Effects of Wastewater-Lagoon Discharge through Wetlands on Water Quality in Bonifas Creek, Gogebic County, Michigan

U.S. DEPARTMENT OF THE INTERIOR
U.S.GEOLOGICAL SURVEY

Open-File Report 00-100

Prepared in cooperation with the Lac Vieux Desert Band of the Superior Chippewa

USGS
science for a changing world

Effects of Wastewater-Lagoon Discharge through Wetlands on Water Quality in Bonifas Creek, Gogebic County, Michigan

By Stephen Scranton Aichele and J.M. Ellis

Open-File Report 00-100

Prepared in cooperation with the Lac Vieux Desert Band of the Superior Chippewa

Lansing, Michigan
2000

USGS
science for a changing world

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY

Charles G. Groat, *Director*

For additional information write to:

District Chief
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, MI 48911-5991

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

ILLUSTRATION

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

MULTIPLY	BY	TO OBTAIN
	Distance	
inches (in.)	25.4	millimeters
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Volume	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot (ft^3)	0.02832	cubic meter
gallon	3.785	liter

Temperature is given in degrees Celsius (^oC), which can be converted to degrees Fahrenheit (^oF) by the following equation:

$$^oF = 32 + (^oC * 1.8)$$

Abbreviations (in addition to those above)
DO, Dissolved oxygen
SC, specific conductance
DS, dissolved solids
BOD_5, five-day biochemical oxygen demand
MRL, minimum reporting level
col/100 ml, colonies per 100 milliliters (of sample water)
µs, microsiemen
cm, centimeter
mL, milliliter
µg, microgram
mg, milligram
L, liter

Effects of Wastewater-Lagoon Discharge Through Wetlands on Water Quality in Bonifas Creek, Gogebic County, Michigan

by Stephen Scranton Aichele and J.M. Ellis

Abstract

The Lac Vieux Desert Band of the Superior Chippewa (LVD) recently constructed a wastewater-treatment facility that discharges effluent twice annually from settling lagoons to wooded wetland areas adjoining the channel of Bonifas Creek, a small stream that flows near the LVD community in Watersmeet, Michigan. This report describes the hydrology of the site and the results of analyses of water samples from Bonifas Creek and the settling lagoons. Water samples were collected from sites on the creek upstream and downstream of the effluent-receiving area, before and after discharge from the lagoons. The concentrations of calcium, magnesium, and bicarbonate increased from the upstream to the downstream site, but the concentrations of sodium, chloride, and sulfate decreased. These changes in water chemistry, however, were similar both before and after the release from the lagoons, and are consistent with known pattern of influxes of ground water into Bonifas Creek. Therefore, it appears that the discharge of wastewater into the area adjoining Bonifas Creek is unlikely to have any immediate effect on the quality of water in the creek.

INTRODUCTION

The Lac Vieux Desert Band of the Superior Chippewa (LVD) are concerned about the water quality of Bonifas Creek, a small stream that flows near the LVD community in Watersmeet, Mich. A wastewater-treatment facility recently constructed by the LVD discharges about 58,000 ft^3 of effluent twice annually from settling lagoons to wooded areas adjoining the stream channel. In 1997, the LVD and the U.S. Geological Survey (USGS) agreed to cooperatively investigate the hydrology and water quality of the wetland, with a specific emphasis on identifying possible short-term changes in water quality as a result of wastewater discharges.

Purpose and Scope

The purpose of this report is to provide LVD with information they can use to manage the wastewater-treatment plant, golf course, and community water supply. The report includes a characterization of the hydrology of the site, analysis and interpretation of water samples collected from Bonifas Creek and the settling lagoon, and an assessment of the likely impacts of the proposed wastewater release.

Study-Area Location

The town of Watersmeet, the LVD community, and Bonifas Creek are all in Gogebic County, in the southwestern part of Michigan's Upper Peninsula (fig. 1). Bonifas Creek flows southeast from Bass Lake, north of Watersmeet, to a junction with the Middle Branch Ontonagan River, approximately 2 miles east-northeast of Watersmeet. During the study, Bonifas Creek was impounded by two debris dams closing the remnants of abandoned railroad grades. The impounded area reached upstream approximately 1 mile from the upper debris dam, almost to Bass Lake. Between the upper and lower debris dam, water from Bass Lake and Bonifas Creek mixes with water from a low-lying area east of Bass Lake. This study focused on the reach of Bonifas Creek extending from Bass Lake to the first impoundment, a reach of approximately 1.25 mi. (fig. 1). The nearest continuous-record streamflow-gaging station is approximately 30 miles away on the Middle Branch Ontonagon River near Rockland, Mich. (04035500).

Settling lagoons for the LVD wastewater facility are north of the abandoned railroad grade and immediately west of the Watersmeet municipal wastewater lagoons (fig. 1). Treated waste is discharged from the LVD settling ponds occurs through an 8-in.-diameter PVC pipe running north and east approximately 200 yards from the lagoons. This waste is discharged into a wooded wetland area at a rate of between 2.0 and 2.5 ft^3/s for a period of about 7 hours twice annually.

METHODS AND APPROACH

In August 1997, the USGS established two water-quality sampling sites on Bonifas Creek, one just below Bass Lake and one at the first impoundment (fig. 1). These sites were selected to provide one sampling point upstream from the wastewater discharge area and one sampling point downstream from the discharge area.

Aerial photography, topographic and geologic maps, and a site reconnaissance were used to characterize the hydrogeology of the study area. Sampling sites were selected and the vegetation and sediment on both sides of Bonifas Creek were examined during the initial site visit in August 1997. Water-quality samples were collected from the upstream and downstream sites in August 1997 and again in September 1997, before any release from the newly constructed settling lagoons. Streamflow measurements also were made at both sampling sites in August and September, but because of the low velocities and diffuse flow at the downstream site, these measurements are classified as “poor” and should be regarded as estimates only.

After the initial release of wastewater from the facility on November 12, 1997, water samples and streamflow data were collected at both sites on December 17 and 18, 1997. During and after a wastewater discharge on June 9, 1998, USGS personnel inspected the receiving area on foot and collected water quality and streamflow data on June 16 and 17. Timing of the post-discharge samples was based on estimates of residence time, given the best available streamflow estimates for the downstream site and an estimated impoundment volume of 2.4 million ft^3. All four samples were collected during periods of decreasing flow, as measured at the nearest downstream gaging station (04035500).

Streamflow measurements were made in accordance with standard USGS procedures, as outlined in Rantz and others (1982). Water-quality samples were collected and handled in accordance with the standard USGS National Water-Quality Assessment (NAWQA) program procedures (Shelton, 1994), with the modification that an acid-rinsed churn splitter was used to divide the chemical samples. Churn splitters have been tested and demonstrated to be interchangeable with cone splitters for samples with dissolved- solids (DS) concentrations less than 1,000 mg/L and mean particle sizes less than 250 mm (U.S. Geological Survey, 1997).

Dissolved oxygen (DO), specific conductance (SC), temperature, pH, and alkalinity were measured in the field with a Hydrolab H20 and individual probes. The USGS National Water Quality Laboratory in Arvada, Colo. (NWQL) analyzed the samples for inorganic materials (table 1). Fecal coliform analyses were done by the USGS on site and in the field laboratory in Escanaba, Mich. using method B-0050-85 (Britton and Greeson, 1988). Five-day biochemical oxygen demand (BOD_5) analyses were contracted to Whitewater Associates of Amasa, Mich., and done using Standard Method 5210 B (Greenberg and others, 1992). The NWQL also analyzed the effluent sample collected from the lagoon. Fecal coliform counts and BOD_5 were not evaluated for the effluent sample.

Study-Area Characteristics

Throughout the study area, Bonifas Creek is an underfit stream in the flood plain of a much larger ancient river. Inspection of maps and aerial photography indicated that the study area consists of outwash overlying crystalline rocks, with an eroded fluvial channel and flood plain incised into the outwash. The boundaries of the flood plain are evidenced by meander scars on the north and south sides of the channel far from the current channel. The radius of these meanders is much larger than the current meander radius of Bonifas Creek. Bluffs formed by these meanders represent a significant discontinuity on the landscape, which is evidenced in vegetation patterns (fig. 1). Surface sediments on bluffs north and south of the channel are well-sorted sands, consistent with deposition by outwash processes. Surface materials between the bluffs tended to be a mix of fine-grained and organic sediments underlain by sands. These findings correspond with those of previous mapping in the area, in which the materials have been classified as glaciofluvial, either stratified drift or outwash deposits (Leverett, 1911; Martin, 1957; Soller, 1998).

The study area is underlain by Precambrian granitic and gneissic rocks (Reed and Daniels, 1987). The unconsolidated alluvium within the flood plain area is likely to have a much

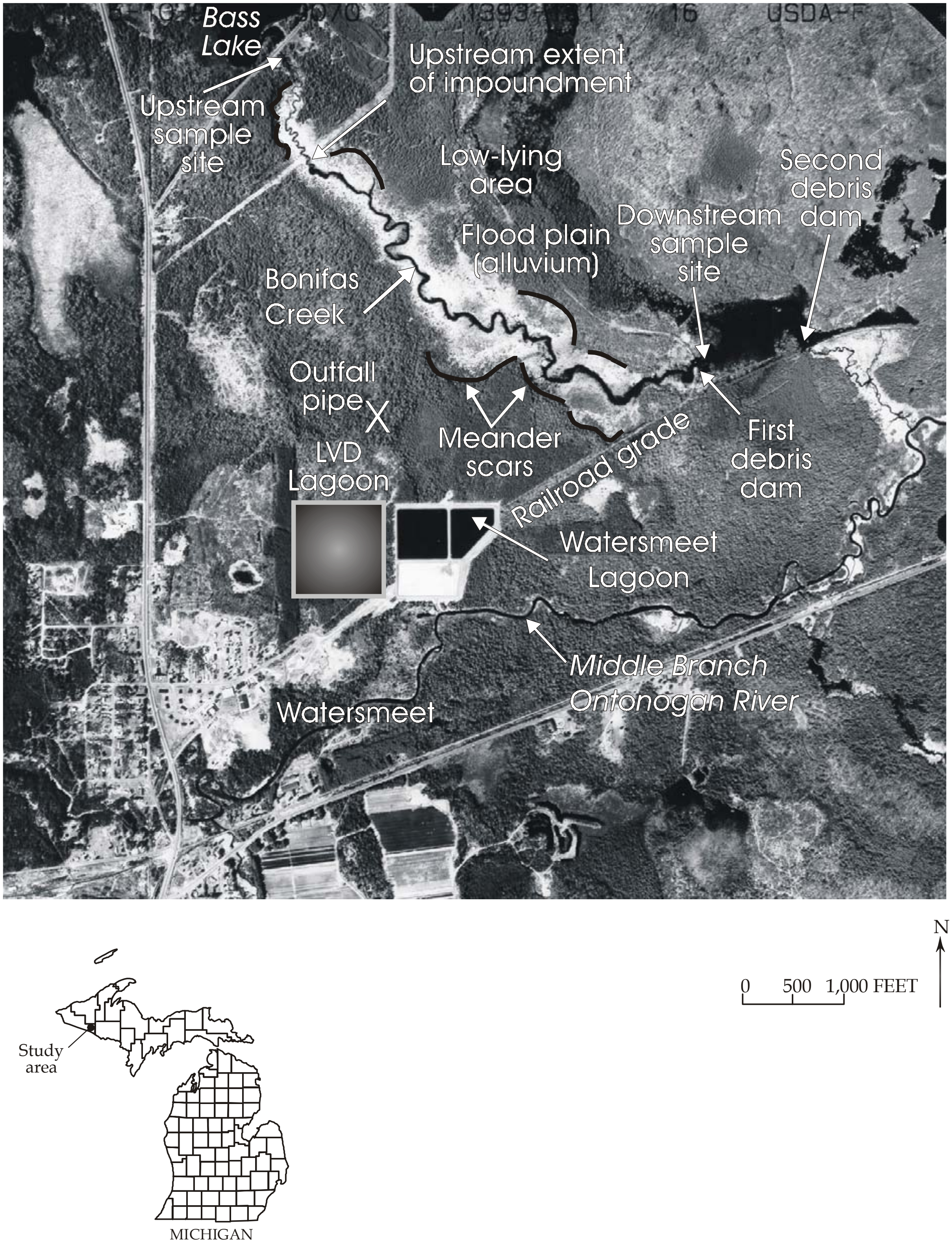

Figure 1. Location of the Bonifas Creek study area, wastewater lagoons, debris dams, impoundments, and meander scars, near Watersmeet, Gogebic County, Michigan. (Photo courtesy of US Forest Service.)

Table 1. Properties and chemical constituents for which water samples from Bonifas Creek were analyzed

[MR: Minimum Reporting Level; mg/L, milligrams per liter; µs/cm, microsiemens per centimeter at 25 degrees Celsius]

Parameter code	Property or constituent	Units	MRL	Method	Reference
403	pH, laboratory	standard units	0.1	I258785	Fishman and Friedman, 1989
530	Residue, total	mg/L	1.0	I376585	Fishman and Friedman, 1989
608	Nitrogen, ammonia	mg/L as N	.02	I252290	Fishman, 1993
613	Nitrogen, nitrite	mg/L as N	.01	I254090	Fishman, 1993
623	Nitrogen, ammonia & organic	mg/L as N	.1	I261091	Patton and Truitt, 1992
631	NO2 + NO3, dissolved	mg/L as N	.05	I254590	Fishman, 1993
665	Phosphorus, total	mg/L as P	.05	I461091	Patton and Truitt, 1992
666	Phosphorus, dissolved	mg/L as P	.004	EPA365.1	U.S. Environmental Protection Agency, 1994
671	Phosphorus, orthophosphate	mg/L as P	.01	I260190	Fishman, 1993
915	Calcium, dissolved	mg/L as Ca	.02	I147287	Fishman and Friedman, 1989
925	Magnesium, dissolved	mg/L as Mg	.004	I147287	Fishman, 1993
930	Sodium, dissolved	mg/L as Na	.06	I147287	Fishman, 1993
935	Potassium, dissolved	mg/L as K	.1	I163085	Fishman and Friedman, 1989
940	Chloride, dissolved	mg/L as Cl	.1	I205785	Fishman and Friedman, 1989
945	Sulfate, dissolved	mg/L as SO4	.1	I205785	Fishman and Friedman, 1989
950	Fluoride, dissolved	mg/L as F	.1	I232785	Fishman and Friedman, 1989
955	Silica, dissolved	mg/L as SiO2	.1	I270085	Fishman and Friedman, 1989
39086	Alkalinity, dissolved	mg/L as CaCO3	1.0	I203085	Fishman and Friedman, 1989
70300	Residue, dissolved 180C	mg/L	10.0	I175085	Fishman and Friedman, 1989
90095	Specific conductance	µs/cm	1.0	I278185	Fishman and Friedman, 1989
90410	Acid neutralizing capacity	mg/L as CaCO3	1.0	I203085	Fishman and Friedman, 1989

higher hydraulic conductivity than the crystalline rocks. Physical characteristics of the stratified glacial deposits beneath Bonifas Creek are unknown. Well logs from public-supply wells in Watersmeet indicate that glacial sediments are primarily sand and gravel with clay lenses interleaved (Doonan and Hendrickson, 1968).

During a site inspection in August 1997, emergent grasses extended from the bluffs to the open channel along the banks of Bonifas Creek. In much of this emergent area, vegetative mats were present below the water surface. These mats were a combination of decaying vegetative matter and the root systems of the grasses, suggestive of a minerotrophic environment (Mitsch and Gosselink, 1993). The impoundment upstream from the first debris dam was approximately 1 mile long, 75 to 100 ft wide, and estimated to average 6 ft in depth (sounding data were not collected). The impounded volume was estimated at a minimum of 2.4 million ft^3.

Further from the channel, on the bluffs, the vegetation transitioned first to tag alders *(Alnus rugosa)* and tamaracks (*Larix laricina*), usually as shrubs but occasionally as small trees, and then to stands of white cedar (*Thuja occidentalis*) and other evergreens as distance from the channel increases. Tag alders, and most other members of the genus *Alnus*, are capable of fixing atmospheric nitrogen (N_2) into a mineral form (NH_4^+) available to the plant (Voigt and Steucek, 1969) through a symbiotic relationship with bacteria of the genus *Frankia* (Berry, 1984). The presence of nitrogen-fixing vegetation implies that the site may be nitrogen limited. Certain nitrogen-fixing species can have a competitive advantage in high-nitrogen environments as well; however, the overall condition of the site (sandy soils, moss ground cover, and the water-quality results discussed later in this report) also suggest a nitrogen-limited soil environment. Discharge of lagoon effluent into this environment would increase the availability of nutrients and could locally alter the plant population.

The forest floor beneath the evergreens is littered with deadfalls and moss. Depression storage was significant, largely because of tree-throw pits. Root plates, tree-throw pits, and deadfalls provide numerous obstructions to overland flow.

Inspection of the site during the June 1998 wastewater discharge indicated that effluent was not flowing overland into the impoundment. The flow was intercepted by the depressions within the forested part of the site, where it either evaporated or infiltrated. Effluent infiltrating with recharge water into the glacio-fluvial sediments could reach Bonifas Creek over time; however, chemical composition of the effluent could be altered as a result of filtration, uptake by vegetation, and degradation before release into the impoundment.

EFFECTS OF WASTEWATER DISCHARGE ON WATER QUALITY

Water-quality characteristics at the upstream and downstream sites were described on the basis of analyses of samples collected twice before discharge from the lagoons and twice after discharges. The resulting data were compared to similar characteristics determined for the lagoon effluent to determine whether the effluent was affecting water quality at the downstream site.

Field-Measured Characteristics

Results for field-measured characteristics are shown in table 2. Specific conductance consistently increased between the upstream (04032915) and downstream (04032919) sites. The largest increases were observed in August 1997 and December 1997. These increases are probably the result of a higher proportion of ground water in the total discharge as compared to the September and June samplings. The August samples were collected during the height of the growing season and peak evapotranspiration; while sampling in December, the entire impoundment was covered by several inches of ice. Continuous streamflow records for the nearest downstream site (04035500) indicate that the August 1997 and December 1997 samples were collected during periods of base flow. The September 1997 and June 1998 samples were collected during periods of runoff. Temperature at the upstream and downstream sites was consistent, with variations of 0.5^0C or less during any sample collection visit.

Concentrations of dissolved oxygen (DO) were consistently lower at the downstream site,

Table 2. Field measurements of water-quality characteristics in Bonifas Creek, and wastewater lagoon (LVD lagoon) at Watersmeet, Mich.

[mm of Hg, millimeters of mercury; µS/cm, misrosiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; --, no data]

Sampling information and water-quality property or constituent	LVD lagoon	Bonifas Creek below Bass Lake (station 4032915) and at Watersmeet (station 4032919)							
		Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet
Date measured	June 5, 1998	August 27, 1997	August 27, 1997	September 25, 1997	September 24, 1997	December 18, 1997	December 17, 1997	June 17, 1998	June 16, 1998
Time measured	1500	1020	1345	900	1500	1000	1300	1130	1345
Air Pressure (mm of Hg)	--	721	721	--	--	713	718	722	714
Water temperature (degrees Celsius)	--	17.5	18	13.5	14	1	.8	21	21
Streamflow, instantaneous (ft^3/s)	--	.5	--	1.6	2.5	1.6	4.6	2.3	2.3
Field Specific Conductance (µS/cm)	--	75	98	68	73	79	93	81	85
Laboratory Specific Conductance (µS/cm)[1]	467	--	--	--	--	--	--	--	721
Oxygen, dissolved, (mg/L)	--	6.8	2.2	--	--	13.2	7.6	7.8	--
pH, field (standard units)	--	6.8	6.2	7.2	6.2	6.9	6.6	7.0	6.9
pH, laboratory (standard units)[1]	7.4	--	--	--	--	--	--	--	--
Bicarbonate, dissolved, (mg/L as HCO_3)	--	38	--	29	36	30	37	30	37

[1]Samples from lagoon outfall were not analyzed in the field. Results of laboratory analyses are provided for comparison

owing to a combination of the physical characteristics of the channel and biological activity. Water flowing through riffles at the upstream site was near saturation for DO in every case, whereas the depth-integrated value for the impounded downstream site averaged about 50 percent of saturation. A more detailed DO profiling, done in August 1997 with a Hydrolab H20, indicated a DO gradient, with concentrations ranging from near saturation in the top several inches to near zero near the bottom. It is unknown whether this gradient is present throughout the year or only during the summer.

The concentrations of bicarbonate increased from the upstream to the downstream site in samples collected in September 1997, December 1997, and June 1998. Field-measured pH decreased from the upstream to downstream sites, counter to what might be expected given increasing bicarbonate concentrations. The largest variation occurred during in September 1997, concurrent with fall die-off of wetland vegetation. The variation may be the result of decomposition of wetland biomass and release of organic acids.

Specific conductance and pH of the effluent from the lagoon were 467 µS/cm and 7.4, respectively. Both of these values are higher than those measured in Bonifas Creek.

Fecal Coliform Bacteria and Biochemical Oxygen Demand

Fecal coliform plates for samples collected from the upstream site contained between <2 and 14 col./100 mL. Plates for samples collected from the downstream site contained between 3 and 50 col./100 mL. These results are summarized in table 3. The presence of fecal coliform bacteria in stream water is not unusual, because fecal coliform bacteria are present not only in human waste but also in virtually all mammalian and avian feces. Given the abundance of wildlife on the land surrounding the impoundment, nonhuman waste is certainly a potential source of bacteria. Were wastewater flowing into Bonifas Creek, one would expect to see higher fecal coliform counts at the downstream site after discharge from the lagoon. The highest coliform count (50 colonies/100 mL) was observed at the downstream site on Bonifas Creek before discharge in August 1997. During the December 1997 and June 1998 samplings, fecal coliform counts were similar at the upstream and downstream.

The 5-day biochemical oxygen demand (BOD_5), a measure of biological activity, was determined for every sample, and no detectable BOD_5 was observed in any sample. Biochemical oxygen demand increases with increased algal and microbial activity.

Inorganic Chemistry

Samples collected at each site and sampling event were analyzed for concentrations of nutrients, including several forms of nitrogen (nitrate, nitrite, ammonia, and organic nitrogen) and phosphorus (dissolved phosphorus, total phosphorus, and orthophosphorus). All measured concentrations were extremely low, most below the Minimum Reporting Level (MRL). The results of these analyses are presented in table 4. If wastewater were reaching the downstream site, the expectation would be that, relative to the upstream site, nitrogen and phosphorus concentrations would be higher in the December 1997 and June 1998 samplings. Combined concentrations of organic nitrogen and ammonia did increase from the upstream to the downstream site, but that pattern was observed both before and after discharge from the lagoons.

Neither nitrate nor nitrite was present in concentrations greater than the MRL in any sample from either site. Ammonia was detected only in the samples collect in June 1998, at the upstream and downstream sites. Organic nitrogen was detected in samples collected upstream and downstream from the area receiving wastewater discharge, before and after wastewater was released. Concentrations are generally larger downstream, consistent with what would be expected if wastewater were present.

None of the phosphorus concentrations were greater than 0.05 mg/L. Total phosphorus concentrations increased downstream; however, this pattern was consistent both before and after wastewater discharge. No dissolved phosphorus was detected in any sample. An orthophosphorus concentration of 0.014 mg/L was detected at the downstream site in the June 1998 sample.

Table 3. Results of analyses for fecal coliform and 5-day biochemical oxygen demand in water samples from Bonifas Creek and wastewater lagoon (LVD lagoon) at Watersmeet,

[mm of Hg, millimeters of mercury; ft^3/s, cubic feet per second; cols./100 mL, colonies per 100 milliliters; ND, not detected; --, no data]

Sampling information and water-quality property or constituent	LVD lagoon	Bonifas Creek below Bass Lake (station 4032915) and at Watersmeet (station 4032919)						
		Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake
Date measured	June 5, 1998	August 27, 1997	August 27, 1997	September 25, 1997	September 24, 1997	December 18, 1997	December 17, 1997	June 17, 1998
Time measured	1500	1020	1345	900	1500	1000	1300	1130
Air Pressure (mm of Hg)	--	721	721	--	--	713	718	722
Water temperature (degrees Celsius)	--	17.5	18	13.5	14	1	.8	21
Streamflow, instantaneous (ft^3/s)	--	.5	--	1.6	2.5	1.6	4.6	2.3
Coliform, fecal (cols./100 mL)	--	14	50	10	3	<2	5	8
Five-day biochemical oxygen demand (BOD_5)	--	ND	ND	ND	ND	ND	ND	ND

Table 4. Results of analyses for selected inorganic chemical constituents in samples from Bonifas Creek and wastewater lagoon (LVD lagoon) at Watersmeet, Mich.
[mm of Hg, millimeters of mercury; mg/L, milligrams per liter]

Sampling information and water-quality property or constituent	LVD lagoon	Bonifas Creek below Bass Lake (station 4032915) and at Watersmeet (station 4032919)							
		Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet	Below Bass Lake	At Watersmeet
Date measured	June 5, 1998	August 27, 1997	August 27, 1997	September 25, 1997	September 24, 1997	December 18, 1997	December 17, 1997	June 17, 1998	June 16, 1998
Time measured	1500	1020	1345	900	1500	1000	1300	1130	1345
Air Pressure (mm of Hg)	--	721	721	--	--	713	718	722	714
Water temperature (degrees Celsius)	--	17.5	18	13.5	14	1	.8	21	21
Streamflow, instantaneous (ft^3/s)	--	.5	--	1.6	2.5	1.6	4.6	2.3	--
Nitrogen, ammonia (mg/L as N)	4.47	< .015	< .015	< .015	< .015	< .02	< .02	.08	.057
Nitrogen, nitrate (mg/L as N)	.03	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Ammonia + organic N (mg/L as N)	5.6	.3	.3	.4	.5	.5	.4	.5	.7
Nitrate + nitrite, dissolved, (mg/L as N)	< .05	< .05	.05	< .05	< .05	< .05	< .05	< .05	< .05
Phosphorus, total (mg/L as P)	1.56	< .01	.03	< .01	.049	< .01	< .01	.01	.02
Phosphorus, dissolved (mg/L as P)	1.45	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Phosphorus, ortho (mg/L as P)	1.16	< .01	< .01	< .01	< .01	< .01	< .01	< .01	.01
Alkalinity, dissolved (mg/L as $CaCO_3$)	--	31	--	24	30	25	30	25	30
Calcium dissolved (mg/L as Ca)	23.7	7.8	11.6	7.6	9.8	8.1	10.3	8.0	10.4
Magnesium dissolved (mg/L as Mg)	6.8	2.37	3.24	2.39	2.82	2.63	3.12	2.41	2.87
Sodium dissolved (mg/L as Na)	46.4	3.3	2.6	3.4	2.6	3.7	3.5	3.6	3.2
Potassium, dissolved (mg/L as K)	14.3	.7	.8	.7	.5	.7	.7	.7	.4
Chloride dissolved (mg/L as Cl)	69.1	5.7	3.9	6.0	4.0	7.0	5.9	6.3	5.6
Sulfate dissolved (mg/L as SO_4)	02.6	1.3	.8	1.7	1.1	2.1	2.1	2.0	1.2
Fluoride dissolved (mg/L as F)	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Silica dissolved (mg/L as SiO_2)	7.2	1.0	6.0	.9	6.6	1.3	5.5	.6	2.8
Residue total (mg/L)	--	2	12	<1	8	11	4	3	1
Residue DIS 180C (mg/L)	292	58	78	58	77	71	81	54	78
ANC, TIT. 4.5, L (mg/L as $CaCO_3$)	112	27	41	26	31	28	36	26	32

Concentrations of major cations (calcium, magnesium, potassium, sodium) and anions (chloride, flouride, sulfate, and bicarbonate) were determined in samples from upstream and downstream sites on Bonifas Creek as well as in the sample from the wastewater lagoon (table 4). Magnesium and calcium were consistently higher at the downstream site, before and after discharge from the lagoon. Potassium was lower downstream in all but the August 1997 sampling, including the two samples collected after discharge from the lagoons. Sodium and chloride concentrations were consistently lower at the downstream site before and after discharge from the lagoon. Chloride is generally considered very conservative; chloride concentrations are seldom affected by biological processes or sorption (Hem, 1985). Sulfate concentrations were typically lower downstream, although concentrations were nearly identical during the December 1997 sampling.

Concentrations of calcium and magnesium in the lagoon sample were about three times the concentrations observed at either site in Bonifas Creek. In contrast, concentrations of sodium, potassium, and chloride in the lagoon sample were more than one order of magnitude greater than any sample collected from Bonifas Creek.

Silica concentrations consistently increased from upstream to downstream before and after discharge from the lagoons. The concentration of DS consistently increased downstream, before and after wastewater discharge. The concentration of suspended solids increased downstream before the wastewater discharge, but decreased downstream after the wastewater discharge, which is counter to the expected effect wastewater would have on Bonifas Creek.

If wastewater is a significant component of the discharge at the downstream site, the sodium, potassium, and especially chloride concentrations would be expected to significantly exceed those measured at the upstream site, whereas calcium and magnesium concentrations should be somewhat greater. However, the opposite was actually observed. Before and after wastewater discharge, calcium, magnesium, bicarbonate, and alkalinity were always higher downstream, whereas sodium, chloride, and sulfate were typically lower downstream.

One possible explanation for this unexpected pattern in constituent concentrations in Bonifas Creek lies in the hydrologic and geologic setting of the site. The vast majority of surface water in this region is derived from ground water (Holtschlag and Nicholas, 1998). Local- to meso-scale flowpaths contributing ground water into Bonifas Creek are primarily within the alluvial and glaciofluvial sediments. Analysis of water from a well completed in the glacial sediments in Watersmeet (Doonan and Hendrickson, 1968) indicated higher concentrations of calcium, magnesium, and bicarbonate than are currently found in Bonifas Creek, and lower concentrations of sodium and chloride. This chemistry is consistent with ground water from glacial sediments derived in part from carbonate materials. Mickelson (1987) identifies the western Hudson Bay, an area noted for reef complexes throughout the Ordovician, Silurian and Devonian periods, as the source area for glacial ice flows in this region. Discharge of ground water derived from these glacial deposits into Bonifas Creek is consistent with most of the observed change in inorganic chemistry between the upstream and downstream sites.

SUMMARY AND CONCLUSIONS

Wastewater discharged from the treatment facility operated by the Lac Vieux Desert Band of the Superior Chippewa community near Watersmeet, Mich. was not observed to travel over land into the Bonifas Creek impoundment. The area between the outfall pipe and the impoundment was observed to have significant depression storage, numerous obstructions to surface flow, and highly permeable surface sediments. The discharge of wastewater into the area adjoining the impoundment is unlikely to have any immediate effect on the quality of water in Bonifas Creek. Discharge from the facility appears to have been detained in depression storage, where it was either evaporated directly, transpired by plants, or recharged to ground water. The presence of tag alders (*Alnus rugosa*), combined with the very low nitrogen levels in the impoundment and the sandy surface soils, strongly suggests that the area between the outfall and edge of the flood plain is nitrogen limited. Multiple wastewater discharges may increase ambient nitrogen levels in the receiving area, allowing other plant species to compete more effectively for water, sunlight, and other resources. Over time, this increase in ambient nitrogen could result in the replacement of tag alders with a some other type of vegetation.

No systematic increase in concentrations of nutrients, bacteria, suspended solids, or BOD_5 was observed in Bonifas Creek following the first two releases of wastewater from the LVD facility.

DEFINITION OF TERMS

Depression storage - accumulation of precipitation or snowmelt in depressions (Bates and Jackson, 1987).

Emergent plants - plants growing in shallow water, with part of their stems and leaves above the water surface (Bates and Jackson, 1987).

Minerotrophic marshes - marshes and fens support vegetation with dissolved nutrients derived from mineral deposits. A minerotrophic marsh or fen receives inputs of water and nutrients from surface-water and ground-water sources in addition to precipitation (Mitsch and Gosselink, 1993).

Nitrogen limited - a shortage of nitrogen, relative to other nutrients, restricts the number, type, or size of vegetation that can grow in that environment.

Underfit stream - a stream whose volume is greatly reduced or whose meanders show a pronounced shrinkage in radius (Bates and Jackson, 1987).

REFERENCES CITED

Bates, R.L., and Jackson, J.A., 1987, Glossary of geology (3d. ed.): Alexandria, Va. American Geological Institute, 788 p.

Berry, A.M., 1984, The actinorhizal infection process - Review of recent research, *in* Klug, M.J., and Reddy, C.A., 1984, Current perspectives in microbial ecology: Washington D.C., American Society for Microbiology, p. 222-229.

Britton, L.J., and Greeson, P.E., 1988, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A4, 363 p.

Doonan, C.J., and Hendrickson, G.E., 1968, Ground water in Gogebic County, Michigan: Michigan Geological Survey Water Investigation 8, 22 p.

Fishman, M.J., 1993, Methods of analysis of the U.S. Geological Survey National Water Quality Laboratory – Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 273 p.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 454 p.

Greenberg, A.E., Clesceri, L.S., and Eaton, A.D., eds., 1992, Standard methods for the examination of water and wastewater: Baltimore, Md. American Public Health Association, 905 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water, (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 249 p.

Holtschlag, D. J., and Nicholas, J. R., 1998, Indirect ground-water discharge to the Great Lakes: U.S. Geological Survey Open-File Report 98-579, 25 p.

Leverett, F., 1911, Map of the surface formations of the Northern Peninsula of Michigan: Lansing, Mich., Geological Survey of Michigan, scale 1:500,000.

Martin, H.M., 1957, Map of the surface formations of the Northern Peninsula of Michigan: Geological Survey Division, Michigan Department of Conservation, Lansing, Michigan, 1 sheet, 1:500,000 scale.

Mickelson, D.M., 1987. Central Lowlands, *in* Graf, W.L., ed., Geomorphic systems of North America: Geological Society of America, Centennial Special Volume 2, p. 111 - 118.

Mitsch, W.J., and Gosselink, J.G., 1996, Wetlands (2d ed.): New York, Van Nostrand Reinhold, 642 p.

Patton, C.J., and Truitt, E.P., 1992, Methods of analysis of the U.S. Geological Survey National Water Quality Laboratory – Determination of total phosphrus by a Kjeldahl digestion method and an automated colorimetric finish that includes dialysis: U.S. Geological Survey Open-File Report 92-146, 39 p.

Rantz, S.E., and others, Measurement and computation of streamflow. Volume 1, measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, 284 p.

Reed, R.C., and Daniels, J., 1987, Bedrock geology of Northern Michigan: Lansing, Mich., Michigan Geological Survey, scale 1:500,000.

Shelton, L.R., 1994, Field guide for collecting and processing stream water samples for the National Water Quality Assessment Program: U.S. Geological Survey Open-File Report 94-455, 42 p.

Soller, D.R., 1998, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-B, scale 1:1,000,000.

U.S. Environmental Protection Agency, 1994, Methods for the determination of inorganic substances in environmental samples: Available from National Technical Information Service as PB94-120821, 169 p.

U.S. Geological Survey, 1997, Comparison of the suspended-sediment splitting capabilities of the churn Splitters: Office of Water Quality Technical Memorandum 97.06, 2 p.

Voigt, G.K., and Steucek, G.L., 1969, Nitrogen distribution and accretion in an alder system: Soil Science Society of America Proceedings, v.33, p. 946-949.