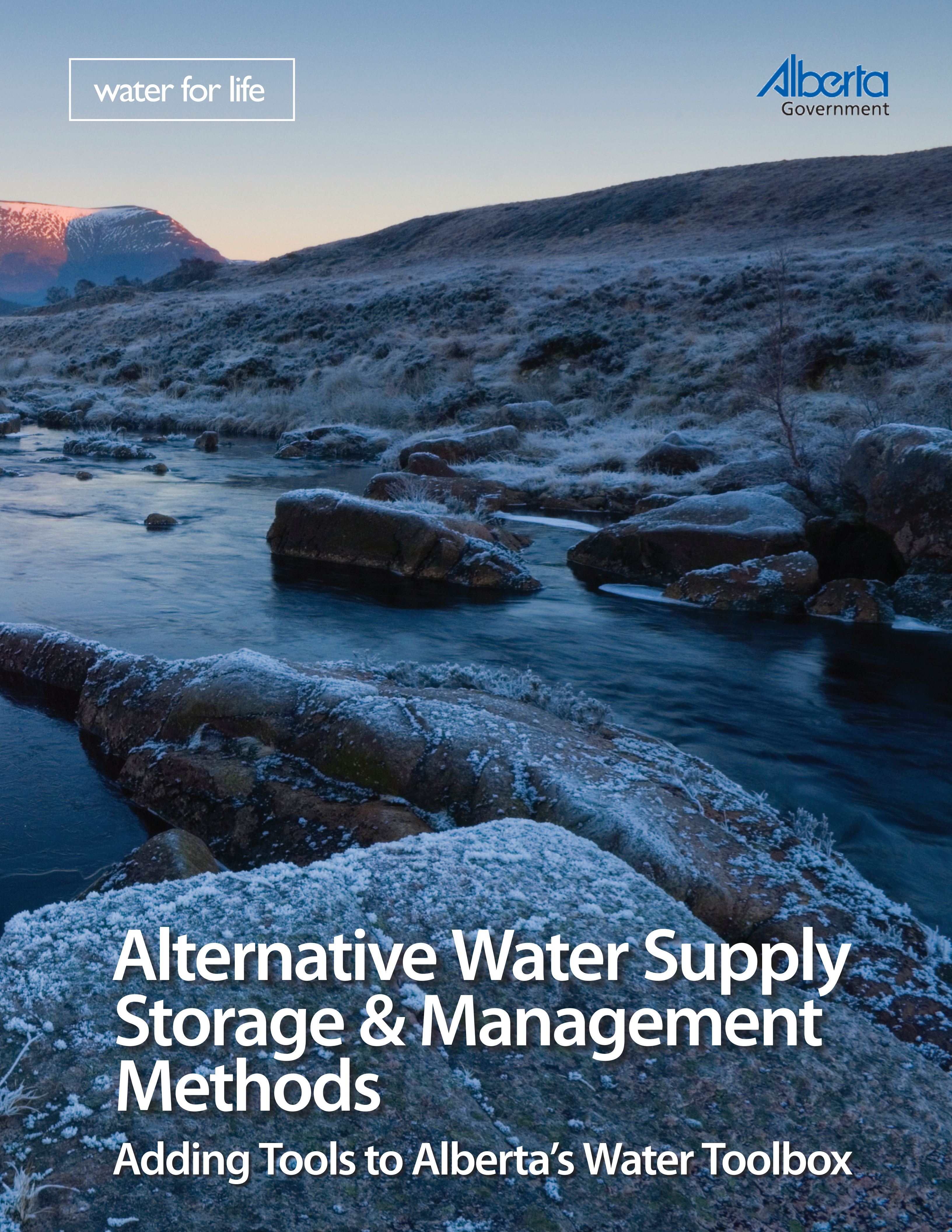
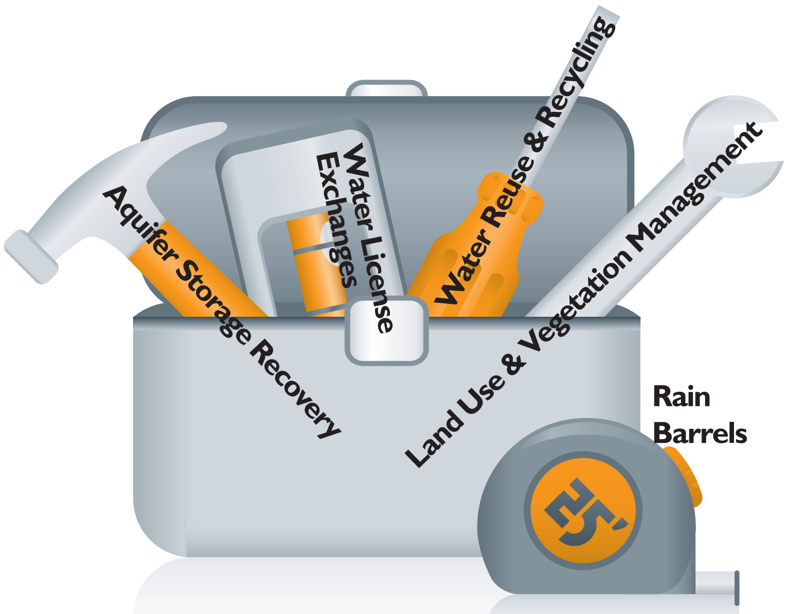
water for life

Alberta Government



Alternative Water Supply Storage & Management Methods

Adding Tools to Alberta's Water Toolbox



Alberta's Water Supply Storage & Management Methods Toolbox

Contents

Introduction

As part of Alberta's **Water for Life** strategy, Alberta Environment (AENV) has conducted studies to assess water supply storage and management methods that support sustainable economic development and the strategic priorities of the province.

In order to meet the objectives of this strategy–and particularly to ensure a safe, secure water supply for Albertans, Alberta's water managers and agencies may consider many potential sources of water, and a wider array of water supply storage and management methods.

Traditional methods for Alberta water supply storage and management have involved direct diversions from rivers, on-channel reservoirs, and smaller off-channel above ground storage sites.

AENV commissioned a review of methods for water supply storage and management that have never, or rarely, been used in Alberta. This brochure introduces the alternative methods identified in that study. All of the methods identified in this brochure are applicable to Alberta's mountain and prairie regions, and all have been used in other parts of the world, including regions with similar topography and hydrology.

For copies of the complete AENV study and further information, contact:

Augustus "Archie" Archampong
Augustus.Archampong@gov.ab.ca
(780) 644-1123
SW Policy Branch
Alberta Environment
Oxbridge Place
9820 – 106 Street
Edmonton, Alberta T5K 2J6

Using alternative methods, such as those profiled in this brochure, can help increase available water supplies, adding tools to our province's water managers' water supply storage and management "toolbox."

Within the profiles of each method, we have provided some examples of where these methods have been attempted or studied in the province, and where they may be applicable in the future.

The methods have been organized within a framework called the **Water Supply Life Cycle** (illustrated on the next page).The alternative water supply storage and management methods presented in this brochure are organized as follows:

Controlled Water Storage Methods for storing water in a controlled facility other than on-channel reservoirs already used in Alberta.

- Off-stream storage and enlargement of existing lakes
- Aquifer storage (and recovery)
- Storage in former mines and mining pits
- Container storage and rain harvesting systems (tanks and towers and rain barrels)

Controlled Water Management and Reuse Methods for "stretching" existing water supplies through reuse and coordinated use of the same water or storage facilities for multiple purposes.

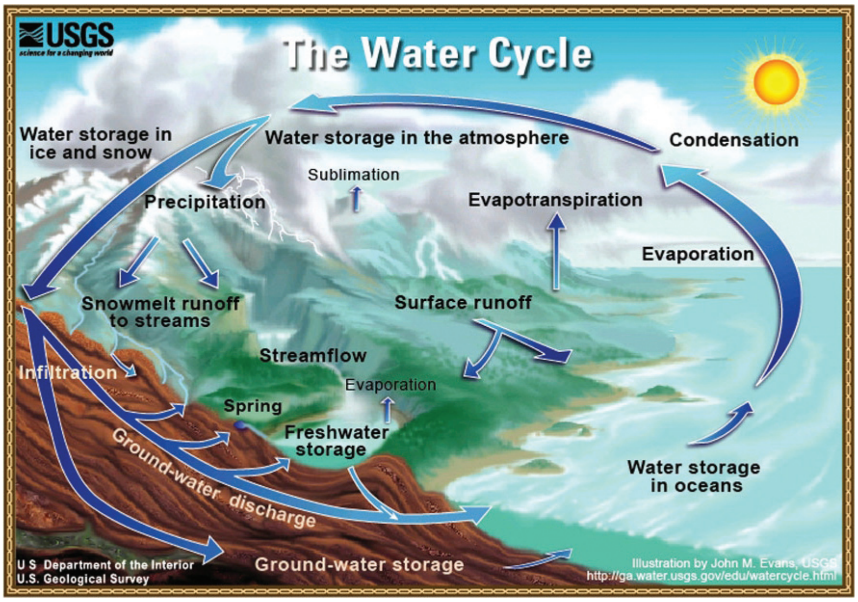
- Water licence exchanges and "water banks" (sharing agreements or licence trading)
- Optimization of stored water for multiple benefits
- Water reuse and recycling (reclaimed water, produced water and greywater reuse)

Water Yield Enhancement Methods for increasing the amount of water that reaches controlled storage facilities and point of use by enhancing the natural processes by which water moves through the **Water Cycle** (illustrated on the next page).

- Land use and vegetation management (forest management and phreatophyte control)
- Precipitation management (cloud seeding and snowpack augmentation)
- Managed aquifer recharge (for streamflow augmentation)

In presenting this brochure, we wish to stimulate a dialogue with water providers and managers, regulatory agencies, Watershed Planning Advisory Councils (WPACs), and other stakeholders. In doing so we can work together to introduce or increase the use of these methods to address Alberta's rapidly growing water needs and security of supply.

Where in Alberta Can Water Be Stored and Managed?

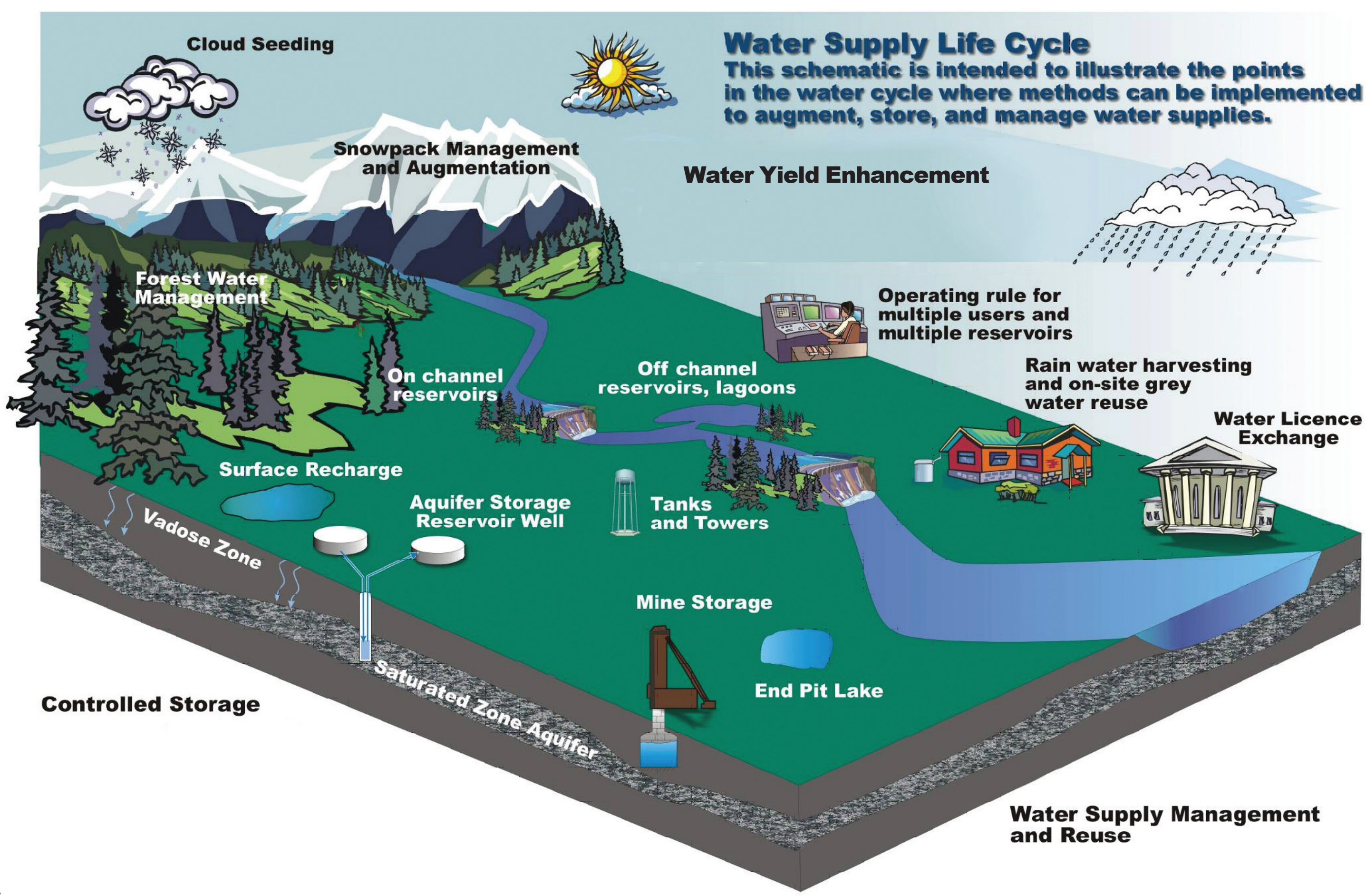


Water moves through a natural cycle (shown above), which includes changes in form (e.g. clouds, precipitation, flowing water), pathways of movement, and natural storage locations. When deciding on a location to deliberately store and manage water to meet specific needs; however, water managers and related agencies need to consider more than just places where water can exist or where water travels naturally.

The **Water Supply Life Cycle** has been developed to provide a framework for water managers and regulatory agencies to consider selection and use of various alternative water supply storage and management methods at different locations within a watershed.

Many of the methods identified provide smaller quantities of water storage or enhanced water yield on a community or household scale. However, the combined use of alternative water storage and management methods throughout a watershed can significantly reduce the need for large, centralized water storage and treatment facilities, and related distribution systems.

As Albertans consider opportunities to apply different approaches to water supply storage and management, it is helpful to consider where the different methods can be applied within a watershed. In some cases, upstream and downstream interests may need to work collaboratively to ensure safe and adequate supplies for all users.



AENV Alternative Water Supply Storage and Management Partnership Initiative

Integrated watershed planning includes both traditional water storage and management methods and various "alternative" methods. Incorporation of alternative methods may require new public education; new arrangements between water providers and associated stakeholders; and new policies, permitting approaches, and forms of regulatory oversight to ensure protection of human health, the environment, and property rights.

When considering how to incorporate alternative methods, water managers, regulatory agencies, and the public need to address such questions as:

- How does this method work?
- Who controls the water?
- Who pays for the operation and management, and who benefits?
- Who are the stakeholders involved, and what are their roles and responsibilities?
- What regulatory oversight is required to ensure safe use of these methods?
- What technical or financial support and incentives can be provided by Alberta's governing agencies?
- What "institutional arrangements," such as cooperative agreements, can be developed to support development and use of each method?

Purpose of Brochure

As part of the Alberta Water for Life strategy, water managers, WPACs, natural resource agencies, and other stakeholders are discussing water planning management priorities.

In providing information on these alternative methods through this brochure, Alberta Environment seeks to gain insights into interest level and concerns related to different methods, and to work in partnership with water managers and other stakeholders, particularly through the provincial WPACs, to determine where these methods can be applied to address water challenges and needs.

AENV has initiated this brochure to:

- Provide a summary of results from the survey of alternative water supply storage and management methods that could be used in Alberta;
- Announce AENV's interest in working with interested parties to support exploration and use of alternative water supply storage and management methods;
- Solicit feedback on potential use of alternative methods identified;
- Identify partner organizations (water providers, WPACs) who are interested in partnering with AENV on exploration and use of specific alternative methods; and
- Identify specific project opportunities or other opportunities to partner on future steps (e.g. development of workshops, surveys of potential sites, feasibility studies).

As partners are identified, AENV will be able to work collaboratively towards identifying and completing next steps in the process of applying these methods "on the ground," where appropriate. Prioritizing alternative water supply storage and management methods to be developed will require input from water providers and managers who would be partners with AENV on projects using the methods outlined in this brochure.

Potential Next Steps

At the end of this brochure, a summary table has been provided identifying some specific "next steps" for each method and general maps showing potential locations for use within the province, where applicable.

The next steps vary and are dependent upon the scale of approach used for implementation (e.g. from household level to watershed level) and to what extent multiple stakeholders will be involved. Next steps–to be completed in partnership with water managers, regulating agencies, and other stakeholders, are likely to include:

- Funding strategies and technical support for feasibility studies and demonstration projects;
- Surveys of current conditions (e.g. buried channel surveys, snowpack assessment, phreatophyte distribution surveys);
- Initial screening evaluations of potential project sites throughout the province or at targeted locations;
- Co-sponsored workshops with international and provincial experts on application of specific methods;
- Development of educational materials to promote changes to current water use habits (e.g. rainwater harvesting, household greywater reuse);
- Facilitated discussions between stakeholders (e.g. on headwaters activities such as forest management that could improve water yield for downstream users, and with neighboring provinces for interprovincial cooperation); and
- Review of permitting processes (e.g. groundwater permitting as applied to aquifer storage and recovery or managed aquifer recharge).

Controlled Storage Methods

Controlled water storage is a critical part of Alberta's water strategy. Conservation and efficiency alone will not meet our growing water demands. While portions of Alberta's mountains and foothills receive more than 500 mm of precipitation per year, our most populated areas only receive 400-500 mm per year. The province's most northern and southeastern regions receive even less.

Alberta's precipitation frequently comes as large events, which may be lost quickly to runoff and evaporation. Because Alberta is situated in a snow-melt dominated area of North America, streams receive higher quantities of water from snowmelt during the spring "freshet." Streamflows are, in some cases, supplemented by glacier melt. With climate change, the timing and quantity of water provided by these snowmelt and glacial contributions are more uncertain.

Often, the times when water is needed most, such as for irrigation of crops. Municipal needs are the times when we have the least amount in our streams and near-surface aquifers.

With so much variety in the timing and quantity of precipitation and related streamflows, Alberta needs to capture water when it is available, store it for later use, and release that water when it is needed. However, there are many alternative approaches to controlled water storage, in addition to the on-stream storage facilities that Alberta has used to date.

Off-stream Storage and Enlargement of Small Lakes

As permitting of on-stream reservoirs has become more challenging in the Western United States, many water providers in that region have turned to the development of off-stream reservoirs In an *on-stream* storage site, a dam is constructed across a stream with controlled releases of water downstream when required. With an *off-stream* storage site, water is pumped or otherwise diverted from a stream to a contained area, which may be lined to prevent seepage loss.

One advantage of off-stream storage sites is that they do not inhibit fish passage or sediment movement in the river channel. However, ecosystem impacts are still an important consideration in selection of potential off-stream storage sites.

Natural water bodies, such as lakes, can be fitted with structures (e.g. wiers) or otherwise enhanced to provide additional water supply storage.

AENV is currently reviewing a proposal for the McMillan Project, an off-stream reservoir in the Oil Sands region along the Athabasca River. Built at the site of McMillan Lake, which currently does not support fish population, this project would capture peak flow water from the Athabasca River, and gradually release the water back to the river to mimic natural flow conditions. Potential sites were selected for minimal ecological "footprint," cost, and land-use conflicts. The project is designed to mitigate in-stream flow needs for fish habitat in accordance with the Athabasca River Water Management Framework.

In 1983, Lesser Slave Lake was fitted with outlet control works for flood management, fish passage, and enhanced recreation. Local stakeholders and AENV are now exploring additional outlet structures at Lesser Slave Lake that would enable this water body to hold additional storage to supply downstream municipal, industrial, and aquatic habitat needs.

Storage in Former Mines and Mining Pits

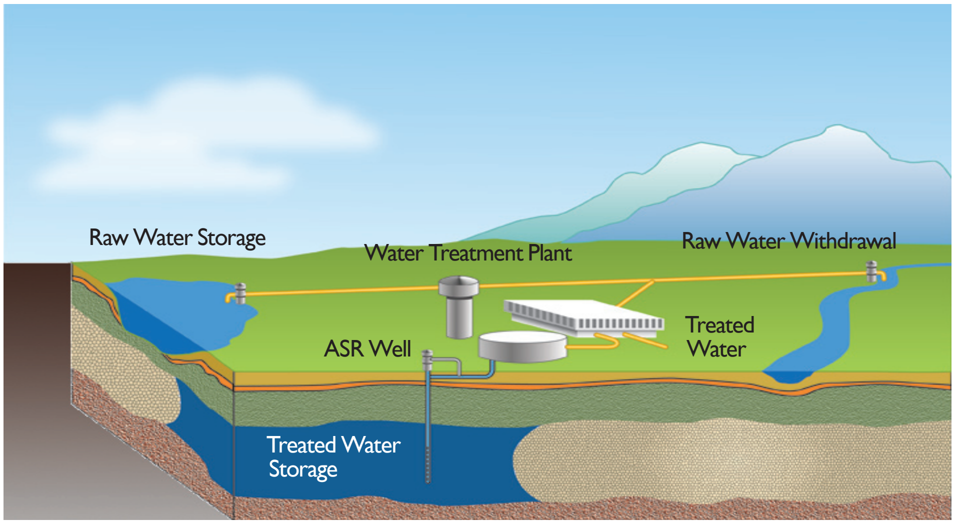
Subsurface voids and open pits created by mining activity have frequently been considered, and sometimes been used successfully, for storage of water.

Former coal mines have been used for water supply storage by municipalities in the Central Appalachia Coal Basin of the US (West Virginia, Kentucky, and Ohio). Former limestone mines in West Virginia are also being studied for use to store industrial cooling water.

While not suitable for large-scale storage, these storage sites have been important for small communities, particularly in remote areas provided that any resulting water quality issues are addressed through treatment prior to use.

Since the 1980s, gravel pits left by small aggregate mines have been used successfully in the US for municipal water storage, particularly in the Front Ranges of Colorado, where gravel pits have been lined and used for storage, or left unlined for groundwater recharge.

Former coal mines and gravel pits throughout Alberta can be surveyed and evaluated for use as small, local water storage sites. Alberta's oil sands pit lakes are being studied for storage that will be used to improve water quality for the reclaimed landscape.



Aquifer Storage and Recovery (ASR)

An aquifer is a porous underground medium (e.g. sands, gravels) that has the ability to produce, and accept, water. ASR involves capture and treatment of water, which is placed into an aquifer "storage zone" through recharge wells or recharge basins for later recovery and use.

ASR is used to store water during wet seasons or years and meet increased demands during dry conditions. This method is used to increase reliability of water supplies, providing "backup" supplies during sustained droughts as well as extreme events (e.g. floods, hurricanes, fires) that can contaminate surface water supplies and impact water distribution and treatment systems.

Water collected for ASR is treated prior to injection and after recovery. The storage zone is also monitored carefully to assess water level changes and prevent contamination of the stored water or native groundwater in the aquifer.

There are large ASR wellfields such as the Las Vegas (Nevada) system, with more than 50 wells developed in extensive sandstone and gravel aquifers. There are also many smaller ASR systems that have been developed for towns that have the desire to reduce their reliance on large, centralized surface water reservoirs or delivery systems owned by major cities. Several systems have been developed in bedrock and channel deposits in the states of Washington and Oregon, as well as in many other parts of the world (e.g. Europe, Australia).

ASR can be used to off-set reduction in groundwater levels from pumping so that more water can be withdrawn cheaply during high demand periods. Alberta Environment licenses and permits ensure that groundwater aquifers are not "mined," and that overdraft does not occur, which could cause land subsidence or collapsing of aquifer pore spaces. Still, well users can cause some reductions in groundwater levels, which can lead to increased pumping costs. ASR can be used to maintain and enhance water levels in aquifers.

In Alberta, several communities are exploring opportunities to develop ASR sites for water storage closer to their treatment plants and point of use.

Use of buried channels to store water for municipal or industrial purposes, including cooling water, is also being explored to reduce the need for development of additional surface storage sites.

Container storage and rainwater harvesting systems

Container storage has been used at different scales, ranging from tanks and towers for farms and small communities to rain barrels and other rainwater collection devices at homes and office buildings. Water tanks have been used to reduce water loses from evaporation and to avoid collection of pesticide and fertilizer contaminated run-off. Tanks can be raised to provide additional pressure for the water distribution system, thus reducing electricity costs for pumping.

In Alberta, some municipalities have used water tanks and towers. These storage methods could be more widely incorporated into local and regional or watershed-based water planning. Lethbridge has been using water tanks to support the city's supply needs, and has developed new storage tank infrastructure to meet increasing water demands and provide security to water users on the west side of the city.

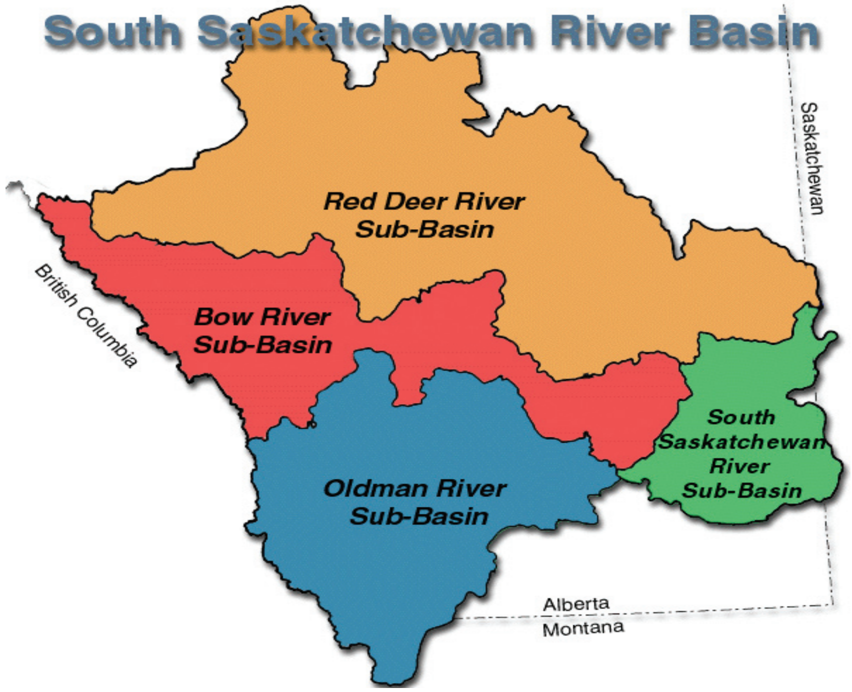
Containers such as rain barrels are incorporated into rainwater harvesting systems, which also include catchment areas on rooftops and land surfaces, changes in land slope and vegetation cover, and water conveyance systems.

Rainwater collection systems are permitted in Alberta. The Edmonton Rain Barrel Project, started in 2002, provides workshops on how homeowners can construct their own systems. This project study found that household rainwater harvesting can decrease the use of treated drinking water for outdoor uses, while also reducing energy and treatment costs.

Multipurpose Water Management and Reuse Methods

Once water has been captured in some sort of controlled storage, structure, or area, there are also methods that are in use to "stretch" these stored supplies, such as market mechanisms (e.g. "water banks"), system optimization and using the same storage facilities for multiple purposes, and water reuse. These methods are designed to serve multiple users and provide multiple benefits.

A collaborative approach is often needed to meet this objective. Strategic water use also provides inherent opportunities for various types of reuse – further ensuring that water supply needs for multiple purposes are met.



Water Licence Exchanges and "Water Banks"

Water licences (also called water rights in other provinces) are a legally protected right to divert and use water. "Prior appropriation" water law establishes a priority system for use ("first in time, first in right"). Water licences provide the right to use water, but do not provide water ownership, which remains with the province. A water licence is a property right that can be exchanged in accordance with governing regulations, as long as other water licence holders are not adversely affected.

A water licence exchange (i.e. sharing agreement, water market or "water bank") facilitates temporary or permanent transfers of water from those with surplus allocation to those with a need for water. Older or "more senior" water licences have greater value, since those receive water first during water restriction periods. Certain water licences may also be desired because of their location.

Typically, water licence exchanges are created when a river basin has been "fully allocated" during normal or dry years. In some areas, such as in California, water banks are used only during drought periods to facilitate temporary exchanges of water rights.

In Alberta, the moratorium on new water licences in the South Saskatchewan River Basin has led to the development of a water licence exchange program.

Started in 2002, this water management approach allows transfer of water licences, with input from four multi-sector stakeholder Basin Advisory Committees for the Red Deer, Bow, Oldman, and South Saskatchewan Rivers, as well as interested public members. Up to 10% of any transfer is left in the stream to maintain in-stream flow and protect the aquatic environment.

Alberta Environment has also been conducting studies on the economic value of water, which is helpful to buyers and sellers participating in a water licence exchange.

Multipurpose Operations and Optimization

Existing water supply and storage facilities can be used more efficiently, with support from computer simulation and optimization programs. Individual storage facilities can be operated to serve multiple purposes (as discussed further below). Operations can be planned to balance considerations of costs, ecosystem needs, water quality, water demands for different uses, and protection from flood damages.

Multiple reservoirs can also be operated together on the same river basin to meet different social, environmental or economic demands within a watershed. In the Upper Colorado River Basin, reservoirs are operated to meet both habitat and hydropower needs, and a portion of the hydropower revenues are used to support fish species recovery efforts and habitat restoration/enhancement.

In Alberta, the Water Resources Management Model (WRMM) was developed in the early 1980s to serve *as a tool for river basin planning and management. An optimization model was developed in 2004 to evaluate how a water market in the South Saskatchewan River Basin might function based on economic impacts of surface water allocation, considering storage volumes and reservoir releases, hydropower, irrigation, and municipal needs.*

Additional capabilities can be integrated into the WRMM to support greater coordination of water storage facilities, including consideration of climate change impacts on historic flows, real-time operating strategies and flow measurements, drought management strategies, and plans to meet instream flow needs to ensure habitat sustainability.

Conversion of Hydropower and Flood Control Storage to Multipurpose Storage

Conversion of existing storage, such as reservoirs for hydroelectric power generation and flood control, is a potentially economical method of providing alternative supply and storage for municipal, industrial, or agricultural water needs. In Colorado, the Chatfield Reservoir is being converted from a dedicated flood control structure to multipurpose use, including storage of water for municipal, industrial and agricultural uses.

Provincial utility providers operate large reservoirs on the South and North Saskatchewan River systems for electricity generation. These reservoirs serve an important role in the provinces' power grid because hydroelectricity can meet rapid changes in power demands, compared to coal-fired plants. Reservoir storage is also used to compensate for variations in wind power generation. Studies are being conducted to determine whether revenue from municipal development can provide sufficient offset to hydroelectric power revenues so that these reservoirs can be operated to serve multiple purposes, including municipal supply.

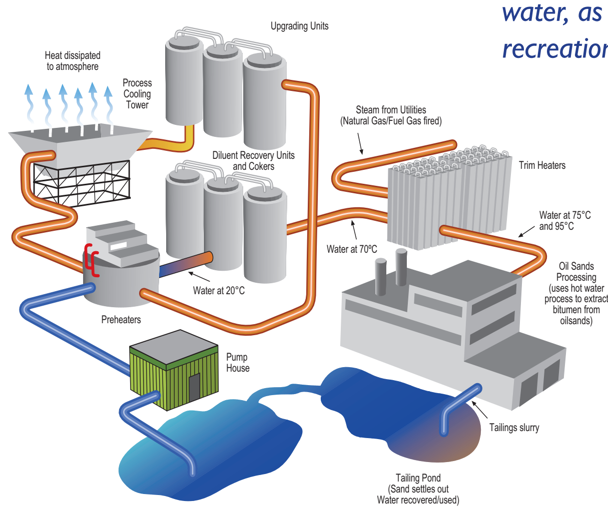
Water Reuse and Recycling

Reclaimed water is effluent that has been captured and treated for reuse (use for the same purpose) or recycling (use for a different purpose), rather than being discharged back to the environment. Water reuse–and treatment to ensure safe reuse–is an important part of water management.

Industrial operations, such as oil sands mining, reuse a high percentage of their water for processing or cooling needs. Each time water is reused or recycled, a portion of the water used is lost to evaporation and the remaining dissolved solids eventually build up. "Make-up" water may be required to keep salinity levels from getting too high.

Reuse has become particularly important for the oil and gas sector to reduce the cost for permitting of new water licences, costs and time for infrastructure development, and more importantly, to reduce the "water footprint" of and industry activity.

Municipalities may develop separate plumbing systems ("purple pipe") for distribution of reclaimed water from their wastewater treatment plants for watering of highway medians, golf courses, or for other irrigation needs. There can also be household-scale recapture and reuse of "greywater," which is a term used for water from residential clothes washers, bathtubs, showers, and bathroom sinks. "Blackwater" is a term typically used for water from kitchen sinks and flushed toilets. If allowed by law, greywater can be treated on-site and reused for toilet flushing and landscape irrigation, as long as separate plumbing systems are established.



Greywater use is currently prohibited under the Alberta Building Code, which views all water that has exited a plumbing fixture as "blackwater." Blackwater must be sent to a municipal treatment centre. However, the Canada Mortgage and Housing Corporation has developed a demonstration house in Okotoks to show how residential water consumption can be significantly reduced as an environmentally responsible alternative to additional municipal water supply and wastewater treatment. This system also uses heat recovery from greywater to reduce heating costs. Regulatory, legislative, and policy changes would be required in Alberta to allow greater reuse of wastewater and household greywater, along with well-defined permitting procedures that explain how operators must demonstrate that reclaimed water is used in a manner that protects human health and the environment.

The City of Edmonton is working with oil sands companies in the Industrial Heartland of Sturgeon County to investigate the use of treated wastewater to replace river water intakes for cooling and boiler process water, as well as for irrigation and recreational areas.

Water Yield Enhancement Methods

Many human activities can have impacts on hydrologic contributions to streams and aquifers — including impacts on evaporation, overland flows, and infiltration. Often most noticeable at the "headwaters" or "source waters" of a river basin, different activities may increase or decrease annual water yield, peak flows, or low flows of streams. Water quality and form of water (such as flowing water, snow, or soil moisture) can also be impacted. Preserving the natural "ecosystem functions" of headwaters is important to the maintenance of water quality at a far lower cost than would be required for the development of water treatment facilities further downstream.

There are management approaches that water managers can deliberately apply. Often involving little or no infrastructure, water yield enhancement methods can provide significant benefits, increase water availability and reduce the need for construction of traditional "controlled storage" structures. Incorporating these "water yield enhancement methods" into an integrated water supply and management plan can be challenging, since it is difficult to use traditional assessments and financial cost-benefit analyses to determine the exact quantity of additional water produced per dollar invested.

These methods often also require collaborative approaches, since it may be necessary for upstream landowners and operations (e.g., logging companies) to develop cooperative agreements with downstream water users (e.g., municipalities and irrigation districts). Alberta government agencies such as Environment, Energy, and Sustainable Resource Development need to assist with water resource decisions and stakeholder education.

Land Use and Vegetation Management

Land use and vegetation management methods may be used to control the amount of vegetative cover for the purpose of managing water yields in a basin. Vegetative cover can change the rate at which water reaches the ground, how it infiltrates to the water table as recharge, how it contributes to stream baseflow, or how it flows directly overland to streams. Vegetation can also change water yield by returning water to the atmosphere through evapotranspiration, and by intercepting snow, which may be sublimated directly back to the atmosphere. Land use activities are typically not managed deliberately to increase water supplies. However, land management activities may be regulated to ensure no negative effects occur to existing water licences. *Land use and vegetation management methods important for Alberta include **forest management** and **phreatophyte control.***

Timber harvesting practices can impact downstream water supply quantity and quality

Forest Management

Forest cover, including interception of snow by tree canopies, affects evapotranspiration, soil moisture, and the amount and timing of runoff including peak flows and summer base flow. The impacts of forest management on streamflows are particularly important for Alberta's snow-melt dominated basins. Forest harvesting tends to increase the annual water yield of a catchment area, but can also change the timing of flows. Timber companies are required to consider water yield impacts in their forest management plans. Deliberate management of forest harvesting to enhance water yield would require collaborative agreements between timber companies and downstream water users, with oversight by Alberta Sustainable Resource Development (ASRD).

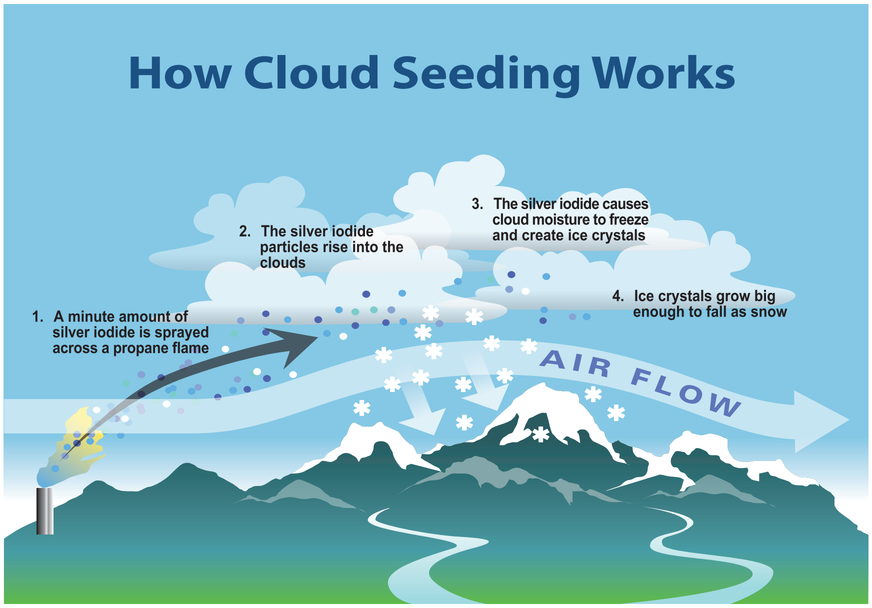
Alberta's forested headwaters are at risk to impacts from catastrophic fires and mountain pine beetle as a result of climate change, which result in changes to soil moisture conditions, runoff and river flow characteristics. Forest management practices to reduce these risks are currently being considered and implemented in some areas.

Phreatophyte Control

Phreatophytes, or "water-loving" plants, are small trees and plants with deep and extensive roots systems that grow along floodplains and tolerate a wide range of soil conditions (i.e. saline or alkaline). Often nonnative species, phreatophytes such as tamarisk (also known as salt cedar) and Russian olive may capture large quantities of water from tributary aquifers before it can reach rivers as baseflow.

There is a wide range of phreatophyte control techniques including mechanical, chemical, and biological methods. Often, implementation of phreatophyte control programs requires cooperative arrangements between agencies at different levels as well as water and land management districts.

The presence of nuisance phreatophytes have been confirmed in the Milk River basin, where they are over-running native species. Other parts of the province, particularly in the prairies, are beginning to search for and take steps to control nuisance phreatophytes in sensitive riparian areas. The shift of warmer climate conditions northward will exacerbate this issue.



Cloud Seeding and Snowpack Augmentation

Mountain or "orogenic" cloud seeding (see figure) is used for snowpack augmentation, particularly in snowmelt-dominated basins like those originating in the Rocky Mountains. This method is different from the warm-weather or "convective" cloud seeding method currently used in the Red Deer-Calgary corridor for hail suppression.

Cloud seeding has been successfully used for snowpack augmentation in the Colorado River basin, where the U.S. Bureau of Reclamation has targeted headwaters in specific tributary streams in upper basin states to help fill Lake Powell and Lake Mead. Cloud seeding has been estimated to produce a 10% increase in seasonal precipitation.

On a smaller scale, for 30 years the Vail ski resort has paid landowners to operate cloud seeding equipment on their property to support snowpack augmentation and improve ski conditions.

Alberta has been a leader in Canadian cloud seeding studies. Alberta Environment currently tracks snowpack measurements, which can be used to support water planning in snowmelt-dominated basins and identify target areas where water yield enhancement could be maximized through cloud seeding and snowpack augmentation.

Managed Aquifer Recharge for Streamflow Augmentation (MAR)

MAR methods for streamflow augmentation are used in alluvial aquifers that are "tributary" to streams in order to enhance baseflow. Baseflow is the source of streamflow during times when there is no rainfall or runoff contribution to channel flow. Maintaining baseflow is particularly important in regions that receive little rainfall for extended periods of time, such as southern Alberta.

Tributary aquifers are often unconfined, water table aquifers overlain by riparian (riverside) land areas. In areas where baseflow is reduced by water withdrawals from nearby wells, or where natural recharge to tributary aquifers is reduced through changes in land use, MAR for streamflow augmentation can be used to offset reductions in stream baseflows.

Streamflow augmentation through MAR can also be used to "re-time" streamflows. Peak streamflows (e.g. from snowmelt in the spring) are captured and diverted injection wells or recharge ponds, also called "augmentation ponds," through which water percolates into the subsurface and slowly travels back to the stream.

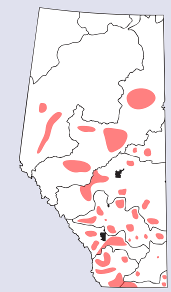
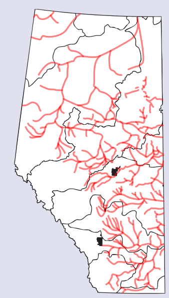
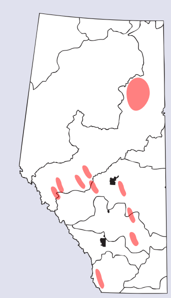
In Colorado, tributary alluvial aquifers have been mapped according to their characteristics to determine the timing of streamflow depletions that would be caused by water withdrawals. These same maps are used to determine streamflow gains that occur from water being placed in "augmentation ponds."

City of Phoenix Tres Rios Recharge Pond

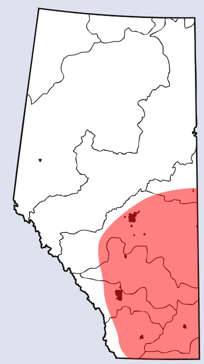
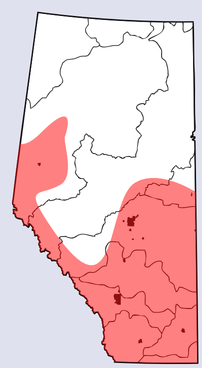
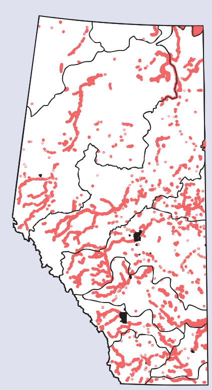
Water is placed in MAR systems during high flow periods, thus off-setting impacts to licence holders that have, or may have, an influence on streams flows during periods of high water demand (i.e. summer). This technique also helps maintain viable stream habitat by ensuring in-stream flow needs and maintenance of backwater areas, which provide refuge for baby fish. Augmentation ponds also replicate seasonal wetland development, which is attractive to migratory waterfowl.

In certain parts of Alberta, impacts to tributary aquifers must be offset through augmentation of streamflows. The connection between riparian land use, recharge of alluvial aquifers, and impacts on baseflow is now being studied through organizations such as the Alberta Riparian Habitat Society (the "Cows and Fish" program). MAR for streamflow augmentation can be considered to offset reductions in aquifer recharge and baseflow that is tied to riparian land use.

Potential Locations and Steps Towards Use of Alternative Methods

Method	Potential Locations	Steps Towards Use	Map
Controlled Storage Methods			
Off-stream Storage and Enlargement of Small Lakes	Small lakes and depressions in the land with low ecological footprint and near population centres or high water demand areas.	Review recently completed "Assessment of Potential Water Storage Sites and Diversion Scenarios for Potential Offstream Storage Sites" (AENV 2008). Coordinate with WPACs and project proponents on selection, evaluation, and development of offstream storage sites and small lake enlargements.	
Aquifer Storage and Recovery (ASR)	Buried channel systems throughout Alberta (east of foothills region)	Support organization of water manager workshops on ASR and its use in regions similar to Alberta. Review potential permitting requirements for safe use of ASR. Support surveys to identify locations of buried channels near surface water supply sources and communities identified as "water-stressed" (currently and in the future).	
Storage in Former Mines and Gravel Pits	Eastern front ranges and foothills (e.g., Crowsnest Pass, Hinton, Drumheller) Abandoned gravel pits and aggregate workings. Future mines	Survey locations of coal mines where small, localized storage may be beneficial; determine whether there is suitable storage capacity. Assess locations and feasibility of abandoned gravel pits where small, localized storage may be beneficial. Assess applicability of mine pit lakes for storage of water for industrial or other use.	
Container storage (tanks, towers, and barrels for rainwater harvesting)	All major basins and sub-basins	Provide educational programs and incentives to communities interested in greater use of tanks and towers. Expand incentives for household use of rain barrels. Compare economic benefits of decentralized container storage with central storage facilities. Perform meteorological and climate studies, and source water reviews, to identify locations for rainwater harvesting.	
Multipurpose Water Management and Reuse Methods			
Multipurpose operations and optimization	All major basins and sub-basins	Use basin-wide modeling to assess water balance and availability of unused portions of water licences. Evaluate opportunities for multipurpose operations at single-purpose reservoirs and facilitate discussions between stakeholders interested in securing water supply storage space in dedicated reservoirs.	
Water Licence Exchanges and Water Banks		Assess locations and volumes of water licences in water-stressed basins, particularly those closed to new water allocations (i.e. Bow, Sounding, Oldman, South Saskatchewan, Milk).	
Water Reuse and Recycling		Continue support for research on reuse and recycling of industrial process water. Assess applications of greywater reuse at the municipal and household level. Review regulations and permitting requirements to be changed, and/or revised. Educate public on safe use of greywater.	

Potential Locations and Steps Towards Use of Alternative Methods

Method	Potential Locations	Steps Towards Use	Map
Water Yield Enhancement Methods			
Land Use and Vegetation Management: forest management	Headwaters area of eastern front ranges (i.e., Oldman, Bow, Red Deer, North Saskatchewan, Athabasca)	Assess risk to water-stressed areas. Educate logging companies and WPACs on management of timber harvest to increase water yield.	
Land Use and Vegetation Management: phreatophyte control	Basins experiencing water deficits (i.e. Milk, Oldman, South Saskatchewan, Sounding, Bow, Red Deer, portions of North Saskatchewan, Beaver)	Conduct surveys to identify areas where nuisance phreatophytes exist and are having negative impact. Support and expand educational programs on phreatophyte control. Coordinate and integrate programs with current Alberta Invasive Plant Species programs.	
Cloud seeding and snow pack augmentation	Headwaters of South Saskatchewan, North Saskatchewan, Peace and Athabasca River systems and targeted winter recreation areas	Provide educational programs on cloud seeding and snowpack augmentation for water yield enhancement. Establish trends in snowpack conditions along eastern front ranges. Identify areas with declining trends. Conduct vulnerability assessments (e.g., glacier supplemented versus non-supplemented) and risk ranking of areas. Conduct studies of potential downwind precipitation impacts.	
Managed Aquifer Recharge (MAR)	Sand and gravel aquifers connected to active rivers and streams	Provide educational programs on MAR and use for streamflow augmentation. Identify locations where land use and groundwater withdrawals may be impacting streamflow and where MAR can be used to augment baseflow conditions.	


water for life

For copies of the complete AENV study and further information, contact

Augustus "Archie" Archampong
Augustus.Archampong@gov.ab.ca
(780) 644-1123
SW Policy Branch
Alberta Environment
Oxbridge Place
9820-106 Street
Edmonton, Alberta T5K 2J6