Irrigation District Water Quality Project

Water quality indices of irrigation water of southern Alberta

VOLUME 7

Alberta

Irrigation District Water Quality Report Series

Volume 1: Salinity, major ions and physical characteristics in irrigation water of southern Alberta

Volume 2: Nutrients in irrigation water of southern Alberta

Volume 3: Metals in irrigation water of southern Alberta

Volume 4: Long-term patterns of pesticides in irrigation water of southern Alberta

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Volume 7: Water quality indices of irrigation water of southern Alberta

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Volume 10: Effects of land use on irrigation water quality of southern Alberta

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Executive Summary

More than 65% of Canada's irrigation occurs in southern Alberta's 13 irrigation districts. The associated irrigation conveyance network supplies water for crops and livestock production, as well as for rural communities and many rural homes. Irrigation water provides wildlife habitat and recreational activities such as fishing, boating, and camping on irrigation reservoirs. Good quality irrigation water is important for all these uses. The quality of irrigation water in Alberta has been previously monitored by several researchers, but differences in study design and objectives made the data difficult to compare. A 10-year study (2006 to 2007 and 2011 to 2018) was conducted by Alberta Agriculture and Forestry, Agriculture and Agri-Food Canada, and Alberta Irrigation Projects Association (now Alberta Irrigation Districts Association) to assess the quality of irrigation water within Alberta's irrigation districts using a long-term, consistent approach. This report is one of a series of reports based on data collected from the 10-year Irrigation District Water Quality project. The focus of this report is the use of water quality indices to interpret the overall/aggregate quality of irrigation water of southern Alberta.

The St. Mary River Irrigation District Main Canal serves as the source water for several irrigation districts in southern Alberta.

A water quality index allows data for multiple parameters to be mathematically combined into a single, easily understood value relative to the suitability of water for a particular use. This suitability is based on adherence to guidelines that are defined for particular water uses, such as irrigation, livestock watering or the protection of aquatic life.

During the Irrigation District Water Quality project, irrigation water was collected from over 100 locations in 12 irrigation districts and from diversion canals operated by Alberta Environment and Parks (AEP). These locations were sampled four times a year and this data was used to generate annual water quality index values for each location. The Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) was used in this project. The CCME WQI incorporates three components into the index value: i) scope — the percentage of parameters that exceed guidelines at least once, ii) frequency— the percentage of all parameter exceedances, and iii) amplitude — the degree to which the guidelines are exceeded. Three WQIs were calculated as an evaluation of the suitability of southern Alberta’s irrigation water for different uses. These uses were irrigation of agricultural crops, agricultural livestock watering and the protection of aquatic life. Alberta Environment and Parks’ Environmental Quality Guidelines for Alberta Surface Waters (2018) were used in the calculation of these indices using the CCME WQI Calculator downloaded from the CCME webpage. These indices were further divided into seven sub-indices, based on groupings of similar parameters, each with 6 to 22 parameters per sub-index. This was to ensure proper parameter weighting within the index. The two sub-indices created for the Agricultural Irrigation Water Quality Index and the Agricultural Livestock Water Quality Index were the general/pesticide sub-index, which included general water quality and pesticide parameters; and the metals sub-index, which included total metals parameters. Three sub-indices were created for the Protection of Aquatic Life Water Quality Index, including general, pesticide and metals sub-indices. Index values range from 0 to 100, and can be grouped according to CCME categories of Poor (0-44), Marginal (45-64), Fair (65-79), Good (80-94), and Excellent (95-100) water quality.

Canola crop being irrigated by a center pivot irrigation system.

The Agricultural Irrigation Water Quality Index used guidelines that are intended to provide a conservative level of protection to all life stages of crop species grown in Canada. The irrigation water quality general/pesticide sub-index demonstrated that water quality was variable, both chronologically and geographically, but when all sites and years were taken into consideration, 78% of sites were considered Excellent or Good quality (i.e., water quality is protected with a virtual absence or minor threat of impairment). Sixteen percent of sites were considered Fair (water quality is usually protected but occasionally threatened or impaired), and the remaining sites were considered Marginal (water quality is frequently threatened or impaired, 4.3%) or Poor (almost always threatened or impaired, 1.5%). Parameters most frequently responsible for general/pesticide guideline exceedances were *Escherichia coli* and the pesticides dicamba and 2-methyl-4-chloropheoxyacetic acid (MCPA).

Importantly, when the irrigation water quality general/pesticide sub-index data was evaluated by the type of site the water was collected from, 95% of irrigation district source water (primary sites) were considered Excellent or Good quality, with 86% of mid-district conveyance water (secondary sites) also considered Excellent or Good. Unused irrigation water returning to the rivers (return sites) showed more degradation in water quality with 65 % of sites considered Excellent or Good quality. This was expected as water quality generally degrades as water flows downstream, or in this case through the irrigation conveyance network, due to inputs of point or non-point source contributions. Return water is typically not used for irrigation of crops so its impairment is unlikely to affect crop health.

The irrigation water quality metals sub-index showed Excellent quality water for almost all sites in all years. One percent of primary sites, zero percent of secondary sites and five percent of return sites were considered Good quality. Similarly, both the livestock water quality general/pesticide and metals sub-indices showed nearly exclusively Excellent quality water for all sites and years for use in watering of livestock. There was only one guideline exceedance of one sample over the 10-years. This indicates that irrigation water is suitable for consumption by livestock species.

Northern leopard frog, a species at risk (threatened) in Alberta, in an irrigation canal.

Protection of Aquatic Life (PAL) guidelines are intended to indicate when levels of a substance or conditions may have adverse effects on growth, reproduction, or survival of aquatic biota. The PAL water quality general sub-index values were considered Excellent or Good at 94% of sites. Parameters most likely to negatively affect the PAL water quality general sub-index values were pH and un-ionized ammonia-N, with sulphate and nitrite-nitrogen also found to occasionally exceed PAL general parameter guidelines. The PAL water quality pesticide and metals sub-indices values were Excellent or Good quality at virtually all sites during the course of the IDWQ project (100% for pesticides and 99.5% for metals). This indicates that the risk of negative effects on aquatic biota from irrigation water is negligible.

Overall, irrigation water of southern Alberta can be classified as Excellent or Good for the irrigation of crops, livestock watering, and the protection of aquatic life as defined by CCME Water Quality Index categories.

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1 Introduction

1.1 Project Background

More than 65% of Canada's irrigation occurs in Alberta's 13 irrigation districts. These districts encompass approximately 8,000 km of district- and government-owned irrigation infrastructure and more than 55 reservoirs that together serve 555,705 ha of irrigated agricultural land (AAF 2019). Irrigation is essential for high agricultural production and crop diversity in southern Alberta. The irrigation conveyance network supplies water to many rural homes and more than 30 communities for household potable water, municipal purposes, parks, and industrial use including food processing plants and factories. The conveyance network also supplies water for other important uses such as livestock production, wildlife habitat, and recreational activities such as fishing, boating, and camping on irrigation reservoirs. Good quality irrigation water is needed for all these uses. High yielding and safe food production requires low concentrations of salts, pesticides 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.

Seven Persons creek conveys unused irrigation water to the South Saskatchewan River in the St. Mary River Irrigation District.

The quality of irrigation water in Alberta has been previously monitored by researchers including Bolseng (1991), Cross (1997), Greenlee et al. (2000), Saffran (2005), Little et al. (2010), and Palliser Environmental Services Ltd. (2011). The extent of monitoring varied greatly among these studies, ranging from a one-time sampling of return sites in select irrigation districts (Bolseng 1991) to a comprehensive study throughout the irrigation districts (Little et al. 2010). Palliser Environmental Services Ltd. (2011) focused on only one irrigation district, whereas irrigation water quality reported by Saffran (2005) was part of a larger study on surface water quality within the Oldman River watershed. Cross (1997) carried out a review of irrigation district water quality based on several data sources from 1977 to 1996. Study designs, parameters, and methodology used among these studies varied, making the data difficult to compare.

> **Irrigation District Water Quality Project Objectives:**
> - Assess quality of irrigation water used for irrigation and livestock watering
> - Assess quality of irrigation water for protection of aquatic life
> - Assess changes in water quality as water travels through the irrigation infrastructure
> - Assess water quality among irrigation districts
> - Assess cumulative effect of irrigation returns on rivers
> - Assess effect of land-use on irrigation water quality

A 10-year study (2006 to 2007 and 2011 to 2018) was conducted by Alberta Agriculture and Forestry, Agriculture and Agri-Food Canada, and Alberta Irrigation Projects Association (now Alberta Irrigation Districts Association) to assess the quality of irrigation water within Alberta's irrigation districts using a long-term, consistent approach. Although minor adjustments and additions were made during the study to accommodate secondary objectives and auxiliary projects, core sites and parameters remained unchanged. This study was supported by the Canada-Alberta Water Supply Expansion Program, Irrigation Rehabilitation Program (special funding) and by Alberta's irrigation districts. This report is one of a series of reports based on the data collected from the10-year Irrigation District Water Quality (IDWQ) project. The focus of this report is to examine the overall quality of irrigation water in southern Alberta as determined through the calculation and assessment of water quality indices that are constructed by the cumulative relationship of water quality parameters to their respective guideline values.

1.2 Water Quality Indices

Frequently, water managers are requested to provide statements on the general health of a water body, or water quality trends with time. Traditionally, water quality data are compared to appropriate guidelines on a parameter-by-parameter basis. However, when large numbers of parameters are monitored, this process becomes complex and cumbersome and requires detailed expertise for interpretation.

A water quality index allows data for multiple parameters to be mathematically combined into a single, easily understood value that indicates the overall suitability of water for a particular use. For example, if water meets the surface water quality guidelines for irrigation of agricultural crops, this means it is suitable for irrigation without causing damage to crops. The index values can then be grouped into categories that qualitatively indicate the general quality of the water for the intended use (i.e., Poor, Marginal, Fair, Good and Excellent). Indices and sub-indices are based on subsets of parameters (e.g., total metals) that can be calculated for the intended use of the water (e.g., irrigation).

2 Methods

2.1 Site Selection

Water sampling sites were defined as primary, secondary, and return site types. Primary sites were where source water entered an irrigation district, such as from a reservoir, a river diversion, or a main canal (Figure 2.1). Secondary sites were on lateral canals that branch off a main canal, or were immediately downstream of a mid-district reservoir. Return sites were located at the ends of the irrigation district conveyance network where unused irrigation water is returned to the rivers. Return sites are divided into watershed returns, where water returns to rivers via coulees or natural drains, and infrastructure returns, where water returns through constructed irrigation canals (Table 2.1). Additionally, three sites owned and operated by Alberta Environment and Parks (AEP) were included in this study. These sites represent water diverted from rivers as it is conveyed towards irrigation districts: one on a canal that diverts water off the Bow River in the southeast part of the City of Calgary (AEP-P2); one on a canal that diverts water off the Bow River at Carseland, (AEP-P3); and one on a canal that diverts water from the Belly River to St. Mary Reservoir (AEP-S2).

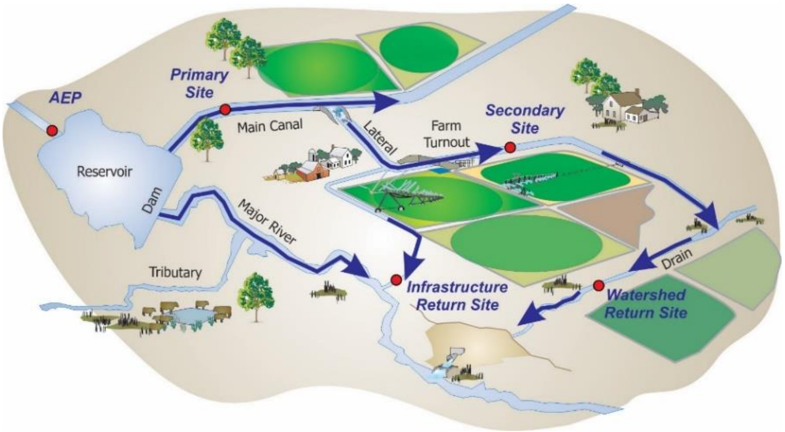

Figure 2.1 Schematic diagram of southern Alberta's irrigation conveyance network with Irrigation District Water Quality project site types.

Irrigation water was sampled at 105 sites in 12 districts from 2006 to 2018 (Figure 2.2) with the number of sites varying per year during the course of monitoring. The irrigation districts sampled were Mountain View (MVID), Aetna (AID), United (UID), Magrath (MID), Raymond (RID), Lethbridge Northern (LNID), Taber (TID), St. Mary River (SMRID), Ross Creek (RCID), Western (WID), Bow River (BRID), and Eastern (EID). There were no sampling sites in the Leavitt Irrigation District (LID) as it is a small district and water quality upstream and downstream of the LID was captured by other sites.

Table 2.1 Sites from which data were used in water quality index calculation.

District	Type	Site
MVID	Primary	MV-P1
	Return	MV-R1[z]
AID	Return	A-R1[y]
UID	Primary	U-P1
	Secondary	U-S1
	Return	U-R2[z]
MID	Primary	M-P1
	Secondary	M-S1
	Return	M-R1[y]
RID	Primary	R-P1
	Return	R-R1[y]
		R-R2[y]
LNID	Primary	LN-P1
	Secondary	LN-S1
		LN-S2
		LN-S3
		LN-S4
		LN-S5
	Return	LN-R1[y]
		LN-R2[y]
		LN-R3[z]
		LN-R4[z]
TID	Primary	T-P1a
	Secondary	T-S1
		T-S2
		T-S3
	Return	T-R1[z]
		T-R2[z]
SMRID	Primary	SMW-P1
	Secondary	SMW-S2
	Return	SMW-R1[y]
		SMW-R2[z]
	Primary	SMC-P1
	Secondary	SMC-S1
		SMC-S2
		SMC-S3
	Return	SMC-R1[z]
		SMC-R3[z]
		SMC-R4[z]
	Primary	SME-P1
	Secondary	SME-S1
	Return	SME-R1a[z]
		SME-R2[y]
WID	Primary	W-P1
		W-P2
	Secondary	W-S1
		W-S2
		W-S3
		W-S4
	Return	W-R1a[z]
		W-R2[y]
BRID	Primary	BR-P1
	Secondary	BR-S1
		BR-S2
		BR-S3
		BR-S4a
		BR-S5
	Return	BR-R1[z]
		BR-R2[y]
		BR-R3[y]
		BR-R4[y]
		BR-R5[z]
EID	Primary	E-P1
	Secondary	E-S1
		E-S2
		E-S3
		E-S4
		E-S5
		E-S6
		E-S8
	Return	E-R1[z]
		E-R2[z]
		E-R2a[y]
		E-R3[z]
		E-R4a[z]
		E-R5[z]
		E-R8a[y]
AEP canal		AEP-P2
		AEP-P3
		AEP-S2

[z] Infrastructure return
[y] Watershed return

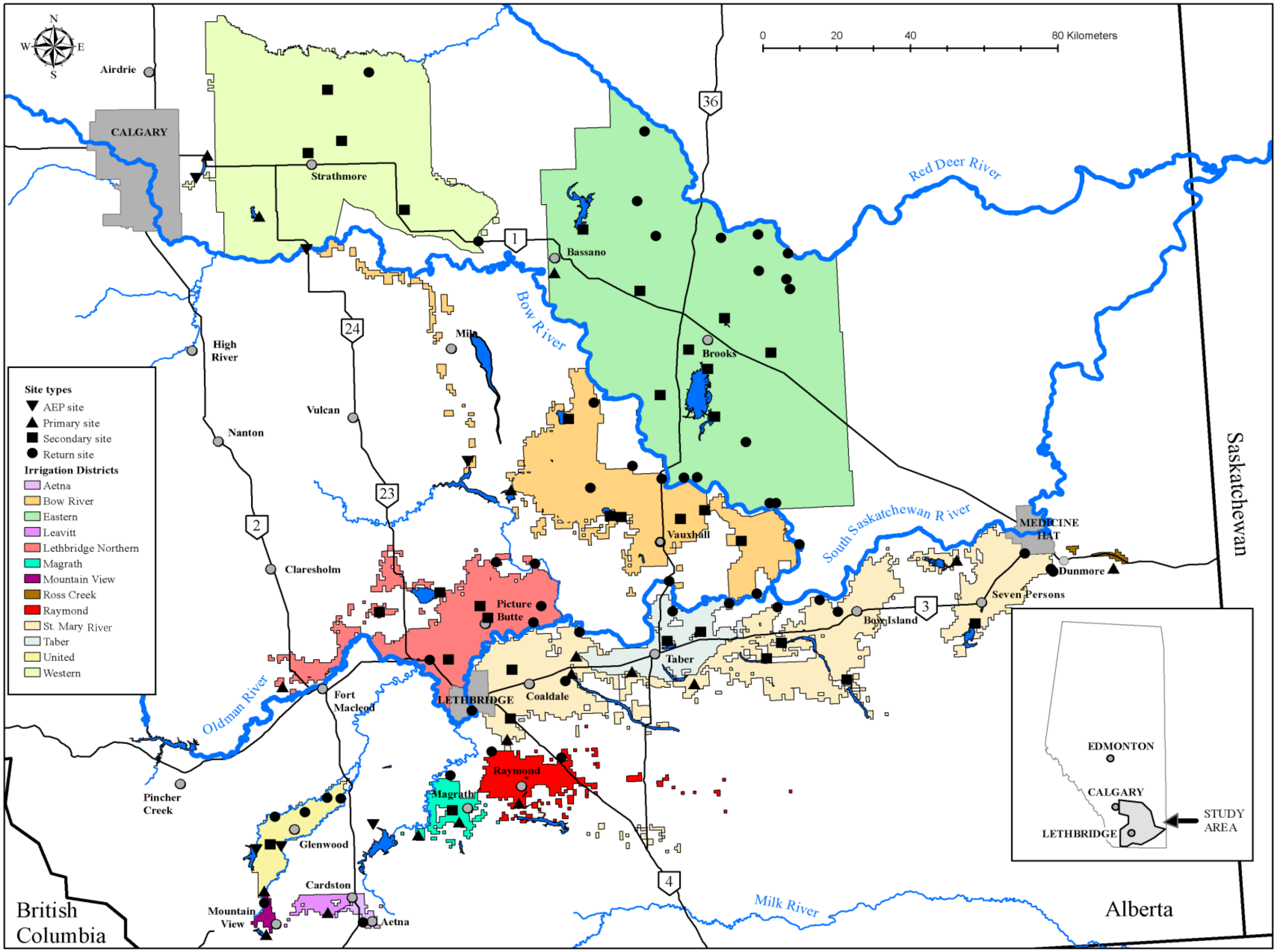

Figure 2.2 Irrigation District Water Quality project sampling site locations within Alberta's irrigation districts.

2.2 Site Nomenclature

Sampling sites were identified using a prefix according to their location, either in an irrigation district (abbreviated to the first one or two letters of the district acronym), or outside of the districts (AEP= Alberta Environment and Parks canal). The St. Mary River Irrigation District was further divided into three areas as distinguished by a third letter in the prefix, (W = west, C = central, and E = east). The site type and numeric identifier were included in the suffix of the hyphenated name. The site type (P = primary, S = secondary, R = return) preceded a numeral used to differentiate sites of the same type, within the same district. Although AEP sites were originally differentiated as primary and secondary, this distinction was later abandoned .For most comparison purposes, AEP sites are considered a site type of their own. Numeric identifiers do not necessarily represent the sequence of sites from upstream to downstream. Finally, the letter ‘a’ was appended to the end of some site names to indicate the replacement of a former site with a similar, but relocated site. Signs were located at each site to identify the site name and sampling location (Figure 2.3).

Figure 2.3 *Sign post at SMW-R2.*

2.3 Sampling Deployment and Intervals

Sites were grouped into sampling areas, with entire irrigation districts (except SMRID) being sampled on the same day. A single team was responsible for collecting samples from each sampling area. Larger districts, such as BRID, LNID, EID, and WID, included two or three areas sampled on the same day. Smaller districts, such as AID, MVID, and UID, were grouped in one area and sampled on the same day. This was also done for RID and MID. The three areas in the SMRID were sampled during three consecutive days.

Sampling was conducted from late May to the beginning of September, with the four sampling events separated by two to five weeks. Collection times were optimized to occur during active irrigation demand. The start of the season or individual sample collections were occasionally postponed as a result of reduced irrigation demand, usually due to rainfall. Three to four days were required to sample all sites during each sampling event. For the purposes of calculating water quality index (WQI) values for individual sites, all sampling events for a site were grouped together for each year of study.

2.4 Sample Collection

Grab samples were collected using a 1-L polyethylene bottle, attached to a telescopic pole with an extension range of four meters. The bottle was filled by pointing the mouth upstream, as close to the middle of the channel as possible, and mid-depth to avoid sampling the water surface or disturbing the bottom sediment (Figure 2.4a). The bottle was triple rinsed with sample water, and the rinse water emptied downstream of the sample site. A new sampling bottle was used at each site.

At each site, the sampling bottle was used to fill laboratory bottles for the analysis of different parameters (Figure 2.4b). Latex gloves and appropriate safety equipment were used when collecting the sample and filling the bottles. Samples were placed in coolers with ice while in the field. At the end of the sampling day, bottles were delivered to their respective laboratories for analysis.

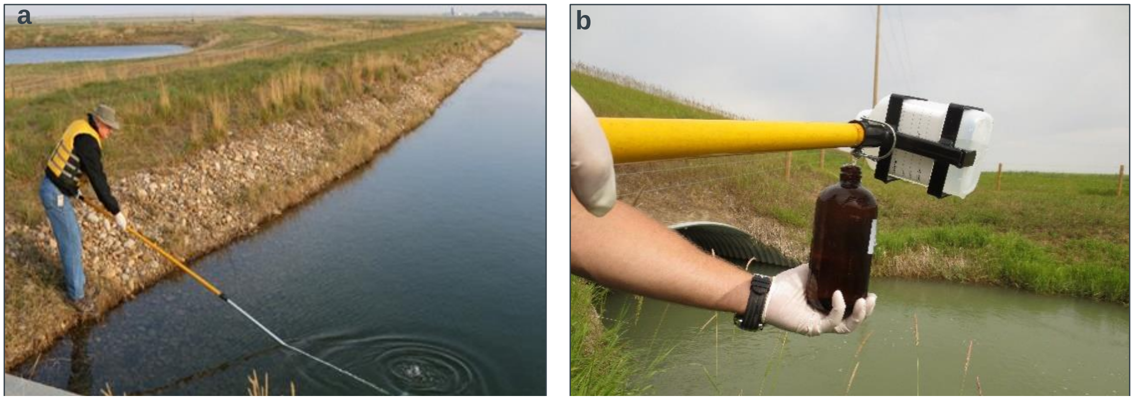

Figure 2.4 Water sampling an irrigation canal with a) a telescopic pole and b) filling a laboratory sample bottle.

2.5 Calculation of Water Quality Indices

The Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) was used in this study. This index has been used extensively within Canada and in other parts of the world (CCME 2017). The CCME WQI incorporates three components into the index value: i) scope –– the percentage of parameters that exceed guidelines at least once, ii) frequency–– the percentage of all parameter exceedances, and iii) amplitude –– the degree to which the guidelines are exceeded. The scope component has a greater contribution to the final index value than the other two components. Equations used to calculate index values are available in Appendix A.1. For this report, index values were generated using the CCME WQI Calculator 2.0 which was downloaded from the CCME webpage (CCME 2020).

Three WQI were calculated as an evaluation of the suitability of irrigation water for different uses. These uses were irrigation of agricultural crops, livestock watering and the protection of aquatic life. The Agricultural Irrigation Water Quality Index uses guidelines that are intended to provide a conservative level of protection to all life stages of crop species grown in Canada. The Agricultural Livestock Water Quality Index uses guidelines that are intended to protect the health of all Canadian livestock species. The Protection of Aquatic Life Water Quality Index uses guidelines for substances or conditions that should be protective of aquatic life; i.e. result in negligible risk of adverse effects on growth, reproduction, or survival of aquatic biota. Alberta Environment and Parks' (AEP') Environmental Quality Guidelines for Alberta Surface Waters (GOA 2018) were used in the calculation of these indices wherever possible. Some substitution of AEP guidelines was required when laboratory method detection limits (MDLs) were greater than guidelines or if calculation of index values was prevented by the hard-coding (i.e., embedment) of other guideline values directly in the CCME WQI calculator. This is documented in Tables 2.2 to 2.4, and further explained in Appendix A.2 and Appendix B.

A review of the sensitivity and behaviour of the CCME WQI recommended that between 8 to 20 parameters should be used in an index to summarize water quality and yield meaningful index results (Tri-Star Environmental Consulting 2012) (see Appendix A.3 for more information). Based on this recommendation, sub-indices were developed based on similar categories of parameters. Two sub-indices, general/pesticide and metals, were created for both the Agricultural Irrigation Water Quality Index and the Agricultural Livestock Water Quality Index. Three sub-indices were created for the Protection of Aquatic Life (PAL) Water Quality Index, based upon general water quality, pesticide, and metal parameters. These sub-indices included between 6 to 22 parameters each (Tables 2.2 to 2.4).

Many parameters analyzed during the IDWQ project had an associated Alberta surface water quality guideline; however, in order to facilitate year-to-year comparisons in WQI values, only parameters that had at least eight years of data and were consistently monitored were included (see Appendix A.4 for more information). An exception to this was metals where five or seven years of data were used dependent on the sub-index. This was because metals were not measured in 2016 to 2018. Furthermore, metals data collected in 2006 and 2007 were not used in calculating the PAL water quality metals sub-index, owing to challenges associated with high MDLs in these years (see Appendix B.3 for more information).

The CCME WQI can be used to compare different sites within the same time period (e.g., all return sites in 2012) or the same site across time (e.g., LN-P1 during the entire study period). However, because some degree of detail can be lost with the natural variability of larger datasets (CCME 2017), for this study, the CCME WQI was run for each individual site and year to maintain comparativeness of the index values. The guidelines to which the data were compared were largely kept consistent among the different sites and years (see Appendix B.1 for ammonia-N exception).

2.5.1 Agricultural Irrigation Water Quality Index

Of the 40 parameters with corresponding irrigation guidelines (GOA 2018), 30 parameters were monitored for at least eight years during the IDWQ project (seven years for the metal parameters). These parameters were split into a general/pesticide sub-index (12 parameters) and a metals sub-index (18 parameters) (Table 2.2).

Individual MDLs were less than agricultural irrigation water quality guidelines for all parameters in the index except dicamba. When guidelines differed by crop species, the guideline for the most sensitive crop was used. Similarly, the irrigation guideline for continuous use, rather than intermittent use, was chosen for selenium, as this reflected the more stringent of the two guidelines. The zinc irrigation guideline was based on soil pH of >6.5, as the average surface soil (0–15 cm) pH is 6.8 in southern Alberta (Penny 2004).

2.5.2 Agricultural Livestock Water Quality Index

Of the 64 parameters with corresponding livestock water guidelines (GOA 2018), 36 were monitored for at least eight years during the IDWQ project (seven years for the metal parameters). These parameters were split into a general/pesticide sub-index (20 parameters) and a metals sub-index (16 parameters) (Table 2.3).

Individual MDLs were less than agricultural livestock water guidelines for all parameters. However, in contrast with other parameters, if an individual phenoxy herbicide was identified as less than MDL in the data set, it was assumed to be zero for summing purposes. Although this may under-estimate the summed concentrations of the phenoxy herbicides when compared against the guideline, there was insufficient data to estimate the distribution of and impute values below the MDL. When guidelines differed by livestock species, the guideline for most sensitive livestock was used.

2.5.3 Protection of Aquatic Life Water Quality Index

Of the 150 parameters with PAL guidelines, 42 parameters were monitored for at least eight years during the IDWQ project (five years were used for the metal parameters because 2006-2007 was excluded, see Appendix B.3). These parameters were split into three sub-indices: a PAL general sub-index (6 parameters), a PAL pesticide sub-index (22 parameters), and a PAL metals sub-index (14 parameters) (Table 2.4).

Individual MDLs were less than PAL guidelines except for five pesticide parameters. Alberta's guidelines for the protection of aquatic life are the most comprehensive and stringent of all environmental quality guidelines for surface waters, reflecting the fact that these organisms typically spend all or most of their life cycle in an aquatic environment. Chronic toxicity guidelines, which are based on continuous exposure over long time periods, were used for calculating the PAL WQI, unless only acute toxicity guidelines were available or parameter MDLs exceeded the chronic toxicity guidelines. In general, chronic toxicity guidelines are more stringent than acute toxicity guidelines.

The CCME WQI has a number of operator functions to calculate guidelines that vary with another parameter. These operator functions did not always work as intended for the PAL sub-indices and several workarounds were developed. These workarounds are documented in Table 2.4 and further explained in Appendix B.

Table 2.2 Parameters and guidelines used to calculate the agricultural irrigation water quality sub-indices.

	Parameter	Guideline	Unit	Source[z]	Notes
General/ pesticide sub-index[y]	Chloride	178	mg/L	CCME 1987	Based on most sensitive crop species (potatoes)
	Coliforms, fecal (*Escherichia coli*)	100	#/100 mL	CCME 1987	
	Sodium Adsorption Ratio (SAR)	5	mg/L	AAFRD 2002	
	Total Dissolved Solids (TDS)	500	mg/L	CCME 1987	Based on most sensitive crop species (strawberries)
	Atrazine	10	µg/L	CCME 1989	
	Bromacil	0.2	µg/L	CCME 1997	
	Bromoxynil	0.44	µg/L	CCME 1993	
	Dicamba	0.026	µg/L	MDL	Method detection limit (MDL) used as guideline because MDL exceeds AEP guideline (0.008 µg/L)
	Diclofop	0.24	µg/L	CCME 1993	Based on most sensitive crop species (crops other than cereals, tame hays and pasture)
	MCPA (4-chloro-2-methyl phenoxy acetic acid)	0.04	µg/L	CCME 1995	
	Metolachlor	28	µg/L	CCME 1991	8 years of data used (2011-2018)
	Simazine	0.5	µg/L	CCME 1991	8 years of data used (2011-2018)
Metals sub-index[x]	Aluminum - total	5	mg/L	CCME 1987	
	Arsenic - total	160	µg/L	CCME 1997	
	Beryllium - total	100	µg/L	CCME 1987	
	Boron - total	500	µg/L	CCME 1987	Based on most sensitive crop species (blackberries)
	Cadmium - total	8.2	µg/L	CCME 1996	
	Chromium - total, trivalent	4.9	µg/L	CCME 1997	
	Cobalt - total	50	µg/L	CCME 1987	
	Copper - total	200	µg/L	CCME 1987	Based on most sensitive crop species (cereals)
	Iron - total	5	mg/L	CCME 1987	
	Lead - total	200	µg/L	CCME 1987	
	Lithium - total	2.5	mg/L	CCME 1987	
	Manganese - total	200	µg/L	CCME 1987	
	Molybdenum - total	10	µg/L	CCME 1987	
	Nickel - total	200	µg/L	CCME 1987	
	Selenium - total	20	µg/L	CCME 1987	Based on continuous use
	Uranium - total	10	µg/L	CCME 1987	
	Vanadium - total	100	µg/L	CCME 1987	
	Zinc - total	5	mg/L	CCME 1987	Based on soil pH > 6.5

[z] conforms with AEP's Environmental Quality Guidelines for Alberta Surface Waters unless otherwise noted. See GOA (2018) for full source information

[y] 10 years of data (2006, 2007, 2011-2018), unless otherwise noted

[x] 7 years of data (2006, 2007, 2011-2015)

Table 2.3 Parameters and guidelines used to calculate the agricultural livestock water quality sub-indices.

	Parameter	Guideline	Unit	Source[z]	Notes
General / pesticide sub-index[y]	Calcium	1000	mg/L	CCME 1987	
	Nitrate + Nitrite-N	100	mg/L	CCME 1988	
	Nitrite-N	10	mg/L	CCME 1987	
	Sulphate	1000	mg/L	CCME 1987	
	Total Dissolved Solids (TDS)	3000	mg/L	CCME 1987	
	Atrazine	5	µg/L	CCME 1989	
	Bromacil	1100	µg/L	CCME 1997	
	Bromoxynil	11	µg/L	CCME 1993	
	Chlorpyrifos	24	µg/L	CCME 1997	
	Dicamba	122	µg/L	CCME 1993	
	Diclofop	9	µg/L	CCME 1993	
	Dimethoate	3	µg/L	CCME 1993	
	Lindane (hexachlorocyclohexane δ)	4	µg/L	CCME 1987	
	MCPA (4-chloro-2-methyl phenoxy acetic acid)	25	µg/L	CCME 1995	
	Metolachlor	50	µg/L	CCME 1991	8 years of data used (2011-2018)
	Phenoxy herbicides[x]	100	µg/L	CCME 1987	
	Picloram	190	µg/L	CCME 1990	
	Simazine	10	µg/L	CCME 1991	8 years of data used (2011-2018)
	Triallate	230	µg/L	CCME 1992	
	Trifluralin	45	µg/L	CCME 1999	
Metals sub-index[w]	Aluminum - total	5	mg/L	CCME 1987	
	Arsenic - total	25	µg/L	CCME 1997	
	Beryllium - total	100	µg/L	CCME 1987	
	Boron - total	5	mg/L	CCME 1987	
	Cadmium - total	80	µg/L	CCME 1996	
	Chromium - total, trivalent	50	µg/L	CCME 1997	
	Cobalt - total	1	mg/L	CCME 1987	
	Copper - total	500	µg/L	CCME 1987	Based on most sensitive livestock (sheep)
	Lead - total	100	µg/L	CCME 1987	
	Mercury- total	3	µg/L	CCME 1987	
	Molybdenum - total	500	µg/L	CCME 1987	
	Nickel - total	1	mg/L	CCME 1987	
	Selenium - total	50	µg/L	CCME 1987	
	Uranium - total	200	µg/L	CCME 1987	
	Vanadium - total	100	µg/L	CCME 1987	
	Zinc - total	50	mg/L	CCME 1987	

[z] conforms with Environmental Quality Guidelines for Alberta Surface Waters unless otherwise noted. See GOA (2018) for full source information.

[y] 10 years of data (2006, 2007, 2011-2018), unless otherwise noted

[x] Applies to the sum of all phenoxy herbicides, including 2,4-D, dichlorprop, 2,4-DB, mecoprop, MCPA, MCPB, and quinclorac

[w] 7 years of data used (2006, 2007, 2011-2015)

Table 2.4 Parameters and guidelines used to calculate the protection of aquatic life water quality sub-indices.

	Parameter	Guideline	Unit	Source[z]	Notes
General sub-index[y]	Ammonia-N -un-ionized[x]	0.016	mg/L	CCME 2001	
	Chloride	120	mg/L	CCME 2011	
	Nitrate-N	3	mg/L	CCME 2012	
	Nitrite-N	0.06	mg/L	BC 2001	Modified from CCME, see Appendix B.1
	pH	6.5 – 9.0	-	CCME 1987	
	Sulphate	429	mg/L	BC 2013	Modified from CCME, see Appendix B.1
Pesticide sub-index	Atrazine	1.8	µg/L	CCME 1989	
	Bromacil	5	µg/L	CCME 1997	
	Bromoxynil	5	µg/L	CCME 1993	
	Chlorpyrifos	0.027	µg/L	MDL	Method Detection Limit (MDL) used as guideline because MDL exceeds AEP guideline of 0.002 µg/L (chronic) and 0.020 µg/L (acute)
	D, 2,4- (2,4-D: 2,4-dichlorophenoxy acetic acid)	4	µg/L	CCME 1987	
	DB, 2,4- (2,4-DB: 4-(2,4-dichlorophenoxy) butyric acid)	25	µg/L	Quebec 1998	
	Diazinon[y]	0.17	µg/L	USEPA 2005	
	Dicamba	10	µg/L	CCME 1993	
	Diclofop	6.1	µg/L	CCME 1993	
	Dimethoate	6.2	µg/L	CCME 1993	
	Endosulfan[x]	0.088	µg/L	MDL	Method Detection Limit (MDL) used as guideline because MDL exceeds AEP guideline of 0.003 µg/L (chronic) and 0.060 µg/L (acute)
	Lindane (hexachlorocycloh-exane)	0.033	µg/L	MDL	Guideline of 0.01 µg/L applies to sum of all isomers. MDL for each isomer exceeded guideline. MDL of gamma isomer only used as guideline. Only gamma isomer measured in 2006 and 2007
	MCPA (4-chloro-2-methyl phenoxy acetic acid)	2.6	µg/L	CCME 1995	
	Mecoprop (MCPP)	13	µg/L	Quebec 2000	
	Methoxychlor	0.03	µg/L	USEPA 1986	
	Metolachlor	7.8	µg/L	CCME 1991	8 years of data used (2011-2018)
	Mirex	0.026	µg/L	MDL	Method Detection Limit (MDL) used as guideline because MDL exceeds AEP guideline of 0.001 µg/L
	Permethrin	0.072	µg/L	MDL	Method Detection Limit (MDL) used as guideline because MDL exceeds AEP guideline of 0.004 µg/L
	Picloram	29	µg/L	CCME 1990	
	Simazin	10	µg/L	CCME 1991	8 years of data used (2011-2018)
	Triallate	0.24	µg/L	CCME 1992	
	Trifluralin	0.2	µg/L	CCME 1993	

Table 2.4 *continued.*

	Parameter	Guideline	Unit	Source[z]	Notes
Metals sub-index[w]	Arsenic - total	5	µg/L	CCME 1997	
	Boron - total	1.5	mg/L	CCME 2009	
	Cadmium - total	varies with hardness	µg/L	CCME 2014	
	Chromium - total, trivalent	5		ECCC 2018	Modified from AEP, see Appendix B.3
	Cobalt - total	varies with hardness	µg/L	ECCC 2017	Modified from AEP, see Appendix B.3
	Copper - total	7	µg/L	AEP 1996b	
	Lead - total	varies with hardness	µg/L	CCME 1987	
	Molybdenum - total	73	µg/L	CCME 1987	
	Nickel - total	varies with hardness	µg/L	CCME 1987	Modified from AEP, see Appendix B.3
	Selenium - total	2	µg/L	BC 2014	
	Silver - total	0.25	µg/L	CCME 2015	
	Thallium - total	0.8	µg/L	CCME 2011	
	Uranium - total	15	µg/L	CCME 2011	
	Zinc - total	30	µg/L	CCME 1987	

[z] conforms with AEP's Environmental Quality Guidelines for Alberta Surface Waters unless otherwise noted
See GOA (2018) for full source information

[y] 10 years of data (2006, 2007, 2011-2018), unless otherwise noted

[x] Calculated from ammonia-N concentrations, pH and temperature. Infrequently analyzed in 2017. Not analyzed in 2018

[w] 5 years of data (2011-2015)

2.6 Water Quality Index Categories

Five different categories were used to describe water quality index values, ranging from Poor to Excellent (Table 2.5) (CCME 2017). These CCME categories differ from those used in previous annual IDWQ reports, which used categories developed for the Alberta Agricultural Water Quality Index (AAWQI) (Wright et al.1999). Although the AAWQI uses the same formula to calculate the WQI, its categories are based upon broad boundaries identified using WQI values of agricultural streams in Alberta during 1996 and 1997 and their corresponding agricultural intensity rankings at the time (Wright et al.1999). The CCME categories were used in the report due to uncertainty on whether the relationship between agricultural intensity rankings and WQI value boundaries remain valid more than 20 years later, and whether boundaries found in the natural agricultural stream systems are applicable for constructed irrigation canals. By using CCME WQI categories, a standardized comparison can also be made to other jurisdictions within and outside of Canada that use the CCME WQI categories. The AAWQI categories are available for comparison in Appendix A.5.

Table 2.5 Canadian Council of Ministers of the Environment Water Quality Index categories.

Category	WQI Value	Statement
Excellent	95.0–100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good	80.0–94.9	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65.0–79.9	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45.0–64.9	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0–44.9	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3 Results and Discussion

When interpreting the WQI values, consideration must be given to the fact that values for each site were calculated based on three to four samples per year. Because of this, a sample with several parameter exceedances can have a large influence on overall WQI values for a given year. The CCME recommends a minimum of 10 samples per year, but unfortunately this was not possible for this study. A higher number of samples collected per year would result in a WQI value more representative of baseline conditions and seasonal events that may occur during the year.

Additionally, some sites had WQI values that were close to the boundaries of different categories (e.g., a WQI value of 94 is considered “Good” while a WQI value of 95 is considered “Excellent”). In these circumstances, water quality conditions are likely similar despite being differentially labelled. However, for the purposes of evaluating patterns and magnitudes of WQIs in this report, the categorization system was upheld and no efforts were made to modify WQI category descriptors based on their proximity to the boundaries. Lastly, comparisons were made on a site-by-site basis, and annual comparisons (e.g., all sites within 2007 versus 2008) were not made as these comparisons are more accurately addressed with statistical trend analysis, which was done in Volume 8 of this report series: Water quality trends in irrigation water of southern Alberta (Kobryn et al. 2021). Sites were also not grouped and compared by irrigation district as this would have introduced bias, given that districts do not have comparable numbers of specific site types. For example, a district with more return sites may have a lower WQI value, but this would not necessarily mean that poorer quality water was used to irrigate crops, as water from return sites is typically not used for irrigation.

3.1 Agricultural Irrigation Water Quality Index

3.1.1 Irrigation Water Quality General/Pesticide Sub-Index

The general/pesticide sub-index for irrigation use demonstrated that water quality was variable, both chronologically and geographically (Table B.1). When all sites and years were taken into consideration, 27.6% of sites were considered Excellent (water quality is protected with a virtual absence of threat or impairment) and 50.3% were considered Good (water quality is protected with only a minor degree of threat or impairment). Sixteen percent (16.3%) of sites were considered Fair (water quality is usually protected but occasionally threatened or impaired), with the remaining sites considered Marginal (water quality is frequently threatened or impaired) (4.3%) or Poor (water quality almost always threatened or impaired) (1.5%).

When the irrigation water quality general/pesticide sub-index values were analyzed by the type of site, 46.3% of primary sites and 42.3% of secondary were considered Excellent, while 7.8% of return sites were classified as Excellent (Table 3.1, Table B.1). Similarly, less than 3% of all primary and secondary irrigation sites had Marginal or Poor general/pesticide sub-index values, while 10.3% of return sites fell into these categories. This was expected, as water quality often deteriorates due to non-point source contributions from agricultural lands as water travels downstream or in this case, through the irrigation conveyance network. Since water at return sites is not typically used to irrigate crops, the effect of these guideline exceedances on irrigated crops is likely low. Infrastructure returns, which by design receive less non-point source contributions, had higher sub-index values than watershed returns where irrigation water mixes readily with other contributions (Table 3.1).

By comparison, primary sites were observed to have more values that were considered Excellent or Good (95%), than AEP canals (85%) (Table 3.1, Table B.1). Alberta Environment and Parks canal sites are located upstream of irrigation districts, which often store their source water in reservoirs upstream of their primary sites. There may be beneficial influences of irrigation reservoirs on general/pesticide parameters relative to irrigation water guidelines.

Table 3.1 Percentage of sites types in the irrigation water quality general/pesticide sub-index categories.

CCME WQI Category	AEP canals (n = 27)	Primary (n = 147)	Secondary (n = 298)	Return			Overall (n = 805)
				All Returns (n = 360)	Watershed (n = 167)	Infrastructure (n = 193)	
Excellent	37.0	46.3	42.3	7.8	3.0	11.9	27.6
Good	48.1	49.0	43.3	56.7	56.9	56.5	50.3
Fair	7.4	4.1	11.4	25.3	28.1	22.8	16.3
Marginal	3.7	0.7	2.0	7.8	9.6	6.2	4.3
Poor	3.7	0.0	1.0	2.5	2.4	2.6	1.5

Parameters most frequently responsible for guideline exceedances within the irrigation water quality general/pesticide sub-index were *Escherichia coli (E. coli),* dicamba, and MCPA. These parameters sometimes exceeded CCME guidelines for irrigation use by as much as 100 times (*E. coli*), 557 times (dicamba), and 3797 times (MCPA). It should be noted that the dicamba guideline used in sub-index calculations was set to the highest MDL used during the project (0.026 µg/L) since the MDL was greater than AEP's irrigation guideline of 0.008 µg/L (GOA 2018). This practice is recommended as per the CCME WQI User Manual (CCME 2017). If the irrigation water quality general/pesticides sub-index had been calculated with a guideline of 0.008 µg/L, sub-index values would likely have been further reduced as more values would have been in exceedance. Total dissolved solids and the sodium adsorption ratio (SAR) also occasionally exceeded guidelines (generally exceedances were within 10 times the guideline).

3.1.2 Irrigation Water Quality Metals Sub-Index

Irrigation water quality metals sub-index values were consistently categorized as Excellent or Good (Table 3.2, Table B.2), indicating that water can be considered suitable for irrigation with respect to metal concentrations. More than 99% of primary and secondary sites and 95.3% of return sites were considered to have Excellent water quality when compared to irrigation water quality guidelines for metals (Table 2.2). No sites were categorized as having Fair, Marginal, or Poor water quality. The metal parameters that did occasionally exceed guidelines were aluminum, chromium, iron, and manganese. All exceedances were within 10 times their respective guidelines.

Table 3.2 Percentage of site types in the irrigation water quality metals sub-index categories.

CCME WQI Category	AEP canals (n = 27)	Primary (n = 105)	Secondary (n = 211)	Return			Overall (n = 571)
				All Returns (n = 255)	Watershed (n = 125)	Infrastructure (n = 130)	
Excellent	96.3	99.0	100.0	95.3	93.6	96.9	97.7
Good	3.7	1.0	0.0	4.7	6.4	3.1	2.2
Fair	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Marginal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poor	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.2 Agricultural Livestock Water Quality Index

3.2.1 Livestock Water Quality General/Pesticide Sub-Index

The livestock water quality general/pesticide sub-index values indicated that water at almost all locations was Excellent for livestock watering throughout the study period (Table 3.3). There were no guideline exceedances (sub-index values of 100 at all sites) except at AEP-P2 (Table B.3). This site had a sub-index value of 93 (Good) in 2015, which was driven by the occurrence of a high concentration (151.9 µg/L) of MCPA on July 6, 2015. This exceeded both the MCPA and phenoxy herbicide guidelines (25 µg/L and 100 µg/L, respectively) and lowered the index value. This site was located 4 km downstream of the City of Calgary on an AEP canal, which carries water diverted from the Bow River near downtown Calgary towards the Western Irrigation District.

3.2.2 Livestock Water Quality Metals Sub-Index

Livestock water quality metals sub-index values indicated that the quality of water at all sites was Excellent for livestock watering throughout the study period (Table B.4). There were no guideline exceedances for any metals included in this sub-index.

3.3 Protection of Aquatic Life Water Quality Index

3.3.1 Protection of Aquatic Life Water Quality General Sub-Index

Nearly all PAL water quality general sub-index values (94%) were in the Excellent and Good categories (Table 3.3, Table B.5), and can be considered suitable for the protection of aquatic life. Approximately 6% of sites were considered to be of Fair quality. Sites with Fair values tended to have repeated Fair values across multiple years, indicating that these exceedances may be related to environmental conditions at the site or consistent land use effects from the surrounding area.

When sites were analyzed based upon site type, primary sites were overwhelmingly of Excellent water quality (95.9%; Table 3.3). As expected, the percentage of index values classified as Excellent decreased as water travelled through the irrigation conveyance network — 80.9% of secondary sites were considered Excellent, while 82.5% of return sites were considered Excellent. Infrastructure returns generally had lower PAL water quality general sub-index values than watershed returns — 80.3% of infrastructure return sites were considered Excellent compared to 85.0% watershed return sites. These results differ from the irrigation water quality general/pesticide sub-index values where infrastructure returns showed more Excellent values. Statistical significance was not tested on this difference and it may be due to the fact that the sub-indices are not directly comparable as the irrigation sub-index included pesticides.

Un-ionized ammonia-N and pH were the parameters most likely to exceed PAL guidelines in the general sub-index. If a sample had a high pH value that exceeded the pH guideline, the un-ionized ammonia-N guideline was also often exceeded due to the dependence of ammonia-N toxicity with pH and temperature. It should be noted that for all sites outside of the Taber Irrigation District, ammonia-N was not measured for most of 2017 and 2018 samples. Including this parameter was an exception to maintaining consistent guidelines among sites. If un-ionized ammonia had been measured at all sites, the PAL water quality general sub-index values during these years may have been lower for these sites. Nitrite-N and sulphate were also found to exceed PAL guidelines. Un-ionized ammonia-N, pH, nitrite-N, and sulphate parameters were responsible for the greater proportion of infrastructure return sites rated as Fair or Marginal.

Table 3.3 Percentage of site types in the PAL water quality general sub-index categories.

CCME WQI Category	AEP canals (n = 27)	Primary (n = 147)	Secondary (n = 298)	Return			Overall (n = 805)
				All Returns (n = 360)	Watershed (n = 167)	Infrastructure (n = 193)	
Excellent	96.3	95.9	80.9	82.5	85.0	80.3	84.3
Good	3.7	2.0	11.4	11.4	10.8	11.9	9.7
Fair	0.0	2.0	7.7	5.8	4.2	7.3	5.8
Marginal	0.0	0.0	0.0	0.3	0.0	0.5	0.1
Poor	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.3.2 Protection of Aquatic Life Water Quality Pesticide Sub-Index

The PAL water quality pesticide sub-index was comprised of 22 pesticides. However a challenge that confronted this sub-index was that five of these parameters had MDLs higher than the guidelines (Table 2.4). (See Appendix B.2 for more information). While the majority of samples did not have detectable levels of pesticides, for these five parameters it is difficult to determine whether Alberta's PAL guidelines were exceeded, and in turn, the potential effect on index values.

Overall, most sites monitored had PAL water quality pesticide sub-index values rated as Excellent (Table B.6). Most sites in the Good category were within one index value of the Excellent category. When sites were compared based upon site type, all primary and over 98.9% of secondary and return sites were classified as Excellent (Table 3.4). One site was found to have a PAL water quality pesticide sub-index rating of Fair, due to a single high MCPA exceedance (58 times higher than the guideline; AEP-P2, July 6, 2015). This is the same site and sample that influenced the general/pesticide sub-index for irrigation use (Table B.1). Two pesticides, 2,4-D and MCPA, were found to be responsible for the PAL pesticide guideline exceedances.

Table 3.4 Percentage of site types in the PAL water quality pesticide sub-index categories.

CCME WQI Category	AEP canals (n = 27)	Primary (n = 147)	Secondary (n = 298)	Return			Overall (n = 805)
				All Returns (n = 360)	Watershed (n = 167)	Infrastructure (n = 193)	
Excellent	96.3	100.0	99.3	98.9	98.8	99.0	99.3
Good	0.0	0.0	0.7	1.1	1.2	1.0	0.7
Fair	3.7	0.0	0.0	0.0	0.0	0.0	0.0
Marginal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poor	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.3.3 Protection of Aquatic Life Water Quality Metals Sub-Index

The majority of sites (95.1%) were categorized as Excellent when calculated with the PAL water quality metals sub-index, with 4.5% classified as Good (Table 3.5, Table B.7). A small number of sites (i.e., three) had PAL water quality metals sub-index values within the Fair category, of which two were returns. The third site, AEP-P2 in 2007, was on an AEP canal diverting water from the Bow River to downstream irrigation districts. Returns had slightly lower proportions of sites within the Excellent category (92.4% versus 94.5% and 98.7% for primary and secondary sites, respectively). Watershed returns had a lower percentage of sites reporting PAL water quality metals sub-index values in the Excellent category (89%) than infrastructure returns (96%), suggesting possible erosion-driven effects on total metals guideline exceedances in the predominantly earthen watershed returns.

The metal parameters that had the highest numbers of guideline exceedances were cobalt, arsenic, and chromium. Zinc, selenium, silver, and lead also occasionally exceeded guidelines. Mercury was excluded from the PAL water quality metals sub-index due to issues with high MDL values for most years of the study. It should be noted that mercury did exceed PAL guidelines when the MDL was sufficiently low as to be comparable with the guideline (site and date dependent; data not shown). Consequently, the PAL water quality metals sub-index values may have been lower if this parameter could have been included in the index.

Table 3.5 Percentage of site types in the PAL water quality metals sub-index categories.

CCME WQI Category	AEP canals (n = 15)	Primary (n= 73)	Secondary (n = 155)	Return			Overall (n = 426)
				All Returns (n=198)	Watershed (n=100)	Infrastructure (n=98)	
Excellent	93.3	94.5	98.7	92.4	89.0	95.9	95.1
Good	0.0	5.5	1.3	6.6	11.0	2.0	4.5
Fair	6.7	0.0	0.0	1.0	0.0	2.0	0.5
Marginal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poor	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4 Conclusions

Water quality indices allow environmental monitoring data to be mathematically combined into a single value. This value can quickly convey qualitative information about a site relative to guidelines designed for a specific water use. Water quality data from the IDWQ project was used to calculate indices for three different end uses: irrigation of agricultural crops, livestock watering, and the protection of aquatic life. Within each WQI, sub-indices were created in order to ensure that WQI values were appropriately calculated and similar parameters were grouped together.

Challenges associated with water quality indices, similar to those encountered when interpreting water quality data, included ensuring the data reflected the variability of the sites (i.e., appropriate sampling frequency) and that parameters and guidelines used in the indices were appropriate. Method detection limits that were variable and/or exceeded guidelines created challenges when calculating WQI values, specifically for the PAL Water Quality Index. Further, the addition or removal of parameters limited the ability of WQI to be calculated for the entire 10-year duration of the project for some parameters.

Of the seven sub-indices calculated for this study, the general/pesticide sub-index values for irrigation use were the most variable. This was primarily due to exceedances associated with *E. coli* and the pesticides dicamba and MCPA. However, despite these exceedances, irrigation water quality was considered to be Excellent (protected with a virtual absence of impairment) or Good (protected with only a minor degree of impairment) in 78% of sites over time. Only 5.8% of sites were considered to be Marginal (frequently impaired) or Poor (almost always impaired) relative to irrigation water quality guidelines for general and pesticide parameters. The majority of sites with values in the poor and marginal categories were return sites, where water returns to rivers and is typically not used for irrigation. The metals sub-index for irrigation use, as well as the general/pesticide and metals sub-indices for livestock water, indicated very little impairment of water quality with few exceedances of guidelines associated with these sub-indices.

Water quality as calculated with the PAL water quality general sub-index was Excellent or Good at 94% of sites. Parameters most likely to negatively affect PAL general water quality sub-index values were pH and un-ionized ammonia-N, with sulphate and nitrite-N also found to occasionally exceed PAL guidelines. Only one site had a Marginal PAL water quality general sub-index value, and no sites were found to have Poor values through the duration of the project.

Similarly, the PAL water quality pesticide and metals sub-index values were categorized as either Excellent or Good quality at virtually all sites during the course of the IDWQ project (100% for pesticides and 99.5% for metals). Concentrations of pesticides and metals at these sites can be considered suitable for the protection of aquatic life.

Primary irrigation sites representing the source water of the irrigation districts generally had WQI values that were Excellent or Good when comparing all seven sub-indices. Water quality index values tended to decrease as irrigation water flowed through the irrigation infrastructure from primary sites through secondary sites to return sites. The degree to which this degradation occurred depended on the sub-index (i.e. parameters and guidelines used). It was most pronounced for the irrigation water quality general/pesticide sub-index and the PAL water quality general sub-index due to increased *E.coli*, pesticides (2,4-D, dicamba and MCPA), pH and un-ionized ammonia-nitrogen exceedances as water moved downstream.

Overall, irrigation water of southern Alberta can be classified as Excellent or Good, as per CCME categories, for the irrigation of crops, livestock watering, and the protection of aquatic life.

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Appendix A Supplementary Information for Water Quality Index Calculations

A.1 Equations Used in Water Quality Index Calculations

The Canadian Council of Ministers on the Environment Water Quality Index (CCME WQI) calculates index values using the following equations (CCME 2017).

F1 **(Scope)** represents the percentage of parameters that exceed their guidelines at least once, relative to the total number of parameters measured:

(Equation A.1)

$$F_1 = \left(\frac{Number\ of\ failed\ parameters}{Total\ number\ of\ parameters}\right) \times 100$$

F2 **(Frequency)** represents the percentage of individual tests that exceed guidelines (i.e., failed tests).

(Equation A.2)

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \times 100$$

F3 **(Amplitude)** represents the degree to which failed test values exceed their guidelines. Amplitude is calculated in three steps.

i) The number of times by which an individual concentration is greater than the guideline (or less than, when guideline is a minimum) is termed an “excursion”, with the term “objective” indicating the value of the guideline. The equation for guideline as a minimum is not shown as it was not applicable to the parameters assessed in the study. The formula for calculating excursions is as follows:

(Equation A.3)

$$excursion_i = \left(\frac{FailedTestValue_i}{Objective_j}\right) - 1$$

ii) The collective amount by which individual tests exceed guidelines is calculated by summing the excursions of individual tests and dividing by the total number of tests (both those meeting guidelines and those exceeding guidelines). This parameter is referred to as the normalized sum of excursions (or nse), and is calculated as follows:

(Equation A.4)

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests}$$

iii) F3 is then calculated by an asymptotic function that scales the normalized sum of excursions (*nse*) to yield a range of 0 to 100.

(Equation A.5)

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right)$$

Once the three components have been calculated, the index itself can be determined by summing the three factors as if they were vectors and using the Pythagoras theorem. With this model, the index changes in direct proportion to changes in all three factors. The divisor 1.732 normalizes the index values to a range of 0 to 100.

(Equation A.6)

$$CCME\ WQI = \left(\frac{\sqrt{{F_1}^2 + {F_2}^2 + {F_3}^2}}{1.732}\right)$$

A.2 Guidelines Used in Water Quality Index Calculations

Data were compared to Alberta Environment and Parks (AEP) Environmental Quality Guidelines for Alberta Surface Waters where possible (GOA 2018). Specifically, guidelines for agricultural irrigation water, agricultural livestock water, and the protection of aquatic life (PAL) were used. Most of AEP guidelines are sourced from CCME, United States Environmental Protection Agency or other provincial sources. However, there were occasions where Alberta-specific guidelines existed but could not be inputted due to hard coding within the CCME WQI calculator. In these circumstances, workarounds were developed (see Appendix B for details).

Method detection limits (MDLs) for some parameters frequently varied through the study period due to changes in analytical laboratories or methodology. Usually, these MDLs were less than the guidelines and thus did not influence the WQI. However, when the MDL was higher than the guideline, the detection limit was used as the guideline, as recommended by CCME (CCME 2017). When the MDL changed with time and all MDL values were greater than the guideline (as occurred for some pesticide parameters), the guideline was set to the highest observed MDL value. These circumstances were evaluated on a case-by-case basis, as in some cases the MDL was substantially higher (>10x) than the guideline. These exceptions are discussed in Appendix B.

A.3 Importance of Choice of Parameters Used in Water Quality Index Calculations

Using too many parameters reduces the importance of any one parameter, while too few parameters result in each parameter having disproportionate weight in the final calculation (CCME 2017). Furthermore, the more parameters included in the CCME WQI, the greater the proportion of sites likely to rank as moderate water quality (i.e., Marginal or Fair categories) in comparison to Excellent or Poor (Tri-Star Environmental Consulting 2012).

When water quality parameters are highly correlated, for example, pH and alkalinity, or turbidity and total suspended solids, the CCME recommends that only one of the correlated parameters be used to calculate the WQI. This prevents a correlated parameter from being counted twice in the WQI. For this reason, only pH was included in the PAL Water Quality Index although guidelines also exist for alkalinity.

A.4 Site, Sampling and Parameter Frequency in Water Quality Index Calculations

Although a review by Tri-Star Environmental Consulting (2012) advised that rivers and streams should have about 10 samples per year to capture variability due to seasonal or storm events, due to the design of this project, only a maximum of four samples per year were possible. As discussed, reducing the number of parameters in a WQI results in the remaining parameters having a stronger influence on the final ranking (Tri-Star Environmental Consulting 2012). Consequently, if more than one parameter were missing from the data set (e.g., missing all pesticide data in a general/pesticide sub-index due to a broken bottle), all data for that site and date was omitted for that index.

A.5 Previously Used Alberta Agricultural Water Quality Index Categories

Alberta Agricultural Water Quality Index categories were developed in 1998 and were used for previous (progress) reports for this project. For this report, CCME categories, as cited in Section 2.6 and Table 2.5, were adopted.

Category	Value	Statement
Excellent	86.0–100	Water is of very high quality, all variables are usually within guidelines.
Good	71.0–85.9	Rare departures from desirable water quality by some variables, usually by a relatively small amount.
Fair	56.0–70.9	Occasional departures from desirable water quality by several variables, usually by a moderate amount.
Borderline	41.0–55.9	Frequent departures from desirable water quality by many variables, and by a relatively large amount.
Poor	0–40.9	Very frequent departures from desirable water quality by many variables, and by a rather large amount.

Appendix B Supplementary Information for Protection of Aquatic Life Water Quality Sub-Index

The CCME WQI calculator has a number of operator functions to calculate guidelines that vary with another parameter. These operator functions did not always work as intended and several workarounds were developed, as explained below.

B.1 Protection of Aquatic Life Water Quality General Sub-index Supplement

The PAL water quality general sub-index consisted of pH, chloride, sulphate, un-ionized ammonia-nitrogen (N), nitrate-N, and nitrite-N. Because the toxicity of sulphate decreases as hardness of the water increases, sulphate guidelines vary with water hardness. Unfortunately, the sulphate operator function in the CCME WQI calculator did not allow for sulphate data to be compared against the appropriate hardness-dependent Alberta PAL guideline. Consequently, a sulphate guideline of 429 mg/L was set for all sulphate data regardless of the hardness value. This guideline corresponds to the highest hardness values (181 to 250 mg/L $CaCO_3$) with a set guideline. Guidelines for sulphate values for water with greater than 250 ml/L CaCO3 must be specifically determined based on site water (GOA 2018). Since this was not done, the 25 samples with hardness values >250 mg/L $CaCO_3$ and sulphate concentrations >429 mg/L may represent false positive exceedances in the WQI. Similarly, the total ammonia-N data provided by the analytical lab could not be successfully compared against guidelines due to unknown issues with the CCME WQI ammonia operator function. To compensate, total ammonia-N data were converted into un-ionized ammonia-N data using sample-specific pH and temperature values and the following formula:

(Equation 6.7)

$$un\text{–}ionized\ ammonia\text{–}N\ concentration = (total\ ammonia\text{–}N\ concentration) \times (f)$$

Where: *(Equation 6.8)*

$$un\text{–}ionized\ ammonia\ fraction\ (f) = \frac{1}{[10^{(pKa-pH)} + 1]}$$

and *(Equation 6.9)*

$$pKa\ = 0.0901821 + \frac{2729.92}{temperature\ in\ {}^{\circ}C + 273.15}$$

The converted data was then compared against the un-ionized ammonia-N guideline of 0.016 mg/L. Total ammonia-N samples reported below the MDL of 0.05 mg/L or 0.025 mg/L were converted using 0.049 mg/L and 0.024 mg/L, respectively. If pH or temperature data were missing, these samples were not used, as no un-ionized ammonia-N fraction could be calculated. Of note, ammonia was only monitored in the Taber Irrigation District sites in 2017 and 2018. For other irrigation district sites, this will result in other parameters having increased weighting in the PAL water quality general sub-index for those years. This was preferable to excluding the ammonia data that was available due to its potential high toxicity to aquatic life. This is an exception to the previous standard of maintaining consistency of parameters among years and sites.

Nitrite-N guidelines vary with chloride; however, communications with scientists who developed the CCME WQI calculator indicated that the calculator was not compatible with setting up a new guideline to reflect this (Vincent Mercier, Environment and Climate Change Canada, pers. comm.). As such, the nitrite-N guideline was set to 0.06 mg/L, the most conservative maximum nitrite-N guideline for the protection of aquatic life (GOA 2018). Of the 10 samples that exceeded 0.06 mg/L nitrite-N, five were false positives upon manual checking (i.e. when chloride concentrations were taken into consideration, no nitrite-N guidelines were exceeded). Consequently, these samples were manually changed to be <0.06 mg/L nitrite-N in the data set. If the false positive had been kept within the data file the WQI would have been reduced erroneously by up to 10 index values (data not shown).

B.2 Protection of Aquatic Life Water Quality Pesticide Sub-Index Supplement

The PAL water quality pesticide sub-index included 22 pesticide parameters that had been monitored for at least eight years in the IDWQ project (Table 2.4). For the majority of these chemicals, the MDLs were lower than the guidelines; however, five pesticides (chlorpyrifos, endosulfan, lindane, mirex, and permethrin) had MDLs higher than the respective guidelines. In these circumstances, the MDL was used as the guideline, as per the CCME WQI user manual (CCME 2017).

Because these pesticides had guidelines set to the MDL rather than those listed in the AEP's Environmental Quality Guidelines for Alberta Surface Waters, it is possible that exceedances occurred but were not detectable. If this was the case, then the WQI values may have been higher than if MDL values were equal to the guideline. However, it should be noted that of the five pesticides with MDL values greater than the guideline, only a very small number of samples (5 of about 3300) were found to have detectable levels of these pesticides (i.e., concentrations greater than their respective MDLs). One sample had detectable levels of chlorpyrifos 15.5 times the guideline. The remaining four samples were found to have measurable levels of hexachlorocyclohexane β (a lindane isomer) ranging between 3 to 13.5 times the (summed) lindane guideline.

B.3 Protection of Aquatic Life Water Quality Metals Sub-Index Supplement

The PAL water quality metals sub-index included 14 metal parameters that were monitored from 2011 to 2015 in the IDWQ project (Table 2.4). In 2006 and 2007, MDLs for several metals (cadmium, chromium, cobalt, mercury, selenium, thallium, zinc) were substantially higher than PAL guidelines. Most of these parameters had MDL values below guidelines in the 2011 through 2015 sampling years. While it would have been preferable to include the 2006 and 2007 data in the WQI analyses, as was done for other metal sub-indices, the high MDL values would have necessitated a higher guideline. Another option considered was to omit only the problematic metal parameters from the PAL water quality metals sub-index in 2006 and 2007. However, since it was desirable to keep the number of parameters and guideline values consistent with time, the decision was made to omit all 2006 and 2007 metals data from the PAL water quality metals sub-index.

In the case of mercury, the MDL was up to 40 times higher than the PAL guideline of 0.005 µg/L, and only 30% of all mercury samples had MDL values equal to the PAL guideline. Because of this, mercury was dropped from the WQI entirely. When mercury was included in the PAL water quality metals sub-index for 2014 and 2015 (years where the MDL was equal to the PAL guideline) the WQI value was found to drop by as much as fifteen index points, though most sites did not change (data not shown).

The PAL guideline for chromium is based on Canada's federal environmental quality guideline of 5 µg/L for hexavalent chromium (freshwater aquatic life) (ECCC 2018) rather than provincial surface water guidelines of 1 µg/L for hexavalent chromium and 9.8 µg/L for trivalent chromium (GOA 2018). This guideline was chosen based on feedback from subject-matter experts in AEP (Joanne Little, pers. comm.). Hexavalent chromium is more soluble than trivalent chromium, and is also more likely to be found in higher proportions in the typically alkaline waters of Alberta. Since the analytical lab did not distinguish between the two forms, the federal guideline for hexavalent chromium struck a balance between the two AEP guidelines.

Another modification used in the PAL water quality metals sub-index concerned upper hardness limits used to calculate metal guidelines. Alberta's PAL guidelines identify specific metal guidelines for hardness values up to and including 400 mg/L $CaCO_3$ (395 mg/L $CaCO_3$ for cobalt). Guidelines are not identified for water with hardness values above these values. In order for the CCME WQI calculator to compare data against guidelines when water samples were >400 or >395 mg/L $CaCO_3$, the upper hardness limit used in the CCME WQI operator code was set to the highest hardness measured in the dataset. For example, hardness values of between 370 through 395 mg/L $CaCO_3$ have a cobalt PAL guideline of 1.8 µg/L (GOA 2018). The CCME guideline was modified such that 1.8 µg/L cobalt was set as the guideline for all samples with hardness values >365 mg/L and ≤1100 mg/L $CaCO_3$ (the highest hardness value observed). If this was not done, all samples with hardness values of >395 mg/L $CaCO_3$ (n = 12 of 1733 total metals samples) would have erred in the calculator. False negatives were not a concern, as very low metal concentrations were observed in all samples with >400 mg/L $CaCO_3$ hardness values.

In the case of total nickel, the operator function only allowed the use of CCME guidelines (CCME 1987). We were unable to manually input Alberta's guidelines due to the complexity of the guidelines varying with hardness. However, when raw data were manually checked against guidelines, nickel concentrations never exceeded chronic guidelines derived by either CCME or AEP.

Table B.1 Irrigation water quality general/pesticide sub-index values and categories.
N/A indicates data was not available, usually due the site not being sampled.
Categories are color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
MVID	MV-P1	100	100	100	100	100	100	100	93.7	100	100
	MV-R1	90.4	92.2	93.9	94.8	81.6	94.9	88.1	88.3	85.1	82.3
AID	A-P1	87.3	85.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A-R1	87.4	85.4	90.0	83.2	72.1	70.0	90.8	86.9	91.5	91.9
UID	U-P1	100	93.5	95.0	100	61.3	100	94.4	93.0	88.9	100
	U-S1	91.5	93.1	58.3	100	80.7	82.7	84.1	51.1	82.6	89.6
	U-R1	81.8	76.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	U-R2	80.9	85.4	47.8	84.4	81.8	72.0	81.2	45.7	83.7	72.9
	U-R3	N/A	N/A	60.6	86.3	74.0	55.7	69.3	N/A	N/A	N/A
	U-R4	N/A	N/A	N/A	93.9	71.9	64.7	71.9	N/A	N/A	N/A
MID	M-P1	100	100	94.1	100	100	95.0	95.0	95.0	100	94.6
	M-P2	86.6	87.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	89.7	88.2	67.3	74.6	85.6	78.8	83.6	93.2
	M-R1	71.3	81.8	90.1	89.9	94.3	71.0	91.8	44.0	87.4	92.5
RID	R-P1	94.0	94.0	95.0	100	89.6	90.0	100	87.7	100	100
	R-R1	76.8	78.1	68.7	73.4	84.0	83.4	88.2	72.4	94.0	92.3
	R-R2	92.7	76.2	75.2	95.0	92.4	74.0	84.3	50.5	81.6	94.2
LNID	LN-P1	94.0	100	100	94.1	94.5	94.5	90.0	89.3	100	100
	LN-S1	93.6	100	95.0	94.4	100	95.0	95.0	79.1	100	100
	LN-S2	100	100	100	100	100	100	100	75.6	93.6	100
	LN-S3	87.7	100	60.1	83.5	68.2	74.4	94.5	86.6	95.0	100
	LN-S4	100	100	94.8	93.6	100	85.1	94.9	94.6	95.0	100
	LN-S5	100	93.5	89.3	86.8	73.3	87.7	91.3	89.0	89.9	100
	LN-R1	88.3	84.1	83.2	87.0	73.1	83.8	84.2	88.7	84.6	90.4
	LN-R2	86.3	92.3	72.8	67.7	60.6	61.0	87.4	76.9	88.2	72.1
	LN-R3	N/A	N/A	73.8	67.9	62.5	52.5	84.6	72.6	73.8	68.2
	LN-R4	N/A	N/A	N/A	71.0	55.5	77.9	74.0	67.4	85.0	94.1
	LN-R5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	90.7	88.1	73.7
	LN-R6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79.3	90.0	74.2
TID	T-P1	76.0	80.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	89.3	88.7	94.7	89.2	77.3	80.7	95.0	94.7
	T-P2	84.6	83.5	89.9	94.9	89.9	94.4	68.2	88.7	100	100
	T-S2	79.3	78.0	84.1	94.6	89.7	87.3	85.9	94.9	100	100
	T-S3	74.1	71.8	84.6	63.1	83.7	77.8	83.2	82.8	89.8	93.4
	T-R1	85.1	80.8	78.5	88.4	89.7	89.6	79.9	77.4	94.9	89.4
	T-R2	77.8	72.8	84.7	82.8	89.2	88.8	66.9	83.6	95.0	94.8

Table B1 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
SMRID	SMC-P1	84.3	78.1	94.3	94.7	100	93.4	86.0	86.8	100	100
	SME-P1	84.5	83.5	87.4	100	94.9	93.9	90.8	95.0	100	95.0
	SMW-P1	94.0	100	89.9	100	100	95.0	95.0	100	100	100
	SMC-S1	91.7	91.2	100	100	100	95.0	100	69.9	100	94.6
	SMC-S2	93.5	85.6	100	100	95.0	95.0	78.2	89.0	100	94.9
	SMC-S3	77.9	77.5	94.3	94.9	95.0	94.6	95.0	75.1	100	100
	SME-S1	94.0	83.2	100	100	100	100	100	100	100	100
	SMW-S1	86.7	94.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	90.0	100	95.0	95.0	95.0	90.1	100	94.8
	SMC-R1	78.0	84.9	95.0	91.0	95.0	95.0	93.6	87.3	87.1	94.1
	SMC-R3	100	71.6	90.0	89.6	95.0	93.0	88.9	80.9	91.6	94.9
	SMC-R4	77.8	68.0	89.5	91.9	89.7	87.2	87.3	85.7	89.5	91.9
	SME-R1	81.5	67.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	94.6	100	100	94.3	94.0	78.1	100	93.5
	SME-R2	N/A	N/A	77.0	89.6	89.1	60.3	80.1	88.8	89.3	81.3
	SMW-R1	72.8	66.8	84.3	57.8	95.0	84.0	87.3	54.4	94.6	93.3
	SMW-R2	69.4	68.1	87.0	82.2	84.8	83.3	84.2	72.7	94.0	94.2
RCID	RC-P1	N/A	N/A	N/A	N/A	93.9	88.5	93.1	N/A	N/A	N/A
WID	W-P1	79.2	81.6	93.9	95.0	95.0	100	88.1	94.6	100	100
	W-P2	84.2	84.3	91.4	90.0	94.6	90.0	90.1	89.7	100	100
	W-S1	73.3	81.0	88.2	88.4	95.0	100	93.6	94.9	94.9	100
	W-S2	78.0	73.5	94.6	60.2	89.7	100	89.3	95.0	100	100
	W-S3	85.0	42.8	92.9	84.3	85.1	100	82.2	77.1	95.0	89.6
	W-S4	82.1	66.5	88.3	85.1	88.9	86.8	85.3	89.7	79.2	93.7
	W-R1a	N/A	N/A	95.0	89.5	84.9	94.4	43.9	83.6	94.1	88.3
	W-R2	70.0	62.0	79.6	80.8	83.0	81.9	80.0	77.6	83.0	83.7
BRID	BR-P1	93.9	94.0	100	100	100	100	92.2	75.0	80.7	100
	BR-S1	93.5	93.7	95.0	100	100	89.8	43.1	83.0	94.8	94.7
	BR-S2	78.0	87.4	83.5	93.9	94.0	100	75.4	N/A	N/A	N/A
	BR-S3	91.4	94.0	100	100	100	94.5	94.6	70.2	100	100
	BR-S4	86.2	94.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	89.9	93.8	92.0	95.0	100	100
	BR-S5	82.8	100	100	100	100	95.0	76.2	94.6	100	95.0
	BR-R1	86.9	87.6	100	100	100	95.0	92.0	88.9	92.6	94.7
	BR-R2	73.0	77.8	80.2	95.0	88.0	89.0	78.2	83.6	88.7	87.8
	BR-R3	65.2	74.0	85.7	77.1	80.7	83.6	77.3	67.4	87.9	80.1
	BR-R4	82.6	91.4	100	95.0	87.3	87.8	66.6	70.7	94.7	93.3
	BR-R5	73.8	94.0	100	95.0	100	89.7	87.4	79.8	100	100
	BR-R6	N/A	86.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	81.5	94.3	92.5	69.5	N/A	N/A	N/A

Table B1 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
EID	E-P1	100	81.8	100	94.6	93.9	95.0	100	100	100	95.0
	E-S1	93.2	93.3	93.9	94.6	100	100	100	95.0	100	95.0
	E-S2	90.2	100	100	100	95.0	100	94.0	88.4	100	100
	E-S3	88.0	82.0	94.4	94.9	89.1	94.9	100	77.9	100	100
	E-S4	94.0	100	49.9	100	91.6	100	100	95.0	95.0	100
	E-S5	100	100	100	100	100	100	94.6	95.0	100	100
	E-S6	94.0	94.0	95.0	95.0	100	100	94.9	89.7	100	100
	E-S7	N/A	N/A	94.4	95.0	83.0	94.8	100	N/A	N/A	N/A
	E-S8	N/A	N/A	72.3	71.3	64.7	71.4	74.1	67.0	87.9	86.5
	E-R1	58.5	54.5	N/A	58.8	86.7	74.0	65.3	65.0	90.0	93.0
	E-R1a	N/A	N/A	82.5	57.7	93.8	88.3	94.8	N/A	N/A	N/A
	E-R2	67.7	62.8	N/A	81.4	45.3	79.5	87.9	47.7	90.8	86.6
	E-R2a	N/A	N/A	57.9	76.1	87.2	50.9	80.2	45.3	84.1	88.9
	E-R3	86.2	87.5	N/A	77.9	92.5	91.8	85.6	52.6	88.8	67.9
	E-R3a	N/A	N/A	68.7	83.1	85.5	87.6	79.4	N/A	N/A	N/A
	E-R4	93.9	81.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	81.2	83.7	90.2	92.8	51.8	88.5	100
	E-R5	74.8	93.8	N/A	100	92.9	92.6	95.0	89.2	100	68.1
	E-R5a	N/A	N/A	66.6	86.3	82.7	75.7	60.9	N/A	N/A	N/A
	E-R6	N/A	N/A	49.8	76.4	82.6	61.1	73.0	N/A	N/A	N/A
	E-R7	N/A	N/A	48.9	80.5	88.6	53.7	56.2	N/A	N/A	N/A
	E-R8	N/A	N/A	71.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	85.7	63.4	73.3	69.5	69.8	54.4	80.7	78.7
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-P2	88.0	74.8	83.7	79.1	95.0	83.7	39.6	N/A	N/A	N/A
	AEP-P3	94.0	89.5	86.0	61.8	89.3	94.8	100	N/A	N/A	N/A
	AEP-S1	100	91.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-S2	94.0	100	90.4	100	95.0	100	89.5	N/A	N/A	N/A
	AEP-S3	94.0	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B.2 Irrigation water quality metals sub-index values and categories.
N/A indicates data not available, usually due the site not being sampled.
Categories are color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
MVID	MV-P1	100	100	100	100	100	100	100
	MV-R1	100	100	100	100	100	100	100
AID	A-P1	100	100	N/A	N/A	N/A	N/A	N/A
	A-R1	100	100	100	100	100	100	100
UID	U-P1	100	100	100	100	100	100	100
	U-S1	100	100	100	100	100	100	100
	U-R1	93.4	100	N/A	N/A	N/A	N/A	N/A
	U-R2	100	100	100	100	93.4	100	100
	U-R3	N/A	N/A	97	89.9	85.2	100	100
	U-R4	N/A	N/A	N/A	100	100	100	100
MID	M-P1	100	100	100	100	100	100	100
	M-P2	100	100	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	100	100	100	100	100
	M-R1	100	100	100	100	100	100	100
RID	R-P1	100	100	100	100	100	100	100
	R-R1	100	100	100	100	100	100	100
	R-R2	100	100	90.0	100	100	100	100
LNID	LN-P1	100	100	100	100	93.4	100	100
	LN-S1	100	100	100	100	97	100	100
	LN-S2	100	100	100	100	100	100	100
	LN-S3	100	100	100	100	100	100	100
	LN-S4	100	100	100	100	100	100	100
	LN-S5	100	100	100	100	100	100	100
	LN-R1	93.1	90.0	90.1	88.2	100	93.4	100
	LN-R2	100	100	100	100	100	100	100
	LN-R3	N/A	N/A	100	100	100	100	100
	LN-R4	N/A	N/A	N/A	100	100	100	100
TID	T-P1	100	100	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	100	100	100	100	100
	T-P2	100	100	100	100	100	100	100
	T-S2	100	100	100	100	100	100	100
	T-S3	100	100	100	100	100	100	100
	T-R1	100	100	100	100	100	100	100
	T-R2	100	100	100	100	100	100	100
SMRID	SMC-P1	100	100	100	100	100	100	100
	SME-P1	100	100	100	100	100	100	100
	SMW-P1	100	100	100	100	100	100	100
	SMC-S1	100	100	100	100	100	100	100
	SMC-S2	100	100	100	100	100	100	100
	SMC-S3	100	100	100	100	100	100	100

***Table B2** Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
SMRID cont'd	SME-S1	100	97	100	100	100	100	100
	SMW-S1	100	100	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	100	100	100	100	100
	SMC-R1	100	100	100	100	100	100	100
	SMC-R3	100	100	100	100	100	100	100
	SMC-R4	100	100	100	100	100	100	100
	SME-R1	97	100	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	100	100	100	100	100
	SME-R2	N/A	N/A	97	100	97	100	100
	SMW-R1	100	100	100	100	100	100	100
	SMW-R2	100	100	100	100	100	100	100
RCID	RC-P1	N/A	N/A	N/A	N/A	97	100	100
WID	W-P1	100	100	100	100	100	100	100
	W-P2	100	100	100	100	100	100	100
	W-S1	100	100	100	100	100	100	100
	W-S2	100	100	100	100	100	100	100
	W-S3	100	100	100	100	100	100	100
	W-S4	100	100	100	100	100	100	100
	W-R1a	N/A	N/A	100	100	100	100	100
	W-R2	100	100	100	97	100	100	100
BRID	BR-P1	100	100	100	100	100	100	100
	BR-S1	100	100	100	100	100	100	100
	BR-S2	100	100	100	100	100	100	100
	BR-S3	100	100	100	100	100	100	100
	BR-S4	100	100	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	100	100	100
	BR-S5	100	100	100	100	100	100	100
	BR-R1	100	100	100	100	100	100	100
	BR-R2	100	100	100	100	100	100	100
	BR-R3	100	100	100	100	100	100	100
	BR-R4	100	100	97	100	96	100	100
	BR-R5	100	100	100	100	100	100	100
	BR-R6	N/A	100	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	100	100	100	100
EID	E-P1	100	100	100	100	100	100	100
	E-S1	100	100	100	100	100	100	100
	E-S2	100	100	100	100	100	100	100
	E-S3	100	100	100	100	100	100	100
	E-S4	100	97	100	100	100	100	100
	E-S5	100	100	100	100	100	100	100
	E-S6	100	100	100	100	100	100	100
	E-S7	N/A	N/A	100	100	97	100	100

***Table B2** Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
EID cont'd	E-S8	N/A	N/A	100	97	100	100	100
	E-R1	100	100	N/A	100	100	100	100
	E-R1a	N/A	N/A	100	100	100	100	100
	E-R2	100	100	N/A	100	97	100	100
	E-R2a	N/A	N/A	97	100	100	100	93.4
	E-R3	100	100	N/A	100	100	100	100
	E-R3a	N/A	N/A	100	100	100	100	100
	E-R4	100	100	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	100	100	100	100
	E-R5	100	100	N/A	100	100	100	100
	E-R5a	N/A	N/A	100	100	100	100	97
	E-R6	N/A	N/A	97	100	100	100	100
	E-R7	N/A	N/A	100	100	100	100	100
	E-R8	N/A	N/A	86.4	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	100	100	100	100	100
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A
	AEP-P2	100	100	100	100	100	100	100
	AEP-P3	100	100	100	85.2	100	100	100
	AEP-S1	100	100	N/A	N/A	N/A	N/A	N/A
	AEP-S2	100	100	100	100	100	100	100
	AEP-S3	100	97	N/A	N/A	N/A	N/A	N/A

Table B.3 Livestock water quality general/pesticide sub-index values and categories.
N/A indicates data not available usually due the site not being sampled.
Categories color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
MVID	MV-P1	100	100	100	100	100	100	100	100	100	100
	MV-R1	100	100	100	100	100	100	100	100	100	100
AID	A-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A-R1	100	100	100	100	100	100	100	100	100	100
UID	U-P1	100	100	100	100	100	100	100	100	100	100
	U-R1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	U-S1	100	100	100	100	100	100	100	100	100	100
	U-R2	100	100	100	100	100	100	100	100	100	100
	U-R3	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	U-R4	N/A	N/A	N/A	100	100	100	100	N/A	N/A	N/A
MID	M-P1	100	100	100	100	100	100	100	100	100	100
	M-P2	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	100	100	100	100	100	100	100	100
	M-R1	100	100	100	100	100	100	100	96.9	100	100
RID	R-P1	100	100	100	100	100	100	100	100	100	100
	R-R1	100	100	100	100	100	100	100	100	100	100
	R-R2	100	100	100	100	100	100	100	100	100	100
LNID	LN-P1	100	100	100	100	100	100	100	100	100	100
	LN-S1	100	100	100	100	100	100	100	100	100	100
	LN-S2	100	100	100	100	100	100	100	100	100	100
	LN-S3	100	100	100	100	100	100	100	100	100	100
	LN-S4	100	100	100	100	100	100	100	100	100	100
	LN-S5	100	100	100	100	100	100	100	100	100	100
	LN-R1	100	100	100	100	100	100	100	100	100	100
	LN-R2	100	100	100	100	100	100	100	100	100	100
	LN-R3	N/A	N/A	100	100	100	100	100	100	100	100
	LN-R4	N/A	N/A	N/A	100	100	100	100	100	100	96.9
	LN-R5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100
	LN-R6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100
TID	T-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	100	100	100	100	100	100	100	100
	T-P2	100	100	100	100	100	100	100	100	100	100
	T-S2	100	100	100	100	100	100	100	100	100	100
	T-S3	100	100	100	100	100	100	100	100	100	100
	T-R1	100	100	100	100	100	100	100	100	100	100
	T-R2	100	100	100	100	100	100	100	100	100	100
SMRID	SMC-P1	100	100	100	100	100	100	100	100	100	100
	SME-P1	100	100	100	100	100	100	100	100	100	100
	SMW-P1	100	100	100	100	100	100	100	100	100	100

Table B.3 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
SMRID Cont'd	SMC-S1	100	100	100	100	100	100	100	100	100	100
	SMC-S2	100	100	100	100	100	100	100	100	100	100
	SMC-S3	100	100	100	100	100	100	100	100	100	100
	SME-S1	100	100	100	100	100	100	100	100	100	100
	SMW-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	100	100	100	100	100	100	100	100
	SMC-R1	100	100	100	100	100	100	100	100	100	100
	SMC-R3	100	100	100	100	100	100	100	100	100	100
	SMC-R4	100	100	100	100	100	100	100	100	100	100
	SME-R1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	100	100	100	100	100	100	100	100
	SME-R2	N/A	N/A	100	100	100	100	100	100	100	100
	SMW-R1	100	100	100	100	100	100	100	100	100	100
	SMW-R2	100	100	100	100	100	100	100	100	100	100
RCID	RC-P1	N/A	N/A	N/A	N/A	100	100	100	N/A	N/A	N/A
WID	W-P1	100	100	100	100	100	100	100	100	100	100
	W-P2	100	100	100	100	100	100	100	100	100	100
	W-S1	100	100	100	100	100	100	100	100	100	100
	W-S2	100	100	100	100	100	100	100	100	100	100
	W-S3	100	100	100	100	100	100	100	100	100	100
	W-S4	100	100	100	100	100	100	100	100	100	100
	W-R1a	N/A	N/A	100	100	100	100	100	100	100	100
	W-R2	100	100	100	100	100	100	100	100	100	100
BRID	BR-P1	100	100	100	100	100	100	100	100	100	100
	BR-S1	100	100	100	100	100	100	96.7	100	100	100
	BR-S2	100	100	100	100	100	100	100	N/A	N/A	N/A
	BR-S3	100	100	100	100	100	100	100	100	100	100
	BR-S4	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	100	100	100	100	100	100
	BR-S5	100	100	100	100	100	100	100	100	100	100
	BR-R1	100	100	100	100	100	100	100	100	100	100
	BR-R2	100	100	100	100	100	100	100	100	100	100
	BR-R3	100	100	100	100	100	100	100	100	100	100
	BR-R4	100	100	100	100	100	100	100	100	100	100
	BR-R5	100	100	100	100	100	100	100	100	100	100
	BR-R6	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	100	100	100	100	N/A	N/A	N/A
EID	E-P1	100	100	100	100	100	100	100	100	100	100
	E-S1	100	100	100	100	100	100	100	100	100	100
	E-S2	100	100	100	100	100	100	100	100	100	100
	E-S3	100	100	100	100	100	100	100	100	100	100

Table B.3 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
EID Cont'd	E-S4	100	100	100	100	100	100	100	100	100	100
	E-S5	100	100	100	100	100	100	100	100	100	100
	E-S6	100	100	100	100	100	100	100	100	100	100
	E-S7	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-S8	N/A	N/A	100	100	100	100	100	100	100	100
	E-R1	100	100	N/A	100	100	100	100	100	100	100
	E-R1a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R2	100	100	N/A	100	100	100	100	100	100	100
	E-R2a	N/A	N/A	100	100	100	100	100	100	100	100
	E-R3	100	100	N/A	100	100	100	100	100	100	100
	E-R3a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R4	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	100	100	100	100	100	100	100
	E-R5	100	100	N/A	100	100	100	100	100	100	100
	E-R5a	N/A	N/A	96.6	100	100	100	100	N/A	N/A	N/A
	E-R6	N/A	N/A	95.9	100	100	100	100	N/A	N/A	N/A
	E-R7	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R8	N/A	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	100	100	100	100	100	100	100	100
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-P2	100	100	100	100	100	100	92.6	N/A	N/A	N/A
	AEP-P3	100	100	100	100	100	100	100	N/A	N/A	N/A
	AEP-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-S2	100	100	100	100	100	100	100	N/A	N/A	N/A
	AEP-S3	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B.4 Livestock water quality metals sub-index values and categories.
N/A indicates data not available usually due the site not being sampled.
Categories color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
MVID	MV-P1	100	100	100	100	100	100	100
	MV-R1	100	100	100	100	100	100	100
AID	A-P1	100	100	N/A	N/A	N/A	N/A	N/A
	A-R1	100	100	100	100	100	100	100
UID	U-P1	100	100	100	100	100	100	100
	U-S1	100	100	100	100	100	100	100
	U-R1	96.3	100	N/A	N/A	N/A	N/A	N/A
	U-R2	100	100	100	100	96.3	100	100
	U-R3	N/A	N/A	100	96.2	95.6	100	100
	U-R4	N/A	N/A	N/A	100	100	100	100
MID	M-P1	100	100	100	100	100	100	100
	M-P2	100	100	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	100	100	100	100	100
	M-R1	100	100	100	100	100	100	100
RID	R-P1	100	100	100	100	100	100	100
	R-R1	100	100	100	100	100	100	100
	R-R2	100	100	96.3	100	100	100	100
LNID	LN-P1	100	100	100	100	96.3	100	100
	LN-S1	100	100	100	100	100	100	100
	LN-S2	100	100	100	100	100	100	100
	LN-S3	100	100	100	100	100	100	100
	LN-S4	100	100	100	100	100	100	100
	LN-S5	100	100	100	100	100	100	100
	LN-R1	96.3	96.3	96.3	95.4	100	100	100
	LN-R2	100	100	100	100	100	100	100
	LN-R3	N/A	N/A	100	100	100	100	100
	LN-R4	N/A	N/A	N/A	100	100	100	100
TID	T-P1	100	100	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	100	100	100	100	100
	T-P2	100	100	100	100	100	100	100
	T-S2	100	100	100	100	100	100	100
	T-S3	100	100	100	100	100	100	100
	T-R1	100	100	100	100	100	100	100
	T-R2	100	100	100	100	100	100	100
SMRID	SMC-P1	100	100	100	100	100	100	100
	SME-P1	100	100	100	100	100	100	100
	SMW-P1	100	100	100	100	100	100	100
	SMC-S1	100	100	100	100	100	100	100
	SMC-S2	100	100	100	100	100	100	100

Table B.4 Continued

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
SMRID cont'd	SMC-S3	100	100	100	100	100	100	100
	SME-S1	100	100	100	100	100	100	100
	SMW-S1	100	100	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	100	100	100	100	100
	SMC-R1	100	100	100	100	100	100	100
	SMC-R3	100	100	100	100	100	100	100
	SMC-R4	100	100	100	100	100	100	100
	SME-R1	100	100	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	100	100	100	100	100
	SME-R2	N/A	N/A	100	100	100	100	100
	SMW-R1	100	100	100	100	100	100	100
	SMW-R2	100	100	100	100	100	100	100
RCID	RC-P1	N/A	N/A	N/A	N/A	100	100	100
WID	W-P1	100	100	100	100	100	100	100
	W-P2	100	100	100	100	100	100	100
	W-S1	100	100	100	100	100	100	100
	W-S2	100	100	100	100	100	100	100
	W-S3	100	100	100	100	100	100	100
	W-S4	100	100	100	100	100	100	100
	W-R1a	N/A	N/A	100	100	100	100	100
	W-R2	100	100	100	100	100	100	100
BRID	BR-P1	100	100	100	100	100	100	100
	BR-S1	100	100	100	100	100	100	100
	BR-S2	100	100	100	100	100	100	100
	BR-S3	100	100	100	100	100	100	100
	BR-S4	100	100	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	100	100	100
	BR-S5	100	100	100	100	100	100	100
	BR-R1	100	100	100	100	100	100	100
	BR-R2	100	100	100	100	100	100	100
	BR-R3	100	100	100	100	100	100	100
	BR-R4	100	100	100	100	100	100	100
	BR-R5	100	100	100	100	100	100	100
	BR-R6	N/A	100	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	100	100	100	100
EID	E-P1	100	100	100	100	100	100	100
	E-S1	100	100	100	100	100	100	100
	E-S2	100	100	100	100	100	100	100
	E-S3	100	100	100	100	100	100	100
	E-S4	100	100	100	100	100	100	100
	E-S5	100	100	100	100	100	100	100
	E-S6	100	100	100	100	100	100	100

Table B.4 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015
EID Cont'd	E-S7	N/A	N/A	100	100	96.3	100	100
	E-S8	N/A	N/A	100	100	100	100	100
	E-R1	100	100	N/A	100	100	100	100
	E-R1a	N/A	N/A	100	100	100	100	100
	E-R2	100	100	N/A	100	100	100	100
	E-R2a	N/A	N/A	100	100	100	100	96.3
	E-R3	100	100	N/A	100	100	100	100
	E-R3a	N/A	N/A	100	100	100	100	100
	E-R4	100	100	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	100	100	100	100
	E-R5	100	100	N/A	100	100	100	100
	E-R5a	N/A	N/A	100	100	100	100	100
	E-R6	N/A	N/A	100	100	100	100	100
	E-R7	N/A	N/A	100	100	100	100	100
	E-R8	N/A	N/A	96.2	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	100	100	100	100	100
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A
	AEP-P2	100	100	100	100	100	100	100
	AEP-P3	100	100	100	95.8	100	100	100
	AEP-S1	100	100	N/A	N/A	N/A	N/A	N/A
	AEP-S2	100	100	100	100	100	100	100
	AEP-S3	100	100	N/A	N/A	N/A	N/A	N/A

Table B.5 Protection of aquatic life water quality general sub-index values and categories.
N/A indicates data not available usually due the site not being sampled.
Categories color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
MVID	MV-P1	100	100	100	100	100	100	100	100	100	100
	MV-R1	100	90.0	100	100	100	100	100	100	100	100
AID	A-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A-R1	100	90.0	100	100	100	100	100	100	100	100
UID	U-P1	100	100	100	100	100	100	100	100	100	100
	U-S1	100	100	100	100	100	100	100	100	100	100
	U-R1	67.6	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	U-R2	90.1	100	100	100	100	100	100	100	100	100
	U-R3	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	U-R4	N/A	N/A	N/A	100	100	100	80.2	N/A	N/A	N/A
MID	M-P1	100	100	100	100	100	100	100	100	100	100
	M-P2	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	100	100	100	100	100	100	100	100
	M-R1	100	100	100	100	100	100	100	100	100	100
RID	R-P1	90.0	100	100	100	100	100	100	100	100	100
	R-R1	100	100	89.9	89.1	90.0	90.1	100	100	100	100
	R-R2	100	100	100	100	100	100	100	100	100	100
LNID	LN-P1	100	100	100	100	100	100	100	100	100	100
	LN-S1	100	100	100	100	100	100	100	100	100	100
	LN-S2	100	100	100	100	100	100	100	100	100	100
	LN-S3	100	100	100	100	80.1	80.1	100	100	100	100
	LN-S4	100	100	100	100	100	90.1	100	100	100	100
	LN-S5	80.1	100	80.2	79.4	90.1	80.2	78.5	100	87.1	87.1
	LN-R1	100	100	100	100	100	100	100	100	100	100
	LN-R2	100	100	100	100	100	100	100	100	100	100
	LN-R3	N/A	N/A	100	100	100	100	100	100	100	100
	LN-R4	N/A	N/A	N/A	100	100	100	100	100	100	89.2
	LN-R5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	89.6
	LN-R6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100
TID	T-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	100	100	100	100	100	100	100	100
	T-P2	100	100	100	100	100	100	100	100	100	100
	T-S2	77.9	78.5	80.1	77.9	76.5	75.3	78.1	89.2	90.0	88.0
	T-S3	78.2	77.3	100	80.1	78.1	76.7	90.1	79.9	90.0	89.2
	T-R1	78.3	100	100	78.1	77.8	74.1	78.4	90.1	100	100
	T-R2	78.4	100	100	79.4	78.4	78.5	90.1	90.1	100	89.2
SMRID	SMC-P1	100	100	100	100	100	100	100	100	100	100
	SME-P1	100	100	100	100	80.1	100	100	100	100	100
	SMW-P1	100	100	100	100	100	100	100	100	100	100
	SMC-S1	100	100	100	100	100	100	100	100	100	100

Table B.5 *Continued.*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
SMRID cont'd	SMC-S2	100	100	100	100	100	100	100	100	100	100
	SMC-S3	100	100	100	89.9	100	100	100	100	100	100
	SME-S1	78.3	80.1	100	79.1	100	80.1	79.3	100	100	87.1
	SMW-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	100	100	100	100	100	100	100	100
	SMC-R1	78.5	100	100	100	100	100	100	100	100	100
	SMC-R3	75.4	100	100	100	100	100	80.1	100	100	100
	SMC-R4	100	100	100	100	100	100	100	100	100	100
	SME-R1	78.5	80.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	100	80.1	100	100	80.1	100	100	88.1
	SME-R2	N/A	N/A	100	100	100	100	100	100	100	100
	SMW-R1	100	100	100	100	100	100	100	100	100	100
	SMW-R2	100	100	80.2	80.1	79.2	79.4	80.1	100	100	100
RCID	RC-P1	N/A	N/A	N/A	N/A	78.3	78.0	75.3	N/A	N/A	N/A
WID	W-P1	100	100	100	100	100	100	100	90.1	100	100
	W-P2	100	100	100	100	100	100	100	100	100	100
	W-S1	100	80.2	100	100	100	100	100	100	100	100
	W-S2	100	100	100	100	100	100	100	100	100	100
	W-S3	100	90.1	100	100	100	100	100	100	100	100
	W-S4	100	100	80.2	90.1	80.2	100	100	100	100	100
	W-R1a	N/A	N/A	90.1	90.1	80.2	100	100	100	100	100
	W-R2	100	100	100	100	90.1	100	100	100	100	100
BRID	BR-P1	100	100	100	100	100	100	100	100	100	100
	BR-S1	100	100	100	100	100	100	100	100	100	100
	BR-S2	71.4	73.6	80.1	78.4	78.0	75.5	77.3	N/A	N/A	N/A
	BR-S3	100	100	100	100	100	100	100	100	100	100
	BR-S4	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	100	100	100	100	100	100
	BR-S5	80.2	100	100	100	100	100	100	100	100	100
	BR-R1	100	100	100	100	100	100	100	100	100	100
	BR-R2	100	100	100	100	100	100	100	100	100	100
	BR-R3	100	100	89.2	90.1	79.2	70.1	90.1	90.0	88.1	100
	BR-R4	100	100	100	100	90.1	90.1	100	100	100	100
	BR-R5	87.5	80.2	100	100	100	100	100	100	100	100
	BR-R6	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	100	90.1	100	100	N/A	N/A	N/A
EID	E-P1	100	100	100	100	100	100	100	100	100	100
	E-S1	100	100	100	100	100	100	100	100	100	100
	E-S2	100	100	100	100	100	100	100	100	100	100
	E-S3	100	100	100	100	100	100	100	100	100	100
	E-S4	100	100	100	100	100	100	100	100	100	100
	E-S5	100	100	100	100	100	100	100	100	100	100

***Table B.5** Continued.*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
EID cont'd	E-S6	80.2	90.0	100	85.1	100	79.4	80.2	100	100	100
	E-S7	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-S8	N/A	N/A	90.0	100	89.0	100	100	100	100	100
	E-R1	100	100	N/A	80.2	100	100	100	100	100	100
	E-R1a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R2	100	100	N/A	100	100	100	100	100	100	100
	E-R2a	N/A	N/A	100	100	100	100	100	100	100	100
	E-R3	100	53.2	N/A	100	100	100	100	100	100	100
	E-R3a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R4	80.2	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	100	100	100	100	100	100	100
	E-R5	100	100	N/A	100	100	100	100	100	100	100
	E-R5a	N/A	N/A	66.6	100	78.4	79.4	78.5	N/A	N/A	N/A
	E-R6	N/A	N/A	80.3	100	100	100	100	N/A	N/A	N/A
	E-R7	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R8	N/A	N/A	89.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	100	90.1	100	100	100	100	100	100
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-P2	100	80.2	100	100	100	100	100	N/A	N/A	N/A
	AEP-P3	100	100	100	100	100	100	100	N/A	N/A	N/A
	AEP-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-S2	100	100	100	100	100	100	100	N/A	N/A	N/A
	AEP-S3	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B.6. Protection of aquatic life water quality pesticide sub-index values and categories.
N/A indicates data not available usually due the site not being sampled.
Categories color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
MVID	MV-P1	100	100	100	100	100	100	100	100	100	100
	MV-R1	100	100	100	100	100	100	100	100	100	100
AID	A-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	A-R1	100	100	100	100	100	100	100	100	100	100
UID	U-P1	100	100	100	100	100	100	100	100	100	100
	U-S1	100	100	100	100	100	100	100	96.9	100	100
	U-R1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	U-R2	100	100	100	100	100	100	100	95.9	100	100
	U-R3	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	U-R4	N/A	N/A	N/A	100	97.2	100	100	N/A	N/A	N/A
MID	M-P1	100	100	100	100	100	100	100	100	100	100
	M-P2	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	M-S1	N/A	N/A	100	100	100	100	100	100	100	100
	M-R1	100	100	97.3	100	100	100	100	93.9	100	100
RID	R-P1	100	100	100	100	100	100	100	100	100	100
	R-R1	100	100	100	100	100	100	100	100	100	100
	R-R2	100	100	100	100	100	100	100	96.8	100	100
LNID	LN-P1	100	100	100	100	100	100	100	100	100	100
	LN-S1	100	100	100	100	100	100	100	100	100	100
	LN-S2	100	100	100	100	100	100	100	100	100	100
	LN-S3	100	100	100	100	100	100	100	100	100	100
	LN-S4	100	100	100	100	100	100	100	100	100	100
	LN-S5	100	100	100	100	100	100	100	100	100	100
	LN-R1	100	100	100	100	100	100	100	100	100	100
	LN-R2	100	100	100	100	100	100	100	100	100	100
	LN-R3	N/A	N/A	100	100	100	97.3	97.2	100	100	100
	LN-R4	N/A	N/A	N/A	100	100	100	100	100	100	100
	LN-R5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100
	LN-R6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	100	100
TID	T-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	T-P1a	N/A	N/A	100	100	100	100	100	100	100	100
	T-P2	100	100	100	100	100	100	100	100	100	100
	T-S2	100	100	100	100	100	100	100	100	100	100
	T-S3	100	100	100	100	100	100	100	100	100	100
	T-R1	100	100	100	100	100	100	100	100	100	100
	T-R2	100	100	100	100	100	100	100	100	100	100
SMRID	SMC-P1	100	100	100	100	100	100	100	100	100	100
	SME-P1	100	100	100	100	100	100	100	100	100	100
	SMW-P1	100	100	100	100	100	100	100	100	100	100
	SMC-S1	100	100	100	100	100	100	100	100	100	100

Table B.6 Continued

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
SMRID cont'd	SMC-S2	100	100	100	100	100	100	100	100	100	100
	SMC-S3	100	100	100	100	100	100	100	100	100	100
	SME-S1	100	100	100	100	100	100	100	100	100	100
	SMW-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SMW-S2	N/A	N/A	100	100	100	100	100	100	100	100
	SMC-R1	91.9	100	100	100	100	100	100	100	100	100
	SMC-R3	100	100	100	100	100	100	100	97.2	100	100
	SMC-R4	100	100	100	100	100	100	100	100	100	100
	SME-R1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SME-R1a	N/A	N/A	100	100	97.3	100	100	100	100	100
	SME-R2	N/A	N/A	100	100	100	100	100	100	100	100
	SMW-R1	100	100	100	100	100	100	100	97.1	100	100
	SMW-R2	100	100	100	100	100	100	100	100	100	100
RCID	RC-P1	N/A	N/A	N/A	N/A	100	100	100	N/A	N/A	N/A
WID	W-P1	100	100	100	100	100	100	100	100	100	100
	W-P2	100	100	100	100	100	100	100	100	100	100
	W-S1	100	100	100	100	100	100	100	100	100	100
	W-S2	100	100	100	100	100	100	100	100	100	100
	W-S3	100	94.8	100	100	100	100	100	100	100	100
	W-S4	100	95.3	100	100	100	100	100	100	100	100
	W-R1a	N/A	N/A	97.3	100	100	100	94.3	100	100	100
	W-R2	100	100	100	97.3	100	97.1	100	100	100	100
BRID	BR-P1	100	100	100	100	100	100	100	100	100	100
	BR-S1	100	100	100	100	100	100	87.7	100	100	100
	BR-S2	100	100	100	100	100	100	100	N/A	N/A	N/A
	BR-S3	100	100	100	100	100	100	100	100	100	100
	BR-S4	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-S4a	N/A	N/A	100	100	100	100	100	100	100	100
	BR-S5	100	100	100	100	100	100	100	100	100	100
	BR-R1	100	100	100	100	100	100	100	100	100	100
	BR-R2	100	100	97.1	100	100	100	100	100	100	100
	BR-R3	100	100	96.5	100	100	100	100	100	100	100
	BR-R4	100	100	100	100	100	100	100	100	100	100
	BR-R5	100	100	100	100	100	100	100	100	100	100
	BR-R6	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	BR-R7	N/A	N/A	N/A	100	100	100	100	N/A	N/A	N/A
EID	E-P1	100	100	100	100	100	100	100	100	100	100
	E-S1	100	100	100	100	100	100	100	100	100	100
	E-S2	100	100	100	100	100	100	100	100	100	100
	E-S3	100	100	100	100	97.2	100	100	100	100	100
	E-S4	100	100	100	100	100	100	100	100	100	100
	E-S5	100	100	100	100	100	100	100	100	100	100

Table B.6 *Continued*

Irrigation District	Site	2006	2007	2011	2012	2013	2014	2015	2016	2017	2018
EID cont'd	E-S6	100	100	100	100	100	100	100	100	100	100
	E-S7	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-S8	N/A	N/A	100	100	100	100	100	100	100	100
	E-R1	100	100	N/A	100	100	100	100	100	100	100
	E-R1a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R2	100	100	N/A	100	97.3	100	100	100	100	100
	E-R2a	N/A	N/A	100	100	100	100	100	100	100	100
	E-R3	100	100	N/A	100	100	100	100	100	100	100
	E-R3a	N/A	N/A	100	100	96.7	100	100	N/A	N/A	N/A
	E-R4	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R4a	N/A	N/A	N/A	100	100	100	100	97.1	100	100
	E-R5	100	100	N/A	100	100	100	100	100	100	100
	E-R5a	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R6	N/A	N/A	100	100	100	100	100	N/A	N/A	N/A
	E-R7	N/A	N/A	100	100	100	100	94.6	N/A	N/A	N/A
	E-R8	N/A	N/A	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-R8a	N/A	N/A	100	100	100	100	100	100	100	100
AEP canals	AEP-P1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-P2	100	100	100	100	100	100	77.0	N/A	N/A	N/A
	AEP-P3	100	100	100	97.1	100	100	100	N/A	N/A	N/A
	AEP-S1	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AEP-S2	100	100	100	100	100	100	100	N/A	N/A	N/A
	AEP-S3	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table B.7 Protection of aquatic life water quality metals sub-index values and categories. N/A indicates data not available usually due the site not being sampled.

Categories color-coded as Excellent Good Fair Marginal Poor

Irrigation District	Site	2011	2012	2013	2014	2015
MVID	MV-P1	100	100	100	100	100
	MV-R1	100	100	95.7	100	100
AID	A-R1	100	100	100	100	100
UID	U-P1	100	100	100	100	100
	U-S1	100	100	100	100	100
	U-R2	100	100	91.5	100	100
	U-R3	95.3	82.8	68.1	95.2	100
	U-R4	N/A	100	100	100	95.6
MID	M-P1	100	100	100	100	100
	M-S1	100	100	100	100	100
	M-R1	100	100	100	91.5	95.7
RID	R-P1	100	100	100	100	100
	R-R1	95.1	95.7	100	91.5	100
	R-R2	87.1	100	100	95.7	100
LNID	LN-P1	95.7	100	91.4	100	100
	LN-S1	100	100	91.5	100	100
	LN-S2	100	100	100	100	100
	LN-S3	95.7	100	100	100	100
	LN-S4	100	100	100	100	100
	LN-S5	100	100	100	100	100
	LN-R1	82.2	80.5	95.7	86.9	95.7
	LN-R2	100	100	100	100	100
	LN-R3	100	100	100	100	100
	LN-R4	N/A	100	100	100	100
TID	T-P1a	100	100	100	100	100
	T-P2	100	100	100	100	95.7
	T-S2	100	100	100	100	95.7
	T-S3	100	100	100	100	100
	T-R1	70.7	100	100	100	95.7
	T-R2	100	100	100	100	100
SMRID	SMC-P1	100	100	100	100	100
	SME-P1	100	100	95.5	100	100
	SMW-P1	100	100	100	100	100
	SMC-S1	100	100	100	100	100
	SMC-S2	100	100	100	100	100
	SMC-S3	100	100	100	100	100
	SME-S1	95.7	95.7	100	95.7	95.7
	SMW-S2	100	100	100	100	100
	SMC-R1	100	100	100	100	100
	SMC-R3	100	100	100	100	100

Table B.7 *Continued*

Irrigation District	Site	2011	2012	2013	2014	2015
SMRID Cont'd	SMC-R4	100	100	100	100	100
	SME-R1a	100	95.7	100	95.7	95.4
	SME-R2	100	100	95.7	100	100
	SMW-R1	100	100	100	100	100
	SMW-R2	100	100	100	100	100
RCID	RC-P1	N/A	N/A	94.7	93.6	92.7
WID	W-P1	100	100	100	100	100
	W-P2	100	100	100	100	100
	W-S1	100	100	100	100	100
	W-S2	100	100	100	100	100
	W-S3	100	100	100	100	100
	W-S4	100	100	100	100	100
	W-R1a	100	100	100	100	100
	W-R2	100	87.2	100	100	100
BRID	BR-P1	100	100	100	100	95.7
	BR-S1	100	100	100	100	95.7
	BR-S2	95.3	95.7	95.4	91.1	95.7
	BR-S3	100	100	100	100	95.7
	BR-S4a	100	100	100	95.7	100
	BR-S5	100	100	100	100	95.7
	BR-R1	100	100	100	100	95.7
	BR-R2	100	100	100	100	95.7
	BR-R3	100	100	95.7	95.7	100
	BR-R4	100	100	100	100	100
	BR-R5	100	100	100	100	95.7
	BR-R7	N/A	100	100	100	95.7
EID	E-P1	100	100	100	100	100
	E-S1	100	100	100	100	100
	E-S2	100	100	100	100	100
	E-S3	100	100	100	100	100
	E-S4	100	100	95.6	100	100
	E-S5	100	100	100	100	100
	E-S6	100	100	100	100	100
	E-S7	100	100	95.7	100	100
	E-S8	100	100	100	100	100
	E-R1	N/A	100	100	100	100
	E-R1a	100	100	100	100	100
	E-R2	N/A	100	100	100	100
	E-R2a	85.6	94.1	100	95.7	86.3
	E-R3	N/A	100	100	100	100
	E-R3a	100	100	100	100	100
	E-R4a	N/A	100	100	100	100

Table B.7 *Continued*

Irrigation District	Site	2011	2012	2013	2014	2015
	E-R5	N/A	100	100	100	100
	E-R5a	100	100	100	100	100
	E-R6	100	100	100	100	100
	E-R7	100	100	100	100	100
	E-R8	82.4	N/A	N/A	N/A	N/A
	E-R8a	100	100	100	100	100
AEP canals	AEP-P2	100	100	100	100	100
	AEP-P3	100	71.6	100	100	100
	AEP-S2	100	100	100	100	100