery are shown in figure 1 and figure 2.

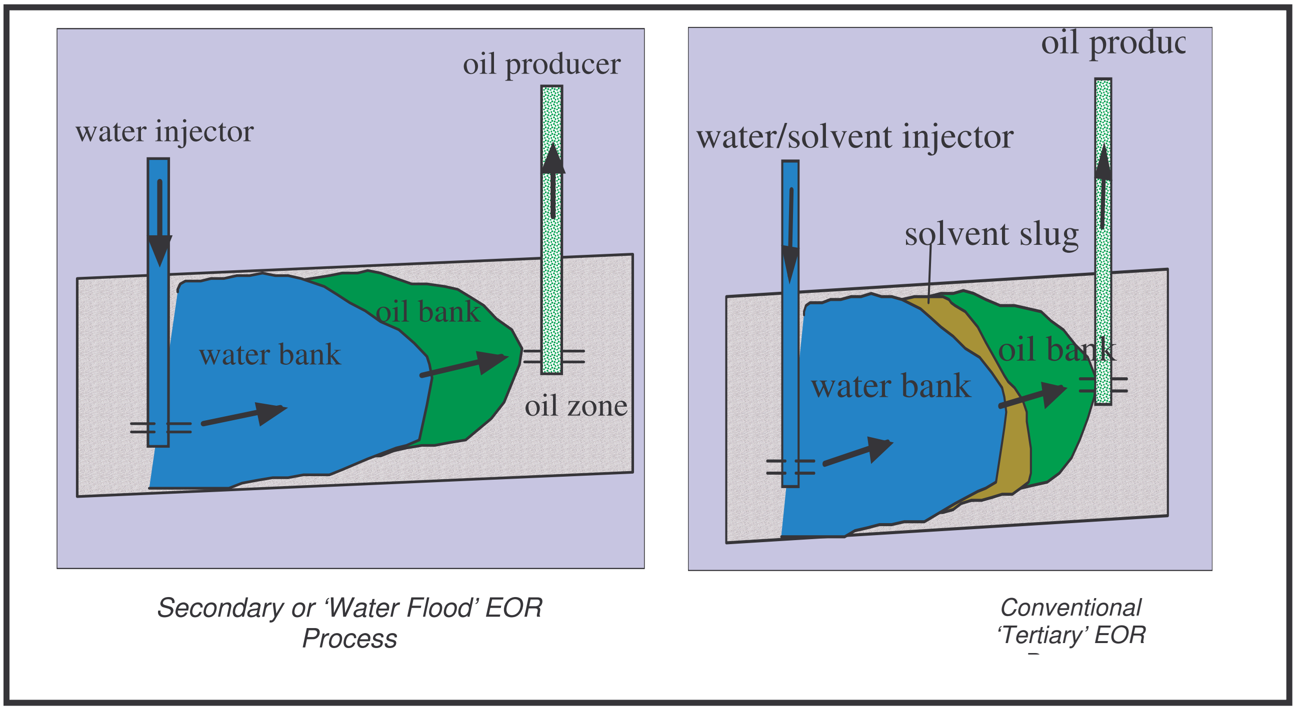

Figure 1. Enhanced Recovery Methods
(conventional) – Alberta Environment

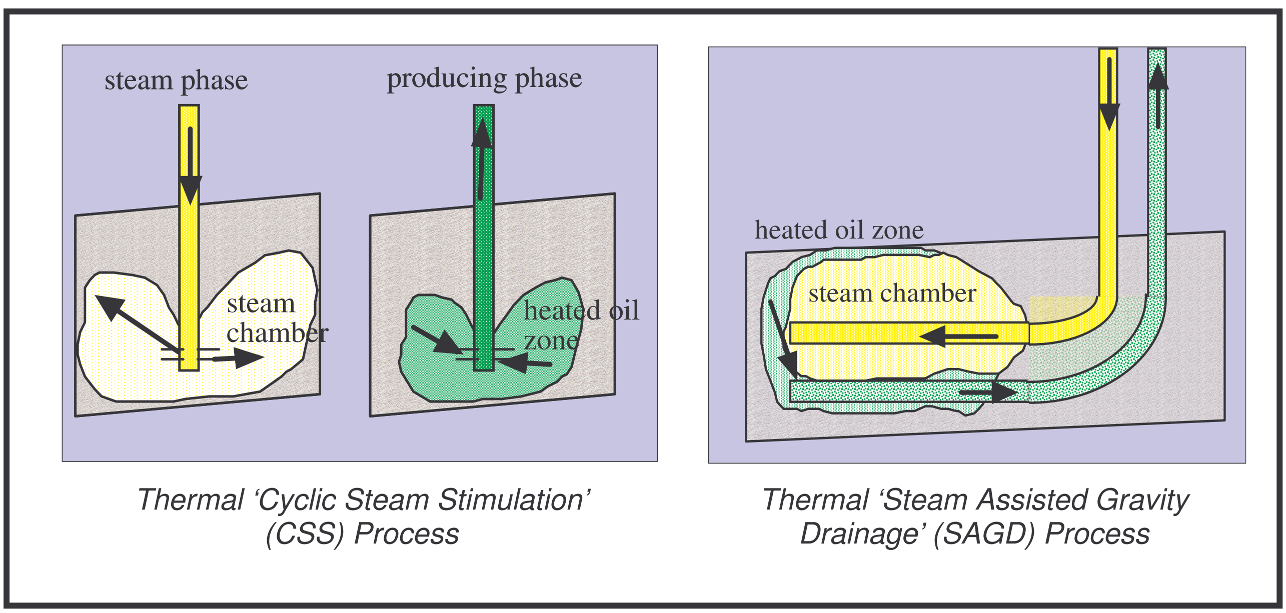

Figure 2. Enhanced Recovery Methods
(thermal) – Alberta Environment

A summary of the water used for enhanced oil recovery in Alberta is shown in figure 3. Over 54 million cubic metres of water was used in 2006 (thermal and conventional). The use of fresh water has been decreasing and the use of saline groundwater has been increasing in recent years.

Water use for Oilfield Injection				
cubic metres				
YEAR	**Total Water Use**	**NON-SALINE**	**SALINE**	**SURFACE**
2001	47,535,842.0	10,858,431.0	9,733,549.0	26,943,862.0
2002	48,043,878.0	11,735,221.0	9,588,078.0	26,720,579.0
2003	53,243,340.0	14,127,107.0	13,638,830.0	25,477,403.0
2004	54,959,680.0	13,965,979.0	18,266,726.0	22,726,975.0
2005	52,297,521.0	13,035,539.0	18,281,552.0	20,980,430.0
2006	54,630,552.0	13,181,055.0	20,722,090.0	20,727,407.0
Conventional use - water flood				
2001	37,288,605.0	5,744,385.0	9,585,653.0	21,958,567.0
2002	35,890,884.0	6,466,129.0	9,340,514.0	20,084,241.0
2003	35,365,405.0	7,503,490.0	8,201,632.0	19,660,283.0
2004	30,017,425.0	6,628,315.0	7,269,045.0	16,120,065.0
2005	27,449,669.0	5,009,912.0	7,256,899.0	15,182,858.0
2006	27,396,698.0	5,287,851.0	7,649,115.0	14,459,732.0
Thermal - in-situ				
2001	10,247,237.0	5,114,046.0	147,896.0	4,985,295.0
2002	12,152,994.0	5,269,092.0	247,564.0	6,636,338.0
2003	17,877,935.0	6,623,617.0	5,437,198.0	5,817,120.0
2004	24,942,255.0	7,337,664.0	10,997,681.0	6,606,910.0
2005	24,847,852.0	8,025,627.0	11,024,653.0	5,797,572.0
2006	27,233,854.0	7,893,204.0	13,072,975.0	6,267,675.0

Figure 3. Summary of water use for Enhanced Recovery (Alberta Environment)

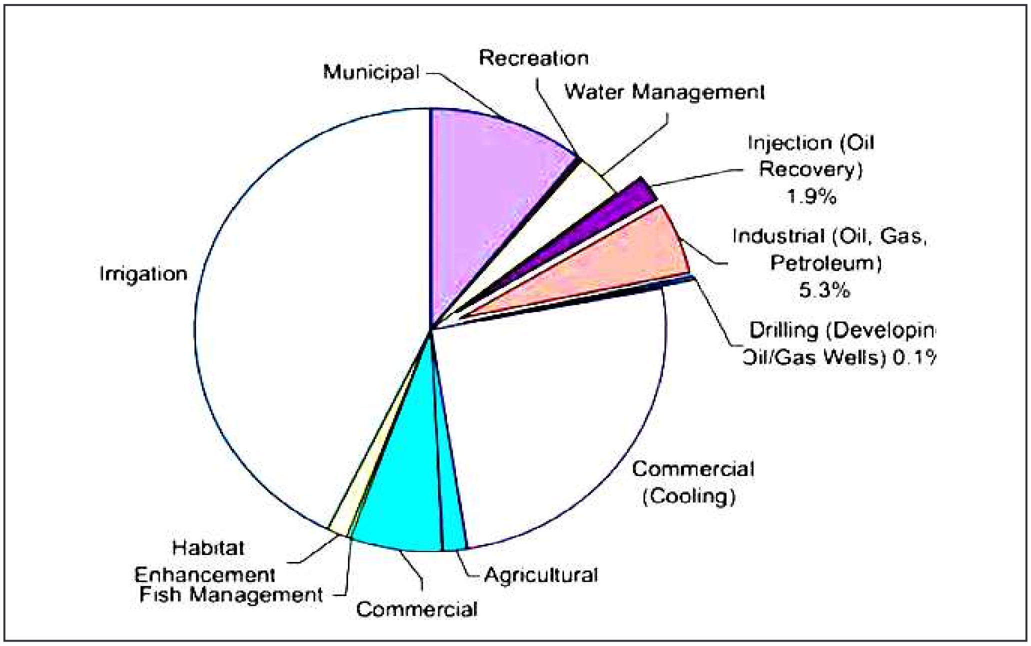

Figure 4. Water Allocation in Alberta 2004 (Alberta Environment)

Overall the use of fresh water for enhanced oil recovery is small compared to other uses such as municipal and domestic water supply and irrigation. Enhanced recovery accounted for approximately 1.9% of all fresh water allocated in the province under *Water Act* licences in 2004. However enhanced oil recovery accounted for more than 18% of all licensed groundwater allocation. The allocation of water in 2004 is illustrated in figure 4.

Less than 30% of the water allocated for enhanced oil recovery was actually used in 2007.

1.1 Conventional "Waterfloods" – Water Use Trends

Conventional oil production is declining in Alberta - production was 19.1 million m^3 in 2001 and less than 16 million m^3 in 2005 (Geowa 2006).

Water used for "waterflood" enhanced recovery has been decreasing since the 1970s. The larger oil pools discovered in earlier decades are mature, with large volumes of recycled produced water re-injected each year and decreasing volumes of oil recovered. Additional water needed to replace the volume of oil produced is now relatively small.

The trend in water use for conventional enhanced recovery across the province is shown in figure 5. From 2001 to 2005 water use for conventional recovery declined more than 25%, from 36.1 to 27.3 million m^3. (Geowa 2006).

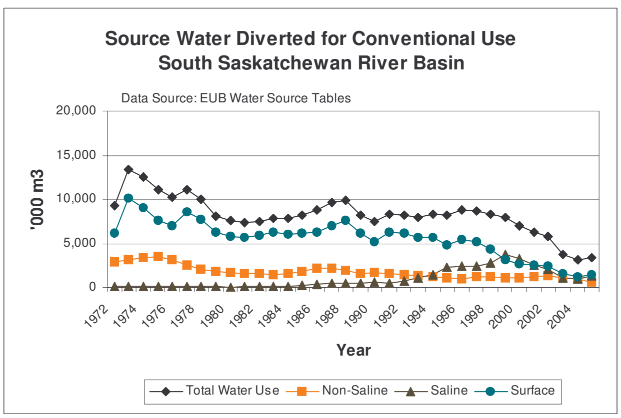

Figure 5. Water use For Conventional oil Enhanced Recovery (Geowa 2006)

The use of water for enhanced recovery in the South Saskatchewan River basin illustrates the decline in conventional water use in the mature oil pools of Southern Alberta (figure 6.). Total water use in the basin was 3,407,332 m^3 in 2005 and fresh water used totalled 2,048,992 m^3 (less than 3% of water use in the basin).

The South Saskatchewan River basin is now closed to new water allocations due to limitations on total water availability and growing pressures from population growth and industrial development. The use of fresh water from surface sources and aquifers for oilfield injection is controversial as the water never returns to the ecosystem. This concern is exacerbated by the growing limitation on water availability in southern Alberta.

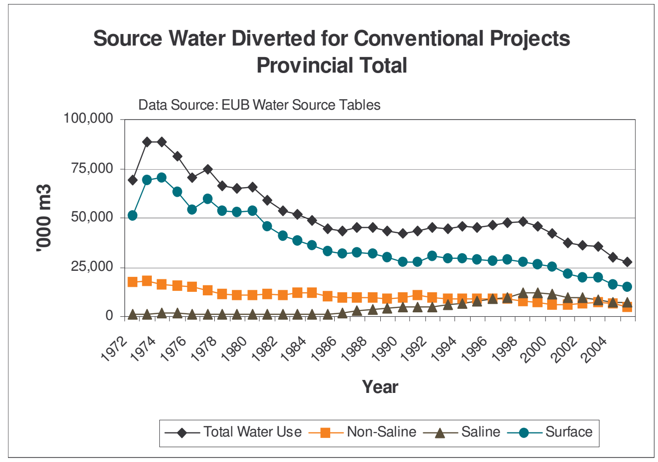

Figure 6. Water use For Conventional oil Enhanced Recovery – South Saskatchewan River Basin (Geowa 2006)

1.2 Thermal Steam Injection –Water Use Trends

Large oilsands deposits underlie much of Northeast Alberta in the Athabasca and Cold Lake deposits and also occur in Northwest Alberta (Peace River deposit). The viscous bitumen in the oilsands cannot be produced by conventional production methods.

Figure 7 illustrates the distribution of oilsands in Alberta. In the vicinity of Fort McMurray the bitumen is mined where overburden thicknesses are less than about 50 metres. In most of the oilsands steam injection is used to heat the bitumen in place to enable production. Cold (saline) water flooding has been used in recent years in the western margin of the Athabasca deposit where bitumen viscosities are lower and reservoir conditions support higher injection pressures.

Production of bitumen using thermal enhanced recovery has increased significantly since 1980 and is projected to continue an upward trend for the foreseeable future. Figure 8 illustrates the trend in water use since initial commercial production in the 1970s.

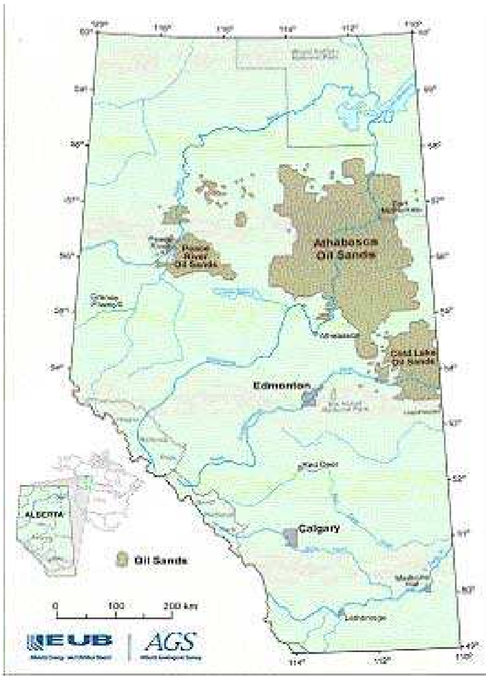

Figure 7. Oilsands Distribution (Alberta Geological Survey)

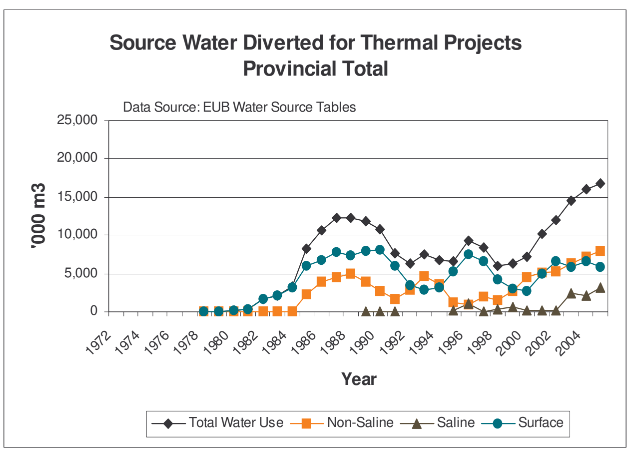

Figure 8. Water use for Thermal Enhanced Recovery of Bitumen (Geowa 2006)

Water use for thermal projects increased from 10.2 million m^3 in 2001 to 16.8 million m^3 in 2005, increasing more than 60%. The bitumen produced using steam in thermal projects also increased by the same rate from 10.7 to 16.6 million m^3 (Geowa 2006).

It is notable that volumes of water used are similar to the volumes of bitumen produced. The steam injection projects have constructed large-scale water treatment facilities that conserve both water and energy. The use of fresh water is greatly reduced by the produced water treatment and re-use – achieving recycling rates of more than 90%.

The use of saline groundwater (over 4,000 mg/L of Total Dissolved Solids) to generate steam is common and increasing as a water conservation measure. Water with salinity over 12,000 mg/L cannot be used to make steam, however high-yield saline aquifers with suitable water quality are common in Northeast Alberta. Their use significantly decreases demand for no-saline groundwater and surface water.

The use of saline ground water has increased from 9.7 to 18.3 million m^3 between 2001 and 2005, however approximately 8 million m^3 of the increase in saline use is attributed to the recent increase in non-thermal (waterflood) bitumen extraction.

The use of surface water for thermal injection has decreased between 2001 and 2005. In 2005 21 million m^3 of surface water were diverted for injection as compared to 28 million m^3 in 2001 (Geowa 2006).

Water use for steam injection is a significant proportion of total water use in the Beaver River Basin and the Athabasca River basin. Individual thermal injection projects produce bitumen from both the McMurray formation near Fort McMurray and the Clearwater Formation near Cold Lake (Beaver River basin). One commercial project is being developed within the Peace River drainage basin near the town of Peace River in western Alberta (Bluesky formation).

In 2005 a total of 57.7 million m^3 of water was injected as steam in all of the thermal enhanced recovery projects in the province, 2.1 million m^3 in the Peace River Deposit, 41.7 million m^3 in the Cold Lake deposit and 13.9 million m^3 in the Athabasca deposit.

Most of the water injected was recycled produced water (40.8 million m^3). Non-saline groundwater injection has increased from 5.1 million m^3 in 2001 to 7.9 million m^3 in 2005. Fresh surface water use has increased from 4.9 million m^3 in 2001 to 5.8 million m^3 in 2005 (Geowa 2006).

Thermal injection projects will increase significantly in future, with several projects undergoing construction or expansion. Several new projects are in planning or design stages. We expect that many more projects will be constructed over the coming decades.

2. WATER CONSERVATION POLICY

Alberta's *Water Act* mandates "*The conservation and management of water, including the wise allocation and use of water* ". However water conservation measures are not a direct regulatory requirement for water use in the province.

Water is allocated by Alberta Environment based on need and application (for large agricultural, industrial, municipal, commercial and oil and gas operations) with a priority for water use issued based on the date of application. Conservation is a discretionary consideration in issuance of water licences and is important in areas where water availability limits have been reached.

Water Management Planning on a basin and watershed scale is being implemented to address potential water shortages in the drier parts of southern Alberta where most of the population growth and economic development is occurring. Water conservation objectives can be established for individual watersheds, river reaches or entire basins in a Water Management Plan.

Water conservation initiatives are being broadly supported by Alberta Environment and other government and non-government agencies through the development of regulatory policy and guidelines, and through education, stewardship and research initiatives to identify water conservation options and opportunities.

2.1 *Water For Life, Alberta's Strategy For Sustainability*

Alberta initiated a broad public consultation regarding water issues and potential water shortages in 2001. The Water For Life Strategy was developed in 2003 as a long-term plan to address the growing water issues in the province.

The Strategy provides three key outcomes and three key directions (changes) that must occur to achieve those outcomes:

Outcomes

- **Safe, secure drinking water supply**
- **Healthy aquatic ecosystems**
- **Reliable, quality water supplies for a sustainable economy**

Key Directions

- **Knowledge and Research**
- **Partnerships**
  Alberta Water Council
  Watershed Planning & Advisory Councils
  Watershed Stewardship Groups
- **Water Conservation**

Water For Life recommended that an overall increase in water use efficiency and productivity of 30% is needed in Alberta by the year 2015. This objective requires efforts from all Albertans and all industries to enable continued economic growth and population growth.

Water conservation is essential in the dry southern part of the province if severe shortages are to be avoided. Water conservation is essential to the future success of Alberta in all economic sectors and in all areas of the province, although actual water shortages will occur earliest in the Southern part of the province.

Enhanced oil recovery is far from the largest water use in the province, but many enhanced recovery operations can potentially use lower quality water, such as saline groundwater and water produced together with oil, instead of fresh water. Replacing the use of high quality "fresh" water with lower quality water is a fundamental water conservation objective for enhanced recovery operations.

2.1.1 The Alberta Water Council – Sectoral Water Conservation Plans

The Alberta Water Council is a stakeholder partnership with representatives from 25 government, industry, and environment advocacy groups in Alberta that provides broadly based leadership to achieve the outcomes of the *Water For Life Strategy.*

The council oversees development of government and non-government initiatives under the Water For Life Strategy and reports to the Minister of Environment on progress and issues related to the strategy.

The development of sectoral water conservation plans within the scope of water management planning is one of the ongoing projects of the Alberta Water Council. It is the objective of this process to reach broad consensus within each water use sector, and between sectors, regarding feasible actions to increase water efficiency and productivity across the province.

A water conservation sectoral plan for the oil and gas industry will address all water uses for drilling, oilsands mining, enhanced recovery and refining or upgrading of petroleum products.

2.2 The Water Conservation And Allocation Policy For Oilfield Injection

In 2006 Alberta Environment completed a new policy to guide water conservation improvements in enhanced oil recovery operations as a component of *Water For Life* conservation initiatives.

The policy incorporates aspects of a previous policy to reduce the use of non-saline groundwater in developed areas of the province (1991), and water conservation and recycling measures that have been required on a site-by-site basis by Alberta Environment and the Energy Resources Conservation Board (thermal enhanced recovery).

The policy was developed through a collaborative stakeholder consultation process with representatives from industry, government agencies and other water users in the province. The recommendations of this *Advisory Committee On Water Use Practice and Policy* were the fundamental basis for policy development (ACCWUPP 2004).

This policy does not set overall enhanced recovery targets for water conservation. The policy objective is to "enhance *the conservation and protection of Alberta's water; and to reduce or eliminate, on a case-by-case basis, the use of non-saline water resources for oilfield injection purposes*."

The policy directs a risk-based evaluation of all enhanced recovery operations that use non-saline water, on a site-by-site basis. A regulatory guideline, the *Water Conservation and Allocation guideline for Oilfield Injection* provides direction regarding the complex technical, economic and environmental review required for each project.

Projects are evaluated by industry and Alberta Environment during regulatory reviews for water licence renewal or application for a new water licence. Small-scale water use in areas of low development and abundant water supplies may use fresh water if preferable options such as saline groundwater and produced water are not available.

In water-short areas of the province enhanced recovery operations must maximize efforts to replace non-saline water use. Non saline water use will be reduced wherever feasible options are identified, with the intent to ultimately eliminate all non-saline water use in these areas of the province. The water-short areas of the province are shown in figure 9.

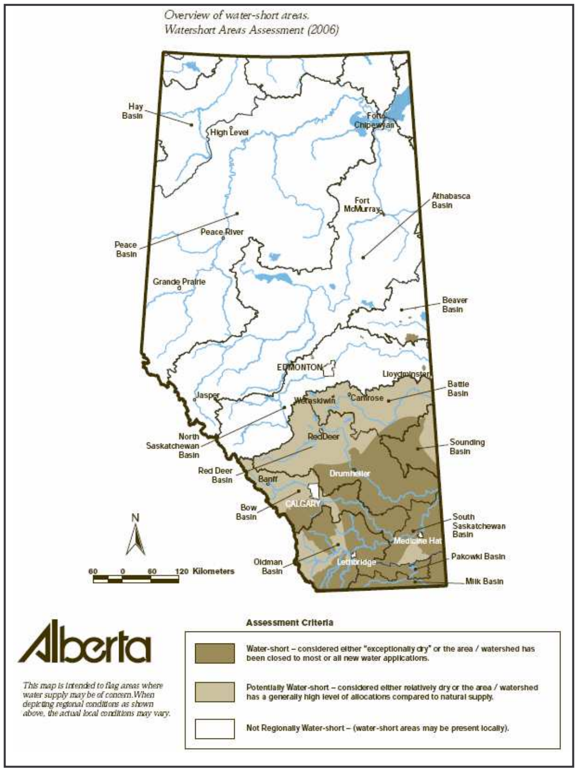

Figure 9. Water-short areas of Alberta (Alberta Environment 2006)

The policy guideline sets out a risk-based evaluation based on *Water For Life* Outcomes, with three "tiers" of projects. Increasing efforts to conserve water are required from low risk "tier 1" projects to the highest risk projects in water-short areas, as shown in figure 10.

3 WATER CONSERVATION OUTCOMES AND PERFORMANCE MEASURES

Significant water conservation improvements will need long-term effort and a focus on the goals to be attained. The *Water Conservation and Allocation Guideline for Oilfield Injection (2006)* sets four outcomes to support the broad *Water For Life* outcome - **Reliable quality water supplies for a sustainable economy.**

1. Reduction or elimination (on a case-by-case basis) of non-saline water use.
2. Improved productivity and efficiency of water use.
3. Conservation and protection of non-saline aquifers and aquatic ecosystems.
4. Improved partnership and research initiatives.

Quantitative and qualitative "performance measures" have been established to measure the attainment of the water conservation goals established in the policy. The policy objectives and the degree to which they have been attained will be measured to improve the policy and inform future policy revisions.

The performance measures are summarized in figure 11. Information will be gathered in 2008 and evaluation of the *water Conservation and Allocation Policy For oilfield Injection* will begin in 2009, based on the performance measures listed in the table.

Water for Life Goals:

	Safe, Secure Drinking Water Supply	Healthy Aquatic Ecosystems	Reliable Quality Water Supplies for a Sustainable Economy
3 Major Impact	• Measurable supply effects up to 10 km • Community-level supply constraints	• Multiple cumulative effects • Measurable permanent effect • Instream flow needs not met	• Extensive development pressure • Many competitors for supply
2 Moderate Impact	• Measurable supply effects up to 1 km • Localized supply constraints (with provision for alternate supplies)	• Few cumulative effects • Measurable reversible effect • Instream flow needs not met at certain (non-critical) times of the year • Aquatic ecosystem remains healthy and productive	• Moderate development pressure • Few competitors for supply
1 Minor Impact	• Measurable supply effects up to 0.5 km • Negligible supply constraints	• Minor cumulative effect • Minor measurable effect • Instream flow needs always met	• Minimal development pressure • Little competition for supply

Figure 10. Risk-based criteria (Alberta Environment 2006)

SREM[25] Outcome	Performance Measure
Reduction/elimination of non-saline water use.	Thermal and conventional ER separately, by basin 1. Per cent allocation reduction between 2005 and 2007. 2. Per cent non-saline water use reduction (surface water, groundwater) between 2005 and 2007. 3. Per cent increase in use of saline groundwater between 2005 and 2007. 4. Per cent increase in use of alternate (non-water) ER methods (per cent increase in ER oil production using alternate methods).
Improved productivity and efficiency of water use.	Thermal and conventional ER separately 1. Resource productivity (ER cubic metres of oil/bitumen per cubic metre of non saline water). A trend line is desirable.
Conservation and protection of non-saline aquifers and aquatic ecosystems.	1. Reduction in water use in water-short and potentially water-short areas (oilfield injection, other consumptive uses). 2. Stakeholder Assessment Process. 3. Qualitative assessment of progress in stewardship, data, knowledge management, overall results. 4. Reductions in allocation and water use for permanent licences.
Improved Partnership and Research initiatives.	1. Qualitative documentation (and evaluation) of partnership and research initiatives. 2. Stakeholder assessment process. 3. Qualitative evaluation by WPACs and AWC.

Figure 11. Performance measures for enhanced recovery (Alberta Environment 2006)

3.1 Water Conservation Progress To Date

Regulatory review of enhanced recovery projects has been ongoing since mid-2006. The review of most projects using non-saline groundwater will be completed by the end of 2008. Further reviews will occur as term licences for groundwater and surface water reach renewal deadlines.

Research to improve water conservation technology is a long-term process, with some pilot projects, such as “toe to heel air injection”, CO_2 injection, and “Vapex” undergoing evaluation by industry. The industry-government supported Petroleum Technology Alliance of Canada promotes water conservation research and supports development of collaborative research projects. Other government and industry agencies are also involved in water conservation research.

The Canadian Association of Petroleum Producers has been proactive in supporting improved water conservation in the oil and gas industry. The annual “stewardship report” of the association highlights increases in water use efficiency as one of the criteria for measurement of water conservation. The “Benchmarking Summary” in the 2007 report indicates water use efficiency of 0.72 m^3 water / m^3 of oil in 2004 and 0.60 m^3 water / m^3 of oil in 2007, a 12% improvement (CAPP 2007).

Alberta Environment evaluates water use for enhanced recovery as an environmental pressure “State of the Environment Indicator” each year. The trends of water use are shown in figure 12.

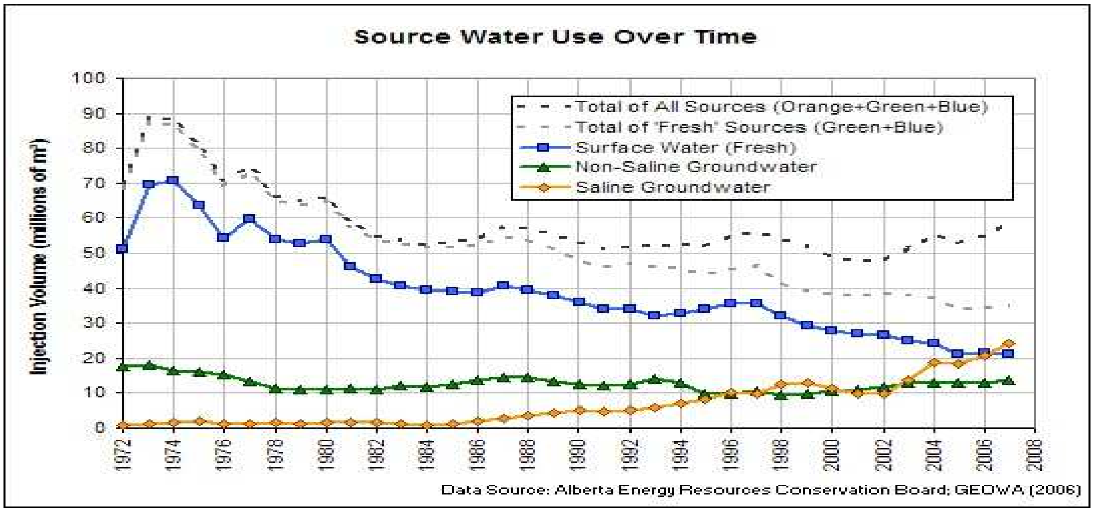

Figure 12. Enhanced Recovery Water Use Trend (Alberta Environment)

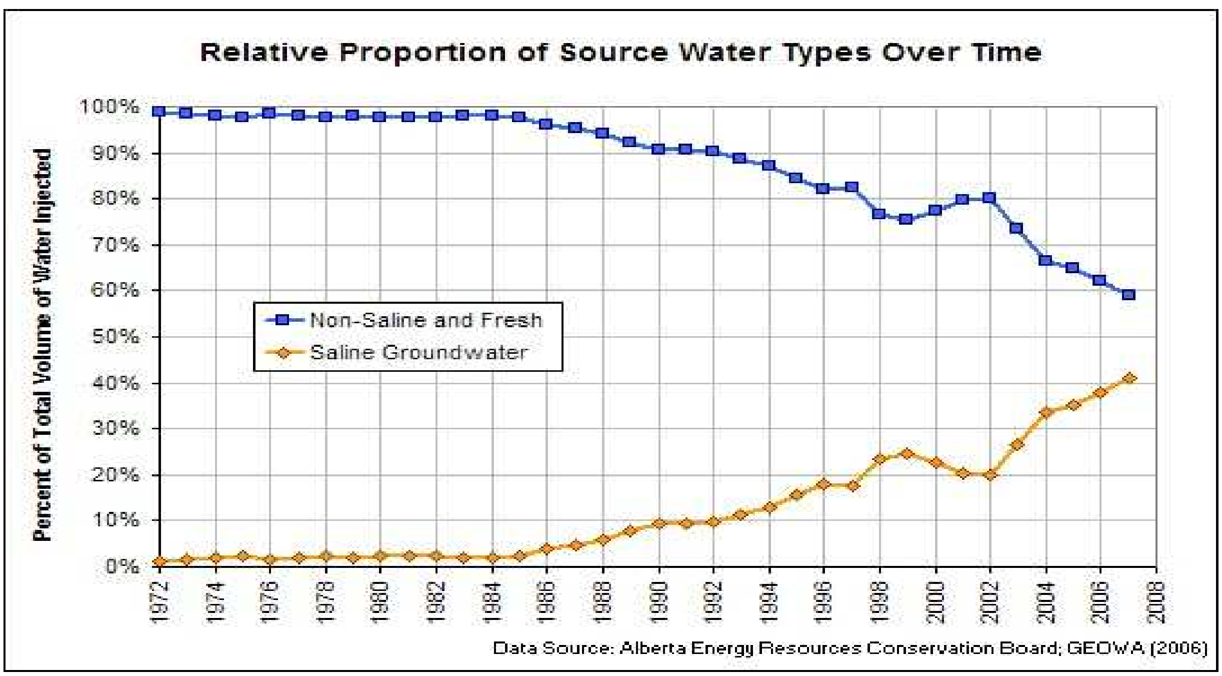

Figure 13. Proportions of saline and fresh water use (Alberta Environment)

The reduction in surface water use and the increasing use of saline groundwater show significant water conservation improvements over time.

The ratio of fresh water (surface plus non-saline groundwater) to the saline groundwater is one important measure of improvements in water conservation for enhanced recovery operations. In 2007, saline groundwater became the largest single source type of water used for oil recovery – 40% – up from only 10% just 15 years ago. The proportion of saline groundwater use over time is shown on figure 13.

4.CONCLUSIONS

Water conservation is increasing as a water management tool in Alberta as development pressures grow and water shortages are becoming apparent. The use of fresh water for enhanced recovery of oil is being replaced with saline groundwater and new technology is being developed to replace water with other fluids and methods that produce oil more efficiently.

Enhanced recovery of conventional light oil is declining as the available reserves decrease, and water use is decreasing. Thermal steam injection to develop bitumen reserves from the oilsands areas in increasing rapidly and overall water use is also increasing, with a growing emphasis on the use of saline groundwater and recycling technology to improve water use efficiency.

The current *Water Conservation and Allocation Policy for Oilfield Injection* was implemented in 2006 and will be reviewed in 2009, based on evaluation of specific performance measures established in the policy.

The development of water conservation policy and other regulatory and non-regulatory initiatives to expand water conservation is an essential aspect of *Water For Life, Alberta's Strategy for sustainability.* The success of water conservation measures in the oil and gas industry, and other water use sectors, will help to assure the long-term availability of water for future generations of Albertans.

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