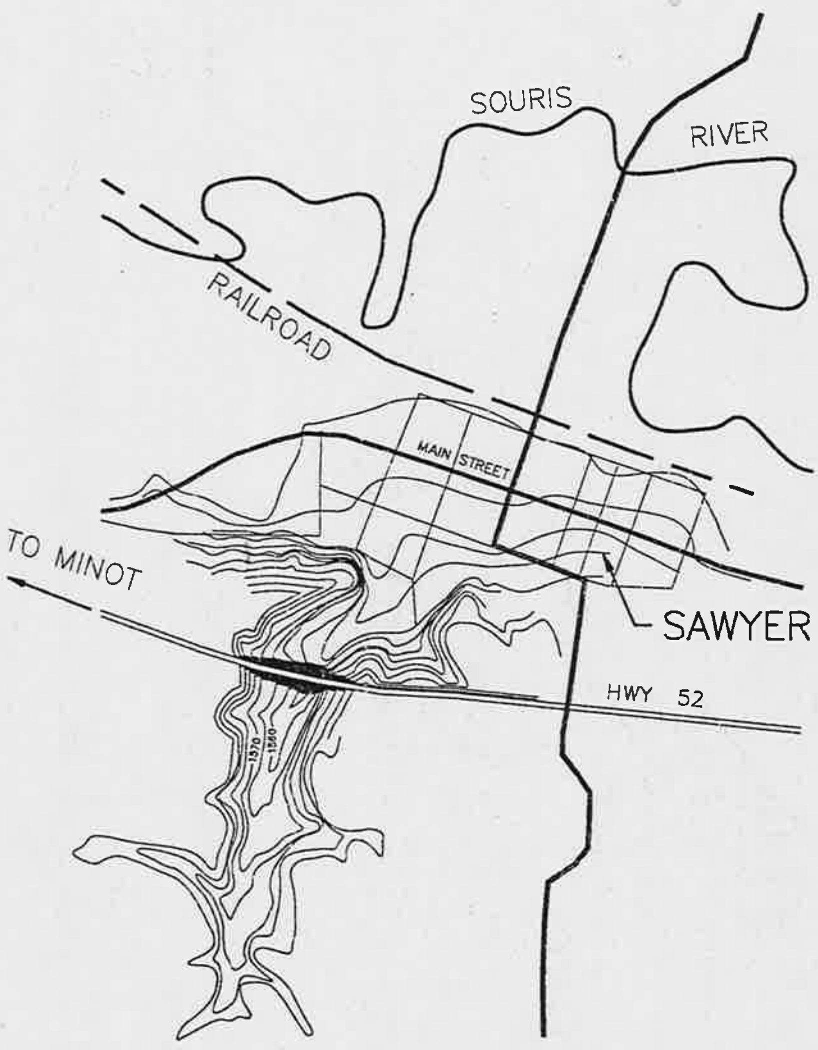
PRELIMINARY ENGINEERING REPORT

SAWYER FLOOD CONTROL

SWC # 1313

WARD COUNTY



NORTH DAKOTA

STATE WATER COMMISSION

APRIL 1994

PRELIMINARY ENGINEERING REPORT

Sawyer Flood Control

SWC Project 1313

May 1994

North Dakota State Water Commission
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TABLE OF CONTENTS

TABLES

TABLE OF CONTENTS (CONT)

FIGURES

APPENDICES

I. INTRODUCTION

Study Objectives:

In April 1991, the North Dakota State Water Commission, entered into an agreement with the Ward County Water Resource District, to investigate the feasibility of reducing the discharge capacity of the 7-foot diameter reinforced concrete pipe (RCP) through US Highway 52 near Sawyer, North Dakota, for the purpose of providing flood control for the city of Sawyer. A copy of the agreement can be found in Appendix A.

Location:

The city of Sawyer is located in southeastern Ward County, approximately 20 miles southeast of Minot, North Dakota, on US Highway 52. The highway crossing is located approximately 1,000 feet south, upstream of the city on an unnamed tributary to the Souris River located in the NE¼SE¼ of Section 10, Township 153 North, Range 81 West (Figure 1).

Geology and Climate:

North Dakota is composed of two physiographic provinces, the Central Lowland and the Great Plains provinces. The project area is located in the Missouri Escarpment District within the Central Lowland physiographic province.

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LOCATION MAP

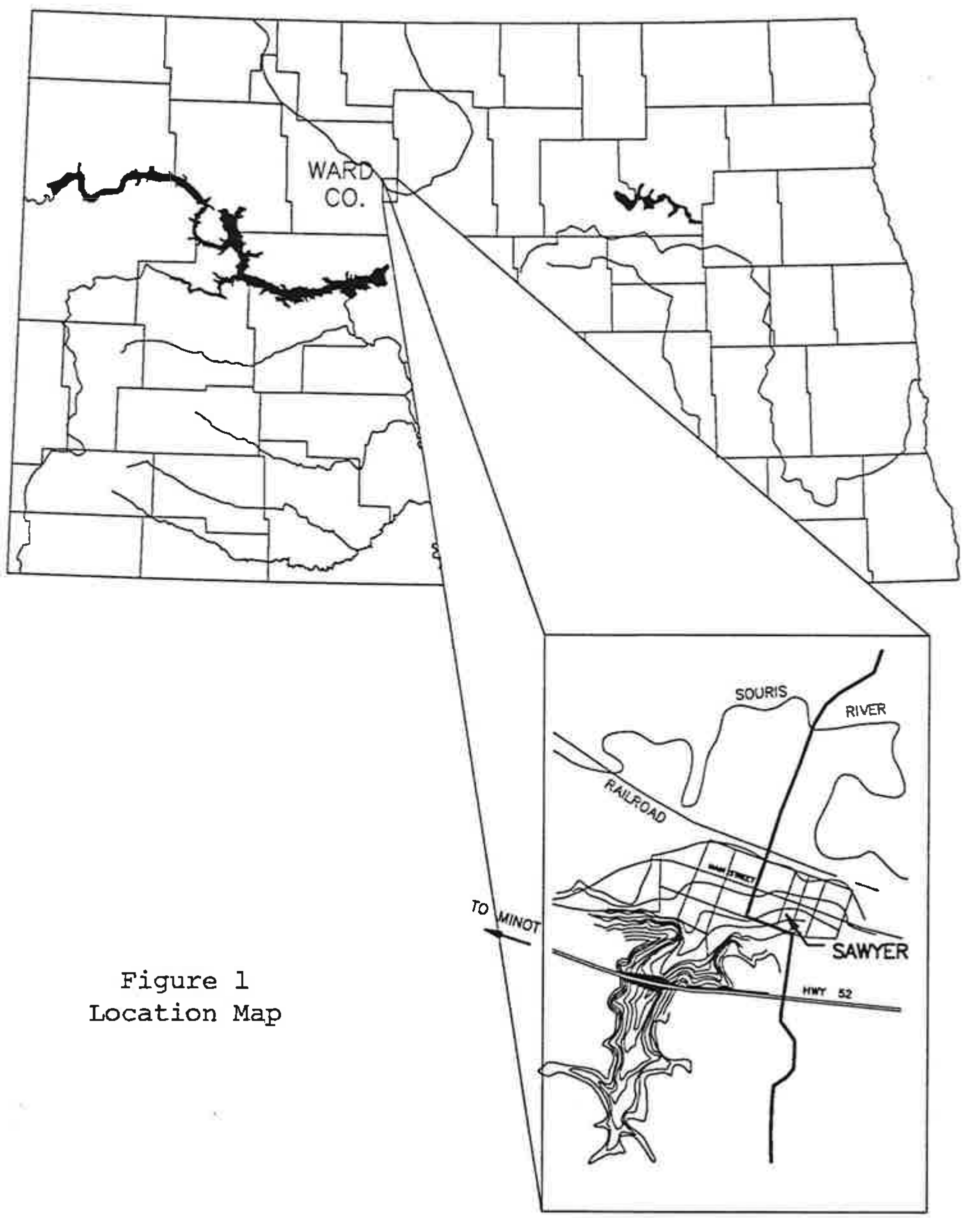

Figure 1
Location Map

The Missouri Escarpment extends from the Des Lacs and Mouse River valleys to the eastern margin of the Missouri Coteau. The surface of the escarpment, which is controlled in part by the underlying bedrock, is inclined rather steeply to the northeast. The northeast-facing escarpment is an abrupt feature along most of its length in Ward County, and local relief may exceed 300 feet (Bluemle 1989).

The area receives approximately 15 inches of precipitation annually, with the majority falling during the growing season, May through September. The area has an annual mean temperature of approximately 39 degrees Fahrenheit, and experiences large annual, daily, and day-to-day temperature changes. Based on the annual precipitation and mean temperature, the climate is classified as semi-arid.

II. BACKGROUND

Historical Background:

The city has experienced flooding many times in the past from runoff upstream of the highway crossing. The watershed upstream of the crossing is fairly steep and narrow. These two factors result in flows reaching Sawyer quickly, with little reduction in peak flows.

Site Description:

The watershed area above the 7-foot diameter RCP is approximately 1.2 square miles. The uplands consist of farmland and account for approximately two-thirds of the total watershed area. The remaining watershed area is pasture land and woody habitat located within the draws. Runoff from the uplands is collected by narrow and steep draws, and flows under US Highway 52 through a 7-foot diameter RCP.

The highway embankment is approximately 40 feet above the channel, with the highway at an elevation of approximately 1593 mean sea level (msl). The upstream invert of the pipe is at an elevation of approximately 1553 msl. The downstream pipe invert is at approximately 1551 msl. The length of the pipe is approximately 200 feet, resulting in a slope of approximately 1 percent.

The North Dakota State Department on Transportation (DOT) requires road crossings to be designed for a particular event, based on the class of road. The design event for US Highway 52 is a 25-year event, and requires the water elevation on the upstream face of the embankment (headwater elevation) be no more than two times the diameter of the pipe, measured from the invert. This results in a maximum headwater elevation of approximately 1567 msl, for the 7-foot RCP.

The flows exit the pipe approximately 500 feet upstream of Sawyer. The flow follows a poorly defined channel for approximately 1,000 feet before passing under 2nd Street through a 4-foot diameter corrugated metal pipe (CMP). The flow then follows an earthen channel on the east side of 2nd Avenue. The flow continues north along 2nd Avenue for approximately 600 feet (2 city blocks), and then turns northwest, eventually entering the Souris River.

The channel varies in cross-section and is poorly defined from where it exits the pipe to the point where it enters the channel along 2nd Avenue. The channel along 2nd Avenue varies from trapezoidal in cross-section with a bottom width of approximately 6 feet and 4:1 side slopes (horizontal to vertical), to triangular in cross-section with 4:1 side slopes. The channel slope ranges from 7 percent, where it exits the pipe, to 1 percent as it enters the channel along 2nd Avenue. Figure 2 shows the local topography and the channel downstream of US Highway 52 to the Souris River.

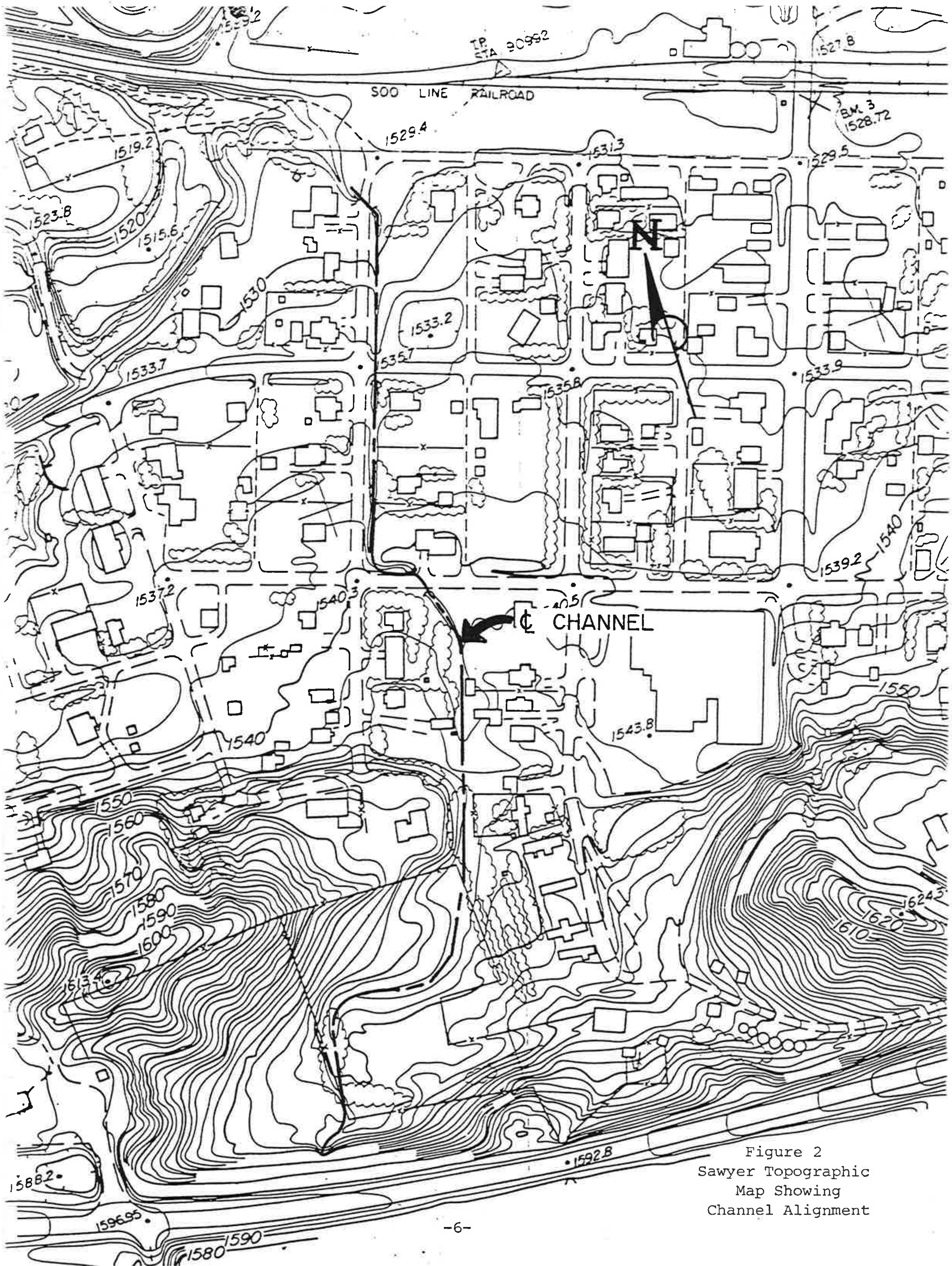

Figure 2
Sawyer Topographic
Map Showing
Channel Alignment

III. PROCEDURES

The HEC-1 and HEC-2 computer models were used to develop the basin hydrology and the hydraulic analysis of the channel downstream of the US Highway 52, respectively. The models were developed by the US Army Corps of Engineers.

The HEC-1 model was used to conduct the hydrologic analysis of the watershed. The model simulates the surface runoff response of a basin to precipitation by representing the basin as an interconnected system of hydraulic components. Each component models an aspect of the precipitation-runoff process within a portion of the basin. The components require a set of parameters which specify the particular characteristics of that component and mathematical relationships which describe the physical processes. The model takes the precipitation for a specified event, and using the parameters for the individual components, calculates the precipitation-runoff response (HEC 1981).

The HEC-2 computer model was used to generate a water surface profile for the channel. The profile is necessary to determine the channel capacity, i.e., the flow the channel can carry before the banks are overtopped and flooding occurs. The profile is calculated proceeding upstream and extends from the point where flow exits the channel along 2nd Avenue entering the Souris River, upstream to where the flow exits the 7-foot pipe. The profile length is approximately 1,900 feet.

The HEC-2 model calculates the water surface profiles based on the flow, the slope of the channel, the channel roughness, the cross-sectional shape, and the distance between cross-sections (HEC 1990).

IV. PRELIMINARY DESIGN

Introduction:

The investigation evaluated existing conditions and two alternatives: 1) modifying the upstream inlet of the 7-foot RCP; and 2) constructing a dry dam upstream of the highway crossing. The existing conditions evaluation includes a hydraulic analysis of the channel through Sawyer, and a hydrologic analysis of the watershed upstream of US Highway 52 to determine the runoff entering Sawyer for a wide range of precipitation events.

Alternatives 1 and 2 use upstream storage to reduce peak flows through Sawyer. The modification of the pipe inlet creates a dam out of the highway embankment. Therefore, the construction of a dry dam or modifying the pipe inlet are both required to meet dam safety requirements.

The inlet modification has to meet the requirement that the structure significantly reduces peak flows from major events while minimizing the backwater on the highway embankment. The goal is to provide Sawyer with 100-year flood protection.

Dam Classification:

The initial step in designing the dry dam or the modified inlet was to determine the respective dam design classifications. Dams in North Dakota are classified according to criteria found in "North Dakota Dam Design Handbook" (Moum, et. al., 1985). The following criteria are used to classify dams for design purposes: 1) the potential hazard to property or loss of life; and 2) the height of the dam. There are three types of hazard classifications: high, medium, and low. A description of these classifications follows.

High - Dams located upstream of developed and urban areas where failure may cause serious damage to homes, industrial and commercial buildings, and major public utilities. There is potential for the loss of more than a few lives if the dam fails.

Medium - Dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, railroads, or cause interruption of minor public utilities. The potential for the loss of a few lives may be expected if the dam fails.

Low - Dams located in rural or agricultural areas where there is little possibility of further development, and if the dam fails, damage to agricultural land, township and county roads, and farm buildings other than residences may result. No loss of life is expected.

The proposed alternatives are in a rural location. US Highway 52 is located immediately downstream of the proposed dry dam and also forms a dam embankment if the inlet is modified. In the event of a dam failure, the potential loss of the highway is likely for both alternatives; therefore, both alternatives carry a medium hazard classification.

The second criteria used to classify dams is the height of the embankment. The proposed dry dam would have a top of crest elevation of 1590 msl. The valley floor is at elevation 1560 msl, resulting in an embankment height of 30 feet. If the inlet to the 7-foot diameter RCP is modified, the embankment height is equal to the highway embankment height, 40 feet. The following table lists the dam classifications based on the hazard category and embankment height:

Table 1 - Dam Design Classification

	Hazard Categories		
Dam Height	Low	Medium	High
Less than 10	I	II	IV
10 to 24	II	III	IV
25 to 39	III	III	IV
40 to 55	III	IV	V
Over 55	III	IV	V

Based on the medium hazard classification and an embankment height of 30 feet, the proposed dry dam is given a class III dam design classification. This class of dam must meet the following requirements: 1) the principal spillway must pass a 25-year precipitation event (Principal Spillway Hydrograph) without flow passing through the emergency spillway; 2) the emergency spillway must pass a 100-year precipitation event within an acceptable range of velocities (Velocity Hydrograph), i.e., 4 to 7 feet per second (fps); and 3) the embankment must have sufficient height to retain a 0.3 Probable Maximum Precipitation (PMP) event (Freeboard Hydrograph) without overtopping.

Modification of the inlet to the 7-foot diameter RCP creates a dam with a class IV design category. A class IV dam must meet the following requirements: 1) the principal spillway must pass a 50-year precipitation event without flow passing through an emergency spillway; 2) the emergency spillway must pass a 0.3 PMP event within acceptable velocities; and 3) the embankment must have sufficient height to retain a 0.5 PMP event without overtopping.

An emergency spillway was not incorporated or necessary in the design of either alternative. In the dry dam alternative, the proximity of the highway embankment did not allow room for construction of an emergency spillway, and for obvious reasons, an emergency spillway was not considered if the inlet to the 7-foot diameter RCP is modified, since this would entail excavating a notch into the highway embankment.

Hydrology:

The HEC-1 model was used to determine the peak inflows, peak stages, and peak outflows for the considered alternatives. A wide range of precipitation events were modelled.

Numerous events were investigated for existing conditions. First, to determine the event the channel through Sawyer can pass before flooding occurs; and second, to measure the impacts of modifying the pipe inlet and construction of a dry dam. Below is a table showing the range of precipitation events modelled:

Table 2 - Sawyer Flood Control Study Design Events

1. 10-Year 2-Hour Rainfall
2. 25-Year 2-Hour Rainfall
3. 25-Year 10-Day Snowmelt
4. 50-Year 2-Hour Rainfall
5. 50-Year 10-Day Snowmelt
6. 100-Year 2-Hour Rainfall
7. 100-Year 10-Day Snowmelt
8. 0.3 Probable Maximum Precipitation
9. 0.5 Probable Maximum Precipitation

The input data required by the model includes the watershed area, precipitation amount and time distribution, soil type and land use, hydraulic characteristics of channels and drainage areas, and the physical characteristics of the reservoir. The result of the modeling process is the computation of inflow and associated volumes for the design events.

The watershed above US Highway 52 was defined using USGS 7.5-minute quadrangle maps of the area. The watershed area is approximately 1.2 square miles. The watershed was considered the same for each alternative, even though the dry dam is located approximately 200 feet upstream of the highway. Figure 3 illustrates the watershed boundary.

The following table shows the precipitation used for each of the design events and the resulting inflow and volumes:

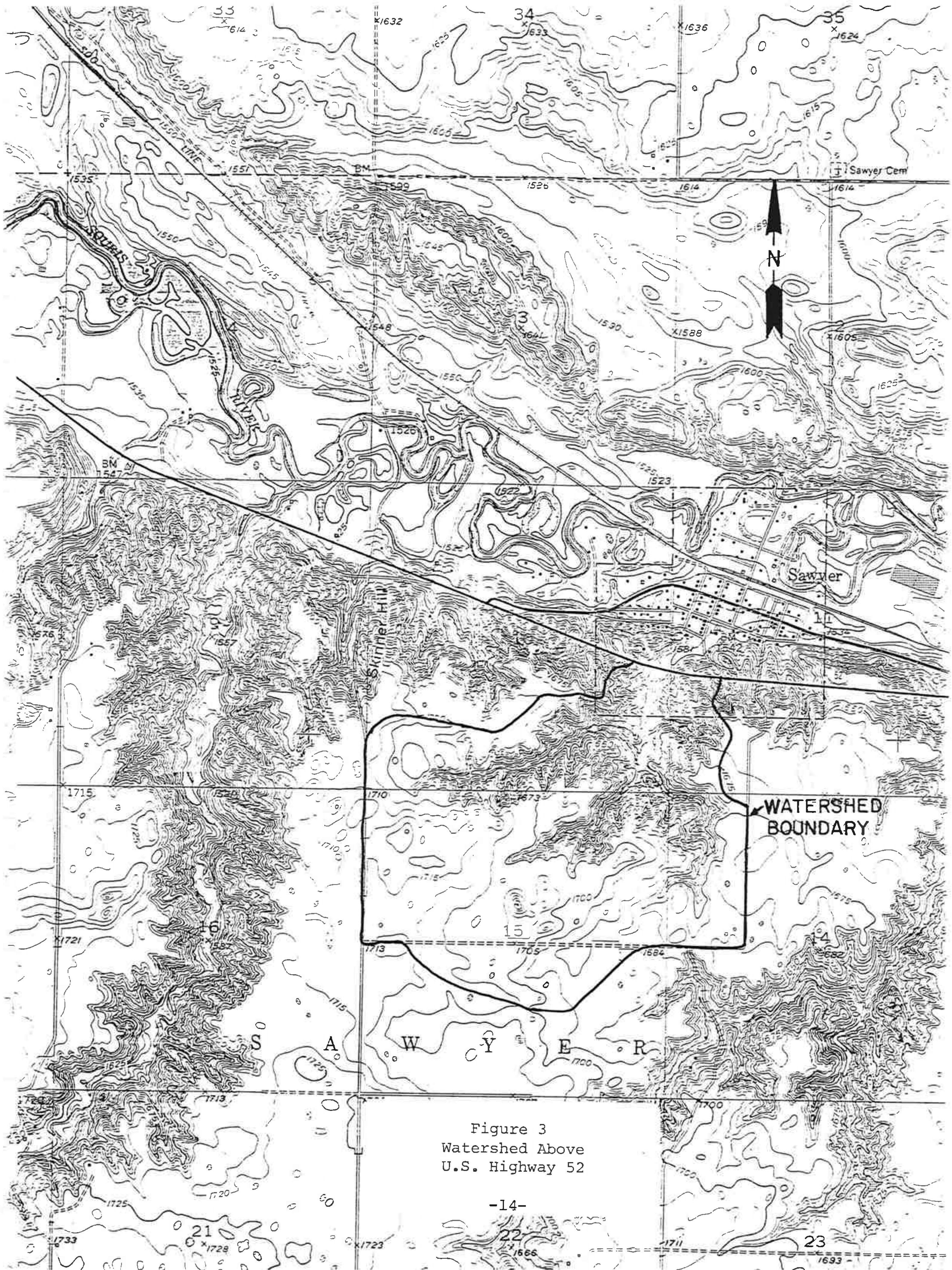

Figure 3
Watershed Above
U.S. Highway 52

Table 3 - Precipitation, Peak Inflows, and Volumes for Design Events

Event	Precipitation (inches)	Peak Inflow (cfs)	Volume (acre-feet)
10-Year 2-Hour Rain	1.7	71	14
25-Year 2-Hour Rain	2.3	147	29
25-Year 10-Day Snowmelt	2.7	99	132
50-Year 2-Hour Rain	2.6	207	41
50-Year 10-Day Snowmelt	3.2	119	161
100-Year 2-Hour Rain	3.0	281	56
100-Year 10-Day Snowmelt	3.8	144	198
0.3 PMP	6.3	1000	211
0.5 PMP	10.5	2088	443

The HEC-1 model requires information on elevation versus storage relationships of the reservoir, and the spillway elevation versus discharge relationships (rating curve) to route inflows. The following table gives the elevation/area/capacity relationships for the area immediately upstream of US Highway 52.

Table 4 Elevation/Area/Capacity Area Upstream US Highway 52

Elevation	Area (acres)	Capacity (acre-feet)
1555	0.0	0
1560	1.4	3
1565	3.8	16
1570	6.6	41
1575	10.0	83
1580	12.3	138

A 7-foot diameter RCP extends through US Highway 52 embankment, with the upstream and downstream inverts at elevations 1553.5 and 1551.4, respectively. The length of the pipe is 200 feet, resulting in a slope of approximately 1 percent. The following table gives the elevation versus discharge relationships for the 7-foot diameter pipe. The pipe inlet controls the flow for the entire range of elevations. Figure 4 is the 7-foot diameter RCP rating curve.

Table 5 - Elevation Versus Discharge
7-Foot RCP

Elevation (ft-msl)	Discharge (cfs)
1553.5	0.0
1556.0	50.0
1557.0	100.0
1558.0	150.0
1559.0	225.0
1560.0	325.0
1568.0	717.0
1576.0	943.0
1582.0	1081.0

The following table shows the response of existing conditions to a wide range of precipitation events:

Table 6 - Hydrologic Results
Existing Conditions

Event	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Stage (ft-msl)
10-Year 2-Hour Rain	71	71	1556.3
25-Year 10-Day Snowmelt	99	98	1556.7
25-Year 2-Hour Rain	147	146	1557.7
50-Year 10-Day Snowmelt	119	119	1557.2
50-Year 2-Hour Rain	207	203	1558.6
100-Year 10-Day Snowmelt	144	144	1557.7
100-Year 2-Hour Rain	281	281	1559.6
0.3 PMP	1000	755	1569.2
0.5 PMP	2088	1069	1581.5

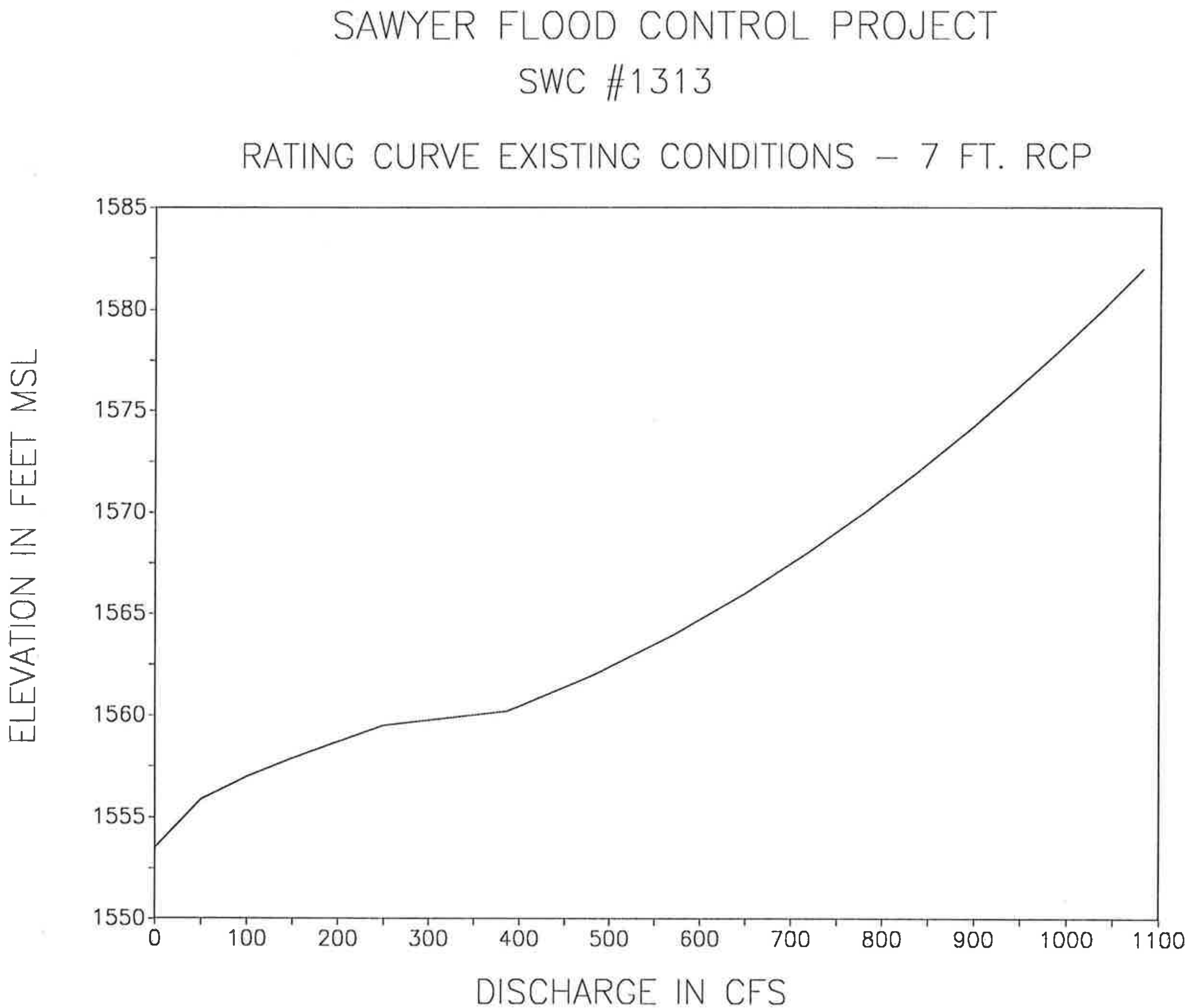

Figure 4 - Rating Curve
7-foot Diameter RCP

The results of the hydrologic analysis for existing conditions indicate the 100-year 2-hour rainfall event produces the maximum outflow, approximately 300 cfs, and is therefore the critical event. The results also indicate all runoff is passed through the 7-foot diameter RCP without any reduction in peak flows, except for the 0.3 and 0.5 PMP events.

The results of the hydraulic analysis of the channel through Sawyer indicate a channel capacity of approximately 60 cubic feet per second (cfs). Referring to the above table, the channel can pass approximately a 10-year event with minimal flooding.

The analysis indicates the 100-year flow overtops 2nd Street and 2nd Avenue, overtopping these roads by approximately 1-foot. This results in approximately 200 cfs breaking out of the channel, flowing in a northwesterly direction, and following the natural topography. The estimated area of inundation for the 100-year flood is shown in Figure 5. Figure 6 shows the channel and the surveyed cross-sections, indicating the area inundated for the 60 cfs flow and the 100-year flow at 300 cfs.

Alternative I - Modified Inlet

Alternative I consists of the construction of a drop inlet structure on the upstream end of the 7-foot diameter RCP. The structure will have a floor elevation equal to the pipe invert of 1553.5 msl, with a weir elevation of 1570 msl, resulting in a

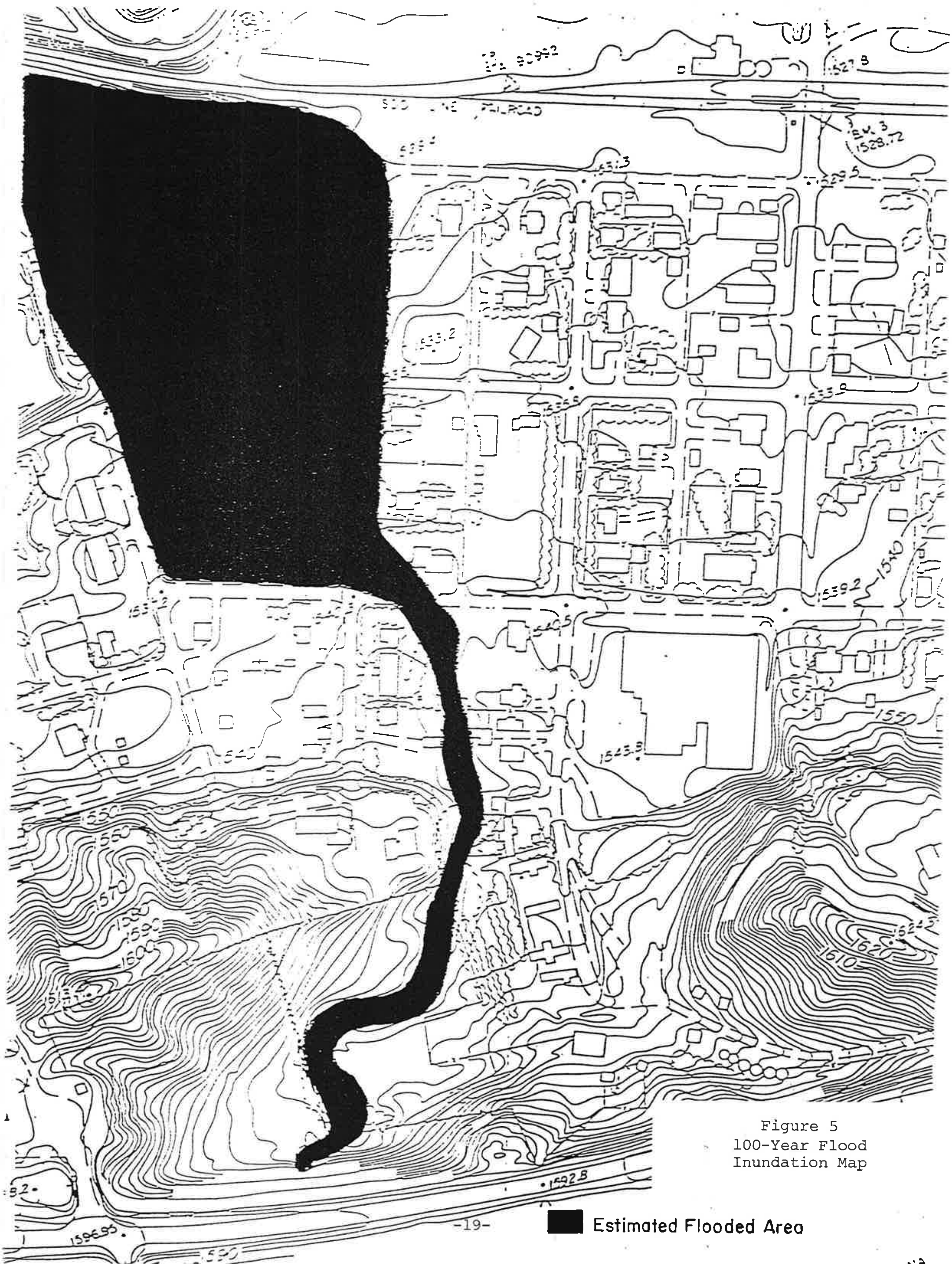

Figure 5
100-Year Flood
Inundation Map