PROGRESS REPORT: LAND USE AND WETLAND DRAINAGE EFFECTS ON PRAIRIE WATER QUALITY STUDY

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Summary

This report is an update on progress made to the end of December 2008. According to our study plan, we should have completed one summer worth of data collection and made progress in laboratory analytical work. Outlined in the report are data collection methods and progress to date made on our research objective of "determining changes in water quality of streams and impacts to ecosystem function associated with wetland drainage".

Considerable progress toward the research objective was achieved during the reporting period, and overall, the project is on schedule.

Smith Creek was broken down into its tributaries (North Fork, South Fork and Thingvalla). Water samples at the outlet and tributaries of Smith Creek were taken on 35 occasions during the spring, summer and fall. Chemical analysis of these samples is 70% complete.

The wetland for the drainage experiment was selected and instrumented with an electronic water level recorder and precipitation gauge. A bathymetry survey of the wetland was carried out and used to compute the volume of water stored in the wetland at different water levels. Water chemistry for the wetland was analyzed 29 times during the spring, summer and fall. Preliminary results show concentrations of DOC increased over the spring and early part of the summer as the wetland evaporated. Concentrations then fell to post-snowmelt values during the unusually wet late summer period. The wetland was drained this fall ahead of schedule due to the needs of the landowner. Once drained, the wetland lost 42% of its volume within 22 hours. Preliminary findings were that the drain was a source of TP during the first 2.5 hours and then transitioned to a sink.

The Benthic Entomology (BENT Lab) of the Saskatchewan Watershed Authority (SWA) provided a preliminary assessment of the biotic health in the Smith Creek watershed. Sampling was conducted in spring 2008, and the progress of this assessment is as follows: a) Four sites were sampled in the watershed; b) 83% of all samples have been processed and identified; c) to date, a total of 9,669 individuals have been identified, representing 80 taxa; and d) of the samples processed, they are characterized primarily by pollution-tolerant fly larvae, and fast growing non-insect taxa typical of seasonal prairie streams. SWA is now preparing plans for additional assessment in 2009, and further evaluation of 2008 results using a reference condition approach and test site analysis in order to obtain robust measures of ecosystem health in the Smith Creek watershed.

Methods

Study Site

The study site is located within the prairie pothole region in southeastern Saskatchewan at Smith Creek watershed (Figure 1). Smith Creek watershed is a sub-basin of the Assiniboine River, which drains into Lake Winnipeg. The watershed is approximately 435 km^2 with an effective contributing area of 58 km^2 (Environment Canada, 2006). Mean annual precipitation at the nearby Yorkton, SK weather station is 450 mm, with 26% falling as snow (Environment Canada, 2004). Localized convective storms are common during late summer. Average seasonal temperatures are -15.5^{o}C and 16^{o}C for the winter and summer, respectively.

Temporary, semi-permanent, and permanent potholes are present throughout of the watershed (Figure 1). Many of the wetlands are typical, isolated prairie potholes that formed in depressions which at average surface water levels have no surface inflows or outflows. Pristine potholes often occupy the lowest point in a small, closed basin, and generally do not contribute to streamflow except in very wet years. Recently, a number of drainage ditches have been constructed to increase agricultural production. These drainage ditches either completely eliminate the wetland or drastically lower the water levels and create downstream connections with other wetlands, roadside ditches, or streams. Between 1958 and 2001 the portion of land cover occupied by wetlands in the Smith Creek watershed has decreased from ~17% to ~9%. The amount of wetland drainage has not been uniform throughout the basin: drainage has been most prolific in the eastern and southwestern portions of the watershed (Figure 1).

Wetland water quality sampling

The dominant factor regulating pothole water quality will be determined by sampling 60 potholes for a suite of water quality parameters. The potholes sampled will encompass a range of catchment land use types and wetland permanence classes. The experimental design will be nested where wetland permanence will be nested within catchment land use. The potholes will be classified using the system outlined in Millar (1976). Land use classes will include agriculture, pasture, grassland, and wooded. For agricultural lands, the type of crop planted each summer will noted and potentially used in the analysis. Potholes to be included in the sampling program will be isolated, meaning they will have no surface inflows or outflows. The potholes will be selected in February 2009 using digital maps obtained from Ducks Unlimited Canada from 2001, and their isolation will be verified in the field prior to sampling. The catchment area of each pothole will be delineated using the ArcGIS PourPoint function and 1 m resolution LiDAR data that will become available for the watershed in February 2009 as part of another project in the basin led by Dr. John Pomeroy (University of Saskatchewan).

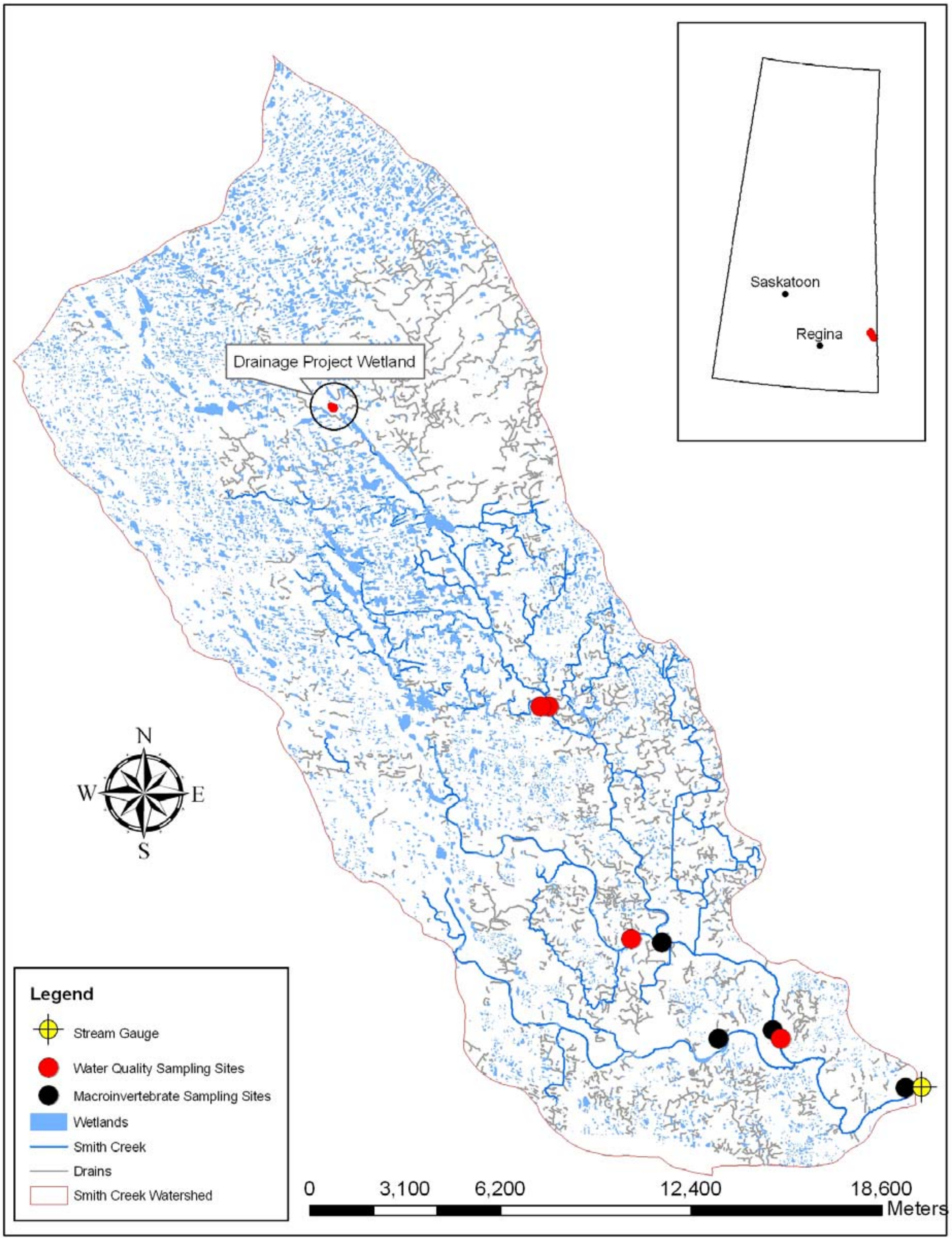

Figure 1: Smith Creek watershed, showing location of wetlands and wetland drains (from 2001), stream channels, and sampling locations.

Sampling will occur at the beginning of May 2009, while temporary and seasonal ponds are still filled with water (i.e. immediately following snowmelt). The duration of the sampling program will be minimized to decrease the effects of temporal variations. Water samples will be collected from roughly the deepest point in the pothole, which is typically the centre of the ponds, at one half the total depth. Multivariate statistics will be used to examine patterns in the pothole water quality data set.

Stream water quality sampling

Samples were collected at three locations along Smith Creek in 2008, and will be collected at these three sites plus at one additional site in 2009. One sample site is the basin outlet, and the other sample sites are the three sub-basins of Smith Creek (Figure 1) where wetland distribution in the sub-basins was historically similar, but recently there have been different amounts of drainage (extensive, intermediate, and minimal) in each. Discharge will be estimated at the time of sampling in 2009 for the three sub-basins using a Marsh McBirney flow meter so that nutrient loads and flow-weighted ionic concentrations can be estimated. The sub-basin areas and their effective contributing areas will be delineated using the ArcGIS PourPoint function and 1 m resolution LiDAR once the LiDAR image becomes available in February 2009. The proportion of land uses for each sub-basin will also be determined using digital images. Stream water quality measurements are taken daily during peak flow (spring runoff), weekly during low flows, and after heavy rainfall events for the ice free period. A water quality sonde was used to continuously measure pH, specific conductance, and dissolved oxygen at the basin outlet during the snowmelt period in 2008, and is expected to be re-deployed for the same purpose in 2009.

Wetland drainage experiment

The water quality of pothole LR3 (refer to Figure 1 for LR3s location in the watershed) was measured weekly between April and October, prior to experimental drainage. As part of another one of my student's (Adam Minke) masters project, water levels were recorded every hour over the same time period using a PT2X pressure transducer. As well, a bathymetry survey of the wetland was carried out using a total station. These data were used to create a digital elevation model (DEM) of the wetland basin. From it, the volume of stored water was computed for various water levels.

The wetland was experimentally drained by a 138 m-long ditch (Figure 2), dug using a track hoe and professional operator between 20 and 21 November 2008. LR3 now drains into Smith Creek via another wetland (Figure 3). Water quality was measured along the ditch length at 35 m intervals (Figure 3) four times over the first 25 hours following drainage. Water samples were collected from the mid-point between the stream/ditch banks at one half the water depth. Water chemistry was also measured in the wetland itself immediately before the drain was dug and then each time the ditch water was sampled.

In addition, we propose to measure water quality along the length of 12 different potholes and their drainage ditches during spring melt in 2009. This will permit statistical inferences of the effects of wetland drainage on stream water quality and complement our wetland drainage experiment. We propose to sample each pothole once, and sample the ditches in four locations along their length. Water samples will be collected from the mid-point between the stream/ditch banks at one half the water depth. Discharge in the pothole drainage ditches will be measured using a Marsh McBirney flow meter. Concentration and loads of the various water quality parameters will be compared to the water quality of the pothole that the ditch drains and then related to ditch length.

Figure 2: Photograph showing the wetland experimentally drained (LR3) on November 20-21, 2008.

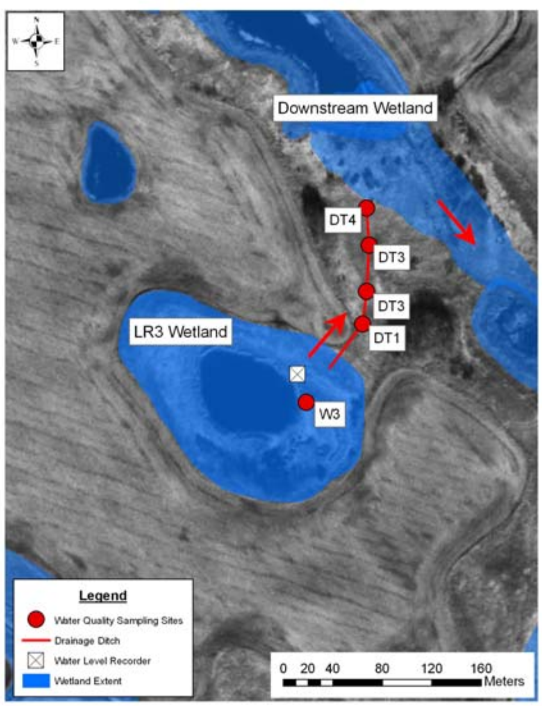

Figure 3: Aerial photograph showing the location of the LR3 pothole, its drain, and the location of water quality sampling locations. wetland drainage experiment, performed 20-21 November 2008.

Water chemical analyses

In situ measurements of dissolved oxygen, specific conductance, pH, and temperature were obtained using hand-held meters at all sample sites. Samples were submitted to SRC Analytical Laboratories (Saskatoon, SK) for analysis of total phosphorous (TP), ortho-phosphate, total Kjeldahl nitrogen (TKN), bacteria (total coliforms and *E. coli*), and dissolved organic carbon (DOC). Major ion concentrations (i.e. Cl^-, Br^-, SO_4^{2-}, NO_3^-, CO_3^{2-}, HCO_3^-, NH_4^+, Ca^+, Na^+, K^+, Mg^+) will be measured using a DIONEX ICS-2000 reagent-free ion chromatography system located at the University of Saskatchewan, which is partly owned by the principal investigator. Dissolved organic nitrogen (DON) concentrations will be estimated using the difference between TN and inorganic N species concentrations. One duplicate and one blank sample are analyzed for every fifteen samples collected for QA/QC. Samples are filtered (as required), kept on ice, and preserved (as required) prior to analysis.

Macroinvertebrates

<u>Sites sampled</u>

Four sites were sampled in the Smith Creek watershed, three of which on Smith Creek itself while a third was assessed in the Langenburg Creek tributary on 8 May, 2008 (Figure 1). We intended the positioning of our sites to be as up-stream as possible in these headwater creeks, and still have reliably assessable benthic macroinvertebrate assemblages.

Because the Smith Creek and its tributaries often cease to flow by midsummer, we chose to sample for benthic macroinvertebrates in the spring 2008. Benthic macroinvertebrate-based biomonitoring approaches are best applied in two time windows through the course of a year; the first is the early spring shortly after ice-off, and the latter is the fall shortly before ice-on (Hilsenhoff 1988).

Although covered in greater detail in the SWA (2008) report to the Ministry of Agriculture on stream assessment, several characteristics of benthic macroinvertebrate ecology necessitate sampling during the early spring time-window for seasonal Great Plains streams such as the Smith Creek. Firstly, benthic macroinvertebrates are best developed going into the winter and shortly before emerging in the spring and thus easier to identify. However intermittent streams often dry in the fall, and as such, samples should be taken during the spring to keep comparisons among sites consistent. Second, insects are morphologically well developed as they prepare to emerge in the spring, and waterbodies possess the greatest abundance and diversity in this time window prior to out-migration associated with drying conditions. Further, sampling of macroinvertebrates during the summer is not ideal because rapid developing taxa that flourish at this time under high energy conditions can bias the water body condition as they often live in the stream for short periods (e.g. two or three weeks). Finally, sampling seasonal waterbodies such as those in southern Saskatchewan, peak flow in the spring is likely the time of year when water flows overland. This is an important period for linking land use and water quality.

As identified in SWA (2008), we recommend future biomonitoring for these waterbodies to be conducted in mid to late April each year in the period of maximum flow.

<u>Benthic macroinvertebrate assessment</u>

At each site we collected both D-frame net samples and Hess samples across the 4 positions assessed in this watershed. Because we were uncertain at the outset of this study whether the seasonal waterbodies would be wide enough for D-frame net assessment or flowing sufficiently for Hess assessment, we included both sampling techniques in 2008 in order to "hedge our bets" and ensure samples were obtained across all sites. D-frame net (base of 0.30 m, 500.00 µm mesh) samples were collected using composite sweep (10 seconds per sweep over an area ~ 1 m) samples taken in a transect across the river. Five samples were taken in each transect; left bank, ¼ distance, ½ distance, ¾ distance, and right bank). All 5 position sweeps were integrated into a single sample per transect. Sampling among sites was standardized by maintaining a constant sweep time (10 seconds) across a constant area (0.30 m^2). Samples were concentrated on a 500 µm mesh sieve and preserved in 80 percent ethanol in the field. Organisms were returned to the laboratory where they were sorted from the organic material under 7 X magnification and stored in 80 percent ethanol until they were identified to lowest possible taxon designation. Samples were subsampled where necessary. Final abundances are expressed as corrected to that of the original sample.

Benthic macroinvertebrates were identified to lowest possible designation using keys for North America (Merritt and Cummins 1996) and Western Canada (Dosdall and Lemkuhl 1979, Brooks and Kelton 1967, Clifford 1991, Larson 2000, and Webb 2002). Voucher series were deposited in both the Saskatchewan Watershed Authority Invertebrate Voucher Collection (Saskatoon, Saskatchewan), and the Royal Saskatchewan Museum (Regina, Saskatchewan).

Progress During the Reporting Period

Progress to date and during the reporting period are the same, and thus are presented only once, in this section.

Wetland water quality

Preliminary selection of the 60 wetlands to be sampled in 2009 is currently underway. We decided to sample the wetland only once for two reasons: 1) to avoid the confounding impact of time in determining the relative importance of land use and permanence on wetland water quality; and 2) 60 samples are sufficient for statistical power in our planned multivariate analyses. This will free up funds to bolster our ability to assess of wetland drainage effects on stream water quality, should the Ministry approve this project change. We propose to measure water quality at 12 wetlands and at four sites along the length of their drains (n = 60). This will permit statistical inference of the effects of wetland drainage on stream water quality, thereby complementing our wetland drainage experiment and adding power to our ability to make conclusive statements regarding wetland drainage effects on prairie streams.

Stream water quality

Water quality samples were obtained at the Smith Creek outlet and just upstream of the North and South Fork confluence on 35 occasions between 13 April and 22 October 2008. The proportion of wetland drainage in the North Fork is high and in the South Fork is low. Thus, we will be adding one additional sampling site in 2009, Thingvalla Creek, where wetland drainage is moderate. So far, samples have been analyzed for TKN, TP, ortho-phosphate, DOC, total bacteria, *E. coli*, and pH. We are currently in the process of analyzing major cations and anions, including dissolved forms of inorganic N in the samples using our ion chromatograph and working up existing data.

A water quality sonde was used to collect continuous electrical conductivity, pH, temperature, and dissolved oxygen data at the basin outlet during the snowmelt period, but low runoff depths permitted only 12 days of data collection. Given the current snowpack in the basin, we anticipate a considerably longer data collection period for the sonde in 2009. Data quality are currently being checked.

Wetland drainage experiment

The wetland drainage experiment was chosen to be conducted on the LR3 pothole because its hydrology was being studied as part of Dr. John Pomeroy's development a prairie hydrological model project. Thus, water levels, water temperature, and precipitation were measured for LR3 between April and October 2008 as part of one of my graduate students' (Adam Minke) thesis. Water quality samples were obtained from LR3 29 times during this period. Thus far, samples have been analyzed for TKN, TP, ortho-phosphate, DOC, total bacteria, *E. coli*, and pH. We are currently in the process of analyzing major cations and anions in the samples using our ion chromatograph.

Preliminary results of the natural variations in wetland water levels and selected water quality constituents are shown in Figure 4. Water levels decreased by 75% in the early summer due to evaporation. During this period DOC concentrations increased nearly linearly. TP and TKN concentrations were more variable and were responsive to rain events. An unusually wet July and August led to a 40 cm increase in the water level, making the wetland water level higher than it was following snowmelt. A sharp decline in DOC concentration was observed but there was no correlated response in TP or TKN. Concentrations of all three water quality constituents remained fairly constant throughout the fall until ice-up.

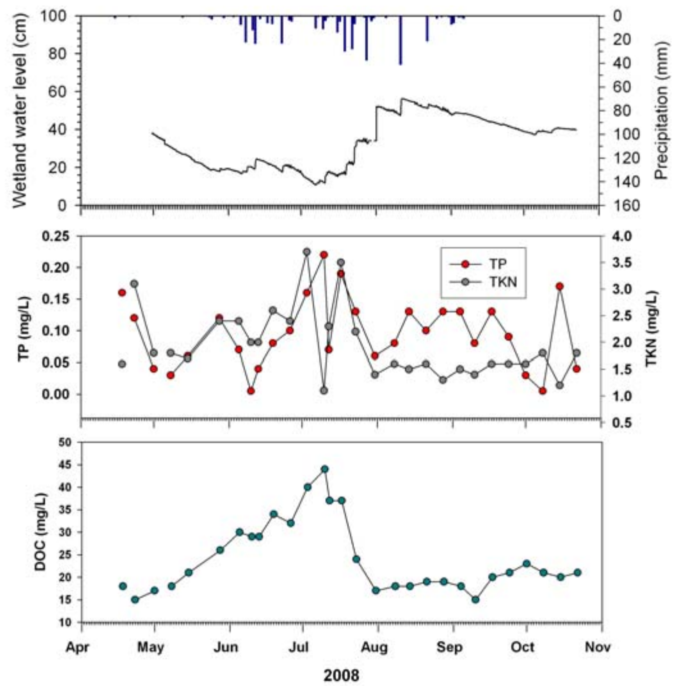

Figure 4: Time series of rainfall, water levels and selected water quality parameters for pothole LR3 prior to drainage.

The wetland drainage experiment happened sooner than planned due to the needs of the landowner. A professional track hoe operator dug the wetland drain on November 20 and 21, 2008. Although the LR3 wetland was frozen at the surface during the experiment, it lost 1455 m^3 or 42% of its water volume within 22 hours of the drain being dug. A water sample of LR3 was taken through the ice just prior to the completion of the drain. Water quality samples were taken 0.5, 2.5, 5 and 22 hours after drainage commenced in LR3 and at the four locations along the drain. Samples have been analyzed for dissolved oxygen, pH, conductivity, TKN, TP, ortho-phosphate, and DOC. Ionic analysis is currently underway.

Preliminary results for changes in the wetlands' TP concentration as water flowed along the drainage ditch are shown in Figure 5. Results show TP is enriched as water leaves the wetland and moves along much of the drain, likely because the freshly exposed soils lining the ditch are easily carried away by the flowing water. However, as drainage proceeded, TP concentrations fell to <10% of those measured in the wetland, suggesting the ditch rapidly transitioned from a source to a sink. Concentrations of the various water quality parameters will be measured in LR3 and its drain again following snowmelt 2009.

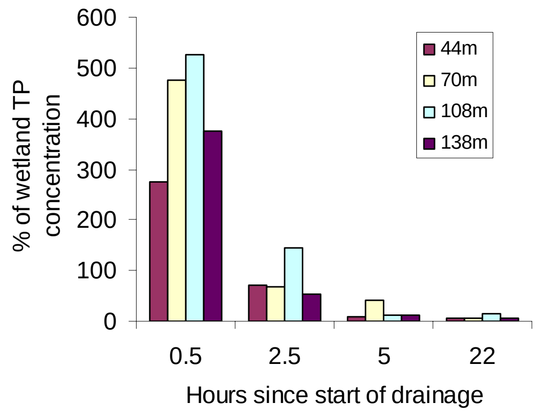

Figure 5: Percentage of wetland TP for different distances along the drainage ditch since the start of drainage.

Macroinvertebrates

A total of 24 macroinvertebrate samples were taken in 2008 (Table 1). Thus far, a total of 9,669 individuals have been identified, representing 80 taxa in the samples taken. As sample processing is 83% complete, we will most certainly increase the number of taxa encountered in this watershed. The samples analyzed to date in the current project are dominated by midge (Diptera: Chironomidae) larvae, no-see-um fly (Diptera: Ceratopogonidae) larvae, nematodes (Nematoda) and seed-pod shrimp (Ostracoda). These taxa have been found to dominate small-order seasonal streams in other studies occurring concurrently throughout southern Saskatchewan in agricultural settings (e.g., Paired Watersheds Project, SWA/MoA Study [SWA 2008]).

Table 1: Site locations and sample summaries for the benthic macroinvertebrate assessment 2008.

Waterbody	Site description	Site code	No. samples D-frame	No. samples Hess
Smith Creek	N of Marchwell	SWA_2008_16	4	4
Smith Creek	E of Langenburg	SWA_2008_17	4	4
Langenburg Creek	E of Langenburg	SWA_2008_18	1	3
Smith Creek	Werle Farm	SWA_2008_19	1	3

Further, D-frame net assessment was possible in all sites allowing consistent comparison with the reference condition approach and test site analysis being developed by the BENT Lab within SWA (see below). Therefore, future analysis aimed directly at assessing biotic health using 2008 data collected here is possible in 2009.

The second stage of the ecosystem health component within the project will involve evaluating the benthic macroinvertebrate assemblage characteristics relative to reference sites with comparable underlying physical characteristics. The concept of 'ecosystem health' encompasses the condition of functions provided by communities (e.g., filtering, decomposition) and assemblage characteristics that track disturbance (diversity, abundance). The ecological health characteristics of the streams studied here are likely comparable to other conditions across the southern prairies. However, understanding what conditions should be expected for each waterbody with minimal human influence, and how far the current conditions may deviate from what is desirable requires further investigation; specifically, application of test site analysis and reference condition approach. These approaches will help discern how watershed characteristics (ecoregion, surficial geology, soils) influence stressor-response relationships. Only by including these sites in test site analysis whereby underlying physical characteristics such as flow are taken into account for comparisons may we be able to indicate healthy, potentially degraded, and degraded designations for ecosystem health.

SWA has developed a macroinvertebrate model capable of assessing ecosystem health in Saskatchewan prairie streams, attributing degree of impact, and identifying stressing human activities. However, it is necessary to first characterize the underlying physical characteristics of the watershed upstream of the sites studied here, before the test site analysis model developed by SWA can be applied and their condition evaluated. Benthic macroinvertebrate samples are not yet completely analyzed for 2008, but will be prepared in time for analysis with samples from 2009 in a final ecosystem health synopsis. Additional sampling in 2009 will compliment the assessment begun in 2008, and allow for a greater resolution of ecosystem health impact in the Smith Creek watershed. Further, using the land-use information accrued by the investigators at the University of Saskatchewan we will be able to provide this site-level ecosystem health assessment in 2009 to compliment both hydrology and water quality condition.

Administrative and Other Aspects

Project personnel

The graduate student who is undertaking the water quality work as her M.Sc. project is Nathalie Brunet. Ms. Brunet was recruited from University of Waterloo, where she completed her undergraduate training in the co-operative Civil Engineering, Water Resources Option program. She started in late June, 2008 and is now in the process of analyzing samples collected this past summer on the ion chromatograph. Ms. Larisa Barber is an undergraduate student enrolled in the Environmental Earth Sciences program at the University of Saskatchewan who worked as a technical assistant on the project this past summer. She will work with Ms. Brunet as a technical assistant in the upcoming 2009 field season. The macroinvertebrate work is being handled by Saskatchewan Watershed Authority, led by Iain Phillips.

Extension meetings

Residents of Smith Creek are quite concerned with their water quantity and quality, and have formed the Smith Creek Watershed Association. We met with the Smith Creek Watershed Association on July 30, 2008 and presented the research project. The community was quite receptive to the work, and excited to help out in any way, including permitting access to their land for wetland sampling in 2009, stream sampling, and helping organize the equipment needed to experimentally drain the LR3 pothole.

Scientific presentations
Dr. Bedard-Haughn was asked to present a talk on prairie wetland biogeochemical cycling at the Saskatchewan Soil Conservation Association Advisors' Workshop. As part of her talk, she included several slides outlining the goals and preliminary results of our project on wetland drainage effects on water quality. The citation for her presentation is:

Bedard-Haughn, A. 2008. Carbon and nitrogen cycles in wetland soils. Saskatchewan Soil Conservation Association Crop Advisors' Workshop, December 4-5, Regina, SK.

Acknowledgements

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