APPENDIX C

EXCERPT FROM H/H AND POLLUTANT LOADING STUDY

(Minnehaha Creek Watershed District, 2003)

F.2. Water Quality

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 due to the difficulties in calibrating a fecal coliform model with existing monitoring data.

Water quality modeling of the watershed was impacted by the limited amount of data available for creeks and water bodies. 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 the same time interval (usually weekly, biweekly, or sometimes monthly), regardless of flow intensities. Sampling during the winter baseflow occurred occasionally in the past, but currently rarely occurs.

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 creek loads based on monitored data. The models are prepared for current conditions and for predicted future conditions in the year 2020. Predicted future land use is based on individual City's 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.

F.2.a. Water Quality Model: PLOAD equations

The EPA's "Simple Method" was used to calculate pollutant loads in PLOAD. This method utilizes two equations to calculate loads. First, the runoff coefficient (Rvu) for each land cover type is derived using the following equation:

$$Rvu = 0.05 + (0.009 * IU)$$

IU = Percent of impervious cover, derived from the MLCCS land cover classification.

Volume of runoff (in acre-feet/year) is calculated using the following equation:

$$Volume = (P * Pj * Rvu * Au) / 12$$

P = Precipitation (inches/year)

Pj = Ratio of storms producing runoff (default = 0.9), used in calibration

Rvu = Runoff Coefficient for each land cover type

Au = Area of land cover type (acres)

Pollutant loads (lbs/year) are then calculated using the land cover/land use data as described above and summed to determine the total pollutant load:

$$Pollutant\ Load = (Volume * Cu * 2.72)$$

Cu = Event Mean Concentration for each land cover/land use type (mg/l)

F.2.b. Event Mean Concentrations and EMC Calibration

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. Total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) were modeled. 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 (such as in the Painter Creek watershed) 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.

Total Phosphorus

A summary of the basic EMC values utilized for the TP modeling are listed in Table II.F.2-1. The actual data input into the modeling was the combination of land cover and land use as described above.

Table II.F.2-1
TP Event Mean Concentrations (EMCs)
Associated with Land Cover and Land Use

Land Cover	Phosphorus (mg/L)
Cropland	0.32
Forest/Shrub/Grassland	0.04
Open Water	0.01
Wetlands	0.01-0.04*
Land Use	**Phosphorus (mg/L)**
Airports	0.28
Commercial	0.28
Farmsteads	0.46
Industrial	0.28

Multi-Family Residential	0.32
Park and Recreation	0.04
Public Industrial	0.28
Public/Semi Public	0.28
Public/Semi Public Not Developed	0.28
Single Family Residential	0.46
Vacant/Agricultural	0.32

*Average for large wetlands and wetland complexes. Individual wetlands could operate as sources or sinks for phosphorus (i.e. Painter Creek watershed).

Due to the less detailed mapping of land use as opposed to the mapping of land cover, certain land use categories such as "Major four lane highway" and "Open water" required a slightly different approach. The land cover mapping associated with these areas was assumed to be more accurate than the land use. For an example, in the case where a land cover/land use combination resulted in a mapped unit of "4 – 10% impervious cover with mixed deciduous trees / Open Water", the land use was disregarded and an assumption was made as to the actual land use based on the land cover. For areas with 4 to 25% impervious cover, it was assumed that the land use was single family residential, and an EMC of 0.46 mg/L was utilized. For those areas with 26 to 75% impervious cover, it was assumed that the land use was multi-family residential, and an EMC of 0.32 mg/L was used. Lastly, for those areas with 76 to 100% impervious cover, commercial land use was assumed, and an EMC of 0.28 mg/L was used.

This same process was followed for the following land use categories from the 2020 land use data: Agricultural, golf course, institutional, open space, parks and recreation, railroads, roads, and water.

Total Phosphorus EMC Exceptions:

Painter Creek Wetlands. Wetlands in the Painter Creek watershed (other than Painter Marsh and South Katrina Wetland) were further classified based on their hydrologic regime, as shown in Table II.F.2-2. This was required because of the significant role that wetlands play in the watershed's hydrology. The data used to adjust the Table II.F.2-2 values came from Metropolitan Council studies of the Lake McCarrons Wetland Treatment System, which exhibits characteristics (high dissolved phosphorus, channelized flow, physical dimensions) similar to many Painter Creek wetlands, as well as general Watershed District information on wetland outflows elsewhere in the watershed.

Table II.F.2-2
TP Event Mean Concentrations Based on Wetland Hydrology

Hydrologic Regime	Phosphorus (mg/L)
LANDLOCKED: Wetlands without outlets to Painter Creek or its tributaries	0.01
OUTLETTED: Wetlands that outlet to a major tributary or ditch of Painter Creek	0.05
FLOWTHROUGH: Wetlands bisected by Painter Creek	0.07

Wetlands where the hydrologic regime could not be determined were classified based on native or non-native vegetation type, according to the numbers in Table II.F.2-3, assuming that non-native wetlands were disturbed, less diverse and more likely to contribute more runoff.

Table II.F.2-3
Further Wetland TP Event Mean Concentrations

Wetlands	Phosphorus (mg/L)
Native Semi-Permanently or Seasonally Flooded Vegetation	0.01
Non-Native Semi-Permanently or Seasonally Flooded Vegetation	0.025

pecial short-term data collection was done by the District on South Katrina Wetland and Painter Marsh in the late 1990s. These studies, although limited in time and extent of data collection, can give a preliminary idea of the total phosphorus concentration in these wetlands, which are suspected to have been recipients of wastewater flow. Wetlands and open water of Lake Katrina, South Katrina, and Painter Marsh were given EMCs based on the limited historical *standing water* monitoring results, as indicated in Table II.F.2-4.

Table II.F.2-4
TP Event Mean Concentrations for Wetlands with Limited Water Quality Data Available

Monitored Wetlands	Phosphorus (mg/L)
Lake Katrina	0.07
South Katrina	0.20
Painter Marsh	0.30

Adjustments in lower watershed. Predicted loads in the lower watershed (Grays Bay and below) were calibrated to data from the Chain of Lakes Study (Minneapolis Chain of Lakes 1991 Clean Water Partnership Project), in addition to Minnehaha Creek loads presented in MCWD Hydrodata reports. Loads generated using the selected EMCs were generally higher than actual monitored loads. For model calibration, EMCs for residential land uses in the lower watershed were decreased by 15%. One possible reason for this difference in EMCs is that street sweeping occurs more frequently in the lower watershed than in the upper, thus leading to the lower TP loads on average.

Total Suspended Solids

Similar adjustments to the TSS EMCs in the lower watershed were made as with the TP EMCs. A 15% decrease to the residential land use EMCs was applied. Load estimates from relatively small areas with few ponds and wetlands compared favorably to monitored load estimates from the Hydrodata reports. However, when estimates from larger areas that contain more open water bodies (areas of TSS removal) were compared to monitored load estimates, the modeled load was generally higher than the monitored in-stream load. This is because this type of model does not take into account particulate settling in lakes, streams, and wetlands. The TSS load estimates are estimates of pollutants washing off of the landscape, but not necessarily the amount of pollutant that eventually makes it to a creek. The model is meant to serve as a tool to identify areas with the potential for generating high pollutant loads, due to the land uses within the area.

Table II.F.2-5 lists the selected TSS EMCs.

Table II.F.2-5
Total Suspended Solids (TSS) Event Mean Concentrations (EMCs)
Associated with Land Cover and Land Use

Land Cover	TSS (mg/L)
Cropland	170
Forest/Shrub/Grassland	10
Open Water	1
Wetlands	25
Land Use	**TSS (mg/L)**
Airports	130
Commercial	140
Farmsteads	100
Industrial	130
Multi-Family Residential	125*
Park and Recreation	50
Public Industrial	75
Public/Semi Public	75
Public/Semi Public Not Developed	75
Single Family Residential	100*
Vacant/Agricultural	125

*EMCs for residential land uses in the lower watershed were decreased by 15% (multi-family residential 106 mg/L, single family residential 85 mg/L).

Total Nitrogen

Nitrogen is generally more difficult to model than phosphorus, since there is less of a connection between nitrogen loads generated in the watershed and what eventually ends up in a downstream water body. Nitrogen gas can enter the system through nitrogen fixation by bacteria, and nitrogen can be lost to the atmosphere through denitrification, also a bacterial process. These difficulties were reflected in our EMC calibration. The EMCs that were used in the model are presented in Table II.F.2-6.

Table II.F.2-6
TN Event Mean Concentrations (EMCs)
Associated with Land Cover and Land Use

	Total Nitrogen (mg/L)	
Land Cover	**Upper Watershed**	**Lower Watershed**
Cropland	5.5	2.8
Forest/Shrub/Grassland	0.75	0.38
Open Water	0.60	0.30
Wetlands	1.3	0.65
Land Use		
Airports	2.3	1.2
Commercial	2.0	1.0
Farmsteads	3.0	1.5
Industrial	2.3	1.2
Multi-Family Residential	2.8	1.4
Park and Recreation	1.2	0.60
Public Industrial	1.5	0.75
Public/Semi Public	1.5	0.75
Public/Semi Public Not Developed	1.5	0.75
Single Family Residential	3.0	1.5
Vacant/Agricultural	2.0	1.0

For EMC calibration, creek loads calculated from monitoring data were compared to the predicted loads based on EMCs. The results were variable, but in general followed the pattern that the monitored loads were approximately 50% higher than the predicted loads. However, the opposite pattern emerged when the model predictions were compared to the storm sewer monitoring data from the Minneapolis Chain of Lakes study (1991). Predicted loads and concentrations were approximately twice as high as the monitored loads and concentrations from that study. The final approach taken was to use different sets of EMCs for the upper and lower parts of the watershed. The EMCs in Table II.F.2-6 were used for the upper watershed, and comparisons to in-stream TN concentrations were generally favorable. The EMCs were cut in half for the lower watershed TN modeling in order to reflect the data from the Chain of Lakes study, in addition to the fact that in-stream TN concentrations in Minnehaha Creek are on the average lower than in-stream concentrations in monitored creeks in the upper watershed. Due to the length of Minnehaha Creek itself, the magnitude of in-stream nutrient transformations may be higher than for a shorter creek.

F.2.c. Pollutant Load Calibration

Pollutant loads were initially calibrated to in-stream monitoring data, where available. Averages of annual runoff volumes reported in the MCWD Hydrodata Reports were used. For each watershed, the parameter Pj (ratio of storms producing runoff, see *PLOAD equations* in section F.2.a) was adjusted until the total modeled volume of runoff equaled the total volume of monitored runoff. The associated modeled loads were then compared to the monitored loads.

In many watersheds, monitoring data were not available for calibration purposes. Therefore, an estimate of long-term mean annual runoff was determined by examining long-term monitoring records and comparing those figures to estimates based on the MN Hydrology Guide. In those cases where monitoring data were available, the monitored data matched fairly well with the annual total runoff estimate from the MN Hydrology Guide. Therefore, for the final PLOAD calibration, the modeled runoff volumes were calibrated to the mean annual runoff depth as shown in the MN Hydrology Guide. Runoff volume varied across the watershed, with higher values occurring in the eastern portion of the watershed.

After the model was calibrated for runoff volume, the same Pj value was utilized for the 2020 conditions model. The predicted volume from that model was then used to calculate the 2020 mean annual runoff. This runoff estimate was used as input to the 2020 lake models.

Pollutant loading estimates from the Lake Minnetonka direct drainage areas were calculated slightly differently. A large proportion of these direct drainage watersheds consists of the lake area itself, which generates low pollutant loading. Including this area would heavily skew the pollutant load estimates when normalized by area; therefore the Lake Minnetonka area and modeled loads were removed from the estimates of pollutant loads per acre. The resulting loading estimates thus represent mostly terrestrial loads, but also include the wetlands and smaller lakes located within the watersheds. This is in contrast to the load per acre estimates in the rest of the watershed; these estimates average out the load over all land covers and land uses, including open water.