Technical Report

A Review of Dugout and Well Water Tested for Livestock Quality in Southern Saskatchewan

Collection Dates: July 5 to October 11 2017

By:

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Introduction

Water supplies for grazing livestock in Saskatchewan come from a variety of surface sources that include dugouts, holding ponds, sloughs, dams, streams as well as underground sources from springs and man-made well structures. All surface and underground water sources contain organic and inorganic compounds and contaminants that may affect odor and taste and/or internal digestive and metabolic function. For livestock producers, there are concerns from elevated concentrations of organic and inorganic compounds that negatively impact livestock. During the summer months when temperatures can exceed 35ºC in Saskatchewan, there will be an increase in water consumption by livestock, furthering the importance and impact that water quality can have.

In the summer of 2017, minimal precipitation and high temperatures increased the importance of water consumption for free range grazing livestock. The calendar year of 2017 was one of the driest on record for the Southern Saskatchewan region and over that period Regina had the lowest amount of precipitation since 1885. For the months of July, August and September Maple Creek, Swift Current and Regina all experienced below normal monthly precipitation with an average of only 8 mm/month at each location (Environment Canada: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html).

For the period of July 5 to October 13, 2017, the Saskatchewan Ministry of Agriculture Regional Services Offices in Moose Jaw and Swift Current received water samples that were tested for quality related to livestock use. The samples were forwarded to the Saskatchewan Disease Control Laboratory (Saskatchewan Ministry of Health) for a general chemical analysis for the tests shown in Table 1. Water samples taken from dugout, well, dam, slough, creek, coulee, pipeline, surface and other sources were tested for general water quality.

This study is focused on submitted dugout and well water samples used for livestock watering, and details the conductivity (EC) in microsiemens per centimetre (µS/cm), sulphate (SO_4) in milligrams per litre (mg/L) and calculated total dissolved solids (TDS) in mg/L in the period of July 5 to October 13, 2017.

Definitions and Abbreviations

Electrical conductivity is measured as µS/cm. Conductivity is a measure of the water's ability to pass an electric current. Conductivity is affected by the amount of ions present in the water (United States Environmental Protection Agency: http://www.epa.gov/national-aquatic-resource-surveys/indicators-conductivity).

Total dissolved solids comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and nitrate (Health Canada 1991; https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-total-dissolved-solids-tds.html).

Ruminant animals have a unique method of sulphur metabolism and as such are at higher risk of adverse reactions to high levels of sulphate in their drinking water. When ruminant animals are subjected to high levels of dietary sulpher they are prone to a central nervous system disorder known as polioencephalomalacia (PEM), a sulphur induced brain tissue necrosis (The Merck Veterinary Manual 2010). High levels of sulphates in ruminant diets can impair thiamine synthesis resulting in a possible thiamine deficit in the animal (Olkowski, 2009). Sulphates also interact with several essential minerals in the animal, having a negative effect of metabolism of these minerals. This can often induce trace mineral deficiency in the animal (Olkowski, 2009). The sulphur component accounts for one third of the sulphate concentration in water which can contribute to elevated consumption of total dietary sulphur.

Abbreviations:
EC = Electrical Conductivity, TDS = Total Dissolved Solids, SO_4 = Sulphate(s), SD = Standard Deviation

Materials and Methods

From July 5 to October 11 2017, water samples from a variety of sources were submitted to Saskatchewan Ministry of Agriculture Regional Service Offices in Moose Jaw and Swift Current. Samples were analyzed by the Saskatchewan Disease Control Laboratory in Regina Saskatchewan for the components in Table 1. Samples were analyzed using the following appropriate methods from *Standard Methods for the Examination of Water and Wastewater*, Rice, E.W., Baird, R.B., Eaton, A.D., Clesceri, L.S., (eds) 22nd Edition, American Public Health Association, Washington, D.C.: American Public Health Association, 2012.

Alkalinity Method 2320 B

pH Method 4500-H^+ B

Conductivity Method 2510 B

Cations and Hardness Method 3120 B

Anions Method 4110 B

Results were identified by source with means and standard deviations calculated for the following parameters: conductivity, total dissolved solid, sulphate, total dissolved solid as a percent of conductivity, sulphate as a percent of conductivity and sulphate as a percent of total dissolved solids. The samples were further sorted and grouped in 1,000 µS/cm conductivity intervals and analyzed for mean and standard deviation with further analysis to determine, sensitivity , specificity and prevalence. Analysis of dugouts and wells were separated from the data set and reported upon individually as they consisted of 75% of the submitted samples. All samples, dugout water and well water were tabulated and ranked by water quality ranges according to Olkowski 2009.

Results and Discussion

Tables

A total of 555 samples were submitted for testing during the period of July 4 to October 11, 2017 (Table 2). The majority of samples (61.8%) originated from surface water sources described by clients as “Dugouts”, followed by “Other” sources (14.6%), well water (13.0%) and “Surface” sources (4.1%). The remaining water sources were identified as dam holding areas, slough, creek, coulee and pipeline. This report will focus on the dugout and well data. The “Other” and “Surface” sources were not unique enough as an identification label to be analyzed as they could be identified with several other category labels.

Table 3 reports the mean values with corresponding standard deviation (SD) for EC, TDS and SO_4 for all samples, dugouts and well water sources. Table 3 also shows TDS and SO_4 means reported as a percentage of conductivity with the corresponding SD. Sulphate means were also calculated as a percentage of TDS (Table 3). In many cases (All Samples: TDS, SO_4, Dugout: TDS, SO_4, Well: SO_4) the SD was greater than the calculated mean. This confirms that there is extreme variation between individual samples in all three categories. This extreme variation between samples suggests that there is little merit in using the mean value for any of these quality indicators as a tool for decision making. These means indicate that each individual sample of water, regardless of source, is unique.

As shown in Table 3 the means of the TDS as a percentage of EC for all samples, dugout and well water were 89.3%, 89.5% and 87.6%. The SO_4 as a percentage of EC for all samples, dugout and well water was 41.1%, 41.0% and 36.6%. The $S0_4$ as a percentage of TDS for all samples, dugout and well water was 44.4%, 44.0% and 40.9%. These calculated percentages indicate a possible trend for well water to record lower percentages of TDS and SO_4 in measured EC (since the SDs of the values 44.4, 44 and 40.9% are larger than the difference between these values this is just a possible trend of decreasing percentage). Current conversion standards for TDS as a percentage of EC have been suggested as ranging from 59-96% with a common percentage of 67% utilized (Olkowski 2009). The results in this report suggest TDS is a larger proportion of measured EC than 67% which should be further analyzed to establish a more accurate benchmark for dugout, well and all water sources for grazing livestock in Southern Saskatchewan.

Dugout and well water sources were further categorized into Good, Satisfactory, Caution and Not Recommended classifications for livestock water quality (Tables 4, 5 and 6). Total dissolved solid levels of 3,000-5,000 mg/L are considered "Cautionary" and >5,000 mg/L "Not Recommended". Sulphate levels of 1,000-2,000 mg/L are considered "Cautionary" and >2,000 mg/L "Not Recommended". When all 555 samples were categorized into livestock quality standards 34.6% and 45.9% of TDS and SO4 were classified as "Not Recommended". When 343 dugout samples were categorized into livestock quality standards 38.2% and 48.4% of TDS and SO_4 were classified as "Not Recommended". When 72 well water samples were categorized into livestock quality standards 13.9% and 29.2% of TDS and SO_4 were classified as "Not Recommended". Based on these comparisons, fewer well water than dugout samples were considered "Not Recommended for Livestock Consumption" and likely a better source for grazing livestock. The extreme dry weather conditions was the probable cause of the inferior quality of the surface water sources which became more concentrated in minerals due to the lack of rainfall and greater evaporation. However, given the extreme variations in standard deviation for all samples when grouped by 1,000 units of TDS or EC, water quality, regardless of source should be tested individually and not estimated by mean values.

Tables 7, 8 and 9 are the calculated mean and standard deviation of TDS, SO_4, TDS% of EC, SO_4% of TDS and SO_4% of EC for all sources, dugout and well water in southern Saskatchewan received between July 5 and October 13 2017 as grouped per 1,000 µS/cm intervals. These tables clearly show that TDS as a percentage of EC steadily increases along with EC. Sulphate as a percent of TDS also increased as TDS increased as expected; ranging from 9 to 63 percent of TDS perhaps reaching maximum conversion sooner than TDS. As the EC reached levels greater than 3000 µS/cm the mean SO_4 reached 49% of TDS. Above 4000 µS/cm EC the mean SO_4 as a percent of TDS ranged from 58 to 67 percent. Suggesting that at higher conductivity readings SO_4 contributes more to TDS than at lower EC readings. This is confirmed when the sulphates are examined as a percentage of EC. With higher readings of EC the percentage of sulphates increases.

Table 10 is the result of calculating sensitivity, specificity, positive predictive value and negative predictive value using electric conductivity on all the water samples as a predictor of high sulphate levels in the water as analyzed at the laboratory. Two separate cutoff values are used for electrical conductivity; >3,500 µS/cm EC compared to high sulphate levels > 2,000 mg/L SO_4 and 4,250 µS/cm EC compared to high sulphate levels>2,500 mg/L SO_4. The goal of sensitivity and specificity testing is to establish confidence that when a water sample is analyzed for electrical conductivity (Murphy 1994, Chu 1999), we can accurately predict a safe level of sulphate in the water. Sensitivity of the diagnostic test (electrical conductivity) refers to the ability of the test to detect water samples with high sulphate levels. Specificity of the diagnostic test (electrical conductivity) refers to the ability of the test to detect water samples that have low sulphate levels. The two sulphate concentrations of 2,000 mg/L (Beede, 2012) and 2,500 mg/L (Alberta Agriculture Agri-Facts 2007) were designated as maximum not-recommended levels to be present in livestock water sources before animal harm may occur and sensitivities and specificities were calculated at both of these levels. For the designated 2,000 mg/L SO_4 cutoff, sensitivity was 99.6% and specificity was 88.2% when EC cutoff is defined at 3,500 µS/cm. For the livestock water samples that tested at >3,500 µS/cm EC, 99.6% of the samples will contain greater than 2,000 mg/L sulphate (true positive) and 88.2% of the samples that tested <3,500 µS/cm will contain less than 2,000 mg/L sulphate (true negative). For the designated 2,500 mg/L SO_4, sensitivity was 100% and specificity was 91.9% when EC cutoff is defined at 4,250 µS/cm. For the livestock water samples that tested >4,250 µS/cm EC, 100% of the samples will contain more than 2,500 mg/L sulphate (true positive) and 91.9% of the samples that tested <4,250 µS/cm will contain <2,500 mg/L sulphate (true negative).

The positive predictive value provides the probability of having high sulphates given that the water tests above the cutoff of electrical conductivity. The negative predictive provides the probability of having low sulphate levels given that the water tests below the cutoff for electrical conductivity. Both of these values are affected by sensitivity and specificity of the diagnostic test, but are also influenced by the prevalence of high sulphate water in our collection of samples. In this set of water samples the prevalence of high sulphate water was 46.3% (using high sulphate definition of >2000 mg/L) or 40.8% (using high sulphate definition of >2500 mg/L). Given that this was a significant drought year in much of Saskatchewan, the prevalence of high sulphate water would be considered high in this sample group. It should be noted that predictive values will change depending on the prevalence of high sulphate water. The positive predictive value for an Electrical conductivity > 3500 µS/cm was 87.9% which means that given a water sample with an electrical conductivity measurement > 3500 µS/cm, we are 87.9% confident that that water will have sulphates >2000 mg/L. The negative predictive value for an Electrical conductivity < 3500 µS/cm was 99.6% which means if a water sample tested below 3500 µS/cm we were 99.6% sure that the sulphate levels in the water were less than 2000 mg/L. Similarly, if the electrical conductivity was >4250 µS/cm we were 89.5% confident that the water contained sulphates >2500 mg/L and if the electrical conductivity was < 4250 µS/cm, we were 100% confident that the water sample contained < 2500 mg/L.

The two cutoff values for defining high sulphate conditions of 2,000 mg/L and 2,500 mg/L of water SO_4 was chosen to allow for interpretation of different feeding parameters associated with each herd consuming the select water source. If feed sources known to contain high sulphur, cattle are consuming less 40% forage (up to 85% grain) in the diet, or ambient temperatures are driving water consumption higher, then a water source with a maximum of 2,000 mg/L (and 3,500 µS/cm) is desired. If grazing ruminants are consuming feeds low in sulphur and the diet is primarily forage based when daytime ambient temperatures are not higher than 24ºC driving higher water consumption, then a maximum of 2,500 mg/L $S0_4$ in the water source may be suitable.

Figures

Figure 1 illustrates the number of water samples categorized in 1,000 µS/cm measured EC intervals for dugout and well sources. Dugout water samples submitted trended from high to low in the intervals ranging from 1-1,000 µS/cm to >20,000 µS/cm. Well water samples remained equal in submission numbers in the EC of 1-4,000 µS/cm intervals and trended lower in higher EC ranges. Approximately half (n=176) of submitted dugout samples had EC of 0-4,000 µS/cm with the remaining samples measuring 4,001 µs/cm and higher (Table 8). Approximately half (n=38) of submitted well samples had EC of 0-3,000 µS/cm with the remaining samples measuring 3,001 µS/cm had higher (Table 9). These results again demonstrate the greater influence of the arid weather conditions on the dugout water sources than on the well samples.

Figures 2 and 3 illustrate the mean of calculated TDS and sulphate content as grouped by 1,000 µS/cm intervals for dugout and well water. Calculated TDS of both dugout and well water increased as the measured EC increased (Figure 2). Standard deviation exhibited much less variation when means are grouped per 1,000 µS/cm intervals, and increasing SD for samples that measured in the 15,001 – 20,000 and >20,000 µS/cm ranges. None of the well samples submitted for testing measured >12,000 µS/cm EC. Measured SO_4 of both dugout and well water increased as the measured EC increased (Figure 3). Standard deviation trends for SO_4 were similar to those for the TDS values. Well water tended to contain less SO_4 mg/L than dugout water per 1,000 µS/cm interval groups.

Figure 4 shows TDS as a percentage of EC and grouped by 1,000 µS/cm intervals for dugout and well water. The TDS was less than 80% for both dugout and well water when EC was 1-1,000 µS/cm. From 1,001 to 9,000 µS/cm, the TDS ranged from 80 to under 100% of EC with a trend to increasing percentage as EC increased in measurement. At an EC of 10,000 µS/cm, TDS was measured greater than 100% for well water and slightly under for dugout water, and from 10,001 to 20,000 µS/cm dugout water tended to calculate greater than 100% of the measured EC. Dugout water TDS increased from 78% to 115% of EC as EC increased 0 to 20,000+ µS/cm. Well water TDS increased from 79 to 107% of EC as EC increased from 0 to 11,000 µS/cm. These results suggest that as EC content increases in dugout and well water the TDS concentration will increase at a slightly higher pace and can surpass the measured EC beyond 11,000 µS/cm. Standard deviation appears to be larger for EC intervals 4,000 µS/cm and lower for both dugout and well samples.

Figures 5 and 6 show sulphate expressed as a percentage of TDS and EC as grouped by 1,000 mg/L intervals for dugout and well water. The SO_4 for both dugout and well samples rapidly increased as a percentage of TDS and appears to plateau at 58-60% of TDS when TDS intervals are 5,000 – 6,000 mg/L. Dugout SO_4 percent of TDS remains between 60-70% after 6,000 mg/L TDS. Well water SO_4 as a percent of TDS rapidly increases until TDS reaches 5,000 mg/L where SO_4 is between 50-60% of TDS, and begins to plateau through to 9,000 mg/L. At 10,000 mg/L TDS and greater well water SO_4 content means between 60-70% of TDS mg/L. Standard deviations were greater for SO_4% of TDS from 1,000 to 10,000 mg/L TDS with lower deviation between interval grouped samples from 11,000 mg/L and higher. As with SO_4% of TDS, both dugout and well water SO_4 increased as a percentage of EC as EC increased in the samples. Standard deviation levels were greater at lower EC measurement interval groups than at higher levels. The sulphates also appear to plateau starting between 50-60% of EC and starting at 5,000 µS/cm.

Conclusions

In the summer of 2017, minimal precipitation and high temperatures increased the importance of water consumption for free range grazing livestock. From July 5 to October 13, 2017 over 555 water samples were submitted and tested for quality related to livestock use. The majority of samples were from dugout water sources (61%) and 13% of the samples were directly identified as well water. Using a maximum of 5,000 mg/L TDS and 2,000 mg/L $S0_4$, 38.2% and 48.4% of dugout water were not acceptable for livestock use. The number of well water samples not acceptable for livestock use by TDS and SO_4 quality standards were 13.9% and 29.2%.

Average values for TDS and SO_4 were not useful to assist in establishing quality levels for an individual water sample due to extreme variation and standard deviation values higher than the calculated means. Thus, it is recommended that each water sample be tested individually for quality and be aware that there is no accuracy in comparing a single sample against calculated averages.

Metering devices that measure conductivity are a common method in establishing the quality of water, and TDS and SO_4 commonly are estimated as a percentage of the EC. It was observed from this data set that TDS and SO_4 content increased as the EC increased. Total dissolved solids as a percent of EC ranged from 87.6% (well) to 89.5(dugout) with lower conversions occurring at lower EC readings. From the water samples submitted in 2017, a conversion factor of 89% is suggested. However there were a number of samples whereby TDS was >100% of the measured EC indicating that in practicality the conversion of TDS from EC is not exact. However, a conversion factor of 87-89% is more prevalent in this data set. When testing subsequent samples from livestock water sources in southern Saskatchewan a conversion of 67% should not be the sole conversion factor considered as it may not accurately reflect the true TDS content of the sample.

Sulphate content also increased as EC increased. The percentage of SO_4 of EC was lowest at lower EC readings. However, at low EC readings, the SO_4 content was highly variable with large SD from 1,000 – 7,000 µS/cm from both dugout and well samples. For all the water samples submitted, SO_4 was 41.1% of EC and 44.4% of TDS. Because sulphates in water are directly implicated in ruminant animal health (polioencaphalomalacia, thiamin synthesis impairment and trace mineral binding), it was desirable to establish an accurate EC to SO_4 ratio to determine a more rapid screening of potential SO_4 content in water.

The water samples submitted in 2017 were highly accurate when analyzed for specificity and sensitivity to establish a confidence of SO_4 content in water when EC is measured. When combined with high rates of positive predictive and negative predictive values, there is strong evidence to suggest that <= 3,500 µS/cm EC is an accurate cutoff value for the water to contain <=2,000 mg/L SO_4 and that <=4,250 µS/cm EC is an accurate cutoff point for the water sample to contain <=2,500 mg/L SO_4.

Table 1. Water Analysis Components tested by the Saskatchewan Disease Control Laboratory, Saskatchewan Ministry of Health, Regina, Saskatchewan.

General Chemistry Panel	**Unit**
Conductivity	µS/cm
pH	pH
Total Alkalinity	mg/L $CaCO_3$
Phenol Alkalinity	mg/L $CaCO_3$
Bicarbonate	mg/L
Carbonate	mg/L
Hydroxide	mg/L
Chloride Dissolved	mg/L
Fluoride Dissolved	mg/L
Nitrate Dissolved	mg/L
Sulphate Dissolved	mg/L
Total Hardness (Calculated) [1]	mg/L $CaCO_3$
Total Dissolved Solids (Calculated) [2]	mg/L
Iron	mg/L
Manganese	mg/L
Calcium	mg/L
Magnesium	mg/L
Potassium	mg/L
Sodium	mg/L

[1] Total Hardness (Calculated): Calculated by adding (components) calcium and magnesium Total Hardness = 2.497 * [Ca, mg /L] + 4.118 * [Mg, mg /L]
[2] Total Dissolved Solids: Calculated by adding (components).
$TDS = HCO_3^- + CO_3^{2-} + OH^- + Na^+ + K^+ + Ca^{2+} + Mg^{2+} + Cl^- + NO_3^- + SO_4^-$

Table 2. Water sample sources submitted for testing to Saskatchewan Ministry of Agriculture, July 4 to October 11 2017.

Source	**Number of Samples**	**Percent**
Dugout	343	61.8
Other [1]	81	14.6
Well	72	13.0
Surface [1]	23	4.1
Dam	13	2.3
Slough	11	2.0
Creek	10	1.8
Coulee	1	0.2
Pipeline	1	0.2
TOTAL	555	100

[1] Sources "Other" and "Surface" were not analyzed in this report due to ambiguous identification of source.

Table 3. Mean and standard deviation of water samples collected in southern Saskatchewan, July 5 to October 11 2017.

Parameter	Unit	Mean	Standard Deviation
All Samples (n=555)			
Conductivity	µS/cm	4,893	4,841
Total Dissolved Solid	mg/L	4,760	5,450
Sulphate	mg/L	2,816	3,682
TDS, % of Conductivity	%	89.3	10.6
Sulphate, % of Conductivity	%	41.1	23.3
Sulphate, % of Total Dissolved Solids	%	44.4	23.2
Dugout (n=343)			
Conductivity	µS/cm	4,948	4,725
Total Dissolved Solid	mg/L	4,831	5,274
Sulphate	mg/L	2,898	3,580
TDS, % of Conductivity	%	89.5	11.1
Sulphate, % of Conductivity	%	41.0	24.5
Sulphate, % of Total Dissolved Solids	%	44.0	24.4
Well Water (n=72)			
Conductivity	µS/cm	3,239	2,417
Total Dissolved Solid	mg/L	2,968	2,438
Sulphate	mg/L	1,523	1,631
TDS, % of Conductivity	%	87.6	8.0
Sulphate, % of Conductivity	%	36.6	18.6
Sulphate, % of Total Dissolved Solids	%	40.9	19.3

Table 4. Distribution of all water samples (n=555) by recommended water quality ranges for total dissolved solids and sulphates. Samples were collected from July 5 to October 11 2017 from locations in southern Saskatchewan.

	Range (mg/L)	Samples	Percent
Total Dissolved Solids			
Good	0-1500	164	29.5
Satisfactory	1500-3000	93	16.8
Caution	3000-5000	106	19.1
Not Recommended	> 5000	192	34.6
Sulphates			
Good	0-500	167	30.1
Satisfactory	500-1000	47	8.5
Caution	1000-2000	86	15.5
Not Recommended	> 2000	255	45.9

Table 5. Distribution of dugout water samples (n=343) by recommended water quality ranges for total dissolved solids and sulphates. Samples were collected from July 5 to October 11 2017 from locations in southern Saskatchewan.

	Range (mg/L)	Samples	Percent
Total Dissolved Solids			
Good	0-1500	108	31.5
Satisfactory	1500-3000	48	14.0
Caution	3000-5000	56	16.3
Not Recommended	> 5000	131	38.2
Sulphates			
Good	0-500	107	31.2
Satisfactory	500-1000	30	8.7
Caution	1000-2000	40	11.7
Not Recommended	> 2000	166	48.4

Table 6. Distribution of well water samples (n=72) by recommended water quality ranges for total dissolved solids and sulphates. Samples were collected from July 5 to October 11 2017 from locations in southern Saskatchewan.

	Range (mg/L)	Samples	Percent
Total Dissolved Solids			
Good	0-1500	25	34.7
Satisfactory	1500-3000	23	31.9
Caution	3000-5000	14	19.4
Not Recommended	> 5000	10	13.9
Sulphates			
Good	0-500	26	36.1
Satisfactory	500-1000	8	11.1
Caution	1000-2000	17	23.6
Not Recommended	> 2000	21	29.2

Table 7. Mean and standard deviation measurements of livestock water (n=555) in south Saskatchewan collected between July 5 and October 11 2017.

		TDS, mg/L		SO_4, mg/L		TDS, % of EC		SO_4, % of TDS		SO_4, % of EC	
EC, µS/cm	Count	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0-1,000	105	433	189	44	56	79	9	9	11	7	8
1,001 - 2,000	73	1,218	287	360	228	84	8	29	17	24	13
2,001 - 3,000	53	2,080	277	945	356	84	6	45	15	38	13
3,001 - 4,000	63	3,097	351	1,542	482	88	6	49	14	44	13
4,001 - 5,000	47	4,116	316	2,401	434	91	4	58	8	53	8
5,001 - 6,000	44	5,013	479	2,987	545	91	6	59	8	54	9
6,001 - 7,000	41	6,081	383	3,629	861	93	5	59	13	56	13
7,001 - 8,000	23	7,195	364	4,477	347	96	4	62	4	60	5
8,001 - 9,000	28	8,154	385	5,137	503	96	5	63	5	60	6
9,001 - 10,000	20	9,434	561	6,098	657	100	5	65	4	64	7
10,001 - 11,000	17	10,705	655	6,935	915	103	5	65	6	66	8
11,001 - 12,000	10	12,132	628	8,177	717	106	4	67	3	72	6
12,001 - 13,000	2	12,524	21	7,610	666	99	0	61	5	60	5
13,001 - 14,000	4	14,618	326	9,659	425	108	3	66	2	72	4
14,001 - 15,000	6	15,659	459	10,371	545	108	2	66	3	72	3
15,001 - 20,000	10	18,601	1,744	12,138	1,331	109	5	65	2	71	6
20,000 +	9	32,132	10,683	20,630	7,914	114	10	63	8	73	14

Table 8. Mean and standard deviation measurements of dugout water (n=343) in south Saskatchewan collected between July 5 and October 11 2017.

		TDS, mg/L		SO_4, mg/L		TDS, % of EC		SO_4, % of TDS		SO_4 , % of EC	
EC, µS/cm	Count	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0-1,000	72	436	213	37	29	78	34	8	6	6	4
1,001 - 2,000	46	1,214	297	363	226	84	7	29	17	24	13
2,001 - 3,000	30	2,045	259	945	365	83	5	46	16	38	14
3,001 - 4,000	28	3,198	346	1,602	482	89	6	50	14	44	12
4,001 - 5,000	22	4,105	315	2,415	459	92	3	59	9	54	9
5,001 - 6,000	30	5,020	505	3,034	550	91	7	60	7	55	9
6,001 - 7,000	29	6,158	356	3,712	832	94	5	60	12	57	13
7,001 - 8,000	14	7,143	326	4,452	293	96	3	62	4	60	4
8,001 - 9,000	18	8,199	433	5,245	527	96	5	64	5	62	7
9,001 - 10,000	16	9,291	531	5,907	586	98	5	63	4	63	6
10,001 - 11,000	10	11,065	546	7,395	526	105	4	67	2	70	5
11,001 - 12,000	8	12,045	676	8,023	725	105	4	67	3	70	5
12,001 - 13,000	1	12,538		8,081		99		64		64	
13,001 - 14,000	2	14,362	111	9,352	402	107	5	65	2	70	6
14,001 - 15,000	6	15,659	459	10,371	545	108	2	66	3	72	3
15,001 - 20,000	7	18,840	1,860	12,494	1,219	111	3	66	2	73	2
20,000 +	4	32,254	10,945	20,955	7,161	115	11	65	4	75	11

Table 9. Mean and standard deviation measurements of well water (n=72) in south Saskatchewan collected between July 5 and October 11 2017.

		TDS, mg/L		SO_4, mg/L		TDS, % of EC		SO_4, % of TDS		SO_4, % of EC	
EC, µS/cm	Count	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0-1,000	12	486	117	91	26	79	18	18	5	13	4
1,001 - 2,000	13	1,137	220	346	234	84	6	30	17	25	13
2,001 - 3,000	13	2,194	302	912	463	82	22	39	16	35	15
3,001 - 4,000	13	2,954	358	1,463	500	88	7	48	15	43	13
4,001 - 5,000	7	4,144	340	2,256	282	91	3	54	5	50	5
5,001 - 6,000	5	4,801	319	2,570	104	92	4	54	3	49	3
6,001 - 7,000	1	5,606	-	2,457	-	85	-	44	-	37	-
7,001 - 8,000	4	7,281	586	4,222	339	97	6	58	2	56	4
8,001 - 9,000	1	8,209	-	4,811	-	93	-	59	-	55	-
9,001 - 10,000	2	10,185	52	6,971	199	107	4	68	2	73	5
10,001 - 11,000	1	10,113	-	6,486	-	99	-	64	-	64	-
11,001 - 12,000	0	-	-	-	-	-	-	-	-	-	-

Table 10. Sensitivity, specificity, positive predictive value and negative predictive value of water sulphate at 2,000 mg/L and 3,500 µS/cm EC and 2,500 mg/L and 4,250 µS/cm EC.

	Sulphate cutoff: 2,000 mg/L, Conductivity cutoff: 3,500 µS/cm			Sulphate cutoff: 2,500 mg/L, Conductivity cutoff: 4,250 µS/cm		
	High Sulphate	Low Sulphate	Total	High Sulphate	Low Sulphate	Total
High Conductivity						
Count	261	36	297	231	27	258
Percent	99.62	11.84	52.47	100.0	8.06	45.58
Low Conductivity						
Count	1	268	269	0	308	308
Percent	0.38	88.16	47.53	0	91.94	54.42
Total						
Count	262	304	566	231	335	566
Sensitivity, %			99.6			100.0
Specificity, %			88.2			91.9
Prevalence, %			46.3			40.8
Positive Predictive Value, %			87.9			89.5
Negative Predictive Value, %			99.6			100.0

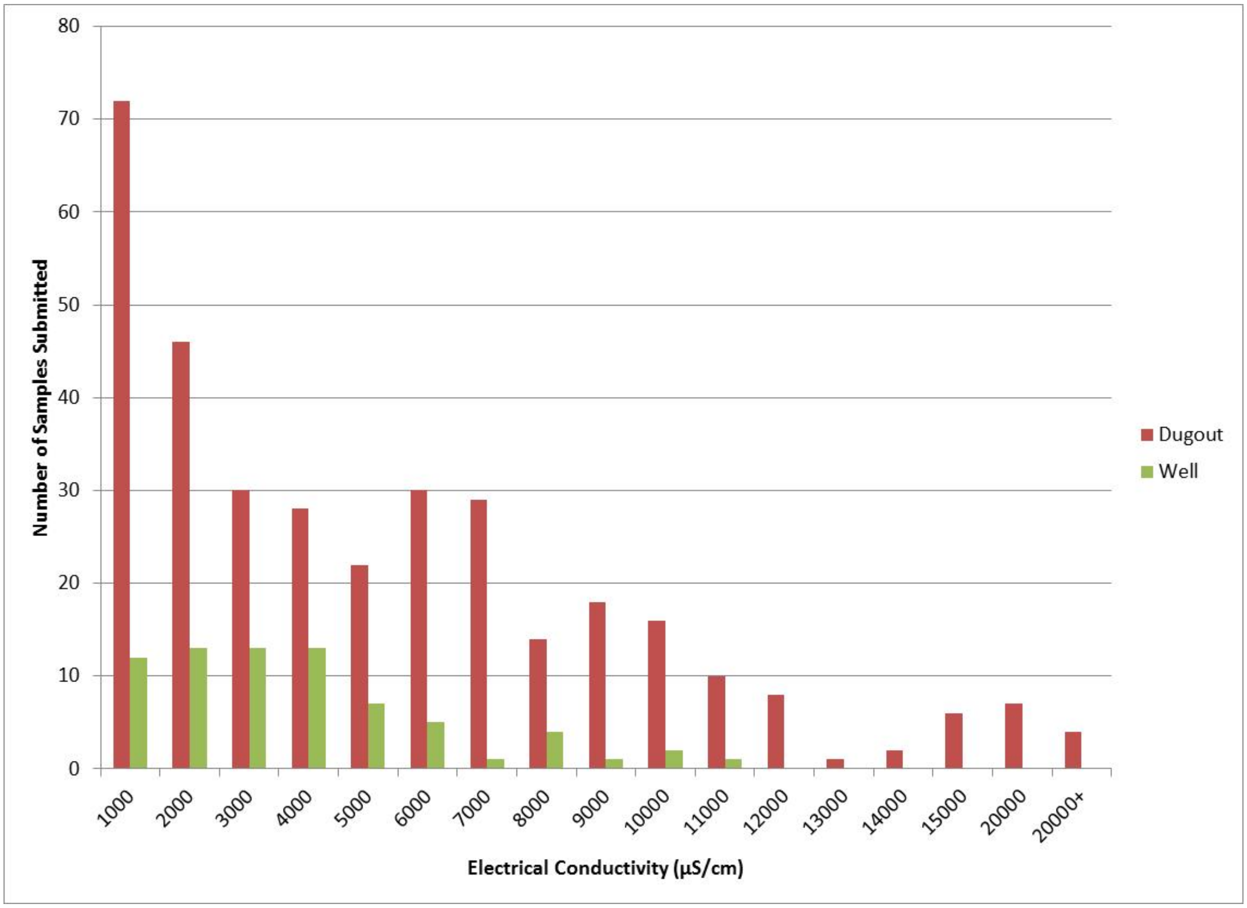

Figure 1. Number of water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Note: samples numbers are categorized per 1,000 µS/cm intervals.

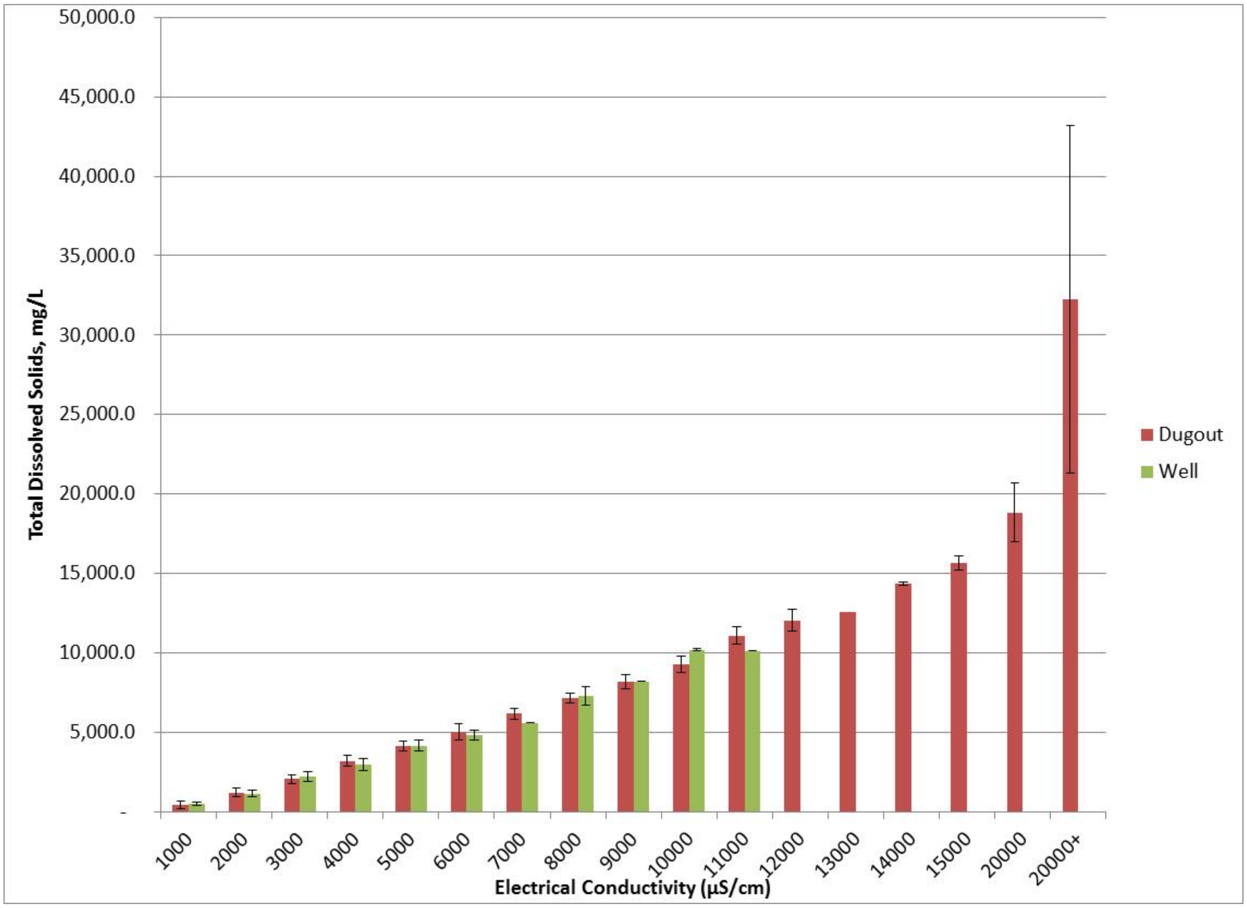

Figure 2. Mean total dissolved solid content (mg/L) of water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Means are for each 1,000 µS/cm intervals and bars indicate standard deviation per grouped interval.

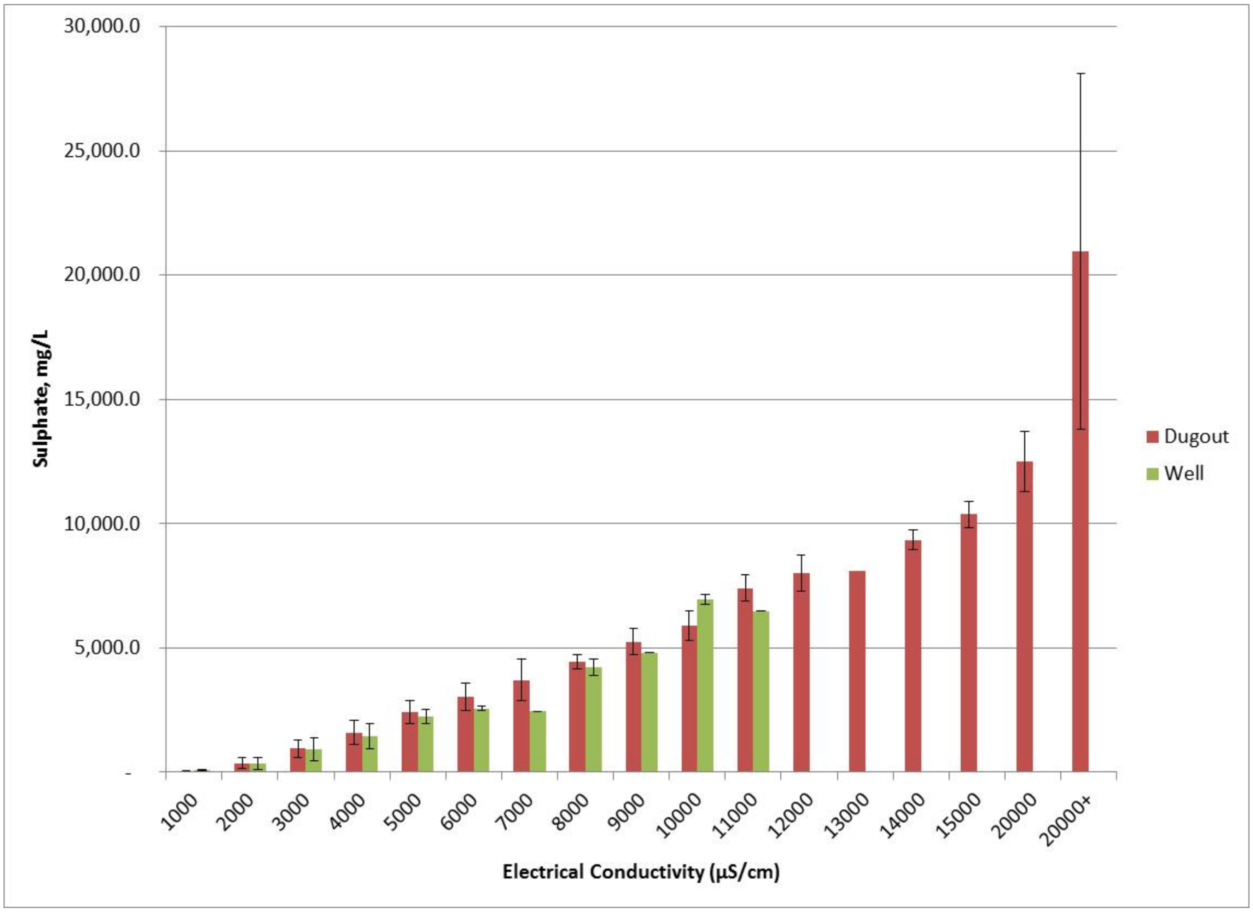

Figure 3. Mean sulphate content (mg/L) of water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Means are for each 1,000 µS/cm intervals and bars indicate standard deviation per grouped interval.

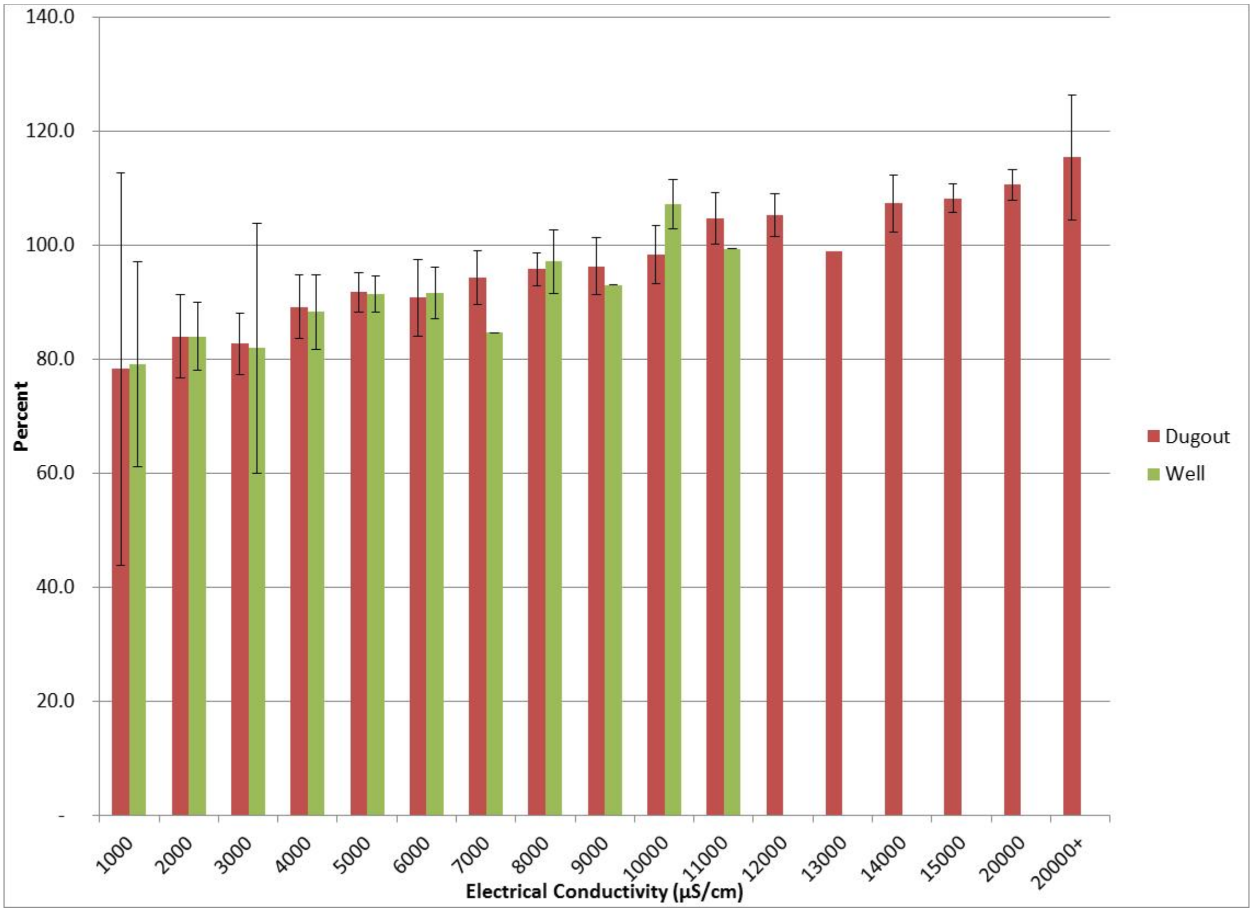

Figure 4. Total dissolved solids expressed as a percentage of electrical conductivity for water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Means are for each 1,000 µS/cm intervals and bars indicate standard deviation per grouped interval.

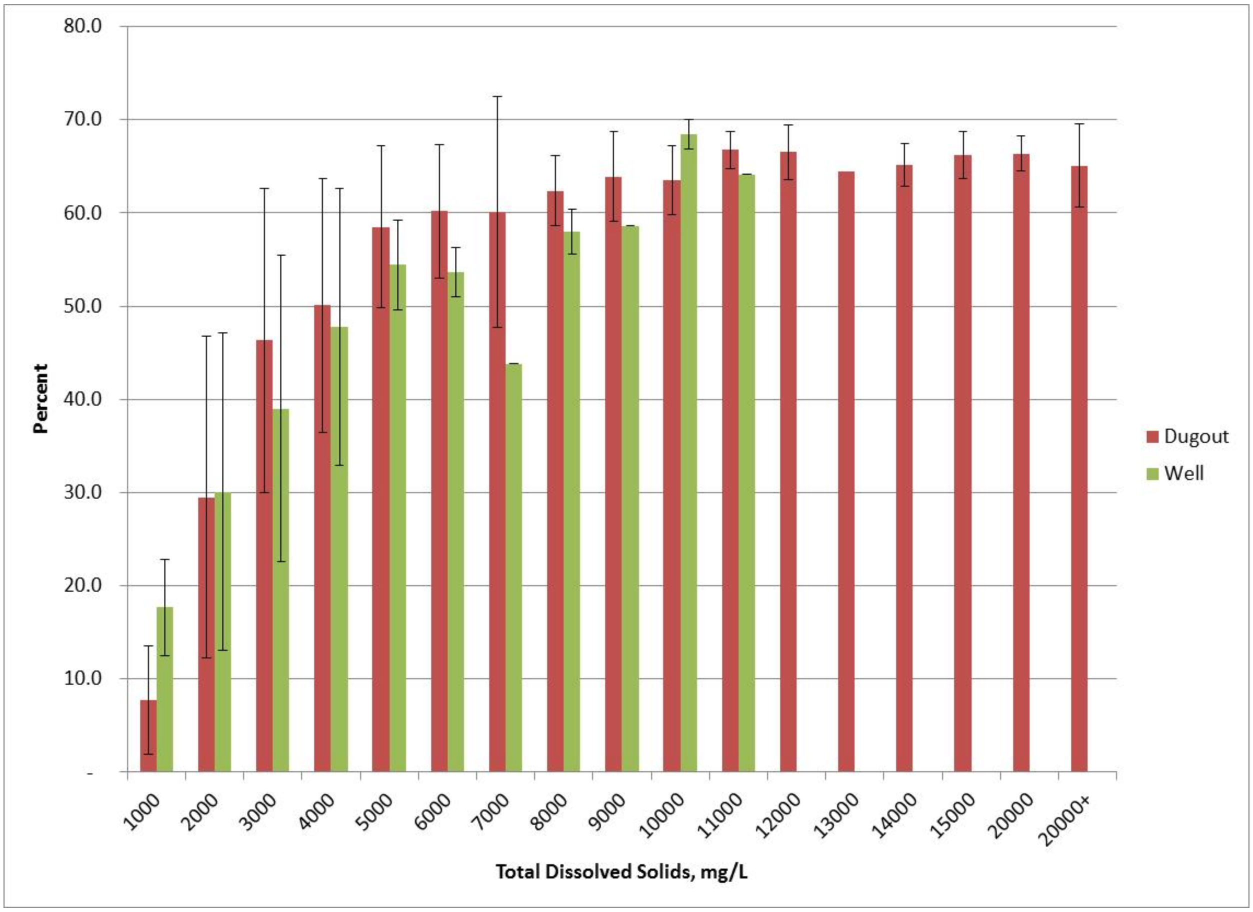

Figure 5. Sulphates expressed as a percentage of total dissolved solids for water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Means are for each 1,000 µS/cm intervals and bars indicate standard deviation per grouped interval.

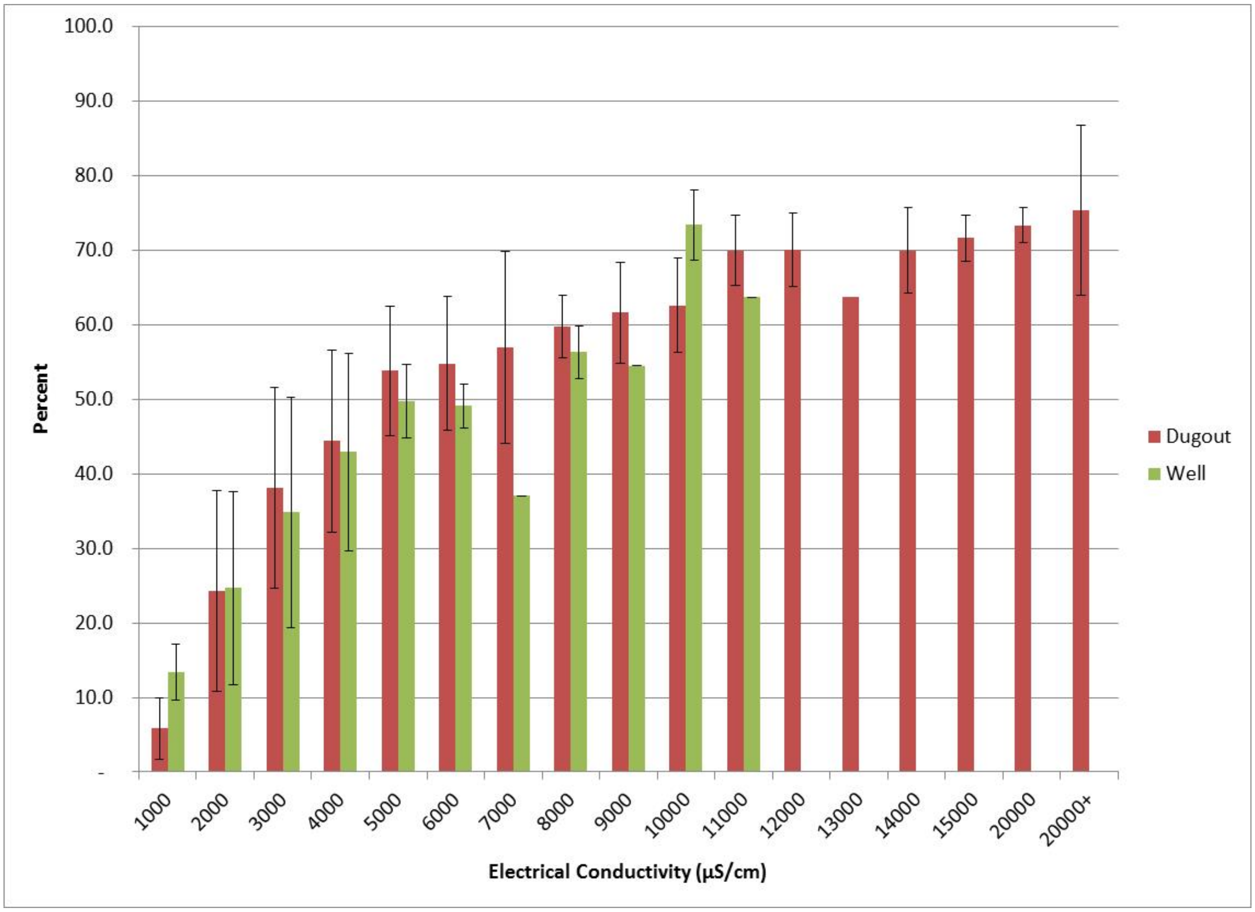

Figure 6. Sulphates expressed as a percentage of electrical conductivity for water samples from dugout and well sources collected between July 5 and September 27, 2017 in southern Saskatchewan. Means are for each 1,000 µS/cm intervals and bars indicate standard deviation per grouped interval.

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