Volume I

Executive Summary

Summary of Volume II - Framework and Methodology

II.A. Introduction

II.A.1. Purpose of Study

In early 2001, the Minnehaha Creek Watershed District (MCWD) began the most ambitious watershed study ever undertaken by a Watershed District in Minnesota. The MCWD initiated a multi-year *Hydrologic/Hydraulic and Pollutant Loading Study*, or HHPLS, to:

- Document the nature of the physical and biological characteristics of the watershed;
- Quantify the amount of water moving through the watershed, and the quality of that water as it moved and as it gathered in various receiving waters;
- Gather detailed public input to assist in problem identification and solution definition;
- Formalize management programs on a sub-watershed basis; and
- Provide the study results to implementation partners in an easily understood manner.

The over-arching goal of the HHPLS is to improve and maintain the surface water, groundwater and associated natural resources of the MCWD. This HHPLS Report presents a compilation of three years of work by District staff, technical consultants, elected officials and the public. This report identifies existing water management issues resulting from current and past land uses. It also seeks to define the impact of future land use changes, and to recommend how the District Managers can address these changes. The HHPLS has been a truly collaborative effort, as described in Section C later in this chapter, as well as *Volume III* of this report. This collaboration will form the basis for effective water management at many levels for years to come.

II.A.2. Connections to Related Efforts

As with any large-scale effort in water resources, the MCWD recognizes that it cannot address all of the needs of the Watershed alone. There are many existing agency and private or citizen programs under way that can assist in achieving the overall goal of good water management. Following are summaries of some of those key programs.

II.A.2.a. NPDES Point and Nonpoint Source Permits

Past Lake Minnetonka water quality problems, and to a certain extent lingering problems, were due to the high loads that the lake received from numerous municipal wastewater treatment plants. Since the 1970s, the State and Metropolitan Council removed all of these point source discharges, and routed the flow of wastewater to more effective treatment facilities that do not discharge to the Lake. However, many of the receiving waters that were in the path of the past wastewater flows still likely harbor some residual pollutants.

Today, only six point source discharges of any treated material occur in the Minnehaha Creek Watershed. These discharges are for non-contact cooling water, groundwater contaminant pump-out, or water treatment iron removal backwash water. The specific impact of each discharge is discussed in *Volume IV: Watershed Modeling and Discussion* .

In March of 2003, the Phase II NPDES nonpoint source management program officially began. This program requires, among other things, that communities operating stormwater systems undertake controls for those systems that improve water quality. The new permit requirements also mandate construction runoff control for sites disturbing as little as one acre of land, whether individually or as part of a larger project. The MCWD will be working closely with the communities within the Watershed to make sure that effective control programs result from this round of nonpoint source permitting.

II.A.2.b. TMDL-Like Process

The HHPLS was intentionally set up to parallel the Minnesota Pollution Control Agency's (MPCA's) "Total Maximum Daily Load" or TMDL program. The TMDL program identifies waterbodies that are "impaired" because they do not meet an adopted water quality or narrative standard. The impaired list of waterbodies, known as the "303d list", is submitted by the MPCA to the U.S. Environmental Protection Agency (EPA) as part of its routine reporting under the Federal Clean Water Act, under Section 303.

The actual 303d list waterbodies in the Minnehaha Creek Watershed are limited to seven lakes, as listed in Table II.A-2, for which "excess nutrients" led to listing. The process to address these problems can begin with the implementation programs proposed as part of the HHPLS, with eventual tie-in to the official MPCA TMDL program. The TMDL process develops a management program wherein input loads are identified and a control program implemented to reduce pollution inputs to the total maximum daily load, or the upper limit of input from all sources. Once this load is determined, control programs work to incrementally reduce its component until the load is no longer exceeded.

The HHPLS effort is referred to as "TMDL-like" because it follows a similar process, going far beyond the state program in some respects. The previous paragraph noted that the HHPLS will provide a framework for implementation, thus completing the process for the seven listed lakes. The HHPLS actually paralleled the TMDL process for every major and minor waterbody (lake and stream) in the Watershed, incorporating also a public input process. Goals recommended through this process are contained within this report. For many of the waterbodies, no goal was established in the District's 1997 Plan, so the recommendations will be the first established.

Some of the seven lakes, plus additional lakes including all of Lake Minnetonka, are also listed for PCB and mercury fish consumption advisories (FCA). Regional control programs for both PCB and mercury removal, are being orchestrated out of U.S. EPA Region 5 (Chicago) and will address the entire EPA Region.

II.A.2.c. Local Surface Water Management

An integral key to effective watershed-wide water management is the relationship between local efforts and those of MCWD. No where is this coordination needed more than in the development and implementation of local surface water management plans.

Most communities within the District have prepared and are effectively implementing local plans. In many cases, the plans are used to coordinate local activities with those of MCWD. For instance, the District will allow communities to implement permitting programs if the community meets the minimum requirements set by the District. In other cases, some communities cannot provide the staff and level of effort needed for permitting, so the District does the permitting.

Recommendations for effective runoff control as new areas develop or previously urbanized areas re-develop are made throughout the implementation program. The development of close coordination between the communities and the District is essential to make sure that the needs of the community for development are met within a framework that also protects water resources.

II.A.2.d. Third Generation Watershed Plan Development

The last MCWD Watershed Plan was adopted in 1997. This plan was a very comprehensive approach to watershed management, but is in need of updating. New information from the HHPLS, as well as numerous other projects, studies and data collection efforts, can now be used to update the manner in which the District implements its programs.

Specific changes related to the HHPLS include: the adoption of revised water quality goals for many lakes; new hydrologic and hydraulic views of water movement and flooding; an up to date inventory of land cover; wetland functions and values (available from the HCD inventory); watershed load limits recommended for receiving water goal achievement; new technical assistance that the District can provide using the HHPLS models; and priority recommendations for capital, monitoring, education and program development.

II.B. Watershed Description

The Minnehaha Creek Watershed extends from the western fringes of the Twin Cities metropolitan area to the Mississippi River at the urban core of Minneapolis. The administrative boundaries of the Minnehaha Creek Watershed District (MCWD) encompass a total land area of 178 square miles within two counties, three townships and 27 cities. The upper watershed, above Lake Minnetonka, is a region of rolling farmland interspersed with numerous lakes and wetlands. Lake Minnetonka, an important regional natural resource, serves as both the recipient of stormwater runoff of the upper watershed and as the source of Minnehaha Creek. Minnehaha Creek flows eastward for about 22 miles and is the physical link that binds together the network of urban lakes, parks and open space that define the western Twin Cities area and south Minneapolis.

The challenges to managing the MCWD are as diverse as the physical and social regions that occupy it. The upper watershed is in transition from agricultural to urban land use. Runoff of nutrients, sediment and pesticides from both of these land uses threaten Lake Minnetonka and other water bodies. Continued loss of wetland functions to urban development in the upper watershed exacerbates this situation. Challenges in the lower watershed include severe erosion within much of the creek channel, resulting in damages to residential and park property and loss of stream habitat diversity due to sedimentation. Within the lower watershed, the Minneapolis Chain of Lakes and the interlinking parkway system comprise one of the most heavily used park systems in the country. Recreational uses in these waterbodies are impacted from stormwater runoff of phosphorus and sediment, and many water bodies are impaired due to high fecal coliform and low oxygen.

The HHPLS used all known information of the watershed, and collected pertinent information where it was not available. The MCWD encompasses a total drainage area of 109,111.7 acres or about 170.5 square miles. The MCWD is contained within 12 major watersheds and 453 subwatersheds. The name of each major watershed, its associated drainage area, and the number of subwatersheds contained therein are shown in Table II.B.1-1.

Subwatersheds vary in size from as little as 6.6 acres (MC-175), located along the lower reaches of Minnehaha Creek in the City of Minneapolis, to over 2000 acres for subwatersheds that encompass large lake and/or wetland areas associated with Lake Minnetonka in the western portion of the MCWD. The average size of subwatersheds is about 241 acres. The locations of major watersheds and subwatersheds are shown Figure II.B-1 and in Figure IV.Appendix.1-1.

II.C. Land Use and Land Cover

The character of the vegetation, or lack of vegetation, on the land, and the land use type have a lot to do with the amount and quality of water runoff, and thus form the basis for both quantity and quality modeling of the watershed (next section). Detailed vegetative cover (ex., forests, wetlands, prairie) data were collected from new and existing sources and placed into a format compatible with the Minnesota Land Cover Classification System (MLCCS). The MLCCS integrates classification of cultural features, non-native vegetation, and natural and semi-natural vegetation into a comprehensive land cover classification system. The percent of imperviousness was assigned for each MLCCS code as described in Table II.C.2-1. It is important to note that the impervious percent for wetlands was based on the hydrologic regime of the wetland. Figure IV.Appendix.3-1 in Appendix 3 (of *Volume IV*) shows MLCCS mapping for the MCWD. A complete description of all MLCCS land cover types is also listed in Appendix 3.

Land use within which the cover exists (ex., residential, commercial, open space/parkland) was documented based on Metropolitan Council Generalized Land Use 1997 for the Twin Cities Metropolitan Area, supplemented in areas undergoing rapid land use change by local comprehensive plans.

The future land use was determined through use of the Preliminary Planned Land Use 2020 figures developed by the Metropolitan Council with data supplied by the communities within the study area. The Metropolitan Council consolidated the data and developed a regional system for classifying land use. EOR cross-referenced this data with local plans as available.

The 2020 land use data was spatially overlaid with the existing MLCCS data through the use of ArcView GIS software. The resulting data set, a combination of existing MLCCS and future Land Use, was used to determine future Land Cover. Each combination of Land Cover and 2020 Land Use was assessed to determine the future Land Cover. Table II.C.3-1 describes the rationale used in this assessment.

II.D. Groundwater

The relationship and interaction of what is seen on the land's surface to what is located below as groundwater is extremely pertinent to wise water management in the Minnehaha Creek watershed. Factors influencing groundwater include soils, groundwater elevation, depth to groundwater, infiltration (shallow) and recharge (deep) potential, and underlying bedrock. These factors become extremely important when certain management practices are considered that might rely upon groundwater behavior, such as infiltration of runoff.

A large amount of soil, geology and groundwater information is available in the form of reports, complex maps, and databases from various government agencies. All of this information was used to accurately portray the groundwater underlying the watershed. Excerpts from some previously published maps are used and referenced in *Volume V: Watershed Issues Integration*.

II.E. Public Involvement

The public involvement component was a major collaborative process between technicians, MCWD staff and managers, and local representatives. It promoted stakeholder understanding, involvement and community action throughout the entire project. It was designed to meet the following key objectives:

- Maintain and enhance MCWD's working relationships;
- Capture stakeholder interest and involvement;
- Develop and enhance stakeholder understanding;
- Progressively integrate city, county and state resources; and
- Generate management recommendations for the MCWD to consider.

The Public/Stakeholder Involvement Process was designed to maximize input, minimize conflict, and instill a sense of ownership in its activities and outcomes. It included the formation of Regional Teams, a Project Advisory Committee and a Technical Advisory Committee.

II.E.1. Regional Teams (RTs)

The nine Regional Teams were the centerpiece of the project. They were formed based upon the premise that local involvement is crucial in applying science to community water quality and water quantity problems successfully. A series of eight meetings with each RT were planned to build trust, engage community pride, develop a common understanding of water resource issues and their relationship to problems identified, provide an opportunity for local prioritization of issues and enhance participant dedication to eventual implementation.

The RT meetings began with a project introduction, and ended with a technical report, with management recommendation, to the MCWD. A more detailed discussion of the Regional Team meeting process, its list of members and a map of the nine Regional Team boundaries, can be found in *Volume III: Public Involvement, A. Description of Process*.

II.E.2. Project Advisory Committee (PAC)

The Project Advisory Committee was comprised of representatives from each of the Regional Teams, the Technical Advisory Committee (TAC), MCWD's Citizens Advisory Committee (CAC), MCWD representatives and local officials. The role of the PAC was to oversee the entire project, monitor the activities of the Regional Teams and TAC, provide strategic assistance and identify community partners to participate in the Regional Teams.

The PAC met a total of nine times and discussed topics ranging from outreach activities to BMP education and project delivery. A more detailed discussion of the PAC process and topics it covered, as well as its membership, can be found in *Volume III: Public Involvement, A. Description of Process*.

II.E.3. Technical Advisory Committee (TAC)

The Technical Advisory Committee was comprised of technical representatives from local, regional, state and federal agencies, as well as representatives from MCWD and its consultants. The role of the TAC was to review data prepared by the consultants, make recommendations regarding data collection and implementation, and provide input to the PAC.

The TAC met a total of five times and discussed technical issues relating to such topics as model selection, pollutant loading factors and natural resource mapping. A more detailed discussion of the TAC process and topics it covered, as well as its membership, can be found in *Volume III: Public Involvement, A. Description of Process*.

II.F. Modeling Methodology

All of the previously mentioned data were used to develop predictive quantity and quality computer models. An extensive effort was put forth to search for and gather pertinent data available in the District to minimize duplication of data collection efforts, and maintain consistency with other public and private entities. The data collected were used in various combinations to characterize subwatersheds and define both hydrologic and hydraulic parameters necessary for model input. In general, the most current data available were used to represent existing conditions. In situations where different sets of data conflicted, the most current data were used, unless considered unrepresentative. Where critical data were either lacking or considered outdated, new data were gathered.

All data sets were incorporated into an overall Watershed geographic information system (GIS) for ease of manipulation and presentation. Output from this system forms the basis for the GIS Tool presented in *Volume XXX.*

II.F.1. Water Quantity

The water quantity (flow, hydraulics, flooding, structure assessment) model used for the HHPLS is the XP-SWMM model. Model output includes both the hydrologic and hydraulic character of various elements within the Watershed. From a hydrology viewpoint, information is generated on single events simulated for the water quantity modeling includes:

- 100-year 24-hour rainfall (6.0 inches)
- 100-year 10-day snowmelt runoff (7.2 inches)
- 1.5-year 24 –hour rainfall event (2.6 inches)

Rainfall, various climatic factors, and sub-watershed hydrologic character all influence the amount and nature of water movement within the Watershed. Details of how these factors are incorporated into quantity modeling are given in *Volume II.F.*

From a hydraulic viewpoint, information can be generated on storage, behavior near structures (weirs, dams, pipes, bridges, drop structures, etc.), and flow routing. To provide accurate representation of water levels and discharge throughout the District, the XP-SWMM model was calibrated to available flow and water elevation data at:

- Painter Creek at West Branch Road;
- Minnehaha Creek at Browndale Dam; and
- Minnehaha Creek WOMP station at 32nd Avenue S.

Model results were generated and analyzed for both existing and 2020 conditions to provide base information and to identify potential problems. The 100-year 24-hour rainfall and the 100-year 10-day snowmelt runoff events were used to evaluate potential flooding and provide design peak flow and HWL information. A 1.5 year magnitude single event was simulated to provide discharge, water level, and volume elevation information representative of higher frequency (smaller) storm events. The 1.5 year magnitude return event generally defines the bank-full elevation in creeks and channels.

Summary information such as the peak discharge and HWL for all modeled basins, structures, and cross-sections is contained in *Volume IV: Watershed Modeling and Discussion, Appendix 1*. Additional information, not easily extracted, remains within the model itself. For example, the unique interactions and timing of water movement within the system are easier to view in the model's dynamic profiles than in a table form.

Other information available from the model includes storm hydrographs and cross sections as shown in Figure II.F.1-15. From this output, the viewer gains insight into regional and local watershed response such as the magnitude and timing of the local versus regional HWL and peak discharge. The time required to return to baseflow is also visible. The 100-year high water levels (HWL) generated for wetlands, lakes and streams as part of the XP-SWMM modeling has been incorporated into flood footprint overlays as shown in Figure II.F.1-16. These flood footprint maps are also available through the GIS interface system created for easier access to output data.

II.F.2. Water Quality

The amount of actual water quality data upon which to evaluate the condition of waterbodies within the watershed is variable. Although some data exist for many years, and thus provides a firm basis upon which to calibrate water quality models for streams and lakes, other areas have little or no data..

The water quality parameters that were modeled were total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Fecal coliform was initially requested by the MCWD. However, through work with the project's Technical Advisory Committee, fecal coliform modeling was eliminated due to the lack of accurate correlations between land use and fecal coliform concentrations, and the difficulties in calibrating a fecal coliform model with existing monitoring data.

Water quality models are constructed using a fair amount of data both as input to model development and as verification of outputs. The routine sampling of creek outflows has provided a number of data points, but these points are not typically keyed to flow. Sample collection in creeks occurred at routine intervals (usually weekly, biweekly, or sometimes monthly), regardless of flow intensities. Sampling during the winter occurred occasionally in the past, but rarely occurs today.

Given the amount of data available, the modeling approach chosen was a loading model (PLOAD) that relies upon published pollutant export coefficients, land use, land cover, and calibrated annual hydrology to estimate loads reaching creeks or other water bodies. The estimated loads are calibrated against calculated annual loads based on monitored data. The models are prepared for current conditions and for predicted future conditions in the year 2020, based on city local comprehensive land use plans as compiled by the Metropolitan Council. Land cover is based on extensive data assembled under the MLCCS described previously and serves as the primary database for the modeling input parameters. The land cover is augmented with the land use in the developed areas of the watershed.

Event mean concentrations (EMCs) for pollutants were developed for each land cover/land use category based on a literature review, knowledge of local water quality monitoring data, and professional assessment. EMCs for modeling purposes are considered the "typical" quality that occurs as a result of a rainfall or snowmelt runoff event. EMC values can be applied to the flow data generated above to predict water quality loading within the watershed. There are some areas within the watershed district with historic wastewater inputs and wetland alterations where these EMC values may not be appropriate. That is, literature values collected on watershed loading do not necessarily reflect the unique local conditions within the watershed where the data are applied. Thus, although the loads generated by the modeling have been calibrated to watershed outflow loads, model results should be considered preliminary until verified with future collected flow-weighted data.

Model calibration was more extensive for the total phosphorus (TP) export model than for the total suspended solids (TSS) and total nitrogen (TN) models. In the MCWD, more monitoring data are available for TP than for the other parameters. For the TSS and TN pollutant loading models, EMCs were mostly determined from literature values, and applied to the runoff volumes calibrated in the TP model. Where TSS and TN monitoring data were available, observed loads were compared to the predicted loads.

II.F.3. In-Lake Modeling

Lake models are empirical tools that use a "best fit" equation to reproduce measured phosphorus, Secchi depth, and chlorophyll-a data. Nutrient concentrations in a cross-section of lakes are a simple function of annual nutrient loading, lake mean depth, and water residence times, which are now the basic components of all commonly used lake models.

A very detailed lake analysis, with in-depth modeling, was done for 14 lakes identified at the beginning of the HHPLS. It became apparent, however, that much more information was needed on additional lakes deemed locally or regionally important, as well as for bays of Lake Minnetonka. As a result, models were prepared for about another 16 lakes, and lake components were done as an integral part of every watershed analysis.

The complexity of the bay drainage system in Lake Minnetonka makes it very difficult in the current HHPLS framework to do a full evaluation of each of the bays. Pollutant inputs to the bays come from external loads, which can generally be quantified, but also from internal sources and from circulation from the rest of Lake Minnetonka, which is not sufficiently quantified. However, due to lake morphology and watershed areas, it was possible to build a preliminary WiLMS model of a subset of the bays. Each of these bays is separated from adjacent bays by a relatively narrow constriction in the lake, and does not have a major bay located upstream, making it easier to determine the drainage areas of these bays. For modeling purposes, phosphorus loads to the bays were assumed to originate either in the watershed or from internal loading; intra-lake circulation (loads originating in adjacent bays) was not taken into account. If more accurate estimates of pollutant loading to the bays are desired, a model of intra-lake circulation must be developed in the future.

II.F.4. Scour and Erosion-Prone Areas

A scour analysis was performed on the six main creek channels in the MCWD using, the 1.5-year storm event (2.6 inch) and the XP-SWMM model. Creek sections with a velocity greater than 1.5 feet per second and local soil composition were used to determine a permissible velocity (see Table II.F.4-1). A 1.5 foot per second average threshold velocity was selected. Ranking criteria for the erosion potential was based on velocity above the established soil permissible velocity. The erosion potential ranking criteria used in this analysis are displayed in Table II.F.4-2 and can be found in the scour analysis sections of *Volume IV: Watershed Modeling and Discussion*.

II.G. BMP Selection

The public input and technical modeling activities both resulted in problem definition and solution recommendations. Integral to that process was the selection of a management scheme that appeared to offer the best promise for success. Recommended management steps then became part of every basin plan reflected in *Volume IV*.

Choosing the proper management practices is an essential element to achieving water quality goals. The Watershed District participated in the development of the *Minnesota Urban Small Sites BMP Manual* in 2001. This manual was prepared to supplement technical assistance that is currently available on larger-scale BMP application.

Throughout the HHPLS effort, the feasibility of using common, effective cold weather BMPs was kept in mind as problems and solutions were discussed. The Regional Team process (*Volume III: Public Involvement*) included presentation of multiple BMP suites that could be used in different applications. The Team members were exposed to the strengths and weaknesses of each suite, and were then asked to recommend specific BMP approaches that had some likelihood for success.

Volume IV: Watershed Modeling and Discussion contains the results of the individual basin assessments that were done for the HHPLS. Throughout this process, BMPs were chosen to achieve a targeted pollutant reduction so that a specific water quality goal could be reached. There also were somewhat generic "stormwater management" recommendations made to encourage improved water management as areas develop or re-develop.

The final selection of BMPs for implementation will not occur until the design stage for any project. The many recommendations made as part of the HHPLS merely provide some thoughts on an effective approach. As techniques improve, new systems become available and data on performance is collected, the view of "effectiveness" might change and selection recommendations revised. Throughout this process, the objective should be to select the best mix of cost-effective BMPs to address the water quality goal of interest.

II.H. GIS Application

The previous discussion on methodology includes parameters that were incorporated via GIS (geographic information system) technology. All of these products will be delivered to the MCWD for its use and further development. A "GIS Tool" is being developed for the District to access the results quickly and easily.

II.I. Implementation Action Priority Ranking

To provide a more effective framework for decision-making and implementation of recommendations of the HHPLS, a ranking was completed for each recommendation. The following criteria applied include:

- <u>Public Access and/or Number of Users Impacted -</u> This parameter gives consideration to whether public access (boat launch, trails, etc.) is provided for the benefited water body. Number of users refers to the number of people either directly or indirectly using the receiving water body. A high ranking is assigned for high use recreational water bodies or those water bodies adjacent to, or within, local and regional parks.

- Visibility of Problem - Resource management problems that are in a highly visible location may have a greater impact on the general publics demand for action. Problems such as erosion, poor water quality and flooding that regularly occur where the problem is perceived as significant by a large number of people receive the highest ranking, while those problems that are not generally visible to the public receive a low ranking.

- High Quality Water or Related Resource - Receiving water bodies with high water quality, high quality wetlands and high quality natural areas are all examples of high quality or related resources. Low quality resources include Lakes with low quality, low quality wetlands and disturbed natural areas.

- Ability to Improve/Protect Downstream Resources - These criteria address the level of positive impact that a given action will have. A high ranking would be assigned to an action that is likely to totally reverse the problem, while a low ranking would be assigned to an action that is unlikely to completely mitigate impacts.

- Costs vs. Effectiveness of Proposed Action - Actions that have a large, positive impact on downstream, receiving waters and yet are low cost are given a high ranking. Actions where the benefits are unclear or low and include high costs are ranked low.

For each action, a final priority ranking of high, medium, or low is assigned. The final ranking of all recommended actions is summarized *Volume IV. Section 6* for each major watershed.

Summary of Volume III - Public Involvement

Volume III contains a discussion of the Regional team (RT) process and summaries of the nine RT technical reports. These results have been folded into the *Volume IV: Watershed Modeling and Discussion* discussions and will not be summarized here to reduce duplication.

Summary of Volume IV - Watershed Modeling and Discussion

Each of the basins or subwatersheds within the Minnehaha Creek Watershed is addressed in *Volume IV: Watershed Modeling and Discussion*. These sections include fairly uniform discussions of basin physical and biological features, existing and future water quantity and quality characteristics, problem identification, and management scenario development. Detailed recommendations are presented for the MCWD to consider for its watershed management program.

The specific *Volume IV* discussion should be referenced for details on any of the material listed above. This portion of the report summarizes the principal findings for each basin.

IV.A. Painter Creek

IV.A.1. Description

The Painter Creek watershed is located in the northwestern portion of the MCWD and within the cities of Medina, Maple Plain, Orono, Minnetrista and Independence (Figure IV.A.1-1). The Painter Creek watershed is 8,667 acres (about 13.5 square miles) in size, and includes 26 subwatershed units. Drainage flows from Katrina Lake, via approximately 6.6 miles of Painter Creek to Jennings Bay. Much of the Creek is ditched, including most reaches passing through South Katrina Marsh, Painter Marsh and the wetland immediately south of Painter Marsh.

The watershed has been influenced by a wastewater discharge from the Maple Plain plant that operated from 1952-1986. This plant was believed to be largely responsible for the degradation of Jennings Bay. Remnants of the discharge still exist in the high phosphorus content of the bay's sediment.

IV.A.2. Issue and Recommendation Summary

Approximately one-third of the total area of the watershed is composed of wetlands, which play a major role in the hydrology and water quality of Painter Creek. In addition, most of these wetlands have been altered with ditches to encourage the movement of water out of wetlands. Since the exact role of these wetlands in the hydrology and nutrient dynamics of the watershed is not fully understood, the District authorized the *Painter Creek Feasibility Study* during 2003. The results of this study will help to define whether wetlands export nutrients, reduce them, or perhaps do both on a seasonal basis.

The role of wetlands in water management is an important issue because of the amount of development expected in the Painter Creek watershed by the year 2020. A transition from agricultural and forest/woodland to urban uses will mean increases in both runoff and pollution load. Management recommendations, therefore, focus on the need to mitigate the impacts of the expected urbanization.

The most serious existing water quantity problems in the subwatershed result from increased runoff from developed areas. Runoff leaving Maple Plain flows in an eroded channel to Katrina Lake and to Painter Creek via several eroded channels to the south. Several other erosive channels are identified in Figure IV.A.4-1.

Jennings Bay has a history of poor water quality. Since Painter Creek contributes the majority of the phosphorus load to the bay, its water quality has been targeted as a substantial pollutant source. A Value Methodology (VM) study was conducted in February 2002 to evaluate alternative approaches to management of Jennings Bay (*Value Methodology Study Expert Panel Report: Lake Minnetonka, Jennings Bay/Painter Creek Water Quality, HDR Engineering, 2002*). A multi-disciplinary panel discussed several scenarios, and evaluated management alternatives for these scenarios. This evaluation and the Regional Team input will be used by the MCWD Board as tools in helping it to make decisions regarding water quality management in the Jennings Bay watershed.

The pollutant loads for TP, TN, and TSS are expected to raise 32%, 25% and 16%, respectively, by 2020 unless measures are taken to hold conditions at current levels. To maintain current pollutant loading rates, the 497 lb. per year increase of phosphorus will need to be removed in the watershed. Similar relative increases in total nitrogen and total suspended solids will also have to be eliminated. Control of this increase begins with good surface water management associated with development.

The reduction in watershed loading will contribute also to the improvement expected for Jennings Bay. A reduction in watershed load together with a significant reduction in internal bay loading should allow the bay to reach the 60 µg/L transition zone between use impairment and limited recreational (body contact) use.

Specific recommendations for action in the Painter Creek watershed include:

- Using the results of the *Painter Creek Feasibility Study* to incorporate wetland management (inclusion or exclusion) into overall watershed runoff management
- Controlling surface water runoff from developed (Maple Plain) and developing (Medina and Minnetonka) parts of the watershed, including District cooperation with the cities on local surface water management and technical guidance on BMPs
- Developing a comprehensive corridor management plan, consistent with the Regional Teams and the VM panel findings that the Painter Creek watershed's wetlands and floodplain could play a more significant role in runoff treatment than they currently do in their ditched forms
- Monitoring of the effectiveness of surface runoff control
- Exploring alum dosing alternatives for Jennings Bay (part of 2003 *Feasibility Study*) required to effectively seal the bottom sediment
- Controlling carp movement into and within the watershed through installation of a flexible fish gate
- Managing horse waste with an effective education program

Table IV.A.6-3 outlines more specific recommendations for a Painter Creek implementation strategy.

IV.B. Dutch Lake

IV.B.1. Description

The Dutch Lake watershed is located along the western boundary of the MCWD and within the Cities of Minnetrista and Mound (Figure IV.B.1-1). The Dutch Lake watershed is 1,888 acres in size (almost three square miles) and includes seven subwatershed units (Figure IV.B.1-2). Flow in the upper part of the Dutch Lake watershed goes through several large wetlands, which eventually outlet into the west side of Dutch Lake. A small stream flows from the northeast corner of Dutch Lake into Jennings Bay of Lake Minnetonka. Wetlands comprise about 20% of the watershed area.

Land use in the north and western portions of the watershed is dominated by agriculture and open space in the form of forests, woodland and wetlands. Moving east through the watershed, land use becomes increasingly dominated by single family residential. As with other urbanizing portions of the Minnehaha Creek watershed, agricultural and forest/woodlands will give way to development over the next 20 years. To protect and enhance the value of the watershed resources, and to minimize further impacts to Jennings Bay, care should be taken to ensure that development impacts are mitigated.

IV.B.2. Issue and Recommendation Summary

The Dutch Lake outlet consists of a poorly maintained culvert which is exposed in a wider channel opening. This culvert frequently washes out. The issue of outlet stability and Dutch Lake fluctuating water levels has been identified in both the City of Minnetrista and City of Mound Surface Water Management Plans. The Metro DNR Waters office stated that work was in progress to address the Dutch Lake outlet with construction of a control dam, but plans are preliminary and no outlet design information is available. Proposed outlet modifications for Dutch Lake should be reviewed to ensure reasonable high water elevations on Dutch Lake, as well as the protection of Dutch Lake creek from potential flow related impacts.

The small creek running from Dutch Lake to Jennings Bay currently experiences erosion at the outlet, and development in the watershed is predicted to increase peak discharge, velocity and volumes received by the creek. To reduce scour potential in the creek, it is important to emphasize both rate and volume control in those developing areas. Local soils and proximity of groundwater may limit the use of volume control practices.

As the Dutch Lake watershed develops, increases of TP, TN and TSS loads generated from the changing land uses are expected to increase by 60%, 35% and 33%, respectively, if measures are not taken to adequately control runoff. The highest current TP loads (per unit area) in the Dutch Lake watershed originate around Dutch Lake and in the area to the northeast of the lake, but the entire watershed is predicted to show increases in phosphorus loading as development proceeds.

The quality of Dutch Lake is currently in the transition zone between non-supportive of swimming conditions and marginally supportive. Attention to surface water management techniques, as identified above, will help in moving the lake toward improved quality. The Regional Team process led to a recommended water quality goal of 40 µg/L TP, which is less than the 1997 MCWD goal.

A mix of agricultural, shoreline and urban BMPs are recommended to reduce pollutant loading within this watershed. Specific recommendations include:

- Stabilizing the Dutch Lake outlet (see previous discussion)
- Minimizing sediment transport in Dutch Lake Creek through erosion control at the lake outlet and in the creek, and through peak discharge and potential volume controls as development occurs
- Dissipating energy at the culvert under Game Farm Road
- Implementing a no net increase in phosphorus loading approach for new development to achieve water quality goals
- Completing an in-lake sediment analysis of Dutch Lake and determining the internal loading potential for future management attention

- Evaluating wetland functions with respect to phosphorus source/sink, using the results of the *Painter Creek Feasibility Study*
- Targeting educational efforts and shoreland BMP grants/funding to direct drainage areas of Dutch Lake and targeting residential BMPs within subwatersheds exhibiting the highest per area loading
- Raise Game Farm Road to increase freeboard over the 100-year HWL.

A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 8*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.C. Langdon Lake

IV.C.1. Description

The Langdon Lake watershed is located along the western boundary of the MCWD and within the cities of Minnetrista and Mound (Figure IV.C.1-1). The watershed is 1,055 acres (about 1.6 square miles), and includes five subwatershed units (Figure IV.C.1-2). Langdon Lake (LL-5) is located at the downstream end of the watershed and is the last in a string of water bodies, including Black Lake and Saunders Lake. Langdon Lake outlets directly into Lost Lake before entering Cooks Bay.

Land use in the watershed changes dramatically across the political boundary between the cities of Minnetrista and Mound. Open space in the form of woodlands, forests, grasslands and maintained natural areas dominates the western portion of the watershed in Minnetrista. The eastern part of the watershed is dominated almost entirely by residential land use types. Single family residential land use surrounds Langdon Lake to the south and north. To the east, the lake is surrounded by commercial and institutional land use. As with many other urbanizing areas, agricultural, grassland and forest/woodlands eventually give way to urban uses as the area develops.

The hydrology of the Langdon Lake watershed is influenced by wetlands, lake large lot rural areas found in Minnetrista, and denser urban development predominantly located in the City of Mound. Despite significant capacity restrictions in several locations, drainage eventually makes its way into Langdon Lake at the downstream end of the watershed.

IV.C.2. Issue and Recommendation Summary

Some parts of the watershed are predicted to experience water quantity problems resulting from increased runoff. Peak flows and volumes should be strictly regulated, especially in the portions of the watershed draining directly to the creek, in order to minimize flooding and increased erosion/scour. Special efforts to minimize sediment transport to Langdon Lake are warranted to avoid exacerbating existing problems in Langdon Lake.

Multiple structures in the Langdon Lake watershed are in need of maintenance and/or repair. Further evaluation/investigation of the structures controlling Black Lake and Saunders Lake is of particular importance due to the current and predicted future development pressures in the subwatersheds containing these lakes. Alterations or repairs of the structures should be implemented prior to or in conjunction with area development. The issue of structure and berm integrity at the outlets of Black and Saunders Lakes has been identified in the City of Minnetrista SWMP.

As the Langdon Lake watershed develops, increases of 52%, 37% and 50% are expected for TP, TN and TSS, respectively, by the year 2020. The majority of the southwest quadrant of the watershed is predicted to change from vacant/agricultural land to single family residential. The highest current TP loads (per unit area) in the Langdon Lake watershed originate from the eastern portion of the watershed. The lowest loading rates are in the less developed areas of the western portion of the watershed. Phosphorus loads in the northwest corner are not predicted to substantially increase.

Langdon Lake is a shallow lake with a mean depth of 8.3 feet. Historically, TP concentrations in the lake have been extremely high, primarily due to the abandoned Mound Wastewater Treatment Plant, which had a capacity of 1.25 MGD, two to three times higher than the other six wastewater treatment plants that operated on Lake Minnetonka. In 1998, the lake was treated with alum and TP concentrations were reduced. However, Langdon Lake still scores a D+ on the 2000 MCWD report card, and by the year 2020, watershed loading is estimated to increase by 52%, from its current level of about 87 µg/L to 111µg/L. Different lake goals were recommended by Regional Teams 6 and 8. The lake itself is located in RT6, with parts of the watershed located in RT8. RT 6 recommended 70 µg/L, while RT8 recommended 50 µg/L. The MCWD will ultimately work with the communities to decide which level should be the goal. (More information regarding the RT6 and 8 goal recommendations can be found in *Volume III: Public Involvement, F. Regional Team 6 and H. Regional Team 8*.)

Watershed load reductions are needed for either of the RT-recommended goals to be reached. Specific recommendations for the watershed include:

- Minimizing erosion and sediment transport in the creek from Saunders to Langdon Lake by emphasizing rate and volume control
- Enhancing or replacing the Saunders Lake and Black Lake outlets
- Investigating the continued influence of the Wastewater Treatment Plant on adjacent wetlands and Langdon Lake
- Retrofitting new stormwater practices into redeveloping areas of Mound and achieving a no net increase in phosphorus for new development.
- Developing a "Roadway Reconstruction Stormwater Management Plan" that incorporates stormwater management improvements and design into roads as they are maintained, upgraded, or newly constructed
- Preserving small wetlands as development pressure increases, with special attention to preservation of a healthy hydroperiod and volume control for areas draining all landlocked pockets
- Monitoring of Langdon Lake to assess phosphorus loading to Lake Minnetonka
- Working with Langdon Lake property owners to implement stormwater management and shoreline BMPs
- Properly maintaining drainage culverts

These recommendations emerged out of discussions as part of the Regional Team 6 and Regional Team 8 public involvement process. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 6 and Regional Team 8*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.D. Six Mile Creek

IV.D.1. Description

The Six Mile Creek watershed is one of the more complex watersheds within the MCWD. It is located along the southwestern boundary of the MCWD and within the cities of Minnetrista, St. Bonifacius, and Victoria, Laketown Township, and Watertown Township (Figure IV.D.1-1). The watershed is approximately 17,000 acres in size (about 27 sq. miles), and includes 66 subwatershed units. Approximately 3,600 acres (~21% of the watershed) are made up of lake and wetland surfaces, which significantly affect the hydrology and water quality behavior of water within the basin.

Lake Pierson, in the southern portion of the watershed, forms the headwaters of Six Mile Creek, which snakes its way north and west through a series of lakes and wetlands before flowing into Halsteds Bay of Lake Minnetonka. Despite its name, Six Mile Creek is approximately 11 miles long from the outlet of Lake Pierson to Halsteds Bay.

The dominant drainage direction of the creek is a northerly direction towards Lake Minnetonka. Pierson Lake, the first in a series of lakes, flows into Marsh Lake and then into Lake Wasserman. Passing through Wasserman, Six Mile Creek flows through a large unnamed wetland, which is also fed by Church Lake and Carl Krey Lake, before flowing into the eastern lobe of Auburn Lake. Also tributary to the eastern lobe of Auburn is Steiger Lake from the east, and Stone, Zumbra and Sunny Lakes from the northeast. From the eastern lobe of Auburn Lake, flow passes through a shallow constriction into the western lobe of Auburn Lake, then through a series of small wetlands (also referred to as the Valley Watershed in the Carver Park Reserve Water Management Plan) before dropping six feet in elevation to the controlled normal water elevation of Lunsten Lake. Very low grade exists between the Zumbra/Sunny Lake system and the controlling rip-rap weir outletting the Valley Watershed wetlands downstream of Auburn.

The Lunsten Lake outlet represents the second significant control point of Six Mile Creek. In addition to the main stem of Six Mile Creek, Lunsten Lake receives tributary discharge from the

Turbid Lake system to its south. The outlet of Lunsten Lake is controlled by a concrete weir structure that delivers discharge to Parley Lake (SMC-47) approximately 4.6 feet in elevation beneath Lunsten Lake. This elevation drop can vary slightly, depending on the elevation of Lake Minnetonka, which can influence the water elevations in the entire lower stretch of Six Mile Creek.

The lower stretch of Six Mile Creek flows through Parley Lake, into Mud Lake, and then through a large wetland (essentially part of Lake Minnetonka) before emptying into the open water portion of Halsteds Bay of Lake Minnetonka. The channel elevation of Six Mile Creek connecting Parley, Mud and Halsteds is lower than the average water elevation of Lake Minnetonka. For this reason, water surface elevations in Lake Minnetonka can have a significant influence on the elevations of Parley and Mud Lakes. Tributary to Mud Lake is drainage from the southern portion of the City of Minnetrista and a large portion of St. Bonifacius.

Land use throughout the watershed is primarily agricultural (about 25%). Residential and commercial land uses within this watershed are primarily confined to the cities of St. Bonifacius and Victoria. Wetlands, forests, woodlands, and grasslands together make up approximately 40% of the landscape. "Natural" areas are primarily confined to the area of Carver Park Reserve (surrounding Lakes Steiger, Auburn, Lunsten, and parts of Zumbra).

Following the same pattern as other developing areas within the MCWD, the biggest percent decreases in 2020 land use are expected for agricultural land and forests/woodlands categories.

The hydrology of the Six Mile Creek watershed contains a few areas of urban development, but is dominated by expansive wetlands, lakes, undeveloped park land and rural areas. Areas of urban residential development include the City of Victoria, City of St. Bonifacius and along the Hwy 7 corridor. The highest density landscape exists in the downtown districts of Victoria and St. Bonifacius. As development proceeds, more parts of the watershed will deliver increasing amounts of runoff. The greatest increases in impervious surfaces are generally predicted to occur in the subwatersheds in and around the Cities of Victoria, St. Bonifacius and parts of Minnetrista along the Hwy 7 corridor.

As Six Mile Creek develops, an opportunity exists not only to protect and maintain resource status, but to make improvements to existing problem areas such as drainage restrictions along Hwy 7 south of St. Bonifacius and water quality problems in Halsteds Bay. The greatest potential for bay improvement exists in areas draining into the lower reaches of Six Mile Creek.

IV.D.2. Issue and Recommendation Summary

Some water quantity related problems are expected to result from the development occurring within the watershed. Areas of the watershed predicted to have a more significant impact on water resources resulting from 2020 land use changes include areas in the City of Victoria and along the Hwy 7 corridor. For example, a wetland located in subwatershed SMC-54 on the northern most tip of the watershed is expected to see high water levels increase 0.5 feet for the 100-year storm event, and high water levels in wetlands on the eastern side of the City of Victoria are predicted to increase 0.3-0.4 feet. Several other predicted HWL increases along the Hwy 7 corridor include wetlands showing modeled increases of 0.3 feet. These wetlands contribute to Mud Lake, which is the last of the Six Mile Creek lakes prior to discharge into Halsteds Bay.

Additional impacts to Six Mile Creek include increased erosion and scour potential due to additional discharge and increased velocities associated with 2020 land use changes. An overall increase of about 30 cfs for the 100-year storm event is predicted to discharge into Halsteds Bay by 2020. Many other areas will experience local increases of 10 cfs or greater.

Special efforts to minimize sediment transport, especially in the lower reaches of Six Mile Creek, are warranted to avoid exacerbating existing problems in Halsteds Bay.

The Carver Park Reserve represents approximately 25% of the area contributing to Six Mile Creek and ultimately to Halsteds Bay. As such, the District should make collaboration with the Carver Park Reserve a priority. The District could, in collaboration with the Park Management, play a key role in facilitating the development of an up-to-date and more structured water management plan that integrates multiple objectives of the park, county, cities, residents and District. This is especially needed for flow structure renovation.

Other quantity related recommendations include:

- Evaluating the Zumbra/Sunny Lake flow/connection system for flood reduction
- Adopting strong volume control standards in all areas draining to landlocked depressions; using low impact development techniques as these areas develop
- Adopting inlet and outlet erosion control measures or energy dissipation designs for identified erosive areas
- Correcting several local flooding problems before 2020 conditions make them worse

Due to both the size of the watershed and its land uses, pollutant loads from the Six Mile Creek watershed are high, contributing to the high nutrient levels in Halsteds Bay. Overall, 2020 pollutant loads in the watershed are expected to increase by 53%, 26% and 32% for TP, TN and TSS, respectively. The highest TP loads (per unit area) in the Six Mile Creek watershed originate from the urbanized portions of the cities of St. Bonifacius and Victoria. The areas of lowest loading rates are in the mostly undeveloped Carver Park Reserve, located surrounding Steiger Lake, Stone Lake, Auburn Lake, and Lunsten Lake. Phosphorus loads in this area are not predicted to substantially increase by 2020.

The water quality of nine lakes within the watershed was evaluated. The lakes range in TP levels from a low of 39 μg/L for Steiger and Pierson, to a high of 85 μg/L for Parley. Many of the lakes relate to each other because they occur in sequence along the creek path. Lakes Wasserman and Parley are listed as impaired waters on the MPCA 303d list.

RT7 recommended new goals for each of the nine lakes, with five of the lakes suggested more stringent than the 1997 MCWD watershed plan. Specific load reductions needed to achieve the lake goals are documented in Table IV.D.5-4.

The Six Mile Creek watershed is the second largest tributary system draining to Lake Minnetonka, excluding Lake Minnetonka itself. The Six Mile Creek watershed is unique in that it contains thirteen lakes and numerous other smaller lakes and wetlands, all of which are generally interconnected with the creek and its tributaries. The Six Mile Creek watershed is also unique in that it contains the largest area of contiguous agricultural land in the District. The often steep to moderately rolling topography, erodible soils, and extensive network of drainage tiles present special challenges, both for existing agricultural land uses, as well as for future residential development.

Specific recommendations for Six Mile Creek and its lakes and wetlands include:

- Preserving landlocked depressions through strict volume control standards as the watershed area develops
- Expanding water quality monitoring sites along Six Mile Creek
- Conducting a tile and ditch inventory of agricultural land
- Implementing a "green corridor" approach for Six Mile Creek and its major tributaries, in cooperation with willing landowners
- Encouraging the use of agricultural, lakeshore, erosion control and urban BMPs, and providing technical assistance related to them
- Evaluating Tellers Road feedlot and the feasibility of wetland treatment system for Pierson Lake
- Implementing boat access shoreland demonstration sites to educate lake residents on shoreline BMPs, including buffers
- Implementing feedlot and pasture management plan for Lake Wasserman
- Undertaking an environmental impact analysis of Six Mile Creek dredging before further consideration is given to this proposal
- Improving the drainage system south of Hwy 7 in St. Bonifacius into Mud Lake
- Installing energy dissipation and erosion control at culverts with high pipe velocities
- Installing and/or protecting lake and wetland buffers, especially on steep slopes and areas where shoreline erosion is occurring
- Stabilizing erosive channel reaches
- Working with the City to Victoria to incorporate effective stormwater management into existing and new development
- Constructing various wetland/treatment pond systems

- Preparing a lake management plan for Mud and Turbid Lakes
- Evaluating the need for Turbid and Lunsten Lake feedlot management
- Partnering with private landowners to implement stormwater improvements
- Developing a Six Mile Creek rough fish management plan
- Updating the Carver Park Reserve stormwater management plan
- Developing a showcase LID development in Laketown Township.

These recommendations emerged out of discussions as part of the Regional Team 7 and Regional Team 8 public involvement process. A complete presentation of the recommendations made for this watershed can be found in *Volume III: Public Involvement, Regional Team 7 and Regional Team 8*. This includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.E. Long Lake Creek

IV.E.1. Description

The Long Lake Creek watershed is located to the north of Lake Minnetonka and within the cities of Medina, Orono, and Long Lake (Figure IV.E.1-1). The watershed is 8,215 acres in size (about 12.8 sq. miles), and includes 53 subwatershed units. Long Lake is situated approximately in the middle of the basin.

Land use in the watershed varies dramatically, from predominantly row crop agriculture and open space comprised of large wetland complexes and forest land, to high density residential development. The most intense land use in the Long Lake Creek watershed is in the city center of Long Lake along the Hwy 12 corridor. "Natural areas" are common throughout the landscape, with wetlands, forests, woodlands, and grasslands comprising about 48% of the landscape; however, dramatic population growth is expected by the year 2020, resulting in loss of some natural areas, higher runoff and poorer water quality.

IV.E.2. Issue and Recommendation Summary

Areas of the watershed predicted to have a more significant impact on water resources resulting from 2020 land use changes are concentrated in the subwatersheds in the City of Long Lake and along the Hwy. 12 corridor portions of Orono. Peak rate and volume controls should be implemented as this area continues to develop.

Landlocked basins in the subwatershed are particularly sensitive to stormwater volumes. For this reason, strong volume control standards are recommended in all areas draining to landlocked areas and pockets of smaller unconnected wetlands throughout the watershed. It is also recommended that low impact development (LID) techniques be employed as the area develops and that the function of the pocket wetland areas be retained.

Several channel reaches with potentially high velocities occur. It is recommended that inlet and outlet erosion control measures or energy dissipation designs are implemented in these areas.

Modeling of the Long Lake Creek watershed predicted that several roads and trails would overtop during larger storm events. There are also a number of roads and trails modeled under existing and proposed conditions that show 100-year water levels close to overtopping the roads and within the freeboard (two feet) required by the District.

Large portions of the northern part of the watershed that are currently undeveloped are slated for rural residential and single family residential land uses by the year 2020. Effective management of runoff from these areas is essential to achieving the recommended Long Lake water quality goal. To achieve the recommended goal of 40-50 µg/L TP for Long Lake, the maximum TP load must remain constant near current levels rather than increase as the subwatersheds upstream of the lake develop.

Before additional alum treatments to Long Lake are considered, the reasons behind the short-lived benefit should be determined. Decisions with respect to the use of alum treatment as a management tool to improve water clarity must also take into account the increased macrophyte growth that follows treatment.

Tanager Lake is located at the bottom of the Long Lake Creek watershed, and flows into Browns Bay of Lake Minnetonka. Tanager is of poor water quality because it essentially serves as a treatment basin for the Long Lake Creek watershed outflow. RT4 recommended a goal of 70 µg/L TP for Tanager, but data are needed to show both current and future water quality. For Browns Bay, currently at a very clean, fully supportive level of 22 µg/L TP, the Team suggested a goal of 20 µg/L TP. Reductions in TP load to attain all of these goals are recommended in the subwatersheds draining to the impacted waterbodies.

Monitoring data and modeling indicate that several stormwater ponds in the Long Lake Creek watershed perform poorly relative to TP removal. Recommendations are made to restore the performance of the ponds to an effective pollutant removal level.

Specific management recommendations for Long Lake Creek include:

- Controlling the volume of water flowing to landlocked basins
- Dissipating energy at critical culverts to prevent further erosion
- Improving the performance of several existing water quality improvement ponds
- Collecting data for Tanager Lake so that a management strategy can be implemented
- Addressing various local drainage and sediment accumulation problems
- Instituting effective runoff controls for Long Lake Creek between the Long Lake outflow and Tanager Lake
- Establishing peak rate and volume control to streams/tributary creeks as the watershed continues to develop
- Monitoring the effectiveness of the new carp gate

A complete presentation of the recommendations made for this watershed by Regional Team 4 can be found in *Volume III: Public Involvement, D. Regional Team 4*. This includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken. The majority of the Long Lake Creek watershed is located within RT4. A small segment in the northeastern portion of the watershed is located in RT3; however, due to the relatively small area of the Long Lake Creek watershed within RT3, this team did not deal with Long Lake Creek watershed issues.

IV.F. Gleason Lake Creek

IV.F.1. Description

Gleason Lake Creek is located in the north-central portion of the MCWD and within the cities of Plymouth, Wayzata, Orono, and Minnetonka (Figure IV.F.1-1). The watershed is 3,765 acres in size (about 5.9 square miles), and includes sixteen subwatershed units including the Hadley Lake drainage. Gleason Lake Creek flows into Gleason Lake from the north, and then out of the Lake on the southwest corner, joining with the Hadley Lake drainage to flow into Wayzata Bay.

The Gleason Lake Creek watershed is dominated almost entirely by single- and multi-family residential land uses. On the whole, the watershed has urbanized and very little open space or natural areas remain, so little change is expected by 2020 in runoff character.

The hydrology of the Gleason Lake Creek watershed is influenced primarily by urban development (high and medium density), lake, and wetland areas. Only a very small area of rural development remains in the northern most tip of the watershed. This northern area is served by Hwy. 55 and is developing very rapidly. It is expected to be converted to commercial and industrial land use in the very near future.

IV.F.2. Issue and Recommendation Summary

Some erosion and high flow problems currently occur in the watershed (Table IV.F.5-1). Peak flows and volumes should be strictly regulated for all new development in the watershed to minimize increased erosion and scour in Gleason Lake Creek and protect the water quality of the resources.

Although increased loads are not expected, under current conditions TP loads (per unit area) in the watershed are relatively high, with lower than average loads in the subwatersheds that contain lakes. The Gleason Lake Creek watershed contains a high proportion of single family residential land uses, with some blocks of multi-family land use mixed in. Commercial and highway uses dominate the far northern subwatersheds. TP loads are predicted to remain relatively stable, due to the fact that these watersheds are nearly fully developed already.

Not unexpectedly, Gleason Lake has a very high TP concentration at 121 µg/L, which should not worsen by 2020. This level is far into the non -supportive range for swimmability. RT3 recommends an interim water quality goal of 80 µg/L, and a longer-term goal of 50 µg/L, which would bring the lake into the partially supported range. Hadley, Snyder and Kreatz are all recommended for some data collection to establish current TP levels, followed by a goal determination of 10% less than observed. Load reductions are suggested only for Gleason.

Specific recommendations for Gleason Lake Creek include:

- Addressing localized flood control and flow structure problems
- Establishing in-lake water quality goals for all watershed lakes, assuming some data are collected for Hadley, Snyder and Kreatz Lakes
- Continuing the macrophyte evaluation of Gleason Lake
- Undertaking channel and shoreline erosion stabilization and restoration at locations identified in the Gleason Lake Management Plan
- Promoting progressive stormwater management to protect resources in newly developing areas
- Working with GLIA and the cities to reduce pollutant runoff.
- Expanding the water quality monitoring program to address all lakes and better address Gleason Lake Creek inflow to Gleason Lake
- Using the stocking program to maintain a piscivore fishery and maintain a proper ecological fish balance
- Continuing winter-only aeration of Gleason Lake to prevent fish kills
- Dissipating energy at culverts under County Roads 101 and 6
- Minimizing sediment transport
- Continuing the goose management program
- Working with GLIA to implement the results of its Gleason Lake Management Plan

These recommendations emerged out of discussions as part of the Regional Team 3 and Gleason Lake Improvement Association public involvement processes. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 3*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.G. Schutz Lake

IV.G.1. Description

The Schutz Lake watershed is located along the southern boundary of the MCWD and within the city of Victoria (Figure IV.G.1-1). The watershed is 969 acres in size (about 1.5 square miles), and includes four subwatershed units, which flow nearly due north into Smithtown Bay of Lake Minnetonka. Schutz Lake is the major hydrologic feature within this watershed.

Land use in the northern part of the Schutz Lake watershed is split fairly evenly between the open space found in Carver Park Reserve and residential land use types found in the east. The southern part of the watershed is dominated by agricultural and residential land uses. Essentially all of the agricultural land and mush of the forest/woodlands will disappear by 2020 as development proceeds.

IV.G.2. Issue and Recommendation Summary

Modeled land use changes associated with predicted 2020 conditions did not produce significant runoff impacts in the Schutz Lake watershed. The greatest flow impacts predicted are in the creek running through the watershed. As this area continues to develop (perhaps beyond 2020) standard peak rate and volume controls should be implemented to ensure the quality of resources are preserved.

Potential channel erosion at the outlet of Schutz Lake and the North Schutz Lake wetland needs to be assessed further. No other quantity related problems were documented.

As the Schutz Lake watershed develops, increases of 46%, 39% and 23% are expected for TP, TN and TSS, respectively. Under current conditions, TP loads (per unit area) in the Schutz Lake watershed are relatively low, with slightly lower loads in the northern subwatershed, the majority of which is located within Carver Park Reserve. TP loads are predicted to increase in the southern portion of the watershed due to a portion of the "vacant/agricultural" land being planned for single family residential land use by the year 2020.

There are no in-lake TP concentration data for Schutz Lake, but modeling indicates that the TP level is approximately 52 µg/L, or slightly within the partially non-supportive range. The RT7 recommendation for a water quality goal for Schutz is 40 µg/L.

Specific recommendations for the Schutz Lake watershed include:

- Working with the Schutz Lake homeowners to implement stormwater management practices, such as ponding, infiltration, rain gardens, and riparian buffers
- Incorporating effective stormwater management into reconstruction of roads and other common infrastructure as improvements are made
- Maintaining pollutant loading from new development at predevelopment levels
- Expanding MCWD water quality monitoring program to include Schutz Lake baseline trend information
- Encouraging the use of agricultural BMPs, such as minimum tillage, contour farming, terracing, riparian buffers and vegetative filter strips
- Conducting a tile and ditch inventory to locate and map tile/ditch locations, verify drainage area boundaries, estimate discharge rates, and where appropriate, collect grab samples for water quality analysis
- Installing and/or protecting lake and wetland buffers
- Assessing damaged culverts and channels

These recommendations emerged out of discussions as part of the Regional Team 7 public involvement process. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 7* , which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.H. Lake Virginia

IV.H.1. Description

The Lake Virginia watershed (including Lake Minnewashta) is located along the southern boundary of the MCWD and within the cities of Victoria, Chanhassen, and Shorewood (Figure IV.H.1-1). The watershed is 3,990 acres in size (about 6.2 square miles), and includes sixteen subwatershed units representing the Lake Minnewashta drainage area, and the portion of the Lake Virginia watershed downstream of Lake Minnewashta). The watershed flows into Smithtown Bay. Figure IV.H.1-2 shows the subwatersheds and their drainage configuration.

Land use north and west of Lake Minnewashta is dominated by single family residential. Lake Minnewashta Regional Park lies to the east of the lake. Within the park, land use is dominated by forest, woodland, wetland and grassland. South of Highway 5, the watershed is also dominated by open space land use types (forest, woodland and wetland). Repeating a common theme in the Minnehaha Creek watershed, much of the agricultural and non-public forest/woodland will change to urbanized uses by 2020.

The hydrology of the Lake Virginia and Lake Minnewashta watershed is influenced by a mixture of rural and urban residential development, lake, and wetland areas. The most concentrated development of the watershed is along the Hwy 7 corridor which runs between Lake Minnewashta and Lake Virginia. As new areas develop, care should be taken to ensure development does not negatively impact the watershed resources.

IV.H.2. Issue and Recommendation Summary

Although 2020 conditions do not predict significant increases in either HWLs or peak discharge, development flows and volumes should continue to be regulated to ensure continued health of the watershed resources, especially within the portion of the watershed that is landlocked. Some minor flooding and erosion problems are noted within the watershed.

As the Lake Virginia watershed develops, increases of 21%, 20% and 21% are expected for TP, TN and TSS, respectively, from the changing land uses. Under current conditions, TP loads (per unit area) in the Lake Virginia watershed are relatively low, with one subwatershed in the northeast portion of the watershed having a higher load (Figure IV.I.5-1). This subwatershed contains a higher proportion of single family residential and commercial land uses than the others. TP loads are predicted to increase upstream of Lake Virginia due to a portion of the "vacant/agricultural" land being planned for single family residential land use by the year 2020, with some multi family residential land use as well.

For Lake Minnewashta, the lake model predicts that in-lake TP concentrations will remain at 22 μg/L from existing to 2020 conditions. Current TP loads to the lake are relatively low, and future development in the watershed is also predicted to be low, leading to predicted stable in-lake TP concentrations. This level is within the fully supportive range for swimming, thus representing one of the best lakes within the MCWD. RT7 recommends that a new goal of 20 μg/L be adopted.

Lake Virginia is expected to increase from 46 μg/L currently to 52 μg/L by the year 2020 as a result of land use changes (Table IV.H.5-3). These values are both within the partially impaired range. RT7 recommends that a new goal of 40 μg/L be adopted.

In general, the recommendations for this watershed focus on protecting the water quality of Lake Minnewashta by maintaining or slightly reducing phosphorus loads, while seeking to achieve significant load reductions for Lake Virginia. Specific recommendations include:

- Encouraging shoreline buffers, especially where lawns extend to the lake's edge, on steep slopes and where shoreline erosion is occurring
- Implementing boat access shoreline buffer demonstration sites that should include educational signage targeted to residents and nonresidents of the lake
- Retrofitting existing developed areas with stormwater BMPs
- Evaluating outlet and channel repair and maintenance needs
- Maintain predevelopment stormwater volumes in landlocked basins
- Emphasizing rate control to minimize erosion and sediment transport

- Maintaining natural hydroperiod in sensitive wetlands.

Several of these recommendations emerged out of discussions as part of the Regional Team 7 public involvement process. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 7*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.I. Christmas Lake

IV.I.1. Description

The Christmas Lake watershed is located along the southern boundary of the MCWD and within the cities of Chanhassen and Shorewood (Figure IV.I.1-1). The watershed is approximately 742 acres in size (about 1.2 square miles), and includes five subwatershed units (Figure IV.E.1-2). Christmas Lake is one of the most pristine lakes in the metropolitan area. Surface flows in the Christmas Lake watershed are routed primarily though a system of culverts connecting small depressions. Flows are received by small pocket wetlands (some landlocked on the north and west sides of the watershed) and then Christmas Lake before ultimately discharging into St. Albans Bay.

Because Christmas Lake is the dominant water body at the center of this small watershed, lakes and open water dominate the land use categories, followed by single family residential. Within this residential setting, isolated undeveloped pockets of woodland, forest and other natural areas exist. Land use immediately adjacent to Christmas Lake is primarily single family residential. Very little additional development is expected for the watershed, but some transition from forest/woodland to urban will occur. The most concentrated development of the watershed is along the Hwy 7 corridor which runs between Christmas Lake and St. Albans Bay of Lake Minnetonka (Figure IV.I.1-1).

IV.I.2. Issue and Recommendation Summary

Although 2020 conditions do not predict significant increases in either HWLs or peak discharge, development flows and volumes should continue to be regulated to ensure continued health of the watershed resources, especially landlocked basins. It is recommended that low impact development techniques be employed as the area develops and that the function of the landlocked pocket wetland areas be retained. Particular attention to volume control and green space planning will greatly ease that burden. Also, some small erosive and high water areas were identified by RT5.

The Christmas Lake watershed is already fully developed; therefore, pollutant loads are expected to increase only minimally (Table IV.I.5-1). Under current conditions, TP loads (per unit area) in the Christmas Lake watershed are relatively low, with a small area of higher loads in the northeast subwatershed. This subwatershed has a higher proportion of single family residential land uses than the other subwatersheds. TP loads are predicted to remain relatively constant.

Current TP levels in Christmas Lake are at an amazingly low 15 μg/L, well within the fully supportive swimming range. For Christmas Lake, the lake model predicts that in-lake TP concentrations will increase slightly to 17 μg/L from existing to 2020 conditions. Current TP loads to the lake are relatively low, and future development in the watershed is also predicted to be low, leading to predicted stable in-lake TP concentrations. RT5 recommends establishing a goal of 15 μg/L TP.

Christmas Lake has the highest water quality of any lake in the MCWD. This condition is due to a combination of factors including lake morphometry, small watershed to lake ratio, low levels of impervious surfaces, substantial areas of native vegetation, and probable strong groundwater-surface water interaction. The general approach, therefore, is to maintain and protect the existing conditions that, taken together, sustain the high quality of Christmas Lake. Since much of the lake is well buffered by natural vegetation and receives minimal runoff, the recommendations are focused on managing the shoreline buffer, minimizing stormwater runoff and addressing several areas of known erosion.

Specific recommendations include:

- Stabilizing the Christmas Lake tributary from the south to prevent further erosion, provide additional storage opportunities and maintain existing landlocked pockets
- Protecting against bluff-line and shoreline erosion
- Controlling stormwater volume, especially in the landlocked portions of the watershed; where possible, stormwater infiltration should be used to lower the rate and volume of stormwater runoff from existing and new development
- Maintaining all landlocked basins

These recommendations emerged out of discussions as part of the Regional Team 5 public involvement process. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement, Regional Team 5*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

IV.J. Lake Minnetonka Direct

IV.J.1. Description

The Lake Minnetonka direct drainage area covers approximately 23,330 acres (about 36.5 square miles). This area includes the surface area of the lake itself (approximately 13,980 acres), which covers a little over half of the total area, as well as that area that drains directly into Lake Minnetonka. It contains portions of Orono, Wayzata, Minnetrista, Minnetonka, Shorewood, Woodland, Mound, Deephaven, Minnetonka Beach, Spring Park, Tonka Bay, Excelsior, and Victoria (Figure IV.J.1-1). The direct drainage area includes 26 subwatershed units (Figure IV.J.1-2).

Surface water (in the form of lakes and bays) covers half the total area in the Lake Minnetonka Direct watershed. In remaining areas, land use is dominated by single family residential. Isolated pockets of forest and woodland are common throughout the watershed, covering slightly more than 10 percent of the upland landscape. Commercial and industrial land uses are concentrated along major transportation corridors such as County Road 15 and State Highway 7. Under 2020 land use conditions, losses are expected to occur in the agricultural land and forest/ woodlands categories.

IV.J.2. Issue and Recommendation Summary

The hydrology of the direct drainage watershed is influenced primarily by low lying wetlands around the fringe of Lake Minnetonka, Lake Minnetonka itself, and stormwater runoff into the lake from immediately adjacent areas. The Lake Minnetonka Direct Drainage has, therefore, been modeled as one subwatershed, which is internally divided into two areas – the lake itself and the immediately adjacent drainage areas. No specific flooding or structure overtopping is indicated by the model for this watershed. However, structures adjacent to Lake Minnetonka near the HWLs computed for this study are at risk of flooding when large single or multiple storm events and/or prolonged wet periods occur.

The identification of lakeshore erosion areas was conducted primarily at the Regional Team meetings, when participants were asked to locate any known erosion areas on a map of the area represented. The RT 5 and 6 meetings identified several locations of lakeshore erosion. These locations are detailed in *Volume III. Public Involvement, E. Regional Team 5 (Figure III.E-1), and F. Regional Team 6 (Figure III.F-1)*. This does not necessarily mean that these are the only erosive locations in Lake Minnetonka; rather, it indicates that the regional team members have only seen these specific problems.

The direct drainage area to Lake Minnetonka is nearly fully developed; therefore, pollutant loads are expected to increase only minimally by the year 2020, with only about a 10% increase in TP, TN and TSS by 2020. The highest TP loads (per unit area) in the Lake Minnetonka direct drainage area originate around Stubbs Bay and Crystal Bay (Figure IV.J.5-1). These areas have less natural areas on the average than the other subwatersheds. The majority of the subwatersheds' loads are not expected to increase by 2020, due to the already fully developed nature of the drainage area.

Water quality goals for 26 of the Lakes Minnetonka bays located within this watershed are recommended in the text. Most recommendations reflect a substantial change from the MCWD's 1997 goals. Without a Lake Minnetonka model, it is difficult to estimate the load reduction necessary to achieve a specified in-lake phosphorus goal. Many of the Lake Minnetonka bays are of relatively good water quality and are at or near their proposed goals; therefore the P loads entering these bays should not be allowed to increase, in order to prevent any degradation in the water quality of the bays.

In addition to the in-lake goal for the bays, specific total phosphorus goals for all of the areas that drain directly into Lake Minnetonka were developed. These were long-term goals designed to achieve a specified total phosphorus flow-weighted mean (FWM) concentration in the runoff. The average FWM concentration for streams in this ecoregion (North Central Hardwood Forests) is 100 µg/L, and this figure is often used as a standard. However, urban streams on average have greater concentrations of TP, and their FWMs consistently range from 300 to 500 µg/L. Therefore, an intermediate FWM concentration of 150 mg/L was selected.

Specific recommendations include:

- Installing a cable skimmer and conducting continuous flow monitoring at Grays Bay Dam
- Retrofitting stormwater improvements into redeveloping urban areas
- Conducting an inventory of natural/constructed stormwater ponds
- Developing a roadway reconstruction stormwater plan that incorporates stormwater management improvements and design into roads as they are maintained, upgraded, or newly constructed
- Working with lakeshore residential development and redevelopment to encourage more low impact approaches
- Drafting language for rules and model ordinances that address shoreline buffers, steep slopes, erosion/sediment control, and bank stabilization within the context of lakeshore redevelopment
- Expanding the District's Water Quality Monitoring Program to lakes and/or tributaries of minor and direct drainage watersheds
- Conducting an analysis of Lake Minnetonka water levels using the new HHPLS tools
- Conducting a Lake Minnetonka shoreline erosion inventory and shoreline stabilization pilot project
- Developing a whole-lake water quality model for Lake Minnetonka
- Controlling carp on Lake Minnetonka tributaries
- Working with other entities to support efforts to minimize boating-related impacts

These recommendations emerged out of discussions as part of the public involvement process for Regional Teams 3, 4, 5, 6, and 8. Additional issues and management recommendations were identified as part of this process. A complete presentation of the recommendations can be found in *Volume III: Public Involvement*, which includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a relative recommendation of when the approach should be undertaken.

IV.K. Minor Watersheds

IV.K.1. Description

Nineteen small watersheds are grouped under the term "minor watersheds" for purposes of this report. Some of these represent a group of subwatersheds that drain into the direct drainage areas described in the previous section and in *Volume IV.J*. None of these watersheds contain lakes that were modeled as part of the water quality portion this report.

These minor watersheds are located around Lake Minnetonka, within the cities of Chanhassen, Deephaven, Excelsior, Minnetonka, Minnetrista, Mound, Orono, Shorewood, Tonka Bay, Wayzata, and Woodland (Figure IV.K.1-1). The total area covered by these watersheds is approximately 9,176 acres (about 14.3 square miles). Details on the watershed configurations are given in Figure IV.K.1-2.

Land use in the minor watersheds changes dramatically from one area to another. Generally, as one moves east through the watershed, land use becomes more intense. In the minor watersheds to the north and west of Lake Minnetonka, land uses are primarily dominated by agriculture and open space, with varying amounts of single family residential land use. The watersheds to the south and east of Lake Minnetonka are generally dominated more by single family residential and commercial land uses. Typical of other developing areas in the MCWD, the biggest change in land use by 2020 will be a gain in single family residential at the cost of agricultural land and forest/woodlands.

The hydrology of this watershed is dominated by runoff from small tributary sub-watersheds into bays of Lake Minnetonka. However, several landlocked drainage basins exist around the lake.

IV.K.2. Issue and Recommendation Summary

Potential increases in both flow and water pollution are expected for the Halsteds Bay and Peavey Lake subwatersheds as they develop over the next 20 years. The landlocked basins and depressions in the minor watersheds area are particularly sensitive to additional stormwater volumes. For this reason, strong volume control standards are recommended in all areas draining to landlocked areas.

As the minor watersheds develop, increases of 16%, 18% and 14% are expected for TP, TN and TSS, respectively, from the changing land uses. Impervious cover is expected to increase only slightly (Figure IV.K.2-2). Watershed pollutant loads in the minor watersheds vary, with the highest TP loads (per unit area) originating towards the eastern portion of Lake Minnetonka (Figure IV.K.5-1). These areas have less natural areas on the average than the other subwatersheds. The magnitude of the predicted load increases by the year 2020 varies across the area.

There were no lakes modeled for water quality within the minor watersheds area. However, several goals were recommended by the regional teams for lakes in these watersheds.

Specific recommendations for the minor watersheds include:

- Retrofitting new stormwater practices into redeveloping urban areas adjacent to Lake Minnetonka not presently receiving adequate stormwater management
- Preserving and managing landlocked basins and pockets (maximize infiltration, bounce, and retention)
- Implementing volume control standards in all subwatersheds draining to or containing landlocked depressions
- Placing special emphasis on control of runoff to Halsteds Bay
- Achieving a no net increase in phosphorus loading for new development
- Developing a "Roadway Reconstruction Stormwater Management Plan" for areas adjacent to Lake Minnetonka
- Working with riparian property owners to implement stormwater and shoreline BMPs
- Incorporating the monitoring of lakes and tributaries within minor watersheds into the District's water quality monitoring program
- Adopting water quality goals for lakes within minor watersheds
- Conducting an inventory of natural and constructed stormwater ponds

- Maintaining stormwater ponds
- Keeping landlocked basins closed as long as problems do not occur

A complete presentation of the recommendations made for this watershed by the Regional Teams can be found in *Volume III: Public Involvement*. This includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken. The minor watersheds discussed in this section of the report are located in every Regional Team except Regional Team 9.

IV.L. Minnehaha Creek

IV.L.1. Description

This report segment addresses the portion of the Minnehaha Creek watershed that is located *downstream* of Grays Bay dam (Figure IV.L.1-1). It is also referred to as the "lower watershed" comprised of 30,920 acres (about 48 square miles) in 184 subwatersheds. The total length of Minnehaha Creek below Grays Bay dam is 21-miles. Thirty-five lakes are located in this portion of the MCWD. Also discussed in this report section are several subwatersheds (Wood/Grass Lake, Powderhorn and Mississippi River direct) totaling 2,417 acres (about 3.8 square miles) that are located within the political boundaries of the MCWD, yet are non-contributing to Minnehaha Creek.

Land use within this part of the watershed is dominated by single family residential. Blocks of parks and recreational areas are scattered throughout the watershed, in addition to areas with a high concentration of commercial and industrial land uses. Percent imperviousness is on the average higher in the eastern portion of the watershed. Very little change in land use will occur by 2020.

More so than the upper part of the Minnehaha Creek Watershed, groundwater plays a significant hydrologic role in this lower portion. The creek changes in its recharge and discharge character as it traverses the distance from Grays Bay to the Mississippi River. A substantial portion of the lower watershed has high infiltration potential based on the soils and depth to bedrock. This would tend to favor infiltration as a possible BMP retrofit.

IV.L.2. Issue and Recommendation Summary

Problems in the "lower" part of the watershed relate to both flow and water quality. High flows have led over the years to several areas where erosion is a concern. Nearly 120 creek sections ranging from 5 to 1000 feet in length were found to have high erosion potential. These areas are particularly problematic because channel erosion deposits material directly into the creek, immediately degrading water quality.

Among the findings of the RT1 and 2 discussions is the identification of several reaches in the Creek where accumulation of sediment has reduced channel capacity. Identification of these problems areas and potential solutions was a high priority for the RTs.

As the Minnehaha Creek watershed develops, small increases (6-11%) are expected in the pollutant loads (TP, TN and TSS) generated from the changing land uses since impervious cover is expected to increase only slightly. Under current conditions, TP loads (per unit area) in the Minnehaha Creek (lower) watershed are lower in the western portion, with several areas of high pollutant loads throughout the rest of the watershed (Figure IV.L.5-1). TP loads are not predicted to increase substantially by the year 2020.

Of the nine lakes that were modeled in the lower watershed, five (Lake of the Isles, Nokomis, Hiawatha, Powderhorn and Diamond) are on the MPCA 303d "impaired waters" list. The nine modeled lakes range in TP levels from an outstanding value of 21 µg/L to a very poor 172 µg/L for Powderhorn. Most of the lakes are expected to worsen in quality by 2020 because of additional loading. Effective implementation of BMPs to address this increase could reverse this expectation. RT 1 and 2 suggested goals for these lakes and for the creek (80 μg/L), since it does flow into Hiawatha.

Specific recommendations include:

- Revise water quality goals for Minnehaha Creek and the lakes of the Lower Watershed.
- Develop Implementation Plan to improve Minnehaha Creek and Lake Hiawatha, including additional water quality monitoring, a mixing study of Lake Hiawatha, identification of where water quality and flood reduction efforts should be focused and identification of partners that can help to implement
- Creating an annual shoreline stabilization program, with an accompanying grants program and shoreline buffer requirements.
- Implementing flood mitigation policies for flooding along Minnehaha Creek and within neighborhoods that look beyond the boundaries of the creek and balance the hydraulic inter-relationship between the creek and the municipal drainage systems (Policy components recommended in *Volume IV.L.6.*).
- Creating incentives and/or matching grants for property owners (commercial and residential) that are willing to create innovative or infiltration practices to benefit runoff water quality.
- Strengthening water quality and construction site management requirements for future highway projects.
- Utilize the H/H Model to better define HWLs for the Chain of Lakes by simulating back-to back 100-year storm events on Chain of Lakes using full range of potential initial conditions.
- Preserve and manage landlocked basins and subwatershed areas to lower peak flow rates and pollutant loads of local stormwater runoff to Minnehaha Creek.
- Implement volume control standards in all subwatersheds draining to or containing landlocked depressions.

A complete presentation of the recommendations made for this watershed by Regional Team 1&2 can be found in *Volume III: Public Involvement, B. Regional Team 1&2*. This includes information regarding the priority of each issue, who would be responsible for undertaking each suggested management approach, and a recommendation of when the approach should be undertaken.

Summary of Volume V - Watershed Issues Integration

There are many issues facing the MCWD that transcend subwatershed-scale and reach across the entire watershed. Discussions with the nine Regional Teams, local officials, citizens and District staff have identified many of these issues. Following is a compilation of those findings that apply District-wide. In addition, the groundwater summary is provided because the scale of groundwater transcends subwatersheds.

V.A. District-Wide Recommendations

V.A.1. Lake Minnetonka

V.A.1.a. Whole-Lake Modeling

Lake Minnetonka is an extremely complex lake, comprised of a collection of many bays and open-lake areas. The preservation of extreme good quality in some parts and the improvement from poor quality in others hinges upon watershed input, internal loading and intra-lake circulation. To better understand the very complicated relationships that occur within the lake and its bays, a whole-lake model that incorporates all of the factors is needed. The watershed input element of the needs for model improvement has been addressed in part by the District through the addition of monitoring stations at several new locations. However, the remaining two items, internal loading and intra-lake circulation, have not been adequately addressed. The District should begin a long-term effort to collect information on all major watershed inputs, internal Lake Minnetonka loading and in-lake circulation for development of a whole-lake model.

V.A.1.b. Water Level Fluctuation and Grays Bay Dam Operation

Users of the lake and residents around it stressed the importance of maintaining a high lake level to maximize the recreational potential of the lake and to maintain property value and lake access for lakeshore owners. However, downstream interests would like to see a continual release of water from the lake, no matter what the lake level conditions are. A minimum release of water would assure a continual Minnehaha Creek flow that would result in better water quality and improved biological conditions. A recommended re-evaluation of the Grays Bay operating plan could include input from the HHPLS model results on changing watershed hydrology for both the upper and lower Watershed. The HHPLS model could be used to determine how these changes will affect water moving into and potentially out of the lake under varying conditions.

V.A.1.c. Eurasian Watermilfoil

The occurrence of dense stands of Eurasian Watermilfoil (milfoil) in Lake Minnetonka was identified by many as a major problem on the lake. Several efforts to control this nuisance aquatic plant were found to be under way. It is, therefore, recommended that the District's role should be one of secondary support, which would include coordination of water level determination for minimizing milfoil growth, information sharing and distribution, and potential financial support.

V.A.2. The Need for Good Surface Water Management (SWM)

V.A.2.a. Assumptions for the Future

Good SWM is key to holding down loads as the watershed develops no matter what type of development occurs. The load analyses that were done as part of the watershed and lake basin goal setting all assumed that no net increase in load would occur between now and the year 2020. For this to actually occur, the District needs to have a comprehensive SWM program and to coordinate its activities with local surface water management efforts. Also, as re-development occurs, the District should look for retrofit opportunities to incorporate good SWM where it has not existed before. This effort should also acknowledge that good SWM is the first step in assuring the protection of groundwater, which is an essential drinking water source for the citizens of the watershed.

V.A.2.b. BMPs

Good technical information upon which to base actions is essential. The suite of best management practices, or BMPs, is very large, but often details on the application parameters and effectiveness of specific BMPs are not available to the person in the field selecting and applying the practices. Customized or topical BMP assistance extracted from the District's existing manual, supplemented with any new information that has become available was recommended by many of the RTs. The topical areas for which these supplemental tools could be prepared include erosion control, homeowner guidelines, shoreland stabilization, public works, use of "natural" areas, golf course management, channel stabilization, farm management, road construction/maintenance, animal waste management, and surface water management for development and re-development.

Providing information on BMPs is only the first step. The effective use of them for all development and redevelopment is the critical step that needs to occur to positively impact runoff. Essential to continued effectiveness of BMPs is the follow-up operation and maintenance, which needs to be emphasized. The District should use and encourage BMPs that are proven to be effective and that best mimic the natural conditions that occurred prior to development of the watershed.

V.A.3. Water Quantity and Flood Control

V.A.3.a. Flood Prevention

Flooding is often an unfortunate result of urbanization. Although the limited scope of the HHPLS did not allow for modeling of every possible event scenario, the tools developed for the District should be used to evaluate more precipitation and runoff scenarios to assure that proper precautions are taken to avoid flooding. The tools can also be used by communities to update their local flood prevention and management efforts, such as updating FEMA mapping.

V.A.3.b. Closed Basins

Several landlocked or closed basin drainage systems occur within the watershed. These basins have had occasional problems associated with them, but are generally functioning without flooding or water quality problems. Unless a current problem exists or is anticipated for the future, these basins should be left in their natural condition.

V.A.4. Setting of Lake/Bay Goals

Many of the lakes and bays within the Watershed had water quality goals established in the District's 1997 Watershed Management Plan. However, many other waterbodies were not assigned a goal. The HHPLS conducted TMDL-like analyses for most lakes and bays within the District, and formulated a list of recommended goals for each of them. Water quality goals should be established for every lake and bay in the watershed to update the District's 1997 plan, with consideration of both existing and 2020 conditions. Data should be collected for water bodies where data do not currently exist.

V.A.5. Targeted Data Collection

To properly asses the condition of waterbodies and the effectiveness of watershed management efforts, an adequate database is needed. Although the District has had a data collection program for many years and has collected very valuable information, there is a need to occasionally evaluate that effort and perhaps re-focus at least part of the program on emerging needs. Targeted data collection is the only way to quantify the behavior of water as it moves through the watershed. When monitoring programs are in the planning phase, the goals of the monitoring should be clearly stated, and the program should be evaluated based on whether or not the data can answer the questions that were set out to be answered.

V.A.6. Institutional Coordination

V.A.6.a. Basin-Wide Linkage

The upper and lower parts of the watershed are closely linked and cannot operate independent of each other, since the actions and needs of each affect the other. To assure effective overall watershed management, the impacts of planning and program implementation must be viewed from a holistic point of view. The District should use all available tools, including the new HHPLS information, to integrate its decision making over the entire watershed.

V.A.6.b. Institutional Improvements

There are many governmental and private entities involved in water resource management within the boundaries of the District. Since no single entity can do everything that needs to be done, cooperation among these entities is imperative to maximize results while minimizing expenditures. Whenever programs of mutual interest exist between the District other entities charged with water and natural resources management, the District should coordinate its activities to the extent possible.

V.A.6.c. Effective Regulatory Programs

Regulatory programs are an essential component of an effective watershed management program. A well structured and fair set of regulations is needed for orderly development to occur. Although new protective programs are not needed, the improved implementation of existing ones does need to occur. The District should conduct periodic regulatory assessments to evaluate its existing program(s) for effectiveness.

V.A.7. Education

Education is a key to solving many of the water related issues in the watershed, yet many of the education vehicles of yesterday are the victims of budget-cutting today. Recent cuts mean that fewer resources than ever are available to educate public officials, homeowners and businesses about good water management. To maximize its resources, the District should identify target populations and structure education programs specifically for them.

V.A.8. Nuisance Management

Geese and carp continue to contribute to water quality problems, and control of the situation does not appear imminent. Although focused efforts in the past have attempted to control these nuisances, it does not appear that they were entirely successful, nor that they will reach an effective level in the future. The District could play an important role in providing technical assistance on the nature of the problem, and what controls work and do not work. The District could also continue its moderate control efforts on a location-by-location basis, as it has done with Painter Creek and occasional lakes. The District should continue to monitor the occurrence of nuisance geese and carp, provide technical assistance, and respond to control needs on a priority basis.

V.B. Groundwater

Geology and groundwater are included in this section because the scale across the watershed is so large that it transcends a subwatershed framework. Following is a brief discussion of important geology and groundwater features that relate to and influence surface water in the Watershed District. Maps and cross sections created for this study, as well as detailed discussions of the features of each major watershed, are included in *Volume IV: Watershed Modeling and Discussion* and *Volume V.B. Groundwater.*

V.B.1. Bedrock Geology

Bedrock geology in the "Twin Cities Basin" is comprised of layers of nearly horizontal sedimentary rocks. From top (youngest) to bottom (oldest) they are:

- Platteville-Glenwood Formation
- St. Peter Sandstone

- Prairie du Chien Limestone
- Jordan Sandstone
- St. Lawrence - Franconia Formation
- Ironton - Galesville Sandstone
- Eau Claire Formation
- Mt. Simon Sandstone

Each of these units is shown in detail in Volume *V.B.*

V.B.2. Surficial Geology and Soils

Three distinct areas of different surficial geology are found in the District. In the west, surficial geology is dominated by high relief, hummocky glacial deposits associated with the Superior Lobe and later Des Moines Lobe periods of the Wisconsinan glaciation. In the middle and east, surficial geology is dominated by outwash deposits from meltwater that ran off stagnant Des Moines lobe ice toward the Mississippi River valley. In the extreme east, surficial geology is dominated by terrace deposits associated with the Mississippi River.

Lake Minnetonka and other nearby lakes are remnants of glacial lakes. The water from the melting glacier followed several west-east channels toward the Mississippi River valley. The Minnehaha Creek channel was apparently the deepest channel and is the last active channel.

Soils vary greatly across the watershed, although they generally reflect their parent material. In the east, terrace deposits and outwash deposits were the origin for relatively sandy soils. In the west, glacial tills created a wide variety of soils, but most were relatively clayey or loamy. Organic mucks are more common in the west where the hummocky terrain and poorly drained soils led to more wetlands.

Maps of the surficial geology and soils are contained in *Volume V.B.*

V.B.3. Groundwater Elevations and Flow

V.B.3.a. Bedrock Aquifers

Groundwater elevations for each of the major drinking water aquifers are shown on maps in *Volume V.B.* Groundwater flow is from areas of higher groundwater elevation (potential) to areas of lower groundwater elevation, generally from west to east in the watershed. Groundwater potential also generally decreases in deeper aquifers, so there is a significant amount of groundwater flow vertically downward.

Recharge of the bedrock aquifers occurs mostly through precipitation and infiltration. Some recharge comes from the west and north, but this is relatively insignificant when compared to the infiltration from above. Discharge points for the bedrock aquifers include lower aquifers, wells, springs along the Mississippi River bluffs, and the Mississippi River itself. Lakes, wetlands, and creeks in the watershed are generally not hydraulically connected to the bedrock aquifers, only the surficial quaternary aquifers. Minnesota Department of Health is currently working on a groundwater model of the northwest part of the Twin Cities area. When it is complete, the model will provide quantitative information about groundwater flow toward drinking water wells.

V.B.3.b. Quaternary Aquifers

The quaternary (glacial) aquifers differ in the east and west part of the watershed. In the west part of the watershed there are two quaternary aquifers; the shallow water table aquifer and the deep buried aquifer. The shallow water table aquifer, as the name implies, is the first groundwater encountered below the ground surface. It may be encountered in any kind of material from clay to sand to organic muck. Groundwater flows into and out of the shallow water table aquifer, lakes, creeks, and wetlands. It is generally not used as a drinking water supply. The deeper buried aquifer is encountered in sandy deposits at depths from about 75 to 300 ft below ground surface. Typical of glacial deposits, the sandy deposits vary in thickness and grain size distribution, and frequently include clayey layers within them. The degree of connection between the sandy lenses and layers is not known. The deep buried aquifer is an important drinking water source for both private and municipal drinking water wells. The extent of the two quaternary aquifers roughly corresponds to the extent of the Des Moines Lobe glacial deposits.

The shallow water table aquifer and deep buried aquifer have very different groundwater elevations (illustrated in Figure V.B-14). Elevations in the deep buried aquifer are typically much lower than the lakes and other surface water features. This leads to the conclusion that Lake Minnetonka and other western lakes are perched on clayey, less permeable glacial deposits. The lakes interact with the shallow water table aquifer, but not with the larger deep buried aquifer. Water levels in the lakes are more controlled by precipitation and evaporation and less by groundwater levels than many other lakes in the Twin Cities area.

Minnehaha Creek is losing water (recharging) to the shallow water table aquifer in many areas, and gaining from the aquifer in others. Several observers have noted that during periods of low water, parts of Minnehaha Creek will continue to flow (although at very low volume) while other parts may be completely dry. This is consistent with the idea that the creek looses or gains water along different reaches.

V.B.4 Depth to Groundwater

A generalized depth to groundwater map is shown in *Volume V.B.* The depth to groundwater information is useful for a number of planning and engineering purposes including design of excavations, foundations, and stormwater management (especially infiltration) structures. No patterns were identified across the watershed. As expected, the depth to groundwater is lowest in low-lying areas near surface water bodies and highest in high-relief areas away from surface water bodies.

V.B.5 Infiltration potential

Infiltration is one of the principal BMPs recommended for reducing the volume of runoff leaving any land area. The goal with infiltration is to mimic hydrologic conditions before land alteration. An infiltration potential map is shown in *Volume V.B.*

Infiltration potential is useful for planning and identifying areas where stormwater infiltration may be a viable stormwater management alternative. It also identifies areas where precipitation is more likely to infiltrate and recharge aquifers. In general the infiltration potential in the west part of the watershed district was identified as medium to low. In the east part of the watershed the infiltration potential was classified as medium to high.