STUDY REPORT

ANALYSIS OF HIGHWAY STORM WATER RUNOFF IMPACTS TO POTABLE GROUNDWATER AQUIFERS

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Prepared for

St. Croix River Crossing
Stakeholder Water Resources Study Group

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PURPOSE

The "worst case scenario" of storm water quality is usually found in heavily urbanized areas where there is a lot of pollution and major traffic volume or congestion. Highway storm water does occasionally contaminate groundwater with minor amounts of petroleum compounds and metals (zinc or lead), and it certainly can contaminate groundwater with salts (sodium and chloride) from winter maintenance road salt applications. However these chemicals are usually present at extremely low concentrations and they tend to be very localized around the DOT right of way. To assess potential treatment options for highway storm water runoff, the following study report addresses concerns regarding potential impacts to potable groundwater sources from proposed highway stormwater runoff infiltration sites. A literature review of previously conducted studies and an analysis of the hydrology, limnology, and available subsurface data for the project area was conducted.

SUMMARY OF RESEARCH FINDINGS

Heavy Metals

Common constituents of highway runoff include trace quantities of aluminum, cadmium, chromium, iron, lead, magnesium, nickel, and zinc which are primarily generated by vehicle body/frames, engines, brakes, and tire wear. Research conducted by Hathhorn and Young (1995) for the Washington State and US Departments of Transportation provided a thorough analysis of fate and transport mechanisms of zinc, lead, copper, and cadmium within stormwater infiltration basins. Based on laboratory and field studies, the authors conclude that natural organic matter in the soil plays a key role in heavy metal sorption by forming organo-metallic complexes at high organics concentrations. The authors suggest that, "infiltration can be a viable alternative in disposing of runoff at low metals concentrations." Loamy-sand was determined to be optimal for both its relatively high infiltration rate and contaminant retention properties. Given the proper site characteristics, sorption of up to 90 percent of heavy metals is possible within the first three feet of soil although the authors do caution that the presence of background metals will affect a soil's potential for metal retention. Though the study was short term, the authors suggest that basin soils may eventually require removal once they become fully saturated with contaminants. Finally, the authors provide guidance for background metal concentrations, and ranges of organic carbon, silt and clay that should be not be exceeded in an infiltration basin soil, and suggest that extending the depth of groundwater to ten feet or more should be seriously considered.

A parallel study the same year suggests that mobilization of heavy metals appears to be caused by use of deicing chemicals (Granato, Church and Stone, 1995). The Granato study concluded that dissolved salts from deicing chemicals temporarily increases migration of heavy metals into nearby shallow aquifers. Sites tested in the study were comprised of 75-95 percent course sand and 2-24 percent silt/clay. Minimal organic matter was present. Shallow wells, located at depths of 18 feet to 55 feet and in close proximity to the roadways studied, exhibited increased heavy metal concentrations associated with applications of deicing salts. Despite the increases, however, none of the shallow well measured concentrations of the major and trace constituents in groundwater exceeded national primary drinking-water standards. The deep wells in the project, screened at approximately 90 feet below grade, were not impacted by highway runoff constituents over the four year testing period.

<u>Chlorides</u>

By far the most common groundwater contaminant from highway storm water is chloride from winter maintenance road salt applications. Chloride dissolves easily into snowmelt and storm water and subsequently the groundwater. Concentrations of dissolved chlorides naturally present in groundwater varies, but are usually less than 10 mg/L. Generally, high chloride levels in water are primarily an aesthetic concern, but elevated chloride levels may be a health risk to those individuals with heart or kidney diseases. With respect to movement of chlorides into groundwater, the consensus of several studies is that dissolved chlorides readily migrate through soils and can be measured at higher levels in shallow groundwater aquifers adjacent to highway storm water infiltration areas (Jones and Sroka, 1997; Ku, 1986; Granato et. al., 1995). Shallow aquifers sampled in various studies did indicate increased chloride levels up to 70 times higher than background levels and many measurements were above the 250 mg/L guideline (Jones and Sroka, 1997). The studies varied in the amount of chloride detected, but none of the wells sampled below 50 feet contained levels of chloride exceeding the accepted agency chloride guideline of 250 mg/L (taste threshold). The well samples below 50 feet were also below the Wisconsin chloride preventative action limit (125 mg/L). Groundwater studies conducted in Washington County, Minnesota, indicated that many groundwater-fed springs contained higher chloride levels, which the authors attributed in part to proximity to Highway 95 (Emmmons & Olivier Resources, 2003). Depending on groundwater flow and transfer mechanisms, there is a risk of increased levels of chlorides in deeper aquifers after sustained of road salt applications.

<u>Bacteria</u>

Given the rural land use in the Wisconsin portion of the proposed project and the potential for manure application, coliform bacteria removal efficiencies were researched in the literature review. "Total coliforms, fecal coliform, and fecal streptococci area know as 'indicator' organisms because they are often considered to indicate the presence of sewage and, ideally, are correlated with the number of pathogens in a water sample (Ku, 1986)." In the study which did sample for bacteria, confirmed coliform counts of upwards of 24,000 organisms in storm water runoff were reduced via natural process during infiltration to three organisms in groundwater samples at a depth of 60 feet. In general, it appears that infiltration through a few feet of soil provides adequate treatment for bacteria.

SUMMARY OF WISCONSIN DATA

Groundwater quality is regulated in Wisconsin by the Wisconsin Department of Natural Resources (Chapter NR 140 – Groundwater Quality and Chapter NR 151 – Runoff Managment). Public welfare groundwater quality standards are listed in NR 140.12. The standards are divided into two categories, Enforcement Standards and Preventative Action Limits which are 50 percent of the established enforcement standard.

Several soil data maps were utilized to ascertain risks to groundwater in the area. The publication "Soils of St. Croix County and their Ability to Attenuate Contaminants" (1987) indicates that in the Houlton area, attenuation of contaminants varied from "Least" to "Best." Since the contaminant attenuation range is relatively large, a site specific survey and soil analysis of potential infiltration basin locations is recommended. The water table map of the area indicates that the water table varies in elevation from 700 feet to 900 feet, which corresponds to an average depth of 20 feet to 40 feet below ground surface. Table 1 shows the average depth to bedrock and bedrock type for the proposed Wisconsin ponding locations. Based on these data sources, there appears to be an adequate thickness of soils beneath the drainage outfall area and ditch line to filter out most common storm water contaminants except the road salts.

Groundwater quality investigations in the area indicate an average groundwater pH of 8.0 and average chloride levels of 4 mg/L. Chloride sampling data for wells located within Houlton, provided by the Wisconsin DNR, all contained chloride concentrations less than the Enforcement Standard. All of the wells, with the exception of two locations, sampled well below the Preventative Action Limit. Of the two wells that exceeded the PAL in some instances, only one well log was located. The well log indicated that it was constructed in 1966, that was only grouted to 43 feet and that the pumping water level was measured at 146 feet. Given the shallow grouting depth, it is reasonable to assume from the previous chloride discussion that road salt migration into the well is quite possible. However, analysis of all available well logs for the sections within which the proposed project is located did not indicate any wells shallower than 90 feet. In addition, the highway storm water chemistry from this area is not expected to be a "worst case scenario". The project location is in a semi-rural area with low traffic volumes and minimal paved surface areas (e.g., two-lane highway as opposed to a six-lane freeway). In light of the previous chloride discussion, it would be acceptable to allow the construction of highway runoff infiltration basins that adhere to the Hathorn and Young (1995) criteria (see heavy metals discussion above). Based on available data, heavy metal or chloride contamination above preventative action limits of potable groundwater at the existing well depths identified via properly constructed infiltration basins appears unlikely.

Table 1: Depth to Bedrock, Bedrock Type, and Soil Type for Proposed Wisconsin Ponding Locations

St. Croix River Crossing

Pond	EB TH36 STA	Surface Elevation from Contours	Bedrock Surface Elev.[1]	Glacial Drift Thickness[2]	Bedrock Type[1,2]	Soil Type[3]
Alternative B-1						
A	510+00	870	650	250-300	Sandstone	Silt Loam, Loam, Sand and Gravel
B	553+00	875	810	150-200	Sandstone	Sandy Loam, Sand and Gravel
C	593+00	865	700	150-200	Sandstone	Loamy Sand, Silt Loam
D	635+00	905	810	50-100	Sandstone	Silt Loam, Sand and Gravel
Alternative C						
A	518+00	875	720	200-250	Sandstone	Silt Loam, Loam, Sand and Gravel
B	549+00	875	810	150-200	Sandstone	Loamy Sand, Silt Loam
C	592+00	865	700	150-200	Sandstone	Loamy Sand, Silt Loam
D	635+00	905	810	50-100	Sandstone	Silt Loam, Sand and Gravel
Alternative D						
A	535+00	680	600	50-100	Sandstone	Udifluvents[4]
B	580+00	875	820	<50	Dolomite or Sandstone	Sandy Loam, Sand and Gravel
C	586+00	870	820	<50	Dolomite or Sandstone	Sandy Loam, Sand and Gravel
D	635+00	905	810	50-100	Sandstone	Silt Loam, Sand and Gravel
Alternative E						
A	533+00	680	600	50-100	Sandstone	Udifluvents[4]
B	580+00	875	820	<50	Dolomite or Sandstone	Sandy Loam, Sand and Gravel
C	586+00	870	820	<50	Dolomite or Sandstone	Sandy Loam, Sand and Gravel
D	635+00	905	810	50-100	Sandstone	Silt Loam, Sand and Gravel

Notes

1. *Ground-Water Resources and Geology of St. Croix County, Wisconsin.* R. G. Borman.
2. *Water Resources of Wisconsin St. Croix River Basin*, USGS Hydrologic Investigations Atlas HA-451. H. L. Young and S. M. Hindall
3. *Soil Survey of St. Croix County, Wisconsin*. USDA Soil Conservation Service.
4. These soils consist of soils deposited by flood waters along rivers and streams. Too variable to be classified.

SUMMARY OF MINNESOTA DATA

Groundwater quality is regulated by the Minnesota Pollution Control Agency. "In the majority of the cases, the MPCA uses the health risk limits (HRLs) set by the Minnesota Department of Health (MPCA Web Site, 2004)" to evaluate groundwater and potential groundwater impacts.

The project area within Minnesota is much more intensively developed than the Wisconsin portion of the project. Generally, the water table elevation is between 700 feet and 850 feet, with the higher water table elevation at the western edge of the project area. Average depth to groundwater based on well logs was determined to be 67 feet. The minimum groundwater depth identified is 0 feet, adjacent to the St. Croix River. Maximum depths of 140 feet to the water table from ground surface are identified west of the river corridor.

USGS maps indicate that sensitivity of water table groundwater systems in the area is moderate (contaminants will reach the system in years to decades) to high (contaminants will reach system in weeks to years). Sensitivity of the Prairie du Chien-Jordan aquifer, the primary drinking water source for wells in the area, is shown in the range of high-moderate to high.

Approximately 31 existing shallow wells were identified in the sections containing the proposed project, all of which are identified as monitoring wells. If further research reveals that a shallow well in the area is utilized for potable water, the potential transmissivity of shallow aquifer groundwater from proposed infiltration basin sites will require evaluation.

CONCLUSIONS

Based on the above literature review, it appears as though transport of heavy metals and chlorides as constituents of infiltrated stormwater runoff into potable aquifer systems must be carefully considered if shallow aquifers are present but can be nearly eliminated in deeper aquifers, provided correct infiltration basin design and construction is employed. Consequently, it is not expected that the existing wells in the project area will experience heavy metal contamination from highway storm water drainage. It is possible that there will be some occasional and temporary increases in salt content, but it is expected that these concentrations to be infrequent (spring season) and within acceptable State water quality health standards.

SOURCES

The following databases and libraries were searched for pertinent studies:

1. http://www.google.com/

2. http://www.pals.msus.edu/ All PALS Libraries including Minnesota Transportation

Libraries (also includes many State of Minnesota College Libraries)

3. http://umnlib.oit.umn.edu/ University of Minnesota Libraries

4. http://ntl.bts.gov/ National Transportation Library

5. http://water.usgs.gov/pubs/ USGS Water Resources Reports Online

6. Mn/DOT Library, St. Paul, Minnesota.

4. University of Wisconsin Water Resources Library.

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3. Borman, R. G., 1976, *Ground-Water Resources and Geology of St. Croix County, Wisconsin*. United State Department of the Interior, Geological Survey.

4. Brusseau, Mark L., 1995, "The Effect on Nonlinear Sorption on Transformation of Contaminants During Transport in Porous Media" *Journal of Contaminant Hydrology* Vol. 17.

5. Emmons & Olivier Resources, 2003. "Lower St. Croix River Spring Creek Stewardship Plan;" Prepared for Marine-on-St. Croix WMO, Carnelian-Marine Watershed District, and New Scandia Township.

6. Granato, Gregory E., P. E. Church, and V. Stone, 1995, "Mobilization of Major and Trace Constituents of Highway Runoff in Groundwater Potentially Caused VY Deicing Chemical Migration;" *Transportation Research Record, No. 1483*.

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8. Huang, C.H., H.A. Elliott, and RM. Ashmead, 1977, 'Interfacial Reactions and the Fate of Heavy Metals in Soil-Water Systems, Water Pollution Control Federation;" *Journal Water Pollution Control*.

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10. Kelly, Walton R. and Steven D. Wilson, 2003, *"Historical Changes in Shallow Groundwater Quality in the Chicago Metropolitan Area;"* Illinois Department of Natural Resources, Illinois State Water Survey.

11. Ku, Henry F. H. and D. L. Simmons, 1986, "Effect of Urban Stormwater Runoff on Ground Water Beneath Recharge Basins on Long Island, New York;" U.S. Department of the Interior, Geological Survey.

12. Patenaude, Robert W., 1989, "Investigation of Road Salt Content of Soil, Water, and Vegetation Adjacent to Highways in Wisconsin: Progress Report IV;" Central Office Materials Soils Section, Bureau of Engineering Operations, Division of Highways and Transportation Services, Wisconsin Department of Transportation.

13. Seawell, Charles and Newland Agbenowosi, 1996, *Effects of Road Deicing Salts on Groundwater Systems.* Virginia Tech. http://www.cee.vt.edu/program_areas/environmental/tech/gwprimer/roadsalt/roadsalt.html

14. Selim, H. Magd Eldin and Michael C. Amacher, 1997, *Reactivity and Transport of Heavy Metals in Soils.*

15. USGS Mapping of St. Croix County, Wisconsin and Washington County, Minnesota.

16. Official County well logs for St. Croix County, Wisconsin and Washington County, Minnesota.

17. Wisconsin Department of Natural Resources Chapter NR 140 – "Groundwater Quality" and Chapter NR 151 – "Runoff Management."

18. Wisconsin DNR, 2004, "Site Evaluation for Stormwater Infiltration;" Conservation Practice Standard 1002.

19. Wiedman, Samuel, 1911, *Soil Survey of Part of North Western Wisconsin.* Published by the State of Wisconsin, Madison, Wisconsin.

20. Yu, Shaw L. PhD. and Thomas E. Langan, 1999, "Controlling Highway Runoff Pollution in Drinking Water Supply Reservoir Watersheds;" Virginia Transportation Research Council for the Virginia Department of Transportations, University of Virginia and U.S. Department of Transportation, Federal Highway Administration.