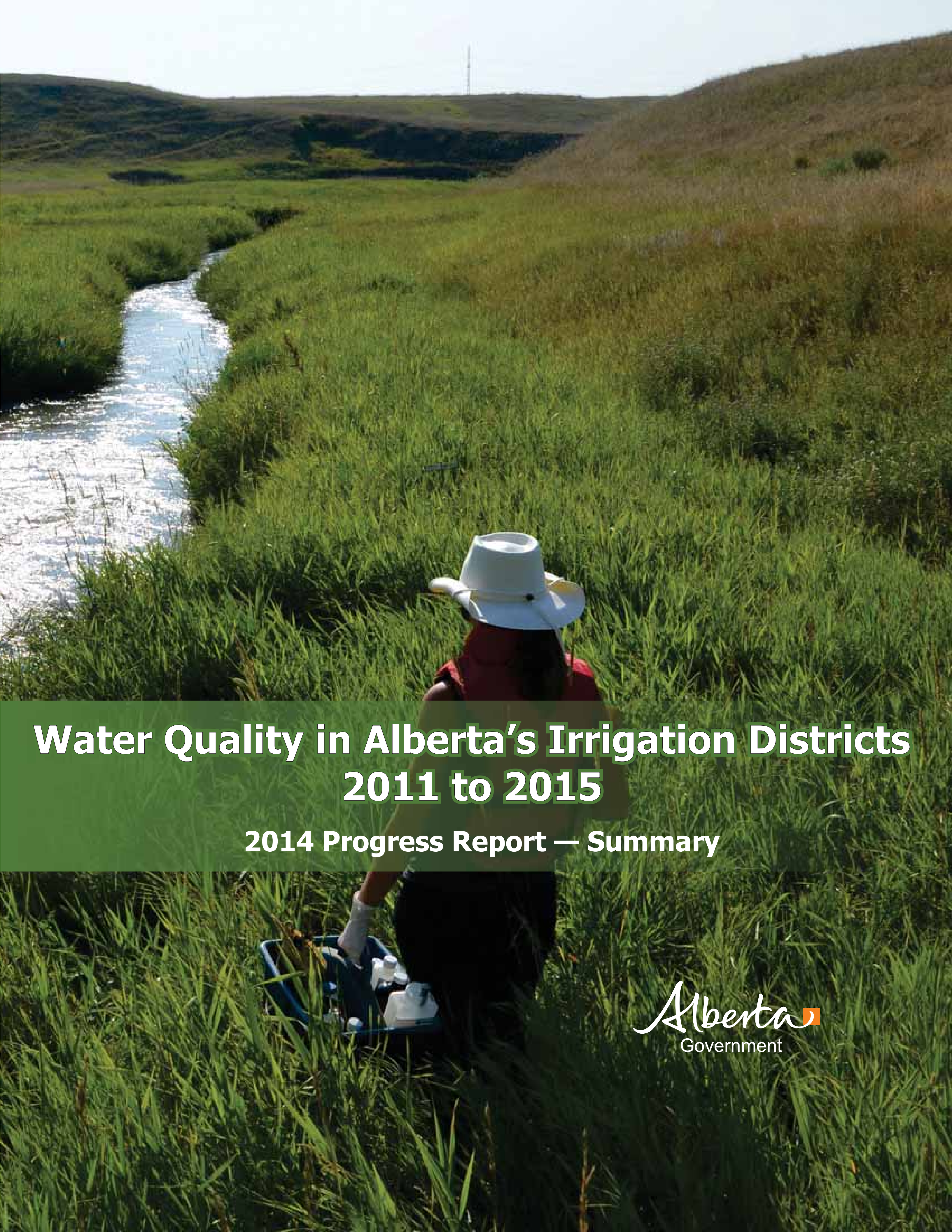

Water Quality in Alberta's Irrigation Districts 2011 to 2015

2014 Progress Report — Summary

Alberta Government

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Introduction

More than 65% of Canada's irrigation occurs in Alberta's 13 irrigation districts. The districts encompass approximately 8,000 km of district- and government-owned irrigation infrastructure and more than 55 reservoirs serving 555,220 ha of irrigated agricultural land.

Irrigation is essential for high agricultural production and crop diversity in southern Alberta. The irrigation conveyance network supplies water to thousands of rural homes and more than 30 communities for household potable water, municipal pools, parks, and industrial use including food processing plants and factories. The conveyance network also supplies water for several other uses including livestock production, wildlife habitat, and recreational activities such as fishing, boating, and camping on irrigation reservoirs.

Good quality irrigation water is needed for all uses. High yielding and safe food production requires low concentrations of herbicides and pathogens. Low nutrient concentrations in water help prevent the growth of aquatic weeds and algae that would otherwise impede water conveyance. Good quality water is also important to minimize treatment costs for rural communities.

A five-year study (2011 to 2015) is being conducted to assess the quality of irrigation water within Alberta's irrigation districts. This report summarizes activities and findings of the 2014 sampling season, which was the fourth year of the study. New to the study in 2014 was a case study to better understand the effects of landscape and canal characteristics on water quality along the conveyance system, and two synoptic surveys on the Oldman River to study the cumulative effects of irrigation returns on the river water quality.

2014 Index Results

Water quality was assessed using environmental quality guidelines for Alberta surface waters to calculate water quality indices. The indices provide a practical reporting method to assess the overall water quality among the sites and the years.

Water quality indices for irrigation, livestock watering, protection of aquatic life, and recreation were assessed. The average score for irrigation (91.9) was excellent in 2014. Average irrigation water quality index scores were 91.2, 94.3, and 92.6 in 2011, 2012, and 2013, respectively. Of the 90 irrigation district monitoring sites, 82% had an excellent rating, 9% had a good rating, 7% had a fair rating, and 2% had a marginal rating for irrigation water quality in 2014. Lower scores were observed at return sites, which are at the end of the distribution system after which water is no longer used for irrigation. Irrigation guideline exceedances for pesticides and coliforms remained the main cause of reduced water quality index scores.

None of the livestock water quality guidelines were surpassed in 2014 and the index score rated 100. The average index score for the protection of aquatic life was 96.1, which was excellent and better than previous years. The recreation index, which is solely based on an *E. coli* guideline, was 86.2, which was still considered excellent and comparable to the 2013 results.

Irrigation water quality index scores and rankings (blue to red) for each sampling site from 2011 to 2014.

Irrigation District	Site	2011	2012	2013	2014
MVID	MV-P1	100.0	100.0	100.0	100.0
	MV-R1	100.0	100.0	100.0	100.0
AID	A-R1	96.8	100.0	100.0	95.7
UID	U-P1	97.3	100.0	58.9	100.0
	U-S1	55.2	100.0	80.8	81.9
	U-R2	52.7	94.5	89.6	73.7
	U-R3	62.9	91.7	77.9	55.8
	U-R4	-	100.0	70.2	66.0
MID	M-P1	93.6	100.0	100.0	97.9
	M-S1	96.6	97.1	81.8	82.2
	M-R1	97.4	97.8	100.0	87.2
RID	R-P1	96.8	100.0	100.0	95.5
	R-R1	87.7	90.2	95.5	95.8
	R-R2	91.6	97.9	100.0	78.8
LNID	LN-P1	100	100.0	95.9	100.0
	LN-S1	97.5	100.0	97.9	100.0
	LN-S2	100.0	100.0	100.0	100.0
	LN-S3	97.9	92.2	71.9	79.4
	LN-S4	97.8	97.3	100.0	95.6
	LN-S5	93.9	93.9	77.3	91.8
	LN-R1	91.6	92.6	89.0	93.3
	LN-R2	86.6	86.4	72.8	67.8
	LN-R3	96.5	100.0	83.6	60.0
	LN-R4	-	83.4	64.9	79.9
TID	T-P1a	97.5	97.9	100.0	97.7
	T-S1	97.9	97.9	97.0	97.5
	T-S2	91.9	96.1	93.8	87.8
	T-S3	86.1	89.7	92.2	89.5
	T-R1	91.2	94.1	96.2	93.0
	T-R2	86.1	88.5	92.5	91.0
SMRID	SMW-P1	95.4	100.0	100.0	97.9
	SMW-S2	95.5	100.0	97.9	97.9
	SMW-R1	93.4	79.4	95.7	96.0
	SMW-R2	90.6	94.5	94.8	94.5
	SMC-P1	97.6	97.8	100.0	97.1
	SMC-S1	100.0	100.0	100.0	97.9
	SMC-S2	100.0	100.0	100.0	97.9
	SMC-S3	97.6	97.9	97.9	97.8
	SMC-R1	100	100.0	100.0	100.0
	SMC-R3	97.9	97.9	100.0	100.0
	SMC-R4	97.6	100.0	97.8	97.8
	SME-P1	92.5	100.0	97.9	97.5
	SME-S1	100.0	100.0	100.0	100.0
	SME-R1a	97.8	100.0	100.0	100.0
	SME-R2	91.4	100.0	97.9	100.0

Irrigation District	Site	2011	2012	2013	2014
RCID	RC-P1	-	-	95.5	97.2
WID	W-P1	94.9	97.6	97.3	100.0
	W-P2	89.5	95.4	96.1	95.3
	W-S1	90.9	94.0	97.0	100.0
	W-S2	95.7	97.7	95.6	100.0
	W-S3	92	94.8	93.6	100.0
	W-S4	94.8	95.6	93.9	100.0
	W-R1a	97.5	97.4	94.7	100.0
	W-R2	93.5	92.4	95.5	95.9
BRID	BR-P1	100.0	100.0	100.0	100.0
	BR-S1	97.5	100.0	100.0	94.4
	BR-S2	92.9	97.5	97.5	100.0
	BR-S3	100.0	100.0	100.0	95.3
	BR-S4a	100.0	100.0	94.6	93.7
	BR-S5	100.0	100.0	100.0	97.7
	BR-R1	100.0	100.0	100.0	100.0
	BR-R2	96.7	100.0	93.3	93.5
	BR-R3	96.9	97.0	94.6	97.0
	BR-R4	97.9	95.7	95.4	97.5
	BR-R5	100.0	97.5	100.0	94.1
	BR-R7		97.4	94.9	100.0
EID	E-P1	100.0	100.0	100.0	100.0
	E-S1	95.2	96.4	100.0	100.0
	E-S2	100.0	100.0	100.0	100.0
	E-S3	94.4	96.9	95.4	96.7
	E-S4	48.4	100.0	89.0	100.0
	E-S5	100.0	100.0	100.0	100.0
	E-S6	97.6	100.0	100.0	100.0
	E-S7	95.5	97.1	79.2	96.1
	E-S8	69.2	70.4	63.5	68.6
	E-R1	-	57.1	90.0	97.4
	E-R1a	84.4	57.5	97.9	95.7
	E-R2	-	89.9	45.5	85.9
	E-R2a	58.1	84.9	97.8	51.2
	E-R3		78.3	91.6	89.8
	E-R3a	81.7	85.7	91.6	93.5
	E-R4a	-	77.0	79.7	87.8
	E-R5	-	100.0	92.2	91.4
	E-R5a	69.6	86.6	81.2	73.2
	E-R6	51.9	74.6	83.0	62.5
	E-R7	49.8	87.3	97.9	52.3
	E-R8a	89.3	70.2	75.7	71.1
AEP canals	AEP-P2	96.3	93.9	100.0	95.4
	AEP-P3	100.0	90.7	100.0	100
	AEP-S2	88.3	97.7	97.9	100
Average	All sites	91.2	94.3	92.6	91.9

Irrigation Water Quality Index

Excellent (85 to 100) Good (70 to 84.9) Fair (55 to 69.9) Marginal (40 to 54.9) Poor (0 to 39.9)

Objectives

The objectives of monitoring were to assess the:

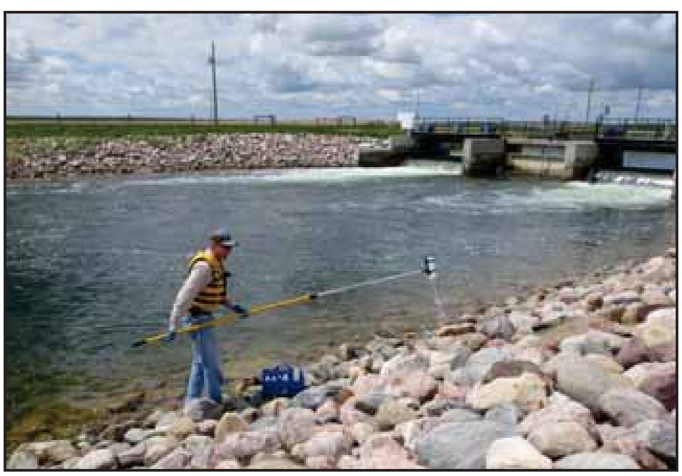
- quality of source water used for irrigation and livestock watering,
- quality of irrigation water for recreational use and for the protection of aquatic life,
- differences in water quality among the irrigation districts,
- changes in water quality in relation to landscape and canal characteristics, and
- cumulative impact of irrigation returns on rivers.

Methods

In 2014, water quality sampling methods remained essentially unchanged from 2013. A total of 90 sites were grab-sampled four times between June and September (June 10 to 12, July 7 to 10, August 6 to 8, and September 2 to 4). Each sample was analyzed for more than 160 water quality parameters including nutrients, salinity, physical parameters, metals, fecal indicator bacteria, and pesticides. In 2014, two new pesticides, clodinafop-propargyl and propiconazole, were added to the analytical suite. The herbicide glyphosate (Roundup®) and two other related compounds were analyzed for a reduced number of sites, and only during the first and last sampling events because of the expensive analytical cost.

In 2012, a qualitative analysis of fecal pathogen was initiated and added to the study. The analysis included *Salmonella*, *Campylobacter*, and *Escherichia coli* (*E. coli*) O157:H7. In 2014, a quantitative assessment of these pathogens was completed. A total of 21 sites were monitored twice, once in July and again in August.

In 2013, Agriculture and Agri-Food Canada (AAFC) approached Alberta Agriculture and Forestry to participate in an assessment for the presence of veterinary pharmaceuticals in southern Alberta surface water. Veterinary antimicrobials are used therapeutically to treat disease and sub-therapeutically to prevent disease and promote growth in livestock production. During the past decade, the use of veterinary antimicrobials has received increased attention because of growing bacterial resistance to antimicrobials used in human medicine and the effect that this may have on the treatment of infectious diseases. In 2014, the monitoring of veterinary pharmaceuticals continued and 24 secondary and irrigation return sites of eight

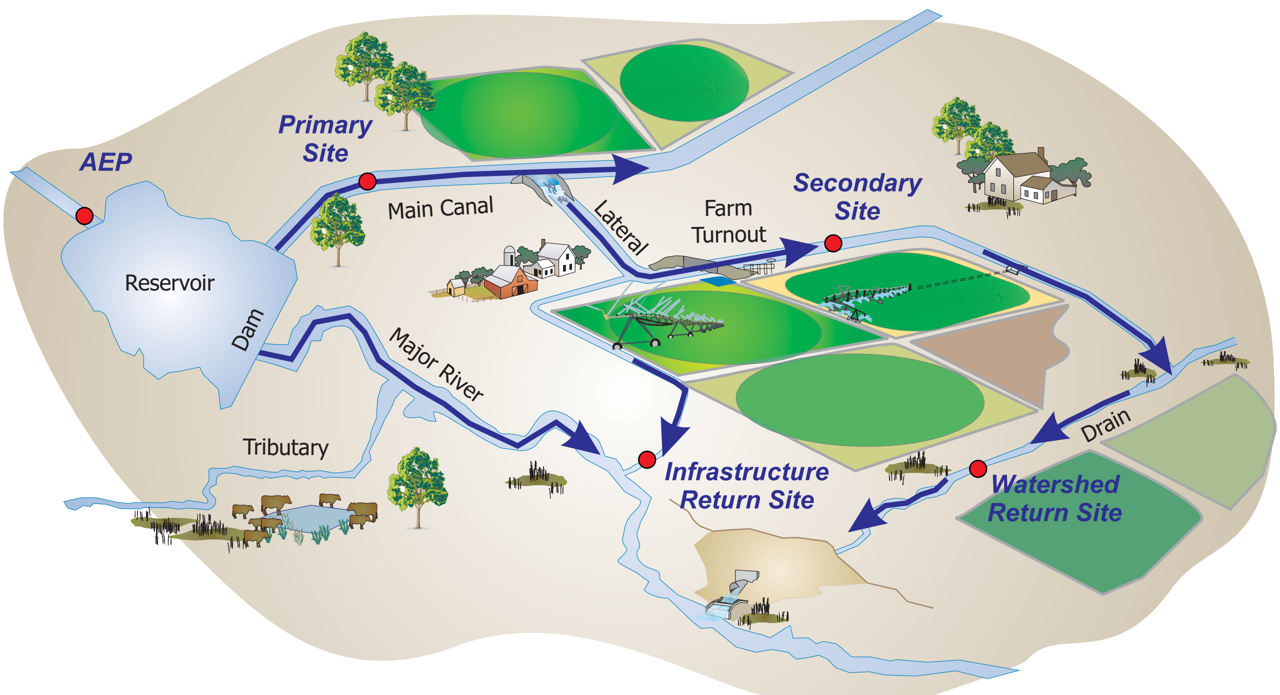


Rinsing a sampling bottle at BRID site BR-S3 on June 11, 2014.

irrigation districts (MVID, UID, LNID, TID, SMRID, WID, BRID, and EID) were sampled. Samples were collected for each of the four sampling events. Each sample was analyzed for seven livestock pharmaceuticals (chlortetracycline, erythromycin, lincomycin, monensin, sulfamethazine, tylosin, and tetracycline) by the National Hydrology Research Centre of Environment Canada in Saskatoon, Saskatchewan.

Sampling sites were categorized by type:

- **Alberta Environmental Protection - AEP** (n = 3): government owned infrastructure where water is diverted from a river.
- **Primary** (n = 14): main canals where source water enters the district.
- **Secondary** (n = 32): lateral canals that branch-off from a main canal or immediately downstream from a reservoir.
- **Return** (n = 41): at the end of the irrigation district infrastructure after which water is no longer used for irrigation. There are two types of returns:
  - – Watershed returns (n = 19): natural channels that collects natural drainage flow, and in some cases, municipal discharge.
  - – Infrastructure returns (n = 22): constructed canals that are generally less influenced by surface runoff than watershed returns.



A schematic showing a simplified irrigation distribution system and the different sampling site types. The red dots show typical sampling site locations.

Irrigation Water Quality Parameters

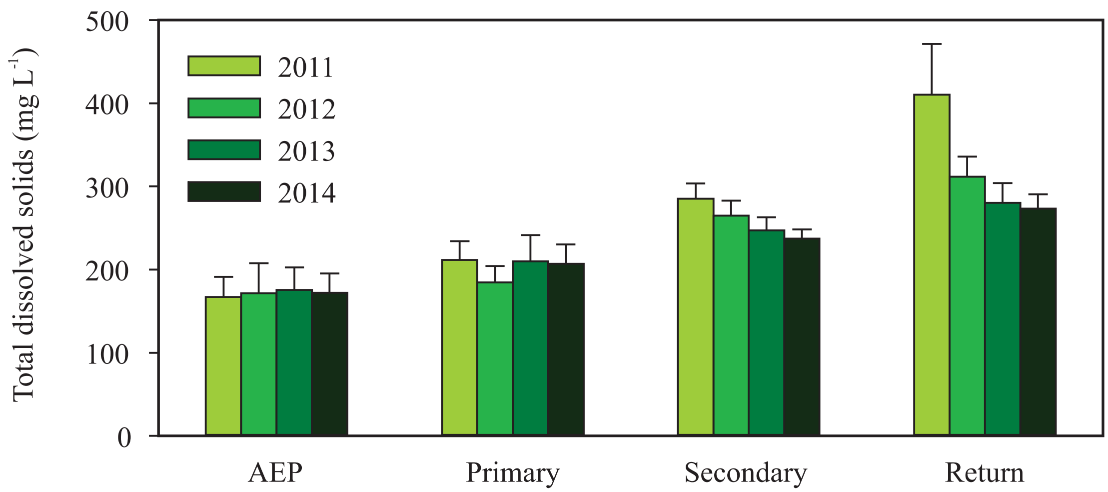
Nutrients

The average concentrations of total phosphorus (TP) and total dissolved phosphorus (TDP) among all sites (n=357) in 2014 were 0.062 and 0.039 mg L^{-1}, respectively. The average concentration of TP in 2014 was lower than in 2011 but higher than in 2012 and 2013. Total dissolved phosphorus concentrations represented more than half of TP at most sites except for the AEP sites where 37% of the TP was in dissolved forms. The proportion of samples that had TDP concentrations less than the method detection limit of 0.005 mg L^{-1} decreased from 22% in 2013 to 12% in 2014, supporting a general increase in TDP concentration since 2012. The average concentration of total nitrogen (TN) among all sites (n=357) was 0.50 mg L^{-1} in 2014, which was higher than in 2013 (0.49 mg L^{-1}) but less than in 2011 (0.59 mg L^{-1}) or 2012 (0.54 mg L^{-1}). There was an increase in average concentrations of N from primary to secondary to return sites in 2014, but the increases were generally less compared to previous years.

Salinity

In 2014, total dissolved solids (TDS) concentration ranged from 89 to 981 mg L^{-1} and averaged 247 mg L^{-1}. The average concentration of TDS in 2014 was less as than the three previous years. A decreasing trend with time was especially noticeable in secondary and return sites. Average TDS concentration increased from the AEP or primary sites to the return sites, but not as much as in previous years. There were lower TDS concentrations in the more westerly districts (MVID, AID, UID, MID, LNID) compared to the other districts.

The irrigation guideline for TDS ranges from 500 mg L^{-1} for strawberries, raspberries, beans, and carrots to 3,500 mg L^{-1} for other crops including oat, rye, wheat, sugar beet, and barley. The irrigation guideline of 500 mg L^{-1} was exceeded in 3.1% (11/357) of the samples in 2014, signifying minimal concern.



Average total dissolved solids concentrations for different site types from 2011 to 2014. Error bars indicate the 90% confidence intervals.

Average values of selected water quality parameters measured in 2014.

Site type	MVID	AID	UID	MID	RID	LNID	TID	SMRID	RCID	WID	BRID	EID
Total Phosphorus (mg L^{-1})												
AEP	-	-	-	0.016	-	-	-	-	-	0.023	0.013	-
Primary	0.017	-	0.004	0.016	0.020	0.028	0.043	0.045	0.355	0.013	0.009	0.019
Secondary	-	-	0.019	0.116	-	0.037	0.053	0.061	-	0.032	0.037	0.042
Return	0.020	0.023	0.083	0.104	0.186	0.095	0.062	0.099	-	0.077	0.068	0.074
Total Nitrogen (mg L^{-1})												
AEP	-	-	-	0.163	-	-	-	-	-	0.350	0.685	-
Primary	0.293	-	0.173	0.278	0.288	0.265	0.303	0.444	1.695	0.288	0.318	0.538
Secondary	-	-	0.288	0.315	-	0.360	0.637	0.610	-	0.338	0.679	0.466
Return	0.295	0.380	0.340	0.583	0.520	0.496	0.663	0.674	-	0.448	0.633	0.473
Total Suspended Solids (mg L^{-1})												
AEP				16.5						16.0	11.8	
Primary	3.4		10.1	4.5	7.5	19.8	4.3	8.9	7.3	6.1	2.3	12.5
Secondary			2.4	18.0		7.8	5.0	10.8		8.9	6.0	10.6
Return	6.3	4.1	75.5	60.0	28.0	52.6	6.6	14.8		6.9	6.1	20.4
Total Dissolved Solids (mg L^{-1})												
AEP	-	-	-	108	-	-	-	-	-	212	197	-
Primary	144	-	102	121	139	157	179	176	510	240	328	201
Secondary	-	-	123	184	-	197	232	189	-	256	357	230
Return	149	147	136	349	341	207	262	215	-	354	419	279
Fecal Coliforms (% guideline exceedance)*												
AEP	-	-	-	0	-	-	-	-	-	50	25	-
Primary	0	-	0	0	0	50	25	0	25	0	0	25
Secondary	-	-	0	25	-	15	9	0	-	19	0	0
Return	25	100	55	100	75	60	0	43	-	63	42	35
Number of Samples												
AEP	0	0	0	4	0	0	0	0	0	4	4	0
Primary	4	0	4	4	4	4	4	11	4	8	4	4
Secondary	0	0	4	4	0	20	11	20	0	16	20	32
Return	4	4	11	4	8	16	8	28	0	8	24	48

*Fecal coliforms are presented as the % of samples that exceed the water quality guidelines of 100 CFU 100 mL^{-1} for irrigation.

Excessive algal growth caused by nutrients in the water can interfere with water conveyance.

Metals

All 25 metals analyzed were detected in 2014. Beryllium, tin, and thallium were detected in only three to nine samples (0.9 to 2.6% detection frequency). The detection frequency of mercury, on the other hand, increased from 0.6% in 2013 to 14.6% in 2014. However, this increase in detection frequency does not reflect an increase in mercury concentration, but rather a decrease in the laboratory detection limit, which changed from 0.1 $\mu g\ L^{-1}$ in 2011, 2012, and 2013 to 0.005 $\mu g\ L^{-1}$ in 2014.

Irrigation and/or livestock watering guidelines exist for 19 of the 25 metals analyzed. The highest concentrations measured for most of the metals were well below irrigation guidelines in 2014. However, chromium, copper, and boron exceeded irrigation guidelines in one to seven of 351 samples (0.3 to 2% detection frequency). The metals that exceeded irrigation guidelines were most likely from geological sources as they were typically well correlated with total suspended solids (TSS). The livestock water guidelines were not exceeded in 2014.

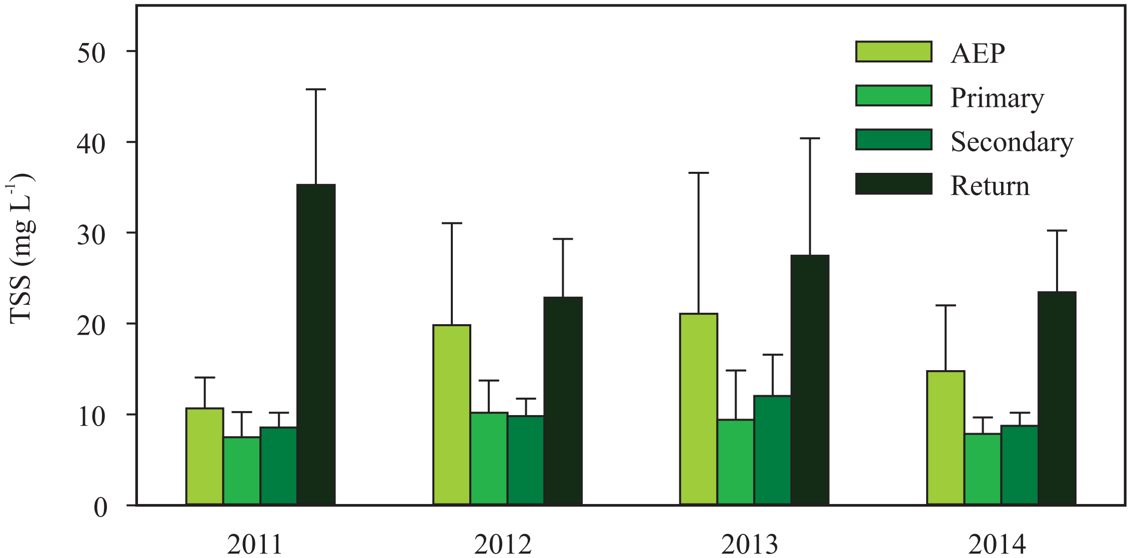
Protection of aquatic life guidelines exist for 16 of the analyzed metals, and nine of these were exceeded at least once in 2014. Frequency of guideline exceedance was the highest for aluminum (60%), iron (27%), and chromium (6%). The protection of aquatic life guidelines were less frequently exceeded in 2014 as compared to 2013.

Physical parameters and pH

The average sample temperature was 18.6°C in 2014 as compared to 19.4°C in 2013, 17.7°C in 2012, and 19.9°C in 2011. As in the previous years (2011–2013), on average, water temperature was cooler at the AEP and primary sites compared to the secondary and return sites. This trend probably reflects the size of the canals and the travel time required for the water to warm.

Fifteen degree celsius is a critical temperature for the development and control of zebra and quagga mussels that are potential invasive species that would be detrimental to the irrigation industry if they become established. Zebra and quagga mussels can spawn at 12°C and 9°C, respectively. During the first sampling event from June 10 to 12, 2014, 74% of the samples had water temperatures greater than 15°C. The proportion increased to 96 and 97% in early July and August, respectively, but decreased to 41% in early September.

Total suspended solids ranged from 1 to 423 $mg\ L^{-1}$ in 2014. The average concentration was 15.5 $mg\ L^{-1}$, which was lower than previous years. The highest average TSS values were at the return sites and there was a decrease in concentration from the AEP to the primary sites. The reduction in TSS concentration could be explained by the sedimentation in Chestermere, McGregor, Travers, and St. Mary reservoirs between the AEP and primary sites. Concentrations of TSS were highest in early July for the AEP, primary, and secondary sites, and this could be explained by the precipitation event at the end of June 2014.



Average concentration of total suspended solids (TSS) for the different sampling site types from 2011 to 2014. Error bars are 90% confidence intervals.

The pH of irrigation water was alkaline and ranged from 7.9 to 9.8 in 2014. As in 2011 to 2013, the 2014 average pH value increased from AEP to secondary sites and then slightly decreased at the return sites. The protection of aquatic life guideline for pH (6.5 to 9.0) was exceeded in 7.6% of the samples in 2014 as compared to 5.9% in 2013.

Biological parameters

In 2014, the median concentration of generic *E. coli* was 44 CFU 100 mL^{-1}. Similar to 2013, overall median *E. coli* concentrations increased from primary to return sites within each sampling period, and this was consistent within each irrigation district. The irrigation guideline for *E. coli* (100 CFU 100 mL^{-1}) was exceeded in 25% (90/356) of the water samples. Specifically, the guideline was exceeded in 25% (3/12) of AEP, 9% (5/55) of primary, 6% (8/127) of secondary, and 46% (74/162) of return site samples. It should be noted that although a large proportion of return sites exceeded the irrigation water quality guideline for *E. coli*, water in returns or at the end of the irrigation water conveyance networks is generally not applied to crops.

Campylobacter spp. was not detected at any of the sites in 2014, although in 2013, detection occurred in five water samples collected at three return sites and one secondary site. *Escherichia coli* O157:H7 was not detected in any of the water samples during 2014 or 2013. Similar to 2013, only one of the 40 samples was positive for *Salmonella enterica* subspecies *enterica* in 2014. Specifically, *Salmonella* serovar Typhimurium was detected from an irrigation return site at a concentration of 23 MPN 300 mL^{-1}. *Salmonella* serovar Typhimurium has been among the top three serovars most commonly reported as causing human salmonellosis in Canada during the past several years. This serovar may be isolated from a variety of animal sources (e.g., cattle, hogs, poultry, and wild birds); however, without advanced molecular subtyping, it was impossible to know the source of the serovar in this particular sample.

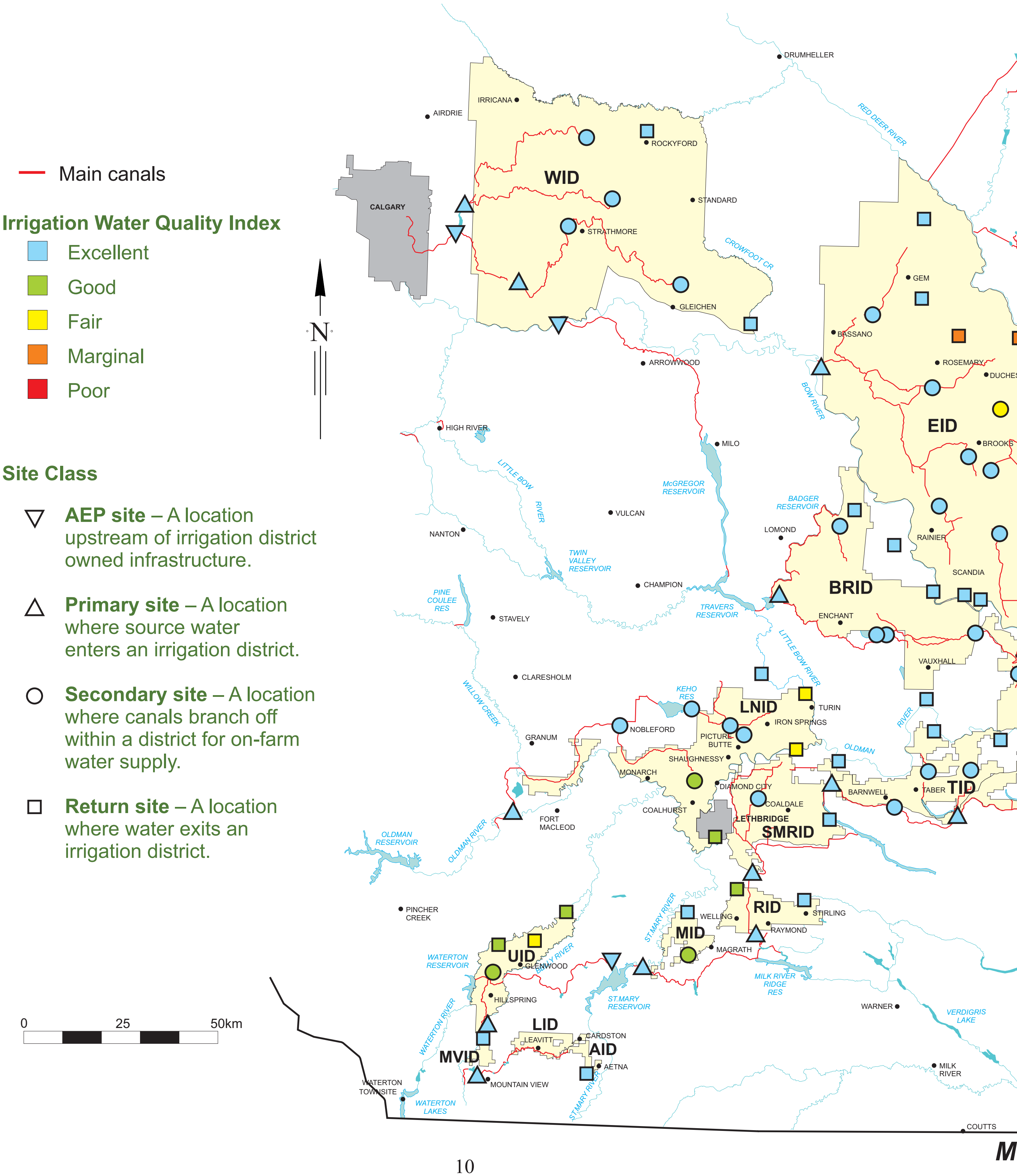
Risk interpretation of fecal pathogens is complicated, given there are no water quality guidelines. Fecal pathogens will likely be present in irrigation water. But, the risk of foodborne illness from Alberta's irrigation water is very low because more than 99% of the crops grown under irrigation are used to feed livestock or are processed prior to consumption, and processing generally destroys pathogens. Further, there are many steps from field-to-plate that will minimize exposure and health risks.

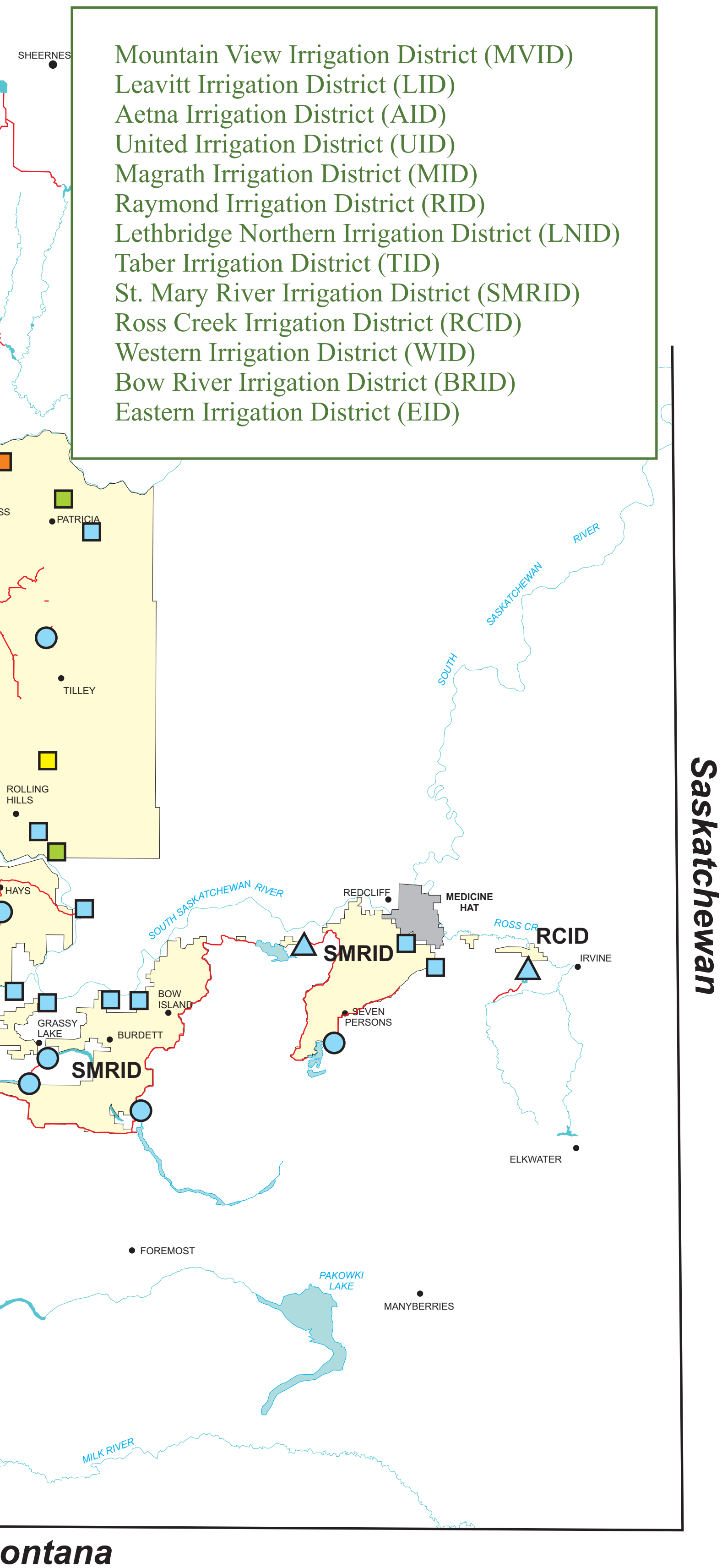
Escherichia coli are present in the intestines of animals and humans, and are used as general indicators of fecal contamination. A high concentration of *E. coli* in surface water (i.e., exceeding irrigation water quality guidelines) indicates that there is an increased likelihood that enteric pathogens (e.g., *Salmonella*, *E. coli* O157:H7, and/or *Campylobacter)* are present. An irrigation water quality guideline exists only for fecal coliform bacteria, but guideline exceedance does not confirm the presence of enteric pathogens. Exceedance of the *E. coli* guideline is of greatest concern for irrigated crops that are consumed raw such as some vegetables (especially leafy greens, which have a large surface area and are difficult to wash) and soft fruits. There is minimal health risk associated with pathogen contamination for processed crops such as potatoes, corn, and grains, as any pathogens that are present are likely destroyed during processing. Likewise, pathogen contamination of forage crops is of minimal concern with respect to human health since consumption of these crops is limited to livestock, and livestock are generally not affected by these pathogens.

A pathogen is a bacterium, virus, or other microorganism that can cause disease. *Campylobacter*, *Salmonella*, and *E. coli* O157:H7 are pathogenic bacteria often found in surface water.

There are a number of precautions that can be taken by growers, processors and consumers to minimize pathogen contamination risks of fresh produce.

IRRIGATION WATER QUALITY INDEX (2014)





Variables and objectives used in the Irrigation Water Quality Index.

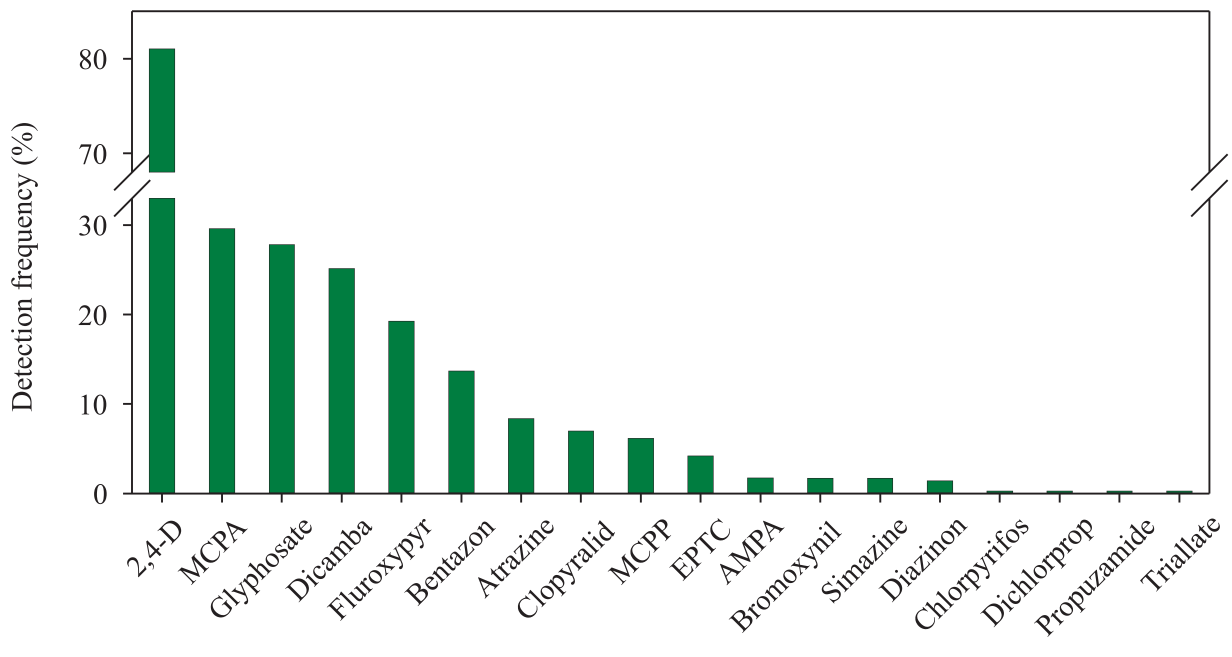
Variable	Objective[z]
Salinity	
Sodium adsorption ratio	5
Chloride	178 mg L^{-1}
Total dissolved solids	500 mg L^{-1}
Metals	
Aluminum	5.0 mg L^{-1}
Arsenic	0.16 mg L^{-1}
Beryllium	0.1 mg L^{-1}
Boron	0.5 mg L^{-1}
Cadmium	8.2 µg L^{-1}
Chromium	4.9 µg L^{-1}
Cobalt	0.05 mg L^{-1}
Copper	0.2 mg L^{-1}
Iron	5.0 mg L^{-1}
Lead	0.2 mg L^{-1}
Lithium	2.5 mg L^{-1}
Manganese	0.2 mg L^{-1}
Molybdenum	0.01 mg L^{-1}
Nickel	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}
Biological	
Escherichia coli	100 CFU 100 mL^{-1}
Pesticides	
Atrazine	10 µg L^{-1}
Bromacil	0.2 µg L^{-1}
Bromoxynil	0.44 µg L^{-1}
Dicamba	0.008 µg L^{-1}
Diclofop-methyl	0.24 µg L^{-1}
MCPA	0.04 µg L^{-1}
Metolachlor	28 µg L^{-1}
Simazine	0.5 µg L^{-1}

[z] Objectives are based on the Environmental Quality Guidelines for Alberta Surface Waters.

Pesticides

Of the 109 pesticides analyzed in 2014, 18 were detected. At least one pesticide compound was detected in 310 of the 358 samples (86.6%) analyzed. The pesticides that were detected included 15 herbicides, two insecticides (diazinon and chlorpyrifos), and one fungicide (propiconazole). No other type of pesticide analyzed (acaricide, nematicide, bactericide, or growth regulator) was detected. The pesticides most frequently detected were 2,4-D (81%), MCPA (30%), glyphosate (28%), dicamba (25%), fluroxypyr (19%), and bentazon (14%). All other pesticides and the metabolite AMPA were detected in 8% or less of all samples. The type of pesticides detected, their detection frequency, and concentrations were generally consistent with previous studies in Alberta.

For pesticides detected every year (2011 to 2014), such as 2,4-D, dicamba, and MCPA, detection frequencies were similar from 2012 to 2014; whereas, detection frequencies were slightly higher in 2011. A number of other pesticides (fluroxypyr, bentazon, atrazine, clopyralid, EPTC, and bromoxynil) had higher detection frequencies in 2014 compared to 2013. For all pesticides detected in 2014, the average detected concentrations were lower in 2014 compared to previous years, but maximum detected concentrations were higher.



Pesticide detection frequencies in 2014.

Pesticide guidelines for livestock watering were not surpassed in 2014. One sample exceeded the protection of aquatic life guideline for MCPA. The irrigation water quality guidelines were surpassed in 25% of the samples for dicamba and 16% of the samples for MCPA. Nine of the 18 pesticides detected in 2014 do not have water quality guidelines (AMPA, bentazon, chlorpyrifos, clopyralid, diazinon, dichlorprop, EPTC, fluroxypyr, and propiconazole). A general increase in pesticide detections and concentrations was observed as the water moved through the irrigation infrastructure. These results were generally consistent with previous Alberta studies.

Veterinary pharmaceuticals

The detection frequency of the seven veterinary pharmaceuticals analyzed ranged from 1 % (sulfamethazine) to 100 % (chlortetracycline and tetracycline). In order of average detected concentrations, veterinary pharmaceuticals ranked as tetracycline (72.0 ng L^{-1}) > chlortetracycline > tylosin > monensin > erythromycin > lincomycin > sulfamethazine (1.5 ng L^{-1}).

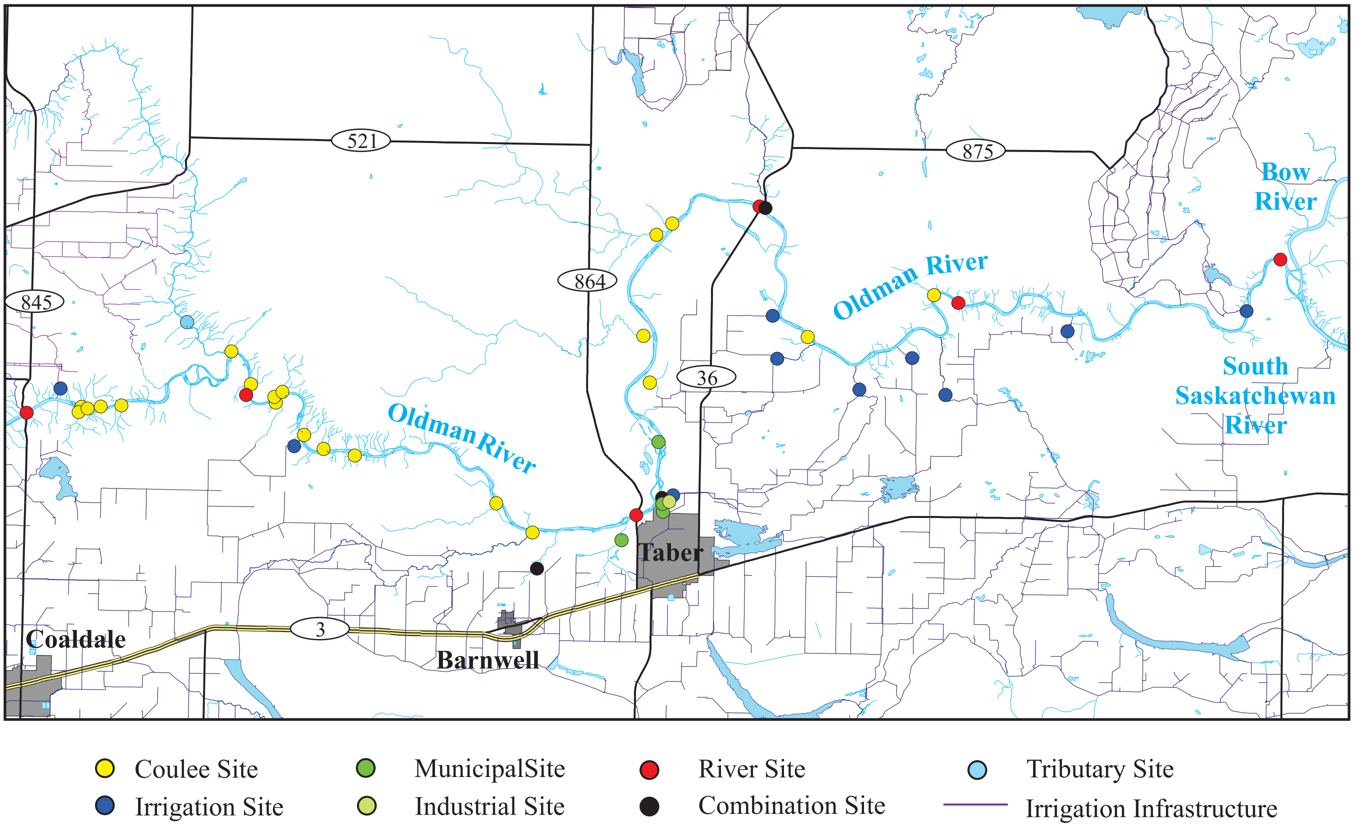
1 ng L^{-1} is equivalent to 1 part per trillion.

Contribution of Irrigation Returns to Rivers

Irrigation districts currently return approximately 20% of diverted water back to the rivers. The quality of return water is usually not as good as source water and this leads to questions regarding the potential effects of irrigation returns on rivers in southern Alberta.

Two synoptic surveys were carried out on a 122-km stretch of the Oldman River in 2014: one during active runoff (June 18) and one during a dry period (August 14). The surveys captured periods when irrigation returns were likely to have the greatest effects on the river. A total of 46 synoptic survey sampling sites were selected. At six sites, the Oldman River was sampled to provide a more detailed description of water quality changes in the river. The 40 potential contributing sources to the river included 21 natural coulees; 12 irrigation returns in the LNID, SMRID, and BRID; four municipal discharges; one industrial discharge; one tributary (Little Bow River); and one site that contained a combination of irrigation, municipal and industrial inputs. Each sample was analyzed for nutrients, salinity, coliform bacteria, pesticides, and physical parameters. Six water quality parameters (TN, TP, TDP, TSS, TDS and 2,4-D) were used for the synoptic survey assessments.

In a synoptic survey, water samples are collected from a single "parcel" of water as it moves down the river. All contributions to the river are also sampled synchronously with the parcel of water. This method can be used to assess the effects of contributions on water quality and how water quality changes within a reach of a river.



Synoptic survey sites on the Oldman River.

Flow from irrigation returns was the dominant contribution during both surveys, especially during the dry-season survey when flow from other contributing sources was reduced. During the runoff synoptic survey, irrigation returns contributed 43% of the total flow inputs to the Oldman River within the study reach. The Little Bow River and coulee runoff were the next largest inputs at 37% and 17%, respectively. During the dry-season synoptic survey, irrigation returns contributed 64% and the Little Bow River contributed about 35% of total flow contributions to the river. Coulee, municipal and industrial had a combined flow contribution of less than 1%. The proportion of irrigation return flow into the river in relation to the river flow was 1% during the runoff synoptic survey and 11% during the dry-season survey. The difference was mainly the result of the lower river flow during the dry-season survey.

As expected, the concentrations of most parameters in the Oldman River were greater during the runoff survey than during the dry-season survey. Generally, parameter concentrations varied little among the six river sites during both surveys with either a slight decrease from upstream to downstream or no consistent trends, despite higher concentrations of most parameters from the contributing sources.

River ratio calculations showed that all contributing sources varied from 1 (TSS) to 74% (2,4-D) of the total load of the river during the runoff synoptic survey. Irrigation, followed by coulee and tributary contributed to the greatest loads for most parameters. The coulees contributed greatest loads for TP and TSS. The pesticide 2,4-D was not detected in the tributary during the runoff survey.

The river ratio is a way to compare the load of a particular contributing source with the load in the river. It is calculated using the following equation:

$$\text{River ratio (\%)} = \frac{\Sigma \text{ contribution source loads}}{\text{downstream river load}} \times 100$$

Loads from all contributions varied from 23 (TDS) to 112% (TP) relative to the river loads during the dry-season synoptic survey. Irrigation contributed the largest load for most parameters followed by the tributary. The only exception was for TSS, in which the Little Bow River tributary contributed the largest load to the river.

River ratios for runoff and dry-season synoptic surveys.

Site type	Flow	TN	TDP	TP	TSS	TDS	2,4-D
	(%)						
Runoff synoptic survey							
All contributions	2.70	3.27	21.9	1.59	1.12	6.43	73.6
Coulee	0.47	1.21	7.74	0.62	0.66	1.62	21.2
Tributary	0.99	0.77	3.47	0.40	0.38	2.05	0.00
Irrigation	1.17	1.21	10.2	0.55	0.05	2.47	45.5
Municipal	0.07	0.07	0.40	0.03	0.025	0.29	6.83
Industrial	0.002	0.006	0.09	0.001	0.00003	0.004	0.14
Dry-season synoptic survey							
All contributions	16.7	52.9	78.5	112.0	111.4	22.3	na[z]
Coulee	0.01	0.03	0.10	0.11	0.09	0.02	na
Tributary	5.90	8.98	14.8	34.5	80.2	7.43	na
Irrigation	10.7	43.3	63.0	76.7	30.9	14.5	na
Municipal	0.11	0.53	0.60	0.65	0.19	0.33	na
Industrial	0.00004	0.006	0.0002	0.0001	0.000004	0.0004	na

[z] na = not applicable, because there was no detection of 2,4-D at downstream river site.

As river water moved from upstream to downstream, it was hypothesized that loading would be cumulative and changes in concentrations and loads would be proportional to the contribution source inputs. However, this was not observed. For example, despite a cumulative TSS contribution from all inputs corresponding to 112% of the downstream river load during the dry-season synoptic survey, the TSS load was reduced by 0.9% from the upstream to the downstream river sites.

During both synoptic surveys, the Oldman River loads were not influenced by any contributing sources, including irrigation returns. During the runoff synoptic survey, the river flow was several orders of magnitude larger than all contribution source volumes so the effect of these inputs was negligible. During the dry-season synoptic survey, the dynamic physical, chemical, and biological processes of the river had more effect on water quality than the contributing sources. While the cumulative effects of contributions to the river were non-measurable, the buffering capacity of natural river processes remains unknown.

Water sampling the Oldman River during the runoff synoptic survey on June 18, 2014.

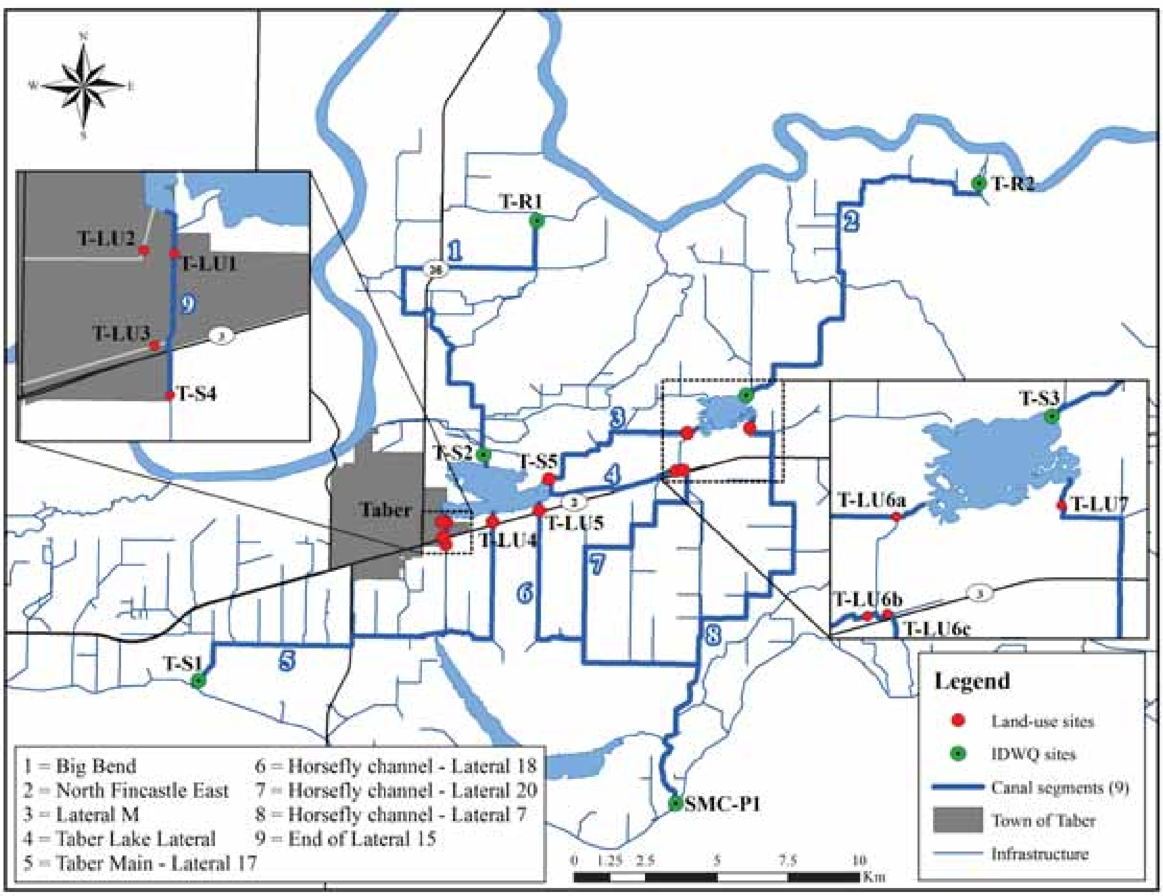
Flow metering of contribution source site 45.4b during the runoff synoptic survey.

Factors Affecting Irrigation Water Quality

Our monitoring study has shown that water quality typically degrades as water flows through the irrigation distribution system. One of the study objectives was to assess relationships between landscape/canal characteristics and irrigation water quality. A literature review revealed that, to date, little work has been done to evaluate relationships between land-use and irrigation water quality. As such, a case study was designed to examine irrigation water quality and the influence of:

- irrigation reservoirs,
- municipal stormwater, and
- canal and landscape characteristics in selected irrigation canal segments.

A total of 17 water quality sampling sites were located throughout the Taber Irrigation District (TID) in an upstream to downstream monitoring design. Six sites were part of the existing study, nine of the new sites were added to assess water quality changes along nine canal segments, and two sites were added to sample municipal stormwater contributions. The sampling sites at each reservoir inlet and outlet were used to assess the influence of the reservoirs on water quality. Sites were monitored for nutrients, pesticides, salinity, and physical parameters during 16 sampling events from March to November 2014.



Land-use water quality sampling sites and studied canal segments in 2014.

Landscape parameters were developed using a Geographic Information System (GIS). Data entered into the GIS included details from a landscape survey that included the locations and flow potential characteristics of all potential flow contributions from drain inlets, as well as the agricultural characteristics along the canals. Topographic landscape characteristics were derived from a digital elevation model created from a Light Detection and Ranging (LiDAR) dataset, while irrigation conveyance characteristics were derived from an irrigation canal geodatabase. Canal and landscape parameters included canal length, type and flow capacity, number and size of drainage inlets, surrounding slopes, crop types, presence of irrigation pivots, and road density within the immediate area.

A drain inlet is any structure designed to allow flow from the landscape to an irrigation canal

Results showed the reservoirs had a positive effect on water quality. Most water quality parameters decreased in concentration from upstream to downstream of Taber Lake and Fincastle reservoirs. The reduction can be attributed to sedimentation, dilution, and chemical and biological processes that occur in the reservoirs. The reduction was especially noticeable during periods when poorer water quality flowed into the reservoirs including during the irrigation district spring flushing event and during runoff events. During the irrigation season when the quality of water was better, a slight increase in salinity, nutrient and pesticide concentrations was measured downstream of the reservoirs. This suggests that the reservoirs have a limited buffering capacity and can also release some of the accumulated contaminants.

For most water quality parameters, the concentrations at the two stormwater sampling sites (T-LU2 and T-LU3) were generally greater than the concentrations in the irrigation canals. Furthermore, the number of different pesticides detected at the stormwater sites relative to the irrigation canals was much higher. Despite the elevated concentrations, relatively small and intermittent flows of stormwater limited the seasonal loading to Taber Lake Reservoir. However, the high concentrations and diversity of pesticides as well as high concentrations of nutrients and salts in the stormwater are undesirable.

Reservoirs are generally beneficial for irrigation water quality because sediments and associated nutrients tend to settle out, resulting in the improvement of the quality of water exiting reservoirs.

An increase in concentration for water quality parameters was generally observed in water as it moved from upstream to downstream sites for each canal segment. The changes in water quality concentrations varied widely among the parameters, sampling events, and canal segments. The largest changes in water quality in the canal segments were observed during the initial flush of irrigation water through the canals, followed by pre-irrigation and runoff events. During the irrigation season, the water quality was generally the best and more consistent in time and space. The changes in concentration were only statistically significant for a few parameters and canal segments.

Correlation analysis was completed to study the relationship between the change in water quality in the canal segments and landscape/canal characteristics. The strongest correlations observed were between water quality and canal characteristics, suggesting that the canal characteristic parameters may have had more of an effect on water quality than the surrounding landscape over the entire season. More degradation of water quality were observed in earth canals as compared to lined canals. A second year of data will be collected in 2015, and these data will help to establish the relationship between the change in irrigation water quality and landscape/canal characteristics.

Drain inlet site T-LU3 draining municipal stormwater into an irrigation canal of TID.

Water mixing downstream of site T-LU6a on September 4, 2014 after a rainfall runoff event.

Future Work

Water sampling will continue at the same sites and follow the same methods for the final year of the project in 2015. The collaboration with Alberta Health Services and the Public Health Agency of Canada will continue for the pathogen sampling as well as the collaboration with AAFC for the pesticide and the veterinary pharmaceutical analyses.

Dry-season synoptic surveys are planned on the lower reach of the Bow and Oldman rivers in 2015.

The evaluation of the relationship between landscape/canal characteristics and irrigation water quality will be continued in TID in 2015 following essentially the same methods used in 2014. One new sampling site may be added and additional data loggers will be installed to more accurately measure flow at all of the sites.

A final report will be produced and will include a trend analysis to statically assess the changes in irrigation water quality from 2006 to 2015.

Irrigation at a sod farm in LNID on July 9, 2014.

Irrigation is important for the economic development of rural communities in southern Alberta, such as the town of Vauxhall which is supplied by the BRID.

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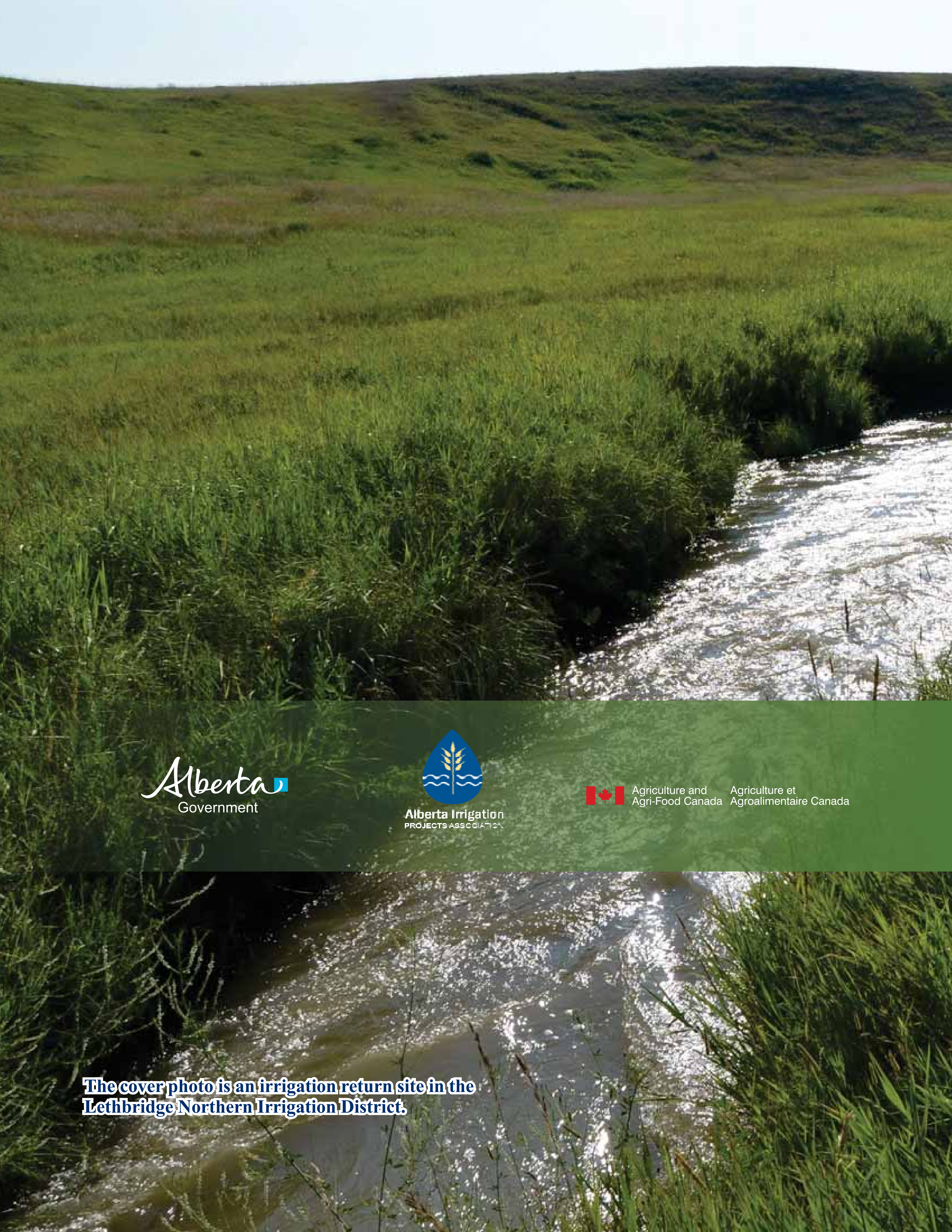
And finally, we are grateful to the landowners who gave permission to enter on their land so we could access some of the sampling sites.



The cover photo is an irrigation return site in the Lethbridge Northern Irrigation District.

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