DRAINAGE BASIN STORAGE
AND
SOIL EROSION PREVENTION STUDY
MADISON/LAKE COUNTY

I. INTRODUCTION, AUTHORIZATION AND PURPOSE

A. Introduction: During the year of 1993, Lake County received 38.65 inches of precipitation, well above the normal annual precipitation of 24.43 inches. In addition to above normal precipitation in 1993, the City experienced a 5.6 inch thunderstorm on July 3, 1993. This thunderstorm was preceded by spring runoff and thunderstorms which resulted in wet, saturated soil conditions immediately prior to July 3rd. The July 3, 1993 storm resulted in flooding throughout Lake County with extensive flood damage to Lake Herman, City of Madison, Lake Madison and Brant Lake areas.

B. Authorization: The Drainage Basin Storage and Soil Erosion Prevention Study was authorized by the City of Madison and Lake County through their Commissioners under an Employment Agreement for Professional Services dated January 24, 1994.

C. Purpose: The purpose of this report is to perform a drainage basin storage and soil erosion prevention study of that portion of Lake County which contributes surface run-off to the City of Madison and the Lake areas of Brant Lake, Lake Madison and Lake Herman. This study will analyze the peak flood flows for the 25, 50 and 100-year storm frequencies using the U. S. Army Corps of Engineers HEC-1 computer program. This study will also establish the baseline flood conditions (flood boundaries) using the U.S. Army Corps of Engineers HEC-2 computer program for each storm frequency. Evaluation of various flood control alternatives will be completed using the HEC-2 computer program.

Flood control alternatives will include wetland restoration, channel cleaning, channel widening, reducing restrictions by increasing bridge and culvert sizes, erosion protection, dams, levees, and evaluation of lake outlet structures. This study will include probable project costs, evaluate the environmental impacts and recommend improvements for flood mitigation.

D. Description Of Study Area: The Study Area is located in Lake County, South Dakota and consists of the water shed above the Brant Lake outlet as illustrated in Figure 1, Drainage Basin Study Area. The watershed has an approximate area of 133 square miles, and contains three major natural lakes.

The major sub-basins are shown in Figure 1 and are described as follows:

1) Lake Herman - contributing area to Lake Herman;

2) Silver Creek - from Lake Herman outlet to confluence with Park Creek;

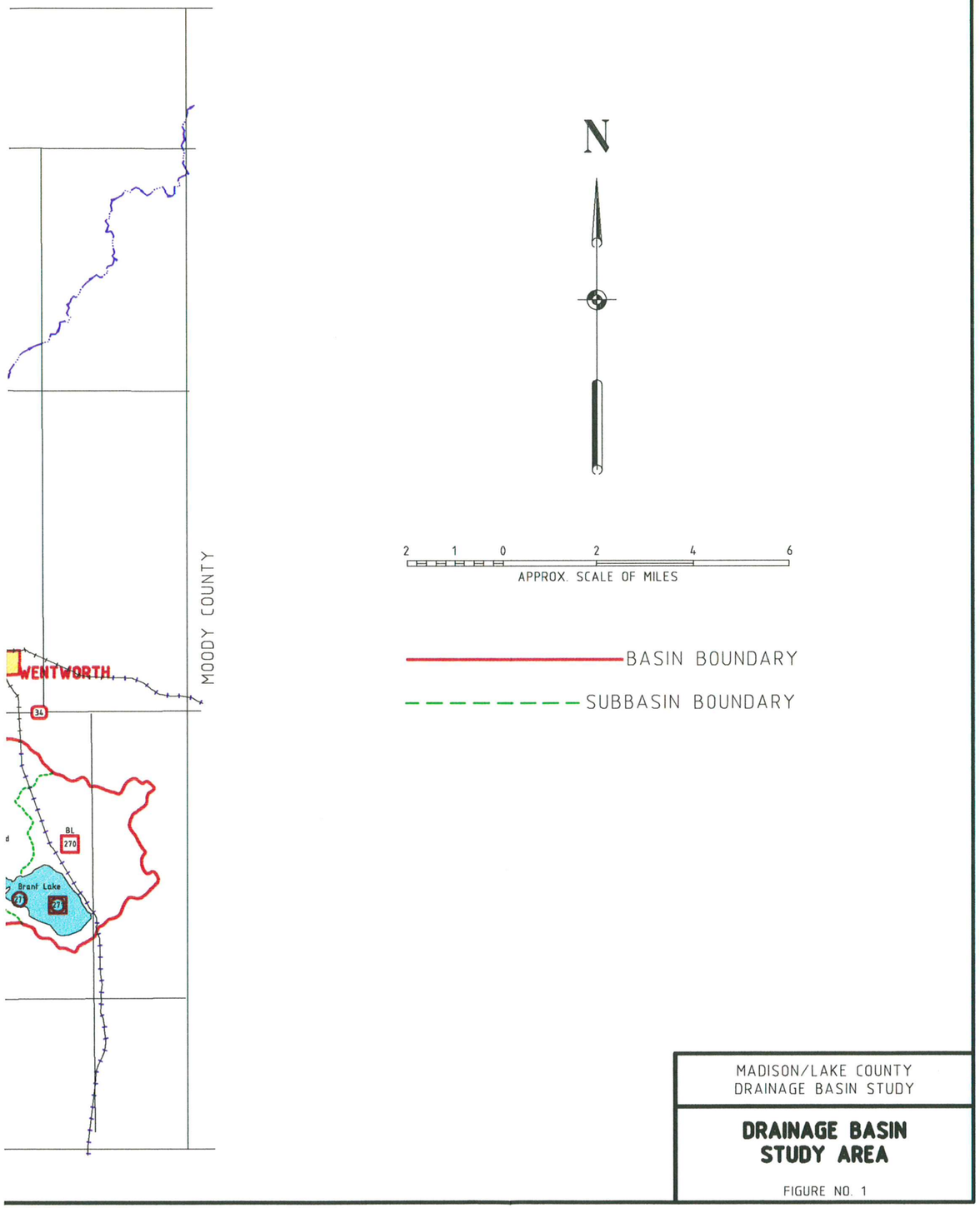
3) Upper Park Creek - Park Creek upstream of Silver Creek confluence;

4) Park Tributary - tributary entering Madison's northwest side; and

5) Lower Park Creek - from Silver Creek confluence through Brant Lake.

II. NEEDS ASSESSMENT

A. Area impacted by the flood: The major flood damage from the July 3, 1993 flood was sustained in the populated areas along the creeks and lakes. Homes and businesses along Park Creek and Silver Creek in the City of Madison were damaged directly by the flood waters. The flood water also surcharged the sanitary and storm sewer systems causing both wastewater and surface water to back-up into house basements. The water and wastewater treatment plants were flooded which resulted in mechanical and electrical equipment damage. An



18" sanitary sewer interceptor line and a 21" sanitary sewer outfall line were also washed out in the floodway. Lake Herman overtopped the road along the east side of the Lake flooding the State Park area, a resort, houses and one farm along the east side of Lake Herman. The water level in Lake Madison and Brant Lake also rose causing erosion and damage to houses along the shore line. The outlet of Lake Madison was breached causing damage to the developed area at the outlet.

The rural areas of Lake County experienced considerable agricultural field erosion; damage to fences, homes, buildings, and livestock dams; and crop damage or loss due to destroyed crops or ground that could not be planted.

B. Estimated Property Damage: Lake County Officials surveyed the county on the day after the flood and determined that 212 families had been displaced from their homes. Seventy days after the flood, 17 families were still unable to return to their homes. The Red Cross gave financial assistance to 202 families for water heaters, rent, clothing, building repair and other emergency needs that amounted to over $87,000. In addition, the Red Cross served 14,000 meals, sheltered 150 people and gave Lake County the majority of the 2,000 clean-up kits distributed in the state. The Red Cross gave over $130,000 in relief to Lake County, more than half of the total for the entire state of South Dakota.

The County sent 622 surveys to agricultural properties in the County. Responses were returned by 193 rural property owners and are summarized in the following table:

	Total Acres	Farms Reporting	Average Acres
Acres Planted	53,977	148	365
Acres Unplanted	33,542	148	227
Acres Lost	15,467	124	125
Acres Destroyed	8,409	70	120
Acres Harvested	41,177	146	282
Acres Unharvested	10,235	52	197

The County spent a total of $162,775 in flood related work of which $133,932 was disaster assistance and $28,843 was force account work. The County had one bridge wash out, several areas of washouts around bridges and culverts and several roads with surfacing and shoulder damage.

The City of Madison sustained substantial damage due to the flood. The major damage was at the Water and Wastewater Treatment Plants. The flood washed out sections of an 18" sanitary sewer interceptor and a 21" sanitary sewer outfall. Other cost incurred by the City included cleanup, well disinfection, Park Creek channel restoration, transformer replacement, street & alley repair, sidewalk repair, bridge repair, pumping and miscellaneous emergency protective measures. The total cost of the damage as assessed by the City is $555,808.

The City of Madison also started a buy out/relocation program to reduce the life/safety hazard within the City limits. The City has bought out 67 homes, and assisted with repairs on 16 homes for a total cost of $2,311,170. The City also spent $291,128 for demolition, equipment rental, asbestos testing and associated miscellaneous work relating to flood damages. In addition, pending offers to purchase or relocate homes results in an estimated cost of $759,655.

III. DATA ACQUISITION AND FIELD RECONNAISSANCE

A. General: The first step in the study included acquisition and review of existing data, reports and flood related mapping. This portion of the study also included site surveys to "fill-in" the gaps of data required to complete the report.

B. Hydrologic Data: The basin characteristics of the watershed basin was developed using USGS 7½ minute quadrangle maps and EROS aerial photographs. Other sources of information include: US Weather Service for precipitation records and rainfalls; rainfall data from the local radio station, KJAM; Soil Conservation Service for soils classification, wetland maps and land use; USGS for stream gaging data; DENR Division of Water Rights/Lakes for area-capacity table and other pertinent data on the lakes within the study limits.

C. Historic Flood Data: Data collected relating to the 1993 flood included aerial photographs of the flooded area taken by Dave Gilbert, US Fish and Wildlife. The July 3, 1993 flood water surface elevation data was also collected from the Corps of Engineers, Omaha Nebraska. Ordinary High Water Mark information and reports for each of the lakes was obtained from the South Dakota Department of Environment and Natural Resources (SDDENR).

D. Hydraulic Data: Bridge, and culvert data pertaining to the hydraulic capacities was obtained from SD DOT, Lake County Highway Department and the City of Madison.

E. Field Reconnaissance: Field surveys were completed along the channels through the City and at the outlets of each lake. Field surveys within the City of Madison consisted of collecting elevations throughout the 100-year flood plain in order to generate a contour map. The structures within Madison were measured and the slope of the structure channel was obtained to model the flood flows through the structure.

F. Miscellaneous Data: Miscellaneous data obtained included the existing Flood Insurance Study; data from an on going sedimentation study conducted by DENR/WRM; City, County and State ordinances, codes, and regulations; and US Department of Interior, National Wetlands Inventory maps.

IV. HYDROLOGIC EVALUATION

A. Introduction: This section on hydrology outlines the procedures used and presents the peak flow values for the basins and lakes being investigated. Standard hydrologic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude which are expected to be equalled or exceeded once on the average during any 25, 50, or 100 year period (recurrence interval) have been selected as having special significance for flood plain management. These events, commonly termed the 25, 50, and 100 year floods, have a 4, 2 and 1 percent chance, respectively, of being equalled or exceeded during any year. Although the recurrence interval represents the statistical probability between events; the rain storm event could occur in consecutive years or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, (1 percent chance of annual occurrence) in any 50 year period is approximately 40 percent (4 in 10), and for any 90 year period, the risk increases to approximately 60 percent (6 in 10). The analysis reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study.

This section of the report was submitted to various interested agencies to obtain concurrence with regard to the hydrologic analysis prior to proceeding with the finalization of the flood profile modelling (HEC-2) through the City of Madison. The model developed herein will also be used to evaluate various watershed modification alternatives. The alternatives may consist of additional upstream storage (wetlands, detention ponds) and/or

diversions, that may be implemented to decrease flooding in Madison and along the lake shorelines.

B. Basin Description: The study area is located in Lake County, South Dakota, with the drainage basin consisting of the watershed above the Brant Lake outlet, as shown in **Figure 1**.

The watershed has an approximate area of 133 square miles, and contains three major natural lakes. Additionally, the watershed includes several large sloughs and depressions that may or may not contribute runoff during a storm, depending on conditions preceding the storm event. The majority of the watershed is rural croplands and pastures in good condition. The only significant urban area is the City of Madison which covers approximately 2 square miles. Additional urban areas (other than farmsteads) include Junius and scattered developments along the lake shores. The watershed has relatively flat to mild slopes throughout the basin with the vertical relief from the basin highpoint to Brant Lake discharge being approximately 270 feet.

C. Previous Studies: In researching available information, no one study was found that addressed the entire basin under the scope of this study. The most significant studies are the Federal Emergency Management Agency (FEMA) **Flood Insurance Study (FIS), City of Madison, South Dakota, January 5, 1982**, and a SDDENR Agricultural Nonpoint Source Pollution Model (AGNPS) analysis, and Sediment Control Structure information for the Lake Herman watershed. A hydraulic analysis was made by SDDENR on the Brant Lake outlet and downstream structures, however the upstream hydrologic analysis was limited.

The FEMA study relied basically on the regionalized analysis presented in the USGS WRI 35-74, *A Method for Estimating Magnitude and Frequency of Floods in South Dakota*. The FEMA FIS indicated the 100-year peak on Park Creek upstream of the Park Creek Tributary to be 2,400 cfs, Park Creek just upstream of Silver Creek confluence to

be 2,700 cfs, and the 100-year peak downstream of Silver Creek confluence to be 3,700 cfs. The AGNPS analysis indicated the 100-year peak inflow to Lake Herman to be 14,050 cfs. A comparison of these peak flows against the finding of this study will be discussed later.

The work on the referenced FEMA study was completed in 1979. In 1980, the USGS published a new regionalized flood estimating methodology, USGS WRI 80-80, *Techniques for Estimating Flood Peaks, Volumes, and Hydrographs on Small Streams in South Dakota.* The methodology uses the following procudures for flood peaks:

$$Q_{100} = 132\ A^{0.65} S^{0.46} S_i^{-0.67}$$

Std error of estimate -> 98% ; range +139% to -58%

$$Q_{50} = 106\ A^{0.63} S^{0.45} S_i^{-0.69}$$

Std error of estimate -> 93% ; range +130% to -56%

$$Q_{25} = 83.4\ A^{0.60} S^{0.44} S_i^{-0.72}$$

Std error of estimate -> 90% ; range +125% to -56%

where A = area in square miles
S = main channel slope (10-85% distance), ft/mile
S_i= soils infiltration index; **3.33** for this area

Using the WRI 80-80 procedure, the 100-year flood peak on Park Creek upstream of the Park Creek Tributary is 1,330 cfs, and upstream of Silver Creek confluence is 1,480 cfs.

Information from various entities was also made available regarding the July 1993 flood including limited rainfall records, measured high water marks, photographs, and videotapes. While the exact frequency of that event is not known, the information provides a useful "yardstick" for the analysis of this report.

D. Gaged Stream Sites: No long-term gaged sites were found to exist within the study boundaries. The USGS maintained a gaging station on Skunk Creek just downstream of the study area for approximately three years (August 1984 to October 1987). However, the period is

too short for analysis, and the location is significantly influenced by the lakes. Therefore, it will not produce representative results for upper basin flooding. Some temporary stage sites have been established in conjunction with a Lake Herman sediment study, however the period of record on these sites are also too short to produce meaningful results.

The USGS does maintain Station 06-481500, Skunk Creek at Sioux Falls. The total basin above this site is 622 square miles, of which 8.5 square miles are probably non-contributing. This gage is not representative due to basin size and influence of lakes and reservoirs on outflow. However, an "order of magnitude" check can be made based on a ratio of watershed area. The prior maximum discharge recorded at that station was 29,700 cfs. Using the ratio (133/613.5) results in approximately 6,400 cfs downstream of Brant Lake.

E. Hydrologic Analysis: Data necessary for the hydrologic analysis was obtained from a variety of sources including USGS 7½ minute quadrangle maps, SCS Soil Survey of Lake County, field observations and field surveys of the lake outlet structures and major stream crossings, and Lake Herman perimeter survey. The hydrologic analysis was performed utilizing the US Army Corps of Engineer's HEC-1 computer program, *Flood Hydrograph Package, September 1990.*

1. General Basin Characteristics: The watershed was divided into 27 subbasins, with appropriate stream reach routings, and 8 reservoir routings for the analysis. The Basin Schematic Diagram of the HEC-1 Input is presented on **Figure 2.** USGS quadrangle maps were used to determine the basin boundaries, basin area, vertical relief, stream course length, and typical reach cross-sections (supplemented by bridge information and field survey data). A summary of the basin characteristics is presented in **Table 1.**

Several large areas including Reynolds Slough and an area approximately 5 miles northwest of Madison are most likely

MADISON FLOOD STUDY

HEC–1 INPUT
BASIN SCHEMATIC DIAGRAM

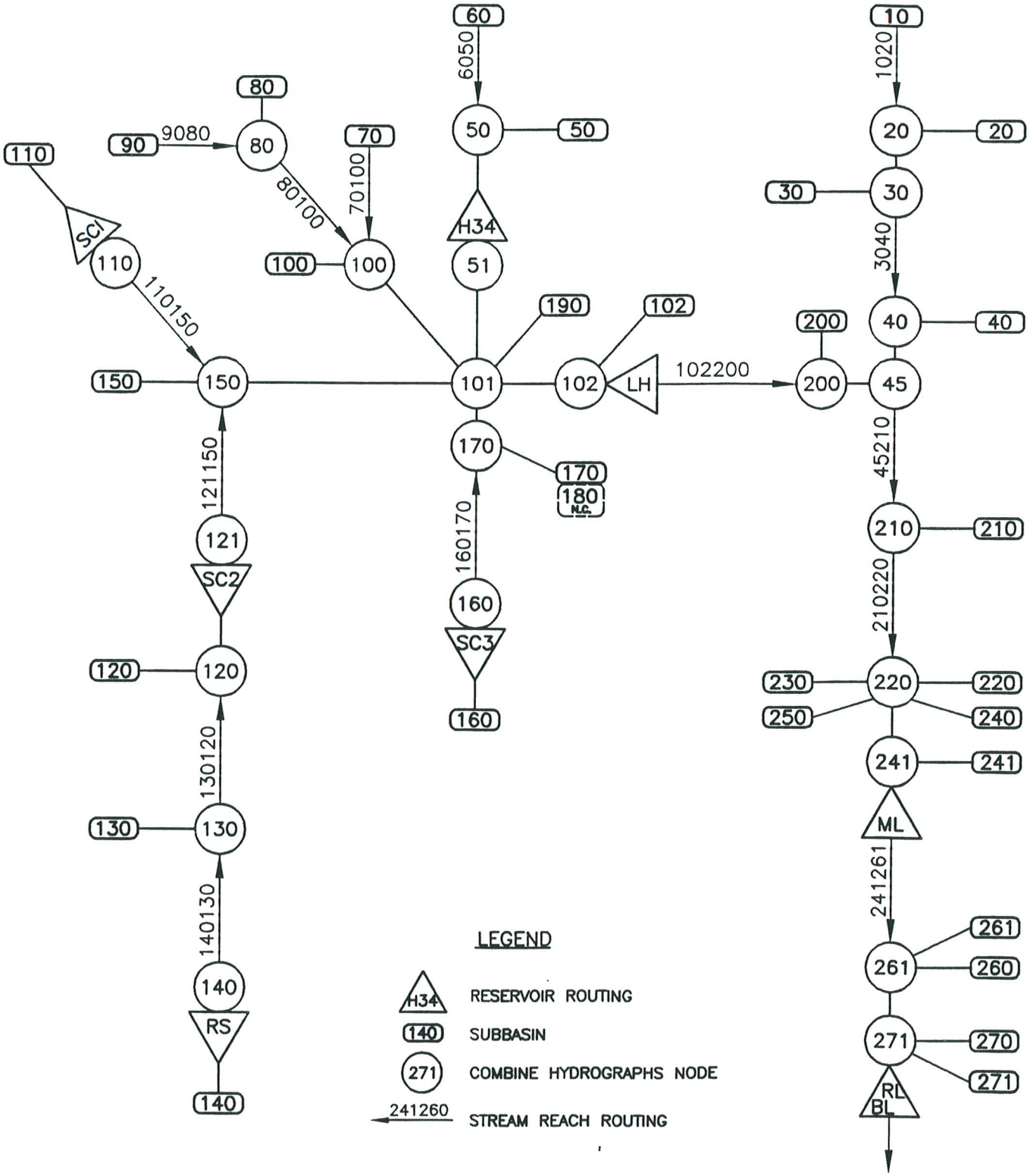


FIGURE 2

TABLE 1

MADISON FLOOD STUDY - Basin Information														
	Areas from USGS Quads		1 sq in =	0.14348	sq miles		miles/ft =	0.000189						
		Reach	Area		High	Low	Elevation	Long streamcourse		Slope,	Tc	Lag		
		feet	sq inches	sq miles	Elevation	Elevation	Differenc	feet	miles	ft/mile	hrs	hrs	Comment	
												(.6 x Tc)		
Park Creek														
10A	PC-4A		-23.25	-3.34	Possibly non-contributing area, depending on "lake" stage at start of rainfall								4-corner lake - Sec. 10,11,14,15	
10	PC-4	25,500	88.90	12.76	1820	1718	102	42,300	8.01	12.73	4.84	2.90		
Net 10				9.42										
20	PC-3	8,360	58.07	8.33	1780	1669	111	32,700	6.19	17.92	3.48	2.09		
Total at North City Limits				**17.75**	**1820**	**1669**	**151**	**67,800**	**12.84**	**11.76**	**7.17**	**4.30**		
30	Upper Park		16.71	2.40	1773	1669	104	16,550	3.13	33.18	1.62	0.97		
40	PC-2	10,350	5.92	0.85	1720	1646	74	9,750	1.85	40.07	1.00	0.60		
Upstream of Silver Creek confluence				**21.00**										
102	Lake Herman			2.00								0.10	acc't for direct rainfall on reservoir	
	H-1			18.56										
50	H-1A		62.90	9.02	1800	1668	132	39,000	7.39	17.87	3.99	2.39	0	
60	H-1B	31,000	66.43	9.53	1830	1737	93	33,900	6.42	14.48	3.88	2.33		
70	H-2	10,000	18.41	2.64	1810	1698	112	18,000	3.41	32.85	1.74	1.04		
80	H-3	18,000	25.04	3.59	1850	1699	151	30,000	5.68	26.58	2.80	1.68		
90	H-4	3,700	77.15	11.07	1870	1710	160	47,000	8.90	17.97	4.59	2.76		
100	H-5	18,700	20.95	3.01	1780	1668	112	20,600	3.90	28.71	2.03	1.22		
	H-6			12.93										
110	H-6A	11,600	16.30	2.34	1810	1713	97	21,300	4.03	24.05	2.23	1.34	Sediment Control #1	
	H-6B			9.24										
120	H-6B1	9,300	11.75	1.69	1820	1710	110	11,800	2.23	49.22	1.08	0.65	Sediment Control #2	
130	H-6B3	6,800	16.06	2.30	1810	1732	78	18,900	3.58	21.79	2.11	1.27	Lower Reynolds SI	
140	H-6B2	3,140	36.56	5.25	1810	1740	70	9,150	1.73	40.39	0.95	0.57	Reynolds Slough	
150	H-6C		9.46	1.36	1790	1668	122	13,700	2.59	47.02	1.23	0.74		
160	H-7	4,900	79.91	11.47	1820	1699	121	35,520	6.73	17.99	3.70	2.22	Sediment Control #3	
	H-8			2.81										
170	H-8A		19.58	2.81	1790	1668	122	11,340	2.15	56.80	0.99	0.59		
180	H-8B		4.65	0.67	1780	1690	90	0	0.00				Non-contributing	
190	H-9		8.72	1.25	1730	1668	62	12,500	2.37	26.19	1.43	0.86		
	Total Basin Area			**69.32**									excl lake area	
200	SC		32.87	4.72	1760	1646	114	21,400	4.05	28.13	2.11	1.27	Silver Creek	
Total Silver Creek at confluence				**74.04**									includ Herman area	
210	PC-1	6,700	27.27	3.91	1770	1616	154	19,100	3.62	42.57	1.65	0.99		
Upstream of Lake Madison				**98.95**										
220	BS-1		35.03	5.03	1720	1600	120	17,000	3.22	37.27	1.59	0.95		
230	BS-2		15.72	2.26	1800	1600	200	11,800	2.23	89.49	0.85	0.51		
Park Creek into Lake Madison				**106.23**										
	Lake Madison			4.38								0.1	acc't for direct rainfall on reservoir	
240	ML-1	1,400	60.77	8.72	1720	1600	120	19,000	3.60	33.35	1.80	1.08	excl lake area	
250	ML-2		11.33	1.63	1650	1600	50	4,400	0.83	60.00	0.47	0.28	excl lake area	
Total Lake Madison Drainage Area				**120.96**										
261	Round Lake		1.67	0.24								0.1	acc't for direct rainfall on reservoir	
260	RL	3,700	27.77	3.98	1710	1597	113	15,500	2.94	38.49	1.46	0.87		
Total into Brant Lake				**125.18**										
271	Brant Lake			1.58								0.1	acc't for direct rainfall on reservoir	
270	BL		41.62	5.97	1740	1594	146	14,600	2.77	52.80	1.23	0.74	excl lake area	
Total @ Brant Lake Outflow				**132.73**										

BANNER

BANNER ASSOCIATES, INC. • CONSULTING ENGINEERS & ARCHITECTS
409 22ND AVENUE SOUTH • P.O. BOX 298 · BROOKINGS, SD 57006 • (605) 692 6342

MADISON/LAKE COUNTY
DRAINAGE BASIN STUDY

TABLE 1
BASIN CHARACTERICS

"non-contributing" in a typical year. A check of an aerial photograph dated August 31, 1991 shows Reynolds Slough holding limited water, and the area to the northwest growing row crops with no ponding evident. On the contrary, in 1993, both these areas were reported to be overflowing prior to the July 3, 1993 storm, and continued to pond water and overflow through the spring of 1994.

2. Precipitation: The rainfall intensity-duration-frequency (IDF) curves selected for this study are the recently (November 1993) adopted City of Sioux Falls IDF curves. This IDF information was checked against the IDF curves presented in the SDDOT drainage manual. Lake County is in the Huron region, but near the line for the Yankton region. **Table 2** compares the intensities for the three areas. The Sioux Falls criteria yields a higher intensity for a given duration, and was thus selected taking a conservative approach. The 100-year 24-hour rainfall is 5.95 inches under this criteria.

As a note, the rainfall reported for the July 2-4, 1993 period varied considerably within a relatively short distance. The highest rainfall (5.6 inches) was recorded unofficially at a radio station, KJAM, in Madison with Wentworth (7 miles east) reporting 3.8 inches, and Howard (20 miles west) reporting 2.65 inches.

3. Loss Rate and Unit Hydrograph: Within the HEC-1 computer model, the SCS triangular unit hydrograph procedure and SCS Curve Number (CN) loss rate were selected. The SCS *Soil Survey of Lake County, South Dakota* indicates on the General Soil Map that the entire County is classified as Hydrologic Soils Group "B". The land use throughout the County is primarily cropland (70-90%) with a mix of straight row and contoured, and the remainder is pasture. **Table 3** presents a summary of CN's for various land uses and soils groups. Based on field and aerial photographs, a CN of 75 was determined for use in all subbasins. The entire watershed is somewhat typical with a mixed land use throughout. A CN=75 (0.25 acre residential lots with 38% impervious) is also appropriate for the City of

TABLE 2

Madison Flood Study

Rainfall Intensity-Duration-Frequency Curves
From SDDOT "Drainage Manual"

INTENSITIES

HURON

	Duration hours	Return Period 25	50	100
(5 min)	0.083	7.4	8.2	9.1
(10 min)	0.167	5.9	6.7	7.4
(15 min)	0.250	5.0	5.6	6.2
(20 min)	0.333	4.3	4.9	5.4
(30 min)	0.500	3.5	3.8	4.2
	1.0	2.1	2.4	2.6
	2.0	1.3	1.5	1.7
	4.0	0.70	0.80	0.90
	6.0	0.51	0.58	0.65
	8.0	0.40	0.46	0.51
	10.0	0.34	0.38	0.42
	12.0	0.29	0.33	0.37
	18.0	0.21	0.23	0.26
	24.0	0.16	0.19	0.21

YANKTON

	Duration hours	Return Period 25	50	100
(5 min)	0.083	6.6	7.2	8.0
(10 min)	0.167	5.5	6.0	6.6
(15 min)	0.250	4.8	5.3	5.9
(20 min)	0.333	4.4	4.8	5.2
(30 min)	0.500	3.5	4.0	4.5
	1.0	2.5	2.8	3.2
	2.0	1.6	1.8	1.9
	4.0	0.86	0.95	1.10
	6.0	0.60	0.69	0.77
	8.0	0.48	0.54	0.60
	10.0	0.38	0.44	0.49
	12.0	0.33	0.36	0.40
	18.0	0.22	0.25	0.28
	24.0	0.17	0.19	0.21

Sioux Falls I-D-F Curves (adopted Dec '93)

(based on TP-40 and HYDRO 35)

PRECIPITATION (inches)

	Duration hours	Return Period 2	25	50	100
(5 min)	0.083	0.43	0.69	0.77	0.85
(10 min)	0.167	0.70	1.16	1.29	1.43
(15 min)	0.25	0.88	1.48	1.66	1.83
(30 min)	0.5	1.19	2.12	2.39	2.65
	1	1.52	2.79	3.15	3.51
	2	1.70	3.05	3.48	3.80
	3	1.80	3.25	3.63	4.21
	6	2.05	3.68	4.25	4.60
	12	2.40	4.25	4.60	5.30
	24	2.70	4.75	5.40	5.95

INTENSITY (inches/hr)

	Duration hours	Return Period 2	25	50	100
(5 min)	0.08333	5.16	8.34	9.27	10.20
(10 min)	0.16667	4.17	6.96	7.76	8.57
(15 min)	0.25	3.52	5.93	6.63	7.32
(30 min)	0.5	2.39	4.25	4.78	5.31
	1	1.52	2.79	3.15	3.51
	2	0.85	1.53	1.74	1.90
	3	0.60	1.08	1.21	1.40
	6	0.34	0.61	0.71	0.77
	12	0.20	0.35	0.38	0.44
	24	0.11	0.20	0.23	0.25

P25 = .293P2 + .669P100
P50 = .146P2 + .835P100

TABLE 3

Madison Flood Study
Hydrologic Soils Classification

Reference: Soil Survey of Lake County, South Dakota, December 1973
SCS, NEH, Hydrology
"Handbook of Hydrology", Maidment, 1993

Using "General Soil Map"
Entire Lake County is Hydrologic Soils Group "B"

Hydrologic Soils Group "B" Land Use Description	Curve Number	
Row Crops,straight, good	**78**	
w/ crop residue, good	**75**	
Row Crops,contoured, good	**75**	
w/ crop residue, good	**74**	
Small grain, straight, good	**75**	
Small grain, contoured, good	**73**	
Rotate meadow, straight, good	**72**	
Rotate meadow, contour, good	**69**	
Farmsteads	**74**	
Residential - .25ac w/ 38% imperv	**75**	
Pasture, grassland, range - fair	69	limited
Urban districts: commercial & business	92	very limited
average	**74**	
approx 2/3 to 3/4 of watershed is straight cropping pattern		

USE CN = 75

Assuming AMC-III

CN above based on AMC-II
Adjusting to AMC-III

AMC-II		AMC-III	
CN	Ia	CN	Ia
69	0.90	84	0.38
75	**0.67**	**88**	**0.27**
78	0.56	90	0.22

Madison itself because the City is mainly residential with only limited commercial areas.

The use of the CN also depends on the Antecedent Moisture Condition (AMC), which reflects the amount of rainfall in a period of 5 to 30 days preceding a particular storm. The two conditions applicable to design floods are: 1) AMC-II, an average condition preceding the flood; and 2) AMC-III, heavy rainfall has occurred during 5 days previous to the storm. For this analysis, both AMC-II and AMC-III have been modeled. Use of AMC-II is more typical for use with 100-year flood events, however, the conditions present in 1993 were more appropriate to AMC-III. Additional assumptions related to the AMC used in this analysis include:

	AMC-II	AMC-III
Base Flow	none	0.5 cfs/sq.mi. of subbasin
Lake Levels	at spillway	OHWM (0.5′ above spillway)
Area	excl non-contrib.	include all areas

The time of concentration, T_c, for each subbasin was determined on the following equation:

$$T_c = (11.9*L^3/H)^{0.385}$$

where T_c = in hours
L = longest watercourse in miles
H = elevation difference in feet

Lag time used for the unit hydrograph equaled 0.6 x (Time of Concentration). In several subbasins, the lag time determined by the above procedure was checked against the Snyder lag time (as modified for slope by the COE) with comparable results. Time of Concentration and Lag Time for each subbasin are provided in **Table 1**.

F. Reservoir Routings: The HEC-1 analysis requires storage and hydraulic data to perform the reservoir routings. Information for the elevation-area was generally planimetered from USGS 7½ minute

quadrangle maps. Due to the significance that Lake Herman discharge may have on the balance of the "system" downstream, field surveys were performed to obtain outlet information and roadway profiles in areas that may be overtopped. Also, a field perimeter survey was conducted to determine an accurate elevation-area relationship. Field surveys were also performed for Lake Madison outlet and road overtop areas, Reynolds Slough outlet and road overtop areas, and Brant Lake outlet area.

Reservoir routings for the three Sediment Control Structures were obtained off the construction plans of the dams. Information for the "reservoir" created by Highway 34 at Lake Herman's north inlet was obtained from SDDOT construction plans. Outlet hydraulics for each reservoir routing were established using the computer program HYDRAIN, version 4.0 and/or weir equations as appropriate.

Based on the survey of the Brant Lake spillway, it appears that when Brant Lake is at its spillway level, Round Lake and Brant Lake are essentially one water body instead of two. Therefore, Round and Brant Lakes were not routed individually, rather a combined elevation-area relationship was used with Brant Lake's outlet structure controlling.

To account for the rainfall occurring directly into the lakes, each lake was considered a subbasin with a basin area equal to its surface area at spillway level. A CN = 100 (no infiltration loss) was used for the area with a lag time of 0.1 hours ($\frac{1}{2}$ computation time interval). This hydrograph was then combined with the regular inflow hydrograph prior to the start of the reservoir routing.

G. HEC-1 Analysis Results: The HEC-1 computer model was performed for AMC-II and AMC-III conditions for the 100-year, 50-year, and 25-year precipitation events. **Table 4** presents a comparison between the AMC-II and AMC-III conditions for each frequency at selected locations within the study area. Note that using the AMC-III condition nearly doubles some of the AMC-II projected flood peaks.

TABLE 4

FLOOD PEAKS at SELECTED LOCATIONS

LOCATION	100-YEAR		50-YEAR		25-YEAR	
	AMC-II	AMC-III	AMC-II	AMC-III	AMC-II	AMC-III
Upper Park Creek						
Just upstream of confluence with Park Creek Tributary (node 20)	4,340	8,030	3,650	7,020	2,880	5,890
Just upstream of confluence with Silver Creek (node 40)	4,620	8,400	3,860	7,340	3,090	6,180
Park Creek Tributary (basin 30)	1,610	2,290	1,360	2,020	1,090	1,720
Lake Herman & Silver Creek						
Hwy 34 crossing (res51) Lake Herman N. inlet at golf course	5,880	8,790	4,850	7,630	3,670	6,410
Hwy 34 crossing (basin 70) 2.0 miles E. of Junius	1,690	2,430	1,430	2,140	1,140	1,820
Hwy 34 crossing (node 80) 1.5 miles E. of Junius	4,760	7,000	3,960	6,080	3,160	5,160
Hwy 34 crossing (basin 90) 0.75 miles E. of Junius	3,610	5,260	3,020	4,590	2,400	3,900
Sediment Control #1 inflow(basin 110)	1,270	1,830	1,070	1,610	860	1,370
outflow	210	560	140	360	70	260
Sediment Control #2 inflow(node 120)	1,920	2,950	1,600	2,590	1,260	2,180
outflow	700	2,010	510	1,400	310	1,120
Sediment Control #3 inflow(basin 160)	4,400	6,380	3,670	5,560	2,940	4,730
outflow	1,810	3,800	1,340	3,040	830	2,130
Total Lake Herman inflow (node 102)	14,030	23,100	11,140	19,630	8,120	15,960
outflow	2,020	8,680	920	5,750	410	3,580
Silver Creek at mouth(node 200)	2,670	8,830	2,250	5,930	1,800	3,690
Lower Park Creek						
Just downstream of confluence with Silver Creek (node 45)	6,860	12,080	5,740	8,990	4,580	7,580
Just upstream of Lake Madison near gravel pits (node 210)	8,360	12,650	6,950	10,980	5,520	9,230
Total Lake Madison inflow (node 241)	16,540	25,020	14,200	21,070	12,100	17,780
outflow	2,410	9,260	1,570	6,720	880	4,370
Total Brant/Round inflow (node 271)	8,170	11,578	6,990	10,250	5,620	8,740
outflow	1,490	4,630	920	3640	560	2570

PEAK LAKE ELEVATIONS

LOCATION				100-YEAR		50-YEAR		25-YEAR	
	spillway	OHWM	overtop	AMC-II	AMC-III	AMC-II	AMC-III	AMC-II	AMC-III
Lake Herman	1668.2	1668.7	1672.5	1673.7	1674.9	1673.3	1674.5	1672.4	1674.1
Lake Madison	1603.1	1603.6	1604.3	1605.6	1606.9	1605.4	1606.5	1605.1	1606.1
Brant/Round Lakes	1596.9	1597.4	1605	1600.4	1604.2	1599.5	1603.0	1598.8	1601.7
Reynolds Slough	1738.4	n.a.	1742.5	1739.7	1742.6	1739.5	1742.4	1739.3	1742.2
Sediment Control Structure #1	1723.0	n.a.	1726.0	1723.5	1724.3	1723.3	1724.0	1723.1	1723.7
Sediment Control Structure #2	1723.0	n.a.	1726.0	1724.9	1726.3	1724.4	1726.0	1723.8	1725.5
Sediment Control Structure #3	1722.5	n.a.	1727.1	1724.2	1725.6	1723.7	1725.1	1723.1	1724.6
Hwy 34 - N. Herman inlet	1670.0	n.a.	1684.7	1687.0	1687.8	1686.7	1687.5	1686.3	1687.1

spillway - spillway crest or culvert invert; from Banner surveys for Lakes & Reynolds Slough
for Sediment Structures, refers to emergency spillways

OHWM - based on SDDENR reports: 0.5 feet above spillway crest

overtop - lowest point on road or top of dam adjacent to outlet; Brant basin overtop to Skunk Creek

FLD_SUM.XLS

Also presented is a comparison of the projected lake levels. One copy of the input and output summary of each computer run has been provided to the City of Madison. Detailed output are not presented due to shear volume of printouts. A floppy of the input files can be provided to reviewing agencies upon request (program HEC-1, version 4.0.1E).

A comparison of flood peaks determined for AMC-II under this study against the 1982 FIS and other miscellaneous studies is presented in **Table 5**. The 100-year, AMC-II flood peak determined in this study are 30% to 80% higher than flood peaks at the same location presented in the 1982 FIS. The flood peaks determined using the USGS 80-80 report are almost half of FIS peak using the average; however using the high end of the error range places the values between the FIS and the current study. The regionalized approaches are not appropriate where the upstream basin is significantly affected by large reservoirs. The flood peak for the inflow into Lake Herman obtained in this study and the AGNPS analysis compare very favorably. Also, the SCS analysis of the sediment control structures inflow matches reasonably well at the 25-year flood event, and the SCS analysis of Sediment Structure #1 & #3 compare to this study's 100-year AMC-III.

Photographs taken on July 4, 1993 by Dave Gilbert were compared against survey data and visible landmarks to estimate lake levels experienced on that date. Lake Herman appeared to be at approximate elevation 1675, Lake Madison appeared to be at approximate elevation 1606, and Brant Lake approximate elevation 1602. The observed lake levels match reasonably close to the 100-year, AMC-III computer modeled elevation, with the observed being slightly lower.

The COE did obtain high water marks within the City and those elevations will more appropriately be checked against the HEC-2 Water Surface Profile computer runs.

TABLE 5

COMPARISON of FLOOD PEAKS with PREVIOUS STUDIES

LOCATION	100-YEAR			50-YEAR		25-YEAR		Comments - "Other"
	Current Study	1982 FIS	Other	Current Study	1982 FIS	Current Study	Other	
Upper Park Creek								
Just upstream of confluence with Park Creek Tributary (node 20)	4,340	2,400	1,330	3,650	1,700	2,880		1980 USGS Regional Analysis method
Just upstream of confluence with Silver Creek (node 40)	4,620	2,700	1,480	3,860	2,000	3,090		1980 USGS Regional Analysis method
Park Creek Tributary (basin 30)	1,610	1,200	520	1,360	880	1,090		1980 USGS Regional Analysis method
Lake Herman & Silver Creek								
Hwy 34 crossing (res51) Lake Herman N. inlet at golf course	5,880		1,160	4,850		3,670	573	SDDOT plan sheets
Sediment Control #1 inflow(node 110)	1,270		1,902	1,070		860	982	SCS plans
outflow	210		717	140		70	193	
Sediment Control #2 inflow(node 120)	1,920		1,959	1,600		1,260	1,014	SCS plans
outflow	700		319	510		310	21	
Sediment Control #3 inflow(node 160)	4,400		6,434	3,670		2,940	3,365	SCS plans
outflow	1,810		4,027	1,340		830	1,356	
Total Lake Herman inflow (node 102)	14,030		14,050	11,140		8,120		AGNPS analysis
Silver Creek at mouth(node 200)	2,670	1,700		2,250	1,300	1,800		
Lower Park Creek								
Just downstream of confluence with Silver Creek (node 45)	6,860	3,700		5,740	2,400	4,580		
Just upstream of Lake Madison near gravel pits (node 210)	8,360		5,017	6,950	2,973	5,520		SDDOT plans - u/s of tributary inflow
Brant outflow (Res 271)	1,490		900	920		560		DENR analysis (625cfs from Madison)

H. Recommendations: The HEC-1 analysis for the AMC-II condition presented in this report will be used for the hydraulic analysis utilizing the HEC-2 computer model. Conditions that existed in 1993 were likely AMC-III conditions, however it appears that those conditions were unusual. If the AMC-III conditions are used to proceed into the hydraulic modelling phase, more than likely an overly conservative approach is being used, and costs for flood mitigation alternatives are likely to increase significantly. Using the USGS regionalized approach cannot adequately address the impact of flood attenuation caused by upstream lakes/reservoirs.

V. HYDRAULIC EVALUATION AND ASSESSMENT OF EXISTING STRUCTURES

A. General: This section of the drainage basin study investigates the existence and severity of the flood hazards in the populated areas of Lake County and the City of Madison, South Dakota. Alternatives will be evaluated to determine necessary improvements to alleviate flood hazards. Initial use of this study will be to buy out and relocate homes within the floodway. Further use of this study will be made by local and regional planners to minimize future flood damage by construction of flood control projects and / or prevent structural development in the flood plain. The incorporated areas of the City of Madison will be studied in detail because of the greatest potential of Life-Safety Hazard.

B. Previous Studies: The 1982 Flood Insurance Study has established a floodway for the incorporated portion of the City of Madison. The 1982 Flood Insurance Study and associated mapping is available through the Federal Emergency Management Agency (FEMA) or the City of Madison. The Hydrology analyses for this report, accepted by various agencies, indicates the projected flows for the 25, 50 and 100 year storms exceed storm flows as published in the Flood Insurance Study. The result is a change in the flood plain. Tables of comparison are presented in Section IV, Hydrologic Evaluation of this report.

C. Hydraulic Baseline: A baseline computer model with existing structures and channels was established on Park Creek and Silver Creek through the City of Madison. The purpose of establishing a baseline is to model the existing conditions from which to measure or compare proposed changes and to identify areas or structures that are causing flooding.

Water-surface elevations of floods for the 25, 50 and 100-year intervals were computed through use of the U.S. Army Corps of Engineers HEC-2 step-backwater computer program. Headlosses at bridges and culverts were computed using bridge and culvert routines contained in the HEC-2 computer program.

Cross sections for the backwater analysis of Park Creek, Park Creek Tributary, and Silver Creek were obtained from a computer generated contour map created from field survey data. Bridges, culverts, and intersection elevations were also determined by field measurements.

Roughness factors (Manning's "n") used in the hydraulic computations were established by field inspections and engineering judgement. Roughness values for the stream channel ranged from 0.025 to 0.040. Roughness values for the overbanks ranged from 0.060 to 0.100.

The existing stream through the City of Madison was modeled for the 25, 50 and 100 year flood peak discharge using the HEC-2 computer model. The model using existing conditions will be referred to as the baseline study. The purpose of establishing a baseline is to model the existing conditions from which to measure or compare proposed changes and to identify areas or structures that are causing flooding.

Figure 3 shows the baseline floodway for the 25-year and 100-year flood. The 100-year baseline model indicates there are four structures that are creating a ponding of water on the upstream side of the structure. One structure on Park Creek is the railroad