BIG MARINE LAKE (82-36)
WASHINGTON COUNTY

HYDROLOGIC STUDY

Minnesota Department of Natural Resources
Division of Waters
&
Carnelian - Marine Watershed District

April 1994
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Introduction

The Carnelian-Marine Watershed District (CMWD) completed construction of an outlet project in 1985. The purpose of this project was to lower extreme high water levels on Big Marine, Big Carnelian and Little Carnelian Lakes. Tolz King Duvall Anderson & Associates (TKDA), engineers for the CMWD, developed a watershed model using the SCS TR-20 computer program as part of this project. Data from this model were submitted to Interagency Hydrology Review Committee on March 13, 1991 by TKDA in order to update the Washington County Flood Insurance Study. One of the primary issues raised by the review committee was whether the existing TR-20 model was adequate for computing flood elevations for Big Marine Lake.

The CMWD and the DNR Division of Waters (DOW) entered into an agreement to conduct a joint hydrologic study of Big Marine Lake and its outlet channel. Both parties were interested in determining as accurate a 100-year flood elevation as possible. In addition, the CMWD wanted data on how well the outlet project was functioning. Lakeshore owners around Big Marine Lake have been expressing continuing concern regarding perceived high water levels.

A major part of this study was an extensive water level monitoring program conducted during 1993. Water levels and flow data were collected from the Big Marine Lake outlet dam to May Avenue (see attached watershed map - Figure 1). Members of the CMWD board of managers collected water level data at seven sites along the outlet channel. Water level readings were generally taken 3 - 4 times per week. In addition, DOW staff installed an automated data logger near the outlet dam at Turtle Lake. This data logger collected both stage and precipitation data. A continuous record of water levels on Turtle Lake was obtained from May through November. Unfortunately, the rainfall data proved unusable. DOW staff also measured flow at three sites along the outlet channel on seven occasions during the year.

1993 proved to be an excellent year in which to conduct a water level monitoring program. Valuable data were collected which help provide an understanding of the hydrologic and hydraulic factors affecting water levels on Big Marine Lake. Two hydrographs of selected data are shown as Figures 2 and 3.

The purpose of this document is to summarize the hydrologic analysis conducted by the DOW to determine the peak 100-year flood elevation on Big Marine Lake and serve as the basis for amending the Washington County Flood Insurance Study. We also wish to use data for Big C. I. Lakes Flood Erosion Study.
Watershed Delineation

The watershed tributary to Big Marine Lake and its outlet channel is still largely rural in character. The area is gradually urbanizing with widely scattered home sites on large lots. The watershed contains numerous woodlots, wetlands, landlocked ponds and open meadows and pastures. The topography can be described as gently rolling.

The watershed delineation contained in the CMWD Overall Plan and as used for project design was reviewed for this study. This delineation was not revised unless specific information was available. A few minor changes were made, primarily in subwatershed III based on field observations during the summer by the District Managers.

The original TR-20 model included one large subwatershed with its outlet at 155th Street North. The watershed was divided into a total of four subwatershed for this study.

Discharge Rating Curves

The outlet dam for Big Marine Lake is located on the north side of County Road 4. The structure consists of a concrete weir/drop structure (the weir is 14 feet long with a runout elevation = 940.58) and a 73" x 45" reinforced concrete pipe arch through County Road 4. There are also two old culverts through the road with invert elevations below the runout of the dam. (The high point in the downstream channel is at approximately elevation 939.0.) The District tries to keep one of these culverts open with varying degrees of success. Periodically during 1993, both culverts were plugged with vegetation, in part due to beaver activity. However, as the collected water level data indicates, tailwater controls outflow from Big Marine Lake during high water. For this analysis it was assumed that these two culverts were plugged.

The purpose of the Turtle Lake Dam is to help maintain water levels in Turtle Lake during low water periods. All stop logs in the dam were removed throughout 1993. The dam had no influence on water levels, e.g., tailwater equaled headwater throughout the year.

Discharge rating curves used in this study are primarily based on the measured flow data collected during 1993 (Figure 4). The rating curve for the Big Marine Lake outlet dam was therefore graphically extended beyond the measured flow data. The Turtle Lake rating curve was extended based on a hydraulic analysis of the downstream culverts at 155th Street North and the 1st driveway. The rating curve at the May Avenue wetland was extended by assuming critical depth at its control section.
Storage Rating Curves

An area-elevation rating curve for Big Marine Lake was developed primarily using the USGS 7.5' quad. Two additional points on this curve were obtained from the USGS Water Resource Investigations Report 85-4176 (1985). Approximately 100 acres was added to the area curve to account for additional storage within Subwatershed I. The resultant storage elevation curve and the area-elevation curve for Big Marine Lake are shown on Figure 5.

Storage - elevation curves for Turtle Lake and for Subwatershed IV were developed using the USGS quads and detailed contour mapping provided by the CMWD.

Unit Hydrograph Parameters

Curve Numbers were estimated using the generally accepted procedures in the MN Hydrology Guide. Soils information was obtained from the District's Overall Plan; Hydrologic Soil Group B was found to predominant throughout the watershed. Time of concentration ($T_C$) values were initially based on values in the old TR-20 model. A sensitivity analysis found that varying $T_C$ does not affect flood levels on Big Marine Lake, and has limited impact on peak discharges along the outlet channel.

Kelley Farms Area (Subwatershed III)

A large portion of Subwatershed III is pasture land owned by Kelley Farms and is used for grazing sheep and cattle. As with the entire watershed, this subwatershed contains numerous depressional areas. Two culverts drain this area across County Road 15. The southern culvert (30' RCP) drains 1.5 square miles directly into Turtle Lake. The northern portion of this subwatershed is drained by a culvert (unknown size) into Mud Lake. This northern culvert was plugged this summer; ponded water was observed west of County Road 15. It was beyond the scope of this project to attempt to accurately model the hydrologic response of this subwatershed. USGS quad maps were used to estimate the surface area of depressional areas. Within the TR-20 model, all of the depressional areas were combined into a single reservoir with an assumed maximum storage of four feet.

For the calibration runs, the northern portion of subwatershed III was not included in the runoff calculations. The entire subwatershed was included for the computation of the 100-year and other return period floods.
Calibration and Testing of the TR-20 Model.

Two storms from 1993 were used to calibrate and test the TR-20 model for Big Marine Lake and its outlet channel (June 16, 17 & August 9). Admittedly TR-20 is not the best tool with which to develop and calibrate a hydrologic model to observed data. Nor is only one year's worth of flow data generally considered sufficient. However, this calibration effort is an attempt to verify that the TR-20 model does a reasonable job of recreating the observed water levels.

Daily precipitation data were obtained for five locations near the watershed from the State Climatologist. One of the stations was in Section 8 of May Township, just north of Turtle Lake. Data from this reader were used for the calibration of the model. Rainfall data obtained for the National Weather Service Minneapolis/St. Paul station were used to develop an hourly time distribution series for the two storms. An antecedent moisture coefficient of 2 was used since over two inches of rain fell during the week preceding the June storm.

Computed water levels were compared to observed levels at the Big Marine Lake outlet, Turtle Lake dam and the wetland above May Avenue. Curve numbers for subwatersheds II and IV were lowered by 14% and 5% respectively. A baseflow of 6 cfs was added in subwatershed II. Results are shown on the attached hydrographs of Figure 6.

The TR-20 model was tested using a second storm in August. There was no rainfall during the week preceding this second event so an AMC of 1 was initially used. The computed hydrograph did not contain a sufficient volume of runoff. After changing the AMC to 2, excellent results were achieved for Big Marine Lake (Figure 7). Not surprisingly, the watershed model is very sensitive to the curve number and the assumptions regarding antecedent moisture conditions.

The TR-20 model only did a fair job of matching the observed data at Turtle Lake (Figures 6 and 7). Hydrologic conditions in subwatersheds II & III are fairly complex. Minimal time was spent trying to adjust the parameters in the TR-20 model to better match the observed data at Turtle Lake since this study was primarily directed toward Big Marine Lake.

Computation of Flood Elevations

A 24-hour Type II distribution storm and a 10-day runoff event were simulated to develop peak flood levels on Big Marine Lake for various return period floods. Total rainfall/runoff amounts were obtained from the MN Hydrology Guide. Starting water surface elevations for Big Marine Lake were set at the runout of the outlet dam. A baseflow of 6 cfs was retained at Turtle Lake from the calibration run. The starting water surface elevation at Turtle Lake was set at an elevation corresponding to 6 cfs. The 10-
day event was found to be the critical event as was the case with the earlier hydrologic analysis performed by TKDA.

For both the 24-hour and 10-day storms, computed waters levels on Turtle Lake were generally higher than the computed levels for Big Marine Lake (Figure 8). Flow reversals (from Turtle Lake toward Big Marine Lake) have been observed during previous floods, supporting the TR-20 model results. The volume of additional flow into Big Marine Lake would be constricted by County Road 4 and was considered negligible. However, there would be no outflow from Big Marine Lake as long as water levels south of County Road 4 were higher. The TR-20 model was revised to eliminate outflow from Big Marine Lake during a 100-year 10-day runoff event which increased the computed 100-year flood level by 0.13 feet.

Conclusions & Recommendations

The outlet for Big Marine Lake does not significantly reduce the lake level bounce following a severe rainstorm and/or snowmelt event. This is due to the large area of Big Marine Lake compared to its contributing watershed area, and the relatively small capacity of the outlet channel.

The outlet does provide for positive drainage once peak lake levels have been reached and the excessive rains stop. Once excessive rains stopped this past summer, lake levels dropped at a relatively constant rate as shown by the recorded lake level data in Figure 2. From July 7 to August 6, Big Marine Lake fell 0.58 feet, and from August 19 to September 15, the lake dropped 0.38 feet. The average drop in lake levels during these two periods was approximately 1.4 inches per week. During these two periods, flow out of the lake ranged from 10 to 14 cubic feet per second or on average, 24 acre feet per day.

Prior to construction of the outlet channel, the surface runout elevation was approximately 942.0. Without the outlet channel, there would not have been any surface outflow from Big Marine Lake this past summer. Water levels would have undoubtedly remained higher for substantially longer lengths of time.

The recommended regulatory flood elevations for Big Marine Lake are shown in the following table. These levels are based on the TR-20 model results assuming no outflow from Big Marine Lake during the 10-day runoff event.

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<tr>
<th>Return Period</th>
<th>Peak Lake Level (NGVD 1929)</th>
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<tr>
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<td>942.5</td>
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<td>500-year</td>
<td>942.9</td>
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Figure 2: Observed water level data - 1993.
Figure 3: Observed water level data - June 1993 storm.
Figure 4: Discharge - elevation rating curve.
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Figure 6: TR-20 model calibration - June 1993 storm.
Figure 7: TR-20 model calibration - August 1993 storm.
Figure 8: Big Marine and Turtle Lakes - computed hydrographs for a 100-yr 10-day runoff event.

Tables

TR-20 model summary input and output data.

TR-20 data files

BIGMAR1: Calibration run for the June 1993 storm.
BIGMAR2: Calibration run for the August 1993 storm.
BIGMAR3: 10, 50, 100 & 500-year 10-day runoff events
Figure 4

BIG MARINE LAKE (83-36)
OUTLET CHANNEL

DISCHARGE RATING CURVES
FLOW MEASUREMENTS BY DNR - DIV OF WATERS

- Big Marine Lake Dam - HW
- County Road 4 - TW
- Wooden Bridge
- Turtle Lake Dam
- 1st Driveway
- May Avenue Wetland
BIG MARINE LAKE
June 1993 Storm
TR-20 MODEL CALIBRATION

- BIG MARINE LAKE
- BIG M OBSERVED
- TURTLE LAKE
- TURTLE LAKE OBSERVED

ELEVATION (MSL)
PRECIP (IN.)


939.4 939.8 940.2 940.6 941 941.4 941.8 942.2 942.6 943 943.4 943.8 944.2 944.6 945 945.4 945.8 946.2 946.6 947
BIG MARINE LAKE
August 1993 Storm
TR-20 MODEL CALIBRATION

PRECIPITATION (IN.)

ELEVATION (MSL)

BIG MARINE LAKE
TURTLE LAKE

BIG MARINE OBSERVED
TURTLE LAKE OBSERVED

941.4 941 940.6 940.2 939.8 939.4
BIG MARINE LAKE
100-YR 10-DAY RUNOFF

TOTAL RUNOFF = 7.3"

ASSUMES OUTFLOW FROM
BIG MARINE LAKE

BIG MARINE LAKE — TURTLE LAKE
**BIG MARINE LAKE AND OUTLET CHANNEL**
**TR20 MODEL RESULTS**

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<th>Subwatershed Number</th>
<th>Contributing Watershed Area (sq. mi.)</th>
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