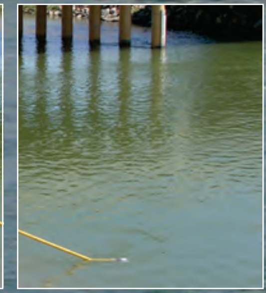
Assessment of Water Quality in Alberta's Irrigation Districts

Summary – Second Edition

November 2010








Government of Alberta

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Revisions

The Second Edition includes revisions to the water quality index, arsenic values, and average concentrations of water quality parameters.

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INTRODUCTION

Alberta irrigates about 675 000 ha of land, which accounts for almost 70% of Canada's total irrigated land. About 520 000 ha of irrigated land is located within 13 irrigation districts of southern Alberta. Irrigated agriculture is an intensive and highly valued industry, which accounts for a large portion of agricultural production in Alberta.

Water quality is intricately linked to agricultural production. Quality production is reliant upon clean source water. Water quality deterioration can occur in a number of ways, including land use impacts from agricultural, industrial, urban, and rural development.

OBJECTIVES

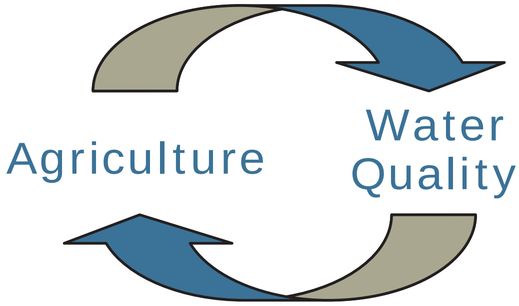
The objectives of this study were to:

- i) assess the quality of source water used for irrigation from a food production perspective;
- ii) assess changes in water quality as water travels through the irrigation infrastructure, from source water to return flow;
- iii) determine if there are differences in water quality among the irrigation districts; and
- iv) determine if there are differences in water quality between two types of conveyance systems.

SCOPE

This study examined about 80 sampling sites in Alberta's irrigation districts. Water was evaluated in 11 districts including the Mountain View (MVID), Aetna (AID), United (UID), Magrath (MID), Raymond (RID), Lethbridge Northern (LNID), Taber (TID), St. Mary River (SMRID), Bow River (BRID), Western (WID), and Eastern (EID) irrigation districts.

In addition, seven sites within the SMRID were sampled to determine differences in water quality between closed pipeline and open channel canals, and seasonal trends in water quality parameters.



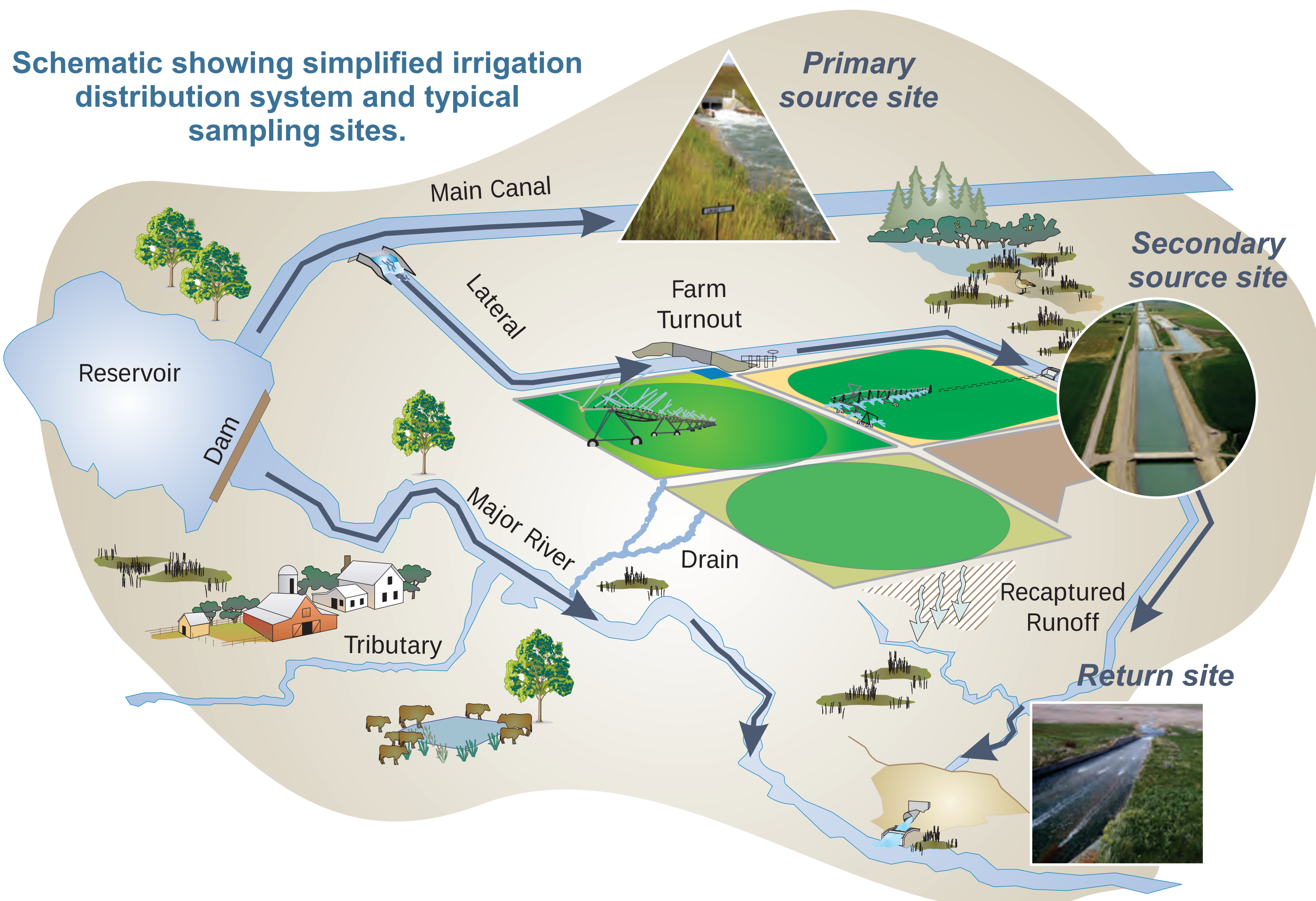
METHODS

Comprehensive Sampling of Irrigation Districts – Irrigation water was monitored at about 80 sites in 11 irrigation districts in 2006 and 2007. Sampling sites were chosen to capture water as it moved through the infrastructure of each irrigation district, from the source water to return flows. Sampling locations consisted of primary sites, where main source water enters the irrigation district; secondary sites, where canals branch off within the district for on-farm water supply; and return flow sites, where water exits the irrigation district. Sites were grab sampled four times each year during the peak irrigation season (June to August).

Representative Sampling in the St. Mary River Irrigation District – The seven sites in the SMRID were grab sampled every two weeks from May to September in 2006 and 2007. A pipeline and open canal with the same source water were selected. The water traveled a maximum distance of about 5 km in the pipeline and 30 km in the canal.

Samples were analyzed for a suite of nutrient, metal, major ion, salinity, pesticide, and bacterial indicators.

Schematic showing simplified irrigation distribution system and typical sampling sites.



Average concentrations of water quality parameters measured in 2006 and 2007.

	MVID	AID	UID	MID	RID	LNID	TID	SMRID	BRID	WID	EID
Total Nitrogen (mg/L)											
Primary source	0.50	0.34	0.12	0.22	0.26	0.16	0.16	0.34	0.60	0.42	0.86
Secondary source	—	—	0.19	0.13	—	0.33	0.56	0.51	0.73	0.62	0.50
Return	0.53	0.33	0.32	0.50	0.39	0.56	0.61	0.84	0.67	0.78	0.36
Total Phosphorus (mg/L)											
Primary source	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.03	0.04	0.02
Secondary source	—	—	0.02	0.01	—	0.02	0.03	0.04	0.04	0.06	0.03
Return	0.03	0.02	0.06	0.06	0.11	0.08	0.04	0.07	0.05	0.13	0.02
***Escherichia coli* (MPN/100 mL)**											
Primary source	2	112	52	78	17	42	199	16	80	33	40
Secondary source	—	—	4	26	—	42	131	24	20	212	17
Return	192	102	152	285	436	407	51	200	188	203	177
Electrical Conductivity (dS/m)											
Primary source	0.21	0.21	0.21	0.22	0.24	0.27	0.29	0.28	0.51	0.47	0.35
Secondary source	—	—	0.20	0.20	—	0.28	0.33	0.32	0.62	0.51	0.35
Return	0.26	0.22	0.23	0.49	0.35	0.32	0.38	0.34	0.67	0.72	0.36

Total nitrogen guideline for protection of aquatic life is 1.0 mg/L.
Total phosphorus guideline for protection of aquatic life is 0.05 mg/L.
Fecal coliform guideline for irrigation is 100 MPN/100 mL. *Escherichia coli* (*E. coli*) are a subset of fecal coliforms.

dS/m = deciSiemens per metre
mg/L = milligrams per litre
MPN = most probable number
mL = millilitre

KEY FINDINGS

1. Water quality for irrigation in Alberta was generally good or excellent.

An Alberta irrigation water quality index was developed in order to summarize quality as assessed by irrigation guidelines. The index included metal, ion, salinity, pesticide, and bacterial indicators. Data were categorized as either 'excellent', 'good', 'fair', 'marginal', or 'poor' based on the scope, frequency, and magnitude of guideline exceedance.

- Overall, water quality for irrigation was 'good' or 'excellent' for most of the source waters.
- One secondary site in the WID and one return flow site in the EID were rated as 'marginal' for irrigation due to elevated concentrations of herbicides, bacteria and in the case of the WID, salinity.
- Return flows generally had poorer quality than source waters.

The WID scores were influenced by pesticides and salinity indicators. All samples that contained more than six pesticides were from the WID. Also, the highest total pesticide concentrations were observed in the WID. The relatively poorer water quality in the WID may be, in part, due to storm water runoff from the City of Calgary and the community of Chestermere. The lower scores observed in the EID returns were due to more frequent detections of dicamba, which has a very low irrigation guideline.

Water Quality Guidelines

Irrigation guidelines help to protect sensitive crop species that may be exposed to toxic substances such as pesticides in irrigation water. They are based on maximum irrigation rates and the sensitivity of crops to pollutants.

Livestock water guidelines are based on how livestock are affected by their drinking water and whether certain substances, such as toxic chemicals, accumulate in the animals' bodies.

Protection of aquatic life guidelines help to protect all plants and animals that live in our lakes, rivers, and oceans by establishing acceptable levels for substances or conditions that affect water quality. The guidelines are based on toxicity data and are science-based benchmarks for the protection of 100% of the aquatic life species, 100% of the time.

2. Water quality guidelines for nutrients and metals were met the majority of the time.

Protection of Aquatic Life

- The total phosphorus and total nitrogen guidelines for the protection of aquatic life were met in 78% and more than 93% of the samples, respectively.
- The nitrite-nitrogen and ammonia-nitrogen guidelines for the protection of aquatic life were met more than 99% of the time.
- The nitrate-nitrogen guideline for the protection of aquatic life was always met.
- Seven metals occasionally exceeded the protection of aquatic life guidelines. Compliance was 99% for iron, lead, manganese, and thallium; 98% for arsenic; 97% for zinc; and 87% for selenium.
- Aluminum concentrations met the protection of aquatic life guideline only 37% of the time.

Agricultural Uses

Irrigation

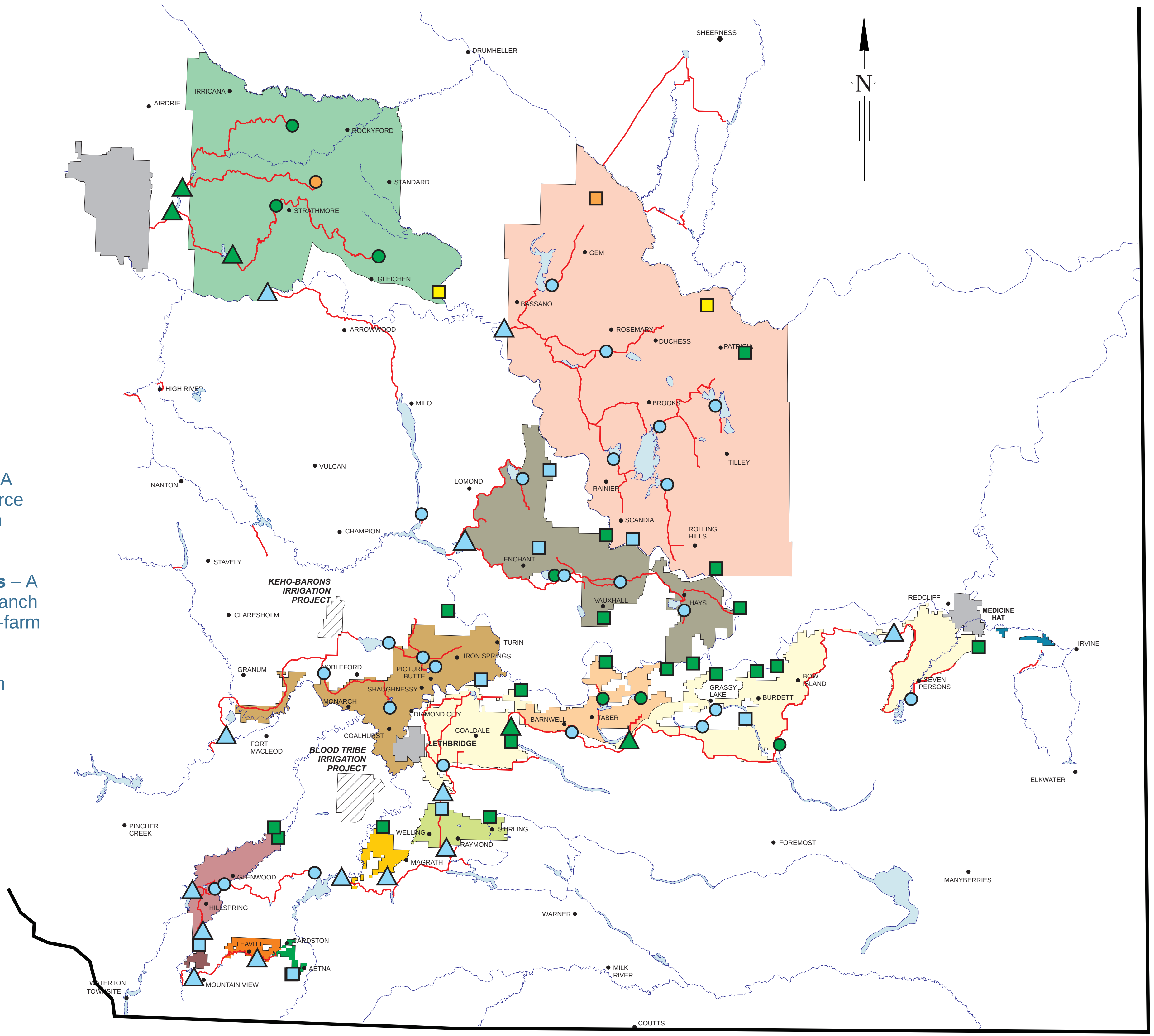
- Irrigation guidelines for boron, lithium, nickel, uranium, and vanadium were always met.
- Three metals occasionally exceeded irrigation guidelines. Compliance was 99% for iron, manganese, and aluminum.

Livestock

- The nitrate- plus nitrite-nitrogen guideline for livestock watering was always met.
- Two metals, aluminum and arsenic, complied to the livestock watering guidelines 99 % of the time.

Other studies of irrigation water in Alberta had similar findings. Background concentrations from natural sources are likely the reason for the metal guideline violations.

Irrigation Water Quality Index Scores (2006 and 2007)



Main canals

Water Quality

- Excellent
- Good
- Fair
- Marginal
- Poor

Primary source sites – A location where main source water enters an irrigation district.

Secondary source sites – A location where canals branch off within a district for on-farm water supply.

Return sites – A location where water exits an irrigation district.

0 25 50km

- Mountain View Irrigation District
- Leavitt Irrigation District
- Aetna Irrigation District
- United Irrigation District
- Magrath Irrigation District
- Raymond Irrigation District
- Lethbridge Northern Irrigation District
- Taber Irrigation District
- St. Mary River Irrigation District
- Ross Creek Irrigation District
- Bow River Irrigation District
- Western Irrigation District
- Eastern Irrigation District

Variables and objectives used in the Irrigation Water Quality Index.

Variable	Objective
Sodium adsorption ratio	5
Chloride	100 mg L^{-1}
Total dissolved solids	500 mg L^{-1}
Arsenic	0.1 mg L^{-1}
Beryllium	0.1 mg L^{-1}
Boron	0.5 mg L^{-1}
Cadmium	5.1 µg L^{-1}
Chromium	4.9 µg L^{-1}
Copper	0.2 mg L^{-1}
Iron	5.0 mg L^{-1}
Lead	0.2 mg L^{-1}
Lithium	2.5 mg L^{-1}
Manganese	0.2 mg L^{-1}
Selenium	0.02 mg L^{-1}
Uranium	0.01 mg L^{-1}
Vanadium	0.1 mg L^{-1}
Zinc	5.0 mg L^{-1}
Escherichia coli	100 MPN/100 mL
Total Coliforms	1000 MPN/100 mL
Dicamba	0.006 µg L^{-1}
MCPA	0.025 µg L^{-1}
Bromoxynil	0.33 µg L^{-1}
Diclofop-methyl	0.18 µg L^{-1}

Objectives are based on CCME and ARD irrigation water quality guidelines.

3. Pesticides were detected in most samples. Herbicide guidelines for irrigation were frequently exceeded, which may be of concern for some specialty crops.

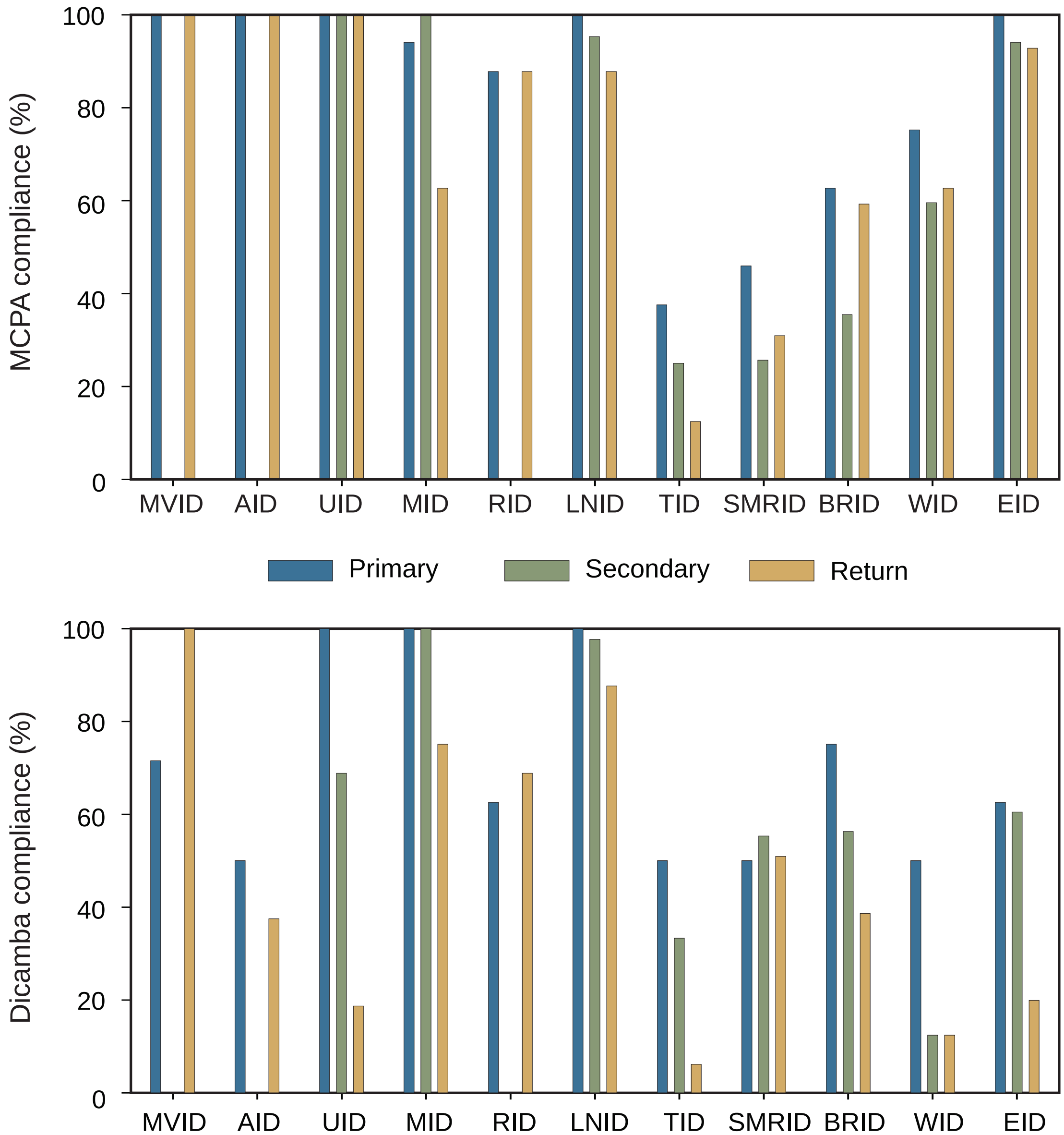
A number of the herbicides detected do not have guidelines. Further, guidelines for individual herbicides do not account for multiple pesticide detections in a sample.

- Of the 25 pesticides (17 herbicides, 8 insecticides) analyzed, nine herbicides were detected.
- Herbicides were detected in more than 90% of the samples.
- The most commonly detected herbicides were: 2,4-D (91%), dicamba (47%), and MCPA (38%).
- The 2,4-D guideline for the protection of aquatic life was met 99% of the time.
- Irrigation guidelines for dicamba and MCPA were frequently exceeded, with overall compliance of 54% for dicamba and 67% for MCPA.
- The MCPA, dicamba, triallate, bromoxynil, and picloram guidelines for the protection of aquatic life or livestock watering were met in all samples.
- No Canadian guidelines exist for the agricultural herbicides clopyralid, dichlorprop, and mecoprop, which were detected in 12% or less of the samples.
- Forty percent of the samples contained more than two herbicides per sample. The maximum number of herbicides per sample was eight.

No work has been done to document potential impacts of herbicides in irrigation water on crop production in Alberta.

Herbicide irrigation guideline exceedances are common in Alberta's irrigation system. Generally, those herbicides with the greatest sales and environmental mobility are the compounds most commonly detected.

Compliance with irrigation guidelines in 2006 and 2007 by irrigation district and site type.



Lettuce is sensitive to MCPA.

Sunflowers tend to be sensitive to dicamba.

2,4-D and MCPA: These phenoxy herbicides have similar modes of action and are registered for agricultural as well as non-agricutlural uses. These herbicides frequently have the highest sales receipts in Alberta.

Dicamba: This benzoic acid herbicide is used in the agricultural sector for weed control in cereals, corn, and pastures. It also has non-agricultural uses. Dicamba is known to be highly mobile in the environment. It is often mixed with 2,4-D, MCPA, or glyphosate.

4. Source water quality varied among the districts for some parameters, even for districts within the same river basin.

Some of the irrigation districts received water from the Oldman River Sub-basin (MVID, LID, AID, UID, MID, RID, LNID, SMRID, TID), while others received water from the Bow River Sub-basin (WID, BRID, EID). However, source water quality from districts within the same sub-basin was not consistent.

- The EID had significantly greater concentrations of nitrate-nitrogen in primary source waters compared to all other districts.
- The EID and AID had greater concentrations of some metals (aluminum, iron, lead - AID only, and vanadium) in primary source waters than all other districts.
- The WID source water quality appeared to be generally poorer than source waters of other districts due to greater numbers of pesticides detected as well as elevated nutrient concentrations and salinity.

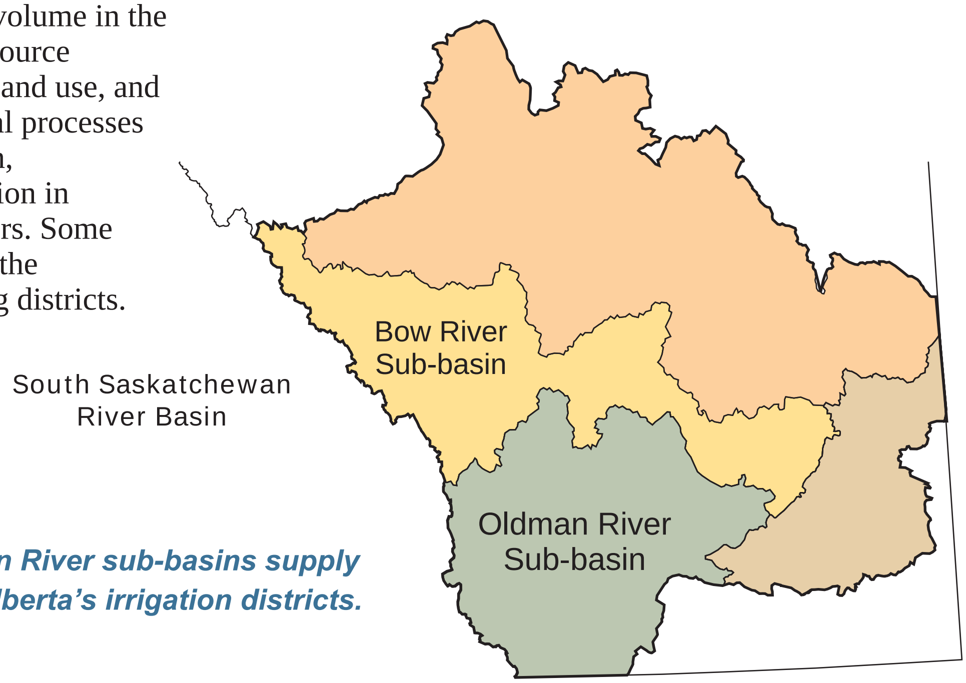
The EID and AID metal concentrations were probably not a concern for crop production as they met irrigation guidelines the majority of the time. The metal concentrations may have been related to elevated total suspended solids concentrations.

Although high nutrient concentrations were not a concern for crop production, they may be of concern for efficient conveyance of water in irrigation canals as aquatic weed growth may be stimulated by dissolved nutrients in the water.

Water quality can be affected by a number of factors including flow velocity and volume in the canals, point and non-point source contributions from adjacent land use, and natural chemical or biological processes including mineral dissolution, denitrification, and assimilation in stream channels and reservoirs. Some of these factors may explain the differences in patterns among districts.

Irrigation Districts

MVID – Mountain View
LID – Leavitt
AID – Aetna
UID – United
MID – Magrath
RID – Raymond
LNID – Lethbridge Northern
TID – Taber
SMRID – St. Mary River
RCID – Ross Creek
BRID – Bow River
WID – Western
EID – Eastern



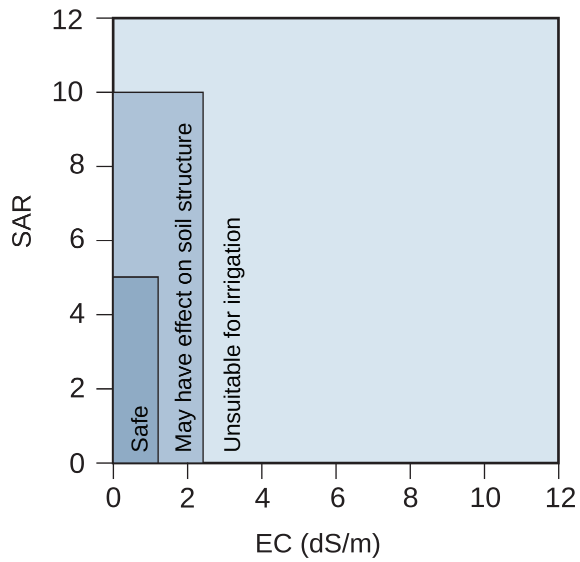
The Bow River and Oldman River sub-basins supply the majority of water for Alberta's irrigation districts.

5. Salinity and major ions were not a concern for most districts, with the exception of the BRID and WID.

- Alkalinity, measured as $CaCO_3$, was greater in all irrigation districts than the recommended optimal alkalinity for greenhouse plants. However, impacts on field crop production were likely minimal.
- Irrigation guidelines for electrical conductivity (EC), total dissolved solids (TDS), sodium adsorption ratio (SAR), and chloride were met in more than 97% of the samples. The sulphate guideline for livestock water use was always met.
- All samples that exceeded guidelines for SAR or EC were from the BRID or WID, and included some source water.
- The BRID had significantly higher EC in source water than all the other districts. The BRID and WID had significantly higher SAR in their source waters than compared to all other districts.

It is unclear why increased salinity was observed in the BRID and WID, but not in the EID, which also has the Bow River as its source. Nonetheless, the levels of salinity and major ions were of minimal concern for successful crop production. However, monitoring should continue and future actions may be warranted to address these issues.

Irrigation water quality guidelines for Alberta examine the EC and SAR concurrently according to a threshold concept.



Electrical Conductivity (EC): indicates the level of dissolved salts by measuring the ability of solution to carry an electric current by ions. A high electrical conductivity indicates high salt content, which will stress plants and cause productivity losses.

Sodium Adsorption Ratio (SAR): A measure of the suitability of water as determined by the concentrations of sodium, calcium, and magnesium ions.

6. Some degradation of water quality occurred as water flowed through the irrigation distribution system.

- Five irrigation districts had significantly greater total phosphorus concentrations in return flows compared with source waters.
  - – Increases in the LNID, RID, and UID were in dissolved and particulate fractions.
  - – Increases in the SMRID and TID were in the particulate fraction.
- Six irrigation districts had significantly greater total nitrogen concentrations in return flows compared with primary source waters.
  - – Increases in the LNID, MID, SMRID, TID, UID, and WID were in the organic form.
- Many districts had significantly greater salinity and major ion concentrations in return flows than in source waters.
  - – For some variables, concentrations in secondary source sites were also higher than primary source sites.
- Pesticide detection frequencies were generally highest in the return flows, followed by the secondary and then primary source waters.
- Water quality parameters tended to peak at the beginning or near the end of the irrigation season when lower flows were common.

Water quality degradation occurs naturally as water travels downstream. However, water quality degradation may be augmented by land use activities and in particular, agricultural production. It has been well documented that as agricultural intensity increases, concentrations of nutrients and agricultural pesticides in agricultural streams tend to increase.

While the water quality received by the irrigation districts is critical for high quality crop production, it is also important to ensure that water returned to the aquatic environment and potential downstream users is of good quality. Measures to mitigate land use impacts on water quality should be undertaken where required.

Total phosphorus: A nutrient essential to the growth of organisms, and is commonly the limiting factor in the primary productivity of surface water bodies. Phosphorus can be present in dissolved or particulate forms.

Organic nitrogen: This form of nitrogen must be mineralized or decomposed before it can be used by plant communities in aquatic and terrestrial environments.

7. Pipelines generally had minimal effect on water quality, except for reducing bacterial indicators.

- While most water quality variables were not significantly different between the SMRID pipeline and earth canal, bacteria counts were significantly lower in the pipeline compared to the lower reaches of the earth canal.

FUTURE STUDIES

Recommendations for future studies were provided at the end of the report and included suggestions for site selection, laboratory analyses, sampling regime, and data warehousing. It was suggested that an assessment of detailed linkages between land use in the irrigation districts and water quality would be beneficial.

Water quality sampling at a pipeline in the St. Mary River Irrigation District.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