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why not

# Strategic Needs for Energy Related Water Use Technologies

# Water and the EnergyINet

*"EnergyINet's Water Management Innovation Program is built on the understanding that Canadians' quality of life depends on a healthy and sustainable water supply for our aquatic ecosystems, our communities, and our economic activity. Recognizing the dependence of the energy industry on water, we have launched this initiative to:*

- *Develop technology to reduce use of fresh water by the energy industry*
- *Implement cost-effective water re-use and recycle systems."*

**February, 2005**

**Bruce Peachey, P.Eng.**

**New Paradigm Engineering Ltd**

# Acknowledgements and Disclaimer

## About the Energy Innovation Network (EnergyINet)

"Energy is critical to Canadians. It drives our economy, it contributes directly to our quality of life, and it brings in external revenues that we rely on to support essential social services. We take it for granted - but we shouldn't. It's now clear that without some significant technological breakthroughs, we will soon find we no longer have sufficient energy to meet all our needs.

Recognizing the urgency of this situation, the Alberta Energy Research Institute (AERI) has brought together interested public and private sector partners from across Canada to collaborate in creating and implementing energy innovation programs.

The vehicle that is emerging to drive this collaborative effort is called the Energy Innovation Network (EnergyINet)."

For more information on the EnergyINet or on how to get involved, please contact ***Alice Hedges*** at (403) 297-8650 or alice.hedges@gov.ab.ca.; http://www.aeri.ab.ca/sec/EIN/index.cfm


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## Disclaimers

This document is **intended as an initial assessment** of technology needs and potential needs assessment processes to address a wide range of water uses and impacts for the Energy Sectors in the Western Canada Sedimentary Basin. It is intended, by the EnergyINet, that this information be used as a starting point for on-going discussions between the EnergyINet and water resources stakeholders, with the ultimate goal of sustainable utilization of water resources by the energy industry.

Any technologies discussed or referred to are intended as examples of potential solutions or solution areas and have not been assessed in detail or endorsed as to their technical or economic viability.

**Note on Use of Volumetric Units and Terminology**

The volumetric units for water and other fluids or gases in this report are given in units of cubic meters ($m^3$) as those are commonly used units for the energy industry in Canada, which is the main target for EnergyINet activities. As water may be used to displace oil or gas, it is useful to compare volumes in similar units. Other industries and hydrogeologists often use other units. Below is a brief conversion to other commonly used units.

1,000 $m^3$ = 1 $dam^3$ = 0.81 acre-feet

1 $m^3$ = 1,000 litres = 35.31 $ft^3$ = 220 Imperial Gallons = 264 U.S. gallons = 6.29 bbls

1 $m^3$ of water = 1 tonne

Terminology used in this report is also that commonly used in the energy industry. Some terms will be defined in footnotes.

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# Strategic Needs for Energy Related Water Use Technologies

**Final Report – February, 2005**

## 1. Executive Summary

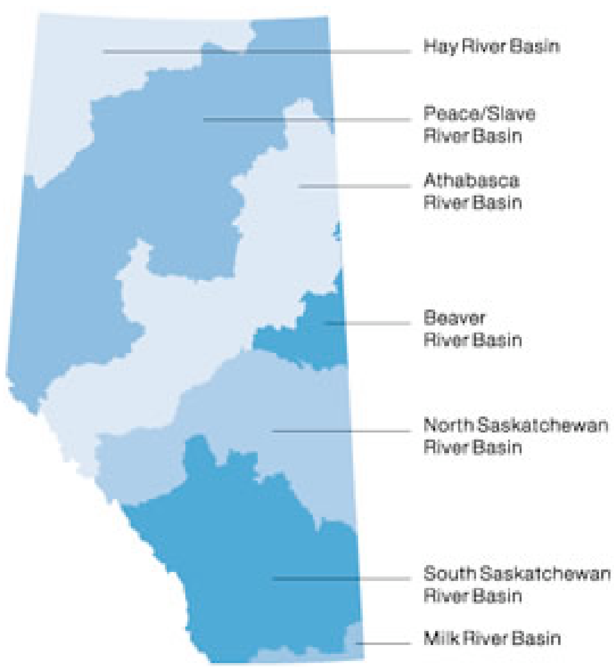
Water issues related to the primary energy industries can have significant impacts on the future development of those industries in the Western Canadian Sedimentary Basin (WCSB) and around the world. This initial assessment of water technology needs, for key energy sectors in the WCSB, concludes that:

- A first step to effectively managing water needs, is to ensure that all users of water resources, both surface and ground water sources, quantify, report on, track, estimate, and analyze their withdrawals, voidage replacement needs and consumption to allow for improved forecasting of water technology needs and priorities.
- Both governments and industry need to develop new water related indicators to monitor the effects of water use to allow for improved water use decisions.
- Water is an enabler of energy development and that energy developments must closely review water resources, both locally and regionally by basin, to obtain a realistic assessment of potential water-related development risks.
- Water and energy strategies and tactics must to be adapted to meet the unique characteristics and needs of each river basin in a region.
- Water impacts almost every other human activity in some way, so it cannot be addressed as a stand-alone issue for the energy industries. Needs assessments and impacts must be assessed by multi-stakeholder groups in each river basin after ensuring that such groups have access to the appropriate and necessary information on water impacts related to economic, environment and security/societal issues.
- A balanced approach is required to address major concerns in Environmental, Economic and Security aspects of water use. A focus on only one area will likely lead to sub-optimal solutions.
- Communication, collaboration and coordination between the broadest possible range of stakeholders is required, to ensure that all aspects of water use are considered in the process of gathering relevant information, and in providing efficient direction and resources to meet future water technology needs.

## 2. Introduction – Water as an Enabler and Cost of Energy Production

Water and energy are closely linked. The most obvious example is direct production of hydroelectricity from water. But water is also used for enhanced oil recovery in conventional oilfields, in the production of bitumen from the oil sands, and it is used as a coolant in refineries, petrochemical plants and coal fired steam power generation. Current methods of shallow conventional gas and coal bed methane production, and to a lesser extent deep gas production, may have the potential to impact surface or ground water flows if they are connected to mobile groundwater sources. And finally, any plans to increase the amount of bio-energy produced from renewable agricultural products, forests or peat resources, except those already available as waste products, would have to take into account the water required for irrigation or changes to water flows due to changes in the land use.

Canada has an abundance of fresh water, 80% of it flows to the Arctic Ocean and is not accessible to the majority of Canadians or Canadian industry. It also has the largest supply of hydrocarbons in Canada (and one of the largest in the world) in the Western Canadian Sedimentary Basin (WCSB), which includes southern prairie regions that are prone to drought and under increasing strain due to a boom in urban and rural population growth[1]. Understandably, communities, businesses, and individuals in the WCSB are concerned about the amount of water used in energy production, and the impact of the energy industries on the quality of their drinking water, as well as the availability of water for irrigation.




3,630 million $m^3$/yr

68,200 million $m^3$/yr

20,860 million $m^3$/yr
(At Ft. McMurray)

653 million $m^3$/yr

7,000 million $m^3$/yr
(Battle 296 Million $m^3$.yr)

9,280 million $m^3$/yr
(Incl. Red Deer, Bow, Oldman)

167 million $m^3$/yr

**Figure 2.1 – Average Annual Basin Discharge Volumes[2] from Alberta – Annual Water Withdrawals for the Prairies Region Estimated to be 6,500 million $m^3$/yr[3]**

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[1] "Pass the Whiskey, Hold the Water – Making the case for water conservation" Canada West Foundation www.cwf.ca. "Balancing Act – Water Conservation and Economic Growth" January 2005 CWF K. Wilke.

[2] Map and average flows out of the province are from Alberta Environment Website and River Basin Summary Information provided on the Website. www3.gov.ab.ca/env/water/basins/BasinForm.cfm

The energy industry has a relatively small proportion of the total fresh water withdrawals allocated in western Canada. Under Alberta's system of water management, the agriculture industry has the largest allocation of surface water, at 44.8%, used primarily in dry summer months for irrigation, out of a total allocated water volume of 9.4 billion $m^3$ of water allocated in 2001[4]. Oil sands mining, by contrast, accounts for 2.6% of allocations, with an additional 1.9% allocated to conventional oil and gas production and in-situ bitumen extraction, which tend to be used at predictable rates throughout the year.

It's less clear what the actual water consumption demands of the various users amounts to. In the oil and gas sector, where actual surface flows are tracked and reported, we know that less than half of the current allocation to this sector is used. However, these measured withdrawals and allocations, do not account for all the water impacts of the energy industry, as many of the impacts occur underground, or are not easily measurable, and can only be assessed through detailed hydrological studies, which have not yet been undertaken on a regional basis. Actual consumption is also not well tracked in the agricultural sector, although Alberta Environment estimates that the irrigation industry actually accounts for about 71% of surface water consumption. Another 12-14%, is estimated to be consumed by commercial cooling, to dump waste energy from power generation, petrochemical, pulp and paper, and other energy-intensive operations. Other impacts are less obvious and result from increased water evaporation from hydroelectric and irrigation reservoirs, rivers and lakes heated by cooling water discharges, or changes in subsurface flows due to production or injection of fluids or gases. Table 2-1 shows some rough estimates of the total water demand for the energy sector with assumed water intensities discussed in later sections of this report.

**Table 2-1: Estimated Annual Water Demand for the WCSB Energy Industry[5]**

| Primary Energy Source | WCSB Production | Water Intensity Indicator | Water Demand $10^6$ $m^3$/yr | River Basins |
|---|---|---|---|---|
| Gas Production ($10^6$ $m^3$) | 197,000 | 10 $m^3$/1000 $m^3$ | 1970 | S. Sask, N.Sask, Athabasca, Beaver |
| Coal Power Generation (MW cap.) | 10,000 | 15000$m^3$/MwCap | 150 | N. Sask, S. Sask, Souris |
| Oilsands Mining ($10^6$ $m^3$) | 25 | 3 $m^3$/$m^3$ | 75 | Athabasca |
| Conventional Oil ($10^6$ $m^3$) | 67 | 1 $m^3$/$m^3$ | 67 | N. Sask, S. Sask, Peace, Souris |
| Thermal Heavy Oil/Oilsands ($10^6$ $m^3$) | 20 | 1 $m^3$/$m^3$ | 20 | Athabasca, Beaver, Peace |
| Hydropower | | ???? | | N. Sask, S. Sask, Peace |
| Biofuels | | ???? | | ???? |
| **Total Annual Water Estimate** | | | 2282 | Approximately 2% of Total River Flow |

[3] Environment Canada Website www.ec.gc.ca/water/en/manage/use/e_wuse.htm download March 2004. Value is for 1996 with most of the water taken from the South Saskatchewan River Basin. Reservoir losses not included.
[4] "Advisory Committee on Water Use Practice and Policy" report
[5] Oil and Gas Production Volumes are from CAPP. Coal Power Generation Production Estimate for Alta and Sask is estimated. Indicators are discussed in more detail in later sections and include measured/allocated withdrawals, assumed voidage make-up volumes. Coal Power water consumption is assumed to be similar to the Genesee Power Plant. Gas and Oil voidage demands may not be met in the year they were created as it may take decades or centuries for water to fill voids and water may come from fresh groundwater, or deep brine sources. Oilsands tailings volumes may also change over long periods of time. **All Water Intensity Indicators should be considered directionally correct but require much more effort to establish more scientifically supported values**.

While the energy industry may, or may not, be the biggest user of water in Alberta, it is a very widespread and visible user to communities who fear for the security and safety of their local water supply, and may not see direct benefits accruing to them from industry water use. Environmental, agricultural, and municipal interest groups have grown in numbers and strength as episodes of drought and water quality problems in Walkerton and North Battleford have intensified public concern – even though those incidents were not linked in any way to energy production. From a Canada-wide perspective, the energy sector is a major user of water, as nationally thermal power (nuclear, coal and gas) generation accounts for 64%[6] of water withdrawals, excluding evaporative losses from hydroelectric reservoirs.

Because water management is an issue that cuts across so many types of energy production, EnergyINet includes a dedicated Water Management Innovation Program, which requires stakeholder input to further define the needs. In the early stages of development, it has been suggested that the program should focus on:

- Getting connected into existing water-related initiatives; determining how to add value and fill in gaps related to water/energy elements.
- Filling the knowledge gap – getting the right players together to ensure that critical data on energy water use and impacts is being collected, analyzed, and communicated in a way that is useful to policy- and decision-makers, as well as the general public.
- Articulating and promoting the business case for reducing fresh water use and discharges of contaminants to the aquatic environment for energy industry operations
- Engaging with energy industry users to determine priority areas for innovation, and supporting research, development and demonstration to fill these critical technology gaps.

[6] Water Uses in Canada – Environment Canada website. Uncertain what water consumption would be as power generation facilities can use a wide range of cooling methods. See report section 8.

# 3. Report Purpose and Development Strategy

## 3.1. Purpose

To support the EnergyINet Initiative though preparation of a water technology needs assessment for energy sectors at both the strategic and tactical levels.

## 3.2. Deliverables

The report will be completed in two levels of assessment.

- **Strategic Level Assessment** will be combined with similar assessments for the other EnergyINet Strategic Areas and developed with the assistance of a communications contractor.
- **The Tactical Level Assessment** is intended to be in more detail with input from experts from various energy sectors, and will document needs, potential opportunities and key constraints for water management and utilization in each sector.

The intent is that these two documents would form a basis for a more in-depth, collaborative analysis, to be launched through PTAC and/or other organizations, and involving key stakeholder representatives, such as the Pembina Institute for Sustainable Development, the Institute for Sustainable Energy, Environment and Economy (ISEEE), technology research providers, energy producers, service and supply companies, water users from the energy industry and departments at all levels of government. The overall end product would be a consensus-based, EnergyINet Water Technology Action Plan, with technology areas focused on specific water uses and analysis of potential impacts on water resources.

## 3.3. Development Strategy

**3.3.1. Assessment of Sectors to be Covered –** The primary sectors of focus are those with the largest impact on the Western Canada Sedimentary Basin where AERI can take a leading role in support of the EnergyINet. Secondary sectors, for this study, are those that might play a greater future role in the WCSB, and which generate unique water technology issues. Excluded from consideration are energy sources, such as large hydroelectric and nuclear power, which can be better addressed by other organizations, governments or groups who may join the EnergyINet at a later date. Generally most of the focus on technology needs is related to water supply and demand issues, as water quality does not appear to be as large an issue in the highly regulated energy industry.

**Primary Sectors:**

- **Oil and Gas Industry** – While this is perceived as a relatively small water demand (based on allocations and measured consumption) it is of large public concern to other water users, and is a key factor in economic productivity and growth for Alberta and other producing provinces. The needs development strategy should cover areas such as fresh water use and ground water volume impacts from enhanced oil recovery (thermal or conventional), gas production (coal bed methane or conventional) and impacts of water recycle streams. Many of these impacts are currently undefined and unassessed.

- **Industrial (Petroleum, Petrochemicals, Oilsands and Coal Mining)** – Focus on water impacts of mining operations, tailings from oil sands and coal extraction or conditioning, water discharges to the environment (intentional or accidental), and deep well disposal issues.
- **Commercial (Cooling)** – Covers water used specifically to dump waste energy from power generation, petrochemical, pulp and paper and other energy intensive operations. By definition this use does not generate revenue directly so should be a key target for application of technologies to recover more of this energy for useful purposes and to conserve water. If waste energy recovery is not feasible the focus could be on developing lower cost cooling methods, which avoid or reduce water use and consumption. Water quality (temperature, contaminants, oxygen content, etc.) can also be an issue where cooling water streams are returned to the source.

**Secondary Sectors:**

- **Irrigation** – The analysis of this sector is needed to strategically assess the potential impacts of moving to biomass energy production in Western Canada. Increasing biomass production will likely require more irrigation, so the irrigation water needs are a key factor for this potential energy source. Also, as this sector has the largest allocation and consumption of water in the WCSB, even small improvements in water use may free up water for other users.
- **Small Scale, Distributed Hydro Power Systems –** Since deregulation dams built for irrigation are increasingly being converted to also provide power generation for local uses. Similarly unique opportunities for small-scale hydroelectric power may be found in some oil and gas operations.

**Excluded Sectors:**

- **Conventional Hydroelectric Generation –** This source represents 60% of Canada's power generation but only 5% about of the WCSB's. Other provinces (Quebec, Ontario, British Columbia and Manitoba) have greater capacity to assess technologies to reduce water consumption (reservoir evaporation), in this industry sector.
- **Nuclear Power** - Even though uranium mines in Saskatchewan are a major component of the international nuclear industry, knowledge centers for the nuclear industry are found in Atomic Energy Canada and nuclear power producers in other provinces.

**3.3.2. Literature Search –** Obtained and briefly reviewed a wide range of materials representative of previous work done for various sectors to assess the water needs, key issues and potential responses already addressed by others. From this a listing of energy related water issues was developed and is provided in Appendix A along with feedback on those issues. An initial annotated list of references sampled is provided in Appendix D. There are likely other useful sources, such as industry reports or studies prepared for applications which did not ultimately proceed that would be useful if they can be found.

**3.3.3. Identify Key Industry Water Specialists** – A few key contacts were established in each industry sector, and with representatives of major user groups, for water issues. Interviews were limited in scope, and were mainly conducted by phone or e-mail communications. The EnergyINet's intent is to hold wider and broader consultations, so Section 12 provides a discussion on key water connections. A partial listing of contacts who may be interested in contributing to further work on water issues and synergies, is provided in Appendix B.

**3.3.4. Preparation of a Strategic Water Technology Needs Document** – A 5-page strategic overview document was prepared early on in the project as input into a combined EnergyINet strategy.

**3.3.5. Investigation of Key Needs and Potential Solutions Areas** – Technology needs and opportunities will vary by geographic location and river basin, so sources of information on basin specific issues were investigated and assessed by energy sector. The investigation also attempted to qualitatively estimate potential impacts of sector water use by assessing historical water use, trends and issues and projecting this use into the future. Key issues and impacts were separated into Economic, Environmental and Security categories to ensure that a full range of sustainable research needs would be addressed. These assessments are reported on in Sections 5 to 11 and a summary table is provided in Appendix C. The three drivers are defined as:

**3.3.5.1. Economic Driver** – What are the main economic factors that would drive energy producers to adopt a new technology or support research to develop a solution in a given area. What is the economic benefit that the local communities, provinces and Canada realize from producing an energy commodity.

**3.3.5.2. Environmental Driver** – What environmental benefits or impacts are energizing the need for a change in a particular energy water use area. These drivers may be related to water supply, GHG emissions, water contamination or other ecological, air, land or water issues of concern to the public and particularly local residents.

**3.3.5.3. Security Driver** – Are longer-term societal factors related to the security and well-being of local economies, society and individuals over many years. These may be related to revenue and cost factors for governments, risk factors for industry, or health, welfare and job-security issues for individuals and their families.

**3.3.6. Tactical Water Needs Report** – A "Draft for Discussion" report of results of investigation and generation of concepts for tactical water needs by **sector and geographic area** was prepared indicating potential technology needs or information areas showing the most need and potential for improvement. After distribution of the Draft for Discussion to selected stakeholder contacts, the report has been finalized and will be issued through the EnergyINet. The final report will include presentation materials summarizing the key issues and needs.

## 4. Motivators for Change in Water Use Practices

While a more detailed analysis of driving forces for specific water technology issues will be provided in later sections, it is useful to highlight the motivators for change at a higher level to avoid repetition of these points in each energy sector discussion.

### 4.1. Adverse Environmental Impacts of Over Consumption or Contamination

The primary driver from an environmental point of view is to ensure that natural ecosystems in any watershed are not jeopardized by water use, contamination or increased flow variability from changes in land use (e.g. forestry and urbanization affecting timing, volumes and quality of surface run-off.). While annual and seasonal water flows in most river systems are highly variable, each part of every river system will have unique minimum flow limits, to avoid damage to riparian and aquatic ecosystems. Thermal or chemical contamination of water streams can have significant impacts on ecosystems that are very difficult to anticipate in advance of the contamination. As the ecological sciences cannot predict impacts with certainty, it is necessary to ensure that impacts are minimized as much as possible, and firm limits set. Such limits must leave considerable room for natural variation, potential impacts of climate change, and minimize potential exposure to unexpected ecological consequences.

### 4.2. Increased Risk for Approvals or Operations Due to Water Unknowns

For the energy industries the largest economic concern, and prime motivator for improved understanding of water issues, is the increased risk associated with their planned or existing operations. As water is a key factor in most energy processes and regulatory licenses or approvals, water unknowns can potentially result in major economic losses if all potential outcomes or issues are not adequately assessed. No corporation wants to risk shareholder investments being compromised by the sudden discovery of a water supply limitation, or have operations shutdown or fined due to unanticipated releases of contaminants that impair downstream water quality.

### 4.3. Loss of Future Energy Recovery Opportunities

From a security of energy supply point of view, the major concern for governments, and people whose future well-being and employment is dependent on the energy sector, is to ensure that energy resources are not wasted or lost to future generations. Water can enable increased recovery of resources by appropriately and effectively managing water production and use, during active operations. However, natural water movement and/or shifts in the availability of water can potentially form a barrier to future energy resource production if those factors are not properly understood or impacts appreciated in advance.

### 4.4. High Cost of Energy for Moving Water

For all major energy users and producers a considerable amount of energy, usually in the form of electrical power, is used to transfer, recycle or dispose of water. On a per unit of energy delivered basis, electrical energy is the most expensive energy source ($20/GJ plus generation and transmission energy losses) and also, generates increased water use and GHG emissions at the power source (normally coal or gas fired generation). While most water is available to all users at no direct cost[7], the cost of pumping and transporting

[7] An exception is where water is sold to the Industry by municipalities or irrigation districts.

large volumes of water provides an economic incentive to reduce water use in most energy operations where power is purchased.

### 4.5. Risks to Operating Facilities

Produced or wastewater from energy industries, or other industrial operations, can also greatly add to costs through it's impact on facility operations and maintenance. Water can produce ideal environments for biological, chemical or mechanical agents to cause facility failures caused by corrosion, plugging, freezing, cavitation or erosion. These failures in turn generate environmental releases of contaminants which must be cleaned-up or mitigated, shutdowns for repairs which result in lost revenues, and potential to cause harm to third parties, resulting in the risk of litigation.

### 4.6. Energy Conservation Opportunities

In many cases water use is an indicator of energy losses, as in the case of industrial cooling which is a major consumer of fresh water. As energy prices increase, the potential to make use of low quality waste heat for power generation, district heating for urban developments or through adoption of less energy intensive processes, becomes much more economic and will result in less water required for heat dissipation. Reusing waste heat also generates benefits by reducing GHG emissions and reducing the consumption of premium quality energy inputs, such as electrical power or natural gas.

### 4.7. Public Concerns about Potable Water Contamination

Concerns about potable water for public use have always been a major driver of water policy and regulation. Recent major events in Walkerton and North Battleford, which were municipal water treatment problems, have further heightened water quality concerns. Even with rigourous regulation and monitoring, water quality assurances by government agencies are no longer always believed, leading to a new imperative to provide the public with a much more in-depth knowledge of water supply systems, and to meet a demand for water choices that are within the control of concerned individuals.

### 4.8. Increased Water Availability and Quality for Future Opportunities

Finally, there is the security issue of ensuring there is water available to take advantage of future opportunities for growth, development or utilization of renewable energy sources. Hydrogen from water has been proposed as a potential method of storing off-peak renewable energy production and as a transportation fuel. Other alternatives would require use of biomass, which requires water for production and impacts natural water processes in biomass producing regions. At the same time use of biomass, from existing waste sources such as intensive livestock operations, has the potential to improve water quality while providing a renewable source of energy. Overall, while renewable energy may mitigate concerns related to GHG emissions, they may increase concerns with water use and availability in already arid regions.

## 5. Conventional Oil Production

**Geographic Distribution** - Conventional oil production occurs throughout most of the Western Canadian Sedimentary Basin (WCSB), which stretches from the Arctic Ocean in the north, down the foothills in the west, the U.S. border to the south and to the edges of the Canadian Shield in the east. Some conventional oil production occurs in every river basin in Alberta and Saskatchewan, except for the Beaver/Churchill system, which arises in east central Alberta before flowing into the Canadian Shield in northern Saskatchewan.

### 5.1. Water for Enhanced Oil Recovery

The main focus in the use of water for Enhanced Oil Recovery (EOR) is related to the benefits of water EOR, water availability and **type of make-up water** used for EOR.

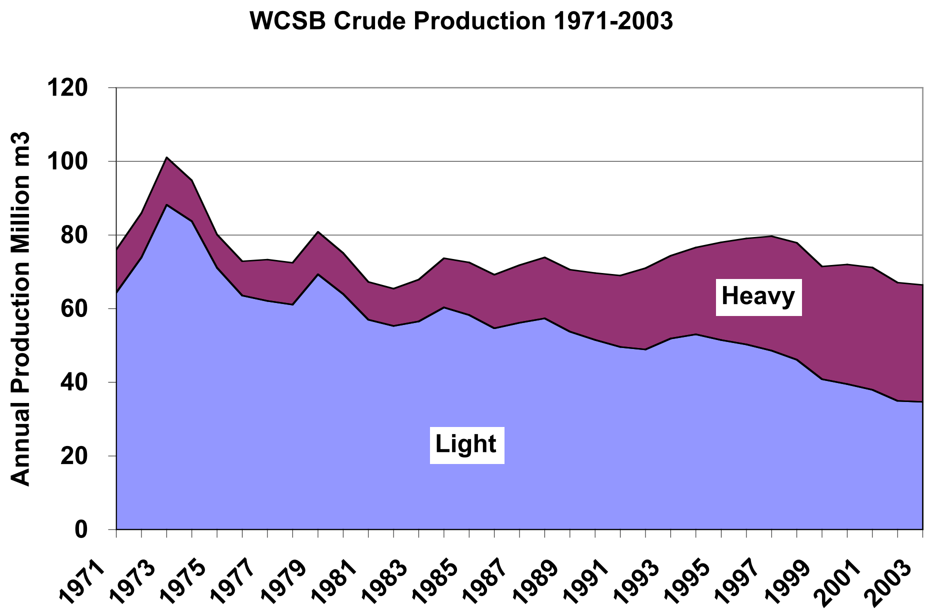


**Figure 5.1 – WCSB Annual Conventional Crude Production[8] - Current assumption is that 1 m3 of make-up water will be required per m3 of oil produced.**

#### 5.1.1. Economic Driver – Oil Production

**Historical Perspective** - Historically water EOR has had a large impact on incremental recovery of oil resources.

- Alberta: Incremental Oil Recovery = 18% of total reserves = 443 million $m^3$ = C$53 billion @ C$20/bbl;
- Saskatchewan: Incremental Oil Recovery = 35% of total reserves = 246 million $m^3$ = C$30 billion @ C$20/bbl.

Note that while it appears that Saskatchewan has made greater use of waterflooding, another major difference between the percentages is likely the impact of the large Devonian Pools like Leduc, Redwater, Bonnie Glen and others

[8] CAPP Statistical Handbook 2004 – Table 3-16A converted daily production to annual production. Eastern Canadian Production subtracted from Total Canadian Light.

in Alberta that did not require water injection because of their location on the prolific Cooking Lake Aquifer. I.e. those reservoirs got the benefit of waterflooding without adding water proactively from the surface.

In Alberta, surface injection waterfloods have only been used in 4-5% of oil reservoirs containing about 35% of the original oil in place. On average waterfloods increase recovery by 5-20%.

**Future Vision** - Higher oil prices should drive more waterfloods to achieve increased recoveries of 5-20% in medium sized pools. To estimate the potential prize a possible result might be an additional 10% increase in total reserves = 250 million $m^3$ = $30 billion @ $20/bbl. Investments will be needed for accessing a water supply, increased water pumping capacity and improved water management systems. From a technology point of view there will be greater need for understanding the impacts of water sources on production rates and ultimate recovery. Key factors will be: a) Impacts of water temperature. b) Impacts of water chemistry or contaminants, reservoir souring. c) Alternate methods for transfer of water between underground zones. d) Capacity of underground zones to deliver water by understanding how the source aquifers are replenished. e) Assessing potential long-term impacts.

### 5.1.2. Environmental Driver – Water Source

**Historical Perspective** - Saskatchewan has historically only used underground water sources, brackish or saline, except for steam projects, while Alberta has mainly used fresh water which tends to be relatively easier to physically access in the province. Saskatchewan's use is highly determined by the fact that most waterfloods are in the arid southern part of the province (Weyburn/Estevan Area), and the limited availability of smaller river sub-basins that are available. Alberta oil pools are mainly located in central and northern parts of the province and are generally close to surface water sources or prolific fresh groundwater aquifers. However, even in Alberta producers are under increasing pressure to reduce use of fresh water for this purpose especially in arid regions, where alternate water sources we already often used. Generally water use for Enhanced Oil Recovery has been in the range of 1 m3 of water per m3 of oil production.[9]

**Future Vision** - Currently many producers are reviewing their water needs and will have to reassess the relative costs of fresh and other sources, even in cases where they have approval for fresh water use. Considerations will be: a) Costs of wells and pumps for brackish groundwater vs. intake stations; b) Alta Env. approvals and allocations; c) Costs for pumps and longer pipelines for fresh or alternate water sources; d) Risk management through hearings etc.

It should also be recognized that, unlike allocations for agriculture and some other uses, water allocations for oil recovery have a limited life as injection stops when the maximum volume of oil has been recovered and the operations are abandoned.

[9] "Water Use for Injection Purposes in Alberta" March, 2003 by Geowa rationalizes water use and sources by type of production, by water basin and between White and Green Zones of Alberta.

### 5.1.3. Security Driver – Oil Left Behind

**Historical Perspective** – Many wells and pools have already been abandoned without being water-flooded or having any other method of EOR applied to them. Early abandonment before the maximum amount of oil has been recovered, results in increased future costs to come back and redrill and redevelop a field to allow recovery of a smaller volume of more expensive to produce oil. It is unknown what volume of original oil in place might already have been lost, however, this should be possible to assess from AEUB and other regulator records.

**Future Vision** - Resource sterilization by other development or potential risk of lost containment of remaining oil over long periods of time (loss of resource) should be a concern. Energy conservation assessments should include conserving the energy resources left behind by early abandonment. Without some type of enhanced oil recovery more than 7 billion $m^3$ of high-value, light to medium oil will be left behind and potentially unavailable to future generations.

**5.1.4. Technology needs** – Actions would focus on assessing access to and understanding of low cost, local and non-potable water sources that can be used without causing public concerns about water supply/quality or producer concerns about recovery. Potential tactics

**5.1.4.1. Hydrogeology** - Geological assessment of brackish water zones especially those deeper than 400-500m, water quantities and qualities, source aquifer refill impacts.

Status – The Alberta Geological Survey and similar Provincial and Federal Surveys have done some work on water resources on the past. However, few activities have focused on the deliverability and total water volumes that might be available from such sources.

**5.1.4.2. EOR Study** - Reservoir comparison of recoveries between Saskatchewan and Alberta reservoirs to quantify water quality impacts.

Status – The EnergyINet is currently funding an EOR Study, however, that work is focused on Alberta and is not looking at the type of water used as a primary focus. A joint project might be developed, with participation by the Alberta and Saskatchewan governments, to assess water quality impacts on production.

**5.1.4.3. Water Sources** - Study of options for using saline water aquifers at low cost (e.g. water dumping from lower zones at higher pressure).

Status – ARC (Ashok Singhal) proposed a study in 2002 to look into the potential for "dump flooding" of oil reservoirs to allow transfers from lower water zones without requiring the water to be lifted to surface first. Currently this work remains unfunded.

**5.1.4.4. Water Sources** - Feasibility of using other lower quality water sources from municipalities, industrial or power plant discharges.

Status – The AEUB has suggested using treated sewage, or industrial waste-water streams to supply water for oilfield injection. The main hurdles identified that require study, are impacts of these streams on reservoirs, pipeline transportation issues and assessment of other impacts of removing these streams. Water discharges from power generation or industrial cooling could also be considered as they are higher quality than sewage or industrial wastes and also may contribute to production by being warm.

**5.1.4.5. EOR Study** – Definition of potential prize for water and other types of EOR.

Status – This work is underway through the EnergyINet study by EPIC Consulting and other collaborators. There are timing issues and trade-offs between use of water for water-floods vs. use of more expensive injectants such as carbon dioxide, nitrogen or other materials.

## 5.2. Produced Water Recycle

The second key strategic area, which affects ultimate conventional oil recovery, is the **average water recycle rate or water to oil ratio (WOR).**

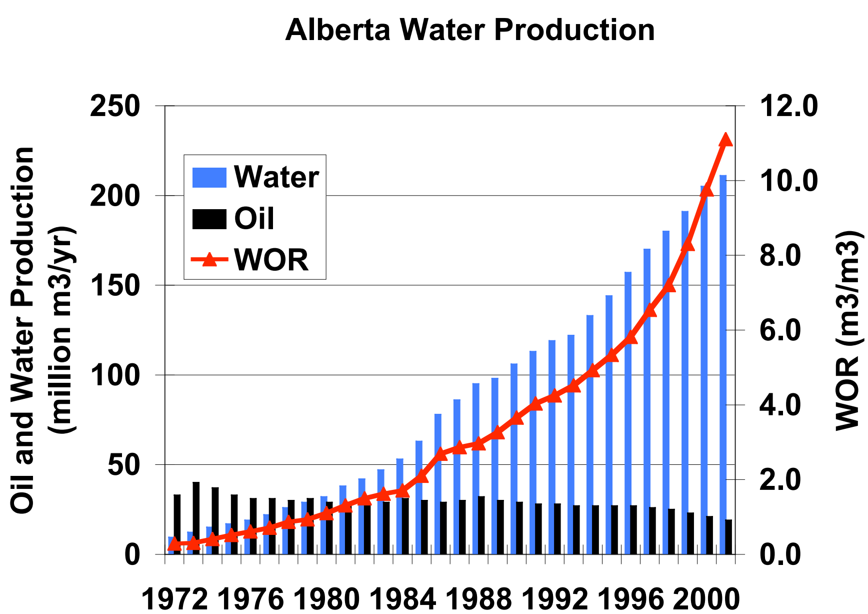


**Figure 5.2 – Increasing Impact of Water Recycle on Conventional Oil Production**

### 5.2.1. Economic Driver - Energy to move and treat water

**Historical Perspective** - In Alberta the average WOR in conventional oil pools has risen from less than 1 $m^3/m^3$ in the early 1970's to over 10 $m^3/m^3$ in 2000[10]. An industry rule of thumb for the cost of handling produced water is US$3/$m^3$ [11], so handling over 210 million $m^3$/yr of produced water might cost the Alberta oil

[10] Water Use for Injection Purposes

[11] Various estimates from various sources with little detail. Recent article "Just the cost of doing business?" by Curtice and Dalrymple, World Oil October 2004, indicates a range of US$0.03/bbl to US$6.50/bbl (US$0.18 to 40/m3). Conservative Average between US$0.10/bbl and US$0.50/bbl (US$0.60 to 3.00/m3) gives a water handling cost of between US$5-$25 billion in the U.S.

industry almost C$1 billion per year, mainly for electrical power for pumping and fuel use in heated oil treaters. Given the changes in power costs in recent years the rule of thumb also likely needs more detailed evaluation, documentation and likely a revision upwards.

**Future Vision** - Low cost water recycle leads to higher oil recovery from a given well. In fields able to produce economically to high WOR's many wells level off and produce oil for many years, however, high water costs mean many wells never reach this stage of production. Redwater field is economic with a WOR of 100-300 $m^3/m^3$ and has reached an oil recovery of 66% of original oil in place just by circulating water. The average recovery of all reservoirs similar to Redwater is only 44% of original oil in place[12] with higher water handling costs. If all similar pools could match Redwater performance an incremental 750 million $m^3$ of light oil could be produced. A more realistic potential might be an increase of 150 million $m^3$ worth C$18 billion @ $20/bbl.

### 5.2.2. Environmental Driver – Corrosion and spills

**Historical Perspective** - High water cut fluids increase corrosion costs and risk of incidents due to leaks caused by corrosion. Corrosion inhibition for pipelines and facilities adds significantly to operating costs and varies greatly with the type of produced water and how well air is excluded from the water system. Large water volumes on surface can spread a spill and increase clean-up costs per incident. Main regulatory concern is to prevent a salt-water leak into potable water sources, surface water bodies or soils.

**Future Vision** – Preferred processes would avoid water production to surface and minimize flow by potable water aquifers, through techniques such as water shut-off or downhole separation to reduce the potential and frequency of leaks to the environment.

### 5.2.3. Security Driver – Water Handling Cost Variability

**Historical Perspective** – The main cost of water handling is capital investment for pumping equipment (producers and injection systems), separators, pipelines, disposal wells, corrosion and treatment chemicals and outside energy costs (gas and power) to run the water management process. The source of the rule of thumb water costs estimate of US$3/$m^3$ of water is unknown and varies by operating area. Despite the fact that conventional oil operations have a low energy and GHG intensity, they are high cost because of the normal practice of using premium electrical energy for fluid pumping. Electrical power costs, including variable fees based on demand, may be anywhere from $20 to $40/GJ vs. <$3-$8/GJ if the input pumping energy was provided using on-site produced gas or cogeneration.

**Future Vision** - Use of purchased power for water pumping creates greater variability and uncertainty about water handling costs. Natural gas and chemicals for treatment are also highly variable, depending on the properties of the produced fluids. Therefore, previously static $/$m^3$ water rules-of-thumb can change rapidly.

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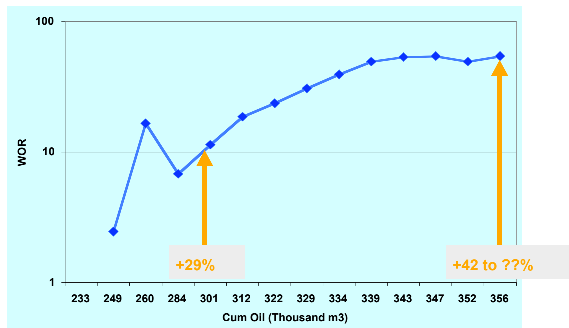
[12] Average recovery includes that for Redwater so the remaining pools tend to be more in the 30-35% range. Recoveries from AEUB data analysis by New Paradigm Engineering Ltd using 1996 data.

This results in the producers losing their ability to forecast operating costs and reserves recovery due to variable costs for handling and reinjecting produced water. Proactive tracking of water handling costs could support implementation of technologies, such as Combined Heat and Power (CHP) systems to power pumping systems and provide heat for treating systems.

### 5.2.4. Technology Needs:

**5.2.4.1. EOR Study** - How many wells level out at a given WOR? Is this predictable? Assess through evaluation of existing high WOR[13] fields like Redwater.




WOR vs. Cumulative Oil Plot for a Redwater Well showing incremental oil recovery as WOR increases above 1m$^3$/m$^3$

**Figure 5.3 – Benefits of Low Cost Water Handling**

Status[14] – Data on well production in AEUB and SIR databases can be used to locate and analyze wells with high WOR's. Unknown if anyone has attempted this type of study.

**5.2.4.2. Water Costs** - Investigate costs for water handling across the industry for pumping, disposal wells, corrosion inhibition, treating, etc. and develop a process for tracking water cost per m$^3$ of oil for individual reservoirs.

Status – A range of estimates for water costs have been developed but no detailed analysis has been found. Ziff Energy has done studies on benchmarking production costs, so may have information for the use of contributors to their benchmarking studies. New Paradigm has recommended using area operating costs divided by total area fluid production as an indicator as most accounting system do not provide enough detail for exact calculation of water costs.

**5.2.4.3. Water Costs** - Lower costs by converting oil production to self-generated power to reduce lifting costs in a deregulated power regime.

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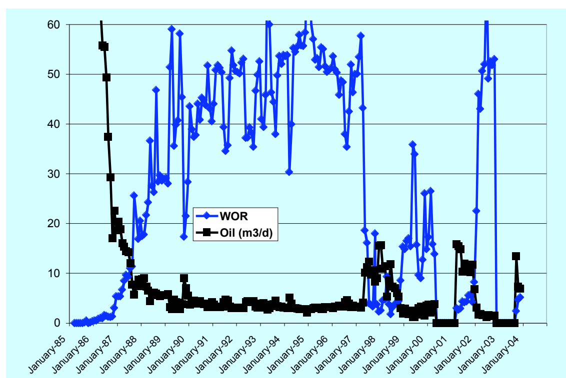
[13] WOR is the volume of water produced per volume of oil so applies to produced water not fresh water.
[14] Data in graph is from the AEUB Database for a Redwater well.

Status – Some efforts have been made to generate power using flare gas, however, it is uncertain how much of this power has been used to displace purchased power for water management. It is likely that the amount is still very low, on the order of only 15 MW, as there are still significant policy, regulatory and standards barriers making distributed generation less attractive[15]. Conventional oil production has the lowest energy and GHG intensity per $m^3$ of oil produced, yet has a high cost per $m^3$ because of the premium paid for purchased electrical energy for pumping.

**5.2.4.4. Reduce Water** - Lower costs for front-end water reduction through water shut-off techniques or with downhole oil/water separation (DOWS with gravity based separation or DHOWS with a hydrocyclone for separation) technologies.




Example of DHOWS potential in a high WOR well in Alberta – Well production 1985-2003; DHOWS installed in 1998. Downtime due to analysis between runs.

**Figure 5.4 – Reducing Water to Surface while Increasing Oil Production**

Status – ARC and others are working on various blocking agents to limit water production, however, most field trials have not been extensive enough to optimize treatments. C-FER Technologies and New Paradigm Engineering Ltd developed the DHOWS concept and believe it is proven and low risk in carbonate formations. However, the technology needs to move into more widespread use to achieve lower costs of manufacturing and reduce replacement times.

**5.2.4.5. Water Costs** - Lower costs for disposal with horizontal or multi-bore disposal wells.

Status – ARC, Nexen in Yemen and some other operators have considered using horizontal water injection wells to lower the energy required for water injection and to improve performance of water-flooding.

[15] Personal communication from Mr. Bert Dreyer, P.Eng.

**5.2.4.6. EOR Study** - Assessment of the ability of abandoned watered out pools to be successfully re-entered to further increase recovery by other means.

Status – AEUB and SIR records could be searched for instances where producers re-entered previously abandoned formations. Unaware of any studies on returning to abandoned pools to increase recovery beyond what was achieved with water-flood alone.

## 6. Thermal Heavy Oil Production

**Geographic Distribution** – In-situ bitumen operations are found in the Beaver/Churchill, Athabasca and Wabasca/Peace River Basins in northeastern Alberta. Until 1986, production was limited to a few pilot operations, however, since that time growth of commercial operations has been rapid and is forecast to accelerate in the next 10-20 years putting increased pressure on water resources in these basins.

### 6.1. Mega-scale Water Needs

The rapid growth in thermal in-situ bitumen operations offers little time to **anticipate and prepare for potential impacts** of increased surface or groundwater water use, increased use of recycled water for steam generation, or to develop and prove the capacity of alternative water sources or disposal horizons.

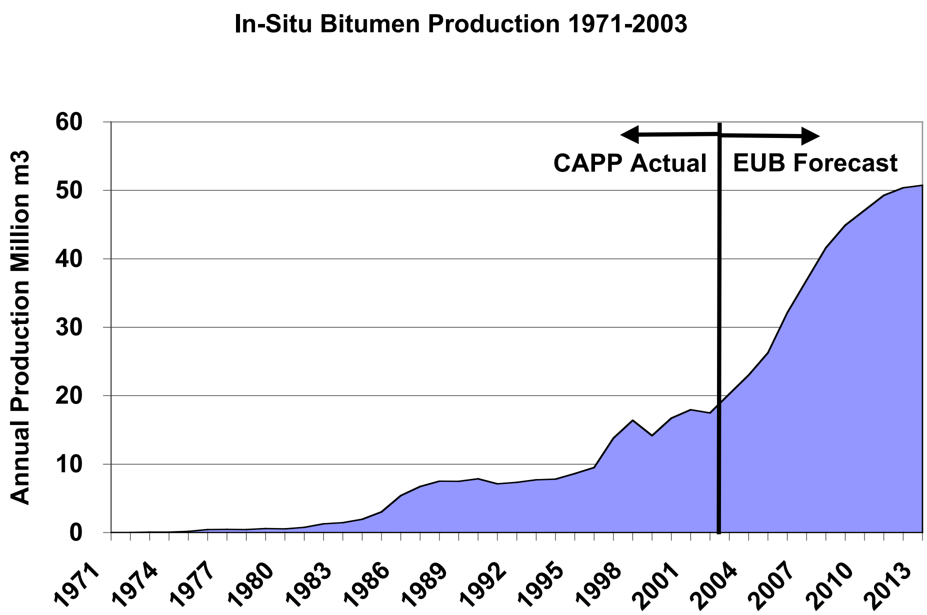



**Figure 6.1 – Actual Production of In-Situ Bitumen[16] and Forecast[17] - Current assumption is that 1 m3 of water will be required per m3 of bitumen produced.**

#### 6.1.1. Economic Driver – High water treatment costs for steam generation

**Historical Perspective** – Heavy oil deposits (conventional and oil sands) require non-standard technologies to extract the oil and, historically, steam processes, using once through steam generators, have been the basis for all commercial development. While water is needed as a heat transfer medium, the thermal recovery processes (SAG-D or Cyclic Steam) work better if water is not allowed to build-up in the reservoir. The main economic driver affecting these operations is produced water treatment for reuse, and management costs to control the mineral content of water entering the steam generators. Minerals contained in the

[16] Actual from CAPP Statistical Handbook 2004 Table 03-16A converted to Annual Production.
[17] Forecast from EUB ST98-2004 In-Situ Production and Forecast which matches CAPP Actual. Converted to Annual Volumes.

formation water must be purged to prevent scaling of generator tubes. In the past this has been accomplished by leaving some water behind in the reservoir (Cyclic operations) or disposing of a "blow-down stream" to a deep aquifer and bringing in make-up water from fresh or brackish water sources. Water supply, treatment and blow-down disposal likely account for over 60% of the capital cost for central production facilities in this sector and the majority of non-energy operating costs in the production plants.

**Future Vision** - Uncertainties about future water supplies and the capacity of underground formations to supply large volumes of brackish water, or to accept blow-down, require that low cost (capital and operating) methods be developed to purge minerals from the active water/steam energy transfer system. If mineral management or alternate heat transfer systems are not developed, which avoid scaling issues or water recycle, then future thermal heavy oil production volumes may be limited by water availability. Economic impacts of limited production volumes are difficult to assess as water capacities are unknown. Most demineralization processes are energy intensive so any gain in reduced water supply and disposal costs, will be negated in some cases by increased water desalination costs.

### 6.1.2. Environmental Driver – Voidage make-up volumes

**Historical Perspective** – The largest thermal operations to date have been cyclic steam production which replaces 50-70% of the oil removed from the reservoir with water and have generally been applied to formations deeper than 400m. Volumes removed in a given region were relatively small until full commercial production began in Cold Lake in 1986 with fresh surface water make-up, water reuse and deep well disposal of surplus water. Cold Lake bitumen formations are located below the Colorado Shale barrier so tend to be isolated from direct communication with shallow aquifer systems. In comparison, the SAG-D process requires that all fluid be removed from the steam chamber to allow oil recovery so, during active production, very little of the produced oil is displaced by water. Most SAG-D development is in formations shallower than 400m so is more likely to impact shallow non-saline water sources. Full-size commercial development is just beginning with SAG-D, and there are many large commercial projects under development at the same time in the Athabasca River basin. Historically the industry, in the Athabasca basin, has no firm basis for assessing the impact of incomplete voidage replacement on surface and shallow water aquifers and no clear understanding of the capacity and impacts of large volume water disposal into deep aquifers in this region.[18]

[18] Technical Note – Water use at conventional and thermal operations have historically all appeared to require approximately 1 m3 of make-up water per m3 of oil removed, however, where the water ends up and potential impacts with other water resources over the life of the project, are different depending on the producing reservoirs and surrounding geology. Water sources (surface or groundwater), the producing zone, and water disposal zones may not be in direct flow communication with each other as unheated bitumen layers, shales, rock or other impermeable barriers will provide at least local isolation between zones. As a result it is necessary to consider water voidage balances independently for each zone affected by an operation. Wherever a voidage imbalance is generated (either by a net removal or a net addition of fluids) the imbalance will provide a new driving force to cause new sub-

**Future Vision** - Shallow (under 500m) development with a non-balanced voidage process causes uncertainties with future impacts on fresh water sources that increase further as the number of developments and volumes involved increase in a particular region. Rapid development of many large parallel projects may result in a significant future problem developing when steaming stops and lower pressures, and the presence of untrapped gas, in the producing formations encourage seepage of water from shallow aquifers into the depleted zones. This could reduce the already limited shallow and surface water supplies while the depleted zones fill. Voidage replacement will ultimately come from surface water flow until affected aquifers in the region are recharged and water tables restabilize.

### 6.1.3. Security Driver – Visioning the End Game for Thermal Recovery Projects

**Historical Perspective** – Near-term local fresh water concerns have historically been the main hurdle for approvals of oil production operations that involve water withdrawals and still have the largest potential to delay or hinder thermal heavy oil development. Unknowns regarding long-term water balances and security of water supply quantities and qualities for other users (including downstream ecosystems) generate concerns with public, government and shareholders causing significant approval delays. This has been deflected somewhat by producers committing to maximize water recycle and only use brackish sources for water make-up during steaming operations. However, the long-term voidage imbalance issue has not been adequately addressed in a public forum. Also, as no commercial thermal oil operation has yet approached the abandonment of even an initial production phase, there has been no significant physical impact detected, or assessment of the potential impact of voidage imbalance on later phase water management strategies. Nor have assessments been made to forecast methods of increasing recovery from these formations with follow-up projects.

**Future Vision** – As the percentage of Athabasca flow diverted for surface mining and in-situ oil sands projects increases, any unexpected variability in water supply, due to voidage imbalances, or brackish zone to deep disposal zone water transfers for thermal operations, could impact either the commercial operations or on downstream water availability until a balance is restored. Historical river flow data, currently used for project planning and licensing, will be of little value if underground voidage imbalances start to be felt on top of oil sands mining withdrawals and any changes due to climate change effects. This would generate extremely difficult decisions for government faced with either compromising water supplies to the environment, or energy supplies to maintain revenues and meet consumer needs.

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surface water flows. On a larger regional scale, some water bearing zones that are isolated in one local area may be hydraulically connected in some other area to allow interchange of fluids to restore an hydraulic balance, the existence of communication paths, and the rate of flows between zones cannot be anticipated until after a voidage imbalance is created.

#### 6.1.4. Technology Needs:

**6.1.4.1. Water Supply** - Independent geological assessment of the capacity of shallow brackish aquifers being targeted as water supplies. Also assess whether these zones will be replenished, how fast and from where.

Status – Alberta Geological Survey has released regional studies in the public domain concerning the stratigraphic framework and geochemical nature of freshwater Quaternary (drift) aquifers in the Athbasca in-situ area. Also AGS is presently embarking on a regional update of Quaternary (drift) aquifer maps in the Athabasca Oilsands Mining Area. These studies are necessary, but not sufficient, inputs into water resource appraisals.[19]

**6.1.4.2. Water Disposal**- Independent geological assessment of the capacity of deep disposal zones to accept blowdown water. Also assess whether these zones will push brine into shallower zones.

Status – Alberta Geological Survey has historical reports on deep flow systems and regional-scale stratigraphic architecture of potential disposal zones. However, except for some site-specific industry studies for their own disposal plans/operations, there has never been a systemic regional assessment of disposal capacity in the oil sands areas. AGS maintains knowledge of the potential for each zone but only in a qualitative sense.[20]

**6.1.4.3. Water Voidage** - Assess water balance implications in producing zones with low voidage replacement. Will voidage be made up naturally and if so from where and how fast?

Status – Some theoretical work may have been done for water inflow and gas outflow during operations. Issue may not have been addressed for post operation phase. Data might be gathered by assessing state of old pilot areas in the Cold Lake region.

**6.1.4.4. Future Recovery** - Impacts on future thermal recovery operations of a partially depleted reservoir being flooded with water either intentionally or naturally.

Status – Long-term water voidage issues have not been addressed in detail. Some producers assume that once oil rates become uneconomic in a portion of an asset, then that area could be used for water disposal/storage, without assessing impacts on potential recovery of the remaining resources.

**6.1.4.5. Water Supply** - Development of regional water balance scenarios including surface flows, underground aquifers and potential climate change impacts to assess cumulative water impacts and the ability to support thermal heavy oil and oil sands development.

[19] Personal communication 2005/01/24 from Kevin Parks, P.Geol. Senior Hydrogeologist and Leader – Groundwater Section, AGS.
[20] Personal communication 2005/01/24 from Kevin Parks, P.Geol. Senior Hydrogeologist and Leader – Groundwater Section, AGS.

Status – The Athabasca River Basin is under study to determine it's capacity to supply water and the Alberta Geological Survey is working on understanding of underground water zones. Long-term monitoring is likely required over the entire region to allow modeling of long-term interactions between surface and subsurface flows. To date little regional water monitoring has been attempted outside of active production areas, but such a system has been proposed.

**6.1.4.6. Water Supply** - Assessment of technologies to allow 100% recycle of water, and the related energy and environmental impacts of the solids removed to allow this. Main purpose of water disposal is to purge minerals produced with formation fluids.

Status – As the water supply becomes more of an issue in the region, producers are increasingly focusing on demineralization of produced water to approach 100% recycle. Technologies developed for low energy desalination of sea water are likely candidate processes, but tend to be sensitive to water composition and fouling by bitumen and clays. Higher water costs must be balanced against increased energy and solids/sludge disposal costs.

**6.1.4.7. Water Supply** - Alternate water sources and disposal methods through regional synergies. e.g. a) blow-down water from a SAG-D operation used in an oilsands extraction process rather than fresh water, or b) recovery of water from combustion emissions as part of a waste heat power generation process.

Status - A water treatment technology network[21] has been suggested to consider and test commercial options for water issues and treatment. New power from waste heat systems could allow for condensation of water from combustion gases, while generating power.[22] Other work is required on assessing the products of water treatment processing, which will tend to be land-filled or land-farmed on surface, which may cause new environmental liabilities.

[21] Suggested by Alex Starosud at University of Calgary and ISEEE.
[22] A candidate system is a Cascade Cycle Propane Rankine Cycle which was recently announced by WOW Energy out of Houston. www.wowenergies.com

## 7. Conventional and Coal Bed Methane Gas Production

**Geographic Distribution** – WCSB shallow gas (shallower than 400-500m) is mainly produced in eastern Alberta and western Saskatchewan, mainly affecting the South Saskatchewan, Beaver/Churchill and Athabasca River Basins. The issue of gas over bitumen (GOB) has somewhat reduced development in the Athabasca Region, while shallow gas development in southern Alberta and Saskatchewan is currently booming.

### 7.1. Water Impacts of Shallow Gas

Hydrologic **voidage balances**, in shallow gas or coal bed methane operations, impacts gas production and potentially could cause changes in surface or ground water flows.

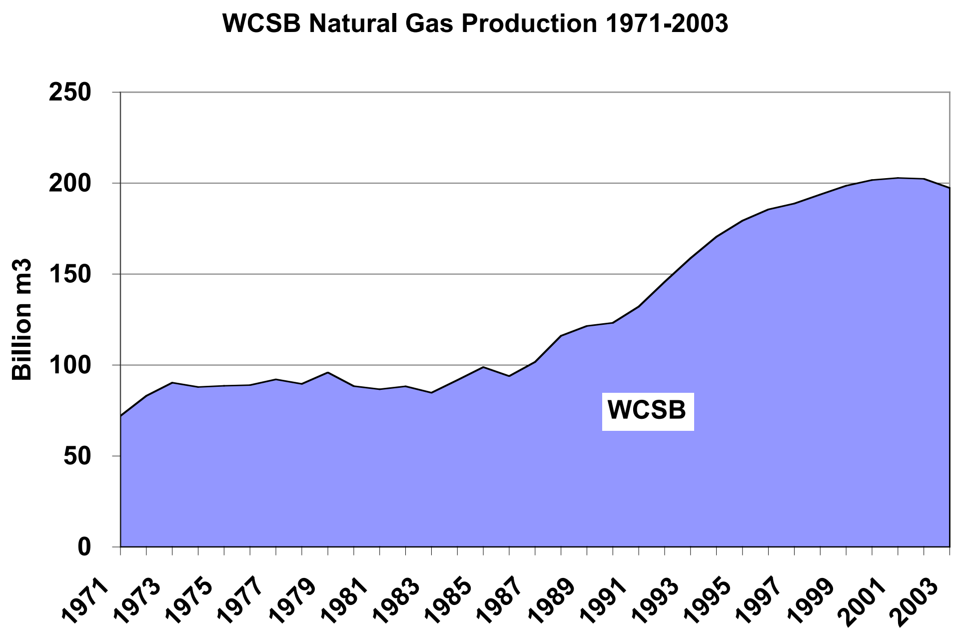


**Figure 7.1 – Historic Natural Gas Production showing gas peak and start of decline. Source CAPP – Voidage Replacement Water demand varies with depth of source reservoir (range 5-50 m3 water/1000 m3 gas depending on reservoir depth).**

#### 7.1.1. Economic Drivers – Decreasing volumes per gas well, increasing value of gas

**Historical Perspective** – The majority (88%) of the gas produced[23] in Alberta to date has come from deep, high pressure formations below 500m depth with initial reservoir pressures of over 5 MPa pressure and individual flow rates of 100 thousand to 1 million $m^3$/d/well. Recovery of initial gas in place has been on the order of 60[24]% with 5-10% of the produced volume being "surface loss" of volumes attributed to NGLs, $H_2S$, $CO_2$ and gas used for fuel, flared or vented. Remaining gas reserves in the WCSB were estimated by the Canadian Gas

[23] Total cumulative gas production to date is 3.3 trillion $m^3$ (116 trillion cubic feet) as reported in the AEUB Publication ST 2004-98; Alberta's Reserves 2003 and Supply/Demand Outlook/Natural Gas

[24] PTAC – Spudding Innovation. And AEUB Statistical Data Series Publications. Includes approximately 88 TCF of undiscovered marketable gas plus associated liquids and fuel consumption.

Potential Committee as being 142 Tcf[25] (4 trillion $m^3$) worth over C$550 billion at $C4/GJ. The 30-40% of the gas resource remaining in place (over 100 Tcf worth over C$400 billion at C$4/GJ) after depletion of known reservoirs, is at least partially due to natural water influx hindering recovery, and partially due to the high capital costs for compression to recover low pressure gas which, until recently, was not highly valued.

**Future Vision**– Production of gas in the future will come from ever increasing numbers of gas wells producing at ever decreasing flowrates and lower wellhead pressures[26]. Low rate production from a very large number of sites restricts the infrastructure and services that can be provided at each site, so water production must be handled cost effectively and locally to make these developments economic. To prevent loss of gas resources to natural water influx, wells will need to be produced as quickly as possible, and be produced to much lower abandonment pressures. Alternatively, new technologies could be developed to prevent water influx trapping gas or hindering gas production from the reservoir. In the case of CBM (potentially 250 to 2600 Tcf) and other types of unconventional gas (tight gas potential 175 to 1500 Tcf) managing low gas flowrates and natural water inflow to the formation and wells will be even more critical to ultimate gas recovery. To date most CBM production is from sources where the discovery gas pressure is below the expected hydrostatic pressure, which tends to indicate these zones are not well connected to surface aquifers. Where the original reservoir pressure is at or near the expected hydrostatic pressure then the potential for groundwater impacts is significantly increased.

### 7.1.2. Environmental Drivers – Voidage Make-up Volumes

**Historical Perspective** - In Alberta 12% of the initial gas reserves are from pools that are less than 500 m deep. The main production areas of this type are in the South Saskatchewan River Basin and Athabasca River Basin that are, or will be, greatly impacted by other water demands. Shallow gas requires more water to displace it than oil or deep gas (as the actual volume of gas at reservoir conditions is higher than for deep gas for the same volume at standard conditions) and the water will have to come from natural flow or seepage from other formations, likely those closer to the surface. As the gas-producing zone gets closer to the surface the impacts can become more acute as the area of drainage is reduced. An initial estimate is that gas recovered from shallow (less than 500 m) zones in Alberta would require 10-15 billion $m^3$ of water[27] to refill the pools vs. only 2.2 billion $m^3$ for all the oil produced in the province to date. If it is assumed that the WCSB average water to gas replacement ration is 10 $m^3$ of gas per 1000 $m^3$ of gas then almost 2,000 $m^3$/yr of water will be required to replace annual gas production. To put these volumes into perspective, Alberta Environment estimates that the total annual groundwater recharge rate, province-wide, is about only 15 billion $m^3$/yr[28].

[25] As reported in PTAC's Spudding Innovation
[26] As reported in PTAC's Spudding Innovation TransCanada note that over the past 5 years initial gas rates from new wells have decrease by almost 50% and first year declines have increased to an average of 21%.
[27] Calculated based on total initial reserves at an average initial reservoir pressure of 3 MPa.
[28] From presentation by David Trew to Insight Press conference on March 22, 2004.

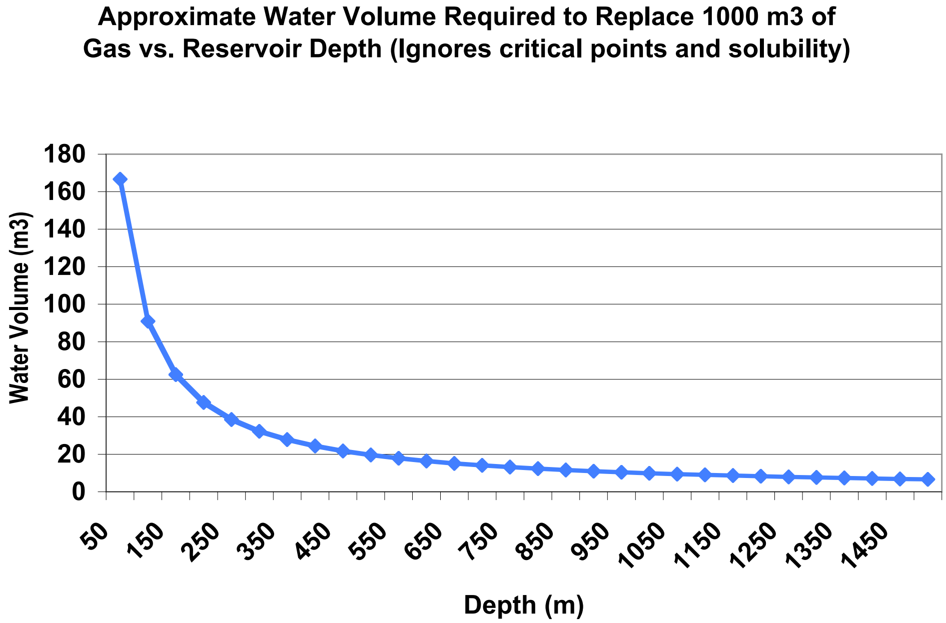


**Figure 7.2 – Approximate Water Replacement Volumes Required vs. Depth**

**Future Vision** – The issue of gas voidage replacement has not been discussed in any of the references reviewed to date, yet should have been recognized, even though there is no "withdrawal" per se. Part of the problem is that it is likely a small impact for each individual well licensed and only becomes significant on a larger regional scale because of the cumulative impacts. Water monitoring and forecasting for river basin management plans should make allowance for potential losses of ground or surface water volumes to local gas production, even though there is no mechanism for allocating the water. Increased understanding of aquifer responses to gas production should provide insights into the potential response of those same aquifers to $CO_2$ or combustion gas sequestration, which might be considered as a method of restoring the voidage imbalance, as it is in Athabasca[29] for resolving the gas over bitumen issue. For CO2 sequestration, the behaviour of the target aquifers will be an important factor to consider. Shallow gas pools will not be able to contain the same amount of gas as deep formations, however, the energy required to sequester would be lower for large shallow gas pools.

### 7.1.3. Security Drivers – Loss of future gas production

**Historical Perspective** - It is uncertain how fast depleted gas reservoirs might recharge with water. If the recharge rates are high, potential gas production may be lost if the reservoirs aren't or can't be quickly depleted and there is a greater chance that groundwater supplies will be adversely affected if the rate of water inflow is high. When gas pools are abandoned before all the gas resource has been produced the 30-40% of the gas remaining in place may be uneconomic to recover at a later date as water influx will compress the gas and trap much of it, making further gas

[29] Paramount Resources is proposing to use combustion gas injection to replace gas produced from gas reservoirs overlying bitumen resources.

production impossible except through depressurization by pumping out all the water to allow the gas to expand and flow out of traps.

**Future Vision** – To avoid water trapping of gas, producing formations should be produced to the lowest practical pressure before abandonment to avoid resource loss or other technologies should be developed to allow maximum production of the gas in place. Once a gas pool is truly depleted, repressuring in a controlled manner from lower water zones or with waste gases would reduce the risk of adverse impacts on other water users.

**7.1.4. Technology Needs:**

**7.1.4.1. Net Voidage** - Revisit depleted and shut-in shallow gas wells to determine if the gas zones are filling with water and monitor the rates of replenishment.

Status – Data on re-entry of gas wells after long-periods of shut-in might be available in AEUB orphan well files. After shut-in monitoring of bottom-hole pressures may allow for assessment of water inflow rates occurring in non-producing gas zones. Estimation of recharge rates is a major challenge in groundwater studies, as the inter-zone flow capacity cannot be assessed until a voidage imbalance is created to generate flow. New techniques may need to be utilized to assess voidage make-up issues over long time frames.

**7.1.4.2. Reserves Recovery** - Assess technologies for rapidly and more completely depleting gas zones to increase gas recovery, while minimizing fuel use.

Status – With increased development of shallow gas and coal bed methane, low cost methods for well dewatering and on-site compression to lower reservoir pressures to increase recovery are being developed. C-FER Technologies and others have proposed shallow well dewatering methods. Vendors supplying vent gas recovery systems for heavy oil are working to reduce the minimum size of compression units and allow modular construction to optimize on-site capacity at minimum capital cost.

**7.1.4.3. Repressuring** - Assess methods for repressuring depleted gas zones with CO2 and/or nitrogen (combustion gases), or dumping of water from deeper water zones to minimize the impact on local fresh water sources.

Status – ARC initiative on "dump flooding" of oil reservoirs by opening channels to deeper, high-pressure aquifers could also have application in preferentially repressuring depleted gas reservoirs from deep saline sources to attempt to minimize impacts on local groundwater. Portable inert gas units designed for underbalanced drilling operations could be used to displace additional methane and/or repressure gas formations with nitrogen and carbon dioxide. This was a major issue in the "Gas Over Bitumen" issue as water influx to depleted gas zones would reduce economic recovery of bitumen as the water would act as a heat sink.

**7.1.4.4. Groundwater Resources** - Geologic assessment of shallow water zones in the areas where shallow gas and/or natural gas from coal may be produced to determine the aquifers' capacities, source of replenishment and likelihood of communications with gas pools.

Status – The Alberta Geological Survey conducted some groundwater surveys in the 1970's across the province including the Medicine Hat region that has since become the focus of shallow gas production. At that time no link was made between groundwater and gas production, however, it is uncertain if the relationship between the two was investigated and shallow gas production volumes in the 1970's where considerably below current levels. Renewing this effort and comparing groundwater resources vs. gas production may lead to an understanding of the impacts of shallow gas on groundwater resources and also to an improved understanding of fresh groundwater replenishment to assess capacity to supply agricultural needs with groundwater.

## 8. Commercial (Cooling)

**Geographic Distribution –** Commercial cooling mainly occurs in thermal power generation facilities, using either simple or combined cycle generation, which are located in the North Saskatchewan, Battle River and South Saskatchewan River Basins in Alberta, and the Souris River Basin in Saskatchewan. Other major evaporative commercial cooling activities are found in refineries, upgraders and petrochemical plants in the North Saskatchewan, Athabasca, Red Deer River Basins near Edmonton, Lloydminster, Ft. McMurray and Joffre.

### 8.1. Valuing the Water Resource – Quality and Quantities

Commercial cooling water use is specifically for **dumping waste energy** from power generation, petrochemical, pulp and paper and other energy intensive operations. This use of water provides no direct economic benefit, but does impact the capital cost of facilities, as well as the quantity and quality of water available downstream of the water users. The chart below shows Environment Canada's estimate of water withdrawals but industry sector in the Prairies Region.

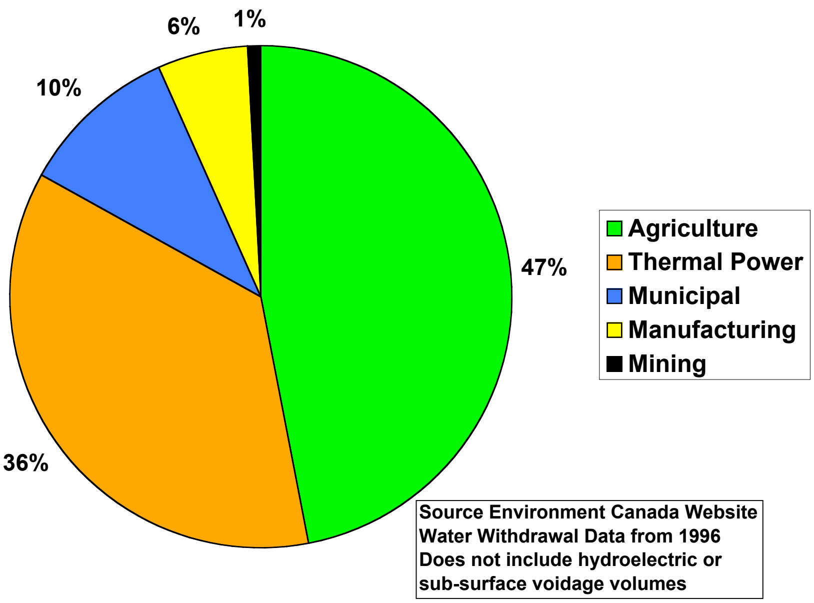


**Figure 8.1 – Water Withdrawals by Type of Use – Note- Power Water Demands Vary with the Cooling Process Used**

#### 8.1.1. Economic Drivers – Cost of Energy

**Historical Perspective** - For coal power generation approximately 1/3 of the energy in the coal is turned into useful power and the rest is dissipated through evaporative cooling or lost up the stack as hot gases and water vapour. Dissipating energy does not generate revenue directly but does come at a capital cost, especially if it requires something more than cooling ponds. Estimated energy lost in Alberta, through thermal power plant cooling (based on 7000 MW from thermal plants) is 365 TJ/yr which could be worth C$1.5 billion/yr if valued at C$4/GJ and an additional C$0.5 billion of energy would be lost up the stack. If some portion of this energy could be used for, or displaced by, cogeneration of heat and power, a significant revenue stream would be generated, as well as reducing natural gas demand and overall fossil fuel consumption. Since 1999 there has been over 1,500 MW of cogeneration capacity (efficiencies of 70% or more) installed at oil sands, petrochemical and pipeline compressor station sites in Alberta, which has reduced demand for stand-alone coal or gas power generation (efficiency of 30%).

**Future Vision** – Studies in the 1970's by Edmonton Power and NRCan showed that, even at that time, cogeneration by utilizing heat from power plants for community or commercial building heating was technically feasible and economic[30]. As energy costs increase and water availability decreases more efficient power generation technologies are becoming viable. Increasing the overall energy efficiency of existing thermal plants by a factor of 50 to 100% would reduce the need for new power facilities and proportionally reduce GHG production and water consumption for thermal power generation. In other industrial applications, higher energy prices should improve the economics of reducing energy intensity of production, which will also reduce demand for evaporative cooling. In summary, higher energy costs should drive a decrease in water consumption for commercial cooling.

### 8.2. Environmental Drivers – Consumption and Mineral Concentration

**Historical Perspective** - Water consumed is evaporated to provide cooling[31] and is therefore not returned to the water sources and is unavailable to downstream users.

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[30] "Demonstration of Co-generation Technology in Alberta" Alberta Energy Brochure Issued in 1990. Further reference to Stanley-Ekono. Edmonton District Heating Feasibility Study. Phases 1 and 2 in 1980.

[31] **Technical note** – The apparent consumption of water by cooling systems is dependent on the system being used: a) **Aerial Cooling** – no water is used in these systems as energy is exchanged with and dissipated into the air. No water is withdrawn or returned. However, this type of cooling is usually the most expensive both in capital and operating costs. b) **Cooling Towers** - are often found in chemical plants where very little, if any, of the water withdrawn will be returned to the water source as any water not evaporated may be sent to deepwell disposal to avoid possible contamination of the water source with minerals or other chemicals. These water-cooled systems minimize water withdrawals and the exact water consumption is known, however, almost all of the water withdrawn will be consumed by evaporation or injection. c) **Hybrid Cooling** – combines aerial cooling and a cooling tower so that cooling is optimized with ambient conditions (e.g. Co-Generation facility at Dow in Ft. Saskatchewan). Water is turned off in the winter time so water consumption is lower than for cooling towers or ponds alone. Capital and operating costs should be lower than for either aerial or cooling towers alone. d) **Cooling Ponds** – work in a similar fashion to Cooling Towers but are lower cost and usually found where there is a cooling demand that has low risk of releasing a toxic contaminant into the return water, but where the cooling demand is large and located a long distance from a water source. (e.g. Genesee Power Plant). Operating costs are minimized by returning anywhere from 15-25% of the water to the water source to maintain acceptable mineral levels in the pond water. Most of the energy is dissipated by water evaporation from the pond surface rather than being returned to the water source. Water emitted can cause localized fog and icing downwind of the pond. e) **Run of River Cooling** – is found where a power plant is located next to a water source, and is usually the lowest cost system for cooling. Cooling is achieved by withdrawing very large volumes of cooling water, cooling the process and immediately returning all the heated water to the source. Water withdrawals may be 10-30 times larger than for a cooling tower or cooling pond system and there will be very little apparent consumption of water (maybe 10% of a cooling pond's consumption per MW of power generation). However, the impact on the downstream ecology may be significantly affected by thermal and other effects, especially if the water source is small (Estevan or Forestburg). Most of the energy will still be dissipated through evaporation, and therefore consumed, however, it will not be measured and estimation of the reduction in downstream water flow will be difficult. Most jurisdictions in North America are moving away from run of river cooling.

As an example the Genesee Power Plant (Phases I and II) consumes over 15,000 tonnes of water per year for each MW of power generation capacity[32]. Water returns to the river are more concentrated in salts, minerals and other contaminants and are usually warmer than normal stream flows, although these effects may be small when the source stream is very high volume. The higher concentrations of contaminants may impact downstream users, at times of low water flow in low flow systems, by increasing water treatment costs, or lead to accelerated salination of soils if the downstream use is for irrigation (e.g. southern Alberta). Higher temperatures may impact river ecologies by reducing ice formation, etc. Many other industrial discharges are sent to deepwell disposal or are closely monitored before release back into the source river system. Industrial releases, either chronic or resulting from accidental spills, have been a major concern to other water users.

**Future Vision** – Public and regulatory pressure is moving increasingly towards the reduction of water use for industrial purposes and the abandonment of "dilution" as an acceptable method of disposing of wastes or waste energy. This is supported by a growing body of scientific evidence, which indicates that even small amounts of certain contaminants, or small variations in water temperature, can have unpredictable impacts on riparian and aquatic ecosystems. The public and environmental groups, despite tight control, monitoring and regulation of disposal systems, also increasingly view deepwell disposal with distrust. Any expression or hint of uncertainty about long-term containment is viewed as potential for future disaster, or undetected contamination of potable water sources. This is gradually forcing industry to move towards cradle to grave assessment of all water emissions and greater efforts to assess life cycle environmental impacts of their operations.

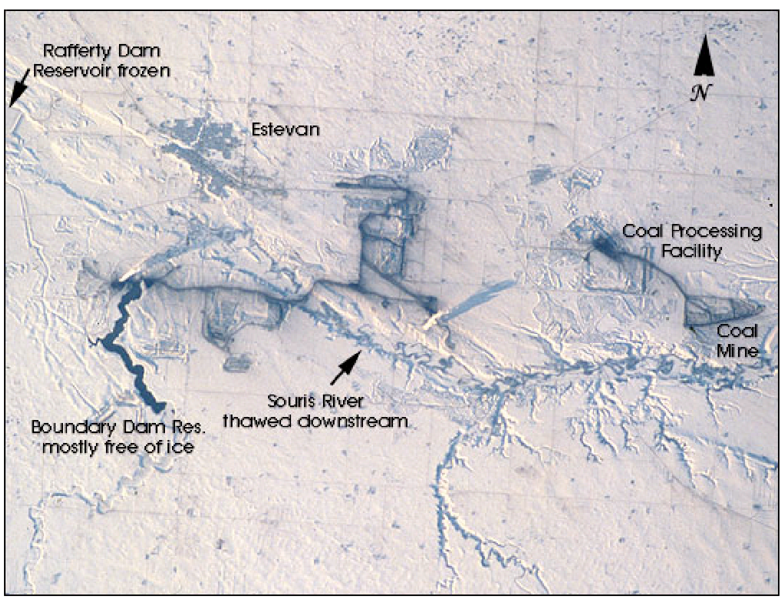


**Figure 8.2 - Photo of Estevan, Saskatchewan Region (February) from a NASA website used to illustrate thermal impacts of power generation. The plumes are the Shand and Boundary Dam coal power plants.**

**Source http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=4722**

[32] "Genesee Power Project 2003 Environmental Report" Downloaded from www.epcor.ca .

## 8.3. Security Drivers – Water Scarcity

**Historical Perspective** - With populations and industries such as feedlots and irrigation growing in more arid southern Alberta water basins, there is an increasing demand for power generation in those regions that are already short of water. In the South Saskatchewan River Basin water supplies are already over-allocated, and growing consumption will eventually result in years where water use will have to be curtailed to meet inter-provincial agreements. Minimizing water use for non-value added cooling leaves more water for other users to generate economic benefit.

**Future Vision** – If climate change results in lower precipitation in the southern regions, as predicted, water shortages could become acute very quickly. While current water allocation regulations in Alberta are based on "first in time, first in right" this may not be adequate to deal appropriately with reducing water supplies and increasing demands of new users. To avoid limiting future development, and even to support existing industry, in the southern regions, some process will be needed to prioritize water use, encourage conservation and, potentially, assess the use of groundwater to meet some needs. From an energy industry perspective, energy processes will have to adapt to the reality of lower water availability in some regions.

## 8.4. Technology Needs:

**8.4.1.1. Reduce Water** - Low cost method of industrial cooling that does not require high volumes of water.

Status – Alternate cooling methods are available, at higher cost, which reduce water demands. Methods include cooling towers, aerial coolers or hybrid coolers.

**8.4.1.2. Reduce Cooling Load** - Increased use of distributed, high thermal efficiency cogeneration to minimize need for less efficient centralized, stand-alone power generation.

Status – Reducing power generation from centralized, stand-alone steam cycle power generation systems or increasing their overall efficiency reduces cooling water demand per MW of power generated. In Alberta, deregulation of power generation has resulted in a growing number of cogeneration facilities. Some efforts are underway in regulated jurisdictions to encourage cogeneration from renewable sources.

**8.4.1.3. Utilize Waste Heat** - Assessment of potential for existing stand-alone thermal power generation waste energy being used for building heating in nearby communities to increase overall energy efficiency.

Status – Conversion of power systems to provide waste heat to local communities has been considered in the past and is in relatively wide spread use in Europe. Edmonton Power conducted two studies in the 1970's which were reported to have shown that heating Edmonton buildings with waste heat from either the Genessee or Rossdale power plants would be both technically and economically feasible[33]. Main barriers appear to be public perceptions and biases for convenience vs. technological barriers. Also, many of the codes, regulations, approval processes and tax regimes currently in place were written from the perspective of centralized generation and will need to be modified to be more in tune with distributed generation.

**8.4.1.4. Utilize Waste Heat** - Assessment of new power cycles (propane or ammonia/water) to increase efficiency of stand alone power generation and reduce water demand for dumping waste heat.

Status – A new process proposed by WOW Energies of Houston www.wowenergies.com is gaining interest as it uses a cascade cycle propane Rankine cycle instead of steam to generate power, yet uses off the shelf components. Propane is a more efficient power fluid than steam as 70% less energy must be dumped to condense propane. At least one oil and gas producer is considering the WOW process for a major gas plant that already has a propane refrigeration plant.

**8.4.1.5. Water Discharges** - Assessment of economic impacts of power generation water use on downstream users of the water especially irrigation and municipalities in the South Saskatchewan, Souris and Battle River Basins. Also, the effects of airbourne pollutants that may eventually precipitate and enter the water streams should be examined in more detail.[34]

Status – The issue should have been raised during the licensing process for all projects, but follow-up studies may still be required to determine potential cost impacts on downstream users that will be most acute during periods of low water flow.

**8.4.1.6. Water Discharges** - Assessment of any potential negative impacts of all contaminants released from energy or industrial operations, to surface or subsurface streams.

Status – Potentially toxic components in any water discharge stream are already highly regulated and reported on. Additional technology development may be needed if current discharge requirements are made more stringent.

**8.4.1.7. Public Education** - Assessment of public education as a means to reduce concerns related to deep well disposal.

Status – Generally regulators see water quality protection as their primary objective and industrial sources tend to be closely regulated and monitored with the major concerns being releases during extreme or unusual events. Greater research efforts may be needed to reassure and inform the public.

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[33] "Demonstration of Co-Generation Technology in Alberta" Alberta Energy Brochure 1990.
[34] "An Emissions Management Framework for the Alberta Electricity Sector Report to Stakeholders" CASA November 2003.

## 9. Oil Sands and Coal Extraction

**Geographic Distribution** – Oil Sands mining and extraction operations for energy production are found in the Athabasca River Basin surrounding Ft. McMurray. Major energy coal mining operations in Alberta are centered on the Wabuman area west of Edmonton affecting the North Saskatchewan River and the smaller Battle River Basin, which eventually joins the North Saskatchewan at North Battleford. In Saskatchewan energy coal mining is mainly found in the southeastern corner of the province near Estevan.

### 9.1. Water Extraction and the Tailings

The key issues in this area are in dealing with the tailings or other residue materials left over after energy extraction. Tailings can affect water by tying up water resources in the near-term and also pose a potential long-term threat to water quality. For oilsands mining and extraction, the main water quality issue is **tailings consolidation** to improve water use efficiency. Long-term water quality issues arise from storage and potential contaminant seepage from any unstable tailings or residue storage.

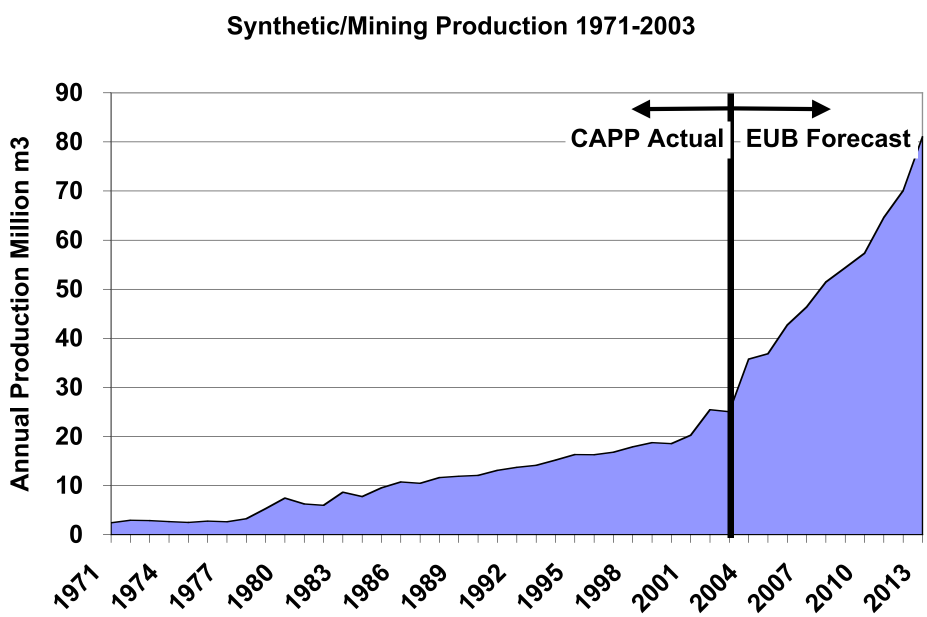


**Figure 9.1 – Actual Production of Synthetic Crude from Mining[35] and Forecast[36] - Water Demand for Tailings Likely 3-5 m3 Make-up Water per m3 Bitumen[37]**

#### 9.1.1. Economic Drivers – Finding Value in Reducing Waste Volumes

**Historical Perspective** - Immense oil sands tailings ponds are extremely costly to build and maintain and have been a major focus of research since the early days of

[35] Actual from CAPP Statistical Handbook 2004 Table 03-16A converted to Annual Production.
[36] Forecast from EUB ST98-2004 Synthetic Production and Forecast which matches CAPP Actual. Converted to Annual Volumes.
[37] "The Future of Water Quality and The Regulatory Environment in Oil Sands and Coalbed Methane Development", Division Report CETC-Devon 04-17 (OP) - R.J. Mikula and K.L. Kasperski, CETC – Devon, Advanced Separation Technologies. Water use per m3 of Synthetic Production will vary with Upgrading Process, amount of fines in the mined ore and the tailings treatment process used.

commercial oil sands mining. Oil and other resources contained in the tailings, or mineable bitumen resources underneath the tailings ponds[38], will be much more difficult to recover at some future date if the high water content tailings ponds continue to grow at current rates. With oil sands extraction consuming 3-5 $m^3$ of water per $m^3$ of bitumen produced[39], water availability will soon constrain future development in this sector, and likely before the availability of natural gas becomes a constraint. While bitumen production volumes from planned projects are projected to reach 5 million bbls per day, there is estimated to be only enough water available during low winter flows in the Athabasca, for 2-3 million bbls per day[40]. Other residues from coal and oil sands production such as flyash, bitumen coke, sulphur and materials produced from mitigation of air emissions, are smaller in volume but may contain relatively high concentrations of other materials of value, if they can be economically extracted.

**Future Vision** – Power and oil sands producers are continually looking for partners and technologies which can potentially find materials of value in tailings or other streams from the mining, extraction, coal combustion or upgrading processes. Potential materials of most interest would be heavy metals and any materials that would help to reduce the water content of the tailings if they were removed, to minimize water consumption and tailings volume. Development of these recovery, or treatment processes have the potential to allow continued expansion of coal power and oil sands production, while at the same time generating new wealth from the resource.

### 9.1.2. Environmental Drivers – Eliminating a Toxic Legacy

**Historical Perspective** - Oil sands extraction requires more fresh water than other oil operations on a per $m^3$ of oil production basis. This water is removed from a single river basin and is tied up for an indefinite period of time. Tailings ponds have already grown to a size, which makes them some of the largest manmade structures on the planet, and already cover an area of over 50 $km^2$ and total surface disturbance is over 150 $km^2$. Oil sands water licenses already total as much as 10% of the Athabasca River's flow during the winter when the river flow is no longer supported by mountain melt waters and groundwater flows. Coal power generation and other oil sands waste streams have less of an impact on water volumes and are more of a water quality concern due to the presence of heavy metals or other substances. These materials are naturally occurring in the original coal or oil sands deposits but are highly concentrated in the waste streams so are more likely to leach out into surface water streams.

**Future Vision** - While the tailings ponds are actively monitored and maintained, the potential for a catastrophic failure of a tailings dyke is low, however, the dykes

[38] Syncrude's June, 1996 Aurora Mine Application indicated that the North Mine Tailings Pond would result in the loss of an estimated 250 million barrels (40 million $m^3$) of recoverable oil, while no appreciable oil would be lost under the South Mine Pond as it was located in an area of lower quality oilsands.

[39] "Improved Stewardship of Water Resources that are Entrusted to Oil Sands Mine" by L. Sawatsky, Golder Associates, presentation to "Water and Land Issues for the Oil and Gas Industry" March 22, 2004.

[40] Assumes maximum withdrawals for ecological protection will be 50% of winter flow, however, the minimum required flow has not yet been established. Assumes best established tailings treatment.

constitute an on-going concern long after operations cease. The total area potentially disturbed by oil sands mining is estimated to be over 1,400 $km^2$ by 2023[41] which is equivalent to 50% of the area of the country of Luxemburg. The longer operations continue without a permanent solution being found or implemented, the bigger the problem will become in the future and the more difficult it will be to implement. Any future failure of containment dykes (reclaimed as lakes) or landfills of other wastes could allow a release of unstable materials into the Athabasca River and would be extremely difficult to recover or mitigate.

As pressure mounts to mitigate air emissions, such as mercury, from coal power generation and heavy metals from oil sands operations, the mitigation activities may create new concentrated deposits of these materials in the watersheds. Care will need to be taken to ensure that the toxic materials removed from the air do not become a potentially larger liability by becoming a concentrated source of water contamination. The ultimate goal for all wastes is to leave them in an intrinsically stable state where there is no potential to have a concentrated release of material into a watershed.

### 9.1.3. Security Drivers – Avoiding Mega-Surprizes

**Historical Perspective** – Although there are no cases of major environmental or economic disasters related to mega coal or oil sands operations in Western Canada, incidents in other industries and other countries show the potentially devastating effect of not planning for the long-term. Potentially relevant concern areas might be found in:

- **Over-allocation of water** in the South Saskatchewan River Basin which is already forcing industries out of new developments in the region, could cause periodic shutdowns of existing businesses in years of low water supply, and is also causing cities and towns to impose limits on their population growth.
- **Failure of Tailings Containment Structures –** World wide there have been major incidents of loss of tailings containment, even in active mining operations, which have caused major ecological disasters and resulted in huge financial losses for the companies involved or major liabilities for the governments if the companies cannot cover the clean-up themselves.
- **Site Sterilization –** Other industries and countries are just beginning to see the impacts of ignoring environmental problems until the last minute. The Tar Ponds in Nova Scotia, and the growing problem of long-term storage of the huge volumes of radioactive materials from decommissioned nuclear facilities are generating problems that were unanticipated at the start of rapid nuclear development, and are only now being fully appreciated by regulators.

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[41] Figure quoted from Oilsands Environmental Research Network website FAQ's www.osern.rr.ualberta.ca and attributed to Alberta Environmental Protection.

**Future Vision** - As former Alberta Environment Minister Lorne Taylor has noted, more wars have been fought over water resources than over energy. While there is still no full understanding of the causes or potential impacts of climate change, it is known that water availability in any region can vary radically over time. The rapid development of over 50 billion dollars worth of oil sands projects, all highly dependent on the same water supply, potentially could mean that those investments may be put at risk if any changes were to occur in the natural water supply system. If a water shortage were to occur, governments and industry would be faced with extremely tough choices in deciding whether to: a) limit or shut-in production; b) build upstream dams to load-level the water supply; or c) construct diversions to transfer water from other river basins. At the other extreme, radical increases in precipitation or weather extremes, in a region, may jeopardize tailings or other containment structures creating the potential for a large, uncontrolled release of toxic materials into a watershed. In either case, the growing public awareness of the need to protect environmental resources, and the concurrent needs to protect local communities from the sudden loss of a major employer, will create considerable social conflicts over any solution proposed.

**9.1.4. Technology Needs:**

**9.1.4.1. Consolidated Tailings** - Continued improvement in tailings treatment to generate inherently stable and low water and toxics content tailings.

Status – Considerable effort and funds have been expended on fine tailings research with some progress and some transfer of the technology to practice. Key research is being conducted through CONRAD with support from producers and governments. Any significant discovery or advancement would take many years to implement into commercial operations and may be difficult to apply retroactively.

**9.1.4.2. Reclamation** - Development of methods to encourage re-establishment of muskeg areas.

Status – Reclamation studies are on-going through CONRAD, producers and various government agencies. The main initial target is to develop a stable reclaimed landscape, however, the result is not a return to the predevelopment state.

**9.1.4.3. Water Supply** - Detailed studies of Athabasca water sources and projections of water availability over the next 50-100 years with various development scenarios.

Status – The Athabasca River is mainly fed by glacier and mountain run-off, although the AGS estimates that up to 15-25% of river channel flows in northeastern Alberta are directly contributed by groundwater[42]. Water

[42] Personal communication from Dr. Kevin Parks AGS. January 24, 2005. Also commented that: "Geochemical studies suggest that most water in our rivers was groundwater at one time and that the pure glacial meltwater signature is very small. The idea that our rivers are aqueducts carrying glacier-fed waters to the oceans is out of date. However, there is a large component of spring runoff that is snowpack fed and changes to the snowpack are critical to cleansing-flood cycles in our rivers.

supplies may be greatly impacted by natural glacier retreat and potentially accelerated retreat caused by climate change reducing mountain snowpack. Detailed studies and projections of source glaciers and mountain precipitation are needed to project future water flows.

**9.1.4.4. Oil Recovery** - Assessment of economic losses of materials in tailings, and oilsands resources sterilized by tailings ponds.

Status – Applications for new oil sands mining projects generally indicate where oil sands resources may be lost due to locations of plants, tailings ponds and mine storage areas. Most applications contain information on resources contained in the tailings that will be lost. Some work has begun looking at methods of recovering materials of value in the tailings.

**9.1.4.5. Water Supply** - Assessment of alternate water sources for extraction. e.g. blowdown water from SAG-D operations.

Status – Blowdown water from SAG-D steam operations may be an alternate source of feedwater to reduce use of fresh surface water. The potential of this source will depend on volumes, distances and water chemistry, which may have to await more commercial scale SAG-D production before it is economic to consider.

**9.1.4.6. Reclamation** - Geotechnical studies of the long-term stability of tailings dykes.

Status – Tailings are a normal result of most mining and extraction processes so there is a considerable body of knowledge for hardrock and coal mining tailings. However, the unconsolidated and large scale nature of oil sands tailings ponds create new problems which may only become obvious in the course of time, but may require options for backup containment, recovery of losses from dyked areas, and adaptation of new tailings storage methods.

## 10. Water Impacts of Biomass Energy

**Geographic Distribution:** The main biomass sources that might be potentially used for energy production are: agricultural sources in the south (potentially through increased irrigation), "mining" of peat or forest resources in the north, urban landfills or agricultural or forestry waste streams.

### 10.1. Water Impacts of Harvesting Energy

The EnergyINet analysis for this sector would focus on a strategic assessment of the potential water impacts of future **biomass energy production** in Western Canada.

#### 10.1.1. Economic Drivers – Ensuring a Net Energy Output

**Historical Perspective** - Currently only small amounts of grain are being used to produce biofuels (ethanol) mainly as a gasoline additive rather than a primary fuel. Energy inputs to produce grain are higher than the energy outputs from ethanol so on a lifecycle basis are currently not a viable primary energy source.

**Future Vision** - Use of less energy intensive biomass (grasses, peat, wood byproducts or landfilled materials) may be economic if energy input costs for irrigation, harvesting, transportation of bulk materials and processing can be kept low. Processing biomass to produce ethanol requires water, so direct combustion of the biomass to generate power, as is already done in some areas, may be more cost effective but would require water for cooling of steam unless an alternate power cycle were used. Generally the economic drivers for increasing irrigation to produce biofuels have not been fully assessed. Less water intensive crops may be preferred to allow greater production without the energy inputs for pumping water and to reduce transportation costs for low water content materials.

#### 10.1.2. Environmental Drivers – Water and Land

**Historical Perspective** - Biofuels will require more irrigation in southern regions or more disturbance of natural peat bogs or forests to generate the biomass, unless it is derived from an existing stream (such as slaughter or lumber mill wastes which are small in comparison to energy demands). Current water allocations for irrigation are mainly used for fodder crops for livestock production with little surplus water for biomass production. In northern regions biomass use for energy has focused on direct combustion of wood waste rather than intentional harvesting of biomass for fuel. Only limited mining of peat is occurring mainly to supply demand for gardening and landscaping.

**Future Vision** - If water use efficiency for irrigation could be improved irrigation systems could potentially be expanded with the same water demand. Water requirements and life cycle nutrient, soil salinity, energy and water balances would also be required for the biomass process to produce ethanol or some other hydrocarbon fuel. Using wood or peat biomass would greatly increase the rate of deforestation in northern regions leading to increased wildlife impacts and soil erosion. Concerns have also been expressed that loss of forests, peat bogs and muskeg will reduce water hold-up in river basins and increase peak water flows, causing flooding, while further reducing flows in off peak periods.

### 10.1.3. Security Drivers – Future Fuels

**Historical Perspective** – Biomass sources were historically the primary energy sources with wood, peat, grasses and dung being used for heating through direct combustion. Use of these sources has resulted in widespread deforestation, which continues in developing countries that cannot afford more concentrated forms of energy like oil, gas and coal. Once these biomass sources are fully utilized or consumed local economies collapse leading to drought, famine and desolation forcing large populations to mobilize and relocate to other areas.

**Future Vision** – Biomass production is limited by availability of land area, water and nutrients in the soil. Replacement of hydrocarbons with biomass will greatly increase pressures on land, water and soils. These potential impacts require greater study and assessment to increase efficiency of production and conversion of biomass to fuels, if it is believed that use of hydrocarbon resources are limited. Biomass may at some point be needed if other fossil fuels become uneconomic or unavailable, at which time the challenge will be to sustainably produce biomass much more efficiently that it is today.

### 10.1.4. Technology Needs:

**10.1.4.1. Net Energy Potential** - Assessment of the biomass production potential, economics and ecological impacts (as part of renewable energy), including water and nutrient needs assessment by water shed.

Status – Saskatchewan has initiated and energized research into alternate ethanol production processes by legislating ethanol content in vehicle fuel. Other studies, mainly university or internationally funded, have attempted to assess the life cycle energy output of various biomass processes from various sources.

**10.1.4.2. Water Supply** - Relative value of water use for production of biomass fuels vs. use for food, industrial or municipal uses.

Status – A number of water research organizations have been formed at the provincial and national level to assess the economic, environmental and societal impacts of water use in arid regions. Much of this work is in the early stages in Canada, spurred on by droughts and forecasts of potential climate change impacts.

**10.1.4.3. Water Supply** - Impacts on watersheds of increased mining of peat resources or forest harvesting.

Status – Ecological studies of watershed impacts of changes in land use have been initiated in some of the more sensitive or active water basins, mainly by university-based researchers. However, long-term ecological impacts are notoriously hard to anticipate.

## 11. Hydroelectric

**Geographic Distribution –** In Canada as a whole 80% of the fresh water flows to the Arctic Ocean, however the distribution of the water and flow directions vary by region. In Alberta 87% of the available surface water flows north, with 13% flowing east into Saskatchewan and only 0.1% flowing south to the U.S. Hydroelectric potential is greatest in areas of high water flow making the Peace River system the largest potential hydroelectric source, however, this large potential is a long way from potential users of the energy.

### 11.1. Multi-Tasking Water Resources

Dam building or river flow generation for hydroelectric energy and water storage is often suggested to address energy and water needs. While Canada is the largest producer of hydroelectric power in the world, and hydro-generation provides over 60% of Canada's electrical power needs, the shortage of water in most of the populated portions of the WCSB means most hydroelectric technology development will be focused in other regions. Opportunities that may be more unique to the WCSB are for hydroelectric power using irrigation dam and reservoir systems in southern basins.

### 11.2. Economic Drivers – Power Production to Balance Power Use

**Historical Perspective** - IrriCan in the St. Mary's River Irrigation District, of southern Alberta, is already generating $5 million/year in revenues from power sales from turbines added to existing dams in its irrigation system. This generation helps to offset the undetermined power consumption of the end-users of the irrigation water, rather than depending on stand-alone power generation from remote coal or natural gas power plants. Power generation capacity will be higher in wet years when irrigation water is in low demand and lower when the water is needed for crops.

**Future Vision** – Multi-tasking irrigation dams increases the benefits derived from the structures and can serve, over the long-term, as a way to improve irrigation economics, by reducing purchased power and transmission losses from distant coal fired plants. Balancing the use of the water for multiple purposes will be a challenge as there will likely be optimum times to use water to generate power or to irrigate.

### 11.3. Environmental Drivers – Reservoir Evaporation not Included in Allocations

**Historical Perspectives** - Reservoirs already exist and are controlled for irrigation purposes so water losses due to reservoir evaporation are already occurring. As a result, hydroelectric power may be supplied from irrigation systems while reducing incremental water consumption in other regions. A major concern in areas of over-allocation of water, is that water losses from reservoirs are not included in allocation totals, despite the reduction in water available to users downstream of reservoirs. In dry years reservoir evaporation will increase as the lower water flows will be warmer which may accelerate the need to limit water use to other users.

**Future Vision** – As the areas under irrigation continue to expand there will likely be a need to construct new dams, reservoirs or sub-surface storage to service those needs, which will increase the non-allocated losses. As power generation grows this may also provide motivation to hold back more water than is needed for irrigation alone which would also increase evaporative losses.

## 11.4. Security Drivers – Competition for Water

**Historical Perspective** - Irrigation systems are less dependent on more costly outside sources of power from coal or natural gas if they can generate their own power. Power generation potential will be highest in years of high water supply, which does not match years of large water demand for irrigation. Most multi-use hydro development has been within the control of the irrigation districts in Alberta, even though they also supply other users including municipalities and Ducks Unlimited.

**Future Vision** – Water availability for irrigation, and hydro use, in some southern basins is being challenged by others such as the United States, and will also face challenges from growing urban development in the region. Municipalities will require diversions for growing communities that may not be compatible with irrigation or power generation needs. Any recreational development of reservoirs also generates problems for balancing the demands of cottagers and recreational users for stable water levels, vs. the needs of drawing down water storage for power or irrigation uses.

## 11.5. Technical Needs:

**11.5.1. Energy Potential** - Assessment of total potential for irrigation hydroelectric systems in the southern WCSB.

Status – Irrican is assessing other sites for potential hydro development. Uncertain what issues, problems or opportunities may be encountered in existing operations.

**11.5.2. Efficiency** - Development of more efficient small-scale hydroelectric power systems that can be economic even with large year-to-year and seasonal variations in water levels and water flows available.

Status – Assumed need for new research and development to maximize efficient use of water for power generation and economic modeling to assist in optimizing the economic return from available water.

**11.5.3. Aquifer Storage and Retrieval** – Underground storage of water as a means of leveling water supplies.

Status – Need for study and adoption of aquifer storage and retrieval (ASR) technologies in some areas where short-term seasonal or annual variability leads to critical water shortages. Technology could be lower cost than surface reservoir storage and reduce reservoir evaporative losses.

## 12. Water Connections

The intent of the EnergyINet Water Initiative is to contribute to existing water-related initiatives and fill in gaps critical to other EnergyINet priorities, such as upgrading, clean carbon/coal, recovery, and bio-energy.

### 12.1. Basic General Water Connections (WCSB Region)

In Alberta, the lead ministry in addressing fresh water issues is Alberta Environment, which launched a *Water for Life* sustainability strategy in November of 2003, which has three key thrusts, one of which is to develop a provincial water research plan. To support the Water for Life initiative the Alberta Water Council was established to coordinate all water issues including the role of advising on and advocating priorities for water research. The Alberta Energy Utilities Board (AEUB), as part of the Department of Energy, regulates the use of brackish water or saline aquifers deeper than 400m, and is a key player responsible for ongoing and appropriate development of Alberta's energy resources. To oversee and manage provincial research the Alberta Science and Research Authority (ASRA) and the Department of Innovation and Science have the mandates of ensuring that research conducted in the public interest is effectively managed.

Other natural water partners in provincial governments include the Saskatchewan Watershed Authority that is responsible, with the support of other departments, for all water resources in the province except municipal use. In B.C. the Department of Energy and Mines takes a lead role and interest in Energy and water availability as a result of the dependence of the province on hydroelectric power, which can be greatly impacted by changes in natural water availability and other uses. In both provinces, the respective provincial Departments of the Environment also retain key roles in assessing ecological impacts. Many Federal Departments are also interested in water use and technology issues and are also key players in managing national and international water issues and technology transfers.

For the EnergyINet, the key areas where greater collaboration is needed on energy and water research issues across all sectors fall into the following categories:

#### 12.1.1. Water Data and Balances

Lead Organizations – Fresh Water (assume all sources shallower than 400m depth) - Provincial and Federal Departments of Environment or equivalent designated agencies; Saline Water – Provincial Oil and Gas Regulators

Objective of Collaboration – Ensure that all sources and uses of surface and near surface water are identified and that a sufficient quantity and quality of data is being collected to allow analysis for assessing energy industry water impacts.

#### 12.1.2. Water Indicators by Sector

Lead Organizations – Energy Industry Associations in Collaboration with Provincial Regulators.

Objective of Collaboration – Develop meaningful water indicators that can be used to steward water performance by producer, operations type, local operating area, river basin and subsurface aquifer system.

#### 12.1.3. Surface Water Basin Studies – Quantities and Qualities

Lead Organizations – Regional water councils and Provincial/Federal Departments of the Environment actively supported by the EnergyINet.

Objective of Collaboration – Define and monitor basin level water use and quality issues. Where required initiate research to investigate and define problems, issue Requests for Proposals to develop technical solutions, develop regulatory, voluntary or industry water practices, policies, regulations or targets. Options might relate to allocation, measurement, use, storage, protection of waters and potential adaptations to natural or climate change driven variability. Prioritize efforts and encourage funding of highest priority issues leading to proactive, sustainable mitigation solutions.

#### 12.1.4. Full-column Hydrogeology

Lead Organizations – Canadian and Provincial Geological Surveys, Energy and Mineral Industry Regulators.

Objective of Collaboration – Use existing information from historic and on-going subsurface oil, gas, mining, irrigation and disposal activities to identify and quantify subsurface natural water resources, volumes and recharge processes. Identify additional monitoring, data collection, sampling or analysis efforts required to increase understanding of subsurface water flows, which may be used to supplement surface flows in areas of high water stress and to predict impacts of energy production or carbon dioxide sequestration activities.

### 12.2. EnergyINet Connections

Water is an enabler to all other priorities in the EnergyINet effort. As a result, many of the water technology issues will either be addressed in the other priority areas, or the other areas will impact what is needed in the Water Priority area. Potential impacts vary greatly and the main focus of collaboration across EnergyINet priorities is to ensure that water impacts are not missed, and that common issues are addressed efficiently through setting water priorities.

#### 12.2.1. Oil and Gas Recovery

Lead Organizations – PTAC in support of Provincial Departments of Energy and Provincial Energy Regulatory Bodies. Focused through EnergyINet Recovery Manager.

Objective of Collaboration - The Energy Innovation Network's (EnergyINet) Natural Gas and Conventional Oil Recovery (NGCOR) Innovation Program is focused on creating the right mix of technology innovation and business imperatives to significantly increase the amount of natural gas and conventional oil recovered from known sources. Water issues affecting Oil and Gas Recovery include:

- EOR Waterflooding – From fresh, produced, subsurface and potentially other novel water sources. Assessing impacts of water type, volumes and impacts. Assessing potential impacts on water demand if alternate injectants, such as carbon dioxide, nitrogen or other waste gases are used.

- Produced Water Recycle – Developing methods of increasing oil and gas recovery by reducing the costs and impacts of high volumes of water produced with the oil and gas, requiring reinjection.

- Impact of Water Influx on Gas Production – Assess impacts of water influx on ultimate recoveries of natural gas.

### 12.2.2. CO2 Management

Lead Organizations – Federal and Provincial Departments of the Environment. Focused through EnergyINet Carbon Manager. Note that, like water, carbon can be either an enabler or disabler of energy production, so carbon management technologies will often cut across all EnergyINet sectors.

Objective of Collaboration - The Energy Innovation Network's $CO_2$ Management Innovation Program is built on a commitment to address climate change, and the firm belief that it is in Canada's strategic interest to develop environmentally sound and pragmatic approaches for the capture, transport, and long-term storage of carbon dioxide in geological formations. Water issues affecting carbon management are:

- Voidage Balances – As with gas production, gas sequestration will cause changes in subsurface water movement.

- Alternative to Waterflooding – GHGs could be used in place of or in combination with water to further enhance oil recovery.

### 12.2.3. Clean Coal Power Generation

Lead Organizations – Federal and Provincial Depts of Energy and Regional Coal Power Generation Corporations. Focused through the Canadian Clean Power Coalition and EnergyINet clean coal manager.

Objective of Collaboration - To demonstrate that it is technologically feasible and potentially commercially viable to: a) Produce electricity from coal and other low-value carbons with virtually no harm to the environment; and b) create a variety of new products from coal ("polygeneration"), including hydrogen, natural gas and raw materials ("feedstocks") for the petrochemical industry. Water issues affecting clean coal are:

- Reducing Water Demand for Cooling – Higher power generation and energy use efficiency in the petrochemical/refining industries will result in lower water consumption for dumping waste energy.

- Reduce Emissions to Air or Water – Fully integrated and efficient processes should encourage economic or low-cost capture of most air or water contaminants and provide for stabilized long-term storage of any byproducts that are of little current value.

### 12.2.4. Oil Sands Upgrading

Lead Organizations – CONRAD and major oilsands producers and refiners. Focused through the EnergyINet Upgrading manager.

Objective of Collaboration - The Energy Innovation Network's (EnergyINet) Upgrading Innovation Program is focused on ensuring that Canadians reap a larger economic benefit from the vast resources of the Alberta oil sands, while reducing the impact on the environment. Water issues affecting upgrading are:

- Source of Hydrogen – Current focus is on SynGas generation, which should not greatly impact upgrader water demands. However, if at some point bio-upgrading or generation of hydrogen by electrolytic processes (such as nuclear reactors) were ever shown to be a viable option they would increase water use by upgraders.

- Process Cooling – Upgraders and refineries usually maximize the use of heat exchangers to minimize net additions of energy to the process, which reduces the volumes of water consumed for process cooling. As energy and emissions costs increase, energy efficiency will also tend to improve reducing demands for cooling water.

- Combined Upgrading/Extraction – Some methods of combined upgrading and extraction (e.g. Taciuk processor, although this has not yet been shown to be an economic option for Alberta oil sands operations) produce dry tailings and would result in a smaller, and more stable tailings stream with a much lower water content. EnergyINet will be considering options in this area as past of Upgrading/Extraction integration.

- Production and Long-term Storage of Wastes – Coke, asphaltenes, sulphur, heavy metals and other streams rejected from upgrading processes need to be stabilized and stored in a manner that will prevent contamination of watersheds.

### 12.2.5. Alternate and Renewable Energy

Lead Organizations – Federal and provincial research organizations and large power utilities. Focus through the EnergyINet Renewable and Alternate Energy Manager.

Objective of Collaboration - The Energy Innovation Network's (EnergyINet) Alternate and Renewable Energy (ARE) Innovation Program is built on the premise that the energy challenges of the next several decades will require power-generating technology that can make better use of existing energy resources, deliver power more flexibly, and reduce greenhouse gas emissions. It has four areas of focus: i) Fuel cell technology; ii) Hydrogen; iii) Bio-energy; iv) Technology and public education to support energy efficiency. Water issues affecting renewables are:

- Hydrogen Supply – As with upgrading, hydrogen from water sources will impact water consumption in the regions where the hydrogen is generated.

- Bio-energy – Generation of extra biomass through additional irrigation or harvesting of natural biomass sources will impact local water resources as well as requiring water for bioprocessing. Where the biomass is already readily available, e.g. landfills, agricultural or forestry waste, the increased use of water should be balanced against the decreased potential for water contamination.

- Education – Much of the energy used in modern society and industry is related to water in some way either through dissipation of heat, consumption of water or production of hydrocarbon resources, which in-turn impacts water. Education to enhance energy efficiency will also tend to reduce water use as well as reducing water and air emissions, which contaminate source streams.

## 12.3. Connections to Other Water Initiatives

With the recent years of drought, which have caused major hardship for the agricultural industry in the southern WCSB and heightened water quality concerns by urban and rural residents, there is a growing body of organizations to address water related issues. Some of these organizations have been in operation for many years while others are just being formed and working to define their own visions, strategies and objectives. In addition to human health, water impacts almost all business and environmental issues in some way. Nationally and internationally water issues are shared and the EnergyINet may be able to obtain information on solutions from other regions or countries, or help to provide solutions developed through the INet.

### 12.3.1. University Based Institutes

Provincial, federal and industry funding has provided resources for the launching of a number of University Based Institutes with various degrees of focus on water issues. Examples are: Alberta Ingenuity Centre for Water Research (Universities of Alberta, Calgary and Lethbridge); Institute for Sustainable Energy, Environment and Economy (U of Calgary); Water Institute for Semi-arid Environments (U of Lethbridge); Prairie Adaptation Research Collaborative (U. of Regina and others); Parkland Institute (U. of Alberta).

Objective of Collaboration – To ensure that work of the various university based institutes is coordinated and to maximize opportunities and incentives for cross-collaboration between institutes and that the EnergyINet is aware of all such activities.

### 12.3.2. Industry Associations

Each sector of the primary energy industries and major energy users have associations which have stated positions on water use by their respective industries and encourage responsible use and protection of water resources by their members. Examples are: Canadian Association of Petroleum

Producers (CAPP); Coal Association of Canada (COAL); Canadian Petroleum Products Institute (CPPI); Canadian Chemical Producers Association (CCPA); Alberta Irrigation; Independent Power Producers of B.C. and others.

Objective of Collaboration – To ensure that water problems and issues that are common between industries are addressed efficiently and in a consistent manner to encourage proactive development of solutions to reduce water impacts and monitor progress.

### 12.3.3. Water Basin Management Committees

Many watersheds in the WCSB now have multi-stakeholder water basin management committees, which meet on a regular basis to discuss, identify and address unique or chronic water issues within their basin. These management committees come with a wide variety of mandates, membership and resources, mainly dependent on the industrial activities in the basin.

Objective of Collaboration – To ensure that all energy and water related issues in a region are being identified, discussed and resolved through consensus based decision-making and follow-up actions, and to share information, knowledge and solutions with other basin committees and other stakeholders, such as the EnergyINet and researchers, who may not normally be represented.

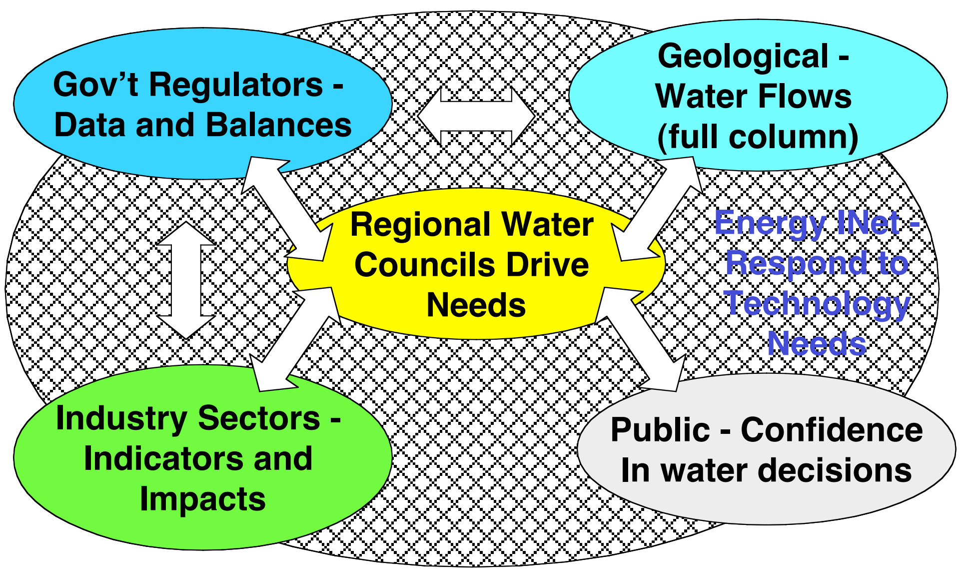


**Figure 12.1 – Regional Water Councils Central to Prioritization of Needs through the Active Participation of the EnergyInet**

### 12.3.4. Regional Think Tanks and Foundations

As discussion of water issues has increased, a number of regional organizations have started to address various policy, environmental and economic aspects of water debates. Examples are: Canada West Foundation, Fraser Institute, Pembina Institute, and others.

Objective of Collaborations – To raise new issues and bring as many viewpoints as possible into discussions of water use and emissions which will ensure key issues are recognized and addressed by any water technologies developed through the EnergyINet.

#### 12.3.5. National Water Connections

While water issues and problems vary dramatically by river basin, even within the same province or region, water issues are of national concern for environmental, economic, security, health and international relations. Also many water issues are shared between basins across the country, so national water networks and Federal departments are necessary to ensure ideas and solutions are made available to all. Examples are: Canadian Water Resources Association (CWRA), Canadian Meteorological and Oceanographic Society (CMOS), Canadian Ground Water Association (CGWA), Canadian Water and Wastewater Association (CWWA), Canadian Council of Ministers of the Environment (CCME), and others.

Objective of Collaboration – To access expertise knowledgeable in all aspects of water resources and users in Canada, which will help ensure that water technologies developed through the EnergyINet do not cause unanticipated problems. Also to ensure that other stakeholders are aware of actions being taken through the EnergyINet and the energy industry, which might impact water resources.

#### 12.3.6. International Water Connections

As a country rich in water and water related technologies, Canada's contribution to world water issues has been significant. Hydroelectric, oil and gas, agricultural, industrial, small community and large municipal water treatment technologies are greatly needed by other countries which are less well endowed with water, and other natural or economic resources. A number of organizations have been set up to transfer appropriate technology and know-how internationally. Examples are: WaterCan, World Health Organization (WHO), International Water Resources Association (IWRA), the World Bank and others.

### 12.4. Connections to the Public

Water is important to everyone and all members of the public are understandably concerned about anything that might affect the quantity or quality of their water supplies. However, in many areas there is a significant disconnect between the public's perception of water related risk and the actual risk associated with a given issue. Many issues are regionally important concerns, but do not pose the same threat in other regions. In other cases, there is insufficient information or knowledge for experts to prove a water impact is small, and the lack of proof is translated into a threat to the public. In many cases the issue is a lack of clear, timely and effective communication with the public, which leaves them to expect or anticipate the worst possible outcome for any issue.

#### 12.4.1. Replacing Uncertainty with Knowledge and Information

One step in the process of reassuring the public is to encourage research in areas where there is a high degree of uncertainty, and which will increase our understanding of water issues. While some areas are unknowable except in hindsight, there are many areas that could be better defined to reduce uncertainty. Aspects such as improved measurement of water use, consumption and quality, and hydrogeological assessments of water resources and natural water replenishment processes have already been pointed out in this report.

Objectives of Collaboration – To provide motivation and direction to accelerate and focus research or studies to reduce uncertainty in areas of highest priority or potential risk to the public related to water use by the energy industry.

#### 12.4.2. Clear Understanding of Impacts – Economic, Environmental and Security

The public also requires additional information on the full-cycle impacts of water and energy on all aspects of their life and the well being of society in general. All human activity creates trade-offs between personal lifestyle, economic, environmental and security issues and those decisions should be made with a clear understanding of the life cycle impacts of those decisions.

Objectives of Collaboration – To provide improved understanding of water and energy related issues for the public and government representatives to ensure that all trade-offs are properly assessed and the impacts balanced and minimized through directed development and application of policies and/or technologies to mitigate negative impacts.

#### 12.4.3. Mending the Disconnects

A key need is for the public and the media to be able to quickly connect with sources of easy to understand information on water and water impacts, that comes from credible, multi-stakeholder endorsed sources. In Alberta, the Clean Air Strategic Alliance (CASA) has come to be seen as a source of information on air issues, and serves as a forum for consultation and prioritization, but covers too broad a range of issues to conduct in-depth analysis, is dependent on volunteer participation, and suffers at times from insufficient technical support resources to enhance the credibility of their recommendations. The Alberta Water Council has indicated that similar organizations and processes, based on the CASA or PTAC models should be developed to help balance the issues. Given the complex technical nature of water issues the composition of any multi-stakeholder groups should include adequate scientific knowledge and resources.

Objective of Collaboration – To support the development of CASA or PTAC type processes for key water use issues and ensure that the process maintains integrity. To ensure that the results are clearly and effectively communicated to the public and media.

## 13. Energizing the Water Technology Process

Water use by the energy industry is under increasing public and political scrutiny and pressure to reduce impacts on fresh water resources in the WCSB. Pressure is building not only to discuss issues, confirm compliance with existing regulations and improve water use forecasts, but also to demonstrate action to reduce use. Actions to reduce use will also serve to stimulate technology development.

### 13.1. Building Consensus-Based Agreement on Issues and Priorities

The multi-faceted nature of energy industry water use means that there are a wide variety of water issues and a large number of factors which impact on water impact mitigation activities. A first step in energizing the water technology process is to build a consensus on the main water-related issues and relative priorities for each energy sector by river basin or region. This should be undertaken through a series of industry specific workshops, sponsored by the EnergyINet, the appropriate energy industry association, and potentially facilitated by the Petroleum Technology Alliance Canada (PTAC). The workshops would be open to all stakeholders and the results could be used to launch multi-stakeholder committee(s) to develop consensus based action plans for each of the major issue areas. To date the most successful model for this type of multi-stakeholder committee activity, including setting targets for change, is the process used by Alberta's Clean Air Strategic Alliance.

### 13.2. Filling the Knowledge Gaps

One of the first actions of the multi-stakeholder committees would be to identify and confirm knowledge gaps related to the key water issues and commission actions to fill those knowledge gaps, to improve understanding of the issues and assessment of options for mitigation. Requests for Proposals (RFPs), or some other process, could be used to determine who would conduct the required research.

### 13.3. Articulating and Promoting the Business Case for Conservation

As information and knowledge are collected and analyzed, the business case for taking action will become better defined based on improved understanding of economic, environmental and security of supply impacts. In cases where technology solutions already exist, the case for implementation of the solutions industry wide can be articulated and targets, backed by any appropriate regulatory guides or best practices can be developed and implemented. Public monitoring of results and progress would demonstrate that progress is being made and help to reassure the public.

### 13.4. Engaging with Industry to Drive Innovation

Where existing technical solutions are not available, or judged to be inadequate or inappropriate to meet the identified needs, then additional resources and RFPs could be allocated through the EnergyINet to encourage the development of new options. To encourage technology development, industry must provide the drive by setting realistic targets that define: What a "successful" technology would look like by specifying upfront target capacity ranges, capital and operating cost ranges and capabilities of any system requested. They must also commit to provide funds for field-testing of prototypes in appropriately selected locations, and adopt new technologies once proven.

## 14. Conclusions and Recommendations

Water issues related to the primary energy industries can have significant impacts on the future development of the energy industry in the Western Canadian Sedimentary Basin and around the world. This initial assessment of water technology needs, for key energy sectors in the WCSB has highlighted a need for early progress in the following areas:

### 14.1. Measure So You Can Manage

Conclusion – Without solid information on water supplies and use by sector and region it is very difficult to determine which area of technology development requires more focus and resources.

Recommendation - Therefore the first actions to be taken by the INet should be to encourage changes in water use reporting and initiate additional hydrogeologic studies to quantify the availability and deliverability of surface and sub-surface water resources in all regions of the WCSB with a priority on those regions (Athabasca and South Saskatchewan River Basins) experiencing rapid growth in water demand.

### 14.2. Water Enabling Energy Production

Conclusion – Water is a major enabler of energy development and highly variable in supply, even without any additional impacts, which might occur with climate change.

Recommendation – Greater effort and study is required to ensure that energy developments adequately address long-term water issues and variability. Increase industry, government and public recognition that each incremental use of water in any given basin will be at higher risk and justifies the incremental research efforts to reduce water use.

### 14.3. Adaptable Energy Technologies

Conclusion – It must be recognized that water and energy strategies and tactics must be adapted to the needs of each river basin, and potentially each sub-surface aquifer basin, in a region. Blanket solutions or objectives will likely not be reasonably applied in all areas.

Recommendations – Water Basin Management Committees should be the base decision unit for assessing water management needs and priorities in a given region. Energy industry representatives on these committees should be closely connected to the EnergyINet to provide input on new technology development requirements and to take back options from the INet for the consideration of the Basin committees.

### 14.4. Integrated Water Needs between Users

Conclusion - Acknowledged that water impacts almost every other human activity in some way, so it cannot be addressed as a stand-alone issue by any one sector in isolation.

Recommendation – The EnergyINet should strive to ensure that potential water issues and impacts are specifically and clearly addressed in all INet projects to ensure that water needs are clearly communicated to allow realistic water use targets and priorities for new technology development.

### 14.5. Balanced Approach Needed

Conclusion – While environmental and health impacts of fresh water use are upper-most in the public mind, the economic and societal security issues are also important considerations. Without a secure and prosperous economy there would be few people living in the region to be concerned about the environment. However, in most cases, technology solutions may be implemented or developed which can provide a balanced result.

Recommendation – In developing water technology needs, specifying research or development projects, the EnergyINet should attempt to ensure that objectives are communicated that cover all three legs of sustainability (Environment, Economics and Security). Single focus efforts tend to be difficult to successfully develop and impossible to implement without regulation.

### 14.6. Communication, Collaboration and Coordination

Conclusion – Due the large number of stakeholders in water and energy issues efficient methods of communication, collaboration and coordination are needed between the broadest possible range of stakeholders to ensure that all aspects of water use are considered.

Recommendation - The process of gathering relevant information and in providing efficient direction and resources to meet future water technology needs should be publicly transparent and encourage widespread participation by all stakeholders. A well-supported, collaborative multi-stakeholder process should be implemented with a greater commitment to provide proactive communication to the public.

**Appendices**

A. **Water Issues Table** – A draft to build on.

B. **Contacts List** – Who can we get involved?

C. **Summary of Key Water Technology Needs** – A place to start.

D. **Water Related References** – Places to look for knowledge and information.

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# Strategic Needs for Energy Related Water Use Technologies
# Water and the EnergyINet

## APPENDICES

**February, 2005**

**Bruce Peachey, P.Eng.**
**New Paradigm Engineering Ltd**

**Appendices**

A. **Water Issues Table** – A draft to build on.

B. **Contacts List** – Who can we get involved?

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*Appendix A*
*Summary of Survey feedback and Comments*

The following are the results of feedback from a number of contacts surveyed by e-mail. The results show a general indication of the respondents perceptions on the issues which were initially formulated by New Paradigm. This does not represent a scientific survey and respondents represented a small but diverse sampling across a number of energy sectors and interest groups. The High, Medium and Low rankings were based on a numerical input received from respondents and also issues which shows a high degree of divergence in opionions.

**Issues by Sector:**

| **#** | **Top10** | **Industry/Public Issue (Water Quality or Quantity** | Comments |
|---|---|---|---|
| | | **1. Upstream Oil Production** | |
| 1a | High | **Fresh water use for Oilfield Injection**<br>➢ Consumption for this purpose is often questioned during periods of low fresh water supply, especially in dry regions.<br>➢ Canada - Fresh water use for this purpose is only 1-2% of water use in Alberta; much lower in Sask. and B.C. and near nil in other provinces<br>➢ Globally – Offshore seawater is used; Other areas unsure of percentage. Max use would likely be $1m^3$ water/$m^3$ oil. | ➢ Might want to indicate what % of non-saline groundwater is allocated in Alberta – not just total water allocation (groundwater proportion is much higher). Figures on % of allocation actually used will be in Final Report of Advisory Committee (report may be published in September).<br>➢ Why mention seawater here? Would be better in 1d<br>➢ EUB fresh water priorities: EOR projects; CBM non-saline water; Drilling Water. EUB focus is on moving away from fresh water use for EOR projects.<br>➢ Alberta based references: Water for Life, Report on Underground Injection of Water.<br>➢ Given the competing interest for Alberta's limited water resources, the use of freshwater or reservoir injection is nevertheless coming under increasing public scrutiny.<br>➢ Seasonal.<br>➢ This issue is ranked highly because it has a disproportionately high level of public and regulatory concern, not because it is a tangible environmental hazard. Perception and emotion drive the issue. The concerns of water shortage (due to drought and overuse in some Southern Alberta basins) are real and justified, but attributing them to oilfield injection is unfounded. No hydrological or watershed scale environmental damage is attributable to oilfield injection of freshwater. The amount of fresh water used for oilfield injection is minor in comparison to other users and statements that the water is removed from the water cycle in comparison to other users (and therefore causes more environmental harm) are not scientifically justified. The vast majority of water used for oilfield injection occurs in basins that are not short of water.<br>➢ Although equally irrelevant on a water cycle basis, a large volume of water is |

*Appendix A*
*Summary of Survey feedback and Comments*

| # | Top10 | Industry/Public Issue (Water Quality or Quantity | Comments |
|---|---|---|---|
| | | | supplied to the surface water cycle through combustion of Albertan produced hydrocarbons than is used for Albertan enhanced oil recovery (thermal or conventional)<br>➢ This could become a bigger issue if water-based EOR is pursued on a larger scale. Some processes using chemicals (polymers, surfactants) are more economic/efficient with fresh water.<br>➢ Use of fresh water is linked to bitumen production as well, particularly for steam generation. Applies to both surface mined and insitu production. |
| 1b | Medium | **Waterflooding for Oil Recovery**<br>➢ Type of water used might impact oil recovery but large number of variables makes analysis difficult<br>➢ Lack of voidage replacement in some pools which rely on poorly understood natural water drive.<br>➢ Good reservoir practice is to maintain reservoir pressure above oil bubble point<br>➢ Global Issue for the Oil Industry | ➢ Comments as per 1a<br>➢ Basic Research<br>➢ Ranked highly because freshwater restrictions may have recovery implications.<br>➢ There is considerable recycle of produced water in waterfloods; probably about 80% of the injected water is from recycled produced water, but I don't have specific data. |
| 1c | Medium | **Energy costs of managing water**<br>➢ Rough estimate is that water management costs in Alberta alone are over C$1 billion/yr mainly in electrical power for pumping<br>➢ Globally Shell estimates water cost number is over US$40 billion/yr<br>➢ Often wells are shut-in or never put on production due to the | ➢ See economic instruments in Water for Life Report<br>➢ What is the basis for the AB water management costs?<br>➢ Water management costs, including both lifting and disposal costs, are a very significant input cost to oilfield production, especially in the high WOR fields. Additionally, corrosion control costs are also very significantly increase with increased WOR and co-produced entrained acid gases.<br>➢ Economic or Economic/Environmental<br>➢ If alternative water sources are used instead of locally available fresh water, more energy may be required for transport.<br>➢ Water treatment costs also apply.<br>➢ This is going to increase as the basin matures further and producing water-oil- |

*Appendix A*
*Summary of Survey feedback and Comments*

| # | Top10 | Industry/Public Issue (Water Quality or Quantity | Comments |
|---|---|---|---|
| | | high costs of managing water. | ratio increases (presently about 15 for conventional production based on AEUB data – up from 11.5 in 2000)<br>➢ By better understanding the costs associated with water management, a more accurate cost-benefit analysis can be performed. By knowing the long-term costs of water management, we can compare this with the long-term costs (and often cost savings) for alternative, more efficient technologies or options. This may lead to the use of more sustainable options that typically have a higher capital cost, but are more cost-effective over the long-term. |
| 1d | High | **Using other water sources for Injection**<br>➢ Underground Saline – issues with water supply potential of saline aquifers and water compatibility between zones,<br>➢ Municipal – issues with bacterial content and pipelining streams to injection,<br>➢ Industrial – issues with toxic contaminants currently going to deepwell disposal which might contaminate oil and pipelining to injection<br>➢ Cooling water – issue with slightly higher mineral content and warm temperature. Potentially other contaminants. | ➢ It would be logical to put 1d after 1a.<br>➢ Changes in shallower saline aquifers may affect pressure and thus flow regime in non-saline aquifers. Emeritus Prof from U of A, Edo Nyland told me about this.<br>➢ Refer to fact that can also use alternatives to water – e.g. CO2 for enhanced recovery – though there are issues with this too.<br>➢ See G-65; commingling<br>➢ Unclear<br>➢ See G-51 and 65<br>➢ Introduction of bacteria into the reservoir can over time result in the field becoming more sour, resulting in increased corrosion costs and higher operating costs.<br>➢ Municipal and Industrial are other sectors. Cooling water – Economic/technology gap<br>➢ Net environmental benefit should be considered. In basins where water is not in short supply, there are few or no tangible environmental issues. Changing the status quo and pipelining non-fresh water supplies to injection points in these basins will require more energy, will require more surface disturbance, will result in more spills, and will leave marginal oil resource behind because of poor economics.<br>➢ My perception is that underground saline sources are being used for many waterfloods.<br>➢ A cost-benefit analysis could be performed, that compares the pros and cons of fresh vs. saline water use, while taking into account the triple bottome line. Some examples that may be explored include, brine spillage and the environmental effects on aquifers, flora and fauna, fresh water shortage, the value of fresh water (socially, environmentally and economically), the economic impacts of different options (saline vs. fresh) and technologies (water treatment, enhanced efficiencies, etc.) etc. |

*Appendix A*
*Summary of Survey feedback and Comments*

| # | Top10 | Industry/Public Issue (Water Quality or Quantity | Comments |
|---|---|---|---|
| 1e | Low | **Drilling impacts on potable aquifers**<br>➢ Mud contamination of acquifers<br>➢ Cementing blocking artesian flows<br>➢ Lack of data on acquifers<br>➢ Local easy to access sources for drilling water needs | ➢ Not sure what last bullet means.<br>➢ This does not fit (re cementing blocking aquifers).<br>➢ Impact on potable water is a very significant concern for surrounding landowners and communities.<br>➢ Knowledge gap/environmental<br>➢ Very localized concerns are justifiable, especially if non-water based muds or additives are used.<br>➢ Lack of data on aquifers in Alberta is a real concern that requires government funding and resources. Caution is given that the government should not rely only on industrial studies to build this knowledge because it will give patchy information in areas of relatively low population. |
| 1f | Medium | **Leakage/spills to surface waters or potable zones**<br>➢ Casing leaks or failures<br>➢ Pipeline leakage | ➢ EUB Field Surveillance Provincial Summary reports give figures on leaks and spills. http://www.eub.gov.ab.ca/bbs/products/STs/st57-2004.pdf<br>➢ EUB has extensive regs covering this<br>➢ Destruction of cropland a significant concern, requiring extensive and time consuming remediation, and loss of land use to landowners. The possibility of ground water contamination also exists.<br>➢ Technology gap/environmental<br>➢ Localized issues persist and should be managed responsibly by the operator in conjunction with the regulator. Remediation should be undertaken where necessary.<br>➢ Comments given for 1d may also apply here. |
| 1g | Medium | **Produced water disposal, saline water leakage**<br>➢ Also an issue for deep well disposal of toxic materials with the water | ➢ Risk earth tremors if over-pressurize, etc.<br>➢ See G 65 & 51<br>➢ Again destruction of cropland a significant concern, requiring extensive and time consuming remediation.<br>➢ Economic/Environmental<br>➢ Localized issues persist and should be managed responsibly by the operator in conjunction with the regulator. Remediation should be undertaken where necessary.<br>➢ This is going to increase as the basin matures further and producing water-oil-ratio increases (presently about 15 for conventional production based on AEUB data – up from 11.5 in 2000)<br>➢ Comments given for 1d may also apply here |
| 1h | Low | **Use of salt caverns for waste** | ➢ Brine from creation of cavern can be disposed in other wells, does not have to go |

| # | Top10 | Industry/Public Issue (Water Quality or Quantity | Comments |
|---|---|---|---|
| | | **disposal**<br>➢ Growing use of caverns for oily waste and sand produced from heavy oil wells. Some caverns used were made during commercial salt production. Often incremental oil is recovered from the caverns.<br>➢ Issues cavern integrity, loss of oil with the waste, forming caverns adds salt to the environment if they are just formed for storage. | into surface environment. There is an issue if non-saline water is used to create caverns for waste disposal – but total volumes less c.f. oilfield injection.<br>➢ See G65 and 51<br>➢ Caverns are also used for storage and treatment.<br>➢ In most cases, the caverns are below the oil recovery zone and as such pose little threat to the environment except for the disposal point itself and ensuring casing integrity. This is regulated. The wash water for developing the caverns is generally disposed of in even deeper formations with no chance for loss of integrity to the surface except for surface handling and injection. |
| 1i | Medium | **Thermal HO – What will ultimate voidage replacement be?**<br>➢ Currently 1 bbl fresh water per bbl of bitumen used but only 0.4 bbl/bbl replacing bitumen, rest goes to disposal | ➢ Not sure about meaning of "rest goes to disposal" – Is the issue that a higher proportion is not recycled?<br>➢ Industry has improved efficiency<br>➢ All scheme approvals have conditions requiring recycle.<br>➢ Need to have a radical assessment of thermal heavy oil technology? Alternative?<br>➢ Cold Lake Operations averages about 0.5 cubic meters of fresh water per cubic meter of bitumen recovered. This is made possible by the >95% produced water recycle rate and the use of brackish water. In thermal operations voidage is also replaced by geomechanical (formation dilation) and thermal effects (rock expansion due to heat and gas evolution from rock and heat)<br>➢ There is talk of the possibility of filling steam chambers with gas at end of expoitation.<br>➢ The more important aspect is the amount of fresh water required for steam generation – 3-4 bbl water/bbl of produced bitumen. Bitumen production is predicted to almost triple in the next 10 years so this will put a lot of pressure on the available water.<br>➢ Technologies for steam generation using brackish or saline water are being developed.<br>➢ Increasing importance, given increasing interest in northern oilsand development and in previously inaccessible reserves (i.e. use of SAG-D, etc). Optimizing the |

| # | Top10 | Industry/Public Issue (Water Quality or Quantity | Comments |
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| | | | voidage replacement can reduce water use/waste, which is also becoming more important in Alberta, given the Alberta Water for Life Strategy. |
| 1j | High | **Thermal HO – What percentage of water recycle is achieveable?**<br>➢ Current Alberta Data indicates 60% of fresh water withdrawals goes to disposal, even though recycle percentages are higher. | ➢ Again – needs to be expressed more clearly. Recycle percentages are higher than what?<br>➢ As per 1i.<br>➢ Need to have a radical assessment of thermal heavy oil technology? Alternative?<br>➢ Col Lake Operations achieves, on average, better than 95% recycle rate of produced water.<br>➢ Research is needed to prove to industry that water recycling is a viable option that could easily (and cost-effectively) be incorporated into traditional operations.<br>➢ See also comments from 1i. |

**Other Issues & Comments:**

- ➢ Demand for non-saline water for HO is likely to increase – major issue. Need to look into alternatives e.g. solvents like Vapex. Demand for new source water for conventional is declining.
- ➢ I believe it's time to have a critical look at the big picture of oil recovery technologies by incorporating the constraints (known or anticipated) up front. Many of the issues are on treatment or management of water rather than minimize water use (i.e. root-cause). Despite the current economics, do we know other technologies that use less or no water?

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| | | **2. Upstream Gas Production and Processing** | |
| 2a | Low | **Impacts of acid gas ($H_2S/CO_2$) injection on disposal zone**<br>➢ Low sulphur prices have resulted in acid gas injection being an alternative disposal method for $H_2S$<br>➢ In some cases acid gas might be used for EOR | ➢ EUB is promoting use of $CO_2$ for EGR projects.<br>➢ Do we know the fundamentals? |
| 2b | High | **Dewatering of Coal Bed Methane and Hydrate formations**<br>➢ Unlike conventional natural gas CBM and Hydrate formations may not be contained by an overlying caprock seal. Gas is physically trapped at the molecular level so once released by dewatering it may not be restricted to flowing to | ➢ This is an issue in non-saline water formations or in close proximity to non-saline water, where there may be interconnectivity.<br>➢ These are not related topics.<br>➢ Remove reference to hydrate<br>➢ Adequately regulated; media problem only.<br>➢ Concern for landowner and community potable water.<br>➢ Disposal of saline water may be an issue depending on the salinity |

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| | | production wells. | of the water pumped from CBM formations. |
| 2c | Medium | **Impact of zone depressuring on hydrological balance**<br>➢ Low density gas requires more water than oil to replace an energy equivalent of production.<br>➢ If the hydrological balance is not maintained groundwater flows will change to fill the voidage over years, decades or centuries but there is little understanding of the impact of this. | ➢ AENV jurisdiction<br>➢ Of increasing importance in Alberta, given the Alberta Water for Life Strategy and the public's perception |
| 2d | Low | **Gas losses due to rapid water influx during production**<br>➢ If water flows into a gas producing zone too rapidly, compared to gas production, some of the gas in place will be trapped by water<br>➢ If a gas reservoir repressures during a lull in gas production a great deal of water will have to be pumped out to recover water trapped gas. | ➢ AEUB has procedures in dealing with gas blowdowns.<br>➢ Coning water because of too rapid gas production is a concern that can significantly harm ultimate gas recovery. |
| 2e | Low | **Dewatering shallow gas wells**<br>➢ Small amounts of water produced with gas can reduce recovery if the water cannot be removed from the well, resulting in a loss of reserves. | ➢ Existing technology includes siphon strings and drip separators. |
| 2f | Low | **Disposal of small volumes of water produced with gas.**<br>➢ Gas wells usually produce small volumes of water or other liquids which must be separated and disposed of at the well or at a centralized facility.<br>➢ Any water in a pressurized gas stream can cause hydrates and increased pipeline pressure losses. | ➢ CBM wells can produce large volumes of water – especially the saline water from the Mannville formation in Alberta.<br>➢ Don't dehydrators solve this problem?<br>➢ Streams are too small for dehydrators.<br>➢ Has the VOC's emission problem from dehydrators been solved?<br>➢ This is unclear |
| 2g | Low | **Hydrate prevention in multiphase lines**<br>➢ Often encountered where gas and hydrocarbon condensates are pipelined together. It is often easier to remove water from gas than | ➢ Industry uses line heaters and methanol injection to control hydrates.<br>➢ Often requires well head dehydration, which of itself can be costly and results in benzene and other VOC emissions in the reprocessing of |

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| | | from the liquid, but water in liquids can cause hydrates. | the glycol. |
| 2h | Medium | **Gas in water wells**<br>➢ Rural water wells often produce methane with the water. If there is an oil or gas operation in the area it is assumed that there has been contamination of the aquifer, but the source may be natural. | ➢ Need to explain that it is biological processes that can cause the gas in rural water wells.<br>➢ More research is needed to develop tools/capacity to identify where source of gas originated, some isotope work initiated at U of S/AGS<br>➢ Even so, still a very high concern for landowners, and often resulting in adverse public relations for the industry. |
| 2i | Medium | **Post-abandonment well integrity**<br>➢ Abandoned wells have sometimes been found to leak as underground formations naturally repressure with water influx. Water can also lead to chemical breakdown of materials used for abandoning the wells. | ➢ Need monitoring program to test well integrity in areas of CBM production – to ensure no gas migration (as happened in San Juan basin in early days of CBM production.)<br>➢ EUB is currently investigating this issue.<br>➢ High concern for landowners and communities. |

**Other Issues and Comments**

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| | | **3. Industrial Cooling** | ➢ |
| 3a | High | **Fresh water use with no economic benefit except lower capital cost.**<br>➢ Water for cooling is used to dump energy which has been input to the process at a high quality, after it has been degraded to lower quality energy. Dumping energy itself generates no revenue it just lowers initial capital investment. | ➢ Section 3 is AENV Jurisdiction.<br>➢ See comments for 1c. |
| 3b | Medium | **Cooling through evaporation so water volume reduced**<br>➢ Only a portion of the water withdrawn is returned to the source. A typical power plant might return 30-60% of the withdrawal the rest is lost to the atmosphere. | ➢ Would be good to show studies where this loss has been measured – and also compare with irrigation using high spray systems. I don't think these losses to a specific watershed are generally recognized – which is why there has been so much public attention on the use of water by the oil industry. We need to educate people on all ways that water is lost from a specific watershed.<br>➢ Alternative cooling/heating technologies and vapour-recovery systems should be explored. Vapour loss is a common occurrence in the industry, and in an untapped source of both |

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| | | | heat and water, both of which may be recaptured and reused to reduce energy consumption and raw water requirements.<br>➢ As much of the power is ultimately utilized in oilfield production, the oil industry indirectly contributes to much of these water losses.<br>➢ Should therefore explore policies that further encourage distributed generation as the environmental footprint is much smaller, and water usage for distributed generation is much reduced or even eliminated. |
| 3c | Medium | **Return water has higher mineral concentration and higher temperature**<br>➢ Streams used for evaporation have all the minerals concentrated in the remaining water increasing the mineral loading on downstream users. | ➢ |
| 3d | High | **Second largest fresh water allocation for withdrawals globally**<br>➢ Water use for cooling is usually 1st or 2nd largest withdrawal in most developed countries. Env. Canada 1996 data indicates 64% of Canadian water withdrawals are used for Thermal Power (coal and nuclear) and 14% for manufacturing. These percentages do not include water for hydroelectric power generation.<br>➢ Generates competition and potential conflicts over water in dry regions. Energy vs. agriculture | ➢ See comments from 3b. |
| 3e | High | **Other contaminants can be included biocides, run-off from site, etc.**<br>➢ Cooling water returns often also contain biocides to reduce cooler fouling, anticorrosion chemicals, and other contaminants that are not at toxic levels but reduce water quality to the environment or downstream users.. | ➢ |
| 3f | Medium | **Thermal impacts on river flora and fauna**.<br>➢ Cooling water is discharged back to sources normally at a higher temperature than the source. Some organisms can be greatly affected by small shifts in water temperature. | ➢ |

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| 3g | Low | **Water used is to dump energy to the environment**<br>➢ Cooling can be provided by evaporative cooling, radiative cooling or heat pumps. Traditionally evaporative cooling has been lowest capital cost for large industrial loads. | ➢ Additional issues like fog around cooling ponds, cooling towers. Need to integrate systems that can use this heat – district heating, greenhouses, etc. |

**Other Issues and Comments:**

➢ In my opinion, these are the operating issues resulting from the assumption of free water, (i.e. purely economic and readily available commodity). We knew very well the answers to all these concerns; just look at the refineries in Saudi countries.

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| | | **4. Energy Mining Oil Sands, Coal and Uranium (Tailings, Dewatering, Processing)** | ➢ |
| 4a | High | **Disposition of water from mine dewatering.**<br>➢ Surface and underground mines must be dewatered to allow operations which may drain water from surrounding areas or groundwater sources<br>➢ Mine water can be of different quality to normal surface waters they may be discharged into. | ➢ The first bullet is a quantity issue and seems related to 4f.<br>➢ The second bullet is a quality issue – should this be separate.<br>➢ Extensive research on tailings management is being conducted by CONRAD<br>➢ Fact of life. |
| 4b | High | **Water sources for extraction and cleaning processes**<br>➢ Most mining operations use water for cleaning or extracting the desired components. Fresh water usually preferred but other options may be available. | ➢ Oil sands processing requires large volumes of fresh water<br>➢ We should list all the options<br>➢ This is going to be a significant issue for bitumen production in light of proposed development; water for hot water/steam separation and for steam generation in in situ recovery projects will increase significantly.<br>➢ Comments from 1d may apply |
| 4c | High | **Water recycle from tailings**<br>➢ Maximizing water recycle from tailings reduces the water content and volume of tailings to be stored. | ➢ As per 4a<br>➢ Economic |
| 4d | Medium | **Water retained in stable tailings**<br>➢ Water retained in tailings can make them unstable over the long-term<br>➢ Water exchange in tailings could cause leaching of tailings components. | ➢ As per 4a<br>➢ Knowledge gap |
| 4e | Medium | **Impacts of loss of water storage in muskeg areas.**<br>➢ In northern areas muskeg or wetlands hold up water | ➢ Refer to AENV<br>➢ Emerging issue, given the increasing oilsand exploration in |

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| | | run-off to level water flows. | northern areas. |
| 4f | Medium | **Watershed alterations and restoration**<br>➢ Many mines require diversion or draining of surface waters and alter natural flows. | ➢ 4f seems to follow after 4a. They are very similar.<br>➢ Refer to AENV |

**Other Issues and Comments:**

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| | | **5. Hydroelectric** | ➢ |
| 5a | Low | **Water losses due to evaporation not included as allocations or withdrawals**<br>➢ Estimates of water evaporation from reservoirs not usually counted as a withdrawal or an allocation. World wide it is estimated that reservoir evaporation adds about 25% to the total water withdrawals. | ➢ This is again something that needs more attention. But with large reservoirs would there be a beneficial effect downwind, due to more water vapour in the atmosphere? |
| 5b | Low | **Unknown volume of evaporation losses.**<br>➢ Generally water losses are estimates. | ➢ |
| 5c | Low | **Concentration of minerals and contaminants.**<br>➢ Evaporation concentrates minerals and contaminants in the water, also increases the average water temperature due to increased solar energy absorbed and loss of water mass. | ➢ |
| 5d | Low | **Release of contaminants in sediments when dams decommissioned or dredged.**<br>➢ Lower water velocities cause silt and other solids to settle out upstream of dams. To maintain storage volumes eventually this material must be removed or it may be released to allow dam replacement. | ➢ |
| 5e | Low | **Impacts of stream flow generation (no storage) vs dams.**<br>➢ Stream flow power generation provides power without a dam so water and sediments are less affected but stream flow provides no storage or control of the flow to prevent flooding or load level supply. | ➢ Stream flow power generation usually regarded as far preferable to dams.<br>➢ AENV jurisdiction |
| 5f | Low | **Reservoir Management – recreation, power or agriculture**<br>➢ Reservoirs serving a number of purposes often suffer if the needs conflict. E.g. stable lake level vs. variable | ➢ |
| 5g | Low | **Impact of reservoir location**<br>➢ Evaporation losses from mountain reservoirs may be less | ➢ |

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| | | than for prairie reservoirs but need longer transmission lines and more susceptible to silting. | |
| 5h | Low | **Impacts of reservoirs on weather**<br>➢ Changes in water distribution can impact local and regional weather patterns | ➢ Irrigated area is far more effective at changing weather because of the greater evapotranspiration from these areas. |
| 5i | Low | **Reservoirs for off peak energy storage and peak shaving**<br>➢ With reservoirs water can be pumped against the flow to store power from renewable sources to meet peak demands | ➢ |

**Other Issues and Comments:**

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| | | **6. Refining, Petrochemical and other Industrial Uses (non-cooling water processes)** | ➢ |
| 6a | Medium | **Deepwell disposal of toxic contaminants.**<br>➢ Similar to oil produced water disposal but higher impacts. | ➢ See G-51 & 65<br>➢ Environmental/technology gap |
| 6b | Low | **Salt contamination from formation of salt caverns.**<br>➢ Formation of salt storage caverns generates large volumes of brine to dispose of unless the salt is removed | ➢ Not sure about this point. We have the issue of creating salt caverns when salt is NOT needed in earlier section. If the petrochemical industry creates salt caverns isn't it because they actually need the salt for their processes – so why would there be large volumes of brine left? I don't know much about this, but maybe it should be clarified.<br>➢ See G-51<br>➢ Brine disposed in class II disposal well (same as O/G produced water disposal)<br>➢ Need to establish a baseline |
| 6c | Medium | **Hot discharge water from pulp-mills**<br>➢ Large volumes of hot water from pulp mills contain a considerable amount of energy that could be recovered and also contain organic material | ➢ Economic |
| 6d | Low | **Water use in bioprocesses to replace current chemical processes.**<br>➢ Most chemical processes using hydrocarbons might be replaced by lower energy processes using bioprocesses to reach the same end-points. | ➢ Don' know anything about this.<br>➢ Economic (have yet seen a viable bioprocess) |

**Other Issues and Comments:**

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| | | **7. Irrigation and biomass fuel production and processing** | ➢ |
| 7a | Low | **Water demands for biofuel processes**<br>➢ Bioprocesses require water that generally is the source of hydrogen needed to breakdown large organic molecules into lighter hydrocarbons. | ➢ This section covered by AENV & Agriculture<br>➢ The issue of competition for water use must be addressed so water is used appropriately. |
| 7b | Low | **Water impacts of biomass sources**<br>➢ Large volumes of biomass will require large volumes of water to produce. | ➢ But at the same time, gas production from biomass and subsequent power generation with it can reduce water consumed in centralized generation AND reduce groundwater (and river water) contamination, as has occurred for example in large feedlot or cattle operations. (e.g. Walkerton) |
| 7c | Low | **Energy use for irrigation water management**<br>➢ Primary cost of irrigation is energy to pump water. Viability of irrigation for low value crops (like cattle fodder) will be reduced as energy costs increase.<br>➢ Globally 2/3 of fresh water use is for crop irrigation. Irrigation constitutes 9% of Canada's withdrawals (Mainly Prairies and B.C.) but is 71% of Alberta's water consumption which all comes from the South Saskatchewan River Basin. | ➢ Are you sure about the 71% figure? I assume it must be for USE, but I didn't know we actually had this figure. The AENV statistics show that 45% of water allocations in Alberta are for irrigation.<br>➢ Economic |

**Other Issues and Comments:**

- No rankings put in this sector – just don't know.
- Agricultural run-off is often a source of contamination to water-sheds.
- Irrigation leads to salinization in much the same way described for hydroelectric dams.
- Excessive withdrawals for irrigation have damaged southern AB watersheds. Droughts cause hardship to this industry and to the watersheds which has created concerns targeted at other industries not using significant water volumes in Southern watersheds.

**Other Sectors that should be included which have a strong link between energy supplies and water use? List and indicate why the Sector should be included.**

- Large hog/cattle operations contribute to the overall use of water in Alberta and also the degradation of water quality (water/waste disposal) for example, E-coli, etc.

*Appendix B*
*Contacts List*

Initial list of contacts believed to have an active interest in water issues for the energy industry. Many have been contacted and have provided input to the current study. Others were involved in water workshops organized through similar initiatives.

**Note - The organizations listed are intended to show the extent and focus of a particular individual's involvement with water issues, rather than being a sole spokesperson representing those organizations.**

| Chapter | Contact(s) | Organization |
|---|---|---|
| 4 | Al Smandych – Environmental Advisor Compliance and Operations Branch 403-297-6154 al.smandych@gov.ab.ca | AEUB |
| 4 | David Trew, – Water for Life; Maanger Water Section Science and Standards Branch David.trew@gov.ab.ca 780-427-3029 | Alberta Environment |
| 4 | Diana Gibson – DGibson@codev.org | Parkland Institute |
| 4 | John Fox - Chief Petroleum Engineer jfox@em.gov.mb.ca 204-945-6574 | Manitoba Energy and Mines |
| 4 | John Mayor – Sask Environment – jmayor@serm.gov.sk.ca 306 787-2758 | Saskatchewan Environment – Green Policy |
| 4 | Linda White – linda.white@gov.abc.a 780-427-6383 | Alta Dept of Energy |
| 4 | Mary Griffiths – maryg@pembina.org 780-433-6675 | Pembina Institute for Sustainable Development, Alberta Water Council |
| 4 | Robert Roach, Sr. Policy Analyst roach@cwf.ca 403-264-9535; Karen Wilkie, Policy Analyst wilkie@cwf.ca 403-264-9535 ext 356 | Canada West Foundation |
| 4 | Ross Curtis – ross.curtis@gems9.bov.bc.ca 250-356-7512 | B.C. Energy and Mines |
| 4 | Stuart Kramer – 306-694-3919. stuart.Kramer@swa.ca | Saskatchewan Watershed Authority |
| 4 | Wayne Patton, Director of Program Development wayne.patton@haskayne.uclagary.ca 403-210-9784 | Institute for Sustainable Energy, Environment and Economy (ISEEE) |
| 5 | Bob Nichol – 780-422-1413 john.r.nichol@gov.ab.ca | Consultant – Oil and Gas Production |
| 5 | Gary Webster, Director, environment and Technology – gwebster@newalta.com 403—206-2688; Clyde Fulton, Sr. Process Engineer Wastewater cfulton@newalta.com 403-232-0878 | Newalta |
| 5 | Kevin Stashin – VP Operations Kevin.stashin@devoncanada.com | Devon Canada/Alberta Water Council |
| 5 | Larry Kratt, Manager Environment, larry_kratt@nexeninc.com 403-699-6207; Jacinta Reid member CAPP's Water Strategy Committee, jacinta_reid@nexeninc.com; Wishart Robson – Wishart_Robson@nexeninc.com | Nexen Inc. |
| 5 | Lloyd Visser, Manager, Environment and Liability – Lloyd.l.visser@conocophillips.com 403-233-3042 Pam Lulman – Pam.S.Lulman@ConocoPhillips.com 403-233-3722 | ConocoPhillips |
| 5 | Richard Baker – Ph 403-444-1466 Email: Richard@epiccs.com | EPIC Consulting |

## *Appendix B*
## *Contacts List*

| Chapter | Contact(s) | Organization |
|---|---|---|
| 5 | Roger Delbaere – roger.delbaere@gov.ab.ca 780-422-9483 | Consultant - Petroleum Engineering |
| 6 | John Pearce – manager Heavy Oil john.pearce@devoncanada.com 403-232-7111 | Devon Canada Corporation |
| 6 | Rick Gallant – Cold Lake Operations Manager – 780-639-5117 rick.j.gallant@esso.ca; Dr. Stuart Lunn; Mark Taylor, Cold Lake Reservoir Engineering Manager | Imperial Oil |
| 8 | Al Kennedy – kennedya@novachem.com | Nova Chemicals/Alberta Water Council |
| 8 | Alex Starosud – astarosud@ucalgray.ca | Davnor Water Treatment Technologies |
| 8 | Bert Dreyer – bertdreyer@shaw.ca | Consultant - Distributed Power |
| 8 | Hongqi Yuan – Pulp and Paper Research scientist yuan@arc.ab.ca 780-450-5391 | Alberta Research Council |
| 8 | Les Johnston – Director, Environment and Sustainable Dev't – ljohnston@epcor.ca 780-412-3488 | Epcor |
| 9 | Allen H. Wright, Executive Director wright@coal.ca 403-262-1544 | The Coal Association of Canada |
| 9 | Cam Bateman manager, Technical Services Fuel Supply, Generation Cam_Bateman@Transalta.com 403-267-7128 (groundwater) Roy Montieth Roy_Montieth@transalta.com 403-267-8423 (hydro) | TransAlta |
| 9 | Don Downing – ddowning@norwestcorp.com 403-237-7763; Zoli Lukacs zlukacs@norwestcorp.com | Norwest Corp |
| 9 | Jim Blum, Sr. Tailings Engineer jim.blum@albiansands.ca 780-713-4485 | Albian Sands |
| 9 | Judy Smith, VP Environment Oil Sands Div – Judy.Smith@shell.ca 403-691-2113 | Shell Canada Ltd/Alberta Water Council |
| 9 | Keng Chung – Upgrading Program Director EnergyINet keng.chung@gov.ab.ca 403-297-3117 | Alberta Innovation and Science |
| 9 | Les Sawatsky, - lsawatsky@golder.com 403-299-5600, Principal, Director of Water Resources | Golder Associates Ltd. |
| 9 | Mike Kelly, Director of Environment, Health, Safety, Mike_Kelly@Transalta.com | TransAlta Utilities/Alberta Water Council |
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## *Appendix B*
## *Contacts List*

| Chapter | Contact(s) | Organization |
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| 12 | Diana Boylen, Regional Planning Coordinator, Diana.boylen@nrcan-rncan.gc.ca 780-435-7269 | Natural Resources Canada, Canadian Forest Service and Prairie Water Council |
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| 12 | Geoff Strong, CMOS – geoff.strong@shaw.ca Mackenzie Valley GEWEX study. | U of Alberta |
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*Appendix C*
*Summary of Key Water Technology Needs*

# *Appendix C – Summary of Key Water Technology Needs*

## 1. Conventional Oil Production

**5.1.4.1. Hydrogeology** - Geological assessment of brackish water zones especially those deeper than 400-500m, water quantities and qualities, source aquifer refill impacts.

Status – The Alberta Geological Survey and similar Provincial and Federal Surveys have done some work on water resources on the past. However, few activities have focused on the deliverability and total water volumes that might be available from such sources.

**5.1.4.2. EOR Study** - Reservoir comparison of recoveries between Saskatchewan and Alberta reservoirs to quantify water quality impacts.

Status – The EnergyINet is currently funding an EOR Study, however, that work is focused on Alberta and is not looking at the type of water used as a primary focus. A joint project might be developed, with participation by the Alberta and Saskatchewan governments, to assess water quality impacts on production.

**5.1.4.3. Water Sources** - Study of options for using saline water aquifers at low cost (e.g. water dumping from lower zones at higher pressure).

Status – ARC (Ashok Singhal) proposed a study in 2002 to look into the potential for "dump flooding" of oil reservoirs to allow transfers from lower water zones without requiring the water to be lifted to surface first. Currently this work remains unfunded.

**5.1.4.4. Water Sources** - Feasibility of using other lower quality water sources from municipalities, industrial or power plant discharges.

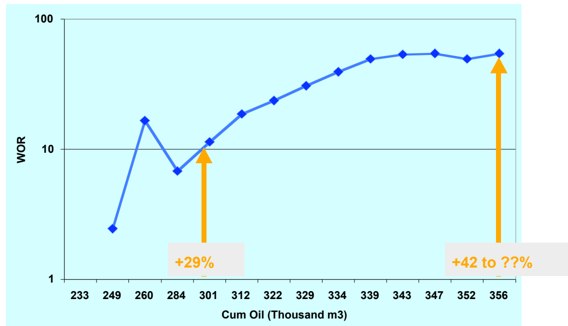
Status – The AEUB has suggested using treated sewage, or industrial waste-water streams to supply water for oilfield injection. The main hurdles identified that require study, are impacts of these streams on reservoirs, pipeline transportation issues and assessment of other impacts of removing these streams. Water discharges from power generation or industrial cooling could also be considered as they are higher quality than sewage or industrial wastes and also may contribute to production by being warm.

**5.1.4.5. EOR Study** – Definition of potential prize for water and other types of EOR.

Status – This work is underway through the EnergyINet study by EPIC Consulting and other collaborators. There are timing issues and trade-offs between use of water for water-floods vs. use of more expensive injectants such as carbon dioxide, nitrogen or other materials.

## 5.2. Produced Water Recycle

**5.2.4.1. EOR Study** - How many wells level out at a given WOR? Is this predictable? Assess through evaluation of existing high WOR[1] fields like Redwater.




WOR vs. Cumulative Oil Plot for a Redwater Well showing incremental oil recovery as WOR increases above $1 m^3/m^3$

**Figure 5.3 – Benefits of Low Cost Water Handling**

Status[2] – Data on well production in AEUB and SIR databases can be used to locate and analyze wells with high WOR's. Unknown if anyone has attempted this type of study.

**5.2.4.2. Water Costs** - Investigate costs for water handling across the industry for pumping, disposal wells, corrosion inhibition, treating, etc. and develop a process for tracking water cost per $m^3$ of oil for individual reservoirs.

Status – A range of estimates for water costs have been developed but no detailed analysis has been found. Ziff Energy has done studies on benchmarking production costs, so may have information for the use of contributors to their benchmarking studies. New Paradigm has recommended using area operating costs divided by total area fluid production as an indicator as most accounting system do not provide enough detail for exact calculation of water costs.

**5.2.4.3. Water Costs** - Lower costs by converting oil production to self-generated power to reduce lifting costs in a deregulated power regime.

Status – Some efforts have been made to generate power using flare gas, however, it is uncertain how much of this power has been used to displace purchased power for water management. It is likely that the amount is still very low, on the order of only 15 MW, as there are still significant policy, regulatory and standards barriers making distributed generation less attractive[3]. Conventional oil production has the lowest energy and GHG

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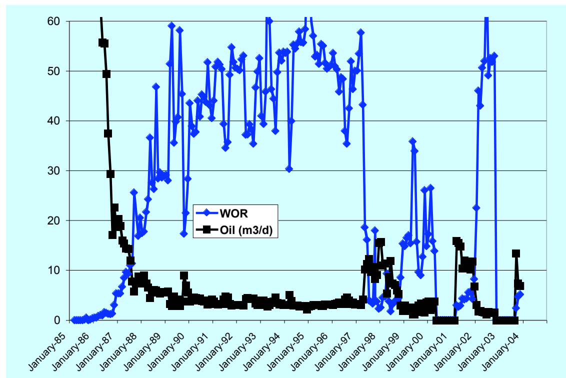
[1] WOR is the volume of water produced per volume of oil so applies to produced water not fresh water.
[2] Data in graph is from the AEUB Database for a Redwater well.
[3] Personal communication from Mr. Bert Dreyer, P.Eng.

intensity per m$^3$ of oil produced, yet has a high cost per m$^3$ because of the premium paid for purchased electrical energy for pumping.

**5.2.4.4. Reduce Water** - Lower costs for front-end water reduction through water shut-off techniques or with downhole oil/water separation (DOWS with gravity based separation or DHOWS with a hydrocyclone for separation) technologies.




Example of DHOWS potential in a high WOR well in Alberta – Well production 1985-2003; DHOWS installed in 1998. Downtime due to analysis between runs.

**Figure 5.4 – Reducing Water to Surface while Increasing Oil Production**

Status – ARC and others are working on various blocking agents to limit water production, however, most field trials have not been extensive enough to optimize treatments. C-FER Technologies and New Paradigm Engineering Ltd developed the DHOWS concept and believe it is proven and low risk in carbonate formations. However, the technology needs to move into more widespread use to achieve lower costs of manufacturing and reduce replacement times.

**5.2.4.5. Water Costs** - Lower costs for disposal with horizontal or multi-bore disposal wells.

Status – ARC, Nexen in Yemen and some other operators have considered using horizontal water injection wells to lower the energy required for water injection and to improve performance of water-flooding.

**5.2.4.6. EOR Study** - Assessment of the ability of abandoned watered out pools to be successfully re-entered to further increase recovery by other means.

Status – AEUB and SIR records could be searched for instances where producers re-entered previously abandoned formations. Unaware of any studies on returning to abandoned pools to increase recovery beyond what was achieved with water-flood alone.

**6. Thermal Heavy Oil Production**

**6.1.4.1. Water Supply** - Independent geological assessment of the capacity of shallow brackish aquifers being targeted as water supplies. Also assess whether these zones will be replenished, how fast and from where.

Status – Alberta Geological Survey has released regional studies in the public domain concerning the stratigraphic framework and geochemical nature of freshwater Quaternary (drift) aquifers in the Athbasca in-situ area. Also AGS is presently embarking on a regional update of Quaternary (drift) aquifer maps in the Athabasca Oilsands Mining Area. These studies are necessary, but not sufficient, inputs into water resource appraisals.[4]

**6.1.4.2. Water Disposal**- Independent geological assessment of the capacity of deep disposal zones to accept blowdown water. Also assess whether these zones will push brine into shallower zones.

Status – Alberta Geological Survey has historical reports on deep flow systems and regional-scale stratigraphic architecture of potential disposal zones. However, except for some site-specific industry studies for their own disposal plans/operations, there has never been a systemic regional assessment of disposal capacity in the oil sands areas. AGS maintains knowledge of the potential for each zone but only in a qualitative sense.[5]

**6.1.4.3. Water Voidage** - Assess water balance implications in producing zones with low voidage replacement. Will voidage be made up naturally and if so from where and how fast?

Status – Some theoretical work may have been done for water inflow and gas outflow during operations. Issue may not have been addressed for post operation phase. Data might be gathered by assessing state of old pilot areas in the Cold Lake region.

**6.1.4.4. Future Recovery** - Impacts on future thermal recovery operations of a partially depleted reservoir being flooded with water either intentionally or naturally.

Status – Long-term water voidage issues have not been addressed in detail. Some producers assume that once oil rates become uneconomic in a portion of an asset, then that area could be used for water disposal/storage, without assessing impacts on potential recovery of the remaining resources.

**6.1.4.5. Water Supply** - Development of regional water balance scenarios including surface flows, underground aquifers and potential climate change impacts to assess cumulative water impacts and the ability to support thermal heavy oil and oil sands development.

[4] Personal communication 2005/01/24 from Kevin Parks, P.Geol. Senior Hydrogeologist and Leader – Groundwater Section, AGS.
[5] Personal communication 2005/01/24 from Kevin Parks, P.Geol. Senior Hydrogeologist and Leader – Groundwater Section, AGS.

Status – The Athabasca River Basin is under study to determine it's capacity to supply water and the Alberta Geological Survey is working on understanding of underground water zones. Long-term monitoring is likely required over the entire region to allow modeling of long-term interactions between surface and subsurface flows. To date little regional water monitoring has been attempted outside of active production areas, but such a system has been proposed.

**6.1.4.6. Water Supply** - Assessment of technologies to allow 100% recycle of water, and the related energy and environmental impacts of the solids removed to allow this. Main purpose of water disposal is to purge minerals produced with formation fluids.

Status – As the water supply becomes more of an issue in the region, producers are increasingly focusing on demineralization of produced water to approach 100% recycle. Technologies developed for low energy desalination of sea water are likely candidate processes, but tend to be sensitive to water composition and fouling by bitumen and clays. Higher water costs must be balanced against increased energy and solids/sludge disposal costs.

**6.1.4.7. Water Supply** - Alternate water sources and disposal methods through regional synergies. e.g. a) blow-down water from a SAG-D operation used in an oilsands extraction process rather than fresh water, or b) recovery of water from combustion emissions as part of a waste heat power generation process.

Status - A water treatment technology network[6] has been suggested to consider and test commercial options for water issues and treatment. New power from waste heat systems could allow for condensation of water from combustion gases, while generating power.[7] Other work is required on assessing the products of water treatment processing, which will tend to be land-filled or land-farmed on surface, which may cause new environmental liabilities.

## 7. Conventional and Coal Bed Methane Gas Production

**7.1.4.1. Net Voidage** - Revisit depleted and shut-in shallow gas wells to determine if the gas zones are filling with water and monitor the rates of replenishment.

Status – Data on re-entry of gas wells after long-periods of shut-in might be available in AEUB orphan well files. After shut-in monitoring of bottom-hole pressures may allow for assessment of water inflow rates occurring in non-producing gas zones. Estimation of recharge rates is a major challenge in groundwater studies, as the inter-zone flow capacity cannot be assessed until a voidage imbalance is created to generate flow. New techniques may need to be utilized to assess voidage make-up issues over long time frames.

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[6] Suggested by Alex Starosud at University of Calgary and ISEEE.

[7] A candidate system is a Cascade Cycle Propane Rankine Cycle which was recently announced by WOW Energy out of Houston. www.wowenergies.com

**7.1.4.2. Reserves Recovery** - Assess technologies for rapidly and more completely depleting gas zones to increase gas recovery, while minimizing fuel use.

Status – With increased development of shallow gas and coal bed methane, low cost methods for well dewatering and on-site compression to lower reservoir pressures to increase recovery are being developed. C-FER Technologies and others have proposed shallow well dewatering methods. Vendors supplying vent gas recovery systems for heavy oil are working to reduce the minimum size of compression units and allow modular construction to optimize on-site capacity at minimum capital cost.

**7.1.4.3. Repressuring** - Assess methods for repressuring depleted gas zones with CO2 and/or nitrogen (combustion gases), or dumping of water from deeper water zones to minimize the impact on local fresh water sources.

Status – ARC initiative on "dump flooding" of oil reservoirs by opening channels to deeper, high-pressure aquifers could also have application in preferentially repressuring depleted gas reservoirs from deep saline sources to attempt to minimize impacts on local groundwater. Portable inert gas units designed for underbalanced drilling operations could be used to displace additional methane and/or repressure gas formations with nitrogen and carbon dioxide. This was a major issue in the "Gas Over Bitumen" issue as water influx to depleted gas zones would reduce economic recovery of bitumen as the water would act as a heat sink.

**7.1.4.4. Groundwater Resources** - Geologic assessment of shallow water zones in the areas where shallow gas and/or natural gas from coal may be produced to determine the aquifers' capacities, source of replenishment and likelihood of communications with gas pools.

Status – The Alberta Geological Survey conducted some groundwater surveys in the 1970's across the province including the Medicine Hat region that has since become the focus of shallow gas production. At that time no link was made between groundwater and gas production, however, it is uncertain if the relationship between the two was investigated and shallow gas production volumes in the 1970's where considerably below current levels. Renewing this effort and comparing groundwater resources vs. gas production may lead to an understanding of the impacts of shallow gas on groundwater resources and also to an improved understanding of fresh groundwater replenishment to assess capacity to supply agricultural needs with groundwater.

## 8. Commercial (Cooling)

**8.1.4.1. Reduce Water** - Low cost method of industrial cooling that does not require high volumes of water.

Status – Alternate cooling methods are available, at higher cost, which reduce water demands. Methods include cooling towers, aerial coolers or hybrid coolers.

**8.1.4.2. Reduce Cooling Load** - Increased use of distributed, high thermal efficiency cogeneration to minimize need for less efficient centralized, stand-alone power generation.

Status – Reducing power generation from centralized, stand-alone steam cycle power generation systems or increasing their overall efficiency reduces cooling water demand per MW of power generated. In Alberta, deregulation of power generation has resulted in a growing number of cogeneration facilities. Some efforts are underway in regulated jurisdictions to encourage cogeneration from renewable sources.

**8.1.4.3. Utilize Waste Heat** - Assessment of potential for existing stand-alone thermal power generation waste energy being used for building heating in nearby communities to increase overall energy efficiency.

Status – Conversion of power systems to provide waste heat to local communities has been considered in the past and is in relatively wide spread use in Europe. Edmonton Power conducted two studies in the 1970's which were reported to have shown that heating Edmonton buildings with waste heat from either the Genessee or Rossdale power plants would be both technically and economically feasible[8]. Main barriers appear to be public perceptions and biases for convenience vs. technological barriers. Also, many of the codes, regulations, approval processes and tax regimes currently in place were written from the perspective of centralized generation and will need to be modified to be more in tune with distributed generation.

**8.1.4.4. Utilize Waste Heat** - Assessment of new power cycles (propane or ammonia/water) to increase efficiency of stand alone power generation and reduce water demand for dumping waste heat.

Status – A new process proposed by WOW Energies of Houston www.wowenergies.com is gaining interest as it uses a cascade cycle propane Rankine cycle instead of steam to generate power, yet uses off the shelf components. Propane is a more efficient power fluid than steam as 70% less energy must be dumped to condense propane. At least one oil and gas producer is considering the WOW process for a major gas plant that already has a propane refrigeration plant.

**8.1.4.5. Water Discharges** - Assessment of economic impacts of power generation water use on downstream users of the water especially irrigation and municipalities in the South Saskatchewan, Souris and Battle River Basins. Also, the effects of airbourne pollutants that may eventually precipitate and enter the water streams should be examined in more detail.[9]

Status – The issue should have been raised during the licensing process for all projects, but follow-up studies may still be required to determine

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[8] "Demonstration of Co-Generation Technology in Alberta" Alberta Energy Brochure 1990.
[9] "An Emissions Management Framework for the Alberta Electricity Sector Report to Stakeholders" CASA November 2003.

potential cost impacts on downstream users that will be most acute during periods of low water flow.

**8.1.4.6. Water Discharges** - Assessment of any potential negative impacts of all contaminants released from energy or industrial operations, to surface or subsurface streams.

Status – Potentially toxic components in any water discharge stream are already highly regulated and reported on. Additional technology development may be needed if current discharge requirements are made more stringent.

**8.1.4.7. Public Education** - Assessment of public education as a means to reduce concerns related to deep well disposal.

Status – Generally regulators see water quality protection as their primary objective and industrial sources tend to be closely regulated and monitored with the major concerns being releases during extreme or unusual events. Greater research efforts may be needed to reassure and inform the public.

## 9. Oil Sands and Coal Extraction

**9.1.4.1. Consolidated Tailings** - Continued improvement in tailings treatment to generate inherently stable and low water and toxics content tailings.

Status – Considerable effort and funds have been expended on fine tailings research with some progress and some transfer of the technology to practice. Key research is being conducted through CONRAD with support from producers and governments. Any significant discovery or advancement would take many years to implement into commercial operations and may be difficult to apply retroactively.

**9.1.4.2. Reclamation** - Development of methods to encourage re-establishment of muskeg areas.

Status – Reclamation studies are on-going through CONRAD, producers and various government agencies. The main initial target is to develop a stable reclaimed landscape, however, the result is not a return to the predevelopment state.

**9.1.4.3. Water Supply** - Detailed studies of Athabasca water sources and projections of water availability over the next 50-100 years with various development scenarios.

Status – The Athabasca River is mainly fed by glacier and mountain run-off, although the AGS estimates that up to 15-25% of river channel flows in northeastern Alberta are directly contributed by groundwater[10]. Water

[10] Personal communication from Dr. Kevin Parks AGS. January 24, 2005. Also commented that: "Geochemical studies suggest that most water in our rivers was groundwater at one time and that the pure glacial meltwater signature is very small. The idea that our rivers are aqueducts carrying glacier-fed waters to the oceans is out of date. However, there is a large component of spring runoff that is snowpack fed and changes to the snowpack are critical to cleansing-flood cycles in our rivers.

supplies may be greatly impacted by natural glacier retreat and potentially accelerated retreat caused by climate change reducing mountain snowpack. Detailed studies and projections of source glaciers and mountain precipitation are needed to project future water flows.

**9.1.4.4. Oil Recovery** - Assessment of economic losses of materials in tailings, and oilsands resources sterilized by tailings ponds.

Status – Applications for new oil sands mining projects generally indicate where oil sands resources may be lost due to locations of plants, tailings ponds and mine storage areas. Most applications contain information on resources contained in the tailings that will be lost. Some work has begun looking at methods of recovering materials of value in the tailings.

**9.1.4.5. Water Supply** - Assessment of alternate water sources for extraction. e.g. blowdown water from SAG-D operations.

Status – Blowdown water from SAG-D steam operations may be an alternate source of feedwater to reduce use of fresh surface water. The potential of this source will depend on volumes, distances and water chemistry, which may have to await more commercial scale SAG-D production before it is economic to consider.

**9.1.4.6. Reclamation** - Geotechnical studies of the long-term stability of tailings dykes.

Status – Tailings are a normal result of most mining and extraction processes so there is a considerable body of knowledge for hardrock and coal mining tailings. However, the unconsolidated and large scale nature of oil sands tailings ponds create new problems which may only become obvious in the course of time, but may require options for backup containment, recovery of losses from dyked areas, and adaptation of new tailings storage methods.

## 10. Water Impacts of Biomass Energy

**10.1.4.1. Net Energy Potential** - Assessment of the biomass production potential, economics and ecological impacts (as part of renewable energy), including water and nutrient needs assessment by water shed.

Status – Saskatchewan has initiated and energized research into alternate ethanol production processes by legislating ethanol content in vehicle fuel. Other studies, mainly university or internationally funded, have attempted to assess the life cycle energy output of various biomass processes from various sources.

**10.1.4.2. Water Supply** - Relative value of water use for production of biomass fuels vs. use for food, industrial or municipal uses.

Status – A number of water research organizations have been formed at the provincial and national level to assess the economic, environmental and societal impacts of water use in arid regions. Much of this work is in the early stages in Canada, spurred on by droughts and forecasts of potential climate change impacts.

**10.1.4.3. Water Supply** - Impacts on watersheds of increased mining of peat resources or forest harvesting.

Status – Ecological studies of watershed impacts of changes in land use have been initiated in some of the more sensitive or active water basins, mainly by university-based researchers. However, long-term ecological impacts are notoriously hard to anticipate.

**11. Hydroelectric**

**11.1.4. Energy Potential** - Assessment of total potential for irrigation hydroelectric systems in the southern WCSB.

Status – Irrican is assessing other sites for potential hydro development. Uncertain what issues, problems or opportunities may be encountered in existing operations.

**11.1.5. Efficiency** - Development of more efficient small-scale hydroelectric power systems that can be economic even with large year-to-year and seasonal variations in water levels and water flows available.

Status – Assumed need for new research and development to maximize efficient use of water for power generation and economic modeling to assist in optimizing the economic return from available water.

**11.1.6. Aquifer Storage and Retrieval** – Underground storage of water as a means of leveling water supplies.

Status – Need for study and adoption of aquifer storage and retrieval (ASR) technologies in some areas where short-term seasonal or annual variability leads to critical water shortages. Technology could be lower cost than surface reservoir storage and reduce reservoir evaporative losses.

*Appendix D*
*Water Related References*

## *Appendix D – Water Related References*

| Chapter # | Reference/Source | Key Information |
|---|---|---|
| 2 | Pembina Institute Oil and Gas Industry Primers | |
| 4 | Environmental Law – New Developments 1995 – Legal Education Society of Alberta | |
| 4 | Water Management in Alberta - Discussion Draft of Legislation & Guide – 1995 | Background to 1999 Water Act in Alberta |
| 4 | Water – The fate of our most precious resource – Marq de Villiers 1999 | |
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| 4 | Water Resources and Freshwater Ecosystems Data – Earthtrends 2003<br>➢ Data for Canada, Mexico, U.S.<br>➢ Global Freshwater Resource Data<br>➢ Definitions list | |
| **4** | **Water Uses in Canada, 1996 – Env Canada website download March 16, 2004; Information on types of water uses; Quickfacts on water** | **Water use distribution by sector and region** |
| 4 | C3 Views – Issue 11 June 2004 - | Discusses energy use for water supply and treatment. 750 MJ/capita = 37.5% of average municipal Energy Use in Canada vs. 12.5% for streetlighting |
| 4 | NEB Appendices to the Annual Report 2003 | |
| 4 | Quenching a Thirst – Drought brings water use issues to the fore – Editorial by Maurice Smith in New Technology Magazine – March 2004 | Summary of issues from oil industry perspective |
| 4 | Houston – We have a problem – World energy Vol 7, No 1 2004 by Robert P. Peebler | Technology issues for Eor in the oil and gas industry |
| 4 | Schema of Energy Indicators for Sustainable Development – Diagram from NRCan website downloaded February 2004 | |
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| 4 | "Energy, Water and Sustainability: What are our options?" Yongsheng Feng – Renewable Resources | |
| 4 | "The Earth's Water Budget – storage and fluxes" – Download from University of Illinois website ww2010.atmos.uiuc.edu | Atmosphere holds 14 Tt water at any one time |
| 4 | "Troubled Waters" by Sandra Postel Thesciences March/April 2000 | |
| 4 | "Energy Technology Futures" – NRCan 1999 | |
| 4 | Energy Alberta 1989 – ERCB Review of Alberta Energy Resources in 1989 | |
| 4 | US DOE Energy Information Administration – International Outlook 2004 Environmental Issues and World Energy Use | Only considered air pollution not water use |
| 4 | "Opportunities for International Participation in Alberta's Energy Industry" Dr. Duke du Plessis, December 4, 2003 Presentation | |
| 4 | "CO2 Environmental Solutions – Building Competitiveness Managing Risk" Presentation by AERI May 10, 2001 | |
| 4 | "An Industry Vision for the Hydrocarbons Sector in 2020 – Energy S&T Forward Plan Discussion" Calgary November 2000 | |
| 4 | "Advisory Committee on Water Use Practice and Policy" Survey by EquusGroup May 10, 2004 | |
| 4 | "Water for Life" Backgrounders 5 and 6 Water allocations and Water storage May 10,2004 www.waterforlife.gov.ab.ca/html/background5.html | |
| 4 | "Water for Life" Backgrounders 7 Water Investments May 10,2004 | Knowledge and Research $218 |

*Appendix D*

***Water Related References***

| **Chapter #** | **Reference/Source** | Key Information |
|---|---|---|
| | www.waterforlife.gov.ab.ca/html/background5.html | Million for: i) emerging issues; ii) surface and ground water Inventories and monitoring; iii) Flood risk mapping; iv) provincial water data warehouse; v) education and knowledge transfer |
| 4 | "Advisory Committee on Water Use Practice and Policy" – Preliminary Report March 31, 2004 | |
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*Appendix D*
*Water Related References*

| **Chapter #** | **Reference/Source** | Key Information |
|---|---|---|
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