Ground-Water Monitoring Plan and Baseline Data for the Devils Lake Outlet Channel

By
W. M. Schuh

North Dakota State Water Commission
Bismarck, North Dakota

SWC Project No. 416-1
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Introduction

In October of 2005 VERIS[tm] transects were measured along the border of the Devils Lake Outlet channel to measure base-line Soil Electrical Conductivity as an indicator of soil salinity, and to provide a basis for future comparison of potential changes in soil salinity during operation of the Devils Lake Outlet. VERIS is a trade name for a process in which a Wenner Array is employed using disc harrow blades as electrodes to measure soil electrical conductivity (EC). The measurement implement is towed behind a pickup truck, with a "real-time" satellite geographical reference corresponding to EC readings. VERIS measurements were conducted by TOTALCROP Inc. under the supervision of Western Plains Consulting Inc. (WPC). A report titled "Soil Classification and Salinity Inventorying Report" was provided by WPC in April of 2006. One area of concern identified in the report included lands south and southeast of the open channel immediately downstream of the Outlet transition structure from the pipeline in 152-067-19 [US Bureau of Land Management nomenclature (USBLM)], shown on Figure 1. In this area the channel follows the base of the moraine and is elevated over the land south of the channel. In addition, the surficial materials consist of coarse glacial outwash (coarse sand to gravel) which formed from glacial meltwaters at the base of the moraine. These coarse deposits are as deep as 30 feet near the Outlet channel, and gradually thin southward over a distance of about a mile.

The WPC (2000) report (p. 28) identified, in the hypothetical case of canal liner failure, potential salinization of "somewhat poorly to poorly drained soils on the fringe of the somewhat excessively drained to moderately well drained outwash areas." WPC (2006) recommended that "observation wells...placed in the somewhat excessively drained to moderately well drained soils near the Outlet...be used to monitor water quality and water levels" (p. 28). It should be noted that the main concern is not for soil salinization *near* the Outlet channel, where water levels in the coarse material are below 10 feet (measured at 16 feet in September 2006). Water tables in these areas are sufficiently deep to prevent evaporative upflux and concentration of salts. Rather the concern is for soils having a shallower water table. These are generally located about a half-mile or more south of the Outlet channel, with the exception of the wetland in the northeast quarter of Section 25 which is mapped to the Fram soil series. The concern is that saline water seepage through the channel lining will pass through the adjacent coarse materials and concentrate in the discharge zones farther south. The recommended well placement was thus intended to monitor transition waters and detect changes before actual enhanced salinization has occurred.

Implementation

Three well sites were constructed in the area of concern to monitor changes in ground-water chemistry. Wells were drilled on August 31, 2006 using a forward rotary drill. Locations were at:

(1) 152-067-19CCD (USBLM), in the north road ditch about 0.2 miles east of the southwest corner of Section 19;

(2) 152-068-25ADD (USBLM), in the west road ditch, almost a quarter mile south of the northeast corner, the same corner identified in (1) above; and

(3) 152-06-25CBB (USBLM), in the east road ditch about 200 feet south of the Devils Lake Outlet channel crossing.

Well locations are shown on Figure 1. Area well lithologies have indicated that the general stratigraphy consists of a shallow (surface to 15 to 30 feet) layer of gravel and coarse sand, overlying till. The till layer extends to bedrock (Pierre shale) at 60 to 120 feet. Lithologies and construction information for all new monitoring wells are appended.

Wells were constructed of 2-inch polyvinyl-chloride (PVC) casing with 18-slot well-screen. Sand pack (#10 sand) was tremmied to about five feet above the well screen. The annulus of shallow wells (upper SI < 13 feet) was sealed from the sand pack to the surface with bentonite chips. The deepest well was sealed with high-solids bentonite grout to land surface. Because of the coarseness of the formation bentonite drilling fluid was required. All wells were developed, first by air lift, and then by pumping with a screw pump to remove drilling fluid from the formation. Wells were secured with six-inch PVC protective casing (PC) and locking caps.

Initial water-level measurements were made on September 6 and 7 of 2006. Water samples for general chemistry and trace elements were collected on September 6, 2006. An additional sample for general chemistry was collected on October 23. Wells were surveyed on September 12, 2006 according to 1929 Datum, with a cross-reference measurement for calculating approximate 1988 Datum, using U.S. Survey Feet Equipment-Trimble 4400 receivers with TSC1 points 37567 to 37578.

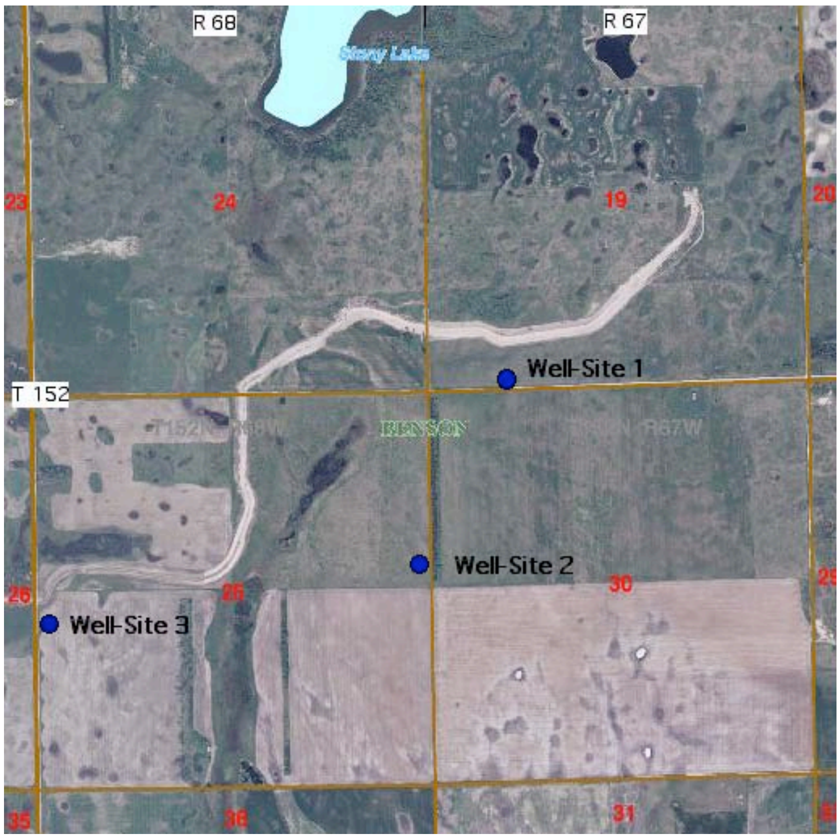

Figure 1. Locations of observation wells for the south channel of the Devils Lake Outlet.

On Site 1 the sand and gravel layer extended to till at 25 feet. The well-screen was placed at 11 to 21 feet. On Site 2 sand and gravel extended to 30 feet. The initial water table was at about 16 feet below land surface. A nest of two wells was placed with screened intervals at 25 to 30 feet (152-068-25ADD for the gravel till boundary) and at

14 to 19 feet (152-068-25ADD2 for the ground-water surface). On Site 3 the sand and gravel extended to only 14 feet, and the well screen was placed at 8 to 13 feet. Well construction details and lithologies are appended.

Initial Piezometric Data: Ground-Water Flow

Initial ground-water elevation measurements taken on September 6 and 7, 2006 are on Table 1. A piezometric interpretation of the local flow system and possible areas of concern for salinization is shown on Figure 2.

Table 1. Initial water level (WL) elevations measured in September of 2006.

Site	Location	Date	Screened Interval (feet)	WL El. (feet amsl)
1	15106719CCD	9/7/2006	11-21	1540.2
		9/6/2006		1540.2
		10/9/06		1539.8
		10/23/06		1539.7
		11/6/06		1539.6
2	15106825ADD1	9/7/2006	25-30	1538.8
		9/6/2006		1538.6
		10/9/06		1538.3
		10/23/06		1538.2
		11/6/06		1538.2
2	15106825ADD2	9/7/2006	14-19	1538.7
		9/6/2006		1538.7
		10/9/06		1538.4
		10/23/06		1538.3
		11/6/06		1538.3
3	15106825CBB	9/7/2006	8-13	1540.4
		9/6/2006		1540.4
		10/9/06		1540.4
		10/23/06		1540.4
		11/6/06		1540.4

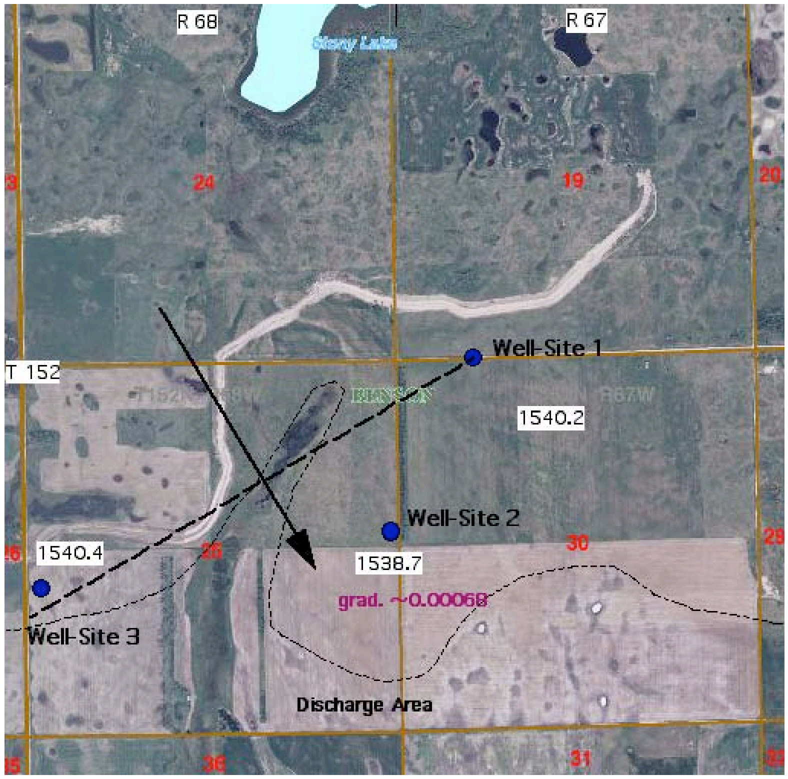

Figure 2. Map illustrating approximate local flow system and possible "vulnerable" areas for salinization if substantial and continuous channel seepage occurs.

Using the estimated hydraulic gradient (calculated using the midpoint of the two upstream points), an approximate storage coefficient of 0.25, and a range of 200 to 500 feet per day for estimated hydraulic conductivities of a coarse sand and gravel, the velocity should be sufficient to travel and carry salt for about 200 to 500 feet per year. At these velocities, changes in ground-water chemistry caused by leakage on Sites 1 and 3 should be detectable within a year, or at most two years. On Site 2, changes would likely be detectable between 5 and 12 years, but may be delayed by difficulties in initial discernment of changes caused by dilution from dispersion in the front of the breakthrough curve. Potential salinization from leakage, should it occur, could begin within three to five years in the center of Section 25, but would take ten to 20 years in the south portion of Section 30. The process once started, would be gradual, and limited by dilution from dispersion over the affected distance. Approximate effects of dispersion could be assessed using an advection-dispersion model. Modeling, however, would not be justified unless effects in wells near the Outlet are actually found in measurements. Soil salinization effects would also be strongly influenced by the nature of leakage if it occurs. For example, a general and consistent leak along the Outlet channel would have a much larger effect than local isolated point-source leak.

It should be understood that this initial analysis is based on a single piezometric measurement, and that flow directions and gradients may change somewhat over time with changing recharge and discharge due to climatic conditions. They may also be altered by the operation of the Outlet, depending on the local integrity of the channel lining. These will be assessed periodically.

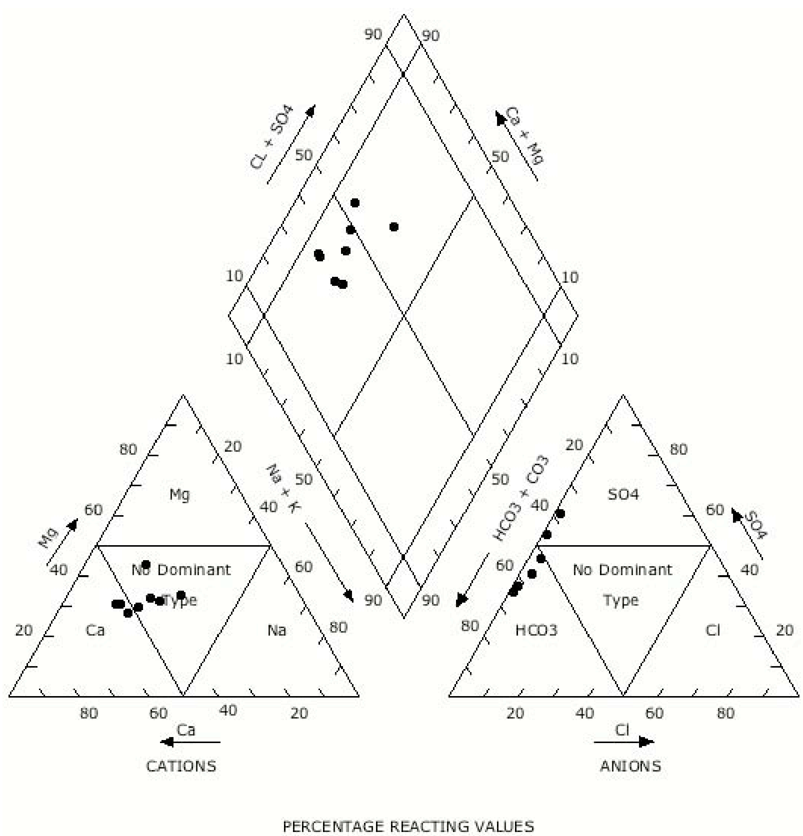

Figure 3. Piper plot characterizing anion and cation chemistry of ground water near the Devils Lake Outlet Channel, Fall 2006.

Table 1. Baseline general chemistry for monitoring wells near the Devils Lake Outlet Channel in Fall, 2006.

Well Site	Location	Date	SI	Ca	Mg	Na	K	HCO3	CO3	SO4	Cl	F	NO3	TDS	CaCO3	NCH	PerNa	SAR	Cond	pH
		m/d/y	feet	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L					
1	152-067-19CCD	9/7/06	11-19	74.4	36.7	47.7	6.03	333	<1	149	4.11	0.276	19.3	523	337	63	23.5	1.13	804	7.96
1	152-067-19CCD	10/23/06	11-19	68.2	34.8	52.9	5.45	333	<1	161	4.07	0.29	22.8	528	314	40	26.7	1.3	820	
2	152-068-25ADD1	9/7/06	25-30	106	41.4	54.2	6.69	387	<1	226	13.6	0.256	2.83	639	435	117	21.2	1.13	960	9.14
2	152-068-25ADD1	10/23/06	25-30	115	38.9	49.8	5.59	367	<1	272	16.8	0.236	0.35	657	448	146	19.4	1.02	1003	
2	152-068-25ADD2	9/7/06	14-19	83.9	31.4	29.8	5.99	318	<1	143	5.18	0.193	0.71	477	339	77	16	0.7	734	8.5
2	152-068-25ADD2	10/23/06	14-19	83.3	30	26.5	5.06	325	<1	147	5.61	0.203	0.53	470	332	64	14.7	0.63	725	
3	152-068-25CBB	9/7/06	13-Aug	122	88.1	59.3	16.3	447	<1	433	11	0.157	6.33	887	668	301	16.1	1	1334	7.8
3	152-068-25CBB	10/23/06	13-Aug	118	76.1	127	14.2	435	<1	583	12.2	0.251	2.74	1020	608	251	31.1	2.24	1546	

Table 2. Baseline values for selected trace elements in monitoring wells near the Devils Lake Outlet Channel in Fall, 2006.

Well Site	Location	Date	SI	WL	B	Fe	Mn	Se	Pb	As	Cd	Al	Be	Cr	Ni	Cu	Zn	Ag	Sb	Ba	Tl
		m/d/y	feet	feet BLS	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	15206719CCD	9/7/06	11-21	16.6	58	0.04	0.026	3.42	3.42	1.3	<1	<50	<1	<1	5.99	1.37	2.95	<1	<1	75.1	<1
1	152-067-19CCD	10/23/06	11-19			0.03	0.028														
2	15206825ADD1	9/7/06	25-30	10.42	66	0.045	0.263	1.81	1.81	2.91	<1	<50	<1	<1	8.01	2.50	1.28	<1	<1	34.1	<1
2	15206825ADD1	9/7/06				0.058	0.423														
2	15206825ADD2	9/7/06	14-19	10.45	51	0.031	0.27	1.19	1.19	<1	<1	<50	<1	<1	6.67	1.33	2.94	<1	<1	137	<1
2	15206825ADD2	9/7/06	14-19			0.024	0.343														
3	152-068-25CBB	9/7/06	8-13	6.33	89	0.067	0.339	3.89	3.89	2.46	<1	<50	<1	<1	11.0	2.73	4.9	<1	<1	155	<1
3	152-068-25CBB	9/7/06	8-13			0.042	0.465														

Baseline Water Chemistry

Ground Water

The baseline water chemistry for monitoring wells installed in September and October of 2006 is shown on Table 2 for general chemistry and on Table 3 for selected trace elements. Generally, the well water is of good quality. Specific conductance is generally low, with the exception of Well Site 3, which is somewhat elevated, likely due to proximity to the wetland complex in the west half of Section 25 and near proximity to areas of higher water table that may function as evaporative discharge areas. The Sodium Adsorption Ratio (SAR) is low, indicating that soil dispersion is unlikely. Nitrate is highest under Well Site 1, but is less than the EPA-MCL drinking water standard of 44 mg/L by half, and is lower than commonly measured in shallow wells under alfalfa fields.

The water is predominantly of the calcium and magnesium bicarbonate type (see Piper diagram on Figure 3) with substantial sulfate presence, and grades slightly toward a marginal sulfate anion predominance on Well Site 3, which is nearest areas of shallow water tables. All trace elements (Table 3) are below levels of toxicological concern.

Outlet Channel Water (Static Water)

Static water in the Outlet channel during non-operational periods is mainly an indicator of minor shallow residual ground-water seepage in the southern reach of the Outlet where the channel bottom is below the water table. In this location water in the channel is primarily from shallow ground water, strongly influenced by soil processes and subsequent evaporative concentration. A Piper plot (Figure 4) of full general chemistry for the Devils Lake Outlet Channel under static and non operational conditions indicates that water anion chemistry is primarily sulfatic rather than bicarbonatic and exhibits a field specific conductance (SC) range and a sulfate range higher than all of the ground-water monitoring sites. Since the measurements made near the discharge point to the Sheyenne River are nearly all static water derived from a shallow and minor residual influx of till ground water in the lower reaches of the Outlet channel, rather than Devils Lake water, this water source will not effect water quality in sand and gravel deposits in the area of concern discussed by Western Plains Consulting.

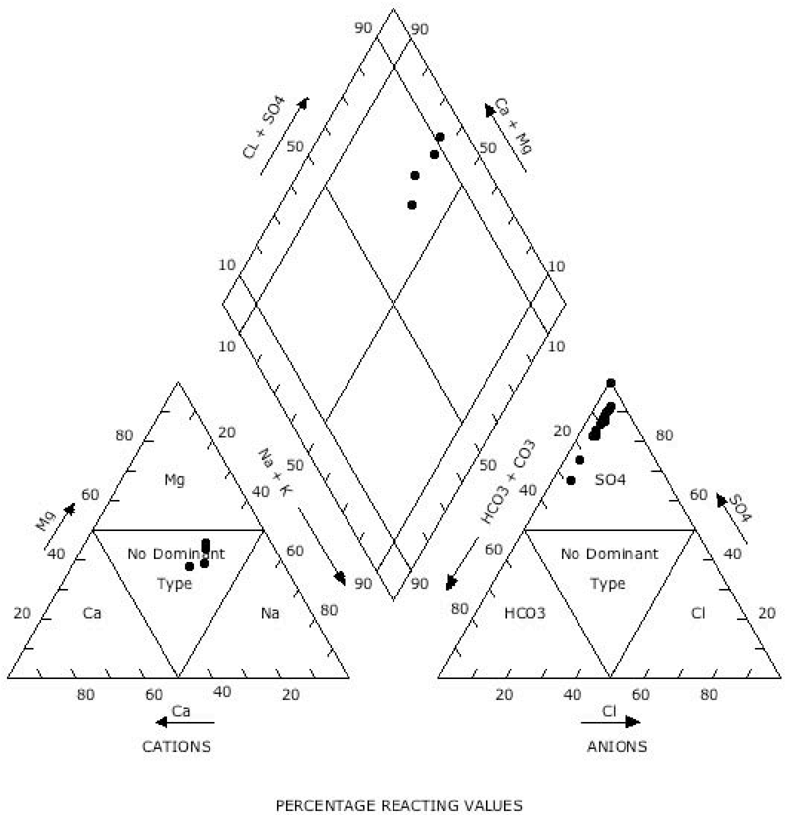

Figure 4. Piper plot characterizing anion and cation chemistry of ground-water in the Devils Lake Outlet channel near the outflow to the Sheyenne River.

Devils Lake (West Bay) Water Chemistry

The North Dakota Department of Health has collected water chemistry data from Devils Lake at various locations since 2001. Of these, the samples in the West Bay, collected at approximately 153-067-25BA (USBLM) best represents the composition of water at the inlet. These data are summarized for 2001 through 2006 on Table 4. Water classification, according to the Piper diagram (Figure 5) is slightly sodium sulfatic, compared with ground water that is dominated by calcium and magnesium bicarbonate.

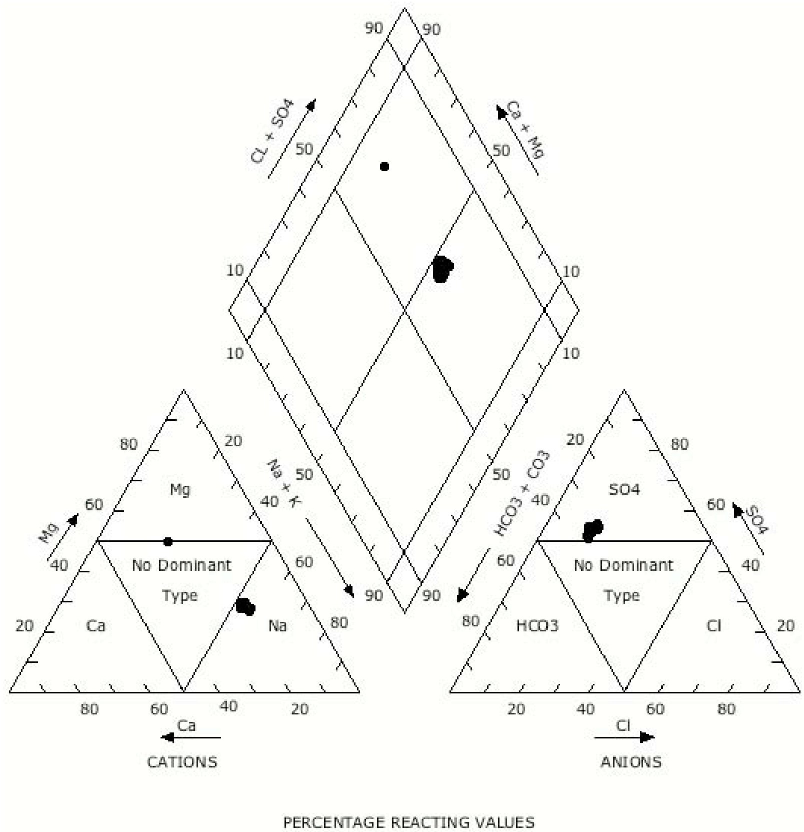

Figure 5. Piper plot of ion species in West Bay of Devils Lake from 2001 through 2006.

Indicators of Potential Channel Leakage

There are several significant differences between Outlet water during active operation (as represented by the West Bay data) and natural ground water at the monitoring well sites identified above. These differences can be used as indicators of channel leakage if identified in the monitoring well chemistry. They include:

(1) A higher proportion of sodium, as indicated by the sodium-adsorption ratio (SAR, Table 1 and Table 3). The Devils Lake water has an SAR of about 5 compared with only 1 for the local ground water. A substantial upward drift of SAR would serve as one indicator of possible channel leakage.

Table 4. Water chemistry for the West Bay of Devils Lake from 2001 through 2006. (*North Dakota Department of Health data, provided by Mike Saue*r). Approximate sample collection location is 153-067-25BA (USBLM).

Date	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	HCO3 mg/L	CO3 mg/L	SO4 mg/L	Cl mg/L	TDS mg/L	CaCO3 mg/L	SAR
3/19/01	89.7	88.7	294	45.2	479	4	632	121	1510	589	5.27
5/14/01	76	73.3	238	36.5	384	14	577	108	1310	492	4.67
10/10/01	79.4	77.4	256	39.1	331	35	591	112	1350	517	4.9
2/12/02	87.1	86	284	39.9	401	37	682	124	1540	572	5.16
5/13/02	77.8	77.1	248	37	367	24	492	93.3	1230	512	4.77
5/13/02	79.2	78.7	252	37.9	381	16	560	105	1320	522	4.8
8/13/02	86.1	85.7	281	85.7	366	36	632	115	1460	568	5.13
10/7/02	86.4	85.3	286	43	361	38	611	125	1450	567	5.22
2/11/03	89.3	89.8	299	45	429	37	745	139	1660	593	5.34
5/7/03	79.4	79.8	264	39.9	381	27	572	113	1360	527	5
5/7/03	78.9	79.3	262	39.6	373	27	569	113	1350	524	4.98
8/12/03	74.8	79.1	266	40.1	357	41	608	118	1400	512	5.11
8/12/03	77.5	81.4	272	41.3	353	45	605	118	1420	529	5.14
10/7/03	74.8	84.1	282	41.5	391	33	636	120	1470	533	5.31
10/7/03	76.8	86.3	291	42.5	396	31	640	120	1480	547	5.41
3/17/04	87.3	98.4	341	49.5	477	19	783	158	1770	623	5.94
5/18/04	73.2	79.6	268	40.4	366	30	599	117	1390	511	5.16
5/18/04	72.6	79.1	40.1	40.1	364	30	584	115	1370	507	5.16
8/10/04	71.4	78.2	262	38.8	346	48	628	120	1420	500	5.09
8/10/04	73.2	79.5	271	39.4	347	47	573	109	1360	510	5.22
10/6/04	76.2	82.6	274	40.5	344	41	625	118	1430	530	5.17
10/6/04	74.1	80.2	268	39.3	353	40	634	120	1430	515	5.13
3/8/05	85.7	91.6	307	44.7	451	22	688	132	1590	591	5.49
3/8/05	87	92.7	312	45.3	461	22	688	132	1610	599	5.54
5/24/05	76.3	80.7	267	39.8	500	14	611	125	1460	523	5.08
5/24/05	75.7	80.3	267	39.5	396	32	612	118	1420	520	5.09
8/16/05	78.4	80.6	263	37.3	344	44	626	119	1420	528	4.98
8/16/05	78.1	80.7	262	37	347	43	623	117	1410	527	4.96
10/11/05	81.5	83.4	257	42.9	374	35	625	119	1430	547	4.78
10/11/05	80.3	81.6	254	42.6	372	36	627	119	1420	537	4.77
2/14/06	92.6	97.6	304	46.2	416	38	703	133	1620	633	5.25
2/14/06	98.8	104	323	49.4	413	37	709	134	1660	675	5.41
5/9/06	78.1	82.1	243	36.8	363	34	605	102	1360	533	4.58
8/15/06	78.1	87.6	269	35	336	53	604	114	1410	556	4.96
8/15/06	77	87.1	270	35	338	43	602	113	1390	551	5
10/9/06	71	77.7	234	30.1	338	51	612	112	1360	497	4.56
10/9/06	70.4	76.7	230	29.6	345	53	611	114	1360	492	4.51

Table 5. Means and ranges for sulfate-to-bicarbonate ratios and chloride-to-bicarbonate ratios for monitoring wells and the West Bay of Devils Lake.

Sample Location	$\overline{X}$ SO_4/HCO_3	Range SO_4/HCO_3	$\overline{X}$ Cl/HCO_3	Range Cl/HCO_3
Devils Lake West Bay	1.65	1.22-1.82	0.31	0.25-0.34
Outlet Wells	0.61	0.45-0.97	0.022	0.012-0.035

(2) A higher proportion of sulfate in the anionic fraction of the lake water. This would likely be best indicated as a ratio of bicarbonate. Ground-water and lake samples have very similar bicarbonate concentrations [the median and range for four ground-water samples are 360 mg/L and 318 to 447 mg/L; compared with 367 mg/L and 331 to 500 for 37 Devils Lake samples]. Sulfate-to-bicarbonate ratios (SO_4/HCO_3) are shown on Table 5. The difference between sulfate-to-chloride ratios are similar to those of SAR, with the mean and range for Devils Lake being about 5 times that of ground water.

(3) A higher proportion of chloride in the anionic fraction of the lake water. Chloride is usually leached from the weathered (oxidized zone), and in most glacial aquifers in North Dakota natural (non-fertilizer) chloride concentrations are governed by concentrations in the underlying Cretaceous shale bedrock formations, and the diffusion distance from the shale to the shallow ground-water deposit. As a terminal body of water and an evaporative sink, Devils Lake is a long-term receiver of chloride from these highly leached units, so that chloride is higher (about 100-120 mg/L) than ground water (commonly from 0 to 50 mg/L) and less than 10 mg/L in the Outlet monitoring wells. Chloride to bicarbonate ratios (Table 4) in the lake water are about 10 times those in the monitoring wells.

These three normalized indices should provide the best indicators of leakage to ground water, should leakage occur.

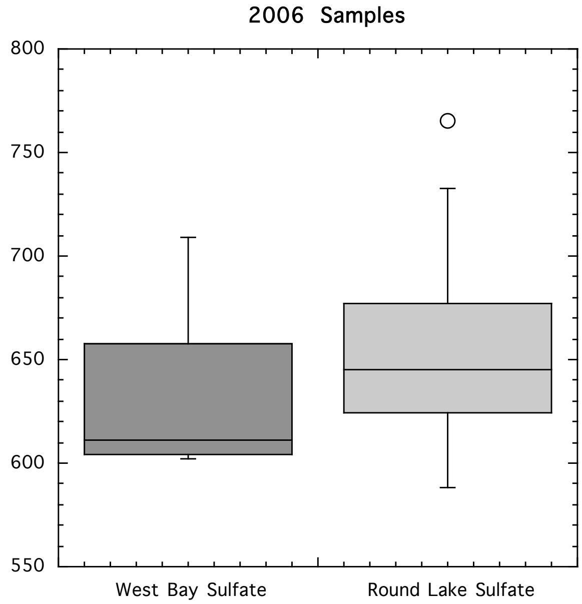

Figure 6. Sulfate concentration distributions in Round Lake and Devils Lake (West Bay) in 2006.

Additional Monitoring Points

Devils Lake water enters the Outlet indirectly through Round Lake. Limited water chemistry measurements (EC and sulfate) were measured in Round Lake beginning in 2006. These limited data indicate that overall sulfate concentrations are similar to the West Bay samples, although slightly higher (Figure 6). There is insufficient supporting data to further determine any potential differences in the chemical composition of Round Lake and Devils Lake West Bay. Hence, we must assume that the general index ratios discussed above hold for both bodies of water.

As with the piezometric measurements, a single data set is insufficient to understand the natural temporal variability of the local ground water. Additional baseline measurements are being made to better ascertain the natural variability of the ground-water chemistry before substantial Outlet operation occurs.

Monitoring Plan and Recommendations

If the Outlet is not operating, initial chemistry of ground water down-gradient of the Outlet channel, and south and southwest of the transition structure should be initially measured at least quarterly (spring, summer and fall). After natural patterns of ground water are understood sample frequencies may be modified or decreased.

If the Outlet is operated, three quarterly water samples (spring, summer and fall) should be collected initially from the monitoring wells. If changes in water chemistry are indicated, more frequent measurements may be necessary. Changing hydrologic conditions affecting the distribution of solute in the event that channel leakage occurs, should be monitored approximately monthly during the operational season.

Based on preliminary flow analysis and the disposition of potentially vulnerable soils shown on Figure 2, one additional well site should be placed in the road ditch near the center of the north border of Section 25, at approximately 152-068-25ABB (USBLM). This well would serve as an early indicator of potential salt movement toward the soil and wetland complex in northwest Section 25.

Citations

Western Plains Consulting. April 7, 2006. Soil Classification and Salinity Inventorying Report: Devils Lake Peterson Coulee Emergency Outlet, Benson County, North Dakota. Prepared by WPC, Inc. PO Box 1401, Bismarck, ND.

APPENDIX

152-067-19CCD

NDSWC 15398

Date Completed:	08/30/2006	Purpose:	Observation Well
L.S. Elevation (ft):	1555	Well Type:	2 in. - PVC
Depth Drilled (ft):	34	Aquifer:	Gravel Sediments
Screen Int. (ft.):	11-21	Data Source:	

Completion Info: 3 bags #10 sand, 5.3 bags bentonite chips.

Surveyed by SWC 9/11/06

Remarks: North road ditch, @ 0.2 miles east of intersection, a lot of bentonite used drilling.

Lithologic Log

Depth (ft)	Unit	Description
0-9	SAND	Medium to coarse with fine gravel - includes detrital shale, carbonates and silicates
9-16	GRAVEL	Fine, abundant detrital shale
16-19	GRAVEL	Medium to coarse, abundant shattered detrital shale, well rounded carbonates
19-20	TILL	
20-25	GRAVEL	Medium to coarse
25-34	TILL	Stone at 31 ft.

152-068-25ADD1

NDSWC 15396

Date Completed:	09/08/2006	Purpose:	Observation Well
L.S. Elevation (ft):	1547	Well Type:	2 in. - PVC
Depth Drilled (ft):	100	Aquifer:	Gravel Sediments
Screen Int. (ft.):	25-30	Data Source:	

Completion Info: 5 bags #10 sand. 3 bags bentonite chips. #18 sell-screen

Surveyed by SWC 9/11/06

Remarks: South well, west of trail

Lithologic Log

Depth (ft)	Unit	Description
0-1	TOPSOIL	Sandy, black
1-15	GRAVEL	Medium to coarse, abundant large detrital lignite fragments
15-30	GRAVEL	Fine to coarse, grayer than above but mainly oxidized, 2 to 5 mm shale fragments, Abundant carbonates and pink quartz fragments
30-94	TILL	Gray, est. 25 -30% clay, gritty
94-100	SHALE	Dark gray, varies in brittleness - slightly brittle to plastic, likely Pierre

152-068-25ADD2

NDSWC 15397

Date Completed:	09/08/2006	Purpose:	Observation Well
L.S. Elevation (ft):	1547	Well Type:	2 in. - PVC
Depth Drilled (ft):	28	Aquifer:	Gravel Sediments
Screen Int. (ft.):	14-19	Data Source:	

Completion Info: 3 bags hole plug, 3 bags # 10 sand

Surveyed by SWC 9/11/06

Remarks: NORTH WELL

Lithologic Log

Depth (ft)	Unit	Description
0-28	SAND & GRAVEL	same as 15203825ADD1 (Well 15396)

152-068-25CBB

NDSWC 15399

Date Completed:	10/08/2006	Purpose:	Observation Well
L.S. Elevation (ft):	1545	Well Type:	2 in. -
Depth Drilled (ft):	31	Aquifer:	Gravel Sediments
Screen Int. (ft.):	8-13	Data Source:	

Completion Info: 18-slot screen, 4 bags # 10 sand, 4 bags bentonite chip

Surveyed by SWC 9/11/06

Remarks: @200 foot south of Outlet channel crossing

Lithologic Log

Depth (ft)	Unit	Description
0-2	TOPSOIL	Black, sandy, est. 15% clay
2-4	LOAM	Gray, sandy (till?)
4-7	GRAVEL	Pred. fine, w/coarse sand. abundant carbonates, rounded
7-9	CLAY	
9-14	GRAVEL	Pred. fine, some medium abundant carbonates and shale, well rounded
14-31	TILL	Gray, fine blocky structure (< 2 mm), est. 25% clay (stone at 16 ft. and at 28 ft.)

152-068-25CDD
USGS #20

Date Completed:	01/01/1946	Purpose:	Test Hole
L.S. Elevation (ft):	1540		
Depth Drilled (ft):	100		
		Data Source:	

Completion Info:

Remarks:

Lithologic Log

Depth (ft)	Unit	Description
0-5	CLAY	Yellow, fine gravel
5-10	SAND	Medium to coarse
10-14	GRAVEL	Fine to coarse, shale pebbles
14-40	CLAY	Blue, fine and coarse gravel, shale pebbles
40-80	CLAY	Gray, sand, gravel (till)
80-100	SHALE	Bedrock (Pierre)