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Irrigation Sector – Conservation, Efficiency, and Productivity Planning Report Appendices

Prepared for:

Alberta Irrigation Sector CEP Plan Steering Committee

Prepared by:

AECOM Canada Ltd.
17007 – 107th Avenue, Edmonton, AB, Canada T5S 1G3
T 780.486.7000   F 780.486.7070   www.aecom.com

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The following listing outlines the contents of appendix material referenced in this report document but compiled under separate cover, ("Irrigation Sector -Conservation, Efficiency and Productivity Planning Report – Appendices").

Glossary of Terms Used in this Report

Application Efficiency: The ratio of the amount of water that is distributed to an irrigated field and that is actually available in the soil root zone for use by the irrigated crop, relative to that total amount of water that is distributed to the irrigated field by some form of application methodology.

Apportionment: An amount of water, measured as either as an identified volume or as a proportion of a volume of water that is committed to being supplied to an adjacent jurisdiction through a formalized sharing agreement. For example, Alberta and Saskatchewan are signatories to an apportionment agreement for water that arises within the South Saskatchewan River Basin within Alberta that must flow into Saskatchewan each year.

Aquatic Ecosystems: The holistic environment that supports plant, vertebrate, invertebrate and micro-organism life that naturally exists within and adjacent to water bodies, whether they are rivers, creeks, lakes, marshes and the like.

Benchmark: Defined as a measurement or standard that serves as a point of reference by which the performance of a process, of components or of a system is measured. Benchmarks are used for comparing performance in an effort to identify progress being made and to identify more efficient and effective processes for achieving intended results.

Consumptive Use: Water that is used for the intended purpose but then is no longer available for re-use (e.g. crop evapotranspiration, oilfield injection, etc.).

Deficit Irrigation: The practice of applying less irrigation water to a crop than it would normally require or consume but providing a lesser amount that ensures sufficient water is available at critical production stages so that yields may be optimized rather than maximized and less water used overall. Within acceptable production yield levels, the intent is to realize higher commodity output relative to the amount of water consumed.

Demand Management: The practice of applying specific water management techniques, in a water use situation, that confines the degree of demand with a goal to minimizing the overall water required to achieve the objective of the water use.

Evapotranspiration: The combination of the physiological process of water consumption by plant life for transpiration functions and the physical process of water being evaporated from the plant (or crop) canopy and from the soil surface supporting the plant growth.

Gross Diversion: The full amount of water that is actually withdrawn from a supply source and represents all water required for consumption purposes, losses and return flows.

Gross Irrigation Diversion Demand (GIDD): The theoretical or computed demand for water, either as a volume or as a rate of flow, for any given time period, that quantifies the predicted gross diversion from the source of water that would be required to satisfy all irrigation-related requirements, including application, storage and conveyance losses, as well as projected return flow.

Irrigated Area: The field area, within any given irrigation season, which actually receives one or more applications of irrigation water.

Irrigation Area: The field area, within any given irrigation season, which is authorized to be irrigated, but which may or may not actually receive one or more irrigation applications.

Instream Flow Need (IFN) The scientifically-determined amount of water, flow rate, or water level that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation or aesthetics. An in-stream need is not necessarily the same as the natural flow.

Licensed Allocation: The defined volume of water that has been authorized, according to provincial government statute, to be diverted for an approved use through the course of a defined period of time, usually not exceeding one year. The allocation could include specific conditions relating to timing of diversions, rate of diversion, restrictions subject to in-stream flows, etc.

Losses: Water that is included as a component within an allocation that can be withdrawn for a particular use, but may become unavailable, either through evaporation, seepage, or unrecoverable return flow and as a result is not available for immediate re-use.

Return Flow: An amount of water that is included in an allocation that is expected to be returned to a watershed after use and may be available for re-use, although the water quality characteristics may have changed during use. Not all return flow is necessarily returned to the original source of diversion or withdrawal.

Rolling-Average (10-year): The average of a time-series of data points that reflects re-computed averages of successive consecutive groupings of data. In the case of 10-year rolling-averages, the annual amounts of each of the 10 years of the initial grouping, starting in year “X”, are averaged, followed by a computation of the average of the succeeding ten-year grouping, beginning at the year “X+1”, and so on. Rolling averages are applied to attempt to reduce the apparent interpretive effects of spikes or depressions in data series in order to generate a more realistic picture of trend lines.

Supply Management: The practice of applying specific water management techniques, in a water use situation, with a goal to ensuring that sufficient water is supplied to meet all water withdrawal and use demands, regardless of the demand or supply conditions.

Target: A measureable quantitative value or qualified condition that defines a goal to be strived for and achieved as an outcome of an implemented process.

Water Availability: The portion of a water supply that can be effectively utilized for specific withdrawal or in-stream purposes. For example, water that flows through a system under flood conditions cannot usually be utilized for specific diversion intentions and so is unavailable to that purpose. The “water availability” is always equal to or less than the “water supply”.

Water Allocation: The amount of water that may be diverted for use, as set-out in water licences and registrations issued in accordance with the Water Act. Allocations include a maximum volume of water that can be withdrawn from a water source, as well as the rate of withdrawal, the identity of the water source, the purpose for which the water is to be used and the location at which the diversion can occur. Allocations reflect the amount of water that will be consumed plus any losses that might occur, and may include an allowance for flows that are returned after use. An allocation is generally based on the maximum amount of water that a licensee expects will be required on either an annual basis or through the licensing period.

Water Conservation: A philosophy within water use that aspires to create an ethic within the water-user community that will be reflected in water being diverted and consumed at reducing levels to achieve the intended purpose. A goal of increasing water-use efficiencies would be a reflection of an ethic toward water conservation.

Water Diversion (or withdrawal): Describes the amount of water being removed from a surface or groundwater source, either permanently or temporarily. Water diversions may be less than or equal to water allocations and may include an allowance for some water to be returned to water bodies after use.

Water Productivity: The amount of water that is required to produce a unit of any good, service or societal value.

Water Supply: Generally considered to represent the total amount of water that is generated (e.g. precipitated) within a watershed through a defined period of time (usually annually) that flows through, is retained within or is lost from the watershed through evapotranspiration and deep sub-surface percolation; and is the total amount from which water users can attempt to withdraw their authorized allocations. This can apply to both surface and groundwater. The “water supply” is always equal to or greater than the water “availability”.

Water Use: Considered to be the combination of actual water consumption plus losses associated with a diversion, or, alternatively, represents the difference between the amount of water actually diverted and the return flow.

Water Use Efficiency: An indicator of the relationship between the amount of water needed for a particular purpose and its ultimate end result versus the total quantity of water diverted for that purpose to achieve that result.

Acronyms Used in this Report

AARD	-	Alberta Agriculture and Rural Development
AENV	-	Alberta Environment
AID	-	Aetna Irrigation District
AIPA	-	Alberta Irrigation Projects Association
BRID	-	Bow River Irrigation District
EID	-	Eastern Irrigation District
GCM	-	Global Climate Model
GIDD	-	Gross Irrigation Diversion Demand
IDIMS	-	Irrigation District Infrastructure Management System
IDM	-	Irrigation Demand Model
IPI	-	Irrigation Productivity Index
IRP	-	Irrigation Rehabilitation Program
IWMSC	-	Irrigation Water Management Study Committee
LID	-	Leavitt Irrigation District
LNID	-	Lethbridge Northern Irrigation District
MID	-	Magrath Irrigation District
MRB	-	Milk River Basin
MVID	-	Mountain View Irrigation District
RCID	-	Ross Creek Irrigation District
RID	-	Raymond Irrigation District
SMRID	-	St. Mary River Irrigation District

SSBWAR	-	South Saskatchewan Basin Water Allocation Regulation
SSRB	-	South Saskatchewan River Basin
TAU	-	TransAlta Utilities
UID	-	United Irrigation District
WID	-	Western Irrigation District
WRMM	-	Water Resources Management Model

Unit Conversion Chart

Area:	1.0 hectare (ha)	=	2.471 acres
Length or Depth:	1.0 millimetre (mm)	=	0.0394 inches
	1.0 metre (m)	=	3.2808 feet
	1.0 kilometre (km)	=	0.6214 miles
Rate of Flow:	1.0 cubic metre per second (m^3/s)	=	35.315 cubic feet per second
	1.0 litre per second (l/s)	=	15.85 US gallons per second
Volume:	1.0 cubic metre (m^3)	=	35.315 cubic feet
	1.0 million cubic metres (million m^3)	=	810.713 acre-feet
Weight:	1.0 kilogram (kg)	=	2.2046 pounds
	1.0 tonne (T)	=	1.1023 tons
Yield:	1.0 kilogram per hectare (kg/ha)	=	0.893 pounds per acre
	1.0 tonne per hectare (t/ha)	=	0.446 tons per acre

Appendix A: Steering Committee Membership and Terms of Reference

Note: The following outlines the final version of the proposed Terms of Reference for the Steering Committee mandated to develop a Conservation, Efficiency and Productivity (CEP) plan for the irrigation sector in Alberta. The proposal includes projected timelines with the understanding that the Committee had responsibilities in achieving certain objectives to meet Alberta Water Council (AWC) timelines. As the Committee's timelines were a preferred and projected schedule, it was also recognized that the uncertainty surrounding pending deliberations and their outcomes, plus final report development, could all require more time than initially projected.

1.0 Introduction

1.1 The Need for a CEP Plan and the Task at Hand

Water For Life has established three goals, namely:

1) safe secure drinking water supply,
2) healthy aquatic ecosystems, and
3) reliable quality water supply for a sustainable economy.

Water for Life also identified a 30% improvement in overall water-use efficiency and productivity from 2005 levels, targeted to be achieved by 2015 as a desired outcome. Meeting these goals will require the active participation of all water-using sectors in defining, developing, implementing, promoting and monitoring practices that improve water conservation, efficiency and productivity (CEP).

In support of sector planning, the Alberta Water Council (AWC), through its Water CEP Team, has developed a foundation for sector planning, including desired outcomes, principles, definitions of terms (conservation, efficiency, and productivity), performance measures and environmental indicators. A draft annotated table of contents has also been developed to guide the formation of Sector CEP Plans.

The Irrigation Sector CEP Project Team (made up of a Steering Committee and a consultant group) will prepare a plan which will address conservation, efficiency and productivity of water use by the irrigation sector using the Draft Annotated Table of Contents and the framework developed by the AWC. The Irrigation Sector CEP Plan is expected to benefit not only those involved in irrigation but also society and the environment. It will consider the needs, opportunities and practices of irrigation districts and private irrigators.

Specifically, the plan will:

- Recognize the value of fresh water in sustaining and enhancing life as well as recognizing its monetary value.
- Identify opportunities to protect aquatic ecosystems and meet ecosystem objectives.
- Recognize the value of water managed and allocated to support sustainable economic development and the strategic priorities of the province.

2.0 Establishment of an Irrigation Sector CEP Plan Steering Committee

2.1 Mandate of the Steering Committee

The Steering Committee is to deliver an Irrigation Sector plan which covers all areas of the province where irrigation is practiced.

The plan is expected to increase understanding, by the irrigation sector, of its water use, and when complete, will instil confidence in the approaches to CEP efforts taken by the water users. The plan will also contribute to the successful achievement of the Water for Life outcomes.

Based on the “Framework” and “Annotated Table of Contents (AToC)”, the Steering Committee will identify a process to encourage the irrigation sector to go beyond the status quo when setting CEP targets and will endeavour to have consistent and unbiased reporting throughout a transparent process.

The development of the Irrigation Sector CEP Plan will be carried out within the context of and with due consideration of the Water Act and the Irrigation Districts Act.

2.2 Steering Committee Guiding Principles

The irrigation sector plan will follow and use, as a guide, the “Draft Annotated Table of Contents for Water Conservation, Efficiency and Productivity Sector Planning”, which has been developed and accepted by the Alberta Water Council as the guide for sector planning.

The Steering Committee will also guide development of the plan, applying the following principles adopted from the CEP Team framework:

- Fresh water is a finite and vulnerable resource, essential to sustain life, economic development and the environment.
- Water has an economic value in all its competing uses.
- Water also has non-monetary values that enhance the quality of life.
- Sectors are accountable for the water that they control.
- Sectors have different opportunities for making progress in water-use conservation, efficiency and productivity and are not necessarily comparable against other sectors.
- Sector plans will make every reasonable effort to protect and enhance aquatic ecosystems and meet ecosystem objectives.

- All stakeholders will work collaboratively, resolve differences through consensus processes and support Best Management Practices.
- The Alberta Government will ensure that goals for water conservation, efficiency and productivity are achieved.

2.3 Steering Committee Membership

The following individuals were selected to represent stakeholder groups who were understood to have vested interests in how the irrigation sector managed its use of water. Appointed as Committee representatives were:

- <u>Gerhardt Hartman</u> – Oldman Water Council, representing basin water management planning interests.
- <u>Cheryl Bradley</u> – Southern Alberta Environmental Group, representing water-based environmental interest organizations.
- <u>Ray Bryant</u> – Town of Taber, representing municipality water-use interests.
- <u>Rich Smith</u> – Alberta Beef Producers Association, representing the livestock industry.
- <u>Roger Hohm</u> – Alberta Agriculture and Rural Development (AARD), representing provincial government interests in agricultural production and rural economy.
- <u>Terrance Lazarus</u> – Alberta Environment (AENV), representing provincial government interests in monitoring and regulating resource development and use.
- <u>Richard Phillips</u> – Bow River Irrigation District (BRID), representing irrigation district needs and perspectives on water use.
- <u>Kent Bullock</u> – Taber Irrigation District (TID), representing irrigation district needs and perspectives on water use.
- <u>Ron McMullin</u> – Alberta Irrigation Projects Association (AIPA), representing the collective interests in water use on the part of all 13 irrigation districts.
- <u>Colleen Dekok</u> – Southern Alberta Private Irrigation Water Users Association, representing the needs and perspectives of private irrigation development projects.

2.4 Steering Committee Tasks

The Committee agreed to the following assignments and principles of functioning:

- AARD, in the person of Roger Hohm, will chair the Committee's activities. The Chair will be responsible for developing agendas, presiding over meetings and ensuring minutes are kept of meetings and that the project is proceeding within the desired timeframe.
- Committee members will work collaboratively and resolve differences through a process of consensus, as guided within the AWC consensus process document.
- The Committee will provide guidance to the Alberta Irrigation Projects Association (AIPA) in the hiring of a consultant who will be contracted to complete the plan.
- The Committee will also support the development of a work plan, identify key tasks and deliverables and outline the timeframe associated with completion of the plan in conjunction with the consultant.

- The Committee will ensure that the plan and all materials used in the development of the plan are written in language that is appropriate and understandable to the broader public audience.
- The Committee and the stakeholder groups they represent will support the AIPA and the consultant in gathering information necessary to complete the plan.

2.5 Proposed Project Timelines

The original proposed timeline for project development and completion was to have the required content, as per the AToC outline, compiled and a draft report submitted for Steering Committee review by November 15, 2008, with feedback returned to the consultant by December 1, 2008 for final report preparation. The report was to be finalized for presentation to the Steering Committee by December 31, 2008, with final submission of the completed report submitted to AENV by January 31, 2009.

It became clear, by November of 2008, that there was still a considerable amount of dialogue required to develop understanding and then consensus around what was being developed as a plan. Not only were the developed CEP targets receiving on-going debate but the whole premise of the document (i.e. report) being prepared was discussed as to whether it adequately could represent a plan, as was originally envisioned, or whether it was a document providing guidance to the irrigation sector in striving to achieve CEP gains.

As a result of the latter prolonged discussions and the extended period of stakeholder review and document editing, the development of a final report lapsed well beyond the originally conceived timeframe. Nonetheless, the substantive material content from the initial draft was able to be presented to AENV by February, 2009, within its acceptable timeframe, and also was able to be conveyed to the irrigation industry, as a whole, during that same period.

Appendix B: Table of Irrigation District Licences

The following is a summary of all the water right licences that have been issued to the 13 irrigation districts and those that are currently in force (as of 2007). The information reveals the amount of licensed allocation from a specific source and the timeframe in which these allocations have been in effect. The information has been compiled from the files of Alberta Environment's water management system and from the information reported within the summary volume of the "*SSRB – Irrigation in the 21st Century*" report produced by the Irrigation Water Management Study Committee, in 2002.

The priority date (or sometimes referred to as the "unique number") indicates the exact reference date for allocation authorization. Despite the very early dates in which some of the licensed diversions were originally authorized, most of the licences have been, in more recent times, reviewed, re-structured as necessary and re-issued. Nonetheless, in almost all cases, the original priority of authorization to divert water remains in effect.

More specifically, the "Priority Date" is configured to provide a consecutive number, wherein the lowest value has the earliest date of authorization. Under a "first-in-time, first-in-right" allocation authorization system, the lower priority date "value" indicates a higher priority licence. For example:

> with a Priority Date (Unique Number) of: **1945063001**;
>
> the **1945** reflects the year of the licence authorization;
>
> the **06** reflects the month (i.e. June) in the specified year of the licence authorization;
>
> the **30** reflects the day of the specified month (i.e. 30th of June) of the licence authorization; and
>
> the **01** indicates the numeric order of authorizations issued on the specified day. (In other words, this was the first licence authorized for June 30, 1945.)

A licence with priority date of 1945063002 would be the second licence issued on that 30th day of June in 1945 and would have a lower priority of use then the licence with priority date of 1945063001. This means that if , for example, a water supply shortage was incurred, the licence with unique number 1945063001 would have first right to have its allocation authorization satisfied before any other licence of a higher value (later date), regardless of the type of use, would be entitled to receive its allocation.

In addition, some licences were issued with specific conditions attached. These could indicate some specific allowances or restrictions imposed within the authorizations defining how water diversions may occur. Particularly in more recent authorizations, these conditions would often include limitations on when and how much water could be diverted at what maximum rate. These allowances and restrictions, relative to respective licences, are also summarized within the following tables.

(Note: Within the following tabular listings, the "Licensed Volume" values are rounded-off conversions from the original imperial units of acre-feet.)

Irrigation District:	**AETNA (AID)**				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m³)**	**Diversion Rate (cms)**	**Unique Conditions**
Belly River	May 15,1992	1945063001	6,784	n/a	- Has right to use return flow
Belly River	Dec. 7, 1992	1991122301	4,317	*(see conditions)*	- Subject to Crown and SSRB Regulation minimum flows.
		TOTAL ALLOCATION =	**11,101**		

Irrigation District:	**BOW RIVER (BRID)**				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m³)**	**Diversion Rate (cms)**	**Unique Conditions**
Bow River	Dec. 30,1982	1908102702	185,022	n/a	- Has right to use return flow.*
Bow River	Dec. 30, 1982	1913032501	185,022	n/a	- Has right to use return flow.*
Bow River	Dec. 30, 1982	1953062501	98,679	n/a	- Has right to use return flow.*
Bow River	Dec. 7, 1992	1992020510	86,344	*(see conditions)*	- Subject to Bow River I/O from Carseland to Bassano. - May request additional water beyond allocation to be put into BRID storages, which would be deleted from following year's allocation. - If preceding year experienced a shortfall in delivery allocation, then can request diversion in excess of licensed quantity for that year. - Has right to use return flow.
		TOTAL ALLOCATION =	**555,067**		

** Licensed estimates for total return flow attached to all three licences = 123.35 million cubic metres.*

Irrigation District:	EASTERN (EID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Bow River	Jan 4,1963	1903090402	939,913	85 at flood 85 at high 28.3 at low 23.4 at non-irrigation	- 246,705,367 m^3 of licensed amount is for diversion from Oct. 1 through April 30 at diversion rate of 23.4 cms - Minimum passing flow of Bow River set at 2.83 cms.
		TOTAL ALLOCATION =	**939,913**		

Irrigation District:	LEAVITT (LID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Belly River	June 18,1992	1939061701	9,559	n/a	- Has right to use return flow.
Belly River	Dec. 8, 1995	1991123004	5,242	*(see conditions)*	- Subject to minimum flows applied by Crown and in SSRB Regulation. - Has right to use return flow.
		TOTAL ALLOCATION =	**14,802**		

Irrigation District:		LETHBRIDGE NORTHERN (LNID)			
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Oldman River	Mar. 25, 1982	1917111601	185,022	n/a	- Has right to use return flow.
Oldman River	Mar. 25, 1982	1974110401	82,643	n/a	- Has right to use return flow.
Oldman River	Aug. 27, 1992	1982041501	61,674	n/a	- Has right to use return flow. - May request additional water beyond allocation be stored in LNID storages for use in following year and be charged against following year's allocation. - If preceding year experienced a shortfall in delivery allocation, then can request diversion in excess of licensed quantity for that year.
Oldman River	Dec. 7, 1992	1991082301	61,674	*(see conditions)*	- Subject to minimum instream flow requirements. - Has right to use return flow. - May request additional water beyond allocation be stored in LNID storages for use in following year and be charged against following year's allocation. - If preceding year experienced a shortfall in delivery allocation, then can request diversion in excess of licensed quantity for that year.
Oldman River	2007	1995080204	21,524	4	- Subject to minimum instream flow requirements.
		TOTAL ALLOCATION =	**412,538**		

Irrigation District:	MAGRATH (MID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
St. Mary River	Nov. 26, 1982	1899020704	11,323	n/a	- Has right to use return flow
St. Mary River	Nov. 26, 1982	1950053108	5,329	n/a	- Has right to use return flow
Waterton River	Nov. 26, 1982	1950053109	16,652	n/a	- Has right to use return flow
Belly River	Nov. 26, 1982	1950053110	3,700	n/a	- Has right to use return flow
St. Mary, Belly & Waterton Rivers	Dec. 7, 1992	1991082204	4,934	*(see conditions)*	- Subject to minimum instream flows applied by Crown. - Has right to use return flow. - After full allocation has been diverted, may request additional water be held in MID's storage for following year. - If allocated amount cannot be delivered, then may request that amount be delivered in following year, in addition to regular allocated amount.
		TOTAL ALLOCATION =	**41,938**		

Irrigation District:	MOUNTAIN VIEW (MVID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Belly River	Dec. 22, 1988	1923071003	9,251	n/a	- Has right to use return flow
Belly River	Dec. 7, 1992	1991121702	617	*(see conditions)*	- Subject to Crown and SSRB Regulation minimum instream flows.
		TOTAL ALLOCATION =	**9,868**		

Irrigation District:	ROSS CREEK (RCID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Gros Ventre Creek	April, 26, 1989	1951030201	3,700	5.7	- Has right to use return flow. - Minimum passing flow on Gros Ventre Creek of 0.06 cms.
		TOTAL ALLOCATION =	**3,700**		

Irrigation District:	RAYMOND (RID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
St. Mary River	May 10, 1983	1899020703	15,098	n/a	- Has right to use return flow.
St. Mary River	May 10, 1983	1950053114	15,431	n/a	- Has right to use return flow.
Waterton River	May 10, 1983	1950053115	30,529	n/a	- Has right to use return flow.
Belly River	May 10, 1983	1950053116	6,784	n/a	- Has right to use return flow.
St. Mary, Belly & Waterton Rivers	Dec. 7, 1992	1991082302	32,071	*(see conditions)*	- Has right to use return flow. - Subject to Crown minimum instream flows. - After the full allocation has been diverted, may request additional water to be held in TID or SMRID storage for use in following year. - If allocated amount cannot be delivered, then may request that shortfall be delivered the following year over and above licensed quantity.
		TOTAL ALLOCATION =	**99,912**		

Irrigation District:	ST. MARY RIVER (SMRID)				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
St. Mary River	Sep. 24, 1991	1899020701	207,438	n/a	- Has right to use return flow. - Subject to Crown minimum instream flows. - If full allocation is used, may request additional water to be held in SMRID storages for use in following year. - In a dry year where the licensed quantity cannot be obtained, may request shortfall be delivered the following year over and above licensed quantity.
St. Mary, Belly & Waterton Rivers	Sep. 24, 1991	1950053107	409,303	*(see conditions)*	- Has right to use return flow. - Subject to Crown minimum instream flows. - If full allocation is used, may request additional water to be held in SMRID storages for use in following year. - In a dry year where the licensed quantity cannot be obtained, may request shortfall be delivered the following year over and above licensed quantity.
St. Mary, Belly & Waterton Rivers	Dec. 7, 1992	1991082309	273,833	*(see conditions)*	- Has right to use return flow. - Subject to Crown minimum instream flows. - If full allocation is used, may request additional water to be held in SMRID storages for use in following year. - In a dry year where the licensed quantity cannot be obtained, may request shortfall be delivered the following year over and above licensed quantity.
St. Mary, Belly & Waterton Rivers	2003 Amendment	1991082309	*(see conditions)*	*(see conditions)*	- An amendment, in 2003, to the 1991 priority allows SMRID to deliver up to 14.8 million cubic metres of water to non-irrigation users.
TOTAL ALLOCATION =			**890,574**		

Irrigation District:	**TABER (TID)**				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
St. Mary River	Aug. 27, 1982	1899020702	41,938	n/a	- Has right to use return flow.
St. Mary River	Aug. 27, 1982	1950053117	41,322	n/a	- Has right to use return flow.
Waterton River	Aug. 27, 1982	1950053118	83,260	n/a	- Has right to use return flow.
Belly River	Aug. 27, 1982	1950053119	18,502	n/a	- Has right to use return flow.
St. Mary, Belly & Waterton Rivers	Dec. 7, 1992	1991082602	9,868	*(see conditions)*	- Has right to use return flow. - Subject to Crown minimum instream flows. - After the full allocation has been diverted, may request additional water to be held in TID or SMRID storage for use in following year. - If allocated amount cannot be delivered, then may request that shortfall be delivered the following year over and above licensed quantity.
		TOTAL ALLOCATION =	**194,890**		

Irrigation District:	**UNITED (UID)**				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Belly River	Jan. 14, 1963	1919032401	62,908	10.14 Flood 10.14 High 4.57 Low	- Has right to use return flow
Waterton River	Mar. 13, 1996	1993051701	20,969	*(see conditions)*	- UID can divert water from AENV's Waterton to St. Mary system. - Subject to minimum instream flows in AENV's 1991 licence. - Has right to use return flow.
Belly River	2003 Amendment	1919032401	-604	10.04 Flood 10.04 High 4.47 Low	- 2003 amendment recognizes transfer of allocation portion to local municipal users. - 0.1 cms deducted from allowable diversion rates.
Belly River	2004 Amendment	1919032401	-1,604	4.2 May 1st to 15th. 5.6 during remainder of year.	- 2004 amendment recognizes transfer of allocation portion to regional water supply system. - Maximum diversion rates substantially reduced. - Subject to 1 cms minimum flow in Belly River.
		TOTAL ALLOCATION =	**81,669**		

Irrigation District:	**WESTERN (WID)**				
Water Source	**Date Licence Issued**	**Priority Date**	**Licensed Volume (x 1000 m^3)**	**Diversion Rate (cms)**	**Unique Conditions**
Bow River	Jul. 2, 1963	1903090401	197,850	21.2 Flood 17.0 High 11.3 Low	- Allocation noted as sufficient for the irrigation of 20,235 hectares.
Bow River	2007 Amendment	1903090401	-2,467	*(see conditions)*	- 2007 amendment recognizes transfer of allocation portion to other regional water use interests.
		TOTAL ALLOCATION =	**195,384**		

Appendix C: Climate Change and Irrigation Water Use Projections

The following is an excerpt from a presentation given to the Canadian Water Resources Association (CWRA) – Alberta Branch at their annual conference on April 4, 2006. The presentation was based on the analysis work carried-out by the co-authors:

Wally R. Chinn, P. Eng. – Irrigation Branch, Alberta Agriculture

Bob Riewe, P. Ag. – Irrigation Branch, Alberta Agriculture

Dr. Anita Shepherd, PhD. – Irrigation Branch, Alberta Agriculture

The presentation was intended to address the subject of evaluating the effects of projected climate change on the intensively irrigated areas of southern Alberta.

1.0 Introduction

The past decade has been witness to a substantial increase in the prognosis for the planet as it may be affected by the projections for global warming (or climate change as driven by global warming). The debate around this subject has been considerable and at times quite heated. It is accepted that the climatic conditions around the planet have, through the course of time, constantly been shifting through the historic millennia of Planet Earth. It is then conceivable that change will continue to occur, with the uncertainties being at what rate and to what extent that change may be.

The following discussion and information is not intended to participate within the specific debate concerning the reality of global warming and climate change effects, but is focussed on a determination of the potential effects that projected global warming could have on the water demand situation for southern Alberta's irrigation industry, should projections become reality at some time in the future.

In accepting the premise that some warming of the climate could take place within the foreseeable future, it would be expected that this may mean a consequential increase in crop-water demand. Gaining an understanding of what that increase may be leads then to an analysis of what degree of impact the southern Alberta irrigation industry could experience and how it may be able to adapt to such projections. This is the focus of the following discussion.

2.0 Computer Modelling

The application of advancing computer technology has enabled practitioners to develop computer programs ("models") that can derive outcomes from simulating naturally-occurring phenomena and their interactions. As computer technology has improved exponentially through the past decade or more, so have the predictability capabilities of a whole range of modelling techniques. Such has been the case with respect to modelling climate conditions and the prospects for climate change through global warming. The next step in the process is to apply the output of projected or modelled climate conditions to specific physical processes that are very much inter-related with climatic factors. As climatic factors drive plant responses and demands for water, the integration of the effects of the two processes can provide indications of potential results from several simulated scenarios.

Of course, the fundamental accuracy and usefulness of any computer modelling application is totally dependent on the integrity of the data that is referenced by the application and on the level of understanding, quantification and qualification of the interactions between data and related physical processes that are represented by mathematical algorithms.

The development of climate change models is an industry unto itself. It is the application of the output from those models, when applied to the simulation of crop-water demands, yielding the consequential results and adaptation opportunities which may exist that are the focuses of this discussion.

2.1 Global Circulation Models (GCMs)

The development of global circulation models (often referred to as global climate models) has been increasing in emphasis for the better part of the last couple of decades. Various versions of GCMs are now available, as constructed, tested and proven by a large number of agencies from around the world. As time has progressed, the predictability of these tools has also proven to be more refined and credible.

Depending on the specific model, such physical parameters as air temperature, solar radiation, atmospheric gas concentrations, geographic location, oceanic influences, and the like, are applied to large regional areas across the continents to firstly replicate what has occurred historically. Then, projections are developed that reflect what the climatic physical conditions and interactions may be, within those specific regions, should certain scenarios of global warming occur. In particular, forecast temperature and precipitation levels are computed for specified geographical locations.

With a variety of GCMs currently available within the scientific community, it was advisable to evaluate a sampling of some of the more recognized model applications to determine if there was a best or better fit for the southern Alberta situation. Five different models were considered, including:

- GCMII - An earlier version produced through the Canadian Centre for Climate Modelling and Analysis (CCCMA).
- CGCMI - A more recent, updated and improved version produced through the Canadian Centre for Climate Modelling and Analysis (CCCMA).
- HADCM3 - A recent and advanced model produced through the Hadley Centre for Climate Prediction and Research in the United Kingdom.
- ECHAM4 - A recent and more advanced application, enhanced on the foundation of the original European model, but developed through the Max Planck Institute for Meteorology in Germany.
- NCAR-PCM - A recent American-developed application produced through the National Center for Atmospheric Research (NCAR) as sponsored jointly by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA).

Although all of the above models were considered to only fairly represent conditions at a relatively large regional scale, it was possible to extrapolate that information to more localized and defined geographical positions, for comparison purposes. In doing so, in consideration that the Canadian CGCMI application was more advanced, more recent and better-linked to oceanic influences than the earlier GCMII model, the CGCMI application was emphasized in the comparative evaluations.

A comparative evaluation of the 30-year mean daily maximum temperatures, at selected representative locations in the irrigated areas of southern Alberta, as predicted by each of the four main models, was carried-out. The predicted future values were compared with the historic mean to evaluate the variability between models. Depending upon the particular model, some predicted highest temperature deviations earlier in the year than others (e.g. Day 100) while others predicted higher temperature shifts around mid-year (e.g. Day 200). An analysis of mean daily standard deviations from historic levels revealed little difference between the models. Therefore, for most subsequent analyses of effects on irrigation water demands, the Canadian CGCMI model output was used.

2.2 Irrigation Demand Model (IDM)

As an integral part of the "*SSRB – Irrigation in the 21st Century*" water management study carried-out by the Irrigation Branch of Alberta Agriculture (as it was known at the time) in partnership with the irrigation districts in Alberta, a computer model, known as the Irrigation Demand Model was developed. It was designed to determine irrigation water requirements starting from the crop in a given field under specific irrigation application practices, accumulating all field demands and applying water conveyance efficiencies for the water delivered to those fields. All these computations and simulations were designed to determine water diversion demands at any given point in time for a specified geographic area and based on the nature of irrigation operations within that area. (More detail on the IDM can be found within Volumes 1 and 4 of the "*SSRB – Irrigation in the 21st Century*" report produced by the Irrigation Water Management Study Committee in 2002.)

The IDM is a leading-edge tool in the area of irrigation water management, due in large part to its intensive field-by-field, day-by-day crop water and irrigation demand computations. The whole process is fundamentally climate driven so if an appropriate climate data package could be constructed, the IDM can provide a cumulative water demand for whatever time step wanted to be considered.

This aspect of climate change impact analysis was considered to be quite leading-edge within the irrigation discipline as much has been forecast as to general prognoses of higher crop water use in irrigated areas, less precipitation and therefore greater demand on scarce irrigation water supplies. However, the degree of impact had never really been truly quantified up to this time, so the output from various IDM and GCM scenarios could take this quantifying assessment quite a bit further.

2.3 Deriving Data to Drive the IDM

It is well understood that the degree of successful use of any computer model is primarily dependent upon the quality of the data available to drive its functions. Regardless of how well-constructed the model and its algorithms may be, if the supporting data is limited or of questionable integrity, modelling results could be quite flawed.

There were a few major undertakings in developing the IDM modelling capabilities, beyond developing the model itself. First was to compile and maintain a very detailed inventory of all irrigated fields within the irrigation districts. This included annual recordings of each type and area of crop grown on each defined field, plus an identification of the type of irrigation system used for water application in each respective field. The irrigation districts have played a most significant part in compiling and annually updating that inventory, in cooperation with the Irrigation Branch (now the Resource Sciences Branch). Secondly, and an area where this same cooperative partnership was equally as effective, was the process of inventorying the whole of the irrigation district water conveyance and storage works. This enabled the IDM to not only model how water was applied to the crop but also how well water was conveyed to each field as crops demanded irrigation. This also reflected water lost through the process and limitations in conveyance to meet demand as well as water returned to downstream receiving streams.

However, first and foremost in driving the irrigation demand and related water use components within the IDM, is the pertinent agro-climatic data. The daily crop consumptive-use data and associated precipitation data would determine whether soil moisture levels were adequate to satisfy daily crop needs or whether irrigation needed to be implemented. An historical database of agro-climatic factors, extending back to 1928 and covering the period up to 1995 (and beyond in some areas), was developed based on the Gridded Prairie Climate Database (GRIPCD) originally compiled by Agriculture and Agri-Food Canada. This database provided daily climate information for geographic points across southern Alberta on a 50 km by 50 km grid spacing. Through the work of the Irrigation Branch, this data was expanded to include daily values of potential evapotranspiration at each grid point, thereby allowing for the determination of crop-specific daily consumptive use within the grid area represented by each respective grid point. (More detail on the GRIPCD and subsequent enhancements can be found within Volumes 1 and 2 of the "*SSRB – Irrigation in the 21st Century*" report produced by the Irrigation Water Management Study Committee in 2002.)

Having constructed an enhanced agro-climatic database, developed from historical data, it was then possible to extrapolate the output data from any of the selected GCMs to fabricate alternative multi-year agro-climatic gridded prairie databases associated with projected climate change scenarios. These forecast GCM agro-climatic databases could be compared with long-term historic data to determine any projected relative shifts in specific climate parameters. Further, the IDM could be run, utilizing the GCM-associated fabricated agro-climatic databases as the consumptive use and soil moisture balance drivers, to quantify projected variances in irrigation water demand under global warming-initiated climate change.

3.0 Simulation Outcomes

A variety of comparisons between the historic agro-climatic data and that derived through the development of a parallel GCM-constructed database were carried out. In addition, IDM computer runs for various irrigation scenarios and locations were completed and analyzed. As mentioned earlier, most GCM-related work utilized the CGCMI application.

As far as irrigation-related impacts are concerned, the main climate change projections that are of most interest are the effects on precipitation levels and the shift in daily temperatures, which correspondingly relates to crop consumptive use. Additionally, depending upon how daily temperature changes occur, it is possible that the length of growing season could also be affected.

Although reporting changes to average values can sometimes be misleading, the generalized regional nature of the current GCMs precludes any benefit in striving for further precision. Therefore, all reported analyses reference an “average” location with “average” conditions within the southern Alberta irrigated area.

3.1 Database Evaluations

In analyzing the temperature shifts that could potentially occur, relative to the historic pattern, and depending on the GCM referenced, the daily maximum temperature shifted anywhere from approximately – 1.5°C to + 5°C throughout the year. Therefore, on average for all GCMs considered, it was noted that the daily maximum temperature was predicted to increase between 0.5°C to 3°C, depending on the time of year.

This overall average temperature increase would have two expected effects; an increase in crop consumptive use and a potential increase in the length of the growing season (i.e. number of days between killing frosts). The increase in temperature coupled with increase in consumptive use could yield earlier maturation of some crops. When added to a longer growing season, the potential for the expansion of double-cropping within one growing season increases. For example, it may be possible that two short-season crops, such as barley silage, may be able to be grown in some years. This would then likely add to the water demand for double-cropping the barley silage as compared with having only grown one such crop in the past.

A limited analysis of change in growing season length was carried-out. Once again, depending on the GCM applied and the geographic location of the area being considered, variations in predictions on change in growing-season length were obtained. For example, when comparing the climate change predictions for a relatively higher-consumptive use geographic area, measuring the extension of growing season as compared with the historic average, the length increased by approximately 14 percent or nearly 23 days. When the predicted growing season change of a lower consumptive-use geographic area was compared with that of a higher consumptive-use area, the extent of change in length of growing season was noted to be up to 11 percent or approximately 18 days greater for the higher consumptive use region. Therefore, the opportunity for global warming-induced climate change to encourage double-cropping will likely be limited to those areas where cropping options are already more varied because of the current longer growing season and will still be limited to specific crop choices. However, extended growing seasons providing opportunities for extended growth for some crops (e.g. forages and some special crops) will, in turn, drive-up expanded demands for water.

The other main element in the crop-growth irrigation-demand equation is the predicted amount of precipitation that may be received. This includes the amount received within the actual crop growing season period as well as that received throughout the year, when soil moisture or reservoir storage reserves may need to be replenished.

Figure 1 quantifies the extent of predicted precipitation change, within the growing season, when compared with 30 years of historic record. The overall result is a forecast net reduction in growing-season precipitation of approximately 7 millimetres or three percent. This is deficit moisture that would be expected to have to be replaced through irrigation.

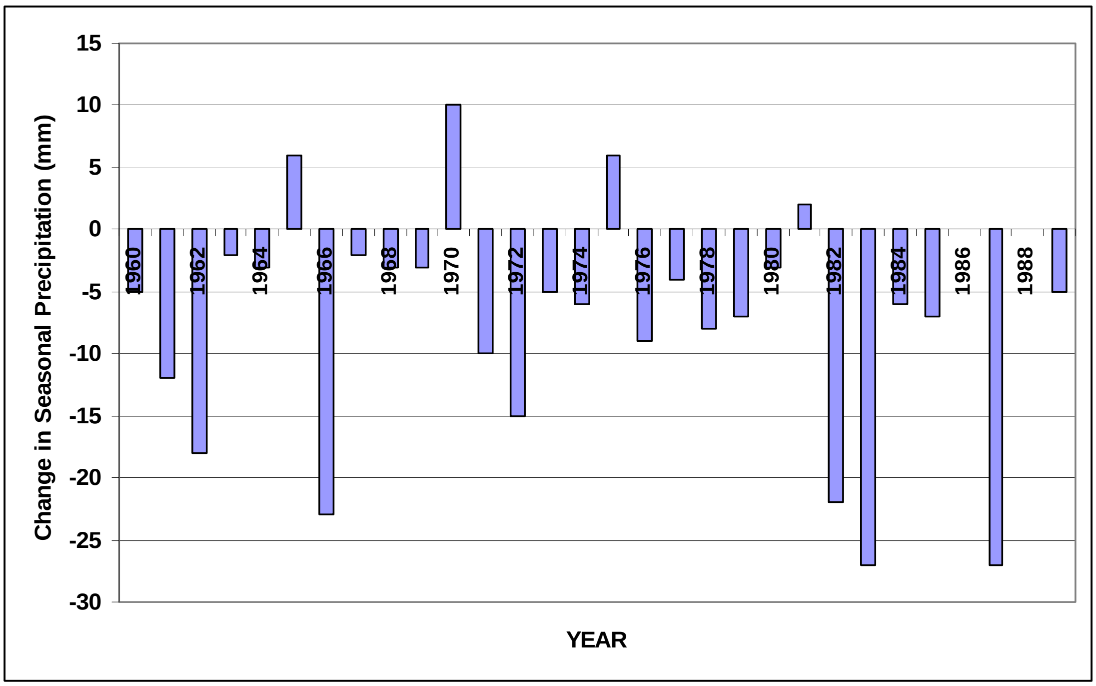

Figure 1. GCM-predicted change in average growing-season precipitation received as compared with a 30-year historic period.

Figure 2 indicates the extent of predicted precipitation change, on an annual basis, when compared with the same 30-year period of historic record. Within this scenario, it is indicated that there would be an overall increase in precipitation received, throughout the year, amounting to an average of approximately 2.3 percent or 9 millimetres more. In those years where notable amounts of additional precipitation are received, the challenge will be to derive ways of capturing that additional moisture to supplement periods when precipitation amounts are below expectations.

Finally, Figure 3 presents the results of combining crop consumptive-use demands, available soil moisture and precipitation into the Irrigation Demand Model (IDM) to derive projections on irrigation demand through the 30-year period 1960 through 1989. Knowing the modelled demands for water, based on historic climate conditions, these are compared with what could be expected under modelled potential climate change conditions. This includes both changes in consumptive use and precipitation. Figure 3 reveals that, overall, the average annual increase in demand for irrigation water could increase by approximately 12.5 millimetres per unit area of irrigation, or by nearly three percent.

It is projected that if the climate change effects are realized to the extents presented above, the southern Alberta irrigation industry should be able to adapt to such effects of increased water demand through the on-going improvements in irrigation water-use efficiency.

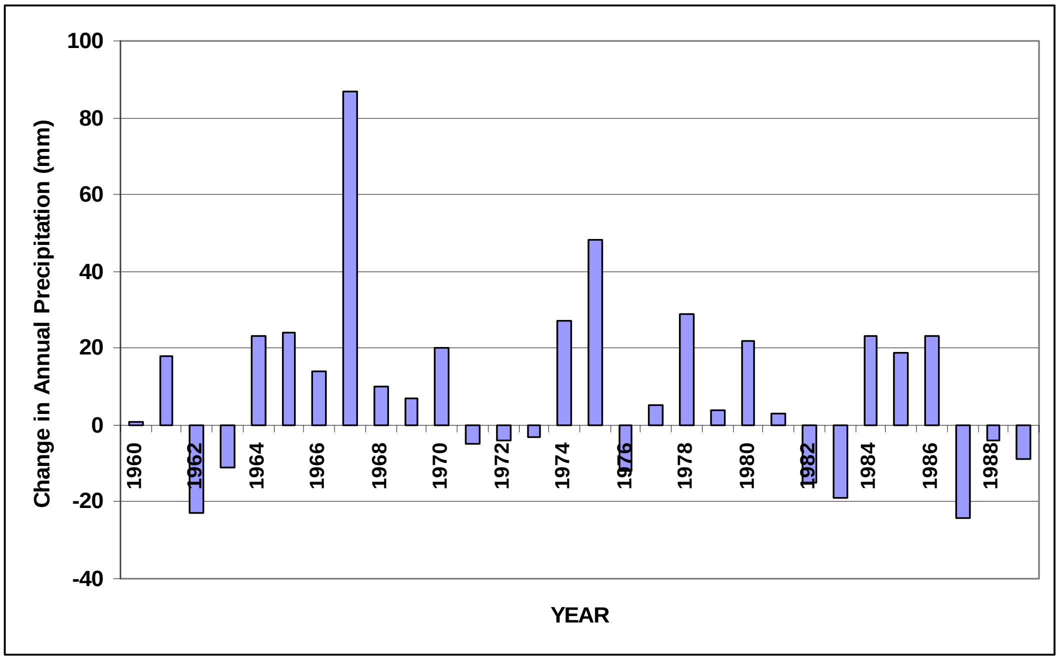

Figure 2. GCM-predicted change in average annual precipitation received in comparison with a 30-year historic period.

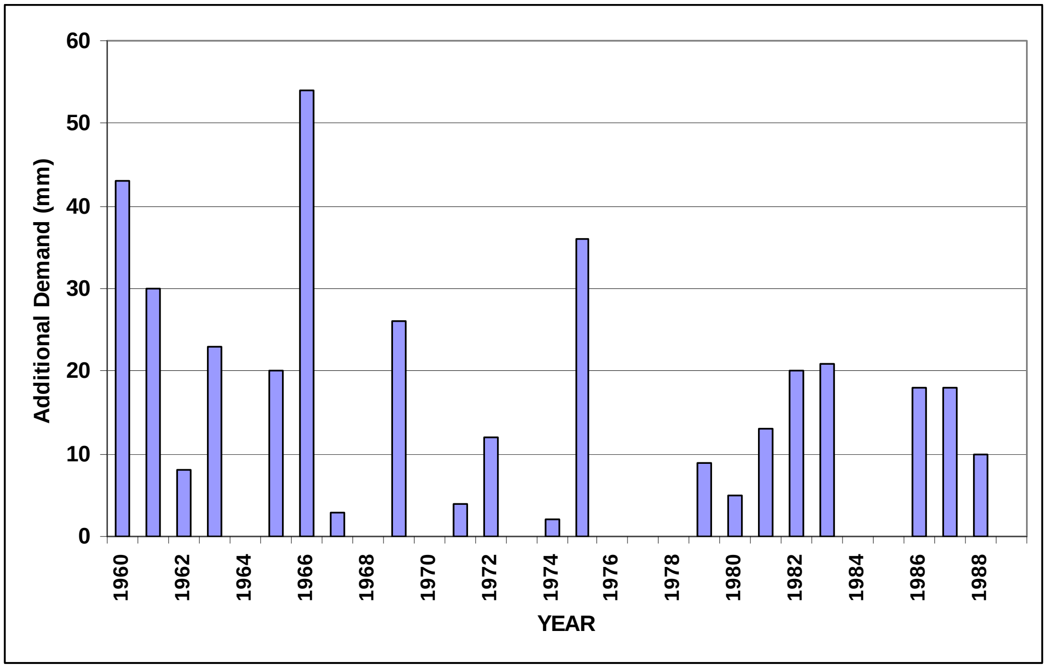

Figure 3. Change in modelled annual irrigation demand under a climate change scenario in comparison with the historic demand modelled through a 30-year period.

Appendix D: Understanding Numeric Water Use Efficiency Expressions

The following information is intended to provide background related to computational aspects of some of the efficiency gain and water-saving improvements that are discussed in The Irrigation Sector – Conservation, Efficiency and Productivity Plan Report. The following serves as a cautionary note in understanding the application of these terms, particularly within Chapters 3 and 4. The correct understanding of the derivations of percentage values expressed and the use thereof is important in referencing, applying and re-calculating such values in the future.

The definition of water use efficiency, as adopted by the Alberta Water Council and as provided in their 2007 report, "*Water Conservation, Efficiency and Productivity: Principles, Definitions, Performance measures and Environmental Indicators*" states:

Water use efficiency is defined as:

- The accomplishment of a function, task, process or result with the minimal amount of water feasible.
- An *indicator* of the relationship between the amount of water needed for a particular purpose and the quantity of water used or diverted.

For irrigation purposes, this *indicator* is usually represented or expressed as a ratio equal to:

$$\frac{\textit{Amount of net* water needed to meet crop water requirements}}{\textit{Total amount of water diverted from a supply source to meet crop water requirements}} \qquad (1)$$

(* Net water refers to that portion of the amount of water that a crop requires for normal processes of evapotranspiration, that is in excess of the amount received through effective precipitation contributions. "Effective precipitation" refers to that amount from precipitation events that remains available for plant uptake and is not lost due to surface runoff or deep percolation conditions.)

In conventional reporting on efficiency levels, regardless of the concept being discussed, a numeric expression of an efficiency level is normally presented in percentage terms (i.e. 65%). The use of percentage terms is a popular convention and can be useful, if properly used, correctly calculated and appropriately interpreted. Unfortunately, these three aspects do not always occur simultaneously, such that expressed percentage terms can lead to misinformation or misinterpretation and result in much confusion.

Therefore, within the Irrigation Sector – Conservation, Efficiency and Productivity Plan Report, some conventions with the use of percentage terms have been generally adopted. Specifically, these are:

1) When the term "*improvement*" is used and quantified in percentage terms, the numeric value is to be interpreted as a relative change from the prior condition to the new condition.

2) When the term "*gain*" is used and quantified in percentage terms, the numeric value is to be interpreted to quantify the exact change in that percentage value from the prior condition to the new condition.

To explain the differences between these two conventions, the following example is used.

Understanding the accepted definition of water-use efficiency and its ratio determination (from above), a statement could be made such as, "On-farm water-use efficiency gains have increased from 45 percent in 1975 to 72 percent in 2005". In using the term *improvement*, the relative change is calculated to be a "60 percent improvement", according to the equation:

Relative improvement = (Final condition – Initial condition) / (Initial Condition)

or

(72% - 45%) / (45%) = 60%

However, the actual change or *gain* in efficiency is 72 percent minus 45 percent equals 27 percent.

Similarly, it could be said that the average *improvement* (relative) in efficiency during the 30-year period has been increasing at two percent per year, determined by 60 percent divided by 30 years. On the other hand it could be said that the *gain* in efficiency averages approximately 0.9 percent per year, determined as 27 percent divided by 30 years. The latter case is correct as each annual *gain* is incrementally cumulative. However, in the former case, where relative improvement is actually an annual multiplier through time, the simplistic two-percent result is incorrect. In actual fact, the correct multiplier is derived through application of an exponential factor resolved as follows, where Z is the multiplier value and Y is the number of years in the accumulating period.

45% x Z(1/Y) = 72% or Z(1/30) = 72% / 45%

Therefore, **Z = 1.01579**

and would be interpreted to read, "*the average annual improvement in efficiency would equal 1.579 percent*".

The same principles apply when discussing net improvements in water use that could also translate into reductions in the use thereof. For example, if there is an overall efficiency gain of 10 percent, this does not mean a reduction in water use of 10 percent. If the 10-percent gain originated at 50 percent and moved to 60 percent, the efficiency *improvement* would be:

60% / 50% = 1.20 or 20 percent

However, this 10-percent efficiency gain does not translate into a 20-percent reduction in water use. In terms of the net reduction in associated water use, this level of efficiency gain (comparing “before” and “after”) has to be converted into relative amounts of water. The above example, would translate into an overall net reduction in water use equal to approximately:

$$\mathbf{(1 / 50\%) – (1 / 60\%) / (1 / 50\%) = 16.67\%}$$

Conversely, using the 2005 efficiency levels and the gains projected for the future, it can be demonstrated that, on average, for every *one percentage point* of efficiency gain achieved in moving from 53.3-percent efficiency to 62.7-percent efficiency, the approximate annual water saving, each year, on a per unit of irrigated-area basis, would be as shown in the following table. In this example, the starting point for 2005 is an irrigation crop water requirement of 235 millimetres that needs to be satisfied. With an overall efficiency of 53.3 percent, the 2005 gross irrigation diversion demand (GIDD) starts at 441 millimetres per unit of irrigated area.

Beginning Efficiency	Ending Efficiency	Proportion of Water Saved	Amount of Water Saved (mm)	Amount of Water Required (GIDD) (mm)
53.3%	54.3%	1.92%	8.5	432
54.3%	55.4%	1.89%	8.2	424
55.4%	56.4%	1.85%	7.9	416
56.4%	57.5%	1.82%	7.6	409
57.5%	58.5%	1.78%	7.3	402
58.5%	59.6%	1.75%	7.0	395
59.6%	60.6%	1.72%	6.8	388
60.6%	61.7%	1.69%	6.6	381
61.7%	62.7%	1.67%	6.3	375
Average per 1%		**1.79%**	**7.3**	

From the above table, it can be concluded that as overall efficiencies improve, the relative impact of those incremental gains becomes less and less. The average water-saving reduction value (e.g. 1.79% per 1.0% efficiency gain) can be used to give some indication of the amount of water (7.3 mm) that can be saved with each incremental efficiency gain. If those 7.3 millimetres were saved across 500,000 hectares each year, for example, the resulting saving would be approximately 36.5 million cubic metres of water. If the full projected 66 millimetres of water per unit of irrigated area could be saved across the 500,000 hectares, more than 330 million cubic metres of water could be accumulated as savings, each year.

One of the most significant areas where some confusion exists is with respect to one of the outcomes associated with *Water for Life* goal of “*Reliable, quality water supplies for a sustainable economy*”. That outcome states:

“The overall efficiency and productivity of water use in Alberta has improved by 30 percent from 2005 levels by 2015”.

This statement uses the term "*improved*" which raises some question as to how this is to be interpreted. Further, there has been little established as to exactly how the desired increases would be calculated. The following presents an approach to determining required gains in order to achieve a 30-percent *improvement* outcome.

Some initial response to the outcome statement considered that efficiency levels were to increase by a *gain* of 30 percent. In other words, if the 2005 efficiency level were 53.3, then by 2015 it may be interpreted that efficiency levels would need to rise to 83.3 percent. On the other hand, if the 30-percent *improvement* is expected to be applied as a multiplier factor of 1.3, then it can be projected that an efficiency *gain* of approximately 16 percent (53.3% x 0.3) would be expected. Alternatively, if, as projected in Section 3.1.2 of the Report, the productivity index trendline (Figure 15, Section 2.5.4) has been computed to equal 8.8 kilograms per cubic metre in 2005, a 30-percent improvement in productivity would mean an increase of 2.64 kilograms per cubic metre. Overall water-use efficiency gains of 9.2 percent have been projected. This represents making 57.5-percent (9.2% / 16%) proportional progress toward achieving the 30-percent *improvement* target. The remaining 42.5 percent proportion would need to be made up through productivity gains. This would be achieved through a productivity gain of 1.12 kilograms per cubic metre (2.64 x 42.5%), meaning that by 2015, the productivity index would need to increase to 9.92 kilograms per cubic metre.

A similar productivity analysis could also be carried-out of the concept of using a 10-year rolling-average value were referenced. In this case, (referencing the values from Figure 15, Section 2.5.4 of the Report) the rolling-average productivity index value for 2005 is 7.38 kilograms per cubic metre. A 30-percent improvement in productivity from this 2005 reference level would mean an increase of 2.21 kilograms per cubic metre. Therefore, in combination with the efficiency gain projection of 9.2 percent, the required increase in productivity would be 0.94 kilograms per cubic metres (2.21 x 42.5%). This means that, by 2015, the rolling-average productivity index would need to increase to 8.32 kilograms per cubic metre (7.38 + 0.94). As an observation, the 10-year rolling-average productivity index for 2007 is approximately 8.30 kilograms per cubic metre.

Appendix E: Irrigation District Supply of Water to Other Uses

1.0 Introduction

1.1 Background on Alternate Water Users

It has been emphasized that water is the “lifeblood” of southern Alberta. It is clearly understood that where humanity exists and thrives, reasonable access to water is a necessity. In regards to the southern Alberta situation, water is naturally not readily available for much of the populated areas. However, this has been facilitated through the works of developed water management and distribution infrastructure, most of which has support to irrigation at its roots. It is the diversion, storage and conveyance infrastructure that has allowed for regional population centres to be sustained and for rural economic development to function and grow.

As a result of the existence of this extensive water management infrastructure, several alternative water uses, beyond irrigation purposes, benefit from the access to water that is regionally distributed, primarily for irrigation purposes. These uses can be grouped into four identifiable groups, namely:

- Municipal – the water needs of towns, villages, hamlets and water co-operatives.
- Industrial – the water required for commercial processing or manufacturing purposes.
- Environmental – the water that is required to sustain wildlife habitat.
- Other Agricultural – the water needed by non-irrigation agricultural activities.

Municipal uses can range from supplying water to meet the total water needs of a community or just providing water to sustain specific park areas and the like. Industrial users could include food processors, manufacturing operations, oil-field developments, etc. but are usually stand-alone operations outside of municipal water supplies. Environmental uses can include a vast array of applications, but generally pertain to the use of water to sustain such features as wetlands or the development and maintenance of vegetative habitat or wildlife watering features. Other agricultural, non-irrigation, operations requiring water could include small and large livestock feeding enterprises, specialized green-house facilities, composting operations, and the like.

1.2 Supplying Water to Other (Non-Irrigation) Users

Water can be supplied by the irrigation districts to each of the aforementioned other sector users in one of two ways.

The water needs of a non-irrigation sector may be provided directly as a portion of the licence allocation to a given irrigation district. Although the water is not being used for agricultural irrigation purposes, an irrigation district may deem it beneficial to its rural community to allocate a small amount of its licensed volume for the use by a non-irrigation entity. Such water supply arrangements could be set-up through a formalized agreement for the purposes of such uses as servicing domestic water needs, small livestock watering facilities, isolated wildlife habitat or temporary water withdrawals for oilfield exploration and development.

The provision of water from a district in these situations can be handled in a variety of ways, up to the discretion of the district authority, in compliance with the Water Act and the Irrigation Districts Act and as agreed to by the water recipient. For example, some districts may deliver water to a large number of small livestock watering facilities, from within the district's own licensed diversion allocation, while other districts may require more independent licensing agreements to be in place, in the name of the end-user.

As is demonstrated below in Table 1, the estimated volume of water going to such non-irrigation purposes in 2007, within the context of the irrigation district licensing allocations, was estimated to be approximately 2.2 percent of the total volume of water diverted through those licensing authorizations in that year.

Table 1. Summary listing of volumes of water delivered to other users by each irrigation district within the licensed volumes of the respective district licence allocations - 2007.

	Volume of Water Supplied for Alternate Uses (m^3)			
Irrigation District	**Municipal**	**Industrial**	**Environmental incl. Wetland**	**Other Agricultural**
Aetna				
Bow River		37,006	16,035,849	104,850
Eastern				9,868,215
Leavitt				
Lethbridge Northern	143,089	150,490	123,353	1,985,978
Magrath				
Mountain View				
Raymond	1,169,383	6,168	1,850,290	
Ross Creek				
St. Mary River	2,507,760	219,568	34,539	3,228,140
Taber	134,454	14,802	4,610,923	134,454
United				123,353
Western	64,143	24,671		49,341
SUB-TOTAL	**4,018,830**	**452,704**	**22,654,954**	**15,494,331**

Secondly, other non-irrigation users, usually entities that have greater water volume requirements and require more reliability in deliveries, will secure their own water licence authorizations for diversion. However, some of these licensees could be quite remotely located, relative to a desirable water source. In these situations, licensing is granted for a diversion that is associated with a specific irrigation district and the water conveyance is authorized "through the works of" one of that specific district. An example of such an arrangement would be a food processor in the Taber area that is licensed to divert a specific volume of water from the St. Mary River and to receive that water "through the works of" either the SMRID or the TID, as pertinent to the licensee's location. A separate agreement between the water conveying district and the licensee would need to be in place prior to any licensing authorizations being issued.

Table 2 provides a summary listing of the amount of water estimated to be conveyed by the various irrigation districts to other users who have their own diversion licence authorizations. The total amount of water estimated to be conveyed to these other licensees, in 2007, is approximately 6.2 percent of the total amount of water diverted from river sources to irrigation district works. Overall, it is estimated that these non-irrigation users received approximately 8.4 percent of the just over 1.95 million cubic metres of water diverted to irrigation works in 2007.

Table 2. Summary listing of volumes of water licensed to other users and delivered to them through the works of specific irrigation districts - 2007.

	Volume of Water Conveyed for Other Licensees (m3)			
Irrigation District	**Municipal**	**Industrial**	**Environmental incl. Wetland**	**Other Agricultural**
Aetna				
Bow River	696,943	330,585	14,802,322	1,106,474
Eastern	7,277,808	8,634,688	37,005,805	1,233,527
Leavitt				
Lethbridge Northern	1,142,246	160,358	60,443	13,019,876
Magrath				
Mountain View				
Raymond	2,467,054		2,467,054	246,705
Ross Creek				
St. Mary River	2,962,931	154,191	65,377	1,777,512
Taber	3,953,454	6,871,978	7,401	621,698
United	557,554			
Western	351,555	1,073,168	9,022,015	4,105,177
SUB-TOTAL	**19,409,545**	**17,224,969**	**63,430,417**	**22,110,969**
TOTAL	**23,428,375**	**17,677,673**	**86,085,371**	**37,605,299**

It is important to note that much of the reported volumes of water diverted to these other non-irrigation uses are *estimated* amounts, as there has traditionally been little in the way of means to actually quantify and report these annual smaller, but noteworthy, additional diversion components.

Appendix F: On-Farm Irrigation Efficiency Factors and Analyses

The following is extracted, in part, from the report, "Irrigation Efficiency Conversion Scoping Study", prepared for Agriculture and Agri-Food Canada by UMA Engineering Ltd. (AECOM) in 2008. It is to be noted that this excerpt deals with more than just irrigation in Alberta but with irrigation across Canada. However, Alberta, with two-thirds of Canada's irrigated area, is a major repository for some of the best quantified technical and statistical information. For more complete detail on the aspects of system conversion projections and associated costs, reference should be made to the full text of the original report.

The following provides a discussion on the irrigation water application efficiencies of various irrigation methods and relates those efficiencies to the amount of water saved and the costs of converting from one methodology to another. The analyses of irrigation efficiency has also been extended (as per the referenced "Irrigation Efficiency Conversion Scoping Study") to include an order-of-magnitude assessment of the capital costs of converting lower efficiency on-farm irrigation systems to higher efficiency types. This information is intended only to complement the assessments provided within Table 4.1 of the main report.

1.1 Irrigation Efficiency

The term efficiency, in the case of irrigation water use, is defined as the ratio between the irrigation-applied water available for plant evapotranspiration use and the water diverted from its source for irrigation purposes.

Depending upon the complexity of an irrigation water supply project, there could be several different components that affect the net water available for plant use. For example, in large irrigation projects, water may be diverted from a river, held in one or more storage reservoirs, conveyed through a network of canals and pipelines, before being diverted into a point of on-farm irrigation use. In some instances, water is passed through the entire system, unused, and returns to the watershed as return flow.

All of the above components have inherent efficiencies (or inefficiencies as they could be portrayed) in the distribution of water for ultimate consumption by crops. For the purposes of this analysis, as required for the evaluations within this study, only the on-farm component of irrigation water use efficiencies is discussed.

1.2 On-Farm Irrigation Efficiency

With reference to on-farm irrigation efficiencies within this study, only the matter of *application efficiency* is being considered. Water lost or otherwise by-passing a farm diversion or turnout due to non-use is not considered a part of this analysis. This is not to say that such a non-use or "down-time" factor is not an important consideration in irrigation water use assessments and planning, but it is beyond the scope of this study.

Application efficiency is defined as the ratio between the amount of irrigation-applied water available for plant use through evapotranspiration and the amount of water diverted to an individual on-farm irrigation application system. There being a great diversity of irrigation system or method-types utilized across Canada, there is also a corresponding wide range of irrigation application efficiencies (hereafter referred to as “the efficiency”) achieved.

There are several factors that can influence the efficiency of water applied through any given system-type or method of irrigation. It is unrealistic to expect that one efficiency number is applicable to a specific system type under all conditions. Therefore, it has been standard practice within the irrigation discipline to define a range of applicable efficiencies to each method of irrigation. Table 11.1 illustrates these accepted irrigation efficiency ranges as adopted by Alberta’s Department of Agriculture, Food and Rural Development in the mid to late 1990s and reported in their Irrigation Water Management Study of 2002.

Table 11.1 - Summary of Common Methods of Irrigation, Respective Application Efficiencies and Potential Water Savings

Irrigation Method	Efficiency Range	Nominal Efficiency	Incremental Efficiency Gain	Equivalent Water Gain (ac-ft/1000 ac)
Gravity – Undeveloped Flood	30% - 50%	35%	n/a	n/a
Gravity – Developed – Not Controlled	50% - 70%	60%	25%	1,091
Sprinkler – Volume gun – Stationary	60% - 68%	64%	4%	95
Sprinkler – Hand Move	60 % - 70%	65%	1%	22
Sprinkler – Volume gun – Traveller	64% - 69%	66%	1%	21
Sprinkler – Wheel-move – 2 Laterals	63% - 71%	67%	1%	21
Sprinkler – Pivot – High pressure Corner	67% - 72%	70%	3%	59
Sprinkler – Wheel-move – 4 Laterals	67% - 75%	70%	0%	0
Sprinkler – Linear – High pressure	69% - 74%	72%	2%	36
Sprinkler – Pivot – High pressure	68% - 76%	72%	0%	0
Sprinkler – Solid Set	70% - 75%	72%	0%	0
Gravity – Developed – Controlled	70% - 85%	75%	3%	51
Sprinkler – Pivot – Low pressure Corner	68% - 81%	77%	2%	32
Sprinkler – Linear – Low pressure	72% - 82%	79%	2%	30
Sprinkler – Pivot – Low pressure	70% - 82%	795	0%	0
Gravity – Undeveloped – Sub-surface	75% - 95%	85%	6%	82
Micro-Spray – Sprinkler	75% - 90%	85%	0%	0
Micro – Drip – Trickle	80% - 95%	90%	5%	60

*Note: Net overall efficiency gain between Gravity-Undeveloped-Flood systems and Micro-Drip-Trickle, assuming an annual net irrigation requirement of 11 inches, is 55% or 1,600 ac-feet over 1,000 acres.

In addition, during the mid-1990s, the PFRA initiated consultations with the four western provinces to derive a system of developing quantifiable Environmental Sustainability Indicators or Indices (ESIs). As an initial broad brush approach for irrigation, on-farm application efficiencies were selected as the proxy measurement system. Based on available research that had been conducted by various agencies over the past few decades, each provincial jurisdiction defined its method-specific efficiency ranges and nominal efficiency value according to system type. The values in Table 11.1 reflect Alberta’s adopted standards. These are likely also applicable to the other major irrigated areas in western Canada.

The right-hand column in Table 11.1 provides examples of water-savings (or water losses) that can be realized across every 1,000 acres where one system is converted to another (i.e. moving from one efficiency level to another). These savings are incremental as the table is reviewed from top to bottom, comparing one system to the preceding system. For example, in moving from a gravity irrigated field that is properly land-formed and utilizes very good water distribution control systems (Gravity-Developed-Controlled) to a low-pressure pivot sprinkler system with a corner attachment (Sprinkler-Pivot-Low pressure-Corner) a net gain in efficiency of 2% is projected. This should result in an annual water-saving of approximately 32 acre-feet, where such a conversion affects 1,000 acres. It is important to note as well in this calculated example, that the applied assumption is that the net annual irrigation requirement is 11 inches. (The significance of this irrigation application amount is discussed in the following section.) Where this annual requirement is less, the water saved through conversion will be proportionately less.

The calculation of water savings, as derived in the above example, involves determining the gross amount of water required for a given system type at its nominal efficiency (i.e. net irrigation requirement ÷ application efficiency value) and multiplying that depth value across 1,000 acres (with unit conversions) to arrive at a gross volume of irrigation water use. The same process is applied for the second system type and associated efficiency to be compared. The difference between the two volumes is the volume of water saved. The following reduced equation illustrates the calculations involved.

$$V_{sw} = ((I_n/E_1) – (I_n/E_2)/12 \text{ in/ft}) \times A$$

where:

V_{sw}	=	Volume of saved-water (acre-feet)
I_n	=	Net annual irrigation requirement (inches)
E_1	=	Application efficiency of System type no. 1
E_2	=	Application efficiency of System type no. 2
A	=	Area over-which the annual irrigation amount is applied (in this case – 1,000 acres)

Accordingly, in the above conversion example, where a 2% efficiency gain is projected, the application of this equation would be configured as:

$$V_{sw} = ((11/0.75) – (11/0.77)/12) \times 1000 = 31.75 \text{ acre-feet}$$

Table 11.1 summarizes the incremental gains in water savings as the table is viewed from top to bottom, from lower efficiency systems to higher efficiency systems. The accumulated water savings can be determined by comparing one system type to another. For example, a conversion from a 2-lateral wheel-move system to a low pressure pivot system would see annual water-savings of:

59 + 0 + 36 + 0 + 0 + 51 + 32 + 30 + 0 = 208 ac-ft per 1,000 acres

assuming a net annual irrigation requirement of 11 inches.

It is well understood that the adoption of newer irrigation technologies and methodologies is resulting in more efficient use of diverted irrigation water. During the past 40 years or so, the Province of Alberta, in concert with the irrigation industry, has maintained a fairly extensive periodic inventory of the different types of irrigation systems in common use in Alberta, particularly within the 13 irrigation districts. Through assigning the nominal irrigation efficiencies of each system type to the associated inventory, an overall weighted average of on-farm irrigation efficiency has been computed on five-year intervals. Figure 1 illustrates the growth in overall water use efficiency from 1965 through 2005.

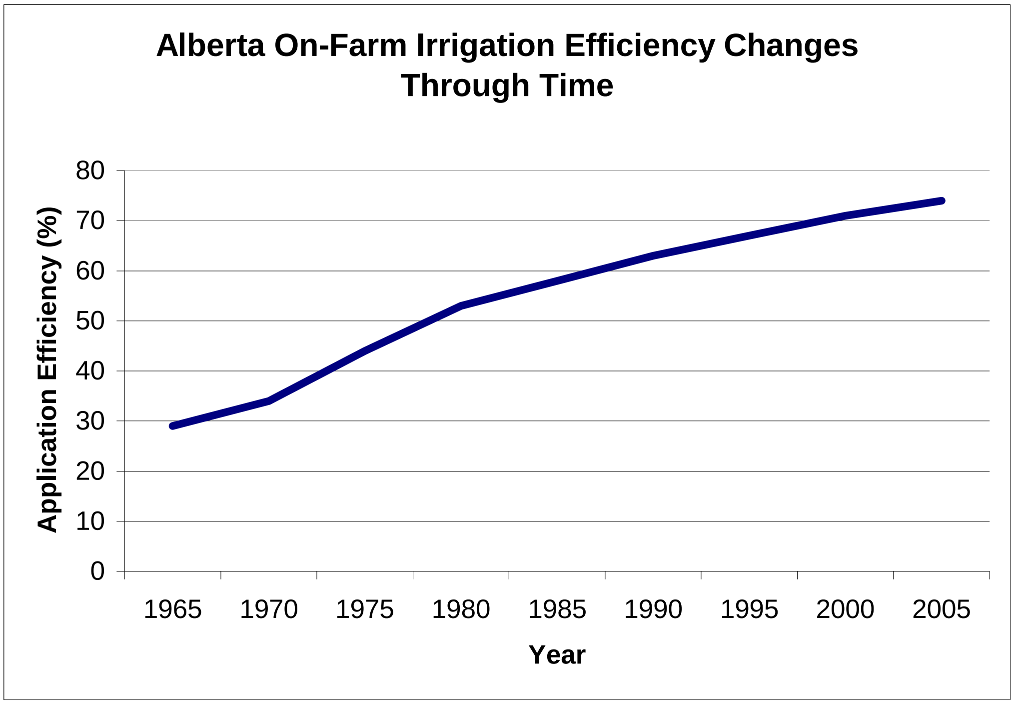

Figure 1: The growth of on-farm irrigation efficiency through time (a result of the increasing adoption of improving application technologies)

One of the most positive outcomes of increasing irrigation efficiencies is the net reduction in irrigation water use. Alberta's tracking of irrigation diversions through time provides an indicator of the diminishing diversions resulting from overall irrigation efficiency improvements. Figure 2 presents the accumulated results as a trend line indicating notable reductions in water use during the last 30 years. These reductions include the effects of efficiency gains associated with several irrigation diversion and water use components. In as much as the on-farm use component represents approximately 70% to 75% of the overall diversion volumes, the on-farm efficiency gains do have a significant effect in reducing irrigation water use and associated diversions.

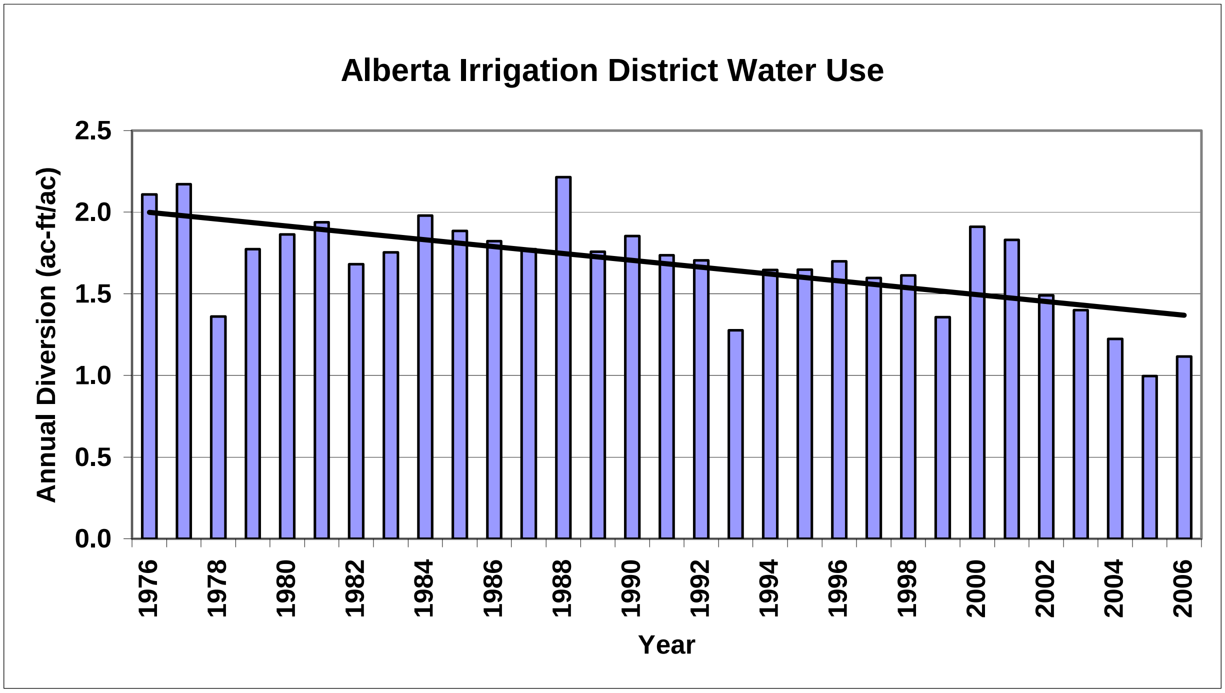

Figure 2: The trend in overall irrigation diversions in Alberta between 1976 and 2006.

Several factors can affect the actual efficiency of a given on-farm irrigation system's water application. These can be summarized as:

- *Aerial Evaporation* - That water lost to the atmosphere as it is sprayed through the air from a sprinkler or spray head orifice. Factors such as wind, relative humidity and spray droplet size can also affect the extent to which evaporation occurs.
- *Surface Evaporation* - That water distributed on the surface of the soil, either as a result of sprinkling, spray or trickle applications, or that which is applied across a field surface through surface irrigation methods and is vapourized to the atmosphere through ambient effects such as air temperature and relative humidity.
- *Deep Percolation* - That water which is applied to and infiltrates the soil surface, but exceeds the soil's capability to retain it within the given crop root zone (as affected by soil texture) and therefore continues to percolate below the region where any uptake can be achieved by the rooting system.
- *Surface "Ponding" and Runoff* - Where application rates exceed the soil's infiltration and hydraulic conductivity capacities, surface accumulations or "ponding" can occur. Where local topography and seeding patterns, such as row crops, provide conducive slope situations, surface water may move down-slope until it either accumulates in field areas in amounts exceeding localized soil water-holding capacities or runs off the useable field area.
- *Application Uniformity* - Application uniformity is a measure of how evenly water is applied across the coverage area of an irrigation system. Uniformity is often confused with efficiency but is a separate operational factor, one which can also affect water use efficiencies. In less than uniform applications, some field areas receive more water than intended while others receive less. Higher applications can lead to runoff and percolation losses while lower applications can mean greater

evaporative losses. Typically, continual traveling systems such as centre pivots will have greater application uniformities than stationary systems such as wheel-roll sprinklers, as the continual movement of the pivot machine can tend to compensate for such factors as wind effects.

- *Irrigation Management* - Likely one of the most significant factors affecting water use efficiencies. Factors such as the timing or scheduling of irrigations and the amount of water applied in a given application all may have corresponding impacts on many of the factors listed above. Typically, the more flexibility and ease (e.g. reduced labour input) with which an irrigator can effectively operate a system, the more likely that better water management, and thereby higher water use efficiencies, will be achieved. Nonetheless, even the best of systems can be mismanaged so that many of the above factors become more prevalent. For example, properly formed gravity or surface-irrigated fields can be quite efficient if managed according to the design of the land-forming and adequate water discharges to the field are controlled in accordance with the field design. However, recommended lengths of run are often exceeded for the convenience of field machinery operations with accompanying extended water application (set) times. These conditions can lead to upper field over-irrigation and considerable tail-water runoff at the lower end of the field, resulting in much reduced water use efficiency. Similarly, the ease of use of centre pivot sprinklers can sometimes lead to the machines moving too quickly around a field, applying small amounts of water/acre but incurring high proportions of evaporative losses resulting in reduced efficiencies.

The intent in providing the preceding listing is to emphasize that it is difficult to assign any one application efficiency number to a given system-type or application method. Consequently, an expected range of efficiencies, as illustrated in Table 11.1, has been defined as being representative of most systems under most conditions. However, in the various processes of determining irrigation water requirements or system design, one single or nominal efficiency value needs to be selected. Commonly-applied method or system-type nominal efficiencies are listed in Table 11.1 for the diverse variety of irrigation practices operating in Alberta. These are likely applicable to the rest of Canada as well.

For the purposes of simplifying the conversion analyses, the diversity of on-farm irrigation methodologies and system-types have been consolidated into seven generalized categories, namely:

1. Gravity (Flood / Surface)
2. General Sprinkler (Solid Set / Hand-Move)
3. Wheel-Move Sprinkler
4. High-Pressure Centre Pivot Sprinkler
5. Low-Pressure Centre Pivot Sprinkler
6. Traveling Volume Gun Sprinkler
7. Drip (Micro-Spray/Sprinkler and Trickle)

From the listing of 18 different system-types in Table 11.1 and their associated Nominal Efficiency ratings, an “averaged” efficiency value needed to be assigned to each of the seven consolidated irrigation method categories. Based on the limited information available with respect to the regional area distributions of these methodologies and the values in Table 11.1, consolidated nominal efficiency values have been derived and are listed in Table 11.2, following the same tabular format as per Table 10.1. The derivation of water-savings through system conversion efficiency gains will reference these specific values.

Table 11.2 - On-Farm Irrigation System Application Efficiencies Applied by Province and by Method

	Gravity to Sprinkler		Gravity to Sprinkler		Sprinkler to Drip		Wheel-Move to Low Pressure Pivot		Travelling Volume Gun to Low Pressure Pivot		High Pressure Pivot to Low Pressure Pivot	
Province	**Various Gravity**	**Wheel Roll Sprinkler**	**Various Gravity**	**LP Pivot Sprinkler**	**Various Sprinkler**	**Micro Drip**	**Wheel-Move to Low Sprinkler**	**Low Pressure Pivot**	**Travelling Volume Gun**	**Low Pressure Pivot**	**High Pressure Pivot**	**Low Pressure Pivot**
British Columbia	60%	68%	60%	79%	72%	88%						
Alberta	62%	70%	62%	79%			68%	79%			72%	79%
Saskatchewan	60%	68%	60%	79%							72%	79%
Manitoba									66%	79%		
Ontario					72%	88%						
Quebec					72%	88%						
Atlantic Region					72%	88%						

Slight variations in efficiency ratings, in Table 11.2, for similar system types, may be noted for Alberta versus B.C. and Saskatchewan. These result from there being a somewhat higher intensity of quality land-formed and controlled surface irrigation systems in Alberta, versus the other two provinces, or where wheel-move systems in Alberta reflect a slightly greater density of coverage (e.g. 4 laterals per quarter-section vs. 2 laterals), resulting in improved water use.

1.3 Determination of Water-Savings

In order to determine the application water-savings gained through system conversions to methods that have inherently higher application efficiencies, it is imperative that these different performance values be related to the quantity of water required to be applied, on a net basis, by system and by region. That is to say, the *average annual irrigation requirement* is the *net* amount of water needed to be applied to meet the shortfall between crop water requirements and precipitation for an average agro-climatic year. Again, individual and specific *average irrigation requirement* values should be determined for each region. System efficiencies are then applied to the assigned net value to determine the *gross* on-farm system irrigation requirement.

As documented, in Alberta Agriculture, Food & Rural Development's irrigation study report of 2002 and in British Columbia's Ministry of Agriculture and Food irrigation manual [e.g. – determination of Maximum Soil Water Deficit], the irrigation requirement varies dramatically from one agro-climatic region to another, from one soil-type to another and from one crop-type to another. It is not possible, within the constraints of this assignment, to reflect that variability. As a result, based on limited available provincial information, a single representative net annual irrigation requirement value has been selected for each province. Available provincial information from Alberta, Saskatchewan and Manitoba has been referenced, interpolated and applied as best estimates for the other regions across Canada. For example, Manitoba irrigation requirements have been quantified and irrigation there is known to be supplemental in nature. Therefore, for other eastern regions of Canada where irrigation is also recognized as supplemental, Manitoba's irrigation requirement is referenced as a relative benchmark. The objective in this reporting is to provide order-of-magnitude values only, as to the water-saving potentials and costs associated with respect to system conversions.

Table 11.3 continues the same presentation format as per Tables 10.1 and 11.2, in order to facilitate comparative analyses. The one addition in Table 11.3 is the column entitled Annual Irrigation Requirement (inches), which specifies, on a province or regional basis, the assigned net average annual irrigation requirement. This amount is applied to respective system conversion efficiency gains to derive annual water savings. It is fundamental that in regions where annual irrigation water requirements are highest, efficiency gains will have the greatest impact on water-savings.

The calculations to derive water-savings follow the same equation configuration as explained in Section 11.2 in relation to Table 11.1. The determinations in Table 11.3 take the respective methodology conversion area in Table 10.1 and apply the average annual net irrigation requirement (depth) to arrive at a net volume of water required for a given methodology-type over the area projected for conversion. The efficiency rating of each methodology is applied to arrive at a gross irrigation requirement volume for each type. The difference between the two becomes the water saved each year (ac-ft/annum).

For example, for projected conversions in Saskatchewan from gravity or surface irrigation systems to low-pressure centre pivot sprinklers, the projected annual water savings are calculated as:

((10.6 in./0.60) – (10.6 in./0.79)) / 12 in/ft x 7,500 ac. = 2,656 ac-ft.

By dividing the associated conversion cost projections from Table 10.1 by the calculated volume of water savings, the conversion cost per acre-foot of water saved is derived (e.g. $4,875,000 / 2,656 ac-ft = $1,835).

The capital investment in system conversion is, for the most part, a one-time investment over the life of the equipment, while the water-savings continue year after year, higher in dry years and less in wet years. The water-saving values in Table 11.3 are considered to be projected averages over time. The capital investment cost should be expressed according to the water-savings projected to be realized each year. In consideration of the longer term of the projected water-savings, a simplified capital cost per acre-foot of water saved per year has been expressed by an approximated amortization of those costs over a ten-year period (e.g. $1,835 / 10 years = $184 per year).

Table 11.3 - Comparative Summary of Annual Water-Savings and Associated Conversion Costs, Amortized Over 10 Years.

Province	Annual Irrigation Requirement (inches)	Gravity to W/M Sprinkler		Gravity to LP Pivot		Sprinkler to Drip		Wheel-Move to Low Pressure Pivot		Travelling Volume Gun to Low Pressure Pivot		High Pressure Pivot to Low Pressure Pivot	
		Water Saved (acre-feet)	Capital Cost ($/ac-ft)*	Water Saved (acre-feet)	Capital Cost ($/ac-ft)*	Water Saved (acre-feet)	Capital Cost ($/ac-ft)*	Water Saved (acre-feet)	Capital Cost ($/ac-ft)*	Water Saved (acre-feet)	Capital Cost ($/ac-ft)*	Water Saved (acre-feet)	Capital Cost ($/ac-ft)*
British Columbia	**11.0**	1,348	$306	919	$177	2,784	$698	941	$346				
Alberta	**12.2**	3,748	$293	28,229	$184			20,154	$323			8,479	$62
Saskatchewan	**10.6**	4,763	$318	2,656	$184							9,048	$69
Manitoba	**5.2**									1,063	$611		
Ontario	**6.0**					1,243	$1,304						
Quebec	**5.5**					580	$1,397						
Atlantic Region	**5.0**					99	$1,629						
Total Water		**9,859**		**31,803**		**4,706**		**21,094**		**1,063**		**17,695**	
Average Annual Cost			**$306**		**$182**		**$1,257**		**$334**		**$611**		**$65**

*Note: Accruals of water savings through conversions are on-going, occurring in successive years following conversion. For the purposes of this study, it is assumed that the capital cost of conversion is spread over 10 years (i.e. 10-year amortization)

Table 11.4 provides a final accumulated summary, on a province-by-province (region-by-region) basis, of projected water savings and average conversion capital cost (amortized) per acre-foot of water saved. This average is derived by dividing the total value of all conversion costs in Table 10.1 by the total volume of water calculated to be saved. (e.g. for B.C. = $26,815,000 / 5,983 ac-ft = $4,482/ac-ft or $448/ac-ft per year when amortized over ten years.)

An alternate form of expressing the water-savings is illustrated in the last column "Total Water Saved (in/ac)". This depth of water saved is derived by dividing the total amount of water saved by the total area where conversions have been projected to be possible. For example, in Alberta, where it is projected that 190,000 acres could see conversions and where 61,553 acre-feet of water could be saved, this reduction in water use is expressed as (61,553 ac-ft x 12 in/ft)/190,000 acres = 3.89 in/ac.

Table 11.4 – Summary of Annual Water Savings and Weighted Average Conversion Costs – Amortized Over 10 Years

Province	Annual Irrigation Requirement (inches)	Overall Conversions' Projected Savings & Costs		Total Water Saved (in/ac)
		Water Saved Per Annum (acre-feet)	Avg. Capital Cost ($/ac-ft)*	
British Columbia	11.0	5,983	$448	2.93
Alberta	12.2	61,553	$132	3.89
Saskatchewan	10.6	16,441	$130	1.79
Manitoba	5.2	1,080	$602	1.30
Ontario	6.0	1,263	$1,283	1.52
Quebec	5.5	579	$1,400	1.39
Atlantic Region	5.0	105	$1,540	1.26
Total Water Saved / Annum		87,005		
Average Annual Cost			$791*	2.97

*Note: Accruals of water savings through conversions are on-going, while, for purposes of this study, it is assumed that the capital cost of conversion is spread over 10 years (i.e.10-year amortization).

1.4 Conclusion

It is evident, from Tables 11.3 and 11.4, that the cost to save an acre-foot of water, based on conversion-related efficiency gains, is extremely variable. Where the requirement for applied irrigation water is high, conversion costs per acre-foot saved are reduced. Further, some conversions may only reflect a few percentage points in efficiency gain but are relatively inexpensive to implement and may have other associated benefits (e.g. energy-savings). When combined with higher levels of irrigation need, the returns on conversion cost investment can be more enticing. Such is the case in regions such as Alberta and Saskatchewan where the conversion from high pressure centre pivot systems to low-pressure drop-tube systems may yield promising dividends in water and energy savings. Where irrigation is more supplemental in nature, the cost effectiveness of conversions may be less, relative to the production returns expected.

Producers typically exhibit a willingness to save on input resources, of which the most significant is the financial cost. Historically, in the major irrigation areas in Canada, the conversion to higher-efficiency irrigation systems has not been driven by a need or ethic to conserve water. It has been the need for reducing labour and cost inputs, and higher quality commodity requirement from the food-processing sector, in particular, that has driven the adoption of better-performing irrigation technologies.

Although the current conditions and costs may dictate that conversions to more efficient systems may not be economically justifiable, future considerations of a different sort may influence the decision-making. For example, the prospect of encountering more limited water supplies, through the effects of climate change or due to environmental protection policies, may make conversions more attractive to ensure an adequate provision of water to irrigated crops.

Appendix G: Summary of Irrigation District Water-Sharing Strategy - 2001

The following is an excerpt from a presentation given to the "*Confronting Water Scarcity Conference*" convened at the University of Lethbridge in July of 2004. The presentation was authored by:

Wally R. Chinn, P. Eng. – Irrigation Branch, Alberta Agriculture, Food & Rural Development

The presentation was to illustrate a water management case study and process that was voluntarily implemented by irrigation water users during a period (2001 and 2002) of significant water shortage within a large portion of the intensively-irrigated area of southern Alberta.

Note: During the time period where this case study was occurring, it was common for irrigation practitioners to continue to use imperial measurement units. Therefore, in illustrating some of the actual computations and allocations that were derived, imperial measurement units will still be used, in part, in the following documentation. Also, some specific values specified refer to those in effect during the 2001 and 2002 periods, which are the principal periods of this case study.

1.0 Introduction

1.1 Background on Irrigation Authorizations

Irrigation producers within southern Alberta are enabled to practice irrigation through two different mechanisms. One is by being an irrigator within one of the 13 structured irrigation districts, where water is supplied "at the farm gate" through an extensive system of reservoirs, canals and pipelines. The other is by operating as an individual irrigator, providing one's own means and works to divert water from a source (e.g. a river). Under both situations, the ultimate authority enabling water to be diverted is through the licences issued under the *Water Act* as administered by Alberta Environment. In the case of irrigation districts, each organization is a licensed user of water and has the authority, under respective licences and the *Irrigation Districts Act*, to deliver water to its individual member water users.

Water users are granted authority to divert water, under the terms of their respective licence(s), within a priority system known as "First-In-Time, First-In-Right (FITFIR)". Under this allocation system, the earlier in time that a specific licence was issued, the higher the priority of that authorization. In other words, in situations where water supplies become limited, licences with higher priority have first call on whatever water is available before more "junior" or newer licence authorizations can attempt their diversions.

Leading up to the turn of the 21st century, water shortages rarely occurred, particularly for irrigation district water users. Therefore, with some minor exceptions, no formal process of limiting water deliveries had been developed, let alone implemented within the irrigation district realm. It was generally accepted that water would be available, on demand. In some small river basins, limitations on water supplies to private irrigators had occurred sporadically, but those were usually managed in an “all or nothing approach” that was very localized.

Nonetheless, the reality is that should water supplies become critically low, Alberta Environment has the authority to curtail water diversions to licensees with lower priority licences to meet the commitments to higher priority authorizations and to in-stream river flow requirements.

1.2 Background on the “Southern Tributaries”

The Southern Tributaries (or Southern Tribs.) refers to the three main rivers in south-western Alberta that are tributary to the Oldman River. These are the Waterton, Belly and St. Mary Rivers. These three rivers and their combined watershed are not large by any means, but they do support a significant amount of irrigation and other uses within southern Alberta, far more than does the Oldman River itself. In fact, the average annual outflow of water generated within the Southern Tribs. watershed is only about 1.5 percent of the total outflow of water from the whole province. Yet, only 65 percent of its 6,683 square-kilometre basin is the effective catchment for the water to supply almost a quarter of a million hectares of irrigation plus supply other users for municipal, industrial, agricultural, habitat and domestic purposes.

Eight different irrigation districts, as depicted in Figure 1 within the shaded areas, totalling 228,300 hectares of assessed irrigation land, receive their irrigation water supplies from the Southern Tribs. In addition, approximately 8,560 hectares of private irrigation (primarily along and adjacent to the three rivers) plus another nearly 10,000 hectares within the Blood Tribe Agricultural Project (BTAP), are all dependent on water from the Waterton, Belly and St. Mary Rivers. Table 1 summarizes all the water licences issued to the eight irrigation districts, as they existed with allocations and priority rights at the turn of the 21st century. (Note: 1 acre-foot = 1,234 m3. 1 acre = 0.405 hectare.)

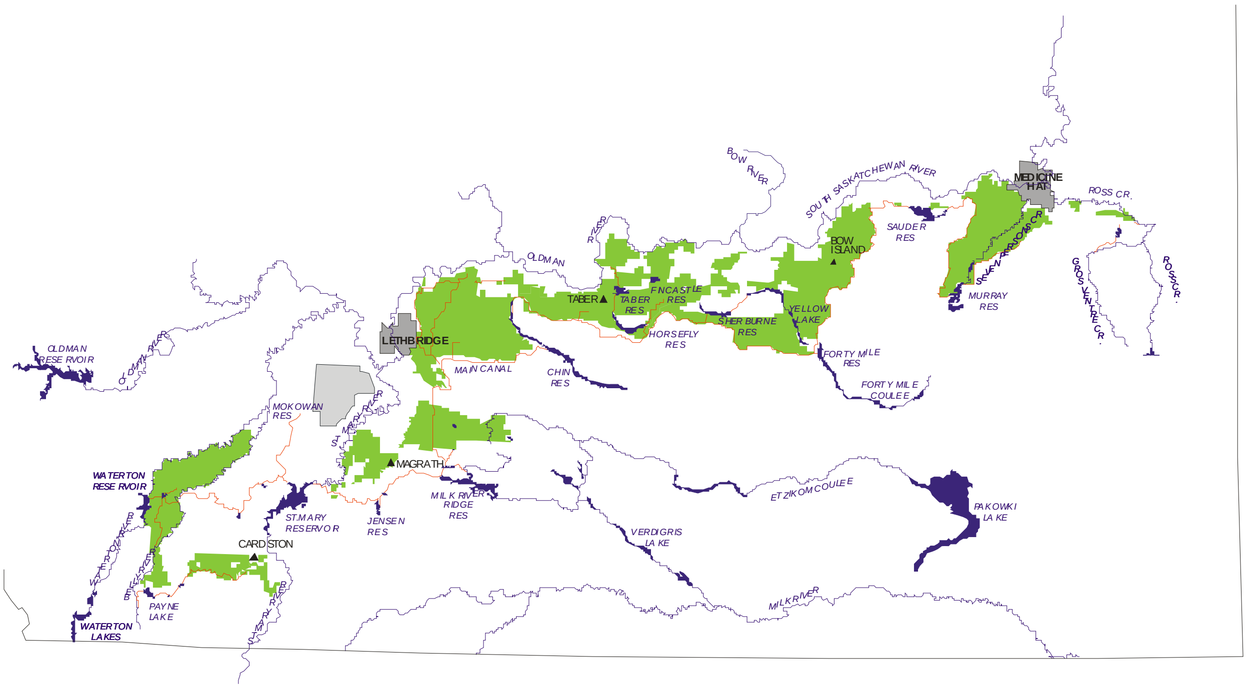

Figure 1. A map of southern Alberta illustrating the "Southern Tribs." and the irrigation district Areas supported through that watershed.

Table 1. "Southern Tribs." irrigation district water licences as of 2001.

Irrigation District	River Water Source	Assessed Irrigation Area (acres)	Licensed Volume		Licence Priority Date
			per Licence (ac-ft)	Total (ac-ft)	
Aetna (AID)	Belly	3,611	5,500	9,000	1945-06-30-01
	Belly		3,500		1991-12-23-01
Leavitt (LID)	Belly	4,763	7,750	12,000	1939-06-17-01
	Belly		4,250		1991-12-30-04
Magrath (MID)	St. Mary	18,300	9,180	34,000	1899-02-07-04
	St. Mary		4,320		1950-05-31-08
	Waterton		13,500		1950-05-31-09
	Belly		3,000		1950-05-31-10
	SM, W, B*		4,000		1991-08-23-02
Mountain View (MVID)	Belly	3,712	7,500	8,000	1923-07-10-03
	Belly		500		1991-12-17-02
Raymond (RID)	St. Mary	46,235	12,240	81,000	1899-02-07-03
	St. Mary		12,510		1950-05-31-14
	Waterton		24,750		1950-05-31-15
	Belly		5,500		1950-05-31-16
	SM, W, B*		26,000		1991-08-23-02
St. Mary River (SMRID)	St. Mary	370,925	168,173	722,000	1899-02-07-01
	SM, W, B*		331,827		1950-05-31-07
	SM, W, B*		222,000		1991-08-23-09
Taber (TID)	St. Mary	82,261	34,000	158,000	1899-02-07-02
	St. Mary		33,500		1950-05-31-17
	Waterton		67,500		1950-05-31-18
	Belly		15,000		1950-05-31-19
	SM, W, B*		8,000		1991-08-26-02
United (UID)	Belly	34,329	51,000	68,000	1919-03-24-01
	Waterton		17,000		1993-05-17-01
			Total Licensed Volume of Water	**1,092,000**	

Although some very early (high priority) licences were issued to a few isolated private irrigation projects, the sum of all their licensed allocations was very small relative to the irrigation district allocations. Most private irrigation projects within the watershed, particularly those of any notable size, were not developed until the late 1970s and on into the 1990s, a time when pumped irrigation technologies had advanced significantly, allowing for reduced labour inputs and more economical pumped pressurization alternatives. The total licensed allocation for all Southern Tribs. private projects, as of 2001, was 26,618 acre-feet (32.8 million m3), and with a 1991 priority number, the Blood Tribe Agricultural Project (BTAP) was authorized to divert up to 40,270 acre-feet (49.7 million m3) for its irrigation development.

In addition, for all other municipal, industrial, agricultural and domestic uses, a total of approximately 53,000 acre-feet (65.4 million m3) were licensed for withdrawal from Southern Tribs. sources for those purposes. From the overall total of approximately 1.21 million acre-feet of water authorized for diversion, irrigation uses accounted for 95.6 percent of that allocated volume and the irrigation district had rights to 90.1 percent of the overall allocation total.

In summary, the commitments to supply water from the Southern Tribs. for authorized diversions or in-stream flow are as follows:

- Irrigation District Use
- Private irrigation use
- Blood Tribe Agricultural Project (BTAP) use
- Other water use, including municipal, industrial, agricultural, domestic and habitat uses
- Minimum in-stream flows on the St. Mary, Belly and Waterton Rivers
- Apportionment to the U.S. St. Mary-Milk River Project (See explanation below.)

In order to ensure a minimal flow within each of these extensively-used rivers, Alberta Environment has established minimum flow requirements on each of the three tributaries. These must be adhered to at all times in order to support a minimum of river ecology. These flow rates are 2.75, 0.93 and 2.27 cubic metres per second respectively for the St. Mary River, the Belly River and the Waterton River. They are measured relative to releases past major dams or diversion weirs on these rivers.

1.3 Water Supplies within the Southern Tribs.

The three major rivers of the Southern Tribs. are almost exclusively dependent on the precipitation falling within the eastern slopes of the Rocky Mountains in southwestern Alberta and northwestern Montana (USA). Most of this dependency relates to moisture received through winter snowpack. However, as the eastern slopes of the mountains border what is otherwise a semi-arid area, it is common for there to be great variability in the amounts of precipitation that accumulate as winter snowpack or run-off from rainfall events during the spring, summer and fall.

Therefore, it is generally expected that there will always be a noticeable variability in the outflow of water from this watershed. Through a recent 35-year period, the average of the **net** annual accumulated outflow from all three of the Southern Tribs. rivers, from each of those years, was only about 70 percent of the total amount of water allocated through licensing. *(Note: NET annual flow means that water that would naturally flow down through the river, prior to any diversions, less that amount assigned to meeting minimum instream flow requirements.*) Consequently, daily flow of the rivers cannot be depended upon to provide any assurance of sustained supplies to meet licensed commitments and daily demands.

As a result, since the 1950s, much has been done to develop both on-stream and off-stream storage to retain water when the Southern Tribs. can supply it and to make it available to irrigation and other users, from storage, when flows in the river cannot meet diversion demands.

Alberta Environment (AENV) owns and operates one on-stream dam on the Waterton River and one on the St. Mary River, plus two off-stream storage reservoirs downstream from the St. Mary reservoir irrigation diversion, namely Jensen Reservoir and Milk River Ridge Reservoir. It also owns and operates a smaller off-stream reservoir (Payne Lake) that retains water diverted from the Belly River to supply the three small irrigation districts: Mountain View (MVID), Leavitt (LID) and Aetna (AID).

In addition, the three districts of what is known as "The St. Mary River Project (SMRP)", that is the St. Mary River Irrigation District (SMRID), the Raymond Irrigation District (RID) and the Taber Irrigation District (TID) own and operate several large and small off-stream reservoirs. The majority of this district storage is owned and operated by the SMRID.

The approximate total effective or live storage capacity of all of these reservoirs is:

- AENV Headworks = 635 million m^3 (515,000 acre-feet)
- District reservoirs = 405 million m^3 (330,000 acre-feet)
- **Overall TOTAL = 1,040 million m^3 (845,000 acre-feet)**

The existence of these reservoirs and their ability to capture and retain the erratic flows of the Southern Tribs. have played a significant role in successfully providing more reliable supplies of water, for all users, during periods of low river flows. They have buffered the effects of what otherwise would appear to be an over-allocation of water from these three rivers.

There is one other complexity that compounds the challenges of managing the limited supplies of water within the Southern Tribs. watershed. One of the early water withdrawal developments from the St. Mary River was the diversion implemented within the northwestern region of the U.S. state of Montana which represents the headwaters of the St. Mary River. Due to the joint interest by Alberta and Montana in utilizing water from the same river, a 1921 Order, under the auspices of the International Joint Commission (IJC) and the Boundary Waters Treaty, defined under what circumstances and by how much water can be diverted by American interests and how much is required to flow north of the international boundary for Alberta (Canadian) use. As the proportion and amount of diversion is affected each year by the river's variable flow regimes, the specific amount that must be available to be shared with Montana also varies from one year to another and is re-calculated throughout each year. In addition, primarily due to infrastructure capacity deficiencies within the American diversion works, the State of Montana usually has diverted, on average, only about 70 percent of its legal entitlement in most years (varying between 23 percent and 103 percent through the period 1969 to 2001).

Therefore, it is necessary to recognize that not all watershed discharge through the Southern Tributaries Basin is available to Alberta needs and users. Regardless of whether American interests have or do not have the capacity to utilize their rightful entitlement, it was deemed prudent, for water management planning purposes, to assume that in most years this upstream diversion could occur to its full legal intent. For planning purposes, it was assumed that 30 percent of the volume of water generated from the headwaters of the St. Mary River Basin was diverted for use under American entitlement, prior to entering Canadian jurisdiction.

2.0 Factors Prompting a Water-Sharing Agreement

2.1 The Water Supply Situation – End of 2000

The watershed yield from the Southern Tribs. in the years 2000 and 2001 were some of the lowest on record. (See Figure 2.) In fact, the year 2001 proved to be the third lowest annual outflow since 1928. Immediately prior, in 1999, major infrastructure re-building work was occurring with respect to the St. Mary Dam spillway. As a result, it was necessary to release an unusually large amount of water from the reservoir during that year in order to accommodate the rehabilitation work. As a result, there was a much lower volume of water in storage at the end of 1999. This then compounded the deficiency in available water during 2000 with the basin's very low outflow that year. The year 2000 was also witness to above-average crop water use coupled with one of the lowest growing-season precipitation levels. This resulted in one of the highest net volumes of irrigation diversion demand experienced that year in the 100-year history of southern Alberta irrigation development. The final result of all these factors was very low volumes of water in storage heading into the 2001 year.

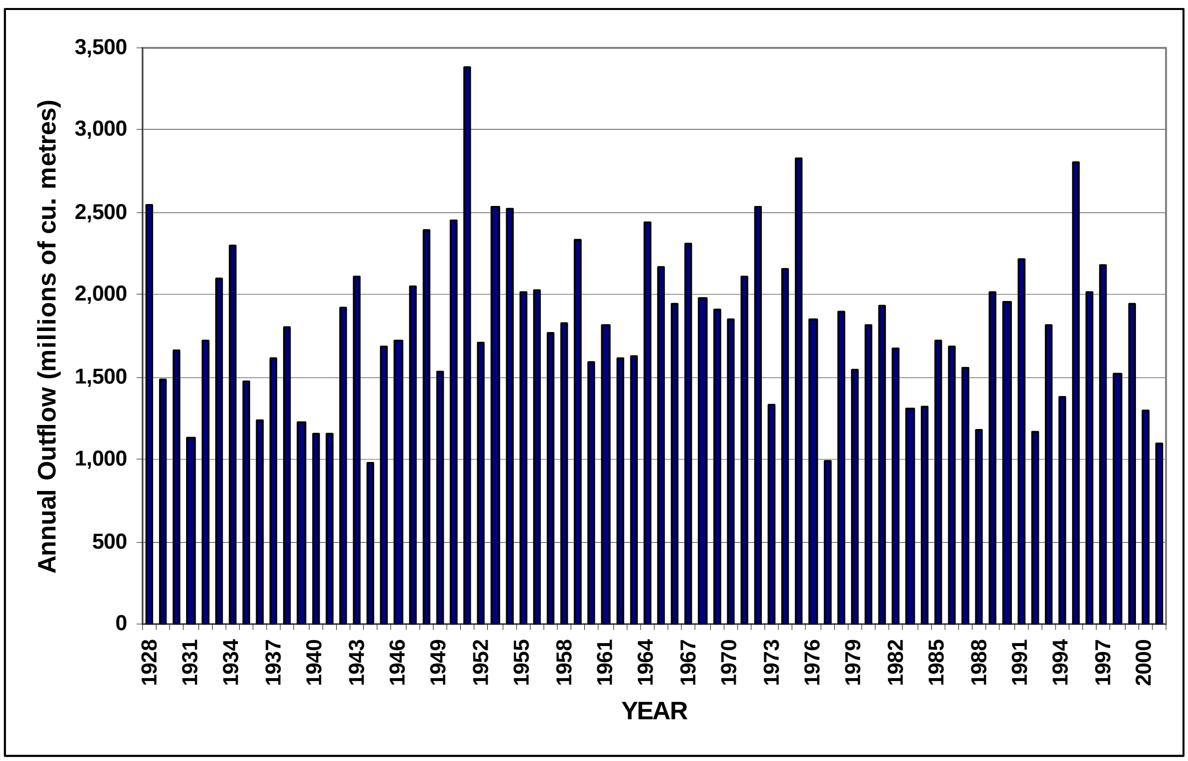

Figure 2. Annual outflow volume from the watershed of the Southern Tributaries.
(Source: Alberta Environment)

2.2 The Process of Coming Together

The common link behind the SMRP was the fact that the three districts all received their water supplies through a single main canal conveyance network. In order to effectively manage the joint interests in that supply canal, the three districts (i.e. SMRID, TID and RID) operated a “Main Canal Advisory Committee (MCAC)”. It was this group that formally recognized, in late 2000, that, going into the year 2001, there was a potentially critical water supply situation looming that required some immediate attention to determine possible measures to manage a pending water supply shortfall. At this stage of discussions, representatives of the Irrigation Branch of Alberta Agriculture, Food and Rural Development (AAFRD) were invited to join the discussions to serve as a technical consultant and advisor in the process of deliberations. Similarly, representatives of Alberta Environment (AENV) were invited to be part of the planning team as ultimate management of licensed water allocations was vested within that Ministry.

Early-on in the discussions, the MCAC and its advisors also recognized that, in the overall interests of irrigation supported by the Southern Tribs. watershed, the remaining five irrigation districts that received their water through one or more of the three rivers should also be invited to the table to formalize a committee that could eventually develop a strategy to manage the potentially very limited water supplies for the 2001 growing season. The invitation was extended to the Aetna (AID), Leavitt (LID), Magrath (MID), Mountain View (MVID) and United (UID) Irrigation Districts. All recognized the pending situation and welcomed the opportunity to participate in developing a strategy that might apportion whatever water was available on some equitable basis. The exception to this was the MVID which felt that they could meet their irrigation needs within their licensed allocations and priorities. *(Note: As a similar shortage was presenting itself, going into the 2002 year, the formalized water-sharing committee continued to meet and assess the situation. At that time, the MVID then joined the group as one of the active participants.)* In a similar manner, representation and committee participation from the region’s private irrigators was also invited. Despite these private irrigators having only an informal assembly of membership, a representative for their needs and interests stepped forward and sat as a full member on what then constituted the Southern Tributaries Water-Sharing Committee (hereafter referenced as “the Committee”).

Later on in the process of developing a water-sharing strategy, the Committee also recognized the need to involve all the other water users who derive their water supplies from the Southern Tribs. These included municipalities, industries, other agricultural users, water cooperatives and wildlife habitat interests. Many of these received their water through the works of the various irrigation districts and so had even more reason to take an interest in what was developing. Therefore, representation from each of these user groups were also invited to the table in order to be kept aware of on-going developments and to express their concerns, needs and abilities to adapt. The Blood Tribe Agricultural Project (BTAP), with its several thousand hectares of irrigation on its Reserve, was also invited to participate in the sharing program. BTAP agreed to be a quiet participant but at the same time did not want to be seen as jeopardizing their political position with respect to water rights.

2.3 Sharing the Resource or Applying the Letter of the Law

Early in the deliberation process with everyone, it became clear that there was great advantage to many of the players that voluntarily entering into a formalized water-sharing strategy could definitely be to their benefit. As indicated earlier, the irrigation districts retained the largest and most senior (highest priority) allocations of water. If AENV was required to invoke the provisions of the Water Act, it could mean that whatever water was available would first be allocated to those senior licensees, while more junior or more recent licences could receive little if anything of the available water.

For example, Table 2 lists several of the oldest irrigation district licences and their respective allocations. It could be seen, as will be demonstrated in a later section of this report, that it was projected that there would only be sufficient supplies of water to satisfy allocations up to and including only a portion of the SMRID licence with priority number 1950-05-31-07.

Table 2: Summary of irrigation district water licences, in chronological order.

Licensee	Priority Number	Volume (ac-ft)	Accrued Volume (ac-ft)
SMRID	1899-02-07-01	168,173	168,173
TID	1899-02-07-02	34,000	202,173
RID	1899-02-07-03	12,240	214,413
MID	1899-02-07-04	9,180	223,593
UID	1919-03-24-01	51,000	274,593
MVID	1923-07-10-03	7,500	282,093
LID	1939-06-17-01	7,750	289,843
AID	1945-06-30-01	5,500	295,343
SMRID	1950-05-31-07	331,827	627,170
MID	1950-05-31-08	4,320	631,490
MID	1950-05-31-09	13,500	644,990
MID	1950-05-31-10	3,000	647,990
RID	1950-05-31-14	12,510	660,500
TID	1950-05-31-17	33,500	694,000

This meant that any licence-holder, with a priority date more recent than May 31, 1950, could very likely receive no water at all. As the vast majority of private irrigation, industrial, water co-op, agricultural and habitat licensees held licences that were "junior" to this cut-off date, it was definitely in their best interest to derive and participate in an equitable water-sharing strategy. Without a sharing plan in place that junior licensees would commit to, AENV would have little alternative but to curtail any diversions of water for all of those junior priority licensees.

It is important to point out two significant concessions that were contributed by much of the irrigation district community. First, they had the right to retain whatever water they could from the available supply and in accordance with their licence priority rights, but chose, for the overall best interest of the region, to find a way to share their rightful water allocations with all other users. Secondly, in formulating a water-sharing plan, the three SMRP districts also agreed to somehow share, with other licensed users in the region, whatever "prior-year water" was currently retained within their respective internal storage reservoirs. In essence, this was water previously diverted to these districts during the previous year as part of that year's allocation, but would now be available for the succeeding year's sharing. *(Note: The exception to this internal storage sharing pertained to that water that was held within SMRID's Forty-Mile Reservoir. As this was the only pumped source of reservoir water, and as SMRID was solely paying the cost of associated pumping, the SMRID retained the right to access that particular storage volume solely for its water users.)*

3.0 Defining the Water-Sharing Agreement

3.1 Determining How Much Water Could be Available to Share

In consultation with AAFRD advisors, the following lists all the water availability factors that were considered to be relevant to defining how much water was projected to be available for sharing amongst all users within the irrigation season:

- Projected watershed yield from active runoff.
- Water currently in storage at the beginning of the apportionment period.
- Water not available for diversion due to in-stream commitments.
- Water not available for diversion from the St. Mary River system due to American entitlements.
- Water not available for shared-use from SMRID's Forty-Mile Reservoir.
- Water lost from reservoir evaporation and from conveyance losses.

Specifically, when it came to deriving how much water may be available for irrigation users only, the amount of water to be diverted for other licensed users (e.g. municipal, industrial, etc.) needed to be subtracted from the net calculations as well.

In determining the projected watershed yield at any given time during at least the spring months of the year, the monthly AENV watershed *Water Supply Outlook* was referenced. It provided forecasts based on existing snowpack and assumptions of average precipitation, on other ambient conditions being normal and on what the volume of runoff could be expected to be. Understanding that actual outcomes can vary substantially due to various influences, the AENV projections are provided relative to certain probability levels, based on historical record. These included the "reasonable minimum" outflow at the 90-percent probability level as well as increasingly higher watershed yield projections derived at the 75-percent, 50-percent and 25-percent probability levels. For the purposes of planning apportionments, the Committee agreed to apply the "reasonable minimum" projection, knowing that it is always easier to increase allotments if conditions improve as opposed to reducing allocations if actual conditions materialize at less than planned-for amounts. The 90-percent probability level meant that there was a 10-percent chance that a lower volume of run-off could occur.

As indicated previously, because of the American entitlements to St. Mary River Basin outflows, it was assumed that 30 percent of the projected yield from that sub-basin would be subtracted from the total watershed yield forecast. Further, the required minimum in-stream flow amount, totalled for the three rivers, of nearly six cubic metres per second, flowing for the full term of the normal diversion period (e.g. 153 days) was deleted from the net watershed projection total. Finally, it was generally assumed that evaporative and seepage losses through reservoir storage and open channel conveyance would be approximately three percent of the watershed yield that would otherwise have been held in storage or conveyed to irrigation users.

As mentioned above, the volume of water licensed to all non-irrigation uses was less than five percent of that total allocated to the irrigation districts. Therefore, irrigation was and is the most notable sector to reference in establishing apportionment guidelines. The Committee generally agreed that if, for example, it were determined that the irrigation sector would only receiving 60 percent of its normal allocation, then the allocation to non-irrigation users should also be reduced to 60 percent. That computed amount was then subtracted from what was projected to be available to irrigation users. Table 3 illustrates a summary of all the determinants that were included in deriving the net amount of water available to the irrigation sector within the region.

Table 3. Example summary of factors affecting net water supply to irrigation use

Parameter	Value at Reasonable Minimum	Value at 75% Probability	Value at 50% Probability	Value at 25% Probability
Reservoir Storage (ac-ft):				
• AENV Headworks	46,900	46,900	46,900	46,900
• District Internal	30,300	30,300	30,300	30,300
SUB-TOTAL (ac-ft)	**77,200**	**77,200**	**77,200**	**77,200**
Forecast Watershed Yield (ac-ft):				
• St. Mary River Sub-Basin *	304,925	346,777	526,144	645,723
• Belly River Sub-Basin	96,731	106,404	170,247	214,743
• Waterton River Sub-Basin	219,518	261,332	444,264	527,890
SUB-TOTAL (ac-ft)	**621,174**	**714,513**	**1,140,655**	**1,388,356**
Other Allocation Commitments (ac-ft):				
• Minimum In-Stream Flows (ac-ft)	64,260	64,260	64,260	64,260
• U.S. Share of St. Mary River (ac-ft) **	91,477	104,033	157,843	193,717
• Other Licensee Apportionments (ac-ft)	23,850	29,150	42,400	50,350
• Storage and Conveyance Losses (ac-ft)	13,248	15,512	26,285	32,401
SUB-TOTAL (ac-ft)	**192,835**	**212,955**	**290,788**	**340,728**
Net Available To Irrigation Users (ac-ft):	**505,539**	**578,758**	**927,067**	**1,124,828**

Notes: Reservoir volumes are discounted to projected "effective" irrigation storage volumes.
** This is the natural flow volume, including the U.S. share.*
*** Derived as 30% of the total natural flow (70% being Canada's portion).*

3.2 Deriving an Agreed-Upon Plan for Equitable Allocation of Water

With almost all affected licensees agreeing to actively participate in a sharing arrangement and with a means of projecting the net water available to be distributed to irrigation use having been derived, one of the greatest challenges still lay ahead. That hurdle was defining on what basis the available water would be apportioned to each participant and that could be considered “equitable”.

Through Committee discussion, it was agreed and understood that some specific characteristic that was known or quantified for each irrigation jurisdiction should be referenced in developing a proportional sharing arrangement. Some of the options considered included:

a) dividing the available water up in proportion to the area actually irrigated within each jurisdiction in the previous year;
b) dividing the available water up in proportion to the area assessed to be irrigated within each jurisdiction in the previous year;
c) dividing the available water up in proportion to the actual volume of water used (diverted) in the previous year by each jurisdiction; and
d) dividing the water up in proportion to the total volume of water allocated within each jurisdiction's licences.

There was considerable debate amongst the Committee members concerning which approach was viewed as being the most equitable for all parties. For 2001, after some contentious discussion, it was agreed to apportion the water according to each jurisdiction's actually-irrigated area as of the year 2000. For the irrigation districts, this was a value documented in annual statistical reporting, but was also thought, by some, to be a subjective number in some cases. For the private irrigators, because there was no reliable statistical information available, it was assumed that the total of all licensed areas were irrigated in 2000.

Going into the 2002 year, the sharing formula was re-visited, with many participants feeling that a more definitive, less subjective and more independent reference value should be used for apportioning purposes. Therefore, following considerable discussion, once again, it was concluded that the most equitable manner in which to apportion the water was in proportion to each irrigation jurisdiction's total licensed diversion volume. In other words, if the total licensed volume of all irrigation districts was 100 million cubic metres of water and one of those jurisdiction's was authorized through all of its licences to divert up to a total of 10 million cubic metres, that entity would be apportioned 10 percent of whatever water was calculated and projected to be available under the limited water availability sharing scenario. All licensed volumes and areas of irrigation for all of the private irrigation projects were combined to represent the calculation basis of these projects as a single jurisdiction entity. This approach was similarly applied to the Blood Tribe projects.

3.3 Determining How to Share Water Allocations Equitably at the "farm gate"

Coming to agreement on the mechanism for apportionment of the total volume of water between defined entities effectively concluded the challenge needing to be resolved, at least in terms of the Committee's primary mandate. The diversion, conveyance and distribution systems to and within the irrigation districts, in particular, as well to and within the BTAP development, could be relied upon for the tracking of on-going diversions into each of these irrigation jurisdictions.

However, one further challenge then presented itself. Once a given irrigation district, for example, knew what its overall volume of allocation was, how would it then apportion that water in an equitable fashion amongst its respective and individual water users? Factors that were prevalent in the ensuing deliberations were:

a) dividing the available water up in proportion to the area assessed to be irrigated in the previous year;
b) dividing the available water up in proportion to the area actually irrigated within each jurisdiction in the previous year;
c) recognition of different crops being grown, some having either varying irrigation water requirements as well as different commercial values;
d) recognition of different means of on-farm water application with varying degrees of water-use efficiency; and
e) the reality of the fact that water distribution to each farm or at each on-farm system delivery was not metered in any real and effective way.

Through these deliberations, it was agreed that neither the Committee nor the management operations of an irrigation entity should be deciding what areas of qualified land could or should not receive water. Rather, if an area was assessed to be irrigated, then provision to receive a portion of the available water needed to be assigned to each assessed area to be irrigated. Further, it was concluded that it was not up to the Committee or the jurisdiction's management operations to determine, on behalf of an irrigation producer, which crop-type was more or less worthy to receive water or whether a more efficient type of irrigation water application system should receive more or less water than a lower efficiency type. It was then concluded that each unit area to be irrigated should be, within each respective jurisdiction, allocated the same amount of water per unit of irrigation area.

The next question was what that portion should amount to, as delivered at the "farm gate". The amount allocated at the large project level also included those water amounts lost or unused through conveyance evaporation, seepage and return flow. Once again, following much discussion and consultation, it was decided that the most practical way to quantify the net amounts of water to be delivered at the "farm gate" was to once again refer to the allocation determinations within the licensing, as were documented within the *South Saskatchewan Basin Water Allocation Regulation – 1991*. Within that order, the amount of water required to satisfy the on-farm irrigation requirements, the amount consumed through conveyance and internal storage losses, plus that amount of unused water that constituted return flow, were all identified and quantified for each respective irrigation district as components of water allocation needs tallied within their respective licences. (See also Appendix H.) Reference was made to the amount of water (expressed as a depth per unit area of irrigation) that was required, pertinent to each irrigation district, to meet on-farm irrigation requirements at the field delivery point. This allowed the Committee to compute the proportion of shared available water allocated to each district that would be expected to be delivered at the "farm gate".

Table 4 illustrates one of the monthly allocation summary tables with the computed values for amount of water to be allocated to farm deliveries for each respective irrigation district.

Table 4. A summary of irrigation allocation volumes as of May 1st, 2002.

Irrigation District or Project	SSReg Licensed Volume (acre-feet)	Shared Proportion of Available Water	Allocated Volume of Available Water (acre-feet)	Farm Gate % of SSReg. Allocation	Allocated Farm Gate Volume (acre-feet)
AID	9,000	0.78%	4,708	58.82%	2,770
LID	12,000	1.04%	6,278	60.00%	3,767
MID	34,000	2.93%	17,786	77.96%	13,866
MVID	8,000	0.69%	4,185	70.75%	2,961
RID	81,000	6.99%	42,373	81.95%	34,724
SMRID	722,000	62.30%	377,699	78.76%	297,462
TID	158,000	13.63%	82,654	81.35%	67,237
UID	68,000	5.87%	35,573	75.00%	26,680
BTIP	40,250	3.47%	21,056	87.58%	18,440
Private	26,618	2.30%	13,925	100.00%	13,925
Total or Average	**1,158,868**	**100.00%**	**606,237**	**79.48%**	**481,831**

Table 4 illustrates that for all irrigation jurisdictions supplied by the Southern Tribs. watershed, 1,158,868 acre-feet of water had been allocated to those entities through all associated irrigation use licences. Relative to this total allocation, the sum total volume within all of the Taber Irrigation District (TID) licences, as an example, was 158,000 acre-feet, or 13.63 percent of the total. As of May 1st, 2002, the net volume of watershed and stored water projected and computed to be available to irrigation interests was 606,237 acre-feet. Therefore, under the terms of the water-sharing agreement, the TID would be entitled to 13.63 percent of that total or 82,654 acre-feet. (Note: At this particular time, the volume of live available storage within SMRID's Forty-Mile Reservoir was considered relatively small and so was considered available for sharing with all irrigation jurisdictions.) It was also assumed, because of the "closed" nature of the water supply infrastructure associated with almost all private irrigation projects, where reservoir and open-channel conveyance losses were virtually non-existent and return flow was not a factor, that 100 percent of the water diverted was delivered to the field irrigation systems.

Knowing the total available water that should theoretically be available, at the "farm gate", it was necessary to convert that into a measurement per unit area of irrigation that irrigation producers could translate to their particular operations. As a result, the respective volumes of available water, as computed to be available at the "farm gate" were converted into a depth per unit area by dividing that "farm gate" allocated volume for each irrigation district or project by the respective assessed area to be irrigated. Therefore, using the TID as an example, with 33,290 hectares (82,261 acres) of assessed irrigation area, each unit area would be entitled to receive 249 millimetres (9.81 inches) of equivalent water depth. For the sake of simplicity, these computed values were generally rounded-off to values such as 250 mm or 10 inches.

Because the nature of each district's irrigation characteristics and licensing allocations were unique, the computed farm delivery volumes, and consequentially depth per unit of irrigation area values, ranged from a high of 249 mm for the TID to a low of 200 mm for the private projects. Following the 2001 water-sharing year and heading into the 2002 year which was, at the outset, appearing as if it may be a worse water supply year than 2001 (due primarily to exhausted reservoir storage at the end of the 2001 season), some irrigation interests argued that it would be more equitable if all irrigation producers within the sharing agreement received the same allocation of water at the "farm gate". Again, as a result of further contentious debate, the Committee agreed that a computed average depth of allocation would be assigned to each irrigation jurisdiction and that value would be a weighted average derived as being the total volume of water calculated to be available at the farm gate for all irrigation districts and projects (i.e. 481,831 acre-feet as in Table 4) divided by the total area to be irrigated within all irrigation jurisdictions (i.e. 246,976 hectares or 610,291 acres). As a result, the weighted-average allocation at the "farm gate" for all irrigation districts or projects, as of May 1st, 2002, was 240 millimetres or approximately 9.5 inches.

3.4 Determining how to quantify water use at the "farm gate"

Despite knowing the volume or depth of water that each irrigation producer was projected to be entitled to withdraw, the challenges continued. As none of the individual field irrigation deliveries or diversions was metered, there was a need to devise some alternative means to quantify actual water use.

Fortunately, during this same period of time, a major water management study (*SSRB – Irrigation in the 21st Century*) was in the final stages of completion and involved a project partnership between AAFRD and the irrigation district community. As a component within that project, the irrigation districts, in consultation with AAFRD, undertook a very extensive inventory of all of the on-farm irrigation water application systems within their respective irrigation areas. This inventory identified both the type of irrigation system operating from each farm delivery as well as the area being irrigated by each irrigation system. In addition to developing the master list of system types to be inventoried by the districts, AAFRD developed a table of standardized or typical system capacities that were unique to each system type and related to flow rates on a per unit of irrigated area. For example, a standard "quarter-section" low pressure centre pivot sprinkler, covering approximately 54 hectares (133 acres) would have an average system flow rate of 58 litres per second (925 U.S. gpm), or 1.074 litres per second per hectare (6.95 U.S. gpm/acre). Therefore, with a complete inventory of system types and respective areas irrigated in place, it was possible to quantify how much water would be used at each system delivery point when the time of operation of that system was known. For example, if the assigned allocation at the farm gate were 250 millimetres and the standard pivot sprinkler referenced above was being considered, it would take that system, with the 58-litre per second capacity, covering 54 hectares, approximately 27 days of operation to fully utilize the 250-millimetre allocation.

Therefore, various reference tools were developed and provided by AAFRD to assist irrigation district water delivery supervisors manage their water deliveries under the restricted allocations. When an irrigator called a water delivery supervisor for water "turn-on" or for water "shut-off", the date and time of those events were recorded and thereby times of water use tracked. If and when, as per the foregoing example, 27 days of use was reached, no further deliveries were allowed.

Table 5 provides a sample of one type of reference chart that an irrigation water supervisor could use to determine total days of use by any particular type of system operating on any specific field.

Table 5. A sample of a proxy water use measurement reference tool.

Gross Farm Gate Diversion Allocation Limit = 250 mm/ha										
On-Farm Irrigation System Capacity (l/s)	**Days Available to Divert Water at Farm Gate for Irrigation to Full Allocation**									
	Field Area Irrigated by On-Farm System (ha)									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	29	58	87	116	145	174	203	231	260	289
20	14	29	43	58	72	87	101	116	130	145
30	10	19	29	39	48	58	68	77	87	96
40	7	14	22	29	36	43	51	58	65	72
50	6	12	17	23	29	35	41	46	52	58
60	5	10	14	19	24	29	34	39	43	48
70	4	8	12	17	21	25	29	33	37	41
80	4	7	11	14	18	22	25	29	33	36
90	3	6	10	13	16	19	23	26	29	32
100	3	6	9	12	14	17	20	23	26	29

This system is dependent on an understanding of what each individual system's flow rate or capacity was. Although the rudimentary reference values were generally reasonably accurate, where major discrepancies were suspected, individual system flow measurement tests were carried out.

As an example of the use of the Table, an irrigation system with a flow rate of 60 litres per second (l/s) and covering a 50-hectare field would use up its 250-millimetre allocation in 24 days. On-line calculators and other such tools were made available for water managers to assist in their derivations of system flow rates (i.e. capacities) and "days of use" values.

Some irrigation districts permitted allocation amounts to be transferred, either in whole in part, between fields and between irrigators so that higher value (e.g. sugar beets, potatoes, etc.) and/or higher water use crops (e.g. alfalfa) could receive more of their required water requirements. This trading would usually occur at the expense of lower value and/or lower water use crops such as barley, feed wheat, etc. that an irrigation producer may have in the overall farm enterprise rotation. Allocation transfers were tracked by district or AENV authorities to be able to manage respective farm deliveries. However, all financial arrangements, if and where they may have occurred between two water users (i.e. purchasing of supplemental water allocations), were handled strictly between the two water users involved in the transaction.

In subsequent years, the information resource being compiled with respect to the inventorying of on-farm irrigation systems was further enabled through computerized systems that individual irrigation districts implemented. These developments further demonstrated the capabilities for improved monitoring of site-specific water use.

4.0 Conclusions

4.1 Lessons learned for future water management strategies

Although, in some respects, the water-sharing arrangement could be seen as being an isolated event, having actually only being necessary to fully implement in the year 2001, the whole process did provide an opportunity to test alternative water management strategies. It is quite conceivable that, as irrigation may continue to expand and potential global warming-induced climate change becomes more of a factor, water supplies could once again be in deficit situations, requiring adaptation to more stringent water-use practices.

The following summarizes some concluding thoughts on the whole experience.

1) Water is southern Alberta's "lifeblood" and as such affects a multitude of users and a vast population base. The water-sharing agreement demonstrated that it is possible to innovate and for everyone to adapt to the challenges that the vagaries of the climate can provide.
2) Proactive leadership, as demonstrated by the three irrigation districts making-up the St. Mary River Irrigation Project, was essential in identifying the potential problem and facilitating a remedial process.
3) Active multi-stakeholder involvement from the outset is critical in fostering awareness, knowledge, understanding and consensus.
4) Communication accuracy, frequency and thoroughness, in all its forms, are essential in keeping affected water user organizations and individuals as well as the general public properly informed.
5) Enabling partnerships with agencies such as AAFRD, who could bring independent technical guidance to the deliberations, and with AENV who were the ultimate regulatory group, legally mandated to enforce licence provisions and water-sharing agreements, was of significant benefit in helping the process move along.
6) The development and application of a "proxy" system of water use measurement proved effective. Subsequent computerized enhancements to that type of system have proved beneficial in helping irrigation districts to better manage water allocations each and every year.
7) With more stringent control of a limited supply of water and the constant demand for irrigation that weather through the 2001 irrigation season created, the amount of water flowing by and through the irrigation districts was recorded as one of the lowest proportions of return flow in the history of southern Alberta's irrigation operations.
8) The "Water Sharing Committee" was presented with a special water conservation award by the U.S.-based Irrigation Association for demonstrating exceptional cooperation and adaptation in effectively managing a limited water resource situation.
9) "Fairness" is a very subjective viewpoint, depending on one's own perspective, but reasonable consensus can be achieved by reasonable people when presented with all the facts.

Appendix H: Irrigation Water Use and the SSBWAR ("*The Regulation*")

Note: During the time period when "*the Regulation*" was being developed and at the time of it being registered as a provincial Order in Council in Alberta, it was still common for irrigation practitioners and associated government agencies to reference imperial measurement units. Therefore, in illustrating some of the actual computations and allocations that were derived, imperial measurement units will still be used within the following documentation. S.I. equivalents are documented within related material found in the *SSRB – Irrigation in the 21st Century: Volume 1* report produced in Alberta by the Irrigation Water Management Study Committee in 2002.

1.0 Introduction

1.1 Background on the Purpose of and Need for a Regulation

The area authorized for irrigation within the South Saskatchewan River Basin (SSRB) represents approximately 98 percent of all the irrigation within the province of Alberta. Irrigation area growth was continuing through the late 1970s and throughout the 1980s, occurring both within irrigation districts and amongst private irrigation development areas. Alberta Environment (AENV), in applying its mandated responsibilities to manage the water resource within the SSRB, was becoming increasingly concerned with the expanding demand for water arising from the continued irrigation area growth. In the 15 years leading up to 1990, the irrigated area within the SSRB had grown by 35 percent. The increased demand for water was becoming more and more of a critical issue for provincial water management agencies, given the limited supplies of water traditionally available within the SSRB.

2.0 Developing an Expansion Limit Regulation

2.1 Evaluating Irrigation Water Requirements

In recognition of the need for a mechanism to control irrigation growth and related increases in diversion demands, it was decided that limits on further irrigation area expansion and associated water allocations needed to be established. Following multiple studies, under the direction and involvement of both AENV and Alberta Agriculture, irrigation water use criteria were evaluated in terms of four specific components, namely:

- Farm irrigation demand for water to meet crop needs and account for irrigation system application efficiencies.
- Water conveyance losses through canal evaporation and seepage.
- Water loss through reservoir evaporation.
- Diversion water that flows through a conveyance and delivery system but which remains unused and is returned to a receiving watercourse.

In approaching the process of determining physical limits on irrigated area and water allocations, the process considered what the water use currently was in each of the component categories and what it could be projected to be in the foreseeable future. These projections considered the potential water use efficiency gains that could be made through the on-going improvements in irrigation infrastructure and water management control that were already occurring. More detailed information on this process is contained within Volume 1 of the report *SSRB – Irrigation in the 21st Century* published by the Irrigation Water Management Study Committee in 2002. However, a brief summary follows.

1) **On-farm Irrigation Water-Use** – The crop mix prevalent in each irrigation district at the end of the 1980s was assumed to characterize the type of production enterprises in each respective district. A weighted-average value of the optimum water requirement was determined for each of the crop mixes in the respective agro-climatic regions. Growing season and non-growing-season precipitation amounts, relative to each agro-climatic region were considered in order to arrive at a net crop irrigation requirement. On-farm irrigation application efficiency of 75 percent was assumed, in all cases, to arrive at a gross irrigation demand for deliveries at the farm level. Although it was expected that the future would likely bring improvements to overall on-farm irrigation efficiency, it was also projected that there could also be a shift in crop mix to higher-value and perhaps higher water-use varieties which may offset gains in application efficiency. Therefore, the determinations in 1990 were considered to be valid for progressing into the future. Based on historic climate information, the 90th percentile gross irrigation demand at the farm, for each respective irrigation district, was identified, meaning that it would be expected that in 10 percent of the years, water demand at the farm could be expected to exceed the licence allocation amount.

2) **Conveyance Losses** – An assessment of the entire canal and pipeline infrastructure within each irrigation district was carried-out, considering the current condition of each reach with respect to its state of rehabilitation and potential for seepage and evaporation losses. From that assessment and the application of specific engineering criteria and analyses, determinations as to the amount of water loss from each district's system of water delivery were determined. Similarly, projections were made for the foreseeable future as to what may be achieved in the way of conveyance efficiency improvements through on-going rehabilitation work (e.g. canal lining, canal replacement with pipelines, etc.). The results of this work provided the projected water allocation requirements that each district would need to have included within their respective overall licence allocations to compensate for water lost through the conveyance systems of the future.

3) **Reservoir Evaporation Losses** – Many of the irrigation districts operated internal reservoirs within their overall infrastructure. These were (and will continue to be) a source for some water loss due to surface evaporation from these reservoirs. Using adopted climate analyses equations, the assessed volume of evaporative losses from each reservoir were determined and were compiled as relative to each irrigation district. As there is little that can be done to effectively reduce overall reservoir evaporation, which could in fact increase in the future should additional off-stream storage be developed, there was no projected change (reduction) in the district-specific amounts for this water-use (loss) component.

4) **Return Flow** – This component of licensed water diversion that existed as unused water had been a very large component of most districts' actual water-use allocation, even though it was the only component that was not actually a consumptive use or loss. Nonetheless, significant improvements in achieving reductions in return flow were projected. The on-going improvements within the water conveyance systems and in the methodologies of on-farm irrigation were seen as the key factors that would enable improved water control, minimize run-off and thereby result in less and less of the water diverted for irrigation purposes being returned to downstream receiving watercourses.

Due to and in recognition of there being a dearth of adequate water measurement systems within the irrigation infrastructure, it was understood that the water-use component values generated were the best scientifically-estimated values that could possibly be obtained at the time. In particular, estimates of return flow values were subject to a broad range of interpretation. Accordingly, best estimates and projections were adopted.

An additional part of the irrigation water use and development analyses included an assessment, for each irrigation district and for private irrigation areas, of how much new irrigation land could be *reasonably* developed relative to proximity to water delivery or supply systems and meet land (soil) irrigability standards.

2.2 Setting Expansion Limits and Maximum Water Allocations

The foregoing analyses derived an amount of water (depth per unit of irrigation area) that was currently (1990) being required for irrigation in each district and the amount that was projected to be required in the future. Through the various SSRB water management planning studies that were occurring at this time, determinations were made as to how much water was projected to be available for irrigation use within each of the three major river basins (Oldman, Bow and Red Deer) and within their associated sub-basins.

In consideration of the respective amount of land that could be irrigated through any expanded works of the irrigation districts or through private irrigation development, and of the amount of water that was projected to be available for use by the irrigation sector, plus the unit area amount of water that was projected to be required by each irrigation jurisdiction, a combination of area expansion limits and maximum water allocation volumes were defined.

The findings of this whole process and the defined area and volume limits for each respective irrigation district are summarized in Table 1. These limits and allocations were defined within and formed part of the South Saskatchewan Basin Water Allocation Regulation (SSBWAR) of 1991, commonly referred to as "*The Regulation*", thereafter. (Note: Within Table 1 there are also some values relative to 2007 that are included for comparison sake and which will be discussed later within this appendix document.)

Table 1. A summary of the 1991 SSBWAR expansion area limits and licence allocation volumes, including a comparison with current assessed irrigation areas and licence allocation volumes as of 2007.

Irrigation District	Farm Irrigation Demand (ac-ft/ac)	Conveyance Losses		Reservoir Evaporation Losses (ac-ft/ac)	Return Flow		Total Diversion Demand circa 1990 (ac-ft/ac)	Total Projected Diversion Demand (ac-ft/ac)	Total "Regulation" Irrigation Area Limit (acres)	Total Irrigation Expansion Area - 2007 (acres)	Total "Regulation" Licence Volumes (acre-feet)	Total Licence Volumes as of 2007 (acre-feet)
		circa 1990 (ac-ft/ac)	Projected (ac-ft/ac)		circa 1990 (ac-ft/ac)	Projected (ac-ft/ac)						
Aetna	1.50	0.80	0.72	0.03	1.65	0.30	3.98	2.55	3,530	5,000	9,000	9,000
Bow River	1.82	0.31	0.27	0.03	0.61	0.27	2.77	2.39	210,000	232,000	502,000	450,000
Eastern	1.89	0.42	0.32	0.22	0.62	0.28	3.15	2.71	275,000	311,000	745,000	762,000
Leavitt	1.50	0.76	0.68	0.02	1.65	0.30	3.93	2.50	4,770	4,770	12,000	12,000
Lethbridge Northern	1.45	0.23	0.23	0.05	0.17	0.17	1.90	1.90	167,000	177,000	317,000	334,450
Magrath	1.45	0.25	0.24	0.00	0.20	0.17	1.90	1.86	18,300	18,300	34,000	34,000
Mountain View	1.50	0.37	0.29	0.03	1.65	0.30	3.55	2.12	3,700	4,240	8,000	8,000
Raymond	1.43	0.15	0.14	0.00	0.20	0.17	1.78	1.74	46,500	46,500	81,000	81,000
Ross Creek	2.25	0.55	0.55	0.00	0.00	0.00	2.80	2.80	1,210	1,210	3,000	3,000
St. Mary River	1.52	0.19	0.18	0.07	0.20	0.17	1.98	1.94	372,000	372,000	722,000	722,000
Taber	1.57	0.15	0.14	0.14	0.20	0.17	2.06	2.02	82,200	82,200	158,000	158,000
United	1.50	0.31	0.23	0.01	1.14	0.26	2.96	2.00	34,000	34,400	68,000	66,210
Western	1.59	1.20	1.00	0.02	1.31	0.32	4.12	2.93	95,000	95,000	278,000	158,400
TOTAL									**1,313,210**	**1,383,620**	**2,937,000**	**2,798,060**
Weighted Average	**1.64**	**0.34**	**0.29**	**0.08**	**0.48**	**0.22**	**2.55**	**2.24**				

2.3 Analysis of "*The Regulation*" Limits and Allocations

Within Table 1, the derived values for individual water use components for each district as of 1990 are indicated. Where applicable, the projected water-use amounts for each component are shown, adjacent to the "circa 1990" values. The exception in the Table is for the on-farm component and for reservoir losses where no change is projected (as discussed above).
For conveyance losses, it was projected that, on a weighted-average basis across all districts, there would be a reduction in unit area distribution system losses of approximately 15 percent, ranging anywhere from no improvement to as much as a 25-percent reduction, depending on the district in question. Overall weighted-average conveyance losses were projected to equal approximately 12 to 13 percent of the unit area gross irrigation diversion demand. (Later studies at the turn of the 21st century, as presented within Volume 3 of the *SSRB – Irrigation in the 21st Century* Report series, would reveal that this component of water loss had been reduced to approximately only three percent.)

With the limited recorded measurements of return flow quantities, the wide-ranging numbers were known to be somewhat subjective, but were, on the other hand, the best information that was available or could be derived in the short-term. From Table 1, it can be seen that the current (as of 1990) estimate of return flow, per unit of irrigation area, ranged anywhere from a high of approximately 41 percent to a low of around nine percent (excluding the Ross Creek Irrigation District situation). As a weighted-average across all districts, the unit area return flow was estimated to be approximately 19 percent of the unit area total diversion demand. That amount was projected to diminish, with time, through on-going water management improvements, to less than 50 percent of where it had been, on a volume per unit of irrigated area basis. Into the future, return flow was projected to equal approximately 10 percent of the projected overall gross diversion demand, again on a volume per unit irrigation area basis.

From the foregoing determinations and projections and the projections of future water supply to irrigation, allocation volumes were defined and associated expansion limits specified. The total volume of water allocated for licensing within the irrigation district jurisdiction, within the context of "*the Regulation*", was a little over 2.9 million acre-feet (3.6 billion cubic metres). On a volume per unit of irrigation basis, the weighted-average total projected diversion demand (2.24 acre-feet per acre) reflected a more than 12 percent reduction in allocation. The total of all expansion area limits, prescribed for all 13 irrigation districts, was almost 1.4 million acres (531,437 hectares).

2.4 Factors Affecting Adoption of the Stipulated Limits

During 1991 and 1992, the water allocation licensing of many of the irrigation districts was amended such that additional licences (with priority dates of 1991 and 1992) were issued to increase the volume of water available to these districts so that overall licensing would correlate with the associated expansion limits. Table 1 lists the "Total Irrigation Area Limit" and the "Total Regulation Licence Volumes" established within "*the Regulation*".

However, as time moved forward, there were some exceptions in terms of the application of the specified values or changing circumstances that influenced where current licence allocations or expansion limits are specified (as of 2007). For some districts, there were, or are, outstanding issues surrounding full licensing, as quantified in "*the Regulation*", or other arrangements or agreements that have superseded some of the details within "*the Regulation*". (The details of these variances are district-specific and individually unique and are not the subject of this documentation.) The current (2007) total licensed volumes for all 13 irrigation districts are listed within Table 1. It can be seen that the prevailing total is approximately 95 percent of what was specified within "*the Regulation*".

There were significant amendments to two major pieces of legislation that came about in 2000 (the *Water Act*) and in 2002 (the *Irrigation District Act*) that played major roles in superseding some of the provisions within SSBWAR of 1991. First, amendments within the Water Act have allowed for and defined a process for transferring water allocations from one licensee to another. Secondly, and perhaps more importantly, the amendments to the *Irrigation Districts Act* have allowed for districts to each establish their own new expansion limit, providing certain requirements are satisfied and subject to the approval of the Irrigation Secretariat, which oversees administration of the *Irrigation Districts Act*. These provisions and process have, since around 2003, allowed several irrigation districts to expand their irrigation area base beyond what was previously established within "*the Regulation*".

Consequently, within Table 1, there is a listing, by irrigation district, of the specified expansion limits as they were authorized, as of 2007. As of that time, the new total irrigation expansion area for all 13 irrigation districts had increased by more than five percent or more than 70,000 acres (28,500 hectares) beyond the 1991 SSBWAR limits.

Appendix I: Summary of Stakeholder Workshop for Irrigation Sector CEP Plan Development

The diversion of water for irrigation use, affects more than just irrigation agricultural producers. Many other sectors (stakeholders) either benefit from or are impacted by the development of water management facilities and their operations that are integral to irrigation water diversion, storage and distribution systems. Therefore, in a process of identifying conservation, efficiency and productivity (CEP) opportunities for the irrigation sector, it was desirable that the broad interests and views of all these stakeholders were taken into account.

To facilitate stakeholder input to identifying CEP opportunities, the Irrigation Sector CEP Project Team (Steering Committee and Consultant) convened a one-day workshop on September 18, 2008. A cross-section of 46 individuals, representing a variety of interests and range of expertise in irrigation water use, was invited to contribute to the deliberations. These participants included representation from:

- Irrigation Districts
- Watershed Councils
- Irrigation Equipment Suppliers
- Agricultural Processors
- Agricultural Commodity Groups
- Environmental Groups
- Lethbridge Community College
- University of Lethbridge
- Municipal Government
- Provincial Government
- CEP Report Consultant

Deliberation Process

The participants were divided-up into seven discussion groups that would spend the majority of the day discussing specific aspects of achieving conservation, efficiency and productivity gains with respect to irrigation water use. Each discussion group was structured, as much as possible, with a mix of stakeholders representing differing interests. An overview of the goals for the day, including the accepted definitions and understanding of CEP terminologies, was initially presented to the participants to help guide the discussions that were intended to lead to the desired outcomes.

The discussion groups were then asked to examine areas where efficiencies in irrigation water use and where more water conservation could be derived. Each group recorded their discussion outcomes and then reported them back to all the workshop attendees. The recorded ideas, concepts, suggestions, etc. were collected and compiled for further analysis at a subsequent time by the Consultant.

Similarly, group discussions were convened in order to have the workshop develop a broader understanding of the concept of water use productivity. Following some introductory explanations by the Consultant the groups tackled the assignment of trying to determine opportunities that would increase irrigation water use productivity. This was a somewhat more difficult task and subject area to address and there were some clearly different lines of thinking expressed. Once again, the results of the discussions, as recorded and reported back to the general assembly, were collected and compiled by the Consultant for later analysis.

Finally, in drawing on all the content of the previous discussions, the workshop participants were asked to return to their group discussions and determine specific opportunities for CEP improvements and derive recommendations for specific initiatives that the irrigation sector could potentially undertake that would address the need to make gains in CEP levels. Participants were asked to "think outside the box" and look for new and innovative concepts that could add to on-going water management improvement actions. In addition, participants were asked to define ways in which progress toward achieving desirable CEP gains could be monitored and measured. Again, the recorded results of each group's discussions were presented to the entire workshop and were collected and compiled by the Consultant.

As a result, an extensive list of CEP opportunities was derived through the workshop discussions. The participants then indicated their individual opinions as to which opportunities they individually thought had the greatest potential for achieving CEP gains. Not all items identified in the list were in the final list of stakeholder preferred selections, but all are shown in the following listing. The identified opportunities were grouped into general categories and are listed, as follows, along with an indicator (Rating) of how much support each received from the participants. The higher the rating number the more support that it received.

Category 1: Water Storage

- Expand or enhance on-stream and off-stream storage opportunities. (Rating = 16)
- Develop more non-conventional forms of water storage such as groundwater reservoirs, detention ponds with day-time storage and night-time pumping. (Rating = 8)
- Development of balancing ponds throughout conveyance works. (Rating = 6)
- Use of reservoir storage that is "surplus" to licensed needs at any given time to assist in aquatic environment enhancements. (Rating = 1)

Category 2: Technology Development and/or Adoption

- Enhance water control and monitoring systems within irrigation conveyance works. (Rating = 15)
- Provide improved access to irrigation management tools and systems to support on-farm irrigation operations. (Rating = 14)
- Development of and/or greater utilization of more efficient on-farm water application systems. (Rating = 11)
- Development of more or improved climate reference information. (No rating)

Category 3: Water Caps / Water Pricing / Water Market

- Impose restricted allocations, by volume, to individual irrigation users. (Rating = 13)
- Develop and apply a schedule of water use fees that charges individual irrigation users based on volume of use. (Rating = 12)

- Limiting the sale of water allocations to that amount of water that can be demonstrated as being conserved water. (Rating = 5)

Category 4: Infrastructure Support

- Continue and increase Irrigation Rehabilitation (IRP) funding. (Rating = 10)
- Tie IRP and similar funding to demonstrated CEP gains. (Rating = 3)

Category 5: Water Policy, Regulations and Legislation

- Develop more regulatory flexibility that allows irrigators to “move water around” from parcel to parcel. (Rating = 7)
- Develop more flexibility for the application of legislation and regulations associated with such controls as temporary water transfers and temporary water use agreements. (Rating = 4)
- Revise application of Land Classification Standards for Irrigation to give priority to the re-allocation of water use on only the best quality land. (No Rating)
- Restrict water allocations in recognition of the need to increase the level of risk of incurring water shortages (e.g. one year in seven) in order to foster more efficient use in good water supply years. (No Rating)
- Imposing restrictions limiting irrigation operations to minimum irrigation parcel size (e.g. 15 hectares), or restricting the use of irrigation systems to those that meet a minimum application efficiency level (e.g. 75%). (No Rating)

Category 6: Research

- Development of crop varieties which are more efficient in their use of water. (Rating = 9)
- Development of new market opportunities for greater local consumption of locally-processed commodities. (Rating = 2)

The preferential rating of the opportunities was a matter of the participants’ individual perspective. They based their choices on what each saw as the preferred solutions to what they perceived as the real need.

The seven concepts or opportunities defined by the workshop and receiving the highest level of preferential rating are analyzed in more detail, with respect to the intended CEP plan, within the main report.

Appendix J: A Review of CEP Initiatives from Other Jurisdictions

Note: In the referencing of irrigation conservation, efficiency and productivity improvements from other jurisdictions, particularly those originating within U.S. jurisdictions, it is common for irrigation practitioners to continue to use imperial measurement units. Therefore, in illustrating some of the findings, where units of measurement are referenced, imperial measurement units may still be used.

1.0 Introduction

1.1 Background on Irrigation CEP Initiatives Originating in Other Jurisdictions

In determining and projecting what opportunities there may be for the Alberta irrigation sector to adopt new practices, procedures and operational physical systems, it was proposed that an examination of initiatives that may be occurring in similar irrigation sectors, within other jurisdictions, could prove beneficial to the Alberta sector in developing or implementing its plan.

It has long been recognized that the operations of significant irrigation organizations within the western United States could be considered somewhat analogous to the operations within Alberta. As a result, they are locations that have been targeted, through a literature review, to determine what opportunities could possibly be further explored within southern Alberta.

Additionally, the experiences and challenges of irrigation practitioners and water managers within the Murray-Darling Basin in southeast Australia have also been recognized as possible sources for irrigation water management alternatives. There has been a bit of an affinity between the situations being experienced in Australia with what may occur in Alberta in the not-too-distant future. Therefore, a reference to that jurisdiction has been undertaken as well.

2.0 Literature Review

The following is a brief overview that summarizes some of the more notable findings from the investigations into CEP initiatives in other irrigation jurisdictions. The vast majority of the information summarizes or highlights technical papers or bulletins that have been produced and that could be referenced in the future, relative to any particular initiatives or concepts.

2.1 Irrigation Systems for Idaho Agriculture, Howard Neibling, University of Idaho

- Idaho has 4,000,000 acres of irrigated land (1994)
- Distribution of irrigation systems is sprinklers (59%), surface irrigation (40%), micro-irrigation (1%).
- The various sub-systems of irrigation within the above 3 main groups is discussed (e.g. sprinklers include set-move, solid-set, centre-pivot, linear-move).

- It is noted that considerable energy cost savings can be achieved if pumps are properly sized for the low-pressure systems. (*Using less energy for pumping could be a consideration for irrigation sector conservation by reducing green house gas emission*)
- Discusses tailwater recovery systems, typically used in surface irrigation to recover runoff from fields in a pond at the base of the field. Recovered water is reused for other irrigation. Can improve surface irrigation efficiencies to 70%.

2.2 Energy-Efficient Crop Irrigation, US Dep't of Energy, 2001, Info. Bulletin

- Discusses use of centre-pivots to apply water-soluble pesticides, fungicides and fertilizers along with the irrigation water application to reduce energy consumption by handling these practices independently.
- Programmable Logic Controllers (PLCs) are integrated with GPS to pre-program centre-pivots and adjust spray nozzles to change the rate of application to suit soil conditions (e.g. shut spray off when over rock outcrops).

2.3 The Water Information Program

- Syndicated newsletter provides water information to communities in SW Colorado; has links to related newspaper articles and papers.
- It discusses Limited Irrigation Management and notes that "…..the key management choices for dealing with insufficient irrigation supplies are to: i) reduce irrigated acreage; ii) reduce amount of irrigation water applied to all acres; iii) substitute low-water requirement crops for high-water requirement crops; iv) delay irrigation until a critical crop-water stage; v) manage soil moisture to more effectively capture precipitation.
- Discusses the importance of irrigation scheduling and accurate flow measurements, including measurement of water delivered to and applied on the field.

2.4 Colorado High Plains Irrigation Practices Guide; Colorado Water Resources Research Institute; 2004; Colorado State University

- Contains 11 information sheets on various practices pertaining to irrigation water conservation. The authors state that the literature reviewed is the most up-to-date and scientifically defensible than any material available for regions surrounding Colorado.
- Irrigated Agriculture consumes 80% of the surface and groundwater used in Colorado.
- Public perception is that agricultural water use is inefficient.
- Transfer of water from a water right is limited to amount for historic consumptive use or only that amount of water that is evaporated or transpired by crops. As a result, management practices that result in improved irrigation efficiencies do not yield transferable supplies.
- Diverted water that is not consumed belongs to the stream system, and thus, to other water rights holders. **These return flows are critical to the functioning of Colorado's water allocation system and are not available to satisfy 'new' water demands**.

- Information Sheet #1 – Irrigation Delivery Systems:
  - Discusses merits and efficiencies of 4 main delivery system types - unlined ditches, lined ditches, buried pipe and on-farm storage systems (similar to AARD data).
- Information Sheet #2 – Farm Irrigation Systems
  - Discusses merits and efficiencies of surface, sprinkler and micro irrigation application methods.
- Info Sheet #3 – Centre Pivot Irrigation Systems
  - Discusses impacts of operating pressure, nozzle type and nozzle height.
  - Operating low pressure sprinkler devices closer to the crop canopy is considered more efficient than high pressure systems. Studies in Texas indicate that water savings by moving sprinklers from the truss to the canopy is 1-2% and increases to 10% by moving sprinklers into the canopy.
  - A concern with low pressure pivots is that nozzle height close to ground level can lead to increased runoff if proper tillage not applied.
  - Low pressure systems use less energy which translates into less green house gases emitted.
- Info sheet #4 - Runoff Control for Centre Pivots
  - Low pressure pivots with sprinkler heads near the ground level reduce the wetted diameter and increase the rate of water application. This can increase the rate of runoff if the rate of application exceeds the infiltration rate. The runoff losses potentially exceed the amount of water saved by lowering the sprinkler heads.
  - Options for reducing runoff are; decrease the application depth, increase surface storage by using appropriate surface residue and tillage management, decrease irrigation capacity and select sprinkler package that provides larger wetted perimeter.
- Info sheet #5 – Furrow Irrigation Systems
  - Mentions the use of tailwater recovery as a means of reusing irrigation runoff. Runoff is directed into a central collection point from where it can be conveyed to a point of redistribution. Water savings of 25-30% can be expected.
  - Other methods of substantially improving furrow irrigation system efficiency include; surge irrigation, irrigating every other row, mixing Polyacrylamide, a polymer, with irrigation water and land levelling.
- Info sheet #6 – Subsurface Drip Irrigation
  - Not really relevant to southern Alberta
- Info Sheet #7 – On-Farm Water Measurement and Control
  - States why proper on-farm water measurement is needed to facilitate implementation of best management practices.
  - Discusses use of open channel and closed pipe measurement devices.
- Info Sheet #8 – Tillage and Crop Residue Management under Sprinkler Irrigation Systems
  - Recommends this practice be applied to irrigated fields to improve water conservation through less soil erosion, less soil compaction, increased infiltration, less runoff, less fuel and labour costs, and lower soil moisture lost.
- Info Sheet #9 – Tillage and Crop Residue Management in Furrow Irrigation Systems
  - Looks at methods for furrow irrigation to achieve the same benefits as per info sheet #8.
- Info sheet #10 – Irrigation Scheduling
  - Proper irrigation scheduling maximizes irrigation efficiencies by applying the correct amount of water needed to replenish the soil moisture to a desired level.
  - Discusses potential efficiency gains and different methods employed.

- Research in Nebraska showed an average 35% savings in water and energy.
- Methods employed to achieve proper scheduling include; the use of portable atmometers to measure evaporation at each farm; local weather station data transmitted over the Internet on a real-time basis, and a computer program (Cropflex) is used to integrate water and nitrogen management.

- Info Sheet #11 – Limited Irrigation and Crop Rotation Options
  - Full irrigation is when the amount of water needed to achieve maximum crop yield, minus rainfall and stored soil moisture, is applied. Limited irrigation strategies are considered when the water supply is insufficient to meet crop demand.
  - Management opportunities for limited irrigation include;
    - reduce irrigated acreage
    - reduce irrigation water applied on a field
    - grow crops that require less water
    - switch to a more dryland crop rotation
    - delay irrigation until critical crop water requirement stages
    - manage the soil-water reservoir to optimize capture of precipitation.

2.4 More with Less: Agricultural Water Conservation and Efficiency in California, Pacific Institute, September 2008

- Founded in 1987, the Pacific Institute is a non-profit organization which conducts research and provides advocacy to create a healthier planet and sustainable economies.
- This study assesses the potential for improving agricultural water-use efficiencies, with a focus on the Sacramento-San Joaquin Delta. Almost half of the water for California's agriculture comes from rivers that once flowed into the Delta.
- The report looked at 4 scenarios for improving water-use efficiencies.
  - <u>Modest Crop Shifting</u> from lower value, higher water using crops to higher value, lower water using crops.
  - <u>Smart Irrigation Scheduling</u>
  - <u>Advanced Irrigation Management</u> (e.g. deficit irrigation)
  - <u>Efficient Irrigation Technology</u> – (e.g. shift from surface irrigation to sprinkler and drip irrigation, where practical)
- It was computed that annual water savings from each of the 4 scenarios ranged from 0.6 to 3.4 million acre-feet. Undertaking these actions would resolve the legal restrictions that have been imposed on the Delta's water withdrawals at significantly less cost than building an equivalent amount of reservoir storage.
- The paper describes, in detail, how each of these scenarios could be developed. It also suggests new government policies, taxes and legislation that should be considered and existing ones that should be changed.

2.5 Use of Water Within the Murray-Darling Basin of Southeast Australia

The complexities of water management within the Murray-Darling Basin have become significant, so much so in the past couple of decades that basin management has evolved from the work of a Commission to that of a federally-constituted Basin Authority with much broader jurisdiction in developing associated water management strategies. As the mandate of and challenges for the Murray-Darling Basin Authority are extensive and complex, irrigation is only one facet, albeit a significant user of water. The following represents a sampling of some of the strategies being employed.

- Revisions to the prevailing Water Act that will facilitate water transfers and water purchases are seen as key accomplishments in allowing for more efficient use of water.
  - Water can be moved (transferred) to irrigation use (or other use) where it may have more efficient use and greater productivity.
  - Water purchase agreements can influence dispersal of water allocations.
  - Re-vamping of irrigation water rights will influence water-use efficiency.
- Application of unique water allocation systems will increase efficient use.
  - Annual allocations to irrigation may be determined based on projections of actual seasonal water availability and not on "water rights entitlements".
  - Licence holders may be allocated 80 percent of the projected water availability entitlement. Any further allocation requirements would have to be purchased on the water market.
  - Development of a water rights information service will facilitate water trading across the Basin.
- Communities will be engaged fully in the overall determination of future water use, with nothing pre-determined or "carved in stone" as far as prior rights are concerned.
- There will be government (Basin Authority) investment in improving irrigation water-use efficiency and in purchasing water for re-distribution.
- More extensive monitoring of diversions and use will be encouraged.

2.6 Canadian Council of Ministers of the Environment (CCME)

In 2006, the CCME produced a report entitled "*An Analysis of Canadian and Other Water Conservation Practices and Initiatives*". The report examined water use and efficiency improvements within a number of different water use sectors, including agriculture and irrigation.

In regards to irrigation water use, the report findings are highlighted with the over-arching comment that, "solving or preventing serious water management problems will almost certainly involve both demand management and supply management approaches". In particular, demand management opportunities exist to:

- minimize water losses in conveyance systems
- better coordinate the scheduling of irrigation use
- use more efficient application technologies
- more effectively determine the net economic return in irrigating certain low-value crops
- more effectively monitor actual water use for improved cost accounting and overall water management

Issues needing to be dealt with by both producers and governments will be:

- cost-sharing formulae of the substantial funding requirements to make required and necessary improvements
- determining appropriate rates of return in arriving at a workable division of funding responsibilities
- full cost accounting and cost recovery as stimulants to improved water use