

URBAN IMPACTS ON GROUND WATER QUALITY AND FLOW
CHARACTERISTICS IN SCHMEECKLE RESERVE

by

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A thesis submitted in partial fulfillment of the
requirements for the degree

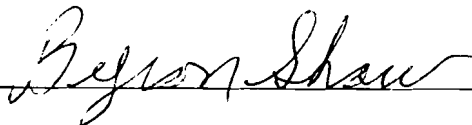
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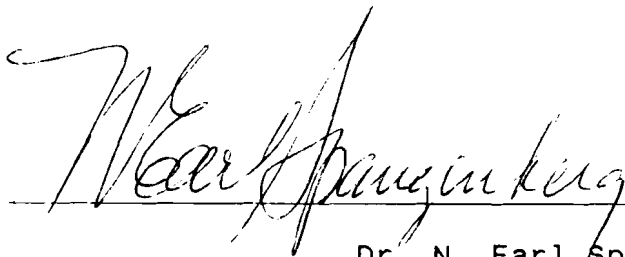
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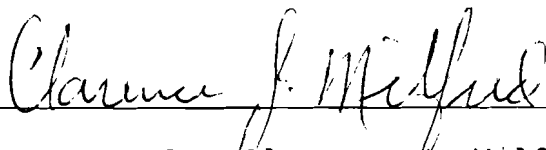
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ABSTRACT

Schmeeckle Reserve is a 190 acre natural area located in the Central Sands Region of Wisconsin. The area is predominantly wetland with sandy loam soil and a depth to ground water of five feet or less. The Reserve is bordered to the north and west by expanding commercial and urban development. Runoff from this development and from major roadways is diverted into the Reserve which functions as a catchment basin. In addition, ground water recharge occurring on these areas flows under the Reserve.

This study was initiated to evaluate the impacts of urban storm water runoff on the ground water quality in the Reserve. Single-depth and nested wells were used to map local ground water flow and to sample for contamination. Land surface contours were mapped to determine storm water runoff drainage patterns.

The study concentrated on chloride and sodium concentrations related to road salt, benzene, toluene, and xylene concentrations related to gasoline and oil, and lead, zinc,

and copper concentrations related to motor vehicles and gasoline. Nitrogen, phosphorus and basic water chemistry parameters were also analyzed to document any water chemistry changes. Sampling began in the fall of 1985 and continued through July of 1987.

Mean chloride concentrations ranged from 1 mg/l at a control well to 2054 mg/l at a well nearest to storm water drainage. Corresponding mean sodium concentrations were 2 mg/l and 655 mg/l respectively. Of the volatile petroleum components, only benzene was detected at concentrations above 1.0 ug/l within the Reserve and then only at one well. The mean benzene concentration at the well was 6.7 ug/l and does not appear to be attributable to runoff. This contamination may be attributable to an underground petroleum storage tank or to improper disposal of petroleum products. Mean dissolved and total concentrations of lead, zinc, and copper in ground water did not suggest contamination was occurring.

A secondary objective was to evaluate atmospheric contributions of metals to the Reserve. Lead accumulations in moss ranged from 16.86 mg/kg at a control site outside the Reserve to 140.90 mg/kg within the Reserve. Zinc ranged from 57.58 mg/kg at the control to 747.72 mg/kg within the Reserve. These data suggest that atmospheric contributions

of lead and zinc to the Reserve are significant.

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INTRODUCTION

Schmeckle Reserve is located in Portage county, in central Wisconsin, within the Sand Plain Province (Fig. 1). The Reserve consists of approximately 190 acres of natural area which is predominantly wetland. Within the Reserve there are fourteen different native plant communities (Fig. 2) which include two coniferous and ten deciduous tree species, 25 shrub species and over 100 ground cover plant species (UWCA, 1977).

The average annual precipitation for the county is 31.6 inches. Winds are predominantly from the west and northwest in winter and from the south in summer (USDA, 1978).

Depth to ground water in the Reserve is less than five feet and soil types are predominantly Point Sandy Loam (UWCA, 1977; USDA, 1978) and Newton Loamy Sand (UWCA, 1977) or Roscommon Muck (USDA, 1978)(Fig. 3). Point Sandy Loam is characterized by moderately rapid permeability in the surface layer and upper subsoil (sandy loam) and moderately slow below (heavy loam) with depth to bedrock of four to 20

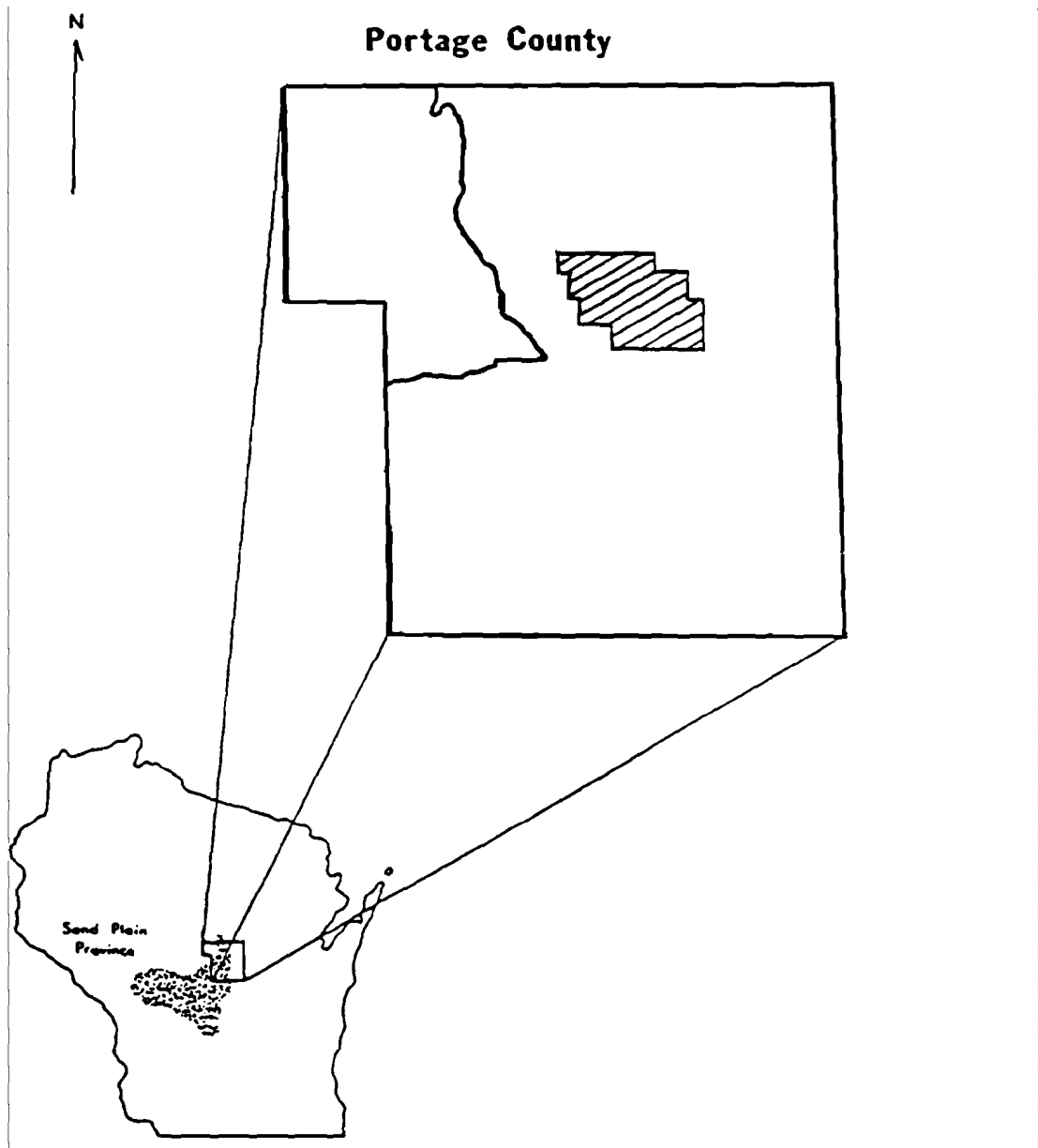


Figure 1. Location of Schmeckle Reserve within the Sand Plain Province, central Wisconsin (modified from Saffigna, 1976).

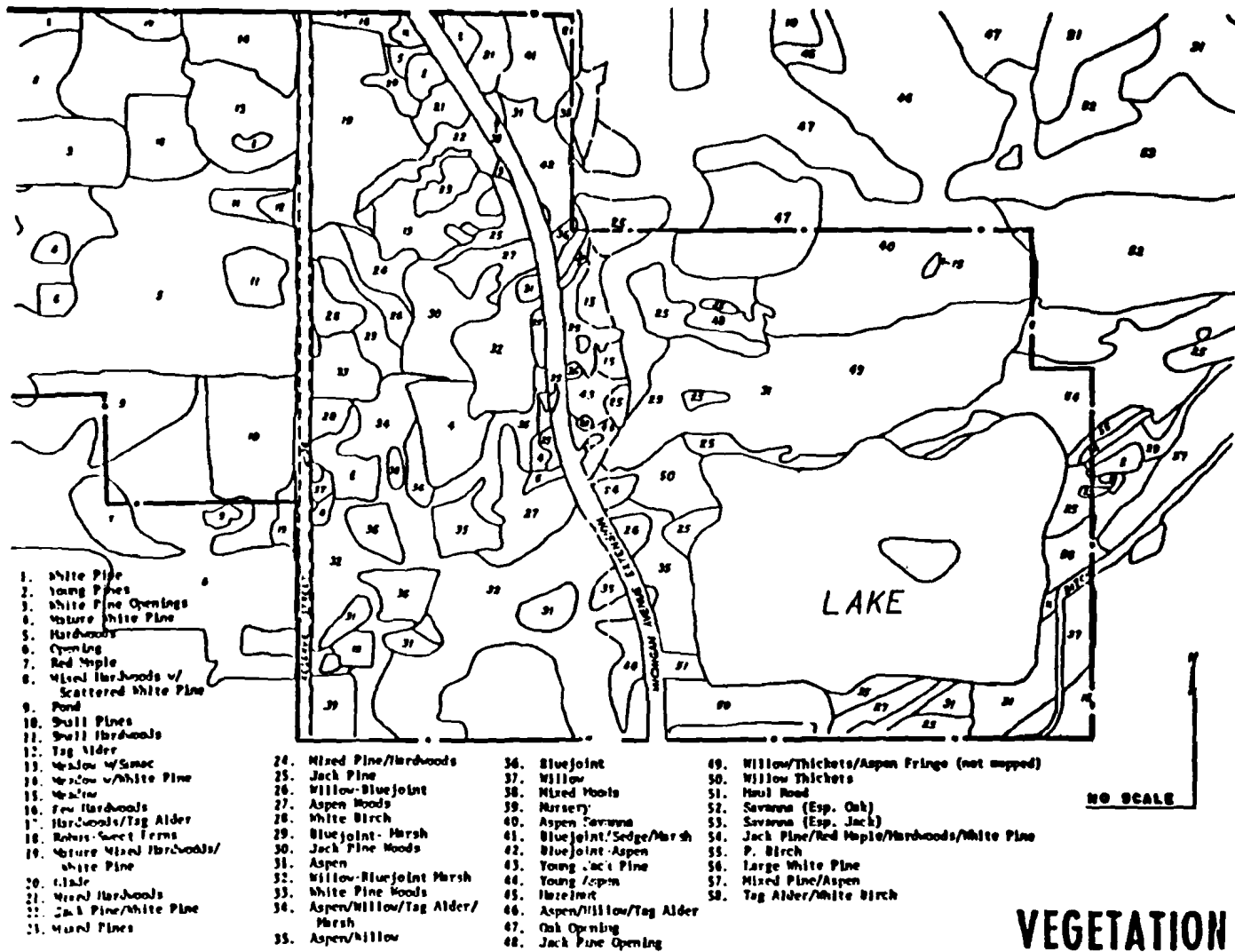
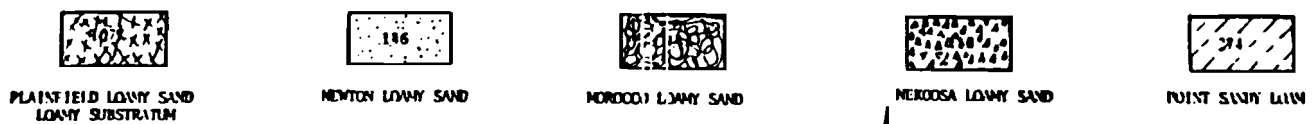
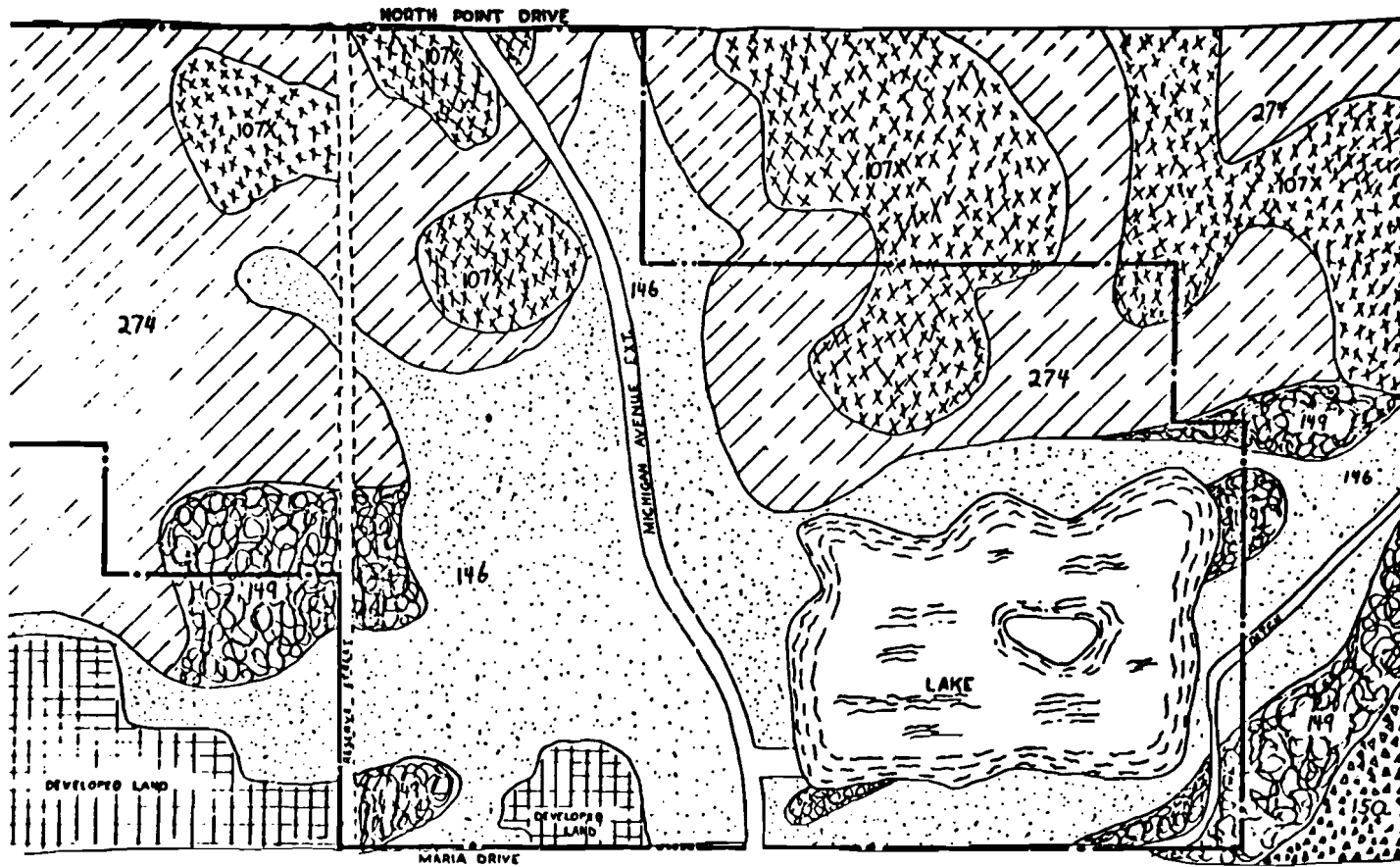


Figure 2. Vegetation survey of Schmeckle Reserve (From UWCA, 1977).



NO SCALE



SOIL SURVEY

Figure 3. Soil survey of Schmeckle Reserve (From UWCA, 1977).

feet. Roscommon Muck soils are found in major drainage-ways on sand plains. They are characterized by rapid permeability with a surface layer of muck, subsoil of medium sand and substratum of sand. Bedrock is at a depth of more than five feet.

The Reserve is surrounded by urban development and serves as a storm water catchment basin. Located at the northern limits of the city of Stevens Point (T24N R8E Sec. 29), the northern and southern boundaries of the Reserve are outlined by North Point Drive and Maria Drive respectively. Adjacent to North Point Drive lies the corporate home office of Sentry Insurance, Inc., which claims approximately 500 acres of land on which is located a large building complex, landscaped turf, and a golf course. Along Maria Drive are the University of Wisconsin-Stevens Point residence halls, maintenance facility, parking lots, power plant, and athletic fields. Private residences and privately owned undeveloped lands border on the east. The west boundary of the Reserve is outlined by Business Highway 51 or Division Street and is an area of increasing business development. Storm water runoff from the highway and from business parking lots collects in a 42 inch diameter storm sewer and is discharged untreated onto undeveloped university property directly adjacent to the Reserve (Fig. 4).

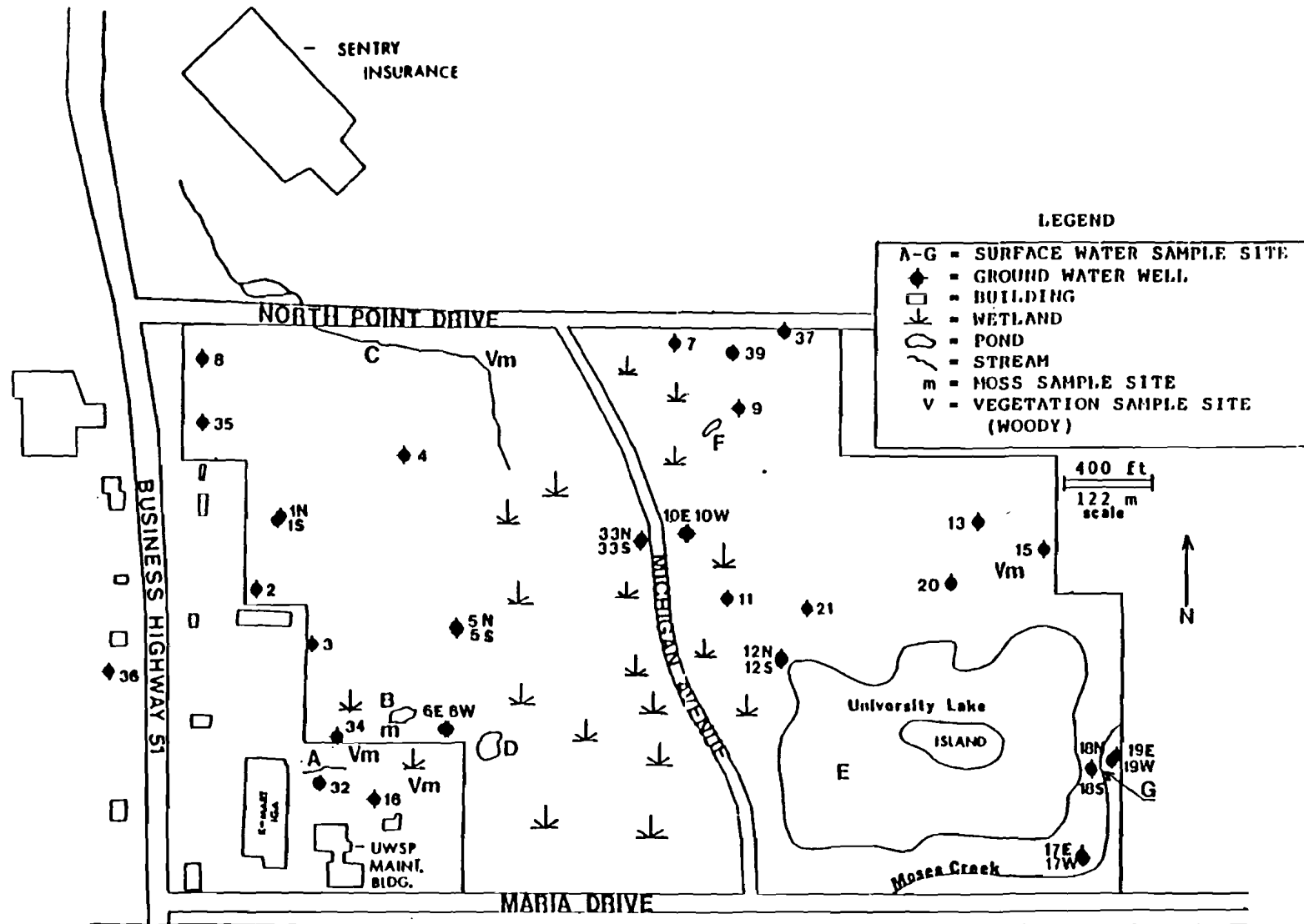


Figure 4. Study area map.

The impacts this storm water discharge has on the ground water quality in the Reserve are of primary concern in this study. In order to define these impacts, an initial survey of the ground water and surface water flow patterns was conducted. Secondly, the ground water quality in the Reserve was quantified and described. The specific objectives of this research were to:

1. Determine and map the surface and ground water flow patterns in Schmeckle Reserve and its immediate watershed.
2. Quantify the chemical characteristics of the ground water in the Reserve.
3. Evaluate the storm water impact on the ground water quality in the Reserve specifically addressing road salts, volatile petroleum residues, and heavy metals.
4. Evaluate the atmospheric contribution of metals to the Reserve.

LITERATURE REVIEW

Highway Runoff

Urban roadway surface contaminants originate from many sources including industrial and land use activities, and roadway usage. Contaminants may include metals such as lead and chromium, inorganic compounds such as road salts and a variety of organic chemicals such as gasoline and oil. During periods of storm water runoff, roadway contaminants are transported into the nearby drainage system and then carried into receiving basins or surface waters where they can constitute a pollution problem.

Although contaminant concentrations in runoff may be low, many of these compounds can accumulate to high concentrations and persist in the environment. For example, in one study pollutants from urban runoff accumulated in the bottom sediments of a river to concentrations of between 1000 to 2000 times greater than the concentrations in the flowing water (Baumann, 1980). As these contaminants concentrate, they can become a threat to biological communities as well as a hazard to public health.

In a nationwide study of urban runoff (NURP), seventy-seven pollutants including 14 inorganic and 63 or-

organics were detected in runoff samples (EPA, 1983). The heavy metals were the most prevalent pollutant constituents in runoff. Organic pollutants were less prevalent in runoff with the plasticizer bis(2-ethylhexyl)phthalate and the pesticide alpha-hexa-chloro-cyclohexane (alpha-BHC) being the two most commonly detected. Coliform bacteria were present at high levels and nutrient concentrations were not considered high in comparison with other potential discharges. Mean annual nutrient runoff loads were reported to be around one order of magnitude less than those from a wastewater treatment plant (median concentrations TP = 0.33 mg/l, SP = 0.12 mg/l, TKN = 1.5 mg/l, NO₂ + NO₃-N = 0.68 mg/l). Oxygen demanding substances produced biochemical oxygen demands (BOD's) approximately equal to those from secondary treatment plant discharges. Total suspended solids concentrations were variable and at times were very high.

Shaheen (1975) reported that the majority of solids deposited on roadways are vehicle dependent but that less than five percent of the solids originated from the vehicles themselves which function primarily as transport mechanisms. However, the solid pollutants originating from vehicles are among the most toxic and include: lead from leaded fuels and tire fillers, zinc from tire fillers and motor oil, and copper from wear of brake linings and other moving parts. Other vehicle related pollutants include pe-

troleum compounds from lubricants, antifreeze, and hydraulic fluids.

Concern over the topic of highway runoff has largely developed due to the potential toxicity of components in the runoff. Heavy metals have been considered to be the most prevalent toxicants present in highway runoff (EPA 1983; Shaheen 1975). Many heavy metals are known to be toxic to aquatic life and animals (Wilber and Hunter 1977) and are potentially hazardous to human health especially if ingested. For example, lead ingestion by humans is most commonly from food constituents with lesser amounts from water and air. Lead poisoning can result in adverse effects on the nervous system and kidneys in humans. At low levels of exposure, a major concern is the subtle effects on neurobehavioral and growth parameters especially in children. Lead is mutagenic (induces mutations), carcinogenic (induces cancer), and teratogenic (causes developmental malformations) in some animal systems (WDHSS 1985). Lead has been demonstrated to bioaccumulate in aquatic organisms (WDHSS, 1985) and has toxic effects on algae, invertebrates, fish, wildlife, and plants to varying degrees (Environment Canada, 1980). The state of Wisconsin has adopted the EPA maximum contaminant level (MCL) for lead of 0.050 mg/l (50 ppb) as the ground water standard (Wisconsin-DNR, 1985). EPA is in the process of reducing this standard to 0.020 mg/l.

Sources of metals in highway runoff were summarized by Harper (1985) which include gasoline (Pb), exhaust emissions (Pb, Ni), oils and grease (Pb, Ni, Zn), tire wear (Cd, Zn), bearing wear (Cu, Pb), coatings for protection and design (Al, Cd, Cu, Zn, Ni, Fe), brake wear (Cu, Cr, Ni), engine part wear (Fe, Mn, Cr, Co), and asphalt paving wear (Ni, V). Of the toxic heavy metals found in highway runoff, Pb, Zn, and Cu are typically the most abundant (Harper 1985, EPA 1983). Wilber and Hunter (1977) found that combined, these three metals accounted for 90 to 98% of the total metals in storm water in New Jersey with Pb and Zn comprising as much as 89 percent.

Due to winter snowfall and ice formation on tarmac, salts are used to depress the freezing point of water and de-ice roadways. Ultimately, these road salts also become potentially toxic components in highway runoff and may result in contamination and damage to ground water, surface water, roadside vegetation, and soils. Sodium chloride is the most widely used road de-icer in Wisconsin although some calcium chloride is also used (Greub et al., 1979).

Salinity (total soluble salts), sodium ions and chloride ions reduce soil fertility and structure, decrease water uptake by plants, and are toxic to plants above certain concentrations. Sodium ions are adsorbed onto soil particles and can replace calcium ions on the soil grains

resulting in soil that is less fertile and less permeable. High sodium levels deteriorate soil structure and results in poor drainage properties. Sodium can interfere with the uptake of the essential plant nutrient potassium. Sodium toxicity causes leaf and twig burning and browning in trees and plants.

Chloride does not adversely affect soil structure but does add to salinity. Possessing a negative charge, chloride ions flow through the soil substrate without being adsorbed. For this reason, chlorides appear as pollutants in ground water. Chloride toxicity initially resembles drought injury and later stages may include premature leaf abscission, leaf and twig burning and browning, and chlorosis.

Calcium is an essential nutrient for plant growth but excessive amounts can cause high salinity and may be toxic to certain plants.

Salinity can interfere with a plants ability to absorb soil water. Water in the soil becomes less available to plants with increasing salt as a result of increasing osmotic potential in the soil solution. The flow of water through the plant root is in the direction of greater salt concentration and therefore, higher salinity in the soil decreases the water taken up by the plant. Grasses are

more tolerant of salt stress than woody plants (Greub, 1979). Salt contamination can have dramatic effects on plant communities. For example, Wilcox (1986) found that nearly all endemic plant species were absent from a section of a bog experiencing high salt concentrations in the water from road salt contamination.

Elevated chloride levels in ground water used for human consumption are not considered toxic to human health but can cause a salty taste if over 250 mg/l (Shaw and Peterson 1986). There is no ground water quality standard set for sodium or calcium, however, elevated sodium levels in drinking water are undesirable. Although food is generally the major source of sodium in the human diet, consumption of water high in sodium has been attributed with infant brain damage and infant deaths (Craun, 1984). In adults, excessive sodium intake may cause hypertension (Craun, 1984).

Some of the most common organic pollutants on roadway surfaces are petroleum products related to motor vehicles. Although common on roadways, petroleum components such as the monocyclic aromatics, benzene, toluene, and xylenes (BTX) were reported as rarely detected in runoff samples in the NURP study due to sampling and/or analytical contamination problems encountered. The potential for these volatile organic compounds (VOC's) to be carried in highway

runoff exists and contamination of ground water recharged by this runoff is possible. Lewis and Penzo (1984) discussed how petroleum based VOC's (BTX) can be retained in the unsaturated zone from petroleum leaks and spills. Water infiltration through petroleum contaminated soil can cause the transport of significant concentrations of dissolved organic chemicals to the aquifer. Once in the ground water, these dissolved organics can migrate through the aquifer at a much more accelerated rate than the immiscible petroleum phase.

The environmental impacts that BTX compounds have are not well documented in the literature. Acute toxicity to freshwater life occurs at 5300 ug/l for benzene and at 17500 ug/l for toluene.

Benzene, toluene, and xylenes are all hazardous to human health. Health risk information derived from contaminated drinking water does not exist for the most part but general human health risks can be surmised from occupational exposure and animal study data. Human exposure to benzene occurs most commonly via inhalation and skin absorption. Benzene is mutagenic, carcinogenic, and teratogenic. Chronic exposure causes myelocytic anemia (condition in which bone marrow is lacking red blood cells, hemoglobin, or blood volume), thrombocytopenia (persistent decrease in number of blood platelets), leukopenia (condi-

tion in which the number of white blood cells in the blood is low), and leukemia (disease characterized by an abnormal increase in the number of white blood cells) (WDHSS, 1985).

Toluene and xylenes have not been found to be mutagenic, teratogenic, or carcinogenic. Most of the human exposure to xylenes and toluene comes through inhalation of air. Human health effects from xylene include central nervous system disturbances and liver disorders. Toluene causes adverse mental changes such as disorientation and unconsciousness and also causes cardiac arrhythmia and liver and kidney dysfunction.

METHODS

Study Design

Monitoring Wells

Twenty six ground water monitoring wells were installed throughout the Reserve in the fall of 1985 and an additional seven wells were added between October 1986 and February 1987. The well shafts were either dug by hand with a soil auger or drilled with a rotary hydraulic drilling rig using four inch augers. One and one-quarter inch outside diameter PVC pipe was used for the well casings. One foot long screens with 0.01 inch slots were attached to the bottom of the casings. Screens were glued onto the original twenty six wells and were threaded onto the other seven wells. Well caps were slipped on or threaded on. Glue was avoided in the later wells to prevent possible contamination of well samples with volatile organic components in the glue. Well shafts were backfilled with clean sand around the screens, topped with the natural subsoil materials and sealed with powdered bentonite clay from approximately one foot below ground level to prevent surface water infiltration. Once completed, each well was developed by bailing and pumping. These thirty three wells along with an additional three wells were utilized to

sample ground water and to measure water table depth in this study (Fig. 4). The three additional wells were older wells which consisted of the Schmeckle Reserve Visitor Center well (#39), an abandoned steel cased house well (#37), and a steel cased city monitoring well (#11).

After all thirty six wells were installed, well casing elevations were determined by leveling with a Dumpy level and Philadelphia rod. Casing elevations in feet above sea level were derived utilizing bench marks of known elevation around the Reserve from previous city engineering projects.

Utilizing aerial photographs, well locations were plotted out with a protractor after initial pacing measurements and bearings were taken with a Brunton compass. Paces were standardized for each terrain type (i.e., forest, wetland) by measuring out a 100 foot distance in each terrain and pacing three times. The average value was then used to give number of feet per pace.

Ground Water Flow

After leveling, the well casing elevations were used to calculate water table elevations in feet above sea level. Monthly water table depth measurements were recorded from August 1986 through July 1987 to the nearest 0.01 foot with a popper attached to a tape measure dropped down the wells. Water table contours of the Reserve were

developed from the July 1987 water elevation data (Appendix I, Table 11). The area to be contoured was digitized on an Altek electromagnetic digitizing table. Contours were derived using the Surface II Graphics system with final modifications made by hand.

Surface Contours

Surface elevations determined by previous city engineering projects were used to develop a surface contour map of the Reserve and bordering lands.

Storm Water and Urban Impacts

From November 1985 through July 1986, the original 26 wells in the Reserve were sampled and the water analyzed for the water chemistry parameters outlined in Appendix I, Tables 1-6 which excluded heavy metals and trace organics. Between January 1987 and April 1987, water samples were collected each month from among all thirty six wells and analyzed for heavy metals and trace organics concentrations in addition to the parameters outlined in Appendix I, Tables 7-10. However, not all wells were sampled every month during 1987. In January, all the wells along the western border of the Reserve were sampled along with a control well since the focus of the research was on the impacts of storm water runoff from Business Highway 51. Each month several other wells throughout the Reserve were sampled along with the wells on the west border. In April,

all the wells were sampled.

In addition, woody vegetation, moss, and sediment samples were collected from throughout the Reserve and analyzed for metals content. These results were needed to help distinguish between metal contamination contributed by storm water and that deposited from the atmosphere. Woody vegetation samples consisted of young twigs and branches collected from the shrubby species European Buckthorn (Rhamnus frangula). This thornless species was chosen due to its availability throughout the Reserve. Metals concentrations in Buckthorn were considered indicators of the concentrations present in soil.

Moss samples consisted of the entire plant body of the genus Brachythecium. Mosses are considered to be useful indicators of airborne pollution (Rao, 1982; Richardson, 1981; Goodman, 1971). Members of the division Bryophyta, mosses lack a vascular system and obtain many of their nutrients from substances in the ambient atmosphere. They have evolved efficient mechanisms for taking up metals and other nutrients from the environment. The majority of the metals content in mosses is accumulated extracellularly over their entire surface via particulate trapping and ion exchange. Therefore, moss samples served to indicate metal loadings from the atmosphere onto the Reserve. Samples were collected from throughout the Reserve and at Jordan

Park, a control site located approximately eight miles northeast of the Reserve.

Sediments from surface water basins and channels within the study area were analyzed for metals content in order to ascertain metal contamination associated with storm water discharge and retention. Sediment samples were collected from the storm water channel (A) the ponds (B,D, and F), a stream (C), University Lake (E), and Moses Creek (G) (Fig. 4).

Stream C was used in this study as a control for runoff and sediment comparisons with the storm water channel (A). This stream originates from the property of Sentry Insurance and potentially receives some roof, parking lot, and lawn runoff. This runoff may contain chemicals and nutrients since the property is highly manicured. Only low flow from the stream enters the Reserve. High flows are diverted via a storm sewer to the perforated storm sewer in place along Michigan Avenue or on to Moses Creek. Therefore, stream C is not an ideal control.

Lake sediments were utilized for comparison with sediment data from the several ponds in the Reserve. The lake, however, is more recent in origin having been constructed by man between 1975 and 1976. Therefore, the lake data should be viewed with this in mind.

Sampling

Dissolved Metals in Water

Preparation for sampling water for metals consisted of cleaning clear plastic 125 milliliter (ml) containers with first soap then 1+1 nitric acid and triple rinsing with distilled water. Samples were collected with a teflon bailer, refrigerated during transport, and filtered through a 0.45 micron filter in the lab. Samples were then transferred to a 125 ml container and preserved with concentrated nitric acid to a pH of 2 or less. Field filtration was not always feasible due to equipment restrictions and the high turbidity of most samples. Field filtration was only done during sampling in April and laboratory filtration was used in January, February, and March 1987. Time between collection and lab filtration was usually less than 45 minutes. After acidification, samples were stored in a refrigerator at approximately 4 C until analysis. A field blank and water blank that were filtered, acidified, and refrigerated at the same time as the samples were also analyzed.

Initially, duplicate samples were filtered and acidified in the field in order to compare the results with samples that were filtered and acidified in the lab. No significant difference in results for metals concentrations were found. Values varied by 0.01 milligrams per liter (mg/l) or less for copper, zinc, iron, and chromium and

there was no variation in lead.

Total Metals in Water

Sampling preparation and collection for total metals in water was identical to that used for dissolved metals except samples were not filtered and were acidified immediately after collection in the field.

Total Metals in Vegetation and Sediment

Vegetation and sediment samples for metals analyses were collected in plastic resealable bags and frozen. Sediments were collected from within the top five centimeters of the sediment layer of the surface water sites. A piece of two inch inside diameter PVC pipe was inserted into the sediment layer to remove a core type sample of which only the top 2.5 cm was utilized as the sample.

Young twigs and branches were collected in March and June 1987, from woody vegetation. The entire plant bodies of mosses were collected in June 1987.

VOC's

Sampling procedures for VOC's were followed as prescribed in EPA Method 602 for purgeable aromatics and Method 601 for purgeable halocarbons. Twenty-five ml volume glass vials with teflon septum screw caps were detergent washed, rinsed with tap and distilled water and dried

at 105 C before use. Water samples were collected using a teflon bailer filling the vials to zero head space followed by refrigeration. Ground water samples received no preservatives.

Water Chemistry

Water samples were collected using a teflon bailer filling 500 ml precleaned clear plastic sample bottles followed by refrigeration. Procedures were followed as prescribed in APHA 1981, 15th edition.

Analyses

Metals

Ground water samples that were filtered and acidified were analyzed directly to quantify dissolved metal concentrations. Prior to the analysis of sediments, vegetation, and ground water that was not filtered, a digestion process was carried out in order to quantify total metals concentrations. Samples were digested using concentrated nitric acid and refluxing until all organic material had been broken down. Complete digestion was checked by the addition of a drop or two of H₂O₂ which caused the elution of yellow gas if any organic compounds were still present. The remaining solutions were filtered through a 0.45 micron filter and refrigerated prior to analysis.

For digestion of vegetation, between one and two grams

of sample was used. Woody twigs and branches were first washed for five minutes with a continuous flow of distilled water. Moss samples were not washed and consisted of only parts of the plant body that could be carefully cut away from the dense plant matt which entrapped soil particles and debris. The vegetation was then dried for 48 hours at 105 F after which a subsample was removed and digested.

Sediments were oven dried for 48 hours at 105 C after which the sample was homogenized and approximately one gram was weighed out and digested.

Spikes, duplicates, and procedural blanks were prepared for each substrate and for each different sample preparation procedure. Digested samples were spiked prior to digestion. Dissolved metal samples were spiked after filtration and at the same time the samples were acidified.

The Varian Model 475 atomic absorption spectrophotometer was used for metals analyses. The graphite furnace attachment was used for the analysis of lead. Flame absorption was used for zinc, copper, iron, and chromium. Calibration standards, spikes, duplicates, and blanks were also analyzed.

Textural analysis of sediments was conducted for comparison with results of metals content. Subsamples were

dried at 110 C for 24 hours and sieved through a 2mm-mesh to obtain the coarse fractions (>2mm diameter). Organic matter content was determined by loss on ignition at 600 C in a muffle furnace (Wilde et al., 1972). Prior to sand, silt, and clay particle size analysis, organic matter was removed from subsamples by the addition of H₂O₂ into and acid (pH 5) adjusted medium (Kunze, 1965). The hydrometer method (Day, 1965) was employed for particulate size analysis.

VOC's

The instruments used for VOC analyses were a Tekmar Purge and Trap Concentrator LSC-3 connected to a Tracor Model 560 gas chromatograph (GC). The GC was equipped with a Model 700A Hall Electrolytic Conductivity Detector, a Model 703 Photoionization Detector, and a column with a 1% SP1000 packing. The methanol flow rate setting was 0.6 ml per minute. Calibration standards, spikes, duplicates, field blanks and reagent water blanks were analyzed in addition to the samples. Chlorobenzene was added to each calibration standard and every sample to function as an internal standard. A Response Factor (RF) was calculated and used to determine concentrations of analytes as described in EPA Methods 601 and 602. The internal standard did not interfere with the detection of analytes.

A five ml portion of each water sample was transferred

via calibrated glass syringe with a teflon plunger and valve from the sampling vials to the purging chamber. The sample was then purged and analyzed on the GC.

Water Chemistry

All ground water samples were analyzed for the following parameters:

<u>Parameter</u>	<u>Source</u>	<u>Method</u>
pH	APHA, 1981	423
Conductivity	APHA	205
Alkalinity	APHA	403
Total Hardness	APHA	314B
Calcium Hardness	APHA	311C
Reactive Phosphorus	EPA, 1974	p. 249
Ammonia	Technicon Autoanalyzer	329-74 W/B
Nitrite + Nitrate	Technicon Autoanalyzer	158-71 W/A
Chloride	Chloride Electrode	
Potassium	APHA	322B
Sodium	APHA	325B

RESULTS AND DISCUSSION

Storm Water Drainage and Ground Water Flow

Surface topography contours of the Reserve and adjacent lands (Fig. 5) indicate that storm water runoff from urban development drains toward the Reserve from the north and west. Surface elevations are highest (1120 ft.) along the northwest margin of the Reserve and gradually decrease in a southeast direction moving across the Reserve. Areas lacking a steep gradient within the Reserve closely approximate the location of wetlands (Fig. 4). The topography of the local watershed indicates that the Reserve is a natural drainage basin. The approximate drainage basin boundaries of the Reserve are depicted in Figure 6a.

As displayed on Figure 6a, the Reserve has a very limited ground water recharge area. The current expanding development along the western border of Reserve which increases the area covered with pavement, can have a substantial impact on the ground water quality in the Reserve. Runoff from these areas makes up a large percentage of the water recharge to the west and especially southwest parts of the Reserve.

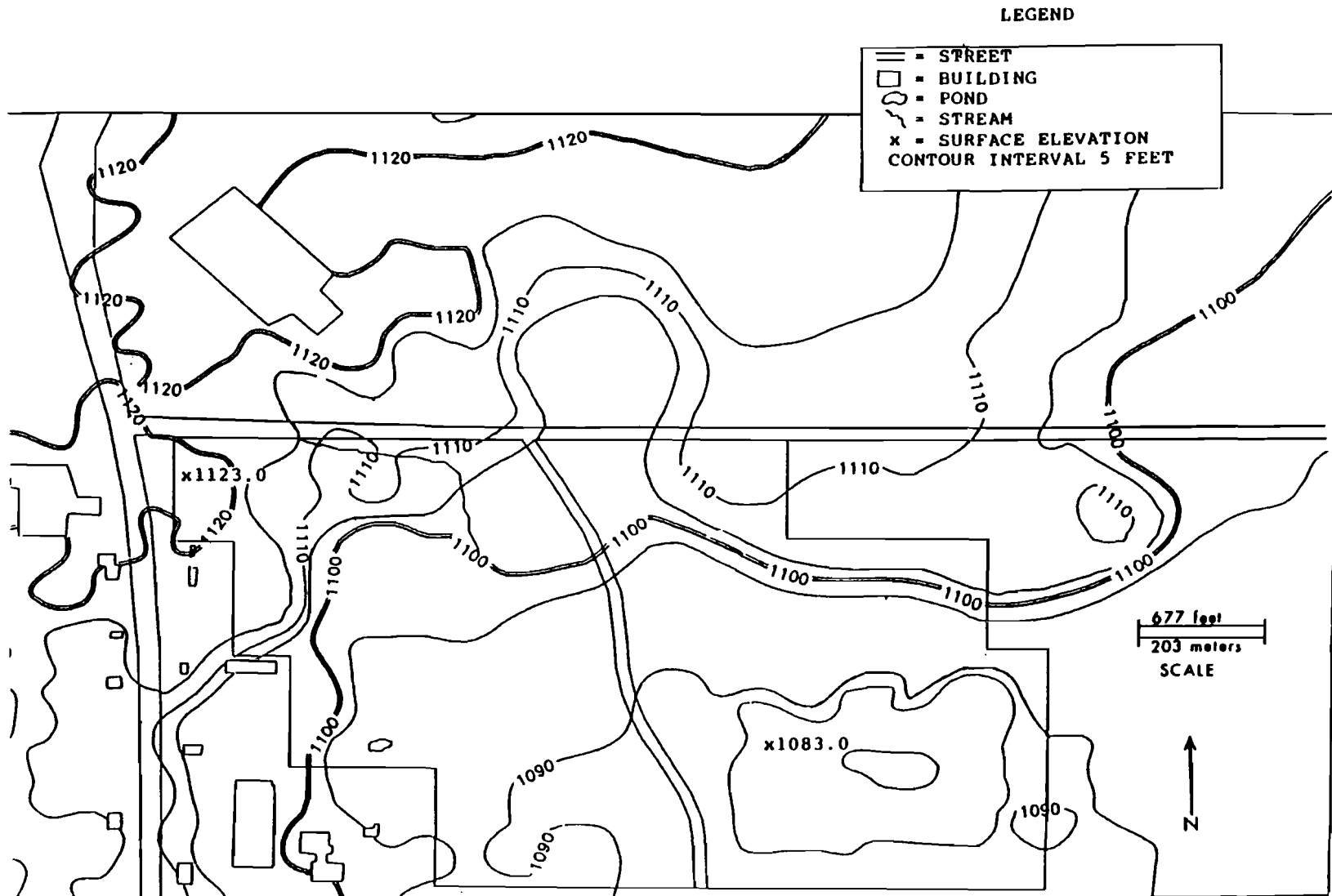


Figure 5. Surface contour map of Schmeckle Reserve and the immediate watershed (feet above sea level).

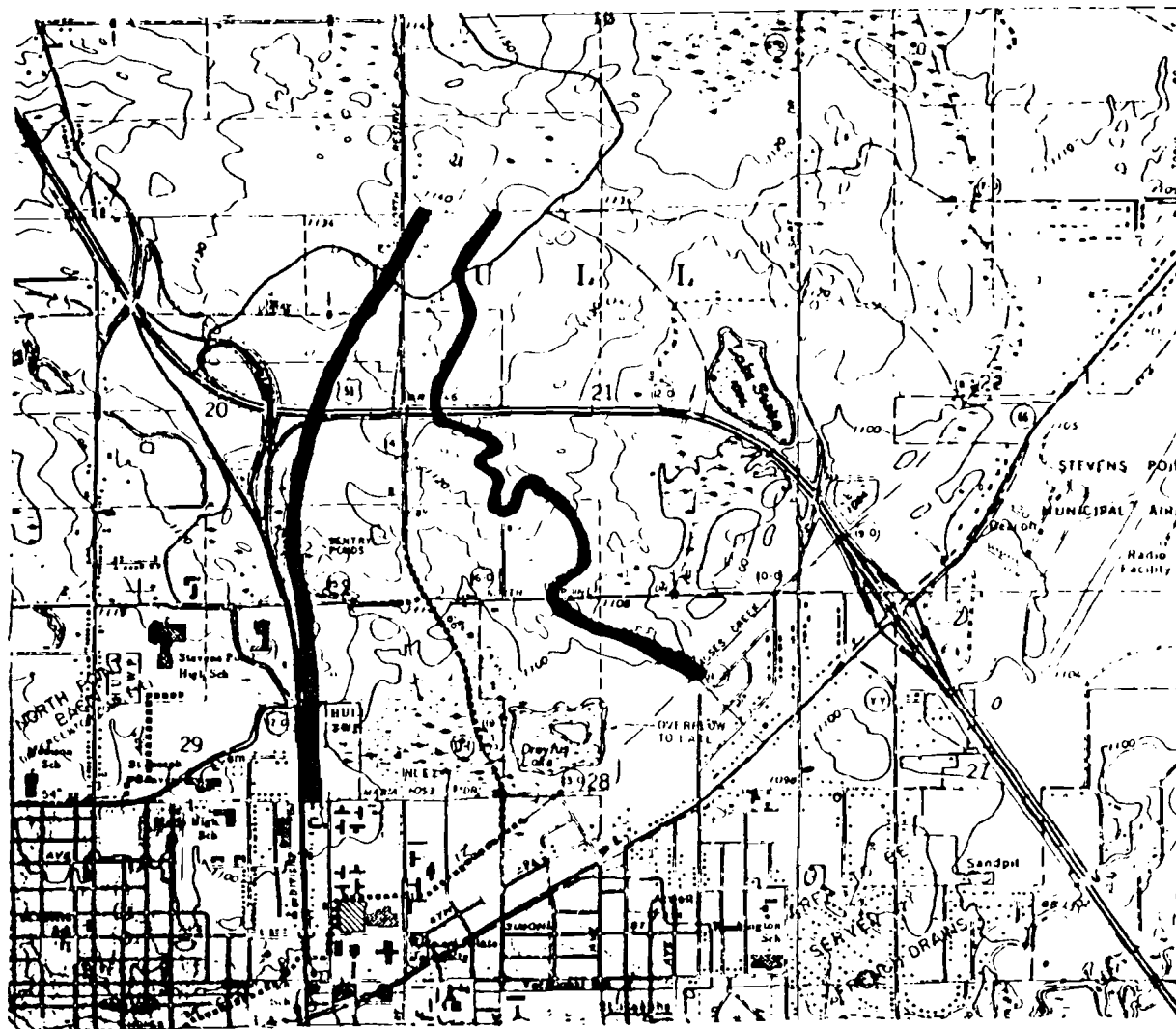


Figure 6A. Study area watershed map. Bold lines approximate the drainage basin boundaries of Schmeckle Reserve (modified from Donohue and Associates, 1980).

Urban storm water runoff draining into the Reserve from the north and west, which infiltrates into the ground water, will move within the aquifer in a southeast direction as shown by the water table contour map, Figure 6b. This figure also indicates that runoff infiltrating from North Point Drive and Sentry Insurance's property will move towards University Lake. This runoff can potentially impact the ground water quality throughout much of the Reserve and may impact the water quality of the lake. Storm water runoff from Business Highway 51 and commercial development adjacent to the highway, is discharged into the Reserve via a storm sewer or from direct inflow from road ditches. Discharge from the storm sewer outlet (A, Fig. 4) will move into the Reserve in both northeast and southeast directions. This discharge can potentially impact the ground water quality in ponds B and D, and wells 32, 16, 34, 6E and 6W before being carried out of the Reserve.

Ground water contours were developed from July 1987 water table data. The direction of ground water flow may vary throughout the year due to seasonal water table fluctuations. However, monthly changes in water table elevation are similar at various locations throughout the Reserve. Therefore, the overall yearly ground water flow direction is likely very similar to that depicted in Figure 6b. Figure 7a displays the seasonal water table fluctuations at two wells within the Reserve. The water

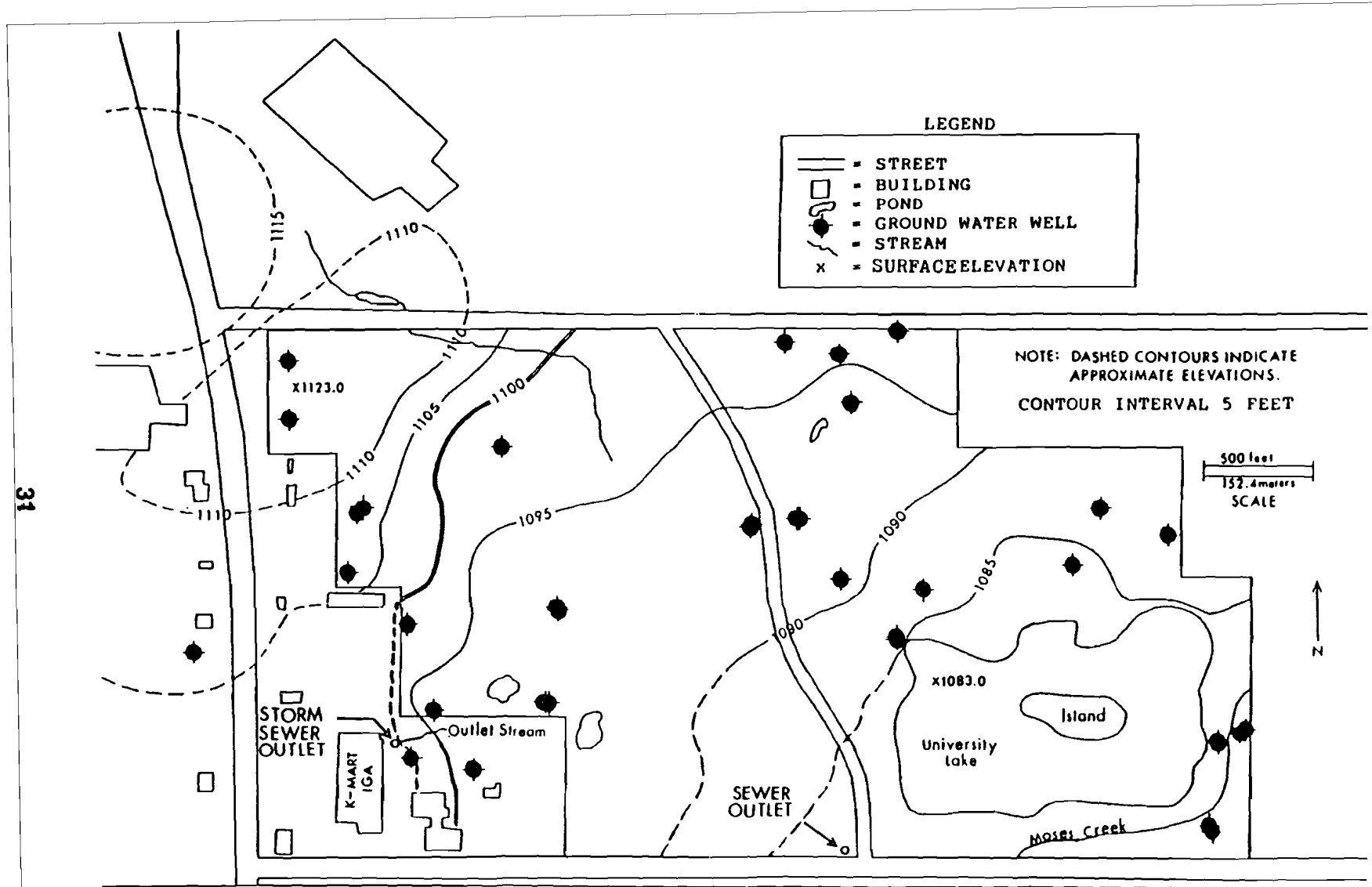


Figure 6B. Ground water contour map of Schmeckle Reserve generated from July 1987 water table data (feet above sea level).

table attained a maximum height in the fall months followed by a second peak in the spring. The water table then decreased to its lowest levels during the summer growing season when plants are transpiring large volumes of water.

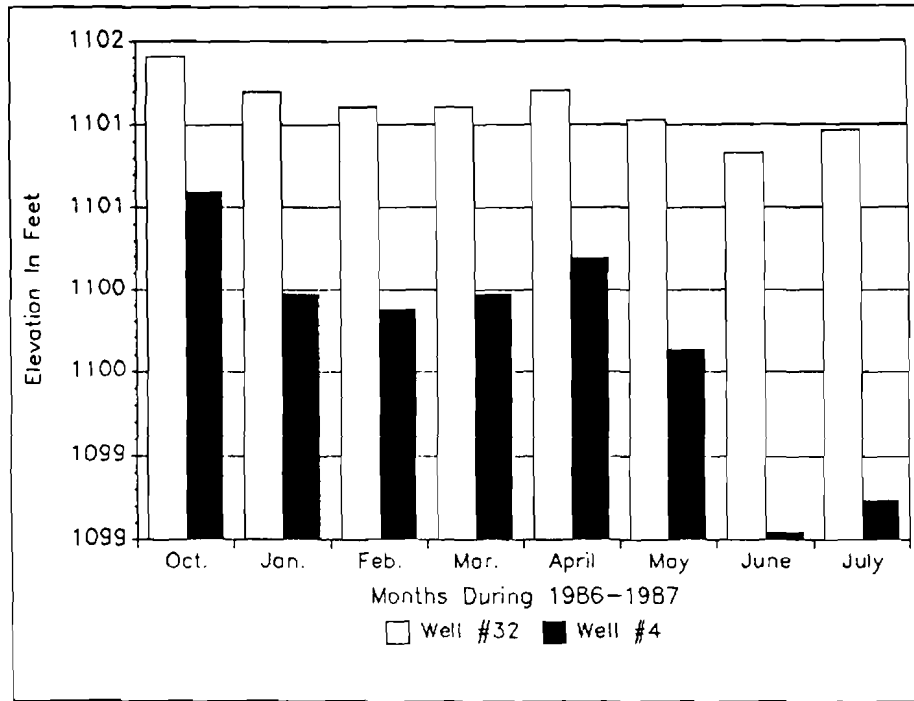


Figure 7a. Monthly water table fluctuations at wells 32 and 4 in Schmeckle Reserve.

As displayed in Figure 7a, well 32 maintained a more constant level throughout the year than well 4. Well 32 is located in a wetland area where there is a continuous recharge or baseflow. Wetland areas in the Reserve are characterized by high permeability soils (sands) which result in a more rapid ground water flow and thus a smoother gradient (Figs. 4 and 6b). Wells in the northwest region of the Reserve, such as well 4, are located in uplands. Upland areas have steep ground water gradients. These steep

gradients depict that ground water is moving slowly likely due to the presence of fine textured soil materials (clays) which are associated with the residuum layer directly above the bedrock. Depth to bedrock in the northwest uplands of the Reserve is very shallow (around 4 feet).

Seasonal water table fluctuations in the wells reflect the soil characteristics. Wells in wetlands (Fig. 7b) maintain a more constant water table level than wells in the uplands (Fig. 7c). In the uplands, the finer soil materials hold water tightly. As a result, after the spring recharge around April water is released very slowly so that by June there is a large decline in water table level in these wells. Contaminants within the ground water will move very slowly. Sandier soils in the wetlands allow water to move faster and there is a more continuous baseflow. As a result, the water table level remains more stable throughout the year and contaminants will spread and move more rapidly in these areas.

Several of the monitoring wells in the Reserve were nested wells (10's, 12's, 1's, 6's, 5's, 33's, 17's, 18's, and 19's) ; two wells installed side by side with one being deeper than the other. Water table fluctuations in nested wells indicate when upwelling or recharging vertical gradients are present at a well location. When the deeper of the nested wells has a higher water table elevation than

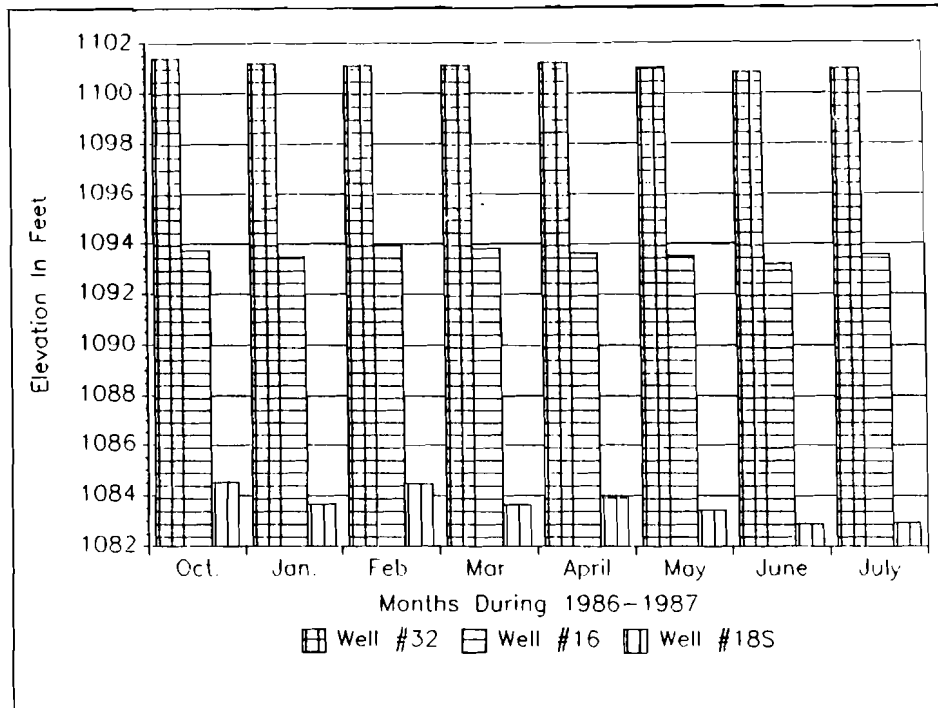


Figure 7b. Seasonal fluctuations of wells in wetland areas of the Reserve.

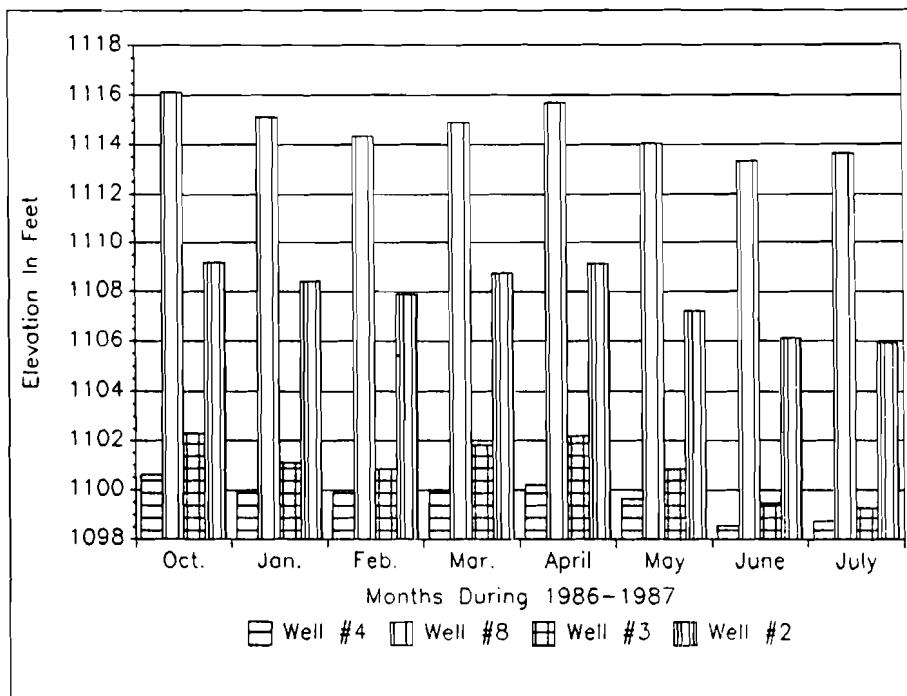


Figure 7c. Seasonal fluctuations of wells in upland areas of the Reserve.

the shallower well, then upwelling is occurring and surface water will not be infiltrating. When the opposite happens, ground water recharge is occurring and surface runoff along with potential contaminants can infiltrate into the aquifer. Figure 7d depicts vertical gradients in wells 10E and 10W. Upwelling occurred during January and infiltration the other months. At wells 12S and 12N (Fig. 7e), upwelling occurred in October and infiltration during January through July. The presence of vertical gradients are evidence of the complex hydrogeological system which operates in the Reserve.

Another factor which adds to the complexity of the hydrological system in the Reserve, is the presence of a perforated storm sewer line which runs along Michigan Avenue. Due to the perforation, this sewer line can at times contribute raw storm water runoff directly to the ground water in the eastern half of the Reserve. During times when the water table is high, this sewer may drain the aquifer. The impacts of this perforated sewer on the hydrological system in the Reserve are not fully understood and require further investigation.

Storm Water Impacts on Ground Water Quality

Petroleum VOC's

Volatile petroleum compounds from storm water runoff were not found to be contaminating the ground water

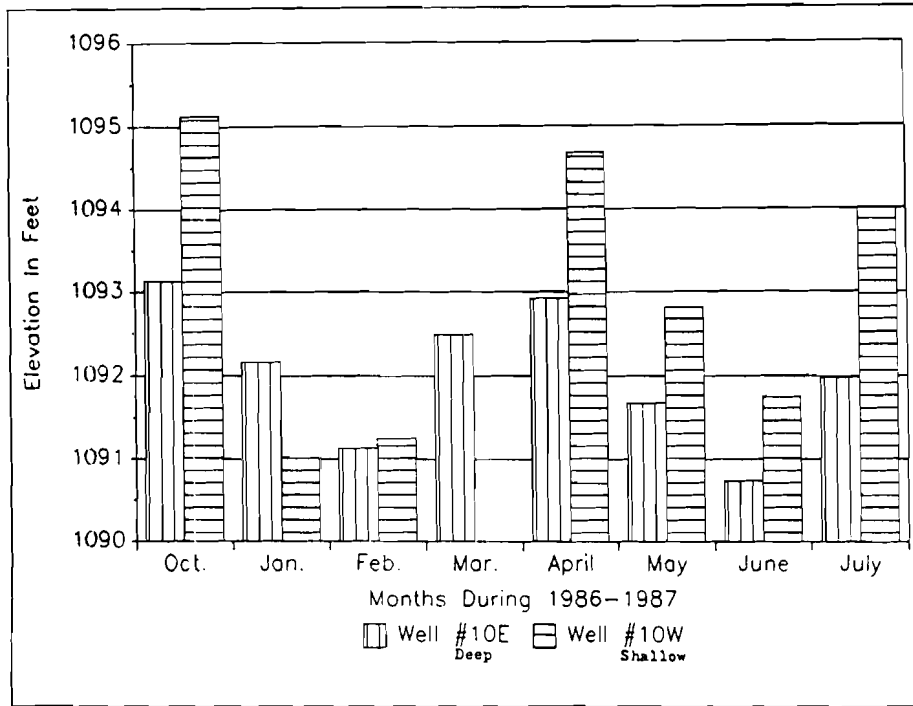


Figure 7d. Seasonal water table fluctuations depicting vertical gradients in wells 10E-deep and 10W-shallow.

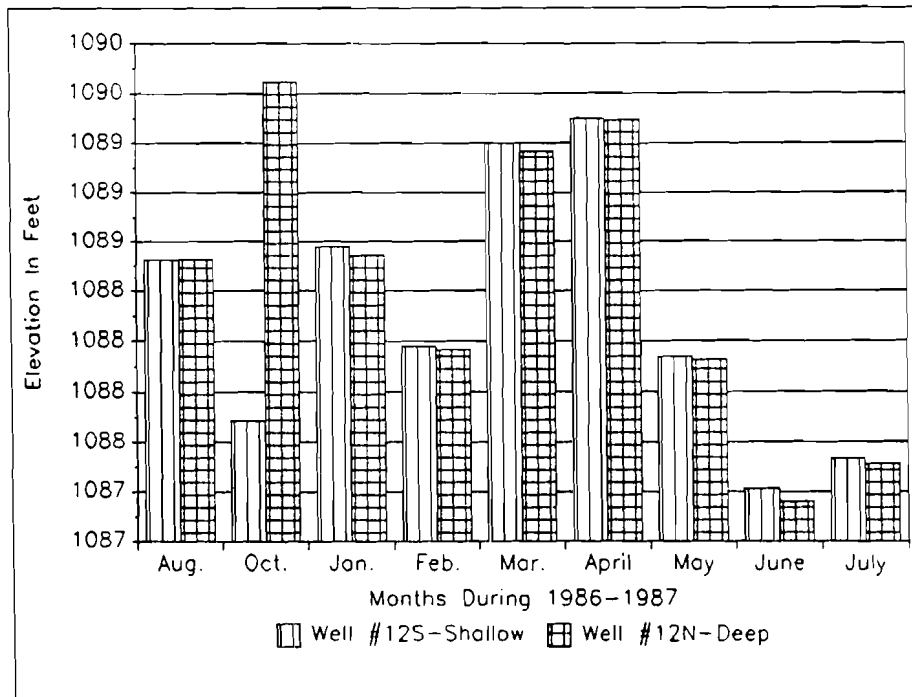


Figure 7e. Seasonal water table fluctuations depicting vertical gradients in wells 12N and 12S.

within the Reserve. Concentrations of benzene, toluene, and xylenes (BTX) were below detection limits (DL's = 0.5 ug/l B and T, 2.0 ug/l X) in most of the monitoring wells during the months sampled (Append. I, Table 12). Two exceptions were wells 16 and 36. Well 16 had a mean benzene concentration of 6.7 ug/l and well 36 had a mean toluene concentration of 14.6 ug/l (Fig. 8). The benzene concentration in well 16 remained consistent during the four months sampled. This concentration is 10 times higher than the Wisconsin ground water standard of 0.67 ug/l and therefore represents a potential health hazard if utilized for human consumption and violates Wisconsin ground water standards. Due to the southeast direction of ground water movement in the Reserve, the benzene contamination is potentially attributable to the infiltration of storm sewer discharge. However, other wells directly impacted by the discharge (32 and 34) were not contaminated with benzene. An additional temporary VOC sampling well was installed between wells 16 and 32 to help determine the pathway of benzene contamination. Here also, no benzene was detected. From this evidence, it appears that the benzene contamination in well 16 is not attributable to storm water discharge. The most likely source of this contamination is an underground petroleum storage tank which is located behind the University Maintenance Building near well 16.

The mean concentration of toluene in well 36 of 14.6

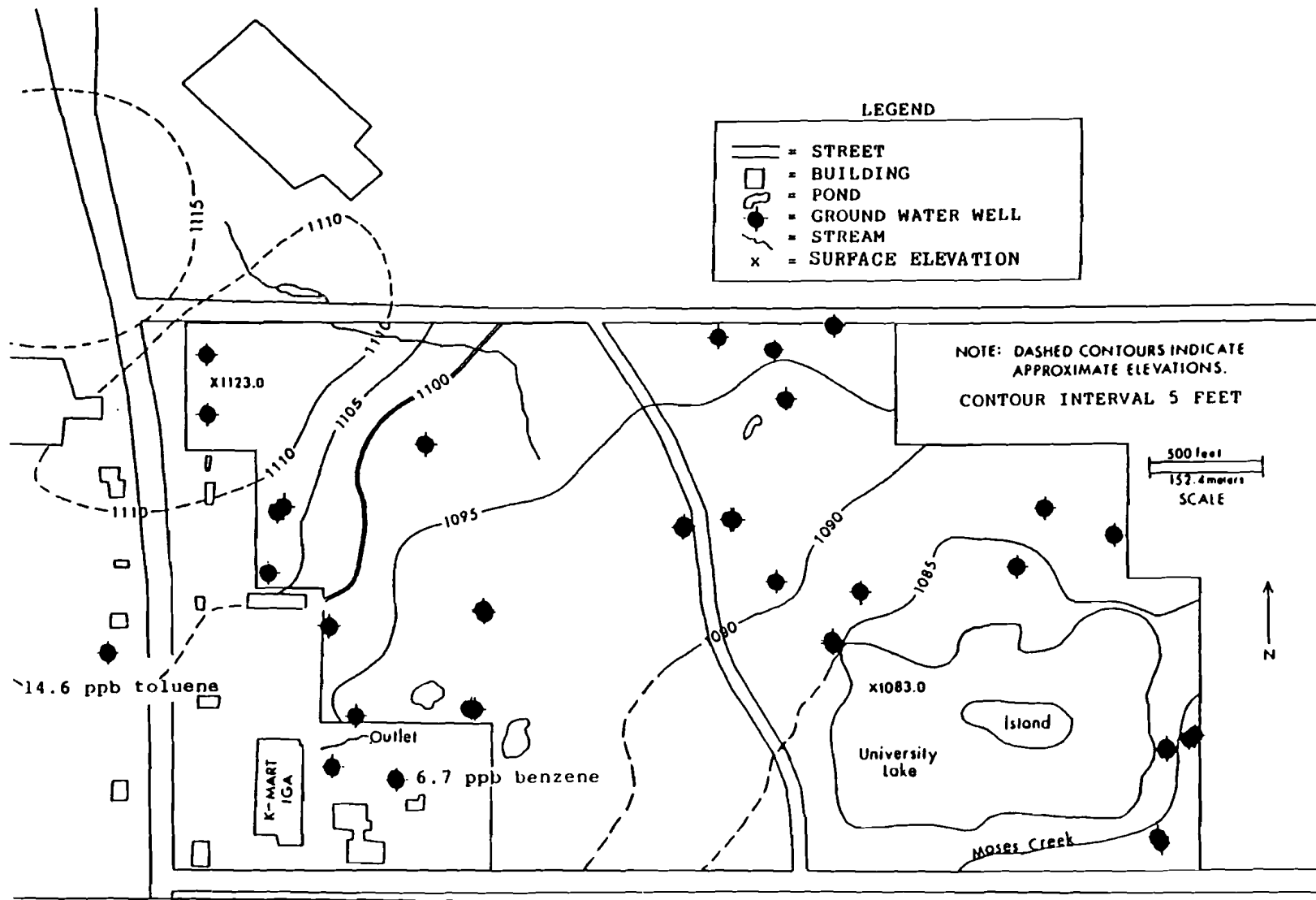


Figure 8 . Mean toluene in well 36 and mean benzene in well 16 in Schmeckle Reserve (ug/l).

ug/l was below the Wisconsin ground water enforcement standard of 343 ug/l and therefore does not pose a human health hazard or violate the state standards. Toluene is not a natural constituent of ground water, however, and is attributable to an urban or direct human impact. During the four months sampled, the toluene concentration in well 36 decreased from 39.2 ug/l in January to 1.6 ug/l in April. This substantial concentration decrease may suggest that the well was inadvertently contaminated upon installation. Sand used to backfill around the well screen may have been contaminated. Other potential sources of the contamination include storm water runoff from adjacent commercial business parking lots or local household or business activities such as ground water disposal of solvents or petroleum products. The existing data, however, is insufficient to determine the source of the contamination. Well 36 is located between two business parking lots in an area that was filled with imported soil material.

Metals in Ground Water

Dissolved and total metals concentrations at monitoring wells throughout the Reserve did not indicate the ground water quality was being impacted from storm water discharge or runoff. Monthly dissolved and total metals results are presented in Appendix I, Tables 13 and 14 and mean values are summarized in Tables 1 and 2. Mean dissolved lead (Pb), zinc (Zn), copper (Cu) and chromium (Cr)

concentrations at all wells sampled were ≤ 3 ug/l, ≤ 0.23 mg/l, ≤ 0.03 mg/l, and ≤ 0.02 mg/l respectively. These values are significantly less than the Wisconsin ground water standards of 50 ug-Pb/l, 5 mg-Zn/l, 1 mg-Cu/l, and 50 ug-Cr/l.

The wells impacted most directly from storm water discharge did not have Pb, Zn, Cu, or Cr concentrations significantly elevated over those of less impacted wells. Mean dissolved and total metals concentrations at four wells in the Reserve are displayed in Figure 9. Wells 16 and 32 are located nearest to the storm sewer outlet and are impacted most directly by storm water runoff. However, concentrations of Pb, Zn and Cu were similar to and in some cases less than those of wells 3 and 37, which are significantly less impacted by storm water runoff.

The data does not suggest storm water as the source of elevated iron (Fe) concentrations in ground water. The mean dissolved Fe concentrations ranged from 0.02 to 63.08 mg/l with several wells having concentrations far exceeding the 0.3 mg/l standard. The highest Fe concentrations were present in the deepest monitoring wells. These high concentrations are most likely a reflection of the natural geology of the area and the anoxic conditions present deep in the aquifer. The high concentrations of Fe do not present a health risk but more a nuisance to potential users of the

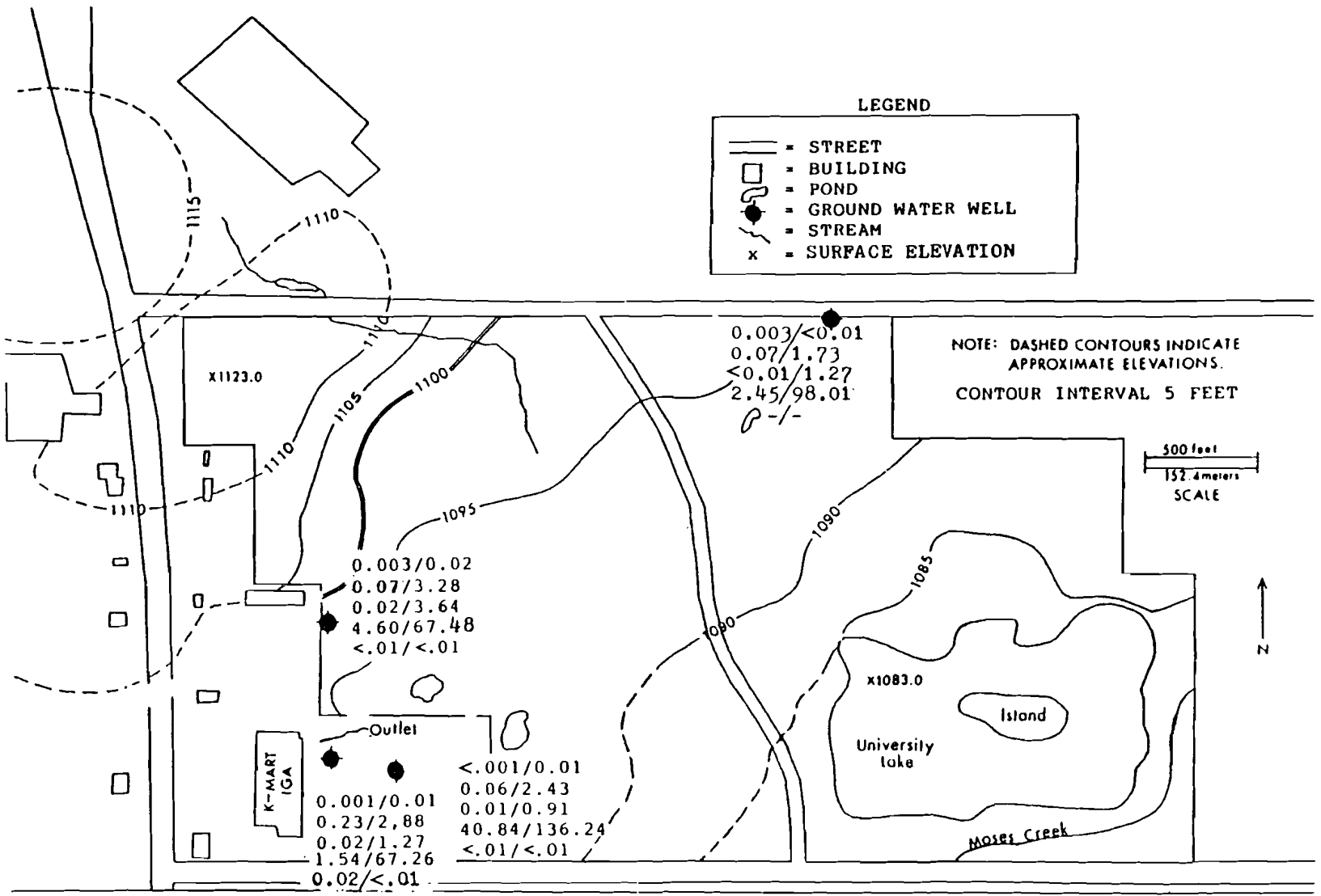


Figure 9. Mean dissolved and total Pb, Zn, Cu, Fe, and Cr concentrations in wells 3, 32, 37 & 16 in Schmeuckle Reserve (mg/l).

resource.

Table 1. Summary of mean concentrations of dissolved lead, zinc, iron, copper, and chromium at individual wells in Schmeckle Reserve.

SITE	Mean Pb	Mean Zn	Mean Fe mg/l	Mean Cu	3-13-87 Cr
1N	< 0.001	0.18	*	0.01	*
1S	*	*	*	*	*
2	< 0.001	0.13	0.02	0.01	*
3	0.003	0.07	4.60	0.02	<0.01
4	< 0.001	0.04	*	< 0.01	*
5N	< 0.001	0.06	7.06	0.01	*
5S	*	0.11	0.12	0.01	*
6E	0.001	0.06	23.14	0.01	*
6W	< 0.001	0.05	0.02	0.01	*
7	< 0.001	0.08	11.00	0.02	*
8	< 0.001	0.15	*	0.02	*
9	*	*	*	*	*
10E	< 0.001	0.04	*	0.01	*
10W	< 0.001	0.06	*	*	*
11	*	*	*	*	*
12N	0.001	0.06	2.82	< 0.01	*
12S	< 0.001	0.08	0.80	< 0.01	*
13	*	*	*	*	*
15	*	*	*	*	*
16	< 0.001	0.06	40.84	0.01	<0.01
17E	*	*	*	*	*
17W	*	*	*	*	*
18N	*	*	*	*	*
18S	*	*	*	*	*
19E	*	*	*	*	*
19W	*	*	*	*	*
20	*	*	*	*	*
21	0.001	0.06	6.68	< 0.01	<0.01
32	0.001	0.23	1.54	0.02	0.02
33N	*	0.04	*	0.02	*
33S	*	0.04	*	0.02	*
34	0.001	0.06	*	0.03	*
35	< 0.001	0.02	*	0.01	*
36	< 0.001	0.05	63.08	0.01	*
37	0.003	0.07	2.45	< 0.01	*
39	< 0.001	0.21	0.01	0.01	*

* Parameter not analyzed

Table 2. Summary of mean concentrations of total lead, zinc and copper at four wells in Schmeckle Reserve.

SITE	Mean Pb	Mean Zn	Mean Fe mg/l	Mean Cu	3-13-87 Cr
3	0.024	3.28	67.48	3.64	< 0.01
16	<0.010	2.43	136.24	0.91	< 0.01
32	0.008	2.88	67.26	1.27	< 0.01
37	< 0.010	1.73	98.01	0.61	*

* Parameter not analyzed

Note: Chromium was analyzed on only one sampling date.

The significant differences between dissolved and total metals concentrations in these results may be cause for concern over experimental error. Since samples for dissolved metals analyses collected in January, February and March were not field filtered, it is possible that oxidized iron may have precipitated out of solution significantly and may have further resulted in co-precipitation of other metals causing low dissolved metals values. This seems unlikely, however, since initially, duplicate samples were field filtered and only differences of < 0.01 ug/l for Cu, Zn and Fe were detected when compared with samples filtered in the lab. No variation was detected for Pb. Further, April samples were all field filtered and acidified and dissolved metals values were comparable to those of previous months (Append. I, Table 13).

One reason for elevated total metals values was the presence of fine sediments in many of the upland well

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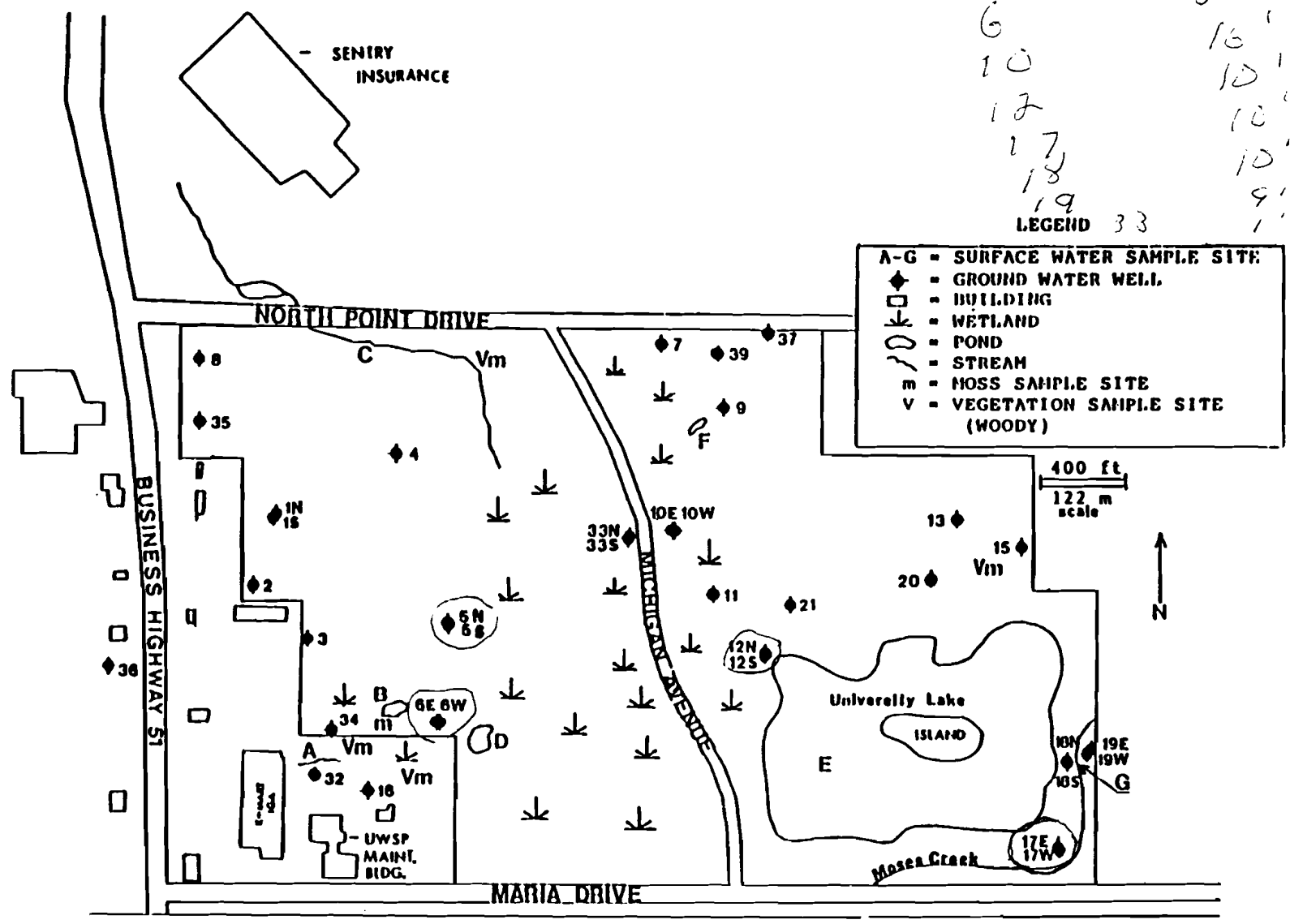


Figure 4. Study area map.

samples. These wells were extensively developed and bailed but complete purging of the fine residuum materials, that are characteristic of these low yielding wells, was not realized. These materials undoubtedly contributed to elevated total metals values in upland wells.

In light of these facts, my findings still are similar to those of other researchers. Harper (1985) analyzed ground water recharged by storm water retention ponds. He filtered samples through a Whatman GF/C glass fiber filter prior to dissolved metals analyses. He reported that dissolved metals fractions for most metals made up about 25% of the total metals. Bourcier and Hindin (1979) analyzed storm water runoff samples. They prepared the dissolved metals fractions by centrifuging 50 mls of sample for 5 minutes at 681 g and analyzed the centrifugate. They reported that less than 5 % of each metal in runoff was in the dissolved-colloidal form. Samples in this study were filtered through 0.45 micron filter prior to analysis and the dissolved metals represented between 1-30% of the total metals with most metals being \leq 12.5%. This evidence gives credibility to my metals results and to those of other authors.

Although the ground water in the Reserve does not appear to be contaminated with metals from runoff, storm water and sediment data indicate that runoff does contribute

significant loadings of metals to the Reserve. For example, lead emitted from automobile exhaust is reported to exist in a predominantly insoluble particulate form (Laxen and Harrison, 1977) greater than 20 microns in size (Wang et al., 1982). In runoff, therefore, total lead concentrations would be representative of roadway deposited lead. The total Pb concentration in a storm sewer sample collected during a low-discharge period was 117 ug/l, compared to < 1 ug/l of Pb in runoff from control stream C (Table 3). Lead concentrations in the storm sewer discharge would likely be even greater during heavy precipitation events. These data demonstrate that storm water runoff does contribute significant loadings of lead to the Reserve.

Table 3. Total metals in surface water samples collected March 14, 1987.

SITE	Pb	Zn	Cu mg/l	Fe	Cr
Culvert A	0.117	3.37	0.84	22.05	0.01
Stream C	<0.001	0.06	<0.01	1.09	<0.01

Similarly, the data in Table 3 is evidence that runoff does contribute significant amounts of Zn, Fe and possibly Cu to the Reserve, although they do not clearly have an impact on ground water quality at this time.

Sediment metals concentrations also demonstrate that storm water discharge has contributed significant amounts

of metals to the Reserve. Sediment metals data are presented in Appendix I, Table 15 and are summarized in Table 4. Mean Pb, Zn, Cu and Fe concentrations in the storm sewer outlet (culvert A) and ponds B and D were notably elevated over background levels (Fig. 10). Ponds B and D sediments contain a higher percentage of fine textured materials (silt, clay and organics) than the control (pond F). Similarly, the culvert sediments were finer textured overall than those in control stream C (Table 5). These fine materials have large surface areas per unit volume and act as metal adsorbants (Striegl, 1987). Therefore these sediments have an increased ability to adsorb available metals and this in part accounts for the increased metals content. More significant though is the source of metals. The culvert carries only runoff water and sediments most likely directly reflect the metals concentrations in storm water. Culvert sediments were approximately 3, 4, 2 and 2 times higher in Pb, Zn, Cu and Fe, respectively, than control stream C. Stream C is a natural intermittent stream which receives ground water drainage and runoff from the Sentry Insurance property. The stream also receives some runoff from North Point Drive but much less than the culvert.

Ponds B and D have the potential to become flooded with storm sewer discharge from overland flow during high volume runoff events due to the relatively flat surface

topography (Fig. 5). Ponds B and D sediments were on the average approximately 52, 4, 3 and 4 times higher in Pb, Zn, Cu and Fe, respectively, than the control pond F. Pond F is relatively isolated in the Reserve and has no obvious impacts.

Concentrations in ponds B and D may reflect metals from storm water drainage as well as atmospheric sources. Both of these ponds are located in close proximity to automobile and smokestack emissions. Exactly what percentage of the metals in the sediments are linked to atmospheric sources cannot be quantified from the available data.

Table 4. Summary of mean concentrations of lead, zinc, iron, copper, and chromium in sediments from Schmeekle Reserve.

SITE	Mean Pb	Mean Zn	Mean Fe	Mean Cu	3/87 Cr
	----- mg/kg dry wt. -----				
Culvert (A) 0 FT [^]	21.24	36.21	6,762.77	12.48	0.70
Culvert (A) 5 FT [^]	14.70	32.67	7,488.97	9.80	*
Culvert (A) 15 FT [^]	19.31	45.06	3,625.15	15.56	*
Pond (B)	44.79	34.03	4,296.63	13.37	0.60
Stream (C)	5.61	10.14	4,174.92	5.74	<0.01
Pond (D)	22.86	48.02	7,280.53	5.61	*
Lake (E)	2.20	306.06	3,290.28	4.40	*
Pond (F)	< 0.65	11.74	1,211.69	3.26	*
Stream (G)	6.88	38.52	6,310.82	7.57	*

* Parameter not analyzed

[^] Distance in feet from outfall

Table 5. Particle size composition of sediments from surface water sources in Schmeckle Reserve.

SITE	% > 2mm	% < 2mm			% Organic
		% Sand	% Silt	% Clay	
Culvert (A) 0 FT.	0	93	0	7	1
Culvert (A) 5 FT.	4	82	8	10	3
Culvert (A) 15 FT.	71	96	0	4	3
Pond (B)	2	83	6	11	5
Stream (C)	0	96	0	4	1
Pond (D)	7	83	9	8	3
Lake (E)	12	96	1	3	1
Pond (F)	1	92	4	4	1
Stream (G)	30	92	2	6	3

Note: Samples were collected and analyzed in July, 1987.

The sediments near the storm sewer outlet were surprisingly lower in some metals than ponds B and D. This is possibly due to the scouring action of high velocity discharges during storm events which may effectively carry metals in suspension some distance away from the outlet and into the Reserve. This is supported by the fact that the outlet sediments contained less fine textured materials and organic matter overall than the ponds, thus reducing metal absorption ability (Table 5).

The outlet sediments were notably elevated in metals concentrations in comparison to stream C, a natural and less impacted stream, but were similar in concentration to metals in sediments from stream site G. Site G is on Moses Creek, a channelized stream which drains wetlands northeast of the Reserve and receives storm water runoff from State Highway 51. Metals impacts on sediments in Moses Creek may

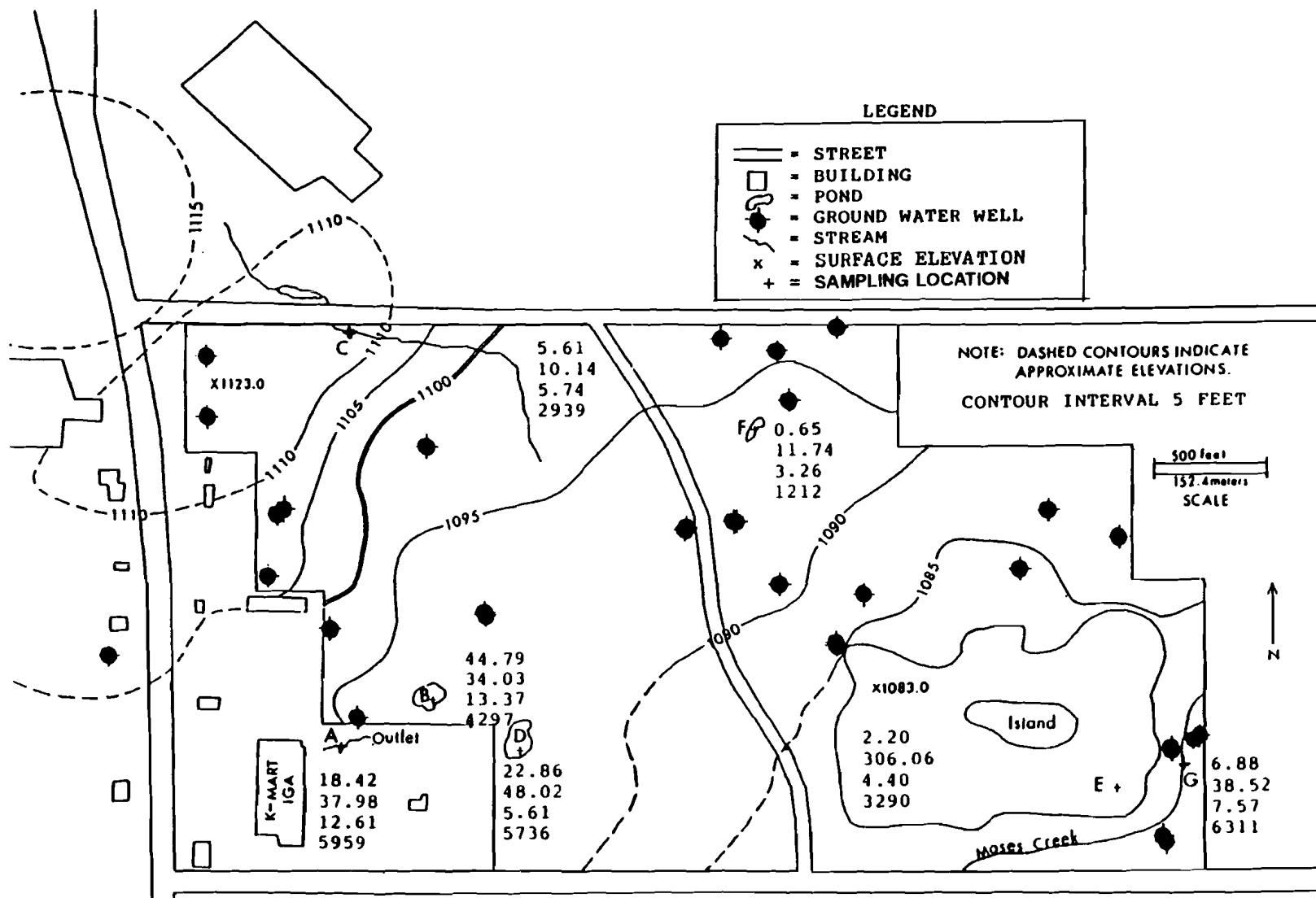


Figure 10. Mean Pb, Zn, Cu, and Fe concentrations in sediments from surface water sources in Schmeckle Reserve (mg/kg dry weight).

be similar to those in the storm sewer outlet.

University Lake sediments were low in Pb, Cu, and Fe but had a Zn concentration around eight times higher than the mean value of the storm sewer outlet sediments. Although there are no obvious sources to which these high Zn concentrations could be attributed, it is likely that this Zn is not naturally occurring and may be attributable to the lake construction process or to atmospheric deposition. The lake was constructed between 1975 and 1976 and elevated Zn concentrations may be due to abandoned materials or imported soils. Atmospheric deposition is another possible source. These potential sources will be discussed in more detail in the following sections.

Road Salt and Other Inorganics

Chemical characteristics of the ground water in the Reserve were quantified for individual monitoring wells and compiled as a data base with which to compare future and continued research. Monthly analytical results are compiled in Appendix I, Tables 1-10 and are summarized in Tables 6-8.

Road salt contamination was most prevalent in monitoring wells nearest to the storm sewer discharge and in wells close to roadways and intersections (Fig. 11). Well 32, which is directly impacted by the storm sewer discharge, had mean chloride and sodium concentrations of 2054 mg/l

Table 6. Summary of mean values for pH, conductivity, alkalinity, and total hardness in ground water from Schaeckle Reserve.

SITE	DEPTH (ft.) OF SCREEN	pH	L/H/#	COND. (umhos)	L/H/#	ALK.	L/H/#	TOTAL HARD.	
								mg/l	
1 N	4.78	6.03	(5.52/7.04/8)	147	(82/242/8)	16	(6/52/8)	48	(14/72/8)
1 S	6.63	6.29	(6.14/7.04/3)	201	(190/221/3)	32	(20/52/3)	68	(60/73/3)
2	3.87	5.40	(5.12/6.30/9)	183	(161/222/9)	5	(4/10/9)	51	(44/58/9)
3	3.79	6.00	(5.16/7.80/10)	364	(303/416/10)	107	(10/152/10)	142	(18/184/10)
4	5.44	5.41	(4.50/7.40/9)	106	(44/475/9)	16	(8/58/9)	30	(12/118/9)
5 N	9.20	6.27	(6.08/6.44/9)	106	(97/138/9)	20	(12/24/9)	34	(22/44/9)
5 S	3.70	6.51	(6.15/7.25/5)	142	(84/295/5)	23	(14/48/5)	45	(34/60/5)
6 E	10.55	5.97	(5.65/6.50/10)	622	(579/686/10)	32	(20/44/10)	98	(90/108/10)
6 W	4.61	5.10	(4.20/6.30/10)	426	(249/1196/10)	11	(nd/17/10)	58	(18/232/10)
7	2.54	6.57	(6.31/7.26/6)	1238	(916/1624/6)	140	(118/180/6)	318	(252/396/6)
8	6.38	5.95	(5.69/6.11/2)	566	(552/579/2)	16	(16/16/2)	145	(144/146/2)
9	6.53	5.59	(4.80/6.86/7)	101	(92/108/7)	10	(2/18/7)	33	(28/40/6)
10 E	20.36	6.45	(6.35/6.80/9)	376	(321/433/9)	139	(100/168/9)	170	(128/204/9)
10 W	3.98	6.55	(6.32/7.20/8)	270	(216/338/8)	56	(38/111/8)	95	(66/140/7)
11	4.27	5.95	(5.63/6.38/7)	186	(153/257/7)	24	(14/54/7)	49	(32/76/6)
12 N	17.56	7.07	(6.80/7.48/8)	222	(206/260/8)	71	(64/90/8)	104	(94/116/8)
12 S	7.85	7.03	(6.90/7.30/8)	390	(225/466/8)	168	(88/204/8)	199	(106/244/7)
13	3.28	6.09	(5.91/6.64/6)	48	(43/56/6)	8	(6/10/6)	19	(14/32/5)
15	6.04	5.80	(5.46/6.60/6)	46	(44/48/6)	8	(4/12/6)	19	(12/28/5)
16	7.44	6.10	(5.92/6.67/10)	1927	(1032/2720/10)	97	(42/156/10)	430	(250/614/10)
17 E	16.90	6.84	(6.51/7.72/7)	172	(151/194/7)	51	(46/66/7)	81	(66/90/7)
17 W	6.60	6.74	(6.43/7.10/7)	51	(29/72/7)	11	(4/22/7)	24	(12/32/7)
18 N	5.30	6.29	(6.10/6.80/7)	231	(89/304/7)	93	(30/130/7)	111	(38/144/7)
18 S	15.40	6.08	(5.88/6.95/7)	126	(116/132/7)	23	(16/46/7)	48	(44/60/7)
19 E	15.40	6.13	(5.91/6.84/7)	154	(134/166/7)	29	(18/38/7)	53	(44/60/7)
19 W	6.38	6.10	(5.75/6.60/7)	174	(23/288/7)	39	(18/80/7)	50	(30/90/6)
20	4.95	6.14	(5.95/6.70/7)	84	(77/87/7)	10	(8/20/7)	26	(22/28/6)
21	6.56	6.99	(6.73/7.51/6)	186	(161/253/6)	93	(66/132/5)	108	(74/196/6)
32	3.23	6.83	(6.20/7.72/10)	5013	(842/6780/10)	228	(86/352/10)	287	(24/904/10)
33 N	4.77	5.95	(5.77/6.26/2)	96	(95/98/2)	15	(14/16/2)	39	(36/42/2)
33 S	3.69	5.76	(5.76/5.76/1)	93	(93/93/1)	16	(16/16/1)	32	(32/32/1)
34	3.61	5.91	(5.85/5.99/2)	88	(73/103/2)	25	(22/28/2)	41	(38/44/2)
35	6.88	6.54	(6.28/6.97/3)	91	(80/98/3)	17	(14/20/3)	31	(28/26/3)
36	9.53	6.37	(6.29/6.52/4)	470	(450/495/4)	166	(152/179/4)	171	(157/186/4)
37	134.00	6.62	(6.47/6.85/2)	104	(103/106/2)	32	(30/34/2)	35	(34/36/2)
39	----	7.28	(7.23/7.34/3)	380	(370/389/3)	125	(124/126/3)	171	(166/176/3)

Note: L = lowest value, H = highest value, # = number of samples

Table 7. Summary of mean values for calcium hardness, reactive phosphorus, ammonia nitrogen, and nitrite + nitrate nitrogen in ground water from Schmeckle Reserve.

SITE	Ca++ HARD.		Reactive P		NH4-N		NO2 + NO3	
	L/H/#	L/H/#	L/H/#	L/H/#	L/H/#	L/H/#	L/H/#	
mg/l								
1 N	29	(10/52/7)	0.004	(nd/.012/5)	0.03	(nd/.13/8)	0.03	(nd/.12/8)
1 S	41	(36/52/3)	0.005	(nd/.012/3)	0.12	(nd/.34/3)	0.02	(nd/.04/3)
2	33	(26/44/8)	0.002	(nd/.005/6)	0.07	(nd/.43/9)	0.04	(nd/.10/9)
3	72	(10/126/9)	0.009	(nd/.055/7)	0.12	(nd/.60/10)	0.05	(nd/.24/10)
4	18	(8/66/8)	0.007	(nd/.035/6)	0.07	(nd/.47/9)	0.19	(nd/.43/9)
5 N	24	(16/44/8)	0.004	(nd/.010/6)	0.09	(nd/.39/9)	0.07	(nd/.50/9)
5 S	26	(18/46/4)	0.009	(nd/.024/3)	0.07	(nd/.16/5)	0.12	(nd/.28/5)
6 E	62	(52/70/9)	0.003	(nd/.008/8)	0.34	(.20/.74/10)	0.01	(nd/.04/10)
6 W	30	(10/146/9)	0.003	(nd/.015/7)	0.13	(nd/.75/10)	0.08	(nd/.50/10)
7	183	(132/240/5)	0.010	(nd/.040/4)	0.21	(.02/.59/6)	0.10	(nd/.50/6)
8	152	(96/208/2)	nd	(nd/nd/2)	0.08	(.06/.09/2)	1.51	(1.50/1.51/2)
9	17	(14/20/6)	0.007	(nd/.025/4)	0.02	(nd/.08/7)	3.47	(1.55/5.05/7)
10 E	109	(76/156/8)	0.002	(nd/.005/6)	0.09	(nd/.37/9)	0.01	(nd/.02/9)
10 W	59	(24/92/7)	0.003	(nd/.010/5)	1.23	(.04/2.80/8)	0.19	(nd/.60/8)
11	32	(18/60/6)	0.002	(nd/.005/4)	0.03	(nd/.10/7)	0.02	(nd/.08/7)
12 N	69	(58/94/7)	0.005	(nd/.015/5)	0.09	(nd/.20/8)	0.03	(nd/.16/8)
12 S	139	(64/220/7)	0.001	(nd/.002/5)	0.07	(nd/.12/8)	0.01	(nd/.02/8)
13	10	(8/12/5)	0.002	(nd/.005/3)	0.02	(nd/.08/6)	0.03	(nd/.06/6)
15	12	(10/14/5)	0.003	(nd/.008/4)	0.02	(nd/.04/6)	0.02	(nd/.06/6)
16	282	(152/400/9)	0.001	(nd/.002/7)	1.33	(.58/1.70/10)	0.05	(nd/.22/10)
17 E	49	(38/72/6)	0.001	(nd/.002/4)	0.03	(nd/.08/7)	0.01	(nd/.03/7)
17 W	17	(10/24/6)	0.007	(nd/.022/4)	0.03	(nd/.12/7)	0.41	(nd/1.24/7)
18 N	65	(24/112/6)	0.002	(nd/.010/4)	0.43	(.04/.76/7)	0.01	(nd/.01/7)
18 S	27	(24/32/6)	0.003	(nd/.010/4)	0.08	(.04/.12/7)	0.03	(nd/.14/7)
19 E	29	(26/30/6)	0.001	(nd/.002/4)	0.05	(nd/.12/7)	0.03	(nd/.14/7)
19 W	45	(28/86/6)	0.002	(nd/.005/4)	0.02	(nd/.06/7)	0.83	(nd/1.62/7)
20	19	(16/22/6)	0.002	(nd/.005/4)	0.02	(nd/.06/7)	0.02	(nd/.04/7)
21	66	(46/96/5)	0.004	(nd/.015/4)	0.08	(.03/.14/6)	0.02	(nd/.07/6)
32	216	(18/610/9)	0.029	(nd/.188/8)	1.72	(.64/2.52/10)	0.03	(nd/.18/10)
33 N	20	(18/22/2)	nd	(nd/nd/2)	0.08	(.06/.11/2)	0.02	(nd/.03/2)
33 S	20	(20/20/1)	nd	(nd/nd/1)	0.08	(.08/.08/1)	nd	(nd/nd/1)
34	17	(14/20/2)	nd	(nd/nd/2)	0.20	(.11/.29/2)	nd	(nd/nd/2)
35	19	(14/24/3)	nd	(nd/nd/3)	0.18	(nd/.51/3)	0.08	(nd/.17/3)
36	108	(94/120/4)	nd	(nd/nd/4)	0.61	(.42/.98/4)	0.07	(nd/.26/4)
37	25	(24/26/2)	nd	(nd/nd/2)	0.01	(nd/.02/2)	nd	(nd/nd/2)
39	103	(100/106/3)	nd	(nd/nd/3)	0.03	(.01/.05/3)	3.57	(3.40/3.82/3)

Note: L = lowest value, H = highest value, # = number of samples

Table B. Summary of mean values for chloride, sodium, and potassium in ground water from Schaeckle Reserve.

SITE	CL-	L/H/#	mg/l			
			Na+	L/H/#	K+	L/H/#
1 N	33	(1/69/9)	6.0	(3.2/8.9/3)	2.2	(2.0/2.7/3)
1 S	32	(26/37/2)	8.0	(6.0/9.0/3)	4.0	(2.0/7.4/3)
2	35	(27/53/9)	13.0	(9.0/15.0/4)	0.6	(nd/1.8/4)
3	28	(1/35/9)	15.1	(14.0/15.7/5)	1.0	(.4/2.4/5)
4	8	(nd/35/9)	3.0	(2.3/4.0/4)	0.4	(nd/1.3/4)
5 N	7	(1/27/9)	5.2	(4.0/8.6/4)	0.9	(.4/1.9/4)
5 S	17	(4/67/5)	16.7	(3.4/30.0/2)	0.8	(.5/1.0/2)
6 E	167	(79/250/10)	74.2	(70.0/77.0/5)	2.0	(1.0/4.7/5)
6 W	114	(49/357/10)	69.3	(40.0/152.0/5)	1.6	(.6/3.0/5)
7	369	(168/581/6)	116.3	(94.0/149.0/3)	1.8	(1.0/3.2/3)
8	183	(160/206/2)	39.2	(38.0/40.3/2)	3.4	(3.2/3.5/2)
9	11	(7/14/7)	5.6	(5.4/5.8/2)	0.7	(.4/1.0/2)
10 E	31	(23/44/9)	14.4	(11.8/15.6/4)	1.3	(.7/2.7/4)
10 W	37	(18/57/8)	11.2	(7.3/17.6/3)	4.2	(1.9/8.2/3)
11	27	(18/53/7)	10.4	(10.4/10.4/2)	0.1	(nd/.1/2)
12 N	7	(5/12/8)	5.0	(4.0/6.6/3)	0.7	(.6/1.0/3)
12 S	12	(1/17/8)	3.8	(3.7/3.9/3)	0.4	(nd/.6/3)
13	2	(2/3/6)	2.8	(2.8/2.9/2)	nd	(nd/nd/2)
15	1	(nd/2/6)	2.4	(2.4/2.4/2)	0.2	(nd/.3/2)
16	543	(285/917/10)	99.1	(24.0/250.0/5)	5.2	(2.5/10.7/5)
17 E	9	(5/16/7)	3.1	(3.0/3.1/2)	0.2	(nd/.4/2)
17 W	2	(nd/5/7)	1.1	(.8/1.4/2)	0.2	(nd/.4/2)
18 N	6	(1/12/7)	3.6	(2.9/4.2/2)	0.8	(.5/1.0/2)
18 S	10	(5/19/7)	4.6	(3.8/5.3/2)	0.9	(.8/1.0/2)
19 E	18	(13/23/7)	9.0	(8.9/9.0/2)	0.6	(nd/1.1/2)
19 W	10	(3/15/7)	20.6	(18.1/23.0/2)	0.1	(nd/.2/2)
20	8	(4/15/7)	4.6	(3.8/5.3/2)	0.2	(nd/.3/2)
21	2	(1/3/6)	2.0	(1.8/2.2/3)	0.2	(nd/.5/3)
32	2054	(81/5000/9)	655.2	(132.0/1190.0/5)	14.7	(5.0/37.1/5)
33 N	2	(2/3/2)	8.1	(3.8/12.3/2)	0.9	(.8/1.0/2)
33 S	2	(2/2/1)	3.7	(3.7/3.7/1)	0.7	(.7/.7/1)
34	2	(1/3/2)	4.1	(3.5/4.7/2)	1.0	(.2/1.8/2)
35	9	(8/9/2)	5.4	(5.0/6.1/3)	1.1	(.6/2.2/3)
36	34	(25/48/4)	14.1	(13.5/14.9/4)	5.1	(3.0/10.7/4)
37	15	(13/17/2)	6.1	(6.0/6.2/2)	0.6	(.6/.6/2)
39	33	(32/34/3)	9.7	(9.2/10.0/3)	0.9	(nd/1.4/3)

Note: L = lowest value, H = highest value, # = number of samples

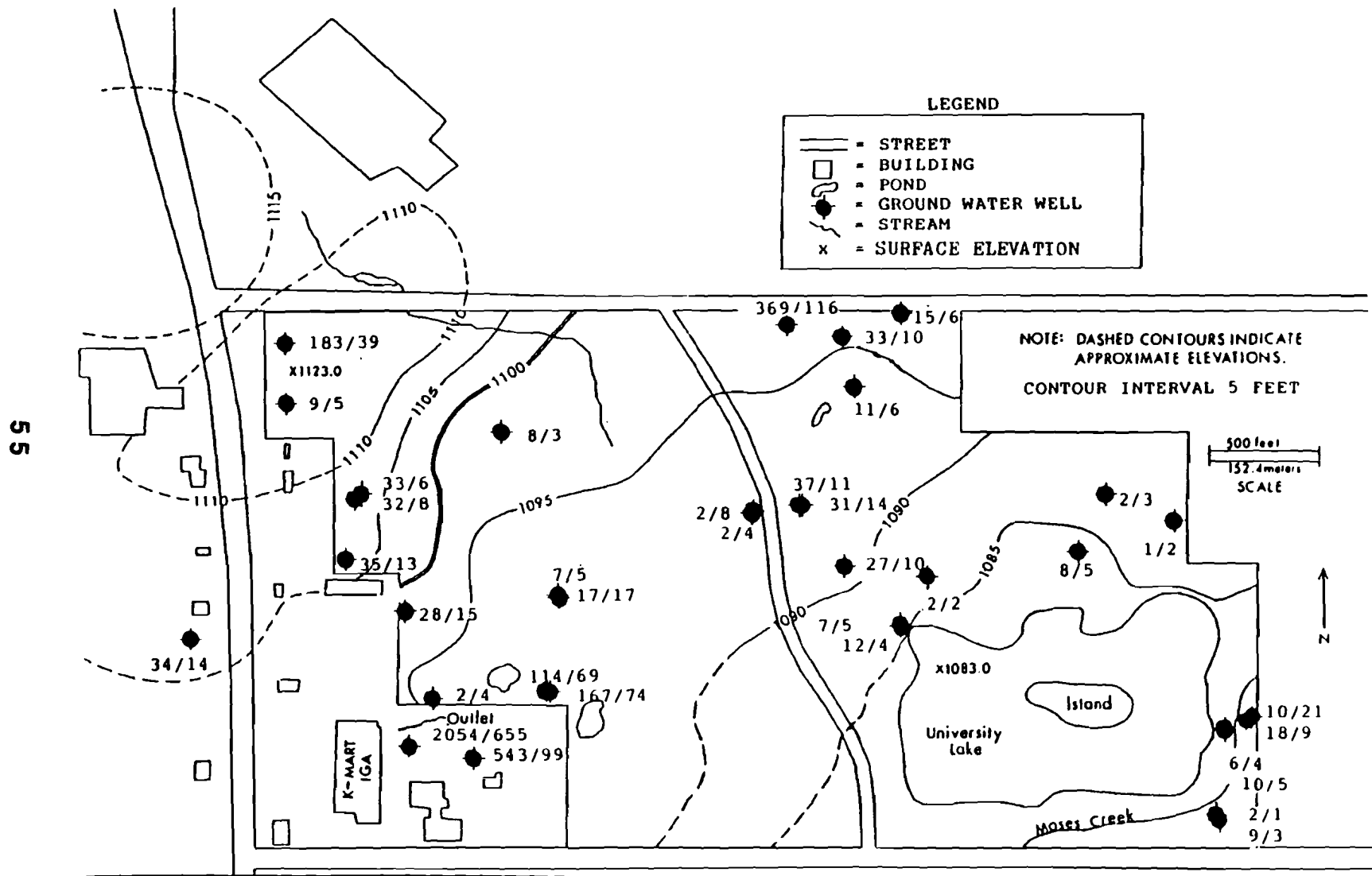


Figure 11. Mean chloride and sodium concentrations at ground water wells in Schmeckle Reserve (mg/l).

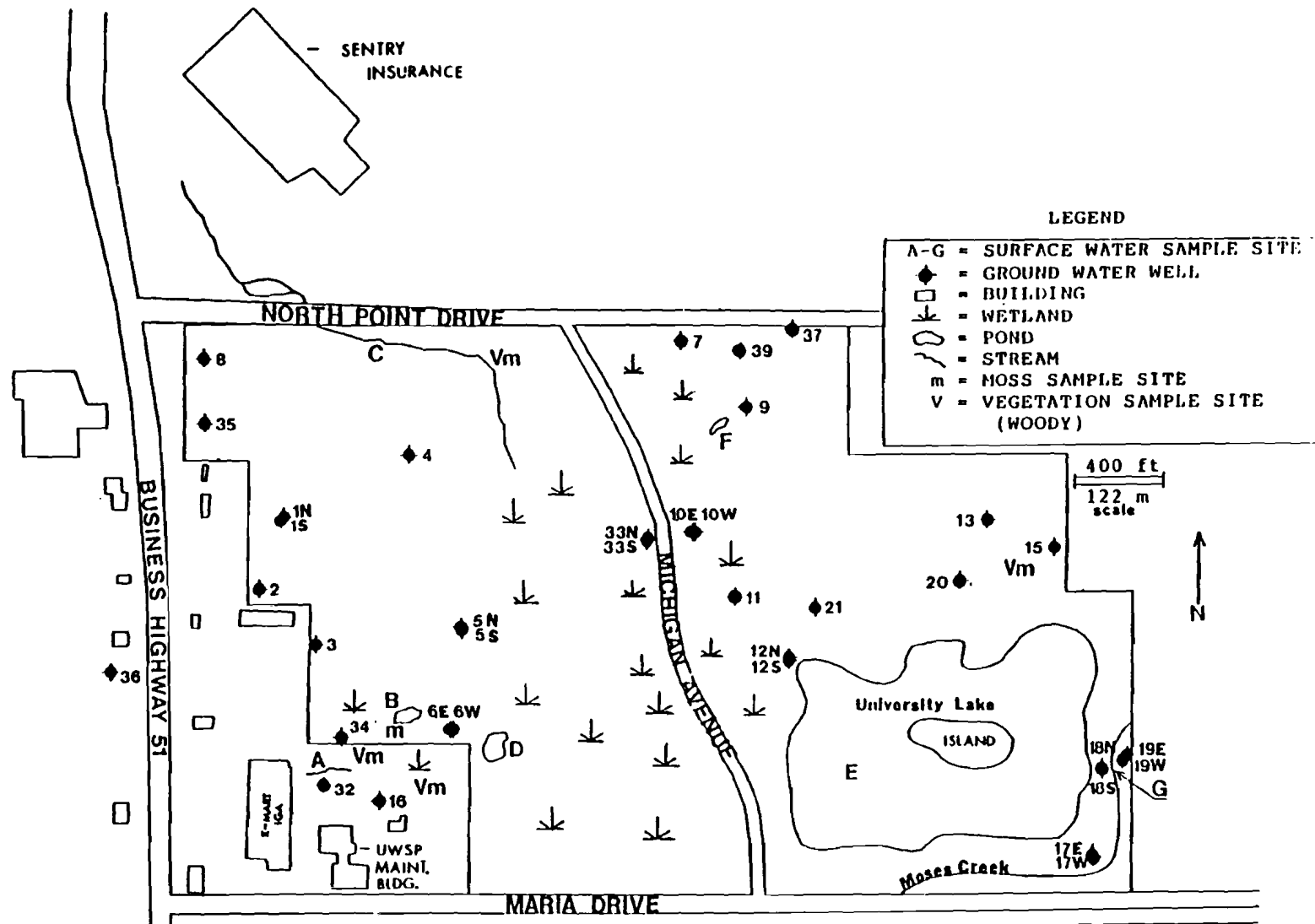


Figure 4. Study area map.

and 655 mg/l respectively. These values represent a significant degree of contamination. Background mean chloride and sodium concentrations in the Reserve ground water were around 1-8 mg/l and 2-5 mg/l respectively. Other wells in the ground water flow path from the storm sewer (16, 6E, 6W) also had significantly elevated sodium and chloride concentrations. Wells located around University Lake were not significantly elevated in salt concentration. Therefore, it appears ground water contamination from the storm sewer discharge does not impact the lake but rather is carried out of the Reserve before reaching the lake, as predicted by the ground water contours.

As ground water moves in a southeast direction, salt concentrations become diluted in the Reserve. Salt contamination at wells 8 (183 mg/l Cl⁻, 39 mg/l Na⁺) and 7 (369 mg/l Cl⁻, 116 mg/l Na⁺) are attributable to roadway runoff. The direction of ground water movement suggests that salt contamination originating near well 7 can potentially impact University Lake. However, the sodium and chloride concentrations in wells surrounding the lake were not highly elevated. Similarly, contamination originating near well 8 could impact areas directly to the southeast but wells located there do not reflect substantial salt contamination. These data suggest that salt concentrations become diluted in the aquifer by ground water recharge occurring in the Reserve and/or by moving to greater depths

in the aquifer. In addition, ground water may be discharging to the surface (upwelling) before recharging to the aquifer thus reducing salt contamination in the aquifer. Several more nested wells would need to be installed in order to assess the vertical hydraulic gradients and their relation to contaminant transport in areas downgradient of wells 7 and 8.

Figure 12 displays how the highest chloride concentrations are present in wells nearest to the storm sewer discharge and roadway intersections. The chloride plumes are carried within the aquifer and concentrations diminish as the ground water moves in a southeast flow direction.

Chloride concentration fluctuations follow the seasonal changes. Concentrations are highest during the peak winter road salting months and decrease during the warmer months (Fig. 13). Chloride concentrations in well 32 reflect those in concentrated storm water runoff. Well 4 is not directly impacted by roadway runoff and serves as a control.

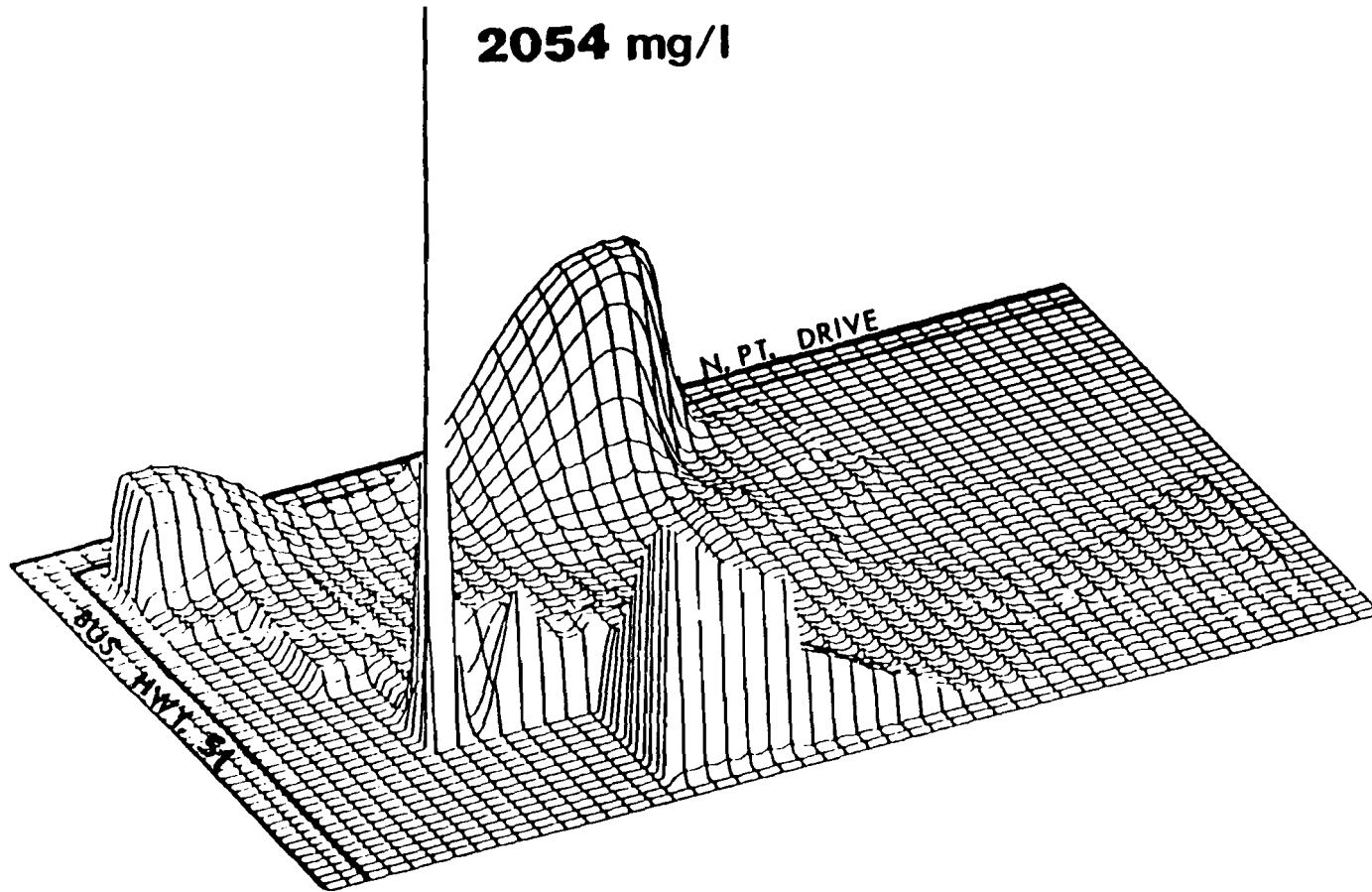


Figure 12. Three dimensional representation of mean chloride concentrations in the ground water of Schmeckle Reserve (mg/l).

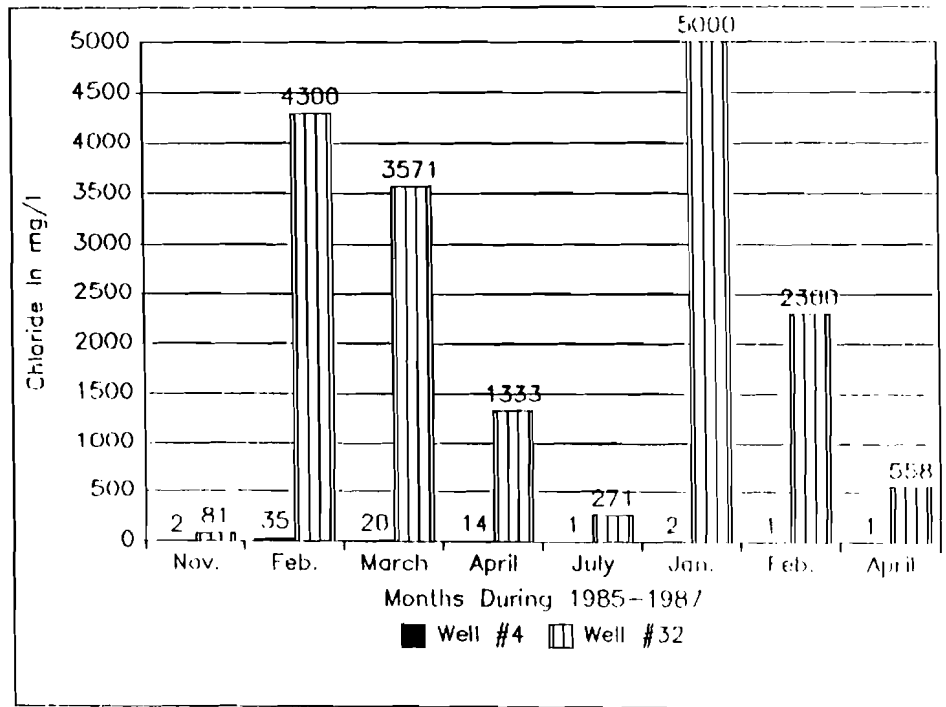


Figure 13. Chloride concentration fluctuations in contaminated well 32 and control well 4 in Schmeckle Reserve.

Storm water contamination may also affect hardness concentrations in ground water. Total and calcium hardness concentrations were elevated in many of the same monitoring wells which were most impacted by road salt (Fig. 14). The total hardness concentrations, which are a measure of calcium and magnesium, appear to be primarily a reflection of calcium concentrations in the Reserve aquifer. At many wells, the mean calcium hardness accounts for the majority of the mean total hardness values. Therefore, the question is whether or not the calcium concentrations are naturally occurring or if they represent a contaminant related to storm water runoff. The coefficient of linear correlation (r) between Cl^- and Ca^{++} concentrations in eight wells im-

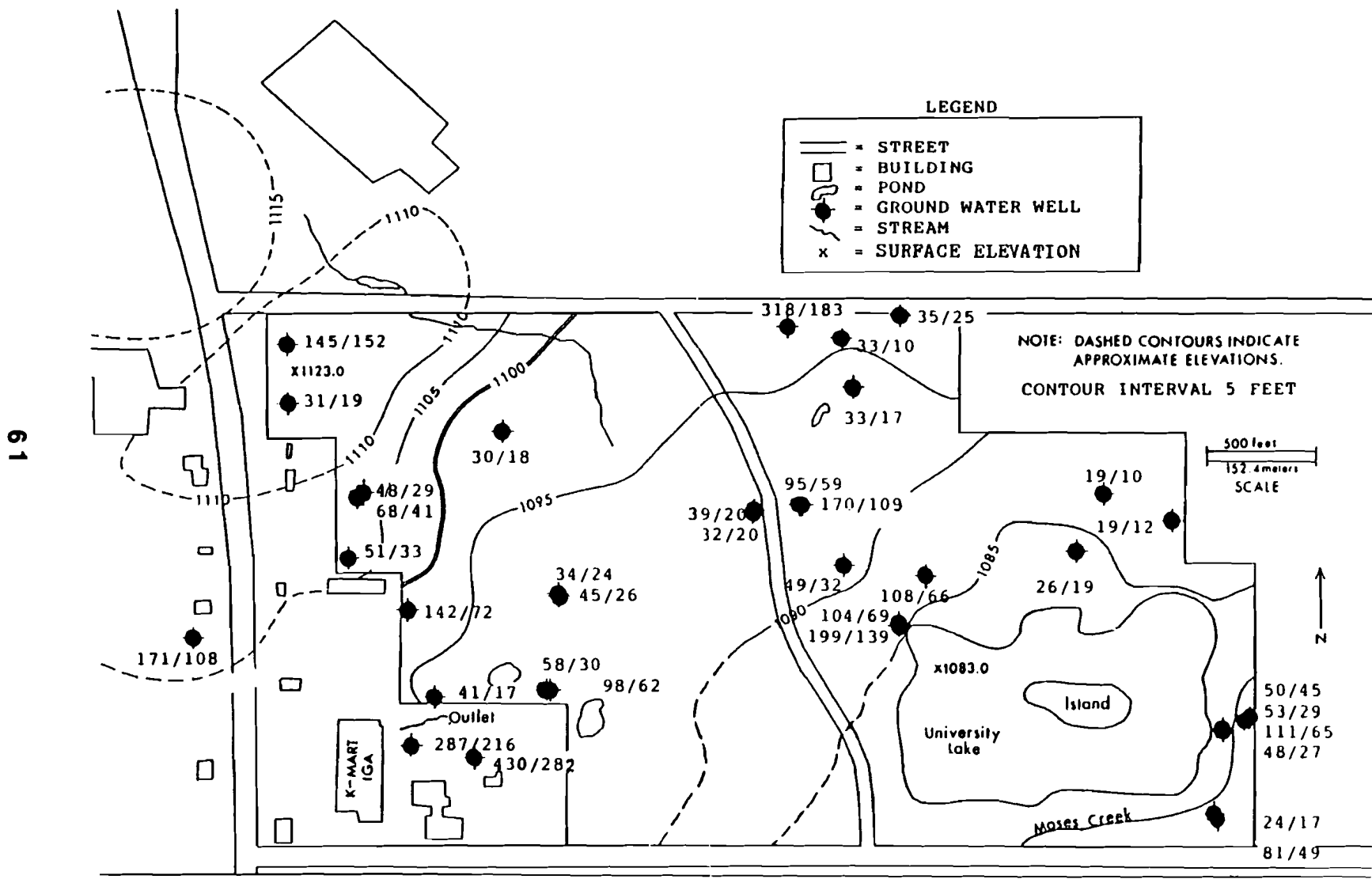


Figure 14. Mean total hardness and calcium hardness concentrations at ground water wells in Schmeckle Reserve (mg/l).

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pacted by road salt (32, 16, 6E, 6W, 5N, 34, 3 and 4) was 0.70. This suggests that Ca^{++} concentrations in ground water are likely related to storm water contamination. Elevated calcium concentrations in ground water could result due to the replacement of Ca^{++} ions in the soil by Na^{+} ions from runoff. This process would free Ca^{++} ions into solution and therefore concentrations in ground water would increase. No strong linear relationship is evident between Na^{+} and Ca^{++} concentrations in ground water ($r=0.60$, Fig. 15). These data suggest that elevated Ca^{++} concentrations in ground water are likely related to runoff. However, how much of the Ca^{++} is directly from the runoff and how much is a result of Na^{+} substitution in the soil is not clear.

Calcium hardness concentrations in storm sewer runoff, during a light snowfall runoff event, were 2.5 times higher than concentrations at control stream C (Table 9). These elevated calcium concentrations in runoff may be originating from the weathering of road surface concrete.

Other Indicators of Urban Impacts on Schmeckle Reserve

Sediments throughout the Reserve had elevated metals contents that can be considered contaminated over background levels. What is not clear however, is how much of this contamination is attributable to storm water runoff and how much is attributable to other sources, especially atmospheric sources. In an effort to evaluate potential atmospheric metals impacts on the Reserve, mosses, which

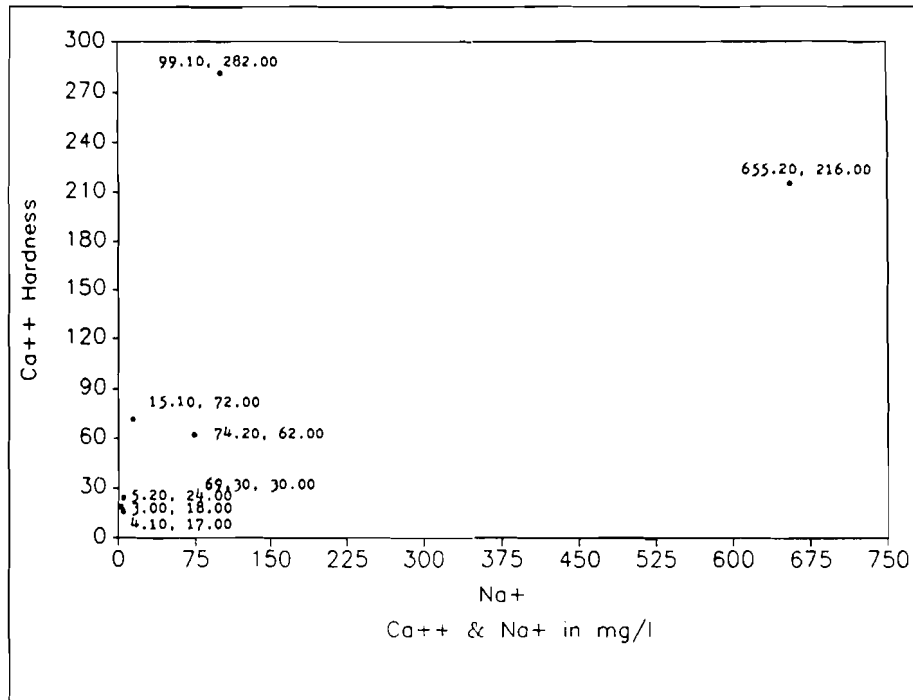


Figure 15. Mean sodium vs. mean calcium hardness concentrations at wells 32, 16, 6E, 6W, 5N, 34, 3, and 4 in Schmeckle Reserve.

Table 9. Inorganic chemistry of surface water samples collected March 14, 1987 during a low volume snowmelt runoff event.

SITE	pH	Cond.	Alk.	Total Hard.	Ca++ Hard.	Cl-	Na+	K+
----- mg/l -----								
Culvert A	6.68	2030	42	84	60	667	380	27
Stream C	6.69	543	28	38	24	153	84	1

are an index of atmospheric loadings, were analyzed for metals composition. Due to the uncertainty of such factors as age of each moss plant sampled, susceptibility of each moss plant to atmospheric contaminants, and accumulation of metals from growth substrates, these results should be

viewed only as indicators of atmospheric conditions rather than quantitative measures.

Concentrations of Pb, Zn and Cu in moss samples collected from within the Reserve were all higher than in moss collected from Jordan Park, a control site located about eight miles northeast of the Reserve (Table 10). Jordan Park was chosen as a control site due to its relative isolation from smokestacks and heavy urban traffic in comparison to the Reserve. Iron concentrations were also much higher in the Reserve moss samples excepting for moss collected near well 15, a Reserve sampling site which is farther removed from urban impacts than other sites (Fig. 16).

Table 10. Heavy metals in moss samples collected in June of 1987 from Schmeckle Reserve and Jordan Park.

SITE	Pb	Zn	Cu	Fe
	----- mg/kg dry weight -----			
15	21.48	199.86	31.52	600.64
16	44.56	747.72	21.63	16,271.00
32	49.69	191.16	43.81	1,869.14
North Pt.	140.90	153.36	25.10	5,546.22
Pond B	27.74	269.21	16.52	1,279.63
Jordan Park	16.86	57.58	11.58	1,117.94

Lead concentrations in moss samples from the Reserve ranged from 21.48 to 140.90 mg/kg. These values were between 1.3 to 8.4 times higher than the control. Lead concentrations were highest in samples collected nearest to the urbanized margins of the Reserve. Moss sampled from more isolated and forested areas in the Reserve were lower

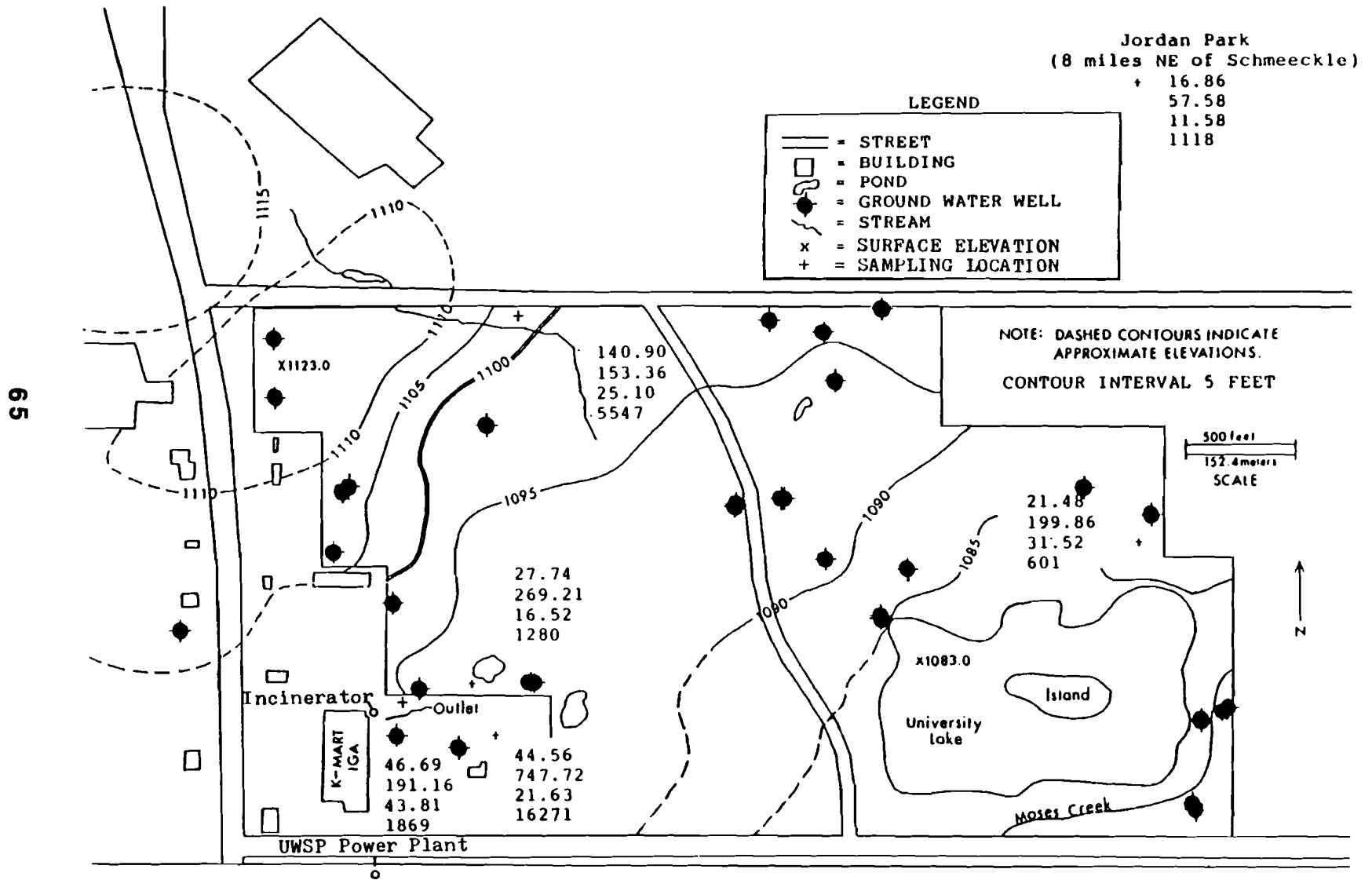


Figure 16. Pb, Zn, Cu, and Fe concentrations in moss samples collected in June of 1987 from Schmeeckle Reserve and Jordan Park (mg/kg dry wt.).

FIGURE BY P. SZEWCZYKOWSKI

in Pb content. This pattern of Pb accumulation suggests that the atmosphere is an important source of Pb to the Reserve.

Concentrations of Fe in moss were also higher in samples collected near the margins of the Reserve. Although iron is an abundant natural geological and soil constituent, the majority of metals are reportedly accumulated extracellularly by mosses. This suggests that iron is deposited from the atmosphere onto the Reserve.

Copper moss concentrations were between 1.4 to 3.8 times higher in the Reserve than at the control site. Overall, concentrations were less variable between all sites than for other metals. Therefore, even if Cu is an atmospheric contaminant, it appears to be less of a problem than other metals.

Zinc concentrations in the Reserve were between 2.7 and 13.0 times greater than the control. Zinc concentrations were highest in mosses sampled from the southwest margin of the Reserve followed by moss sampled from just north of the lake. A similar pattern was evident in pond and lake sediments (Fig. 10). Zinc concentrations in sediments were elevated in the southwest region of the Reserve but were highest in the lake. The lake sediments had a Zn concentration 26 times (306 mg/kg) higher than in the

control pond F. The lake contamination, as mentioned previously, is potentially attributable to the lake construction activities. However, even if the lake data is discounted, the pattern of Zn contamination in the moss samples is still evident. These data suggest that Zn is deposited from the atmosphere onto the Reserve.

The University of Wisconsin-Stevens Point power plant disperses emissions out over and adjacent to the Reserve. Also, an incineration smokestack disperses emissions from the burning of wastes from IGA over the Reserve. These, along with automobiles and household furnaces, are potential sources of airborne metals in the Reserve (Fig. 16) since the prevailing wind directions are from the west and northwest in winter and from the south in summer. The heating plant burns coal and fuel oil. Lead concentrations in coal are between 1 and 85 mg/kg and combustion of fossil fuels is one of the main sources of Pb to the atmosphere. Zinc is present in motor oils and automobile tires and coal contains 4 to 60 mg/kg. Air emissions are considered the primary anthropogenic sources of Zn to the environment. Copper can be contributed to the atmosphere by fossil fuel and waste incineration. Copper emissions from coal burning were reported as 0.002 to 0.015 kg-Cu/tonne (Environ. Can., 1980). Iron is also potentially emitted from coal burning.

Metals concentrations in European Buckthorn were quantified for comparison with metals concentrations in moss

(Append. I, Table 16) and data are summarized in Table 11. Correlations between the two species were calculated in order to detect relationships, however, larger sample sizes would be needed to demonstrate more sound statistical relationships.

Similar to mosses, Buckthorn samples collected from nearest to roadways had higher concentrations of Pb (Fig. 17). The Pb accumulation in Buckthorn may be a result of extracellular depositions from automobile emissions. Samples were washed for five minutes with distilled water to remove extracellular metals, however, the efficiency of this technique was not evaluated. Lead concentrations in moss and Buckthorn from similar sampling sites did not appear linearly related ($r=0.40$, Fig. 18a), therefore both species may reflect different lead sources. The high levels of Pb found in the moss in the Reserve are most likely a result of atmospheric deposition. The Pb in Buckthorn is most likely a reflection of soil concentrations near its vascular roots. This evidence suggests that atmospheric deposition of Pb is significant, however, the Pb either does not become efficiently incorporated into the soil to be available to plant roots or Buckthorn can selectively avoid or limit its Pb uptake.

Table 11. Summary of mean lead, zinc, iron, and copper in the woody species European Buckthorn from Schmeekle Reserve.

SITE	Mean Pb	Mean Zn	Mean Fe	Mean Cu
	----- mg/kg dry weight -----			
15	0.11	28.81	29.92	3.50
32	0.75	29.82	56.18	3.86
16	0.62	31.41	179.00	7.38
North Pt. Dr.	0.59	26.17	30.11	3.00

Zinc and iron concentrations between the two species were more highly correlated ($r=0.76$, Fig. 18b; $r=0.93$, Fig. 18c). These data suggest that either both species reflect atmospheric Zn and Fe via uptake through different routes or moss uptakes these metals substantially from the substrate. Given the premise that mosses accumulate metals predominantly through particulate entrapment, then I conclude that both species reflect atmospheric deposition of zinc and iron on the Reserve via different uptake mechanisms (particulate entrapment vs. root uptake). This implies that Zn and Fe fallout from the atmosphere efficiently becomes incorporated into the soil and is available for root uptake.

No strong linear relationship existed between Cu in Buckthorn and moss from similar sampling sites ($r=0.46$) and concentrations do not clearly indicate the sources of Cu.

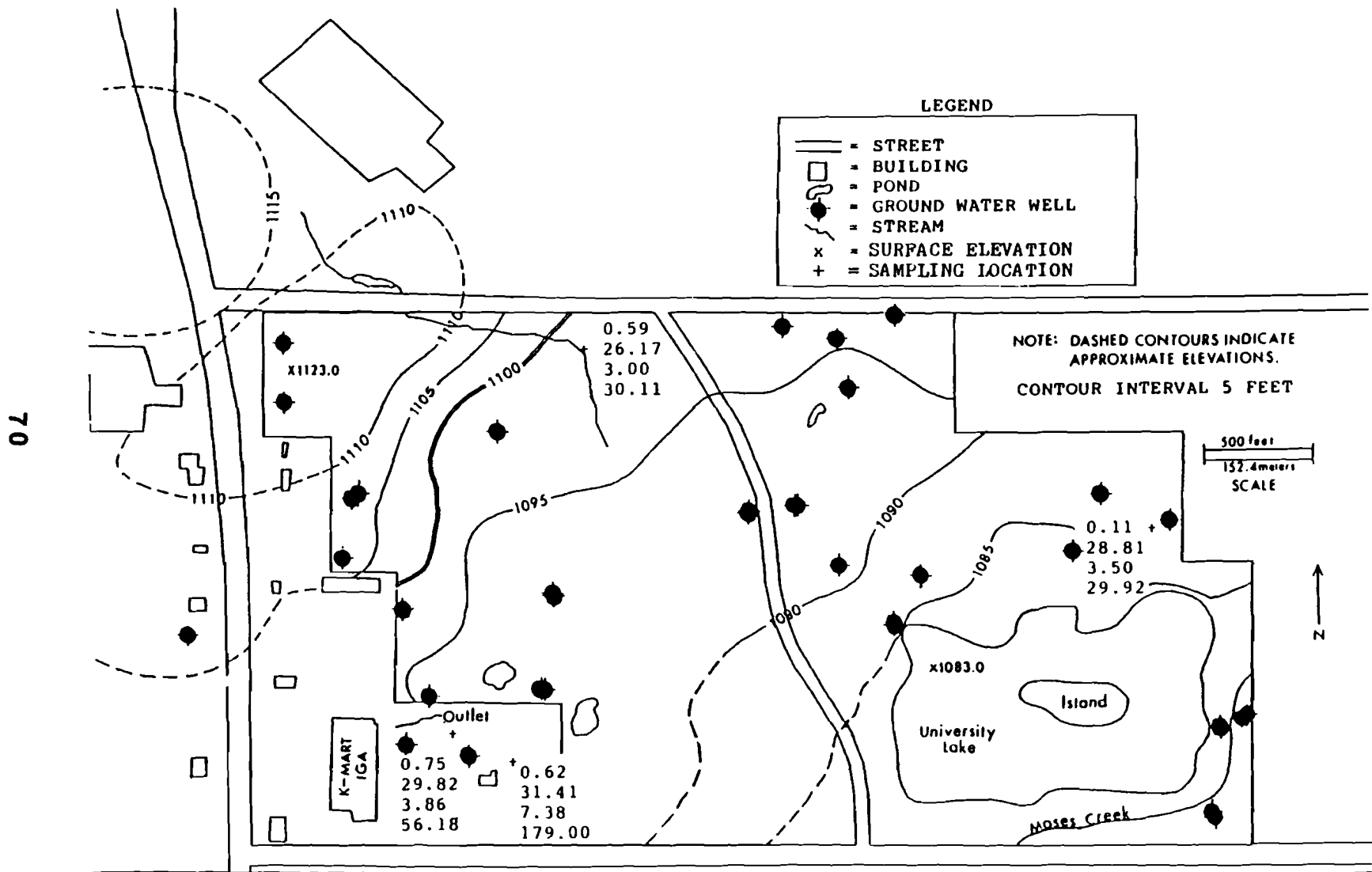


Figure 17. Mean Pb, Zn, Cu, and Fe concentrations in European Buckthorn in Schmeckle Reserve (mg/kg dry weight).

FIGURE BY P. SZEWCZYKOWSKI

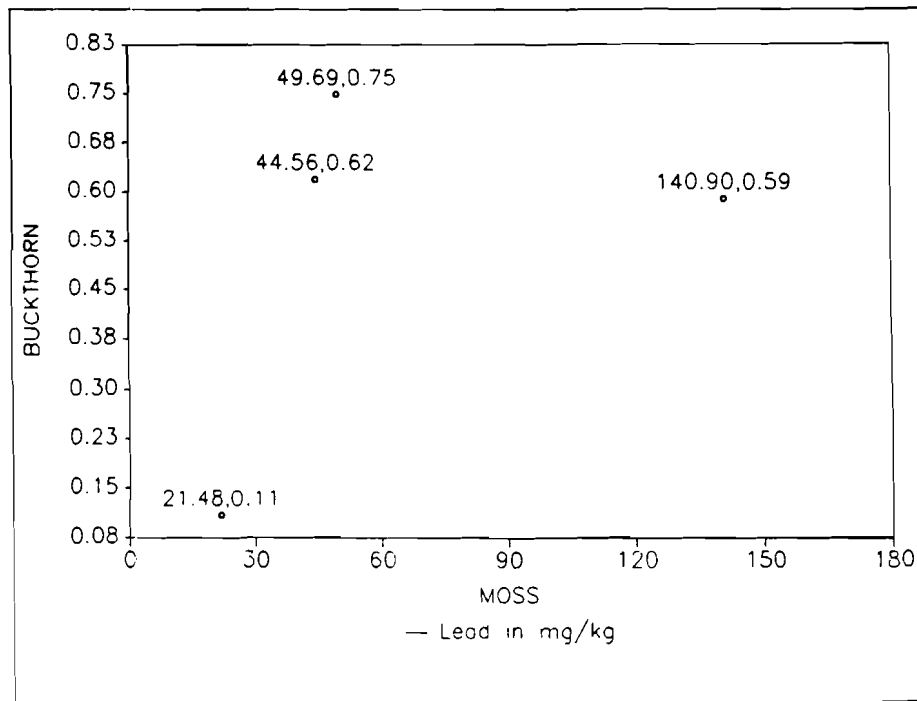


Figure 18a. Mean lead concentrations in European Buckthorn vs. mean lead concentrations in moss from similar sampling locations in Schmeckle Reserve.

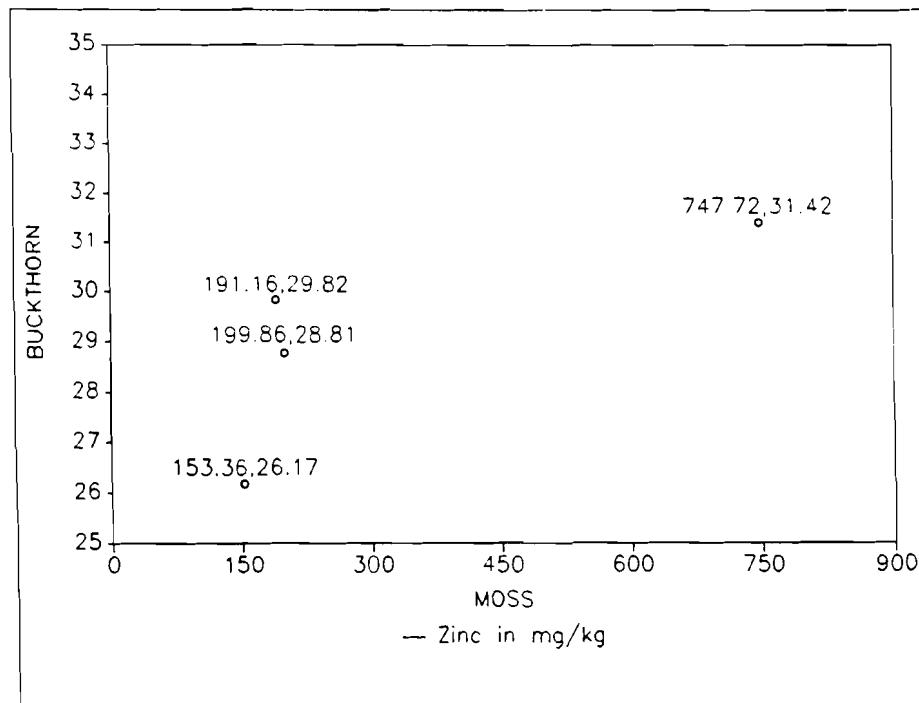


Figure 18b. Mean zinc concentrations in European Buckthorn vs. mean zinc concentrations in moss from similar sampling locations in Schmeckle Reserve.

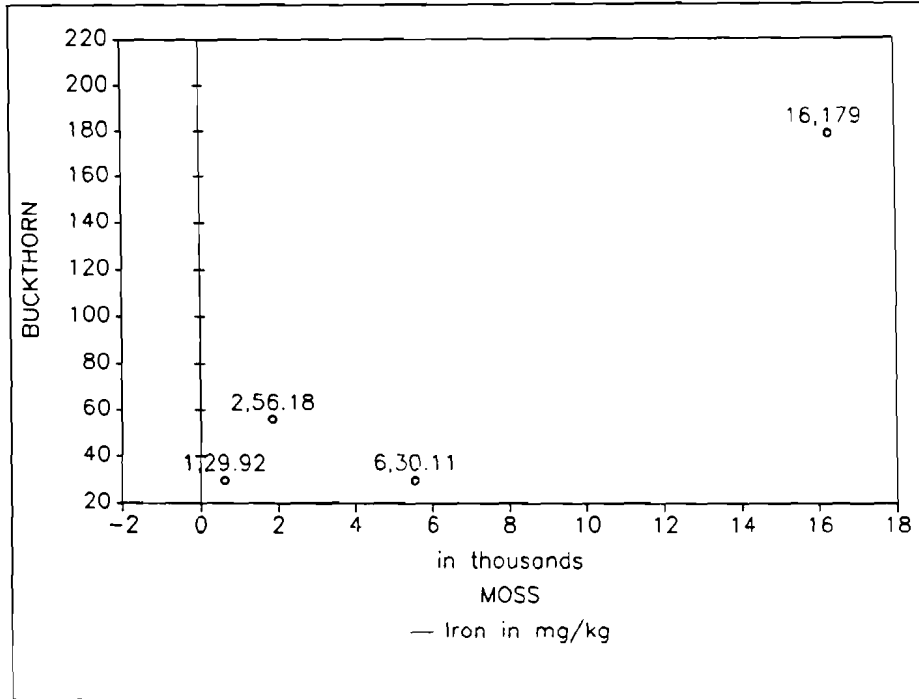


Figure 18c. Mean iron concentrations in European Buckthorn vs. mean iron concentrations in moss from similar sampling locations in Schmeckle Reserve.

CONCLUSIONS AND RECOMMENDATIONS

Storm water runoff from urban development bordering the Reserve does impact the ground water quality of the Reserve. Perhaps the most evident impact is that from road salt contamination. Contaminated ground water had mean chloride concentrations of up to 456 times (2054 mg/l) higher than background concentrations and eight times higher than the Wisconsin ground water enforcement standard of 250 mg/l. Mean sodium concentrations were up to 187 times (655 mg/l) higher than background concentrations. These data are alarming and are cause for concern. Both elevated chloride and sodium concentrations are well documented to cause plant stress, illness, and mortality. Continued salt contamination of the ground water in the Reserve may have serious chronic deleterious implications for the natural floral communities present. Continued monitoring of chloride and sodium contamination of ground water in the Reserve and further research into the salt impacts on vegetation is recommended.

Volatile petroleum components of runoff do not contribute to ground water contamination in the Reserve.

These volatile compounds (BTX) are either volatilized, biodegraded, or photodegraded before they can infiltrate into the ground water. In this study, volatile components in storm water runoff were not quantified. Quantification of petroleum components in runoff during all stages of a runoff event is recommended in order to provide a clearer understanding of the processes which are limiting to a ground water impact.

Benzene contamination of well 16 may be attributable to the University's underground gasoline storage tank or a localized gas spill. Since the contamination concentration remained fairly consistent over the months sampled, it is possible that the storage tank is leaking. The mean concentration of benzene in the ground water was ten times higher than the Wisconsin ground water standard and is a potential health hazard if utilized for human consumption. The storage tank should be more intensively monitored for leaking and the ground water adjacent to the tank should be quantified more thoroughly for benzene contamination. If conclusive evidence displays that the tank is leaking, then the tank should be removed.

The source of toluene contamination in well 36 is not evident. Decreasing concentrations over the months sampled may suggest that the well was inadvertently contaminated upon installation. Continued monitoring of this well is

suggested to determine if the contamination is persistent. If so, more comprehensive well installations and monitoring would be necessary to assess the extent and source of the contamination.

Other storm water research (EPA, 1983) has indicated that the organic compound bis(2-ethylhexyl)phthalate is a highly prevalent pollutant in runoff which may be very persistent in the environment. Analyses of both storm water runoff and ground water in the Reserve for this and related compounds is recommended in order to assess all potential chemical threats to the resource.

There were no clear impacts on ground water quality from metals associated with storm water. Storm water does contribute significant amounts of metals to the Reserve but these metals appear to be efficiently adsorbed and bound in the sediments and surface soils. How much of these metals the soils and sediments can hold before they are released into the ground water is not known and needs further research. More extensive quantification of total metals in storm water during all stages of runoff events is recommended. These data along with soil cation exchange capacity determinations are necessary in order to predict and prevent the potential for metals contamination of the ground water.

The atmosphere appears to be an important source of

lead and zinc contamination to the Reserve. Lead concentrations in moss in the Reserve ranged from 21.48 to 140.90 mg/kg. These lead values were up to eight times higher than the control. Lead concentrations were highest in moss samples collected near roadways and in sediments impacted by storm water runoff. However, lead concentrations were not elevated above background levels in University Lake sediments. These data suggest that lead contamination in the Reserve is most attributable to motor vehicle emissions. If smokestacks had been important sources of lead, concentrations in moss and sediments throughout the Reserve would likely be more uniform since contaminants in the stack emissions would be carried over larger areas due to the stack height. Also, smokestack emitted lead would likely be reflected by elevated concentrations in the lake sediments. The lake which has a large surface area, functions as a trap for airborne contaminants which are carried long distances. Elevated lead concentrations in sediments impacted from storm water, are likely due to lead fallout from vehicle exhaust being washed off roadway surfaces by runoff.

Zinc concentrations in vegetation and sediments in the Reserve appear to be attributable to atmospheric deposition. Concentrations in moss ranged from 153.36 to 747.72 mg/kg and were up to 13 times higher than the control. The concentration in a University Lake sediment sample was 26

times (306 mg/kg) higher than in a control pond in the Reserve. Due to the uniform elevated concentrations in moss throughout the Reserve and an elevated concentration in the lake, zinc contamination appears to originate from smoke-stack emissions. The pattern of values in moss and sediment mimics that of the wind movement from the incinerator and power plant stacks since the prevailing wind direction is from the west and northwest in winter and from the south in summer. Zinc values in moss and sediments are highest in areas directly east and north of the stacks and values decrease moving to the northeast. Values are lowest in the northwest region of the Reserve. Elevated zinc concentrations in the storm sewer outlet and in ponds B and D suggest that storm water runoff also contributes zinc to the Reserve.

The pattern of iron values in vegetation and sediments in the Reserve suggests that iron may be contributed to the Reserve from the atmosphere and highway runoff. Concentrations were highest in sediments impacted by storm water runoff and are potentially related to automobile deterioration. The relationship of iron accumulation in moss and Buckthorn suggests a common atmospheric source, although no one definitive source is obvious based on the prevailing wind direction.

More extensive analysis of moss and soils on a

transect basis is necessary in order to clearly define the specific sources of atmospheric lead, iron and zinc to the Reserve. In addition, precipitation and smokestack emissions analyses would also aid in defining atmospheric loads of metals.

Lead accumulations in vegetation and soils in the Reserve may be harmful to children and wildlife. With lead concentrations in moss approaching 141 mg/kg and 45 mg/kg in sediments, it is recommended to quantify lead concentrations in surface soils and forage plant tissues throughout the Reserve. Animals and children may ingest lead contained in soil and plant tissues. Ingestion of soil exceeding 500 mg-Pb/kg can strongly increase blood-Pb in children. Greater than 150 mg-Pb/kg can cause excessive blood-Pb levels in sensitive or highly exposed children. Research indicates that blood-Pb levels in children must not exceed 15 ug/dl (1 dl = 0.1 liter) to avoid deleterious effects (Chaney and Mielke, 1986).

The toxicity of Pb in animals is dependent on a variety of factors including species, age, reproductive state, rate of lead ingestion, and the animal's overall health. Lead poisoning can lead to death and is preceded by impairment of the central nervous system, gastrointestinal tract and muscular system. Less severe symptoms include excitement, depression, anorexia, colic, diarrhea, and blindness

(NAS, 1972). Lead levels of between 5 and 10 mg/kg body weight are regarded as toxic in most species. Lead is transmitted to the eggs of ducks and results in eggshell thinning. Ducks dosed with 8 to 12 mg/kg body weight per day had an average survival of 25 to 28 days. In cattle, 6 to 7 mg/kg per day of lead caused poisoning symptoms. Horses ingesting 2.4 mg/kg per day from hay died and chronic lead poisoning resulted from the ingestion of spring water containing 0.5 to 1.0 mg-Pb/l and grasses containing 5 to 20 mg/kg of Pb (dry basis) (Environ. Can., 1980).

Zinc concentrations found in vegetation do not appear to present a health hazard to wildlife or humans. Zinc is an essential element in the human diet and is not considered toxic unless in concentrations exceeding around 1000 mg/l in drinking water. Oral doses of 150 mg-Zn/day have been administered with no adverse effects (Environ. Can., 1980). Wildlife also have a high tolerance for zinc. Muskrats living in an area where aquatic vegetation had a mean zinc concentration of 4887.9 mg-Zn/kg (dry weight) accumulated more zinc in their liver and bones, but did not suffer any detrimental effects. In cattle, diets containing 16.7 to 628 mg/kg caused no observable effects. A value of 1000 mg-Zn/kg of diet is estimated as being potentially harmful to animals (Environ. Can., 1980). Quantification of zinc concentrations in various forage vegetation

species throughout the Reserve is recommended in order to assess if a potential threat to wildlife exists.

The high concentration of zinc in University Lake sediment (306 ppm) may be cause for concern. A potential threat to aquatic life in the lake may exist if zinc concentrations in the water are also high. The federal criterion to protect freshwater aquatic life is 47 ppb as a 24-hour average for chronic exposure (EPA, 1986). Therefore, quantification of zinc concentrations in the lake water is recommended in order to assess if a potential threat to aquatic life exists.

Although iron concentrations in the Reserve appeared high in some areas, iron is a universally abundant element in the environment and is not considered an environmental or health threat.

In summary, the most apparent urban impacts on the Reserve are: 1) chloride and sodium contamination of the ground water throughout the Reserve attributable to road salt in storm water runoff, 2) local benzene ground water contamination potentially attributable to an underground petroleum storage tank and 3) lead and zinc depositions on the Reserve attributable to atmospheric sources. Continued research in these areas is recommended in order to assess and protect the quality of this nature conservancy.

APPENDIX I

Table 1. Summary of ground water chemical data for the sampling date November 22, 1985 in Schmeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.	Ca++ HARD.	REACT. P	mg/l						C.O.D.
							NH4-(N)	NO2+NO3	CL-	K+	Na+		
1 M	5.98	82	10	24	16	<.002	<.01	0.01	14	2.0	3.2	*	
1 S	**												
2	5.26	170	6	50	30	<.002	<.01	0.01	28	< 1	9.0	*	
3	5.16	304	52	100	64	<.002	<.01	<.01	35	1.0	14.0	*	
4	4.50	54	12	22	12	<.002	<.01	0.42	2	< 1	4.0	*	
5 N	6.08	138	20	40	26	<.002	<.01	0.02	16	1.0	8.6	*	
5 S	6.20	295	20	60	46	<.002	0.08	<.01	67	1.0	30.0	*	
6 E	**												
6 W	6.18	1196	8	232	146	<.002	0.25	0.03	357	3.0	152.0	*	
7	6.32	916	180	252	140	<.002	0.02	<.01	169	1.0	94.0	*	
8	**												
9	6.25	94	18	28	16	<.002	<.01	1.55	9	1.0	5.4	*	
10 E	6.42	373	150	172	108	<.002	0.04	<.01	25	1.0	11.8	*	
10 W	6.32	224	44	82	76	0.004	0.04	0.60	26	2.5	7.2	*	
11	5.68	153	22	32	22	<.002	0.03	0.08	23	< 1	10.4	*	
12 N	7.42	260	90	116	94	0.015	<.01	0.16	12	1.0	6.6	*	
12 S	7.01	385	118	196	162	<.002	0.04	<.01	11	< 1	3.8	*	
13	5.91	45	10	20	12	<.002	<.01	0.03	2	< 1	2.8	*	
15	5.46	48	10	24	14	<.002	<.01	0.02	2	< 1	2.4	*	
16	6.08	2720	42	614	394	0.002	1.24	0.22	858	6.0	250.0	*	
17 E	6.61	151	48	66	38	<.002	<.01	<.01	6	< 1	3.0	*	
17 W	6.90	70	22	32	24	<.002	0.03	1.24	5	< 1	1.4	*	
18 N	6.29	291	128	136	76	<.002	0.48	0.01	6	1.0	4.2	*	
18 S	5.88	125	22	44	28	<.002	0.04	0.01	5	1.0	3.8	*	
19 E	5.91	157	34	52	30	<.002	0.01	0.02	18	< 1	9.0	*	
19 W	6.14	288	80	90	86	<.002	<.01	1.62	6	< 1	23.0	*	
20	6.03	77	8	28	16	<.002	<.01	<.01	7	< 1	3.8	*	
21	7.51	253	118	126	96	<.002	0.04	<.01	2	< 1	2.2	*	
32	7.14	842	338	212	192	<.002	1.08	0.04	81	5.0	132.0	*	
33 N	**												
33 S	**												
34	**												
35	**												
36	**												
37	**												
39	**												

* Parameter not analyzed

** Samples were not collected this month

Table 2. Summary of ground water chemical data for the sampling date February 6, 1986 in Schaeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.	Ca++	HARD.	REACT. P	mg/l				
								NH4-(N)	NO2+NO3	CL-	K+	Na+
1 N	6.10	200	8	56	28	*	0.04	0.02	50	*	*	*
1 S	**											
2	5.30	171	5	44	38	*	0.02	0.06	28	*	*	*
3	6.60	303	10	18	10	*	<.01	0.24	1	*	*	*
4	6.70	54	58	118	56	*	<.01	0.02	35	*	*	*
5 N	6.40	104	24	44	22	*	<.01	<.01	3	*	*	*
5 S	7.10	94	14	36	22	*	<.01	0.27	4	*	*	*
6 E	6.50	583	42	100	52	*	0.28	0.01	130	*	*	*
6 W	6.30	409	6	40	20	*	0.01	<.01	105	*	*	*
7	**											
8	**											
9	6.19	92	4	22	14	*	0.08	3.10	8	*	*	*
10 E	6.80	397	148	178	112	*	0.04	<.01	34	*	*	*
10 W	6.41	304	38	114	50	*	0.38	0.11	57	*	*	*
11	5.93	167	22	38	18	*	0.04	<.01	18	*	*	*
12 N	7.40	220	68	104	58	*	0.12	<.01	5	*	*	*
12 S	7.07	444	204	232	140	*	0.08	<.01	13	*	*	*
13	6.07	56	6	14	8	*	0.04	0.04	3	*	*	*
15	5.68	47	4	12	10	*	0.03	0.04	2	*	*	*
16	6.20	2460	108	540	256	*	1.15	<.01	740	*	*	*
17 E	6.80	183	52	90	48	*	0.02	<.01	11	*	*	*
17 W	6.80	56	8	24	12	*	0.02	0.30	2	*	*	*
18 N	6.30	304	130	144	112	*	0.42	<.01	7	*	*	*
18 S	6.10	123	46	60	32	*	0.06	0.14	5	*	*	*
19 E	6.10	161	38	60	28	*	0.07	<.01	16	*	*	*
19 W	5.91	23	38	60	52	*	0.03	0.96	6	*	*	*
20	5.85	87	10	24	20	*	0.06	0.02	6	*	*	*
21	**											
32	6.20	12200	86	904	610	*	4.00	<.01	4300	*	*	*
33 N	**											
33 S	**											
34	**											
35	**											
36	**											
37	**											
39	**											

* Parameter not analyzed

** Samples were not collected this month

Table 2. Summary of ground water chemical data for the sampling date March, 11 1986 in Schœeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.		Ca++	HARD.	REACT. P	NH4-(N)	NO2+NO3	CL-	K+	Na+	C.O.D.
				mg/l	mg/l									
1 N	6.30	242	6	72	44	<.002	<.02	<.2	69	†	†	†		
1 S	**													
2	6.30	161	4	46	28	<.002	<.02	<.2	31	†	†	†		
3	7.80	356	122	160	76	<.002	0.02	<.2	31	†	†	†		
4	7.40	121	8	20	10	<.002	<.02	0.2	20	†	†	†		
5 N	6.80	101	20	34	18	0.008	0.04	<.2	5	†	†	†		
5 S	**													
6 E	6.30	579	44	90	58	<.002	0.25	<.2	126	†	†	†		
6 W	4.20	416	<2	96	18	<.002	<.02	<.2	109	†	†	†		
7	**													
8	**													
9	4.80	107	2	28	16	<.002	<.02	2.8	14	†	†	†		
10 E	6.60	395	158	182	122	<.002	0.04	<.2	29	†	†	†		
10 W	7.20	338	44	114	58	<.002	2.80	<.2	54	†	†	†		
11	6.00	175	22	46	24	<.002	<.02	<.2	21	†	†	†		
12 N	7.40	207	66	94	66	<.002	0.04	<.2	5	†	†	†		
12 S	7.30	418	204	230	146	<.002	0.04	<.2	11	†	†	†		
13	**													
15	6.20	45	8	12	10	<.002	<.02	<.2	1	†	†	†		
16	6.20	2140	82	470	292	<.002	0.58	<.2	494	†	†	†		
17 E	7.20	194	66	86	72	<.002	<.02	<.2	12	†	†	†		
17 W	7.10	38	6	12	10	<.002	<.02	<.2	< 1	†	†	†		
18 N	6.80	253	116	130	60	<.002	0.52	<.2	4	†	†	†		
18 S	6.40	131	20	46	26	<.002	0.08	<.2	14	†	†	†		
19 E	6.40	149	32	52	30	<.002	<.02	<.2	14	†	†	†		
19 W	6.60	132	22	30	28	<.002	<.02	<.2	13	†	†	†		
20	6.70	87	12	26	22	<.002	<.02	<.2	6	†	†	†		
21	**													
32	7.30	12290	164	338	242	<.002	2.52	<.2	3571	†	†	†		
33 N	**													
33 S	**													
34	**													
35	**													
36	**													
37	**													
39	**													

† Parameter not analyzed
 ** Sample not collected this month

Table 4. Summary of ground water chemical data for the sampling date April 8, 1986 in Schmeckle Reserve.

SITE	pH	COND. (uohos)	ALK.	TOTAL HARD.	Ca++	HARD.	REACT. P	NH4-(N)	NO2+NO3	CL-	K+	Na+	C.O.D.
1 N	5.77	109	8	42	†	0.005	0.04	<0.2	25	†	†	†	
1 S	**												
2	5.39	173	4	52	†	0.005	0.04	<0.2	30	†	†	6.2	
3	6.99	380	116	156	†	0.055	0.28	<0.2	28	†	†	†	
4	6.68	62	16	14	†	0.035	0.08	<0.2	14	†	†	†	
5 N	6.27	110	20	36	†	0.010	0.08	0.5	4	†	†	†	
5 S	7.25	144	48	60	†	0.024	0.16	<0.2	5	†	†	†	
6 E	6.07	600	32	90	†	0.008	0.30	<0.2	176	†	†	†	
6 W	5.67	337	12	28	†	0.015	0.12	0.5	108	†	†	3.1	
7	6.65	1211	132	328	†	0.040	0.24	0.5	398	†	†	†	
8	**												
9	6.56	108	12	38	†	0.025	0.04	5.0	14	†	†	†	
10 E	6.35	433	168	204	†	0.005	0.08	<0.2	30	†	†	†	
10 W	6.56	263	44	66	†	0.010	2.56	<0.2	42	†	†	†	
11	5.63	166	16	44	†	0.005	0.10	<0.2	32	†	†	†	
12 N	6.87	220	64	102	†	0.005	0.12	<0.2	7	†	†	†	
12 S	6.98	396	180	214	†	0.002	0.20	<0.2	16	†	†	†	
13	6.07	51	8	16	†	0.005	0.08	<0.2	2	†	†	†	
15	5.79	45	12	14	†	0.008	0.04	<0.2	< 1	†	†	†	
16	5.97	2320	48	492	†	<.002	1.50	<0.2	917	†	†	71.0	
17 E	7.72	181	48	84	†	0.002	0.08	<0.2	16	†	†	†	
17 W	6.78	29	4	12	†	0.022	0.02	<0.2	< 1	†	†	†	
18 N	6.20	264	96	128	†	0.010	0.76	<0.2	12	†	†	†	
18 S	5.96	131	16	48	†	0.010	0.12	<0.2	19	†	†	†	
19 E	6.07	134	28	52	†	0.002	0.12	<0.2	20	†	†	†	
19 W	6.17	240	44	66	†	0.005	0.06	0.8	14	†	†	†	
20	6.17	79	8	28	†	0.005	0.02	<0.2	8	†	†	†	
21	7.03	170	72	196	†	0.015	0.12	<0.2	2	†	†	†	
32	7.72	3630	352.00	76.00	†	0.188	0.88	<0.2	1333	†	†	63.50	
33 N	**												
33 S	**												
34	**												
35	**												
36	**												
37	**												
39	**												

† Parameter was not analyzed
 ** Sample was not collected this month

Table 5. Summary of ground water chemistry data for the sampling date May 6, 1986 in Schaeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.		Ca++	HARD.	REACT. P	NH4-(N)	NO2+NO3	CL-	K+	Na+	C.O.D.
				mg/l	mg/l									
1 N	6.30	118	14	42	20	*	0.13	0.02	21	*	*	*	*	
1 S	**					*					*	*	*	
2	5.60	171	4	50	26	*	<.01	0.06	29	*	*	*	*	
3	6.10	388	112	144	<20	*	0.04	0.02	31	*	*	*	*	
4	6.71	44	6	30	10	*	<.01	0.20	1	*	*	*	*	
5 N	6.37	104	12	22	22	*	<.01	<.01	27	*	*	*	*	
5 S	6.15	92	14	36	20	*	<.01	0.02	5	*	*	*	*	
6 E	6.07	635	20	92	60	0.008	0.26	<.01	79	*	*	*	*	
6 W	5.83	378	8	42	16	*	<.01	<.01	101	*	*	*	*	
7	6.94	1382	118	*	218	*	0.12	<.01	452	*	*	*	*	
8	**					*					*	*	*	
9	6.86	104	10	40	20	*	<.01	5.05	7	*	*	*	*	
10 E	6.35	418	160	202	156	*	0.06	0.01	23	*	*	*	*	
10 W	6.82	246	50	68	56	*	1.81	0.12	31	*	*	*	*	
11	5.75	186	14	44	22	*	<.01	<.01	18	*	*	*	*	
12 N	6.95	224	68	116	84	*	0.07	0.03	5	*	*	*	*	
12 S	7.20	466	200	244	220	*	0.05	<.01	1	*	*	*	*	
13	**					*					*	*	*	
15	5.84	44	6	28	14	*	<.01	0.02	< 1	*	*	*	*	
16	5.92	2290	56	484	400	*	1.27	<.01	402	*	*	*	*	
17 E	6.67	186	46	90	50	*	<.01	<.01	9	*	*	*	*	
17 W	6.64	36	6	32	14	*	<.01	0.58	< 1	*	*	*	*	
18 N	6.17	206	76	106	80	*	0.38	0.01	6	*	*	*	*	
18 S	5.99	132	18	46	26	*	0.07	0.02	8	*	*	*	*	
19 E	6.08	155	24	44	26	*	0.02	0.14	13	*	*	*	*	
19 W	6.21	197	34	42	38	*	<.01	0.74	3	*	*	*	*	
20	6.13	87	8	22	20	*	0.02	0.04	4	*	*	*	*	
21	6.96	185	76	82	80	*	0.03	0.07	1	*	*	*	*	
32	7.40	2180	214	24	18	0.018	0.64	0.06	*	*	*	*	*	
33 N	**										*	*	*	
33 S	**										*	*	*	
34	**										*	*	*	
35	**										*	*	*	
36	**										*	*	*	
37	**										*	*	*	
39	**										*	*	*	

* Parameter not analyzed
 ** Sample not collected this month

Table 6. Summary of ground water chemical data for the sampling date July 22, 1986 in Schmeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.	Ca++	HARD.	REACT. P	mg/l					
								NH4-(N)	NO2+NO3	CL-	K+	Na+	C.O.D.
1 M	5.62	44	8	14	10	*	<.01	0.12	1	*	*	*	
1 S	**												
2	5.33	165	4	48	28	*	0.02	0.04	27	*	*	*	
3	6.71	324	92	136	68	*	0.08	0.18	*	*	*	*	
4	6.36	50	8	12	8	*	<.01	0.43	1	*	*	*	
5 N	6.08	97	16	34	16	*	0.08	0.01	3	*	*	*	
5 S	**												
6 E	6.01	591	28	100	56	*	0.33	0.01	146	*	*	*	
6 W	5.52	402	10	38	22	*	<.01	0.02	109	*	*	*	
7	7.27	1084	136	288	132	*	0.08	0.04	168	*	*	*	
8	**												
9	6.57	99	10	30	18	*	0.02	3.65	10	*	*	*	
10 E	6.43	363	142	180	112	*	0.08	0.01	29	*	*	*	
10 W	6.39	216	66	64	24	*	1.34	0.02	18	*	*	*	
11	5.94	257	16	76	44	*	0.05	0.01	53	*	*	*	
12 N	6.90	206	66	98	58	*	0.11	0.01	6	*	*	*	
12 S	6.99	429	204	222	144	*	0.12	0.01	17	*	*	*	
13	6.02	47	10	14	10	*	0.02	0.02	2	*	*	*	
15	**												
16	5.86	2370	64	542	302	*	1.48	0.02	691	*	*	*	
17 E	6.64	163	46	78	44	*	0.08	0.02	6	*	*	*	
17 W	6.43	72	18	32	20	*	0.12	0.40	2	*	*	*	
18 N	6.10	212	72	94	40	*	0.44	0.01	7	*	*	*	
18 S	5.96	116	20	48	24	*	0.10	0.01	9	*	*	*	
19 E	6.06	153	18	60	28	*	0.06	0.01	20	*	*	*	
19 W	5.75	181	18	38	32	*	0.02	1.12	15	*	*	*	
20	6.18	86	2020	28	18	*	0.02	0.04	15	*	*	*	
21	6.85	161	132	80	52	*	0.04	0.02	3	*	*	*	
32	7.06	1306	232	248	172	*	1.66	0.02	271	*	*	*	
33 N	**												
33 S	**												
34	**												
35	**												
36	**												
37	**												
39	**												

* Parameter not analyzed
 ** Sample not collected this month

Table 7. Summary of ground water chemical data for the sampling date January 14, 1987 in Schaeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.		Ca++	HARD.	REACT. P	mg/l		CL-	K+	Na+	C.D.D.
									NH4-(N)	NO2+NO3				
1 N	**													
1 S	6.14	221	24	73	36	<.002	0.34	0.02	56	7.4	9.0	*		
2	5.12	210	6	54	36	<.002	0.43	0.05	53	1.8	14.0	*		
3	6.23	373	126	167	126	<.002	0.60	0.01	35	2.4	15.0	*		
4	5.88	475	11	18	12	<.002	0.47	0.11	1	1.3	3.0	*		
5 N	6.26	105	24	24	24	<.002	0.39	<.01	2	1.9	4.3	*		
5 S	**													
6 E	5.65	649	22	106	70	<.002	0.74	<.01	220	4.7	77.0	*		
6 W	5.58	249	17	24	12	<.002	0.75	<.01	64	2.4	40.0	*		
7	6.31	1213	129	328	184	<.002	0.59	0.02	445	3.2	106.0	*		
8	**													
9	**													
10 E	6.38	361	113	148	104	<.002	0.37	<.01	44	2.7	15.6	*		
10 W	6.50	320	111	140	58	<.002	0.73	0.05	38	8.2	8.7	*		
11	**													
12 N	**													
12 S	**													
13	**													
15	**													
16	6.11	1407	124	326	210	<.002	1.44	0.02	320	10.7	128.0	*		
17 E	**													
17 W	**													
18 N	**													
18 S	**													
19 E	**													
19 W	**													
20	**													
21	**													
32	6.83	6370	250	330	226	<.002	2.10	<.01	5000	37.1	1190.0	*		
33 N	**													
33 S	**													
34	5.99	103	22	44	20	<.002	0.29	<.01	1	1.8	4.7	*		
35	6.28	80	14	30	14	<.002	0.51	0.08	8	2.2	5.0	*		
36	6.29	495	179	180	112	<.002	0.98	<.01	32	10.7	14.0	*		
37	**													
39	**													

* Parameter not analyzed
 ** Sample not collected this month

Table B. Summary of ground water chemical data for the sampling date February 13, 1987 in Schoeckle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.	Ca++	HARD.	REACT. P	NH4-(N)	NO2+NO3	CL-	K+	Na+	C.O.D.
1 N	6.40	190	20	60	36	<.002	0.02	<.2	37	2.7	8.9	*	
1 S	6.40	190	20	60	36	<.002	0.02	<.2	37	2.7	8.9	*	
2	5.33	222	8	58	44	<.002	0.02	<.2	45	0.2	15.0	*	
3	6.44	385	140	176	80	<.002	0.05	<.2	27	0.5	15.4	*	
4	5.97	48	12	14	12	<.002	0.04	<.2	< 1	0.3	2.3	*	
5 N	6.15	94	20	34	22	<.002	0.14	<.2	1	0.4	4.0	*	
5 S	**												
6 E	5.95	686	36	108	64	<.002	0.34	<.2	200	1.2	76.0	*	
6 W	5.69	260	16	18	10	<.002	0.03	<.2	49	0.6	40.1	*	
7	**												
8	5.69	579	16	144	96	<.002	0.06	1.5	160	3.2	40.3	*	
9	**												
10 E	6.39	321	100	128	76	<.002	0.07	<.2	33	0.7	15.0	*	
10 W	**												
11	**												
12 N	**												
12 S	**												
13	**												
15	**												
16	6.31	1032	156	250	152	<.002	1.70	<.2	285	2.5	82.0	*	
17 E	**												
17 W	**												
18 N	**												
18 S	**												
19 E	**												
19 W	**												
20	**												
21	**												
32	6.46	6780	144	520	326	<.002	2.35	<.2	2300	14.0	1110.0	*	
33 N	5.77	95	16	42	18	<.002	0.11	<.2	2	0.8	12.3	*	
33 S	5.76	93	16	32	20	<.002	0.08	<.2	2	0.7	3.7	*	
34	5.85	73	28	38	14	<.002	0.11	<.2	3	0.2	3.5	*	
35	6.62	98	20	36	24	<.002	0.02	<.2	9	0.6	5.0	*	
36	6.41	458	172	162	94	<.002	0.44	<.2	25	3.2	13.5	*	
37	**												
39	7.28	389	124	176	100	<.002	0.01	3.4	32	1.2	10.0	*	

* Parameter not analyzed
 ** Sample not collected this month

Table 10. Summary of ground water chemical data for the sampling date April 24, 1987 in Schneectle Reserve.

SITE	pH	COND. (umhos)	ALK.	TOTAL HARD.	Ca++	HARD.	REACT. P	mg/l					C.O.D.
								NH4-(N)	NO2+NO3	CL-	X+	Na+	
1 N	7.04	191	52	72	52	0.012	<.01	0.04	26	2.0	6.0	*	
1 S	7.04	191	52	72	52	0.012	<.01	0.04	26	2.0	6.0	*	
2	5.95	206	10	58	36	<.002	0.05	0.10	43	0.3	13.9	12	
3	7.00	412	152	184	108	<.002	0.09	0.07	32	0.6	15.2	41	
4	6.61	48	10	18	12	<.002	<.01	0.32	1	0.1	2.6	*	
5 N	6.44	99	22	34	44	<.002	0.09	0.06	3	0.4	4.1	*	
5 S	7.08	84	18	34	18	0.002	0.11	0.28	6	0.5	3.4	*	
6 E	6.11	657	32	100	64	<.002	0.33	0.04	250	1.5	70.0	28	
6 W	6.08	294	14	22	12	<.002	0.05	0.17	69	1.0	65.0	*	
7	6.62	1624	142	396	240	<.002	0.20	0.03	581	1.3	149.0	41	
8	6.11	552	16	146	208	<.002	0.09	1.51	206	3.5	38.0	16	
9	6.77	101	12	34	20	<.002	<.01	3.15	12	0.4	5.8	*	
10 E	6.52	326	112	140	80	<.002	<.01	0.02	33	0.8	15.2	*	
10 W	6.76	251	50	134	92	<.002	0.15	0.60	33	1.9	17.6	*	
11	6.38	198	54	52	60	<.002	<.01	0.05	26	0.1	10.4	*	
12 N	7.48	217	74	100	58	<.002	0.09	0.02	8	0.6	4.4	*	
12 S	6.94	225	88	106	64	<.002	<.01	0.02	11	0.4	3.7	*	
13	6.64	43	6	14	8	<.002	<.01	0.06	2	<.1	2.9	*	
15	6.60	46	8	18	12	<.002	<.01	0.06	1	0.3	2.4	*	
16	6.67	1243	144	292	252	<.002	1.31	0.17	375	4.0	11.6	85	
17 E	7.06	146	48	74	42	<.002	<.01	0.03	5	0.4	3.1	*	
17 W	6.85	56	14	22	20	0.005	<.01	0.34	< 1	0.4	0.8	*	
18 N	6.55	89	30	38	24	<.002	0.04	<.01	1	0.5	2.9	*	
18 S	6.85	122	22	44	24	<.002	0.07	0.03	10	0.8	5.3	*	
19 E	6.84	166	30	54	30	<.002	0.07	0.05	23	1.1	8.9	*	
19 W	6.57	154	40	36	32	<.002	<.01	0.55	14	0.2	18.1	*	
20	6.37	84	16	26	18	<.002	<.01	<.01	7	0.2	5.3	*	
21	7.28	161	66	74	46	<.002	0.08	0.03	2	0.5	2.0	*	
32	7.70	1640	210	144	110	<.002	1.25	0.18	558	8.0	249.0	44	
33 N	6.26	98	14	36	22	<.002	0.06	0.03	3	1.0	3.8	*	
33 S	**												
34	**												
35	6.97	95	18	28	18	<.002	<.01	0.17	9	0.6	6.1	*	
36	6.52	450	160	186	120	<.002	0.61	0.26	48	3.5	14.9	34	
37	6.85	106	34	36	26	<.002	<.01	<.01	13	0.6	6.0	*	
39	7.34	370	126	166	102	<.002	0.05	3.82	33	<.1	9.2	*	

* Parameter not analyzed

** Sample not collected this month

Table 11. Monthly water table elevations at individual wells in Schmeckle Reserve.

SITE	DEPTH (ft.) OF SCREEN	AUGUST	OCTOBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY
		1986	1986	1987	1987	1987	1987	1987	1987	1987
		WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
		TABLE	TABLE	TABLE	TABLE	TABLE	TABLE	TABLE	TABLE	TABLE
----- feet above sea level -----										
1S	6.63	*	*	1,111.63	1,111.27	1,112.15	1,112.75	1,111.40	1,110.23	*
1M	6.03	*	1,112.81	*	1,111.26	1,112.14	1,112.71	1,111.33	*	*
2	3.87	1,107.26	1,109.18	1,108.41	1,107.90	1,108.76	1,109.12	1,107.23	1,106.14	1,105.92
3	3.79	1,100.32	1,102.31	1,101.10	1,100.84	1,101.83	1,102.20	1,100.83	1,099.47	1,099.26
4	5.44	1,099.25	1,100.60	1,099.98	1,099.88	1,099.98	1,100.20	1,099.64	1,098.55	1,098.74
5M	9.20	1,091.70	1,093.02	1,092.19	1,091.22	1,092.46	1,092.80	1,091.26	1,090.26	1,090.25
5S	3.70	1,091.80	1,093.22	*	*	1,091.83	1,093.03	1,091.57	1,090.49	1,090.44
6E	10.55	1,091.36	1,092.15	1,091.79	1,091.25	1,091.96	1,091.96	1,091.08	1,090.27	1,090.88
6W	4.61	1,091.41	1,092.19	1,091.84	*	1,091.92	1,091.90	1,091.00	1,090.20	1,090.79
7	2.54	1,097.16	1,097.65	1,096.57	*	1,097.77	1,097.61	1,096.76	1,096.74	1,096.87
8	6.38	*	1,116.12	1,115.12	1,114.34	1,114.90	1,115.69	1,114.06	1,113.33	1,113.64
9	6.53	1,094.61	1,095.26	1,095.38	*	1,095.27	1,095.07	1,094.28	1,093.26	1,093.79
10E	20.36	*	1,093.13	1,092.16	1,091.13	1,092.49	1,092.92	1,091.67	1,090.74	1,091.98
10W	3.98	*	1,095.13	1,091.02	1,091.25	*	1,094.68	1,092.81	1,091.75	1,094.00
11	4.27	1,090.18	1,091.56	1,090.83	1,090.04	1,091.52	1,091.47	1,090.33	1,089.19	1,090.52
12M	17.56	1,088.59	1,089.67	1,088.62	1,088.05	1,089.25	1,089.44	1,087.99	1,087.14	1,087.37
12S	7.85	1,088.59	1,087.63	1,088.67	1,088.07	1,089.30	1,089.45	1,088.01	1,087.22	1,087.40
13	3.28	1,086.90	1,089.44	*	*	*	1,089.06	1,088.69	1,087.19	1,087.06
15	6.04	*	1,087.94	1,088.52	1,087.88	*	1,088.75	1,087.83	1,086.60	1,086.22
16	7.44	1,093.48	1,093.73	1,093.47	1,093.95	1,093.83	1,093.63	1,093.51	1,093.19	1,093.57
17E	16.90	1,083.74	1,084.90	1,083.48	1,083.20	1,083.50	1,083.88	1,083.19	1,082.58	1,082.62
17W	6.60	1,083.64	1,085.03	1,083.64	1,083.35	1,083.80	*	*	1,081.62	*
18N	5.30	1,083.53	1,084.59	1,083.69	1,083.52	1,083.69	1,083.95	1,083.48	1,082.99	1,082.99
18S	15.40	1,083.42	1,084.53	1,083.66	1,084.46	1,083.64	1,083.92	1,083.43	1,082.89	1,082.96
19W	6.38	1,083.23	1,084.62	1,083.25	1,083.06	1,083.40	1,083.70	1,083.02	1,082.36	1,082.55
19E	15.40	1,083.21	1,083.55	1,083.24	1,083.09	1,083.42	1,083.71	1,083.03	1,082.39	1,082.55
20	4.95	*	1,087.25	*	*	*	1,087.12	1,086.00	1,084.66	1,084.50
21	6.56	1,088.42	1,090.33	1,089.07	1,088.46	1,090.06	1,090.16	1,088.39	1,087.22	1,087.07
32	3.23	*	1,101.41	1,101.20	1,101.11	1,101.11	1,101.21	1,101.03	1,100.83	1,100.97
33S	3.69	*	1,093.30	1,091.81	1,091.31	1,092.25	1,092.71	1,091.12	1,090.37	1,090.37
33W	4.77	*	1,093.03	1,091.85	1,091.36	1,092.29	1,092.74	1,091.16	1,090.29	1,090.34
34	3.61	*	1,095.86	1,095.48	1,095.25	*	1,095.74	1,094.57	1,093.26	1,093.05
35	6.88	*	*	1,115.02	1,114.47	1,115.05	1,116.41	1,115.07	1,114.09	1,113.61
36	9.53	*	*	1,109.15	1,108.61	1,109.83	1,110.78	1,109.53	1,108.84	1,108.47
37	134.00	*	*	*	1,097.01	1,097.44	*	1,097.39	1,096.74	1,096.79
Lake (E)		*	*	*	*	*	*	*	*	1,083.00
Pond (B)		*	*	*	*	*	*	*	*	1,091.81
Stream (C)										
at N.Pt.Dr.		*	*	*	*	*	*	*	*	1,111.61
Stream (C)										
at Reserve Path		*	*	*	*	*	*	*	*	1,099.19

Note: Water table elevations were collected in the middle of the month on sampling dates.
* Data not collected.

Table 12. Summary of volatile petroleum components in ground water from Schaeckle Reserve.

SITE	1-14-87			2-13-87			3-14-87			4-24-87		
	Benzene	Toluene	Iylenes	Benzene	Toluene	Iylenes	Benzene	Toluene	Iylenes	Benzene	Toluene	Iylenes
	ug/l											
1 N	†	†	†	†	†	†	†	†	†	†	†	†
1 S	nd	nd	nd	nd	nd	nd	†	†	†	†	†	†
2	nd	nd	nd	nd	nd	nd	†	†	†	nd	< 1.0	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	†	†	†
4	nd	nd	nd	nd	nd	nd	†	†	†	†	†	†
5 N	nd	nd	nd	nd	nd	nd	†	†	†	†	†	†
5 S	nd	nd	nd	†	†	†	†	†	†	†	†	†
6 E	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	< 1.0	nd
6 W	< 1.0	nd	nd	< 1.0	nd	nd	nd	nd	nd	nd	nd	nd
7	nd	nd	nd	†	†	†	†	†	†	nd	1.0	nd
8	†	†	†	nd	nd	nd	†	†	†	†	†	†
9	†	†	†	†	†	†	†	†	†	nd	nd	nd
10 E	nd	nd	nd	nd	nd	nd	†	†	†	†	†	†
10 W	nd	nd	nd	†	†	†	†	†	†	†	†	†
11	†	†	†	†	†	†	†	†	†	†	†	†
12 N	†	†	†	†	†	†	nd	nd	nd	†	†	†
12 S	†	†	†	†	†	†	nd	nd	nd	†	†	†
13	†	†	†	†	†	†	†	†	†	†	†	†
15	†	†	†	†	†	†	†	†	†	†	†	†
16	10.4	nd	nd	4.6	nd	nd	6.0	nd	nd	5.9	nd	nd
17 E	†	†	†	†	†	†	†	†	†	†	†	†
17 W	†	†	†	†	†	†	†	†	†	†	†	†
18 N	†	†	†	†	†	†	†	†	†	†	†	†
18 S	†	†	†	†	†	†	†	†	†	†	†	†
19 E	†	†	†	†	†	†	†	†	†	†	†	†
19 W	†	†	†	†	†	†	†	†	†	†	†	†
20	†	†	†	†	†	†	†	†	†	†	†	†
21	†	†	†	†	†	†	nd	nd	nd	†	†	†
32	< 1.0	nd	nd	< 1.0	< 1.0	nd	< 1.0	< 1.0	nd	nd	1.0	nd
33 N	†	†	†	†	†	†	†	†	†	†	†	†
33 S	†	†	†	nd	nd	nd	†	†	†	†	†	†
34	nd	< 1.0	nd	nd	nd	nd	†	†	†	nd	1.7	nd
35	nd	nd	nd	nd	nd	nd	†	†	†	†	†	†
36	nd	39.2	nd	nd	16.1	nd	nd	1.6	nd	nd	1.6	nd
37	†	†	†	†	†	†	< 1.0	< 1.0	nd	†	†	†
39	†	†	†	nd	nd	nd	nd	nd	nd	†	†	†

† Parameter not analyzed
 Note: nd = not detected

Detection Limits: Benzene 0.5 (ug/l), Toluene 0.5 (ug/l), Iylenes 2.0 (ug/l)

Table 12.--continued

SITE	Mean Benzene	L/H/#	Mean Toluene	L/H/#	Mean Xylenes	L/H/#
----- ug/l -----						
1 N	---	---	---	---	---	---
1 S	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)
2	nd	(nd/nd/3)	< 1.0	(nd/< 1.0/3)	nd	(nd/nd/3)
3	nd	(nd/nd/3)	nd	(nd/nd/3)	nd	(nd/nd/3)
4	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)
5 N	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)
5 S	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
6 E	nd	(nd/nd/4)	< 1.0	(nd/< 1.0/4)	nd	(nd/nd/4)
6 W	< 1.0	(nd/< 1.0/4)	nd	(nd/nd/4)	nd	(nd/nd/4)
7	nd	(nd/nd/2)	0.8	(nd/1.0/2)	nd	(nd/nd/2)
8	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
9	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
10 E	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)
10 W	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
11	---	---	---	---	---	---
12 N	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
12 S	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
13	---	---	---	---	---	---
15	---	---	---	---	---	---
16	6.7	(4.6/10.4/4)	nd	(nd/nd/4)	nd	(nd/nd/4)
17 E	---	---	---	---	---	---
17 W	---	---	---	---	---	---
18 N	---	---	---	---	---	---
18 S	---	---	---	---	---	---
19 E	---	---	---	---	---	---
19 W	---	---	---	---	---	---
20	---	---	---	---	---	---
21	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
32	< 1.0	(nd/< 1.0/4)	< 1.0	(nd/1.0/4)	nd	(nd/nd/4)
33 N	---	---	---	---	---	---
33 S	nd	(nd/nd/1)	nd	(nd/nd/1)	nd	(nd/nd/1)
34	nd	(nd/nd/3)	0.9	(nd/1.7/3)	nd	(nd/nd/3)
35	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)
36	nd	(nd/nd/4)	14.6	(1.6/39.2/4)	nd	(nd/nd/4)
37	< 1.0	(< 1.0/< 1.0/1)	< 1.0	(< 1.0/< 1.0/1)	nd	(nd/nd/1)
39	nd	(nd/nd/2)	nd	(nd/nd/2)	nd	(nd/nd/2)

Note: nd = not detected Detection Limits: Benzene 0.5 (ug/l), Toluene 0.5 (ug/l), Xylenes 2.0 (ug/l)

Table 13. Summary of dissolved metal concentrations in ground water from Schaeckle Reserve.

SITE	Pb			Zn				Fe		Cu			Cr
	1-13-87	2-13-87	3-14-87	1-13-87	2-13-87	3-13-87	4-24-87	3-13-87	4-24-87	2-13-87	3-13-87	4-24-87	3-13-87
ng/l													
1 N	< 0.001	< 0.001	*	0.15	0.22	*	*	*	*	0.01	*	*	*
1 S	*	*	*	*	*	*	*	*	*	*	*	*	*
2	< 0.001	< 0.001	*	0.31	0.03	*	0.04	*	0.02	0.01	*	< 0.01	*
3	< 0.001	< 0.001	0.009	0.03	0.11	0.09	0.06	4.69	4.50	0.01	0.04	0.01	< 0.01
4	< 0.001	< 0.001	*	0.03	0.06	*	*	*	*	< 0.01	*	*	*
5 N	< 0.001	< 0.001	*	0.05	0.07	*	0.07	*	7.06	0.01	*	0.01	*
5 S	*	*	*	*	*	*	0.11	*	0.12	*	*	0.01	*
6 E	< 0.001	< 0.001	0.002	0.04	0.06	0.08	0.06	24.78	21.50	0.01	< 0.01	0.01	*
6 W	< 0.001	< 0.001	< 0.001	0.03	0.04	0.07	0.06	0.03	0.02	< 0.01	< 0.01	0.01	*
7	< 0.001	*	*	0.05	*	*	0.12	*	11.00	*	*	0.02	*
8	*	< 0.001	*	*	0.15	*	*	*	*	0.02	*	*	*
9	*	*	*	*	*	*	*	*	*	*	*	*	*
10 E	< 0.001	< 0.001	*	0.03	0.04	*	*	*	*	0.01	*	*	*
10 W	< 0.001	*	*	0.06	*	*	*	*	*	*	*	*	*
11	*	*	*	*	*	*	*	*	*	*	*	*	*
12 N	*	*	0.001	*	*	0.06	*	2.82	*	*	< 0.01	*	*
12 S	*	*	< 0.001	*	*	0.08	*	0.80	*	*	< 0.01	*	*
13	*	*	*	*	*	*	*	*	*	*	*	*	*
15	*	*	*	*	*	*	*	*	*	*	*	*	*
16	< 0.001	*	< 0.001	0.07	0.05	0.07	0.06	48.93	32.75	0.01	< 0.01	0.02	< 0.01
17 E	*	*	*	*	*	*	*	*	*	*	*	*	*
17 W	*	*	*	*	*	*	*	*	*	*	*	*	*
18 N	*	*	*	*	*	*	*	*	*	*	*	*	*
18 S	*	*	*	*	*	*	*	*	*	*	*	*	*
19 E	*	*	*	*	*	*	*	*	*	*	*	*	*
19 W	*	*	*	*	*	*	*	*	*	*	*	*	*
20	*	*	*	*	*	*	*	*	*	*	*	*	*
21	*	*	0.001	*	*	0.06	*	6.68	*	*	< 0.01	*	< 0.01
32	< 0.001	*	0.001	0.26	0.31	0.23	0.11	1.23	1.86	< 0.01	0.01	0.03	0.02
33 N	*	*	*	*	0.04	*	*	*	*	0.02	*	*	*
33 S	*	*	*	*	0.04	*	*	*	*	0.02	*	*	*
34	0.001	*	*	0.05	0.07	*	*	*	*	0.03	*	*	*
35	< 0.001	*	*	0.02	0.03	*	*	*	*	0.01	*	*	*
36	< 0.001	*	< 0.001	0.03	0.03	0.06	0.07	55.65	70.50	*	< 0.01	0.02	*
37	*	*	0.003	*	*	0.07	*	2.45	*	< 0.01	< 0.01	*	*
39	*	< 0.001	< 0.001	*	0.10	0.31	*	0.01	*	0.01	< 0.01	*	*

* Parameter not analyzed

Table 14. Summary of total metal concentrations in ground water from Schaeckle Reserve.

SITE	Pb			Zn			Fe			Cu			Cr
	3-13-87	7-22-87	Mean	3-13-87	7-22-87	Mean	3-13-87	7-22-87	Mean	3-13-87	7-22-87	Mean	3-13-87
----- mg/l -----													
3	0.043	< 0.010	0.024	3.63	2.92	3.28	61.32	73.64	67.48	7.00	0.27	3.64	< 0.01
16	<0.010	< 0.010	<0.010	1.38	3.48	2.43	96.39	176.08	136.24	1.64	0.18	0.91	< 0.01
32	0.011	< 0.010	0.008	1.63	4.14	2.88	13.02	121.51	67.26	1.96	0.58	1.27	< 0.01
37	*	< 0.010	< 0.010	*	1.73	1.73	*	98.01	98.01	*	0.61	0.61	*

* Parameter not analyzed

Table 15. Heavy metal concentrations in sediments from Schmeckle Reserve.

SITE	Pb		Zn		Fe		Cu		Cr
	3/87	6/87	3/87	6/87	3/87	6/87	3/87	6/87	3/87
----- mg/kg dry weight -----									
Culvert (A) 0 FT.	25.60	16.88	48.70	23.72	8,140.00	5,385.54	21.50	3.46	0.70
Culvert (A) 5 FT.	*	14.70	*	32.67	*	7,488.97	*	9.80	*
Culvert (A) 15 FT.	*	19.31	*	45.06	*	3,625.15	*	15.56	*
Pond (B)	25.30	64.28	23.80	44.26	4,317.00	4,941.32	8.10	18.64	0.60
Stream (C)	3.80	7.42	8.90	11.38	4,836.00	3,513.83	4.20	7.28	<0.01
Pond (D)	*	22.86	*	48.02	*	7,280.53	*	5.61	*
Lake (E)	*	2.20	*	306.06	*	3,290.28	*	4.40	*
Pond (F)	*	< 0.65	*	11.74	*	1,211.69	*	3.26	*
Stream (G)	*	6.88	*	38.52	*	6,310.82	*	7.57	*

* Parameter not analyzed

Table 16. Heavy metal concentrations in the woody species European Buckthorn from Schaeckle Reserve.

SITE	Pb			Zn			Fe			Cu		
	3/87	6/87	Mean	3/87	6/87	Mean	3/87	6/87	Mean	3/87	6/87	Mean
----- mg/kg dry weight -----												
15	< 0.05	0.21	0.11	14.00	43.62	28.81	37.50	22.33	29.92	3.50	3.50	3.50
32	< 0.05	1.47	0.75	24.80	34.84	29.82	71.80	40.57	56.18	1.50	6.23	3.86
16	< 0.05	1.21	0.62	28.20	34.62	31.41	302.30	55.69	179.00	7.20	7.55	7.38
North Pt.	< 0.05	1.15	0.59	26.30	26.04	26.17	25.20	35.02	30.11	2.50	3.51	3.00

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