
Technical Memo



Project Name: Campus Hot Spot Assessment

Client: St. John's University

To: Brother Linus Ascheman, Physical Plant

File No: 1332-03-102

From: Wesley Saunders-Pearce, Rich Brasch

Date: January 16, 2004

Re: Summary of Findings

Contents

1	Introduction.....	2
2	Data Collection.....	2
2.1	Drainage.....	2
2.2	Soils.....	2
3	Water Quality Modeling.....	4
4	Interpretations.....	6
4.1	Key Hot Spots.....	6
4.2	Key Sources.....	6
5	Key Findings and Recommendations.....	7
5.1	Priority Areas for Immediate Focus.....	7
5.2	Priority Areas for Future Management.....	9
5.3	Other Practices.....	10
5.4	Lake Sagatagan Inputs.....	10
6	Recovery of East Gemini Lake.....	11
6.1	Literature Review.....	11
6.2	Lake Recovery Factors.....	11
6.3	Recommendations.....	12
7	Figures.....	14
8	Maps.....	16

Bonestroo, Rosene, Anderlik and Associates, Inc.

□ **St. Paul Office:**
2335 West Highway 36
St. Paul, MN 55113
Phone: 612-636-4600
Fax: 612-636-1311

□ **Milwaukee Office:**
1516 West Mequon Road
Mequon, WI 53092
Phone: 414-241-4466
Fax: 414-241-4901

□ **Rochester Office:**
112 7th St. NE
Rochester, MN 55906
Phone: 507-282-2100
Fax: 507-282-3100

□ **Willmar Office:**
205 5th Street SW
Willmar, MN 56201
Phone: 320-214-9557
Fax: 320-214-9458

□ **St. Cloud Office:**
2008 8th St. North
St. Cloud, MN 56303
Phone: 320-251-4553
Fax: 320-251-6252

1 Introduction

This Technical Memorandum represents the findings for the St. John's University "hot spot" analysis. This analysis was initiated as a result of a watershed characterization completed for the University in January 2003. The watershed characterization was a broad scale investigation into the sources and magnitude of pollutant (i.e., phosphorus) loadings to the University's lakes.

The purpose of this hot spot analysis was to identify, at a fine level of detail, the sources and magnitude of sediment and nutrient loadings within the impervious areas of the campus. The objective of the project was to produce a clear understanding of the hot spots, including:

- ❑ Distinguishing the critical storm sewer outfalls that are the greatest contributors to degradation of lake water quality.
- ❑ Highlighting the area(s) within individual sewersheds¹ of the critical storm sewer outfall that are serving as the likely generator of pollutant load.
- ❑ Recommending on-the-ground improvements that the University can implement to retrofit their drainage infrastructure and campus community to protect lake water quality.

2 Data Collection

2.1 Drainage

The stormwater drainage patterns of the campus were defined according to major sewersheds, which are comprised of smaller sub-sewersheds. The major sewersheds show which sections of the campus drain to a particular lake. The sub-sewersheds further define the specific areas of a campus section draining to individual storm sewer outfalls.

To determine the major and sub-sewersheds within the campus, a base map was prepared which consisted of:

- ❑ one-foot topographic contours
- ❑ the University's storm sewer system including catch basins, manholes and outfalls
- ❑ the campus infrastructure including roadways, buildings, sidewalks and open space

The impervious areas of the campus were then field inspected and corroborated with the base map. This enabled verification of drainage boundaries and allowed for observing any unusual or important features that may be contributing to water quality issues on a local level. The drainage boundaries were ultimately delineated based on curb and gutter flow (catch basins) and building placement as well as overland sheet flow and topography. These data are reflected in Map 1 (maps are at the end of this Memo), which illustrates the campus land use, structural drainage network and the major and sub-sewersheds.

2.2 Soils

The nature of the local soils can indicate potential hot spots and can also reflect possible opportunities. To that end, two aspects of the local soils were investigated: background concentrations of phosphorus in the soil (soil-P) and the soil permeability.

Soil samples were taken at twenty locations across the campus in an effort to understand background concentrations of soil-P. The locations of soil samples, as well as their relative phosphorus content, are presented in Map 2. The locations included areas that were suspected of having high soil-P due to fertilizer applications as well as "reference" sites that were thought to have not been influenced by turf management practices. At each sample

¹ Sewershed: an area of land that is serviced by catch basins and storm sewer pipes to drain stormwater runoff.

site, several soil plugs were composited into one sample. Soils samples were sent to the University of Minnesota Extension for analysis. The annotated results (relative to phosphorus content only, excluding other nutrients or soil characteristics) are presented in Table 1, below.

Table 1 – Results of soil sampling

Sample Identification	Campus Sewershed ^a	Relative P-Content	Soil P-content (ppm)	
			Olsen Method ^b	Bray 1 Method
1222	ST8	Very High	-	57
1223	SG3	Very High	33	60
1224	SG3	Very High	27	41
1225	GE1	Very High	41	68
1226	GE1	Med-High	15	17
1227	GE1	Med-Low	9	26
1228	GE3	Very High	-	63
1229	GE4	Very High	-	58
1230	ECU1&2	Very High	32	51
1231	n/a	Very High	-	94
1232	n/a	Very High	-	100+
1233	GE1	Med-High	-	15
1234	Lake Sag	Very High	-	100+
1235*	n/a	Very High	-	100+
1236	ST3	Very High	38	42
1237	ST5	Very High	29	1
1238	ST5	Med-Low	9	15
1239	ST5&6	High	-	19
1240	ST6	Very High	42	28
1241	ST6	Very High	32	1
1242	ST2	Very High	42	44

*This site was selected as the “reference” site prior to soil sampling.

a) “n/a” indicates that the sample was outside of the campus sewershed boundary.

b) In some cases, the lab was not able to measure soil P-content by the Olsen method.

Information regarding fertilizer application rates, schedule and product were obtained from the University’s account representative for TruGreen ChemLawn. This vendor has reportedly not used phosphorus in their fertilizers for at least ten years. They currently utilize a fertilizer NPK² mix of 17-0-5 applied at ¾ pounds per 1,000 square feet (approximately equal to 33 pounds of fertilizer per acre).

The characteristics of local soils were determined from the USDA SCS Soil Survey of Stearns County. This provided details on the soil types present within the immediate campus area, including their general locations and typical permeability. The soils of the campus are entirely comprised of the Cushing-Mahtomedi association. This is characterized as well drained and excessively drained soil of coarse and moderately coarse texture. There are various soil types found within this association at the campus. Overall, the campus soil types are identified as belonging to hydrologic groups A and B, meaning they have moderate to high infiltration rates when thoroughly wet.

² NPK: nitrogen, phosphorus, potassium, respectively

3 Water Quality Modeling

Water quality modeling was conducted using W.W. Walkers P-8³ computer model. P-8 is a simulation model for predicting the generation and transport of pollutants in storm water runoff in urban watersheds. The model simulates pollutant transport and removal in a variety of treatment devices (Best Management Practices) including grassed swales, buffer strips, ponds, and infiltration basins. The only removal mechanisms directly simulated by the model are sedimentation and filtration. Biological and chemical mechanisms of contaminant removal in treatment devices are not directly considered. The model is initially calibrated to predict runoff quality typical of that measured under the U.S. EPA's Nationwide Urban Runoff Program (NURP). Modeling for this assessment was based on the median (as opposed to extreme) runoff concentration profile.

The model predicts inflow and outflow concentration as well as removal efficiencies for total suspended solids, total phosphorus, total kjeldohl nitrogen, copper, lead, zinc, and hydrocarbons. Hourly precipitation and temperature data from the Minneapolis/Saint Paul International Airport between 1949-1989 was used to provide the base data to run the simulation for Twin Cities Metro Area conditions.

For the purposes of this assessment, total suspended solids (TSS) and total phosphorus (TP) are the key pollutants of concern, and the modeling results are expressed in terms of these two parameters. Total suspended solids are of interest because many urban runoff contaminants are largely associated with suspended solids. Thus, measures which reduce suspended solids loads in stormwater, also reduce a wide variety of other pollutants. Phosphorus is of particular concern because of its role in the eutrophication (nutrient enrichment) of aquatic systems, which in turn affects the suitability of those systems to support desired uses.

The P-8 model is specific to urban/developed landscapes and relies on an accurate assessment of impervious area to predict pollutant loads from watersheds. Determining impervious areas for the campus began with digitizing the sewersheds by GIS. The different types of land uses, and their respective areas, were isolated through GIS. In this manner, the percent of impervious area for each sewershed was assessed and input to the P-8 model. Certain assumptions were made for the P-8 model, including:

- All impervious areas are currently not swept and had a uniform coefficient of 0.9.
- All pervious areas had a uniform permeability, represented by a curve number of 61 (equates to grass cover on greater than 75% of pervious space, in good condition and on hydrologic group B soils).
- Pollutant loading for the ST2 sewershed was scaled up by 50% to account for the current coal storage and handling methods directly adjacent to catch basins.

The model was based on eighteen storm sewer outfalls, grouped into major sewersheds by the lake into which they discharge. Further, discharges into Stumpf Lake were grouped based on whether they were upstream of the causeway or downstream. The two outfalls at the Institute for Ecumenical and Cultural Research which discharge to Stumpf were excluded from the model because of the very small drainage area of this facility.

The model was used to estimate average annual loads of TSS and TP that are being conveyed to receiving waters from storm sewer outfalls. To further characterize pollutant loads generated within the campus, TSS and TP loads were expressed on a pounds per

³ P-8: "Predicting Pollutant Particle Passage thru [sic] Pits, Puddles and Ponds"

unit area basis. Results from water quality modeling for existing land use under average conditions are presented in Table 2, below.

Table 2 – Results of P-8 modeling of campus

Sub-sewershed	Drainage Acres	Impervious Fraction	Total Load (lbs/year)		Unit Load (lbs/acre/year)	
			TSS	TP	TSS	TP
SG1	0.82	68%	351	1.1	429	1.4
SG2	1.12	36%	254	0.8	227	0.7
SG3	10.30	39%	2,540	8.2	247	0.8
SG4	1.45	72%	661	2.1	455	1.5
SG5	3.67	33%	765	2.5	208	0.7
Sagatagan	17.36	50%	4,571	14.7	263	0.8
ST1	0.46	91%	264	0.9	574	1.8
ST2	4.74	64%	2,852	9.2	601	1.9
ST3	8.78	52%	2,893	9.3	330	1.1
ST4	1.31	53%	436	1.4	334	1.1
Upstream Stumpf	15.29	65%	6,445	20.8	422	1.4
ST5	10.70	46%	3,112	10.0	291	0.9
ST6	9.08	31%	1,779	5.7	196	0.6
ST7	3.91	61%	1,507	4.8	386	1.2
ST8	11.67	48%	3,551	11.4	304	1.0
ST9	3.29	46%	956	3.1	291	0.9
Downstream Stumpf	38.64	46%	10,905	35.0	282	0.9
GE1	29.18	38%	7,018	22.6	240	0.8
GE2	0.68	61%	262	0.8	384	1.2
GE3	4.11	25%	650	2.1	158	0.5
GE4	5.17	76%	2,482	8.0	480	1.5
Gemini	39.14	50%	10,412	33.5	266	0.9

4 Interpretations

4.1 Key Hot Spots

Five of the eighteen outfalls were identified as critical contributors to water quality impacts. These hot spots were determined based on their overall load of TSS and TP to receiving waters. Specifically, the upper quartile (75th percentile) of loads were isolated as hot spot areas. The key hot spot sub-sewersheds are presented in Table 3, below, and are listed in descending order of load as well as drainage area.

Table 3 – Key hot spot sub-sewersheds

Sub-sewershed	Drainage Acres	Impervious Fraction	Total Load (lbs/year)		Unit Load (lbs/acre/year)	
			TSS	TP	TSS	TP
GE1	29.18	38%	7,018	22.6	240	0.8
ST8	11.67	48%	3,551	11.4	304	1.0
ST5	10.70	46%	3,112	10.0	291	0.9
ST3	8.78	52%	2,893	9.3	330	1.1
ST2	4.74	64%	2,852	9.2	601	1.9

The loadings that are associated with each hot spot are a result of two dominating factors. The proportion of the drainage area that consists of impervious surface is one factor. The size of the drainage area that is serviced by a single outfall is the other factor. The key hot spot sub-sewersheds are noted on Map 3 and are listed in order of priority (discussed in Section 5).

4.2 Key Sources

Pollutant loads from stormwater runoff can stem from various sources. Land use and land management activities have a strong influence on the sources of pollution. Urbanized areas, or areas of large impervious coverage, often have similar culprits of pollutant sources. The St. John's University campus has a mix of key sources for pollutants. Some are case-specific to the University (numbers 1 and 4, below) while others are more generic to impervious land use (numbers 2 and 3, below).

1. High concentrations of soil-P

Soil levels at 80% of sampled areas (sixteen out of twenty sites) were evaluated as having "very high" phosphorus concentrations. Of the sixteen sites of "very high" soil-P, eleven were within sub-sewershed areas defined for this project. The implication is that although phosphorus free fertilizer is used, it will still be important to address runoff from pervious/turf grass areas.

2. Surface parking lots

These facilities are often "lightening rods" for sediment and pollutants. This is a result of the nature of parking lots, which are highly impervious and subject to intensive automotive usage. Vehicles track and deposit particulate material. Auto emissions and leaks can also deposit pollutants in lots in the form of hydrocarbons and metals.

3. Interconnected drainage

The degree to which drainage areas, especially highly impervious areas, are directly connected to the storm sewer system can exacerbate pollutant loading. The campus has a high degree of interconnected drainage as reflected by the extensive storm sewer system and overall number of catch basins. While this is beneficial for localized flood control, it has the result of directly conveying pollutants to downstream resources.

4. **Disturbed/exposed/unstable soils**

At the time of the field visit, several construction activities were underway creating disturbed soils. As well, various areas of the campus were observed to have exposed and unstable soils in the form of rills. Most of these were small and localized thus were not directly accounted for in the P-8 model. The exception to this is the coal storage area at the power plant, which was accounted for in the P-8 model.

5 **Key Findings and Recommendations**

Individual sub-sewersheds that are key hot spots of pollutant loading are indicated on Map 3. The hot spot symbols on the map reflect the rank (or priority) of the hot spot area. This map also illustrates the key recommendations for retrofitting the campus to improve stormwater quality.

The hot spots were prioritized based on the following criteria:

1. The estimated load of TSS and TP delivered to receiving waters, based on P-8 modeling.
2. The ability (i.e., cost and practicality) to retrofit the sub-sewershed for improvements to address the source of TSS and TP loading.
3. The anticipated relative level of treatment provided by improvements (i.e., the amount of “bang” for the buck).

Of the five hot spot areas, the three for which watershed retrofits are the most feasible and likely are presented in Section 5.1 with a discussion on approach and a range of costs. The other two areas are presented in a Section 5.2 as conceptual strategies for future consideration and do not have cost estimates associated with them.

5.1 **Priority Areas for Immediate Focus**

For this assessment, the recommendations presented for treating stormwater quality are based on managing rainfalls of small magnitude but high frequency. Storms that are between 0.5 and 1.5 inches are responsible for conveying approximately 75% of the annual pollutant load in stormwater runoff. Historically in Collegeville⁴, over 90% of the rains from spring through fall are less than 1.0 inch.

Priority area 1 – ST8

The ST8 area is rated as the highest priority because it has the strongest balance between pollutant load and ability to retrofit the watershed for treatment. This area has the second largest drainage area and pollutant load. It has a large parking lot facility (approximately 1.6 acres) adjacent to the Mary Residence that disproportionately contributes to the stormwater impacts. ST8 has soils that are very high in soil-P with localized areas of instability (Figure 1). Last, the ST8 outfall is adjacent to the outlet of Stumpf Lake. As such, Stumpf Lake does not provide any assimilative capacity for nutrients or sediment delivered from ST8; pollutants are almost immediately conveyed to Gemini.

Recommendation

Divert pipe flow to create an infiltration gallery (a.k.a. rainwater garden) to provide stormwater treatment. Preliminary calculations indicate that runoff from rains of up to ¾-inch could be treated before entering Stumpf Lake. A two-cell infiltration gallery was evaluated on the west side of the major four-way intersection at the campus entrance. If

⁴ Precipitation station 211691, 1971-2000 averages

this recommendation is implemented, moving directly into system design would be an appropriate next step.

Basic Description

Stormwater would be intercepted at the manhole immediately north of the parking lot adjacent to the Mary Residence. This would bring runoff from small storms to the first cell of the infiltration system, situated on the southwest quadrant of the four-way intersection. The first cell would be connected by a pipe below County Road 159 to a second cell in the northwest quadrant of the intersection (Figure 2). Any runoff at this system that did not infiltrate would be conveyed back to the main storm sewer pipe serving ST8. The design of this system would need to address the existing coniferous trees screening the parking lot in ST7.

Cost Estimate

The potential range of costs for this improvement are from \$55,000 to \$75,000. This includes anticipated construction costs for mobilization, materials and labor. However, it does not factor in the cost of actual design, construction administration, inspection or other typical engineering fees.

Priority area 2 – ST2

This area is highly influenced by the coal storage practices at the power plant (Figure 3). It also has a substantial amount of impervious area (64%). Particulates and TSS are the key pollutants of concern in this area. Several opportunities exist to address this hot spot.

1. Construct a covered facility for coal storage and handling.
2. Install a structural treatment device such as a swirl concentrator unit.
3. Retrofit the parking lot adjacent to the Liturgical Press to provide a vegetated filter strip, treating the overland discharge of pipe flow at this location.

Recommendation

Retrofit the existing drop manhole on the west side of County Road 159 with a swirl concentrator unit. Preliminary calculations were made assuming this recommendation would be implemented with a V2B1-type swirl concentrator (model 4) which is sized to handle a peak runoff flow of up to 4.3 cfs. This would accommodate peak runoff from storms over 1.0 inch (almost up to 1.5 inches). If this recommendation is implemented, moving directly into system design would be an appropriate next step.

Basic Description

The existing corrugated metal pipe and concrete drop manhole that are above grade would be removed. New manholes would be installed in conjunction with the V2B1 unit. This allows for low flows (up to 4.3 cfs) to be routed into the swirl concentrator while disruptive high flows from infrequent storms are allowed to bypass the system. This approach also allows for the new structures and treatment system to be placed below grade, improving the visual aesthetics of the area.

Cost Estimate

The potential range of costs for this improvement are from \$40,000 to \$60,000. This includes anticipated construction costs for mobilization, materials and labor. However, it does not factor in the cost of actual design, construction administration, inspection or other typical engineering fees.

Priority area 3 – GE1

This sub-sewershed has the largest annual pollutant load of the 18 outfalls, almost *four times* the average load for the campus. The estimated annual TP input to East Gemini from GE1 is 22.6 pounds, one-sixth of the total annual TP load contributed by the wastewater

treatment plant discharging at 0.3 ppm. This load is predominantly a factor of the size of the drainage area, which is also four times the average area. In contrast, GE1 has a relatively low amount of impervious surface⁵. Water quality benefits can be addressed by reducing the volume of runoff that is conveyed from this drainage area.

Recommendation

Use a diversion approach to route stormwater runoff to Cichy Pond, allowing it to store and treat runoff from GE1. Preliminary modeling indicated that TP and TSS annual loads to East Gemini at GE1 could be reduced by over 50% through a diversion of stormwater runoff, bringing the discharge more in-line with campus averages. If this recommendation is implemented, a feasibility study would be an appropriate next step prior to designing a system.

Basic Description

The diversion approach was based on capturing and re-routing flows at a manhole north of the stadium, adjacent to the McNealy Palaestra. A new pipe would be laid below the paved road that bounds the south side of the field house and then extend to Cichy Pond to outlet. The pipe capacity would be sized to accommodate flows from the existing storm sewer system design event (typically a 10-year storm). The new pipe and diversion manhole would effectively preventing any further flow to GE1 from the upper portion of the GE1 sub-sewershed.

Cost Estimate

The potential range of costs for this improvement are from \$90,000 to \$130,000. This includes anticipated construction costs for mobilization, materials and labor. It also assumes that the pipe would be installed through the major berm for the road by means of an open cut. A feasibility study would provide a detailed evaluation of this approach as well as the alternative of directional boring. Finally, this cost estimate includes an allowance for potential modifications to Cichy Pond such as an outlet structure. However, it does not factor in the cost of a feasibility study, actual design, construction administration, inspection or other typical engineering fees

5.2 Priority Areas for Future Management

Priority area 4 – ST5

Interconnected drainage dominates this hot spot area. Here, the major source of pollutant loading comes from rooftop drainage. Breaking up the storm sewer pipe flow with vegetated swales or buffer strips would be an appropriate way to provide treatment of stormwater. Infiltration of stormwater would also be effective in treating stormwater runoff. Approaches to managing this hot spot could consist of utilizing the open courtyard area in ST6 for incorporating treatment alternatives.

One scenario might consist of diverting pipe flow at Sexton Commons to an infiltration gallery established in the turf plaza in front of Bernard and Boniface Residence halls. Creating small buffers around beehive catch basins in this area would be recommended in conjunction with this approach. More dramatic stormwater management techniques could also be explored for this area. However, the investment would likely not be in scale with this sub-sewershed's current impact on Stumpf's water quality.

Another scenario may be to create an infiltration gallery at the beehive casting adjacent to Roger's Gallery by the county road. Due to the small footprint available, an infiltration

⁵ The artificial turf installed at Clemens Stadium was considered open space, not impervious, because it likely does not have the pollutant load typically associated with impervious surfaces such as roads or rooftops.

gallery here would only treat very small volumes of runoff. As such, a capital investment may provide only modest benefit.

Priority area 5 – ST3

The primary issue with this area is the extent of interconnected drainage and the relative lack of open space to implement improvements. The size and impervious fraction of the drainage area indicates that infiltration may not be cost-effective. Further, the feasibility of treatment at or below the outfall is limited due to the steep slope of the existing channel (over 15% slope).

The recommendation for this area is to employ good housekeeping efforts within the drainage area itself. For example, it would be beneficial to maintain the roadways and paths here on a more vigorous level by means of sweeping. Another option for future consideration might be procuring and installing catch basin filtration devices at key junctions within ST3 to treat stormwater runoff as it enters the conveyance system. Inspection of the device is typically performed quarterly, with maintenance being performed as needed. Vacuuming of accumulated sediment and debris is followed by evaluation/replacement of the filter media. A common alternative to this filtration device is to utilize manholes that have a sump feature. However, in this case, any existing manholes would need to be entirely removed and replaced with a new manhole and sump.

5.3 Other Practices

Aside from the specific recommendations posed above, there are other BMP/good housekeeping efforts to employ for managing stormwater quality. General recommendations to help protect water quality include:

- ❑ Establish erosion and sediment control (ESC) guidelines for construction projects within the campus and require contractors to implement ESC techniques.
- ❑ Purchasing and frequently using a street sweeper (approximately three to four times per year) is an effective method for controlling sediment and nutrient inputs to receiving waters from roadways and parking lots (Figure 4).
- ❑ Promptly stabilize areas of exposed or unstable soils.
- ❑ Continuing current turf management practices is encouraged (e.g., not discharging clippings into street, phosphorus free fertilizer).
- ❑ Random, independent testing of commercially applied fertilizer to confirm no-P content.

5.4 Lake Sagatagan Inputs

There were no critical areas of the campus identified through modeling that impact Lake Sagatagan water quality. This is chiefly a result of the relatively small areas that discharge to the lake, even though they are disproportionately high in impervious coverage. Further, all outfalls discharging to Lake Sagatagan have a substantial overland flow path prior to reaching the lake. However it will be important for the University to manage and maintain these overland flow paths to ensure that they do not become unstable, similar to the Prep School ravine condition. The water quality of Lake Sagatagan is excellent and as such, appropriate management efforts should be implemented to ensure that it remains in that condition. Any changes to land use or inputs to Lake Sagatagan should be closely evaluated for potential impacts to water quality.

6 Recovery of East Gemini Lake

6.1 Literature Review

In the January 2003 watershed characterization report, the University's WWTP was clearly identified as a hot spot of phosphorus loading to East Gemini Lake. Two questions of interest to St John's University are to what degree and how fast water quality in East Gemini Lake will improve once the discharge quality from the WWTP is improved. The watershed characterization report provided estimates of equilibrium (steady-state) water quality under a variety of load reduction scenarios. These scenarios are summarized in detail on page 24 of the watershed characterization report.

The rate of recovery of Gemini Lake was of interest in this assessment. That is, *the question presented is how long it will take for the lake to recover to a new, improved equilibrium condition once the external load from the WWTP is reduced.* To attempt to answer this question, a cursory literature review was conducted. This review looked at the actual rate and degree of recovery of shallow hypereutrophic lakes in response to a dramatic reduction in external nutrient loading, often due to diversion of—or improvement in—the quality of sewage effluent. The case studies examined included lakes in Hungary, Denmark, Sweden, Turkey, the U.S. and Canada. Many of these case studies involved detailed, research-level examinations of the watershed as well as the physical, chemical, and biologic of the in-lake environment.

The “take home” message from this review is that the science has not yet advanced to the point that lake scientists are able to reliably predict the recovery period. As one benchmark paper put it, “...As (predictive) models are based on systems in equilibrium, however, they cannot adequately describe the transient phase following a loading reduction before a new equilibrium is established...Quantification of the processes behind the equilibration and recovery period is generally not well described...” (Sondergaard, Jensen, and Jeppesen, 2001).

6.2 Lake Recovery Factors

There are several factors that strongly influence the rate of recovery of a lake. These factors are:

- Flushing rate
- Pollutant loading history
- Chemical nature of the lake sediments
- The structure of the biologic community

Flushing rate

This factor refers to the length of time it takes for inflow to a lake to completely replace the lake's volume. In general, the higher the rate of inflow and the shorter the residence time, the more quickly the lake will respond to a new equilibrium condition caused by a change in incoming water quality. Based on the precipitation/runoff modeling that was completed for the watershed characterization report, East Gemini Lake has a very rapid flushing rate of about 60 days. Extrapolations of “snapshot” base flow measurements at the outflow of Stumpf Lake (MFRA Hydrologic Study, 1987) suggest that the flushing rate may be even more rapid. *This factor favors a rapid response in the lake.*

Pollutant loading history

This factor refers to the size and length of time pollutant loads have been entering the lake. East Gemini has served it's historical purpose well: to receive and assimilate loads from the WWTP. However, the larger the loads and the longer those loads have discharged to the lake, the slower the rate of recovery. East Gemini has a long history of large incoming loads from the WWTP. *This factor does not favor a rapid response in the lake.*

Chemical nature of the lake sediments

This factor has to do with the degree of contamination of the sediments with the pollutant of concern. In general, prolonged loading causes an accumulation of some pollutants like phosphorus in the sediments. Even when inputs are eliminated, accumulated phosphorus can be released back into the water column, causing a continued impact on lake quality.

Sediment analysis completed as part of the first phase of this project indicates that the sediments in East Gemini Lake are quite enriched. The levels of phosphorus in East Gemini sediments are approximately four times greater than similar lakes in the region (MPCA, 1996). How rapidly the accumulated phosphorus is exhausted will depend on:

- how deep phosphorus is found in the lake sediment
- the quality of the overlying water column (better quality will encourage a faster release and shorter time to exhaust the accumulated phosphorus)
- how rapidly the released phosphorus is carried out of the lake system

Structure of the biologic community

This factor refers to whether the abundance and composition of the lake's biologic community – algae, rooted weeds, fish, etc. – is resistant to change. In general, lakes with a healthy rooted native weed population are desirable, but are only possible when the water is relatively clear (algae populations are low). Similarly, rough fish like carp that can stir up the bottom sediments retard a lakes ability to improve. Little is known about the biologic community of Gemini Lake, so this factor is difficult to assess. Currently, the lake appears dominated by algae with little desirable rooted aquatic weeds in evidence. If water clarity can be improved enough, a more favorable environment would be created for rooted aquatic weeds, which in turn could promote long-term water clarity.

6.3 Recommendations

The recommendations presented below are ways to address the aquatic aspect of managing in-lake water quality of East Gemini. It is also essential to incorporate the watershed management aspect, notably the loadings from the hot spot sub-sewersheds of ST8 and GE1, to fully address water quality in East Gemini.

1. **Improve and maintain the best quality effluent reasonably possible from the WWTP.** While the improvement in WWTP plant effluent will be dramatic even if it achieves a 1 ppm phosphorus concentration, any further improvement in effluent quality should be pursued vigorously through refinements in plant operations where possible. The better the plant effluent, the more rapidly sediment phosphorus is likely to be exhausted, since leakage to the overlying water column is in part a function of the difference in phosphorus concentration between the two. However, modeling and calculations suggested that additional capital investments to either isolate, infiltrate or divert effluent would provide only marginal-to-modest supplemental benefit to water quality.
2. **Allow the lake a chance to recover naturally.** We recommend that the lake be allowed to recover naturally for a period of 2-3 years after the commencement of improved quality discharge from the WWTP. The rapid flushing times calculated for Gemini Lake suggest that the lake may have a greater recovery potential than is typical for many other lakes. This is also the most financially efficient way to proceed at this point, since spending funds on chemical treatment may not be very cost-efficient if the lake will recover on its own anyway.
3. **Develop and implement a monitoring program to assess the degree of lake recovery.** This can be as simple or as complex as resources and interest dictate. At a minimum, water clarity readings should be taken every two weeks throughout the May

through September period. The response of East Gemini Lake will of interest to the scientific community at large. Thus, more intense monitoring of biological and chemical conditions within the lake, as well as tracking of the effluent loading, is highly desirable. We strongly encourage the University to look at this as a learning prospect for the scientific community it houses and see great opportunity for the monitoring to be conducted as part of an scientific academic endeavor.

4. **Consider other more active management options.** If the monitoring results show a need to enhance the lake's ability to recover, the University can consider more active lake management options. Or these options could be used if the University wishes to "jump start" the recovery process, without pursuing the passive approach of seeking potential improvements through natural lake flushing. These options can include chemical treatment of the lake sediments with alum or iron compounds to slow or stop sediment release (estimated cost range of \$80,000 to \$130,000) or isolation of the plant effluent from the majority of the lake. Alternatively, a physical removal of sediment could be pursued to improve the lake. In this scenario, the lake would be drawn down and dewatered to expose the sediments. A bobcat or bull dozer would then proceed to remove the top layer of muck (approximately one foot) from the lake and dispose the spoil off-site. The estimated cost range for this scenario is \$115,000 to \$240,000, which is for excavation costs only.

By improving the efficiency of the WWTP, the University has already taken a significant step in addressing water quality in East Gemini Lake. Yet there are many factors affecting the water quality dynamics of East Gemini Lake and potential strategies for continuing to improving the lake. As such, it is difficult to predict the timeframe and magnitude of lake response beyond a relative comparison.

7 Figures

Selected areas of problems and potentials

Photos taken May 2003

Figure 1 – Unstable slope behind tennis court



Figure 2 – Illustration of a roadside rainwater garden



Figure 3 – Clogged catch basin at power plant



Figure 4 – Street and parking lot sweeping is critical



8 Maps

Map 1 – Campus Drainage and Land Use

Map 2 – Phosphorus Levels in Campus Soils

Map 3 – Campus Stormwater Management Assessment