Section I
BASIN EVALUATION

Section I

BASIN EVALUATION

PLANNING AREA DESCRIPTION

The Beal Slough Basin area includes approximately 13.5 square miles located on the south side of Lincoln. The elliptically shaped watershed begins near the Village of Cheney in the east and flows 8 miles westward to its mouth at Salt Creek, generally following Nebraska Highway 2. The watershed location is shown on Figure I-1.

Portions of the basin are outside the city limits; however, all of the watershed is within the city's planning and zoning jurisdiction. The unincorporated community of Cheney is at the top of the watershed. The watershed was initially developed on the north slopes of the lower and middle portions of the watershed. Steady growth rates were maintained until the late 1980s with rural residential development occurring in Upper Beal Slough and urban residential development occurring in Tierra Branch and Middle Beal Slough. Since the beginning of this decade the watershed has experienced a tremendous rate of development and, based on the data provided by the Lincoln Planning Department, was approximately 75% urbanized by the end of 1996.

"Watershed shape can have a profound effect on the hydrograph and stream behavior, particularly from small watersheds, and especially in relation to the direction of storm movement."[1] Watershed eccentricity (t) is a parameter that accounts for the location of the outlet, emphasizes the lower portion of the watershed which is where the flood peak is generated, provides a degree of predictability, and is easily measured.

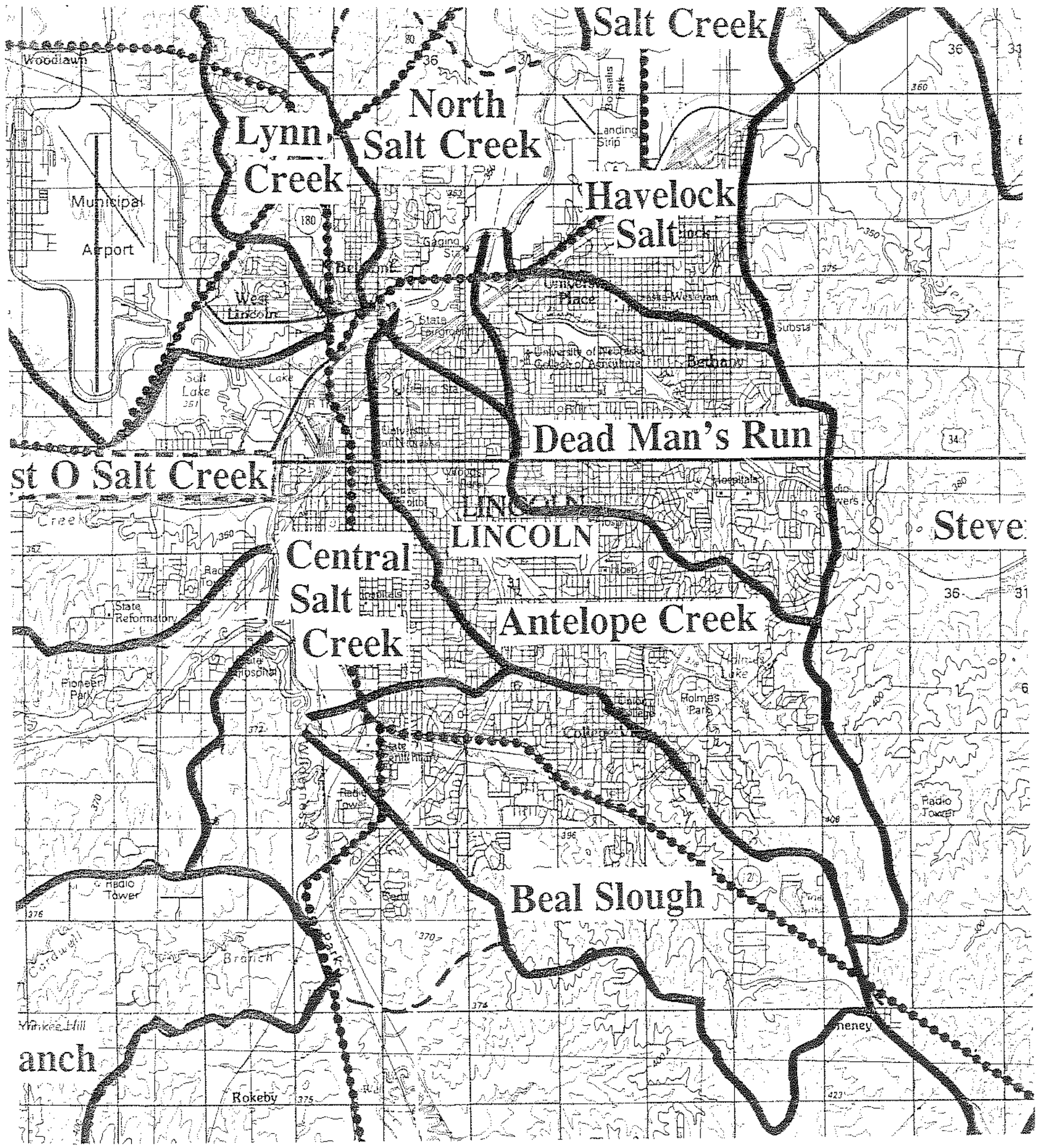
$$t = (|\,L_C^{\,2} - W_L^{\,2}\,|)^{0.5} / W_L$$

L_C	-length from the outlet to the centroid of the watershed, feet.
W_L	-width of the watershed at the basin centroid measured perpendicular to L_C, feet.
t	-watershed eccentricity is a watershed shape parameter that effects runoff behavior.

Low values of t are typically associated with high flood peak potential. High values of t are associated with low flood peaks under the assumptions that the storm uniformly, instantaneously, and completely covers the watershed model.[2] The Beal Slough Basin has a medium eccentricity which can be associated with medium flood peak potential. General hydrologic parameters for the basin are provided in Table I-1.

[1]Watershed Hydrology, Peter E. Black, page 261

[2]ibid, page 371



Hydrologic Parameters of the Basin

Parameters[1]	
Area, square miles	13.51
Basin Width, W_L (feet)	14,400
Length, L (feet)	44,000
Length to Centroid, L_C (feet)	19,200
Eccentricity, t (dimensionless)	0.88
Maximum Elevation	1425
Minimum Elevation	1165
Weighted Slope, S_{wtd} (percent)	0.60

FLOODING HISTORY

Flood events that have occurred in Beal Slough have generally been short in duration. Many storm events are handled by designated stormwater containment areas but others have overtopped these facilities and caused flooding to roadways and residential areas.

This was the case on Saturday, July 20, 1996 when over five inches of rain fell on portions of south Lincoln in less than eighteen hours. A number of roadways, including portions of Highway 2, residential basements, and recreational areas, experienced flooding. Flooding occurred near 33th Street and Pioneers Boulevard and in many areas along Tierra Branch in the Tierra, Williamsburg, Seven Oaks, and Cripple Creek Subdivisions and other areas.

A heavy rainfall event also occurred in Beal Slough in 1989. Stormwater filled, then overtopped the creek and spread to Tierra and Briarhurst Parks and nearby open spaces. This storm's effect on Beal Slough was consistent with projections of the Flood Insurance Study for the City of Lincoln, Nebraska published by FEMA. The FIS report described flood events along Beal Slough as occurring with little warning and being short in duration. This type of flooding is not unique to Beal Slough and has the potential to occur in Antelope Creek, Cardwell Branch, Elk Creek, Lynn Creek, Stevens Creek, Stevens Creek Tributary, and Deadman's Run.

MODELS

Digital terrain modeling and the subsequent topographic 2-foot contour mapping was developed by Merrick & Company for the City from aerial photography exposed in January 1997. This information was used to delineate stormwater subbasins, channel cross-sections, and channel reach lengths as a basis for analysis of the hydrologic and hydraulic characteristics of the watershed.

Hydrologic and hydraulic modeling software can be used to estimate the response of a watershed to precipitation. Watershed conditions can be simulated and the effectiveness of stormwater management practices can be compared. Two software packages were selected to model the Beal Slough basin. Visual HEC-1® was developed by Haestad Methods to create, modify, display, and run HEC-1 data in a Windows® environment. HEC-1, developed by the Corp of Engineers Hydrologic Engineering Center, is designed to simulate the surface runoff response of a watershed to precipitation by representing the watershed as an interconnected system of hydrologic and hydraulic components. HEC-RAS, a river analysis system software, also developed by the Corps of Engineers, performs one-dimensional steady state flow calculations to generate water surface profiles. Flow rates generated in HEC-1 are used in HEC-RAS to determine water surface profile

HEC-1 estimates watershed runoff response using one of several methods. Based on the availability of data, local acceptance, experience of anticipated users, applicability to other area watersheds, and limited availability of calibration data, the TR-20 method was chosen for use in this master planning effort. The TR-20 method utilizes lumped parameters to emulate the process of converting precipitation into runoff. These parameters are described in more detail in the Hydrology potion of this report. To address the range of stormwater management issues expected, a series of six rainfall frequencies were analyzed: the 2-, 5-,10-, 25-, 50-, and 100-year average return frequency events. A storm duration of 24 hours is appropriate for evaluation of stormwater master planning components and was used to develop the hydrographs. Precipitation data were extracted from the U.S. Department of Commerce, Weather Bureau, Technical Paper-40, Rainfall Frequency Atlas of the United States for the 2-, 5-, 10-, 25-, 50-, and 100-year storms. Historical precipitation data gathered from weather station sites in south Lincoln were provided by the City.

The hydrologic information from HEC-1 and the Corps of Engineers procedure for the HEC-RAS hydraulic model were used to estimate water surface profiles along the mainstem and tributaries of Beal Slough. Hydraulic stream characteristics were determined from 1997 aerial photography, topographic mapping, digital terrain models, and field observations. The respective return frequency flood events modeled by the HEC-RAS analysis are assumed to be generated by the corresponding frequency design storm, i.e., the 10-year flood is generated by the 10-year rainfall. The HEC-RAS analysis of Beal Slough is discussed in more detail in the HYDRAULICS section.

GEOGRAPHICAL INFORMATION SYSTEM

Introduction

Olsson Associates and Wright Water Engineers developed a hydrologic model which is integrated and linked to the City's geographic information system (GIS). This PC-based computer software application will provide a user-friendly computer environment that relating the schematic modeling components of the hydrologic model for the Beal Slough watershed (developed using Visual HEC-1), to the physical features that help define that model such as land use characteristics, soil types, and basin delineation boundaries (which are stored in a GIS). It is intended the underlying framework used to develop the Beal Slough software package will be transferred to other watersheds throughout the Lincoln metropolitan area for future master plan modeling.

Functional Requirements

The functional requirements for this application include those elements which are necessary in order to operate the application software. This includes:

- ArcView GIS 3.0

  ArcView is a geographic information system (GIS) software application built by the Environmental Systems Research Institute (ESRI). ArcView provides tools for viewing, analyzing, querying and modifying geographic (spatial) data. ArcView is available for both the MS Windows and UNIX operating systems.

  The Beal Slough application was developed in ArcView's internal programming language, Avenue, and is intended to be run on a PC using the Windows operating system. A Windows operating system is necessary because of the developed linkage between ArcView and the Windows-only applications of Visual HEC-1 and Visual Basic. Visual Basic is a Windows programming language used to develop a user-friendly "front-end" menu system for all of the Beal Slough model applications (i.e., hydrologic model, hydraulic model, and water quality model).

  The ArcView portion of the Beal Slough application can also be run on the UNIX version of ArcView; however, all linkage to Visual HEC-1 would be lost in the UNIX operating system. To overcome this, the recommended approach is to have ArcView running on Windows, accessing data files sitting on a central UNIX server through a network connection.

- Visual HEC-1

  Visual HEC-1 is a user-friendly, Windows-based version of the U.S. Army Corps of Engineers' hydrologic model, HEC-1. The model uses interactive graphics that allow the user to construct the drainage features spatially. In addition, the data input process is greatly facilitated by the Windows environment. Visual HEC-1 will generate flood flows from multiple return frequency events, perform channel and reservoir routing, enable the evaluation of alternatives, and provide the basis for the development of water surface profiles using the hydraulic model, HEC-RAS. Finally, the Windows-based nature of Visual HEC-1 allows for the desired linkage with GIS.

- GIS data

  GIS data are required to be maintained in ArcView's native format, called shape files. Shape files are comprised of three data file types for each data layer or feature layer. The three data file types are:

  1. *.shp* or shape files that make up the vector information that define the feature.
  2. *.dbf* or database files that make up the attribute information about each feature.
  3. *.shx* or cross-reference files that link together *.shp* and *.dbf* files.

  Additionally, the *.apr* file, or ArcView project file, needs to be accessible.

  Data layers for the Beal Slough application include:

  1. Watershed - Subbasin boundary delineations are defined by the topographic ridge and valley lines that make up the watershed. Each subbasin within the GIS contains attribute information such as name, area, lag-time, and composite curve number (CN).
  2. Reach - Reaches represent the drainage paths through each watershed subbasin. Each reach within the GIS contains attribute information that describes the characteristics of the reach such as reach name, channel slope, roughness coefficient, bottom width, and side slope.
  3. Pond - Pond locations are shown in the GIS for location information only and include retention ponds and "ponding" along channels created by culverts, bridges, and trestles.

4. Grid - The Beal Slough watershed was broken down into a 200-foot by 200-foot grid. This provides tools for analyzing the subbasin at smaller scales and for developing composite values that make up the watershed attribute information. Attributes within this layer include basin name, 1997 land use, future land use, hydrologic soil types, and 1997 and future curve numbers (based on land use and hydrologic soil types).

Additional data layers may be added to the ArcView project file in order to provide additional or background reference/location information. This could include, but not be limited to, streets, utilities, parcels, and orthophotography.

Menu Process Flow

The menu process flow for each software package explains in detail how each software is intended to be used on this project.

ArcView

This application maintains all existing ArcView functionality. Advanced users of ArcView will have access to all of the existing tools and pull-down menus within the ArcView application. Additional pull-down menus specific to the Beal Slough project have been added. These include:

1. Subbasin - Within the Subbasin pull-down menu, the user has the opportunity to change the basin name, change the composite curve number, or to recalculate the area in the event that a subbasin boundary is modified. If a basin name is changed, the same basin name must be updated manually within the Visual HEC-1 software. This common name maintains the link between the two software applications. Whenever a subbasin's boundary is modified, the basin's area must also be recalculated so that the Visual HEC-1 model can be rerun to reflect the modification.
2. Grid - Within the Grid pull-down menu, the user has the opportunity to change the basin name assigned to the grid cell, change the curve number, change the 1997 or future land use designation, change the soil hydrologic code designation, or to recalculate the composite CN for all grid cells within a subbasin.
3. Reach - Within the Reach pull-down menu, the user has the opportunity to change characteristics about the channel such as name, channel slope, roughness coefficient, bottom width and side slope. As with Subbasin, the Reach name in ArcView must match the Reach name assigned in Visual HEC-1 in order to maintain a data link.
4. Visual HEC-1 - Within the Visual HEC-1 pull-down menu, the user has the opportunity to update the watershed information and/or Reach information stored in Visual HEC-1.

Visual HEC-1

Once ArcView has been used to update/modify the model components and the Visual HEC-1 model input has been updated from within ArcView, the user will then rerun the Visual HEC-1 model. Using a split screen, the user can have both applications active concurrently.

Summary

Using a link between the hydrologic model, Visual HEC-1 and GIS, Olsson Associates and Wright Water Engineers have provided the City of Lincoln with a PC-based computer software application relating the schematic modeling components of the hydrologic model for the Beal Slough watershed to the physical features that help define the model. This framework facilitates analysis of stormwater management scenarios for the watershed. Further, the underlying software application can be transferred to other watersheds throughout the Lincoln metropolitan area for future master plan modeling.

DRAINAGE BASIN DESIGNATIONS

For reference during basin evaluation and master planning, the watershed was divided into four primary drainage areas, see Figure I-2.

Upper Beal Slough is generally located southeast of the 56th Street bridge and contains approximately 5.13 square miles. This area has several rural residential developments built 20 or more years ago but also contains the majority of land still available for future development. A dominant feature is Sanitary Improvement District #2, "Pine Lake Heights," and the lake around which the development lies. The projected land use in this drainage basin is largely rural residential, although nearly half of subbasin 1 is expected to change from agricultural to commercial land use according to the Comprehensive Plan.

Tierra Branch is generally located south of 27th Street and Highway 2 and contains approximately 2.84 square miles. This drainage basin is completely urbanized. It contains two regional stormwater retention storage facilities in the Williamsburg development and several on-site detention facilities within other subdivisions. Regional storage facilities are designed to reduce peak flow rates for more than one development, as opposed to on-site facilities designed to control peak flow rates from one development. During the heavy rains in 1996, runoff from previously developed areas below the Williamsburg facilities caused flooding of homes, businesses, and roadways.

Middle Beal Slough generally lies north of Pine Lake Road and between 27th Street and northwest of the 56th Street bridge. It contains approximately 3.51 square miles. Most development of this area occurred over 20 years ago, although in-fill development continues. It is mostly residential, although a large commercial area is located at 56th and Highway 2.

Lower Beal Slough generally lies between 27th Street and Salt Creek and contains approximately 1.98 square miles. The majority of the industrial land use is in this portion of the basin. Undeveloped and under-developed land exists in this area and some further urbanization of this area will likely occur.

LAND USE

Land use has direct implications on the hydrology of a watershed. In the late 1970s, when the data used for the Flood Insurance Study (FIS) were determined, approximately 40% of the watershed was urbanized, with limited rural acreage development in the upper part of the watershed. Currently 90 percent of the watershed is urbanized, with more homes and business being built every year. As urbanization occurs, runoff volumes and runoff rates typically increase due to increased impervious areas and more efficient conveyance through paved streets and storm drain pipes. Unless anticipated during the design process, increased runoff volume and rates may cause new problems or exacerbate existing problems in the storm drain system, such as increased flooding, more frequent flooding, channel degradation, or bridge replacement needs.

Table I-2 provides a summary of 1997 land uses based on information included in the Lincoln Lancaster

County Comprehensive Plan. Figure I-3 shows the spacial distribution of 1997 Land Use in the Beal Slough watershed. The remainder of the watershed is expected to become substantially urbanized within the 20-year planning period used for comprehensive planning. Six tributaries, of which Tierra Branch is the largest, convey water to the mainstem. The Burlington Northern and Santa Fe Railroad runs generally from the east-southeast to the west-northwest and parallels the stream through the entire length of the watershed. Nebraska Highway 2 parallels Beal Slough from 14th Street east to 56th Street then continues to the community of Cheney at the top of the watershed. Nebraska Highway 77 crosses the lower portion of the watershed.

Table I-2

Summary of 1997 Land Use in the Beal Slough Watershed

Urban Residential	Rural Residential	Commercial and Industrial	Agri-cultural	Grass-lands	Water Bodies	Total
6.9	2.3	1.4	2.3	0.5	0.1	13.5 sm
51	17	10	17	4	1	100 %

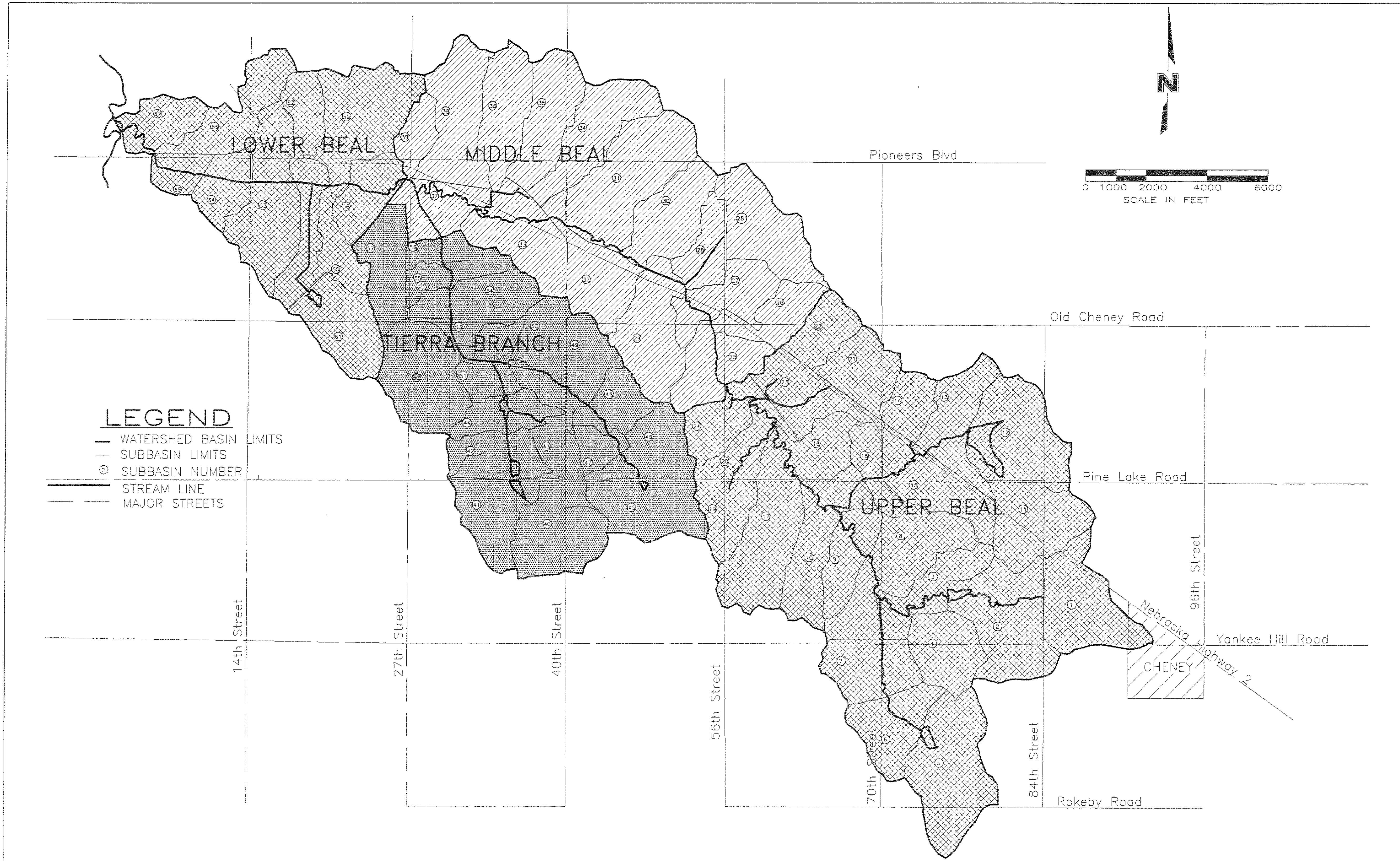
Projections of land use through the year 2015 from the Lincoln-Lancaster Comprehensive Plan were used to determine future hydrologic conditions in the watershed. Figure I-4 shows the spacial distribution of Projected Future Land Use in the Beal Slough watershed. Based on the current rate of growth in Lincoln, the remaining undeveloped areas in the Beal Slough Basin will be substantially developed before 2015, see Table I-3.

Table I-3

Development in the Watershed

Parameters[(1)]	
Area, square miles	13.5
Percent Developed - 1997 conditions	75
Percent Developed - Future conditions (2015)	96

(1) A more detailed description of modeling parameters is presented in the Hydrology section



6/30/1999 12:00 P.M. FILE: F:\Projects\960280\dwg\FIG-1-2.dwg SCALE: 3000

	DRAWN BY: JJM DATE: JUNE 99 REVISIONS:	BEAL SLOUGH MASTER PLAN LINCOLN, NEBRASKA	BASIN MAP	FIGURE I-2

SOILS

Soil type can have a profound effect on the amount of precipitation that becomes runoff. The amount of precipitation that infiltrates into the soil does not immediately become runoff. The predominant soil associations found in the Beal Slough watershed are listed in descending order of approximate area. Approximately 60% belongs to the Wymore-Pawnee association which erodes easily, consists of deep, nearly level to strongly sloping, moderately well drained, silty soils that formed in loess and loamy soils that formed in glacial till. This soil association has a very slow infiltration rate (high runoff potential) when thoroughly wet and is found on uplands. The Pawnee-Burchard association consists of deep, gently sloping to steep, moderately well drained and well drained, loamy and clayey soils that formed in glacial till. These soils erode easily, percolate slowly, have a slow infiltration rate (high runoff potential) when thoroughly wet, and are found on uplands. The Kennebec-Nodaway-Zook association consists of deep, nearly level and very gently sloping, moderately well drained to poorly drained, silty soils that formed in alluvium. This soil erodes easily, has a moderate to slow infiltration rate when thoroughly wet, is subject to flooding, and is found in floodplains. Outcrops of the Dakota Sandstone formation are shown near 27th Street and Highway 2 and near 14th Street and Highway 2. The Wymore-Pawnee and the Pawnee-Burchard soil associations are generally found in the upland areas of the watershed. The Kennebec-Nodaway-Zook soil association is generally found on floodplain areas in the watershed, Table I-4 provides a comparison of the soil associations found in Beal Slough. Figure I-5 graphically displays these soil associations.

NRCS soil scientists have classified soils into four hydrologic soil groups according to their minimum infiltration rate when thoroughly wetted. The manual for TR-20, Urban Hydrology for Small Watersheds provides the following definitions:

"Group A soils have low runoff potential and high infiltration rates even when throughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B soils have moderate infiltration rates [and moderate runoff potential] when throughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C soils have low infiltration rates [and high runoff potential] when throughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission.

Group D soils have a high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission."

The Lancaster County Soil Survey does not identify any Group A soils in the basin. Group B soils are found generally along the mainstem and tributary channels. A very small amount of Group C soils are located near 14th Street and Pioneers Boulevard and near 56th Street between Old Cheney Road and Pine Lake Road. Group D soils are the predominant hydrologic soil group found mostly in the uplands. Table I-5 provides a soil legend and description of the soils found in the Beal Slough watershed. Figure I-6 displays the hydrologic soil groups found in Beal Slough.

Table I-4

Comparison of Soil Associations Found in the Watershed (USDA, SCS Soil Survey of Lancaster County, NE)

Property		Soil Series					
		Pawnee	**Wymore**	**Burchard**	**Nodaway**	**Zook**	**Kennebec**
Parent Material		Formed in glacial till	Formed in loess	Formed in calcareous Kansas till	Alluvium, occurs in narrow drainage ways	Formed in alluvium along streams	Noncalcareous colluvial silty sediment from the dark upland soils
Drainage		Moderately drained on uplands, slow permeability	Moderately well drained on uplands, slow permeability	Well drained on uplands, slow permeability	Moderately well drained, moderately permeable	Deep, poorly drained, slow permeability	Deep, moderately well drained, moderate permeability
Surface Layer		Very dark brown clay loam, very dark grayish brown, weak fine granular structure, slightly hard	Very dark brown silty clay loam, weak fine granular structure, hard	Very dark brown clay loam, very dark grayish brown, weak fine granular structure, slightly hard	Very dark grayish brown silt loam, weak fine granular structure, slightly hard	Very dark gray silty clay loam, weak fine granular structure, slightly hard	Very dark gray silt loam, weak fine granular structure, hard, friable
Subsoil	**Upper**	Very dark grayish brown clay, moderate fine and medium subangular blocky structure	Dark brown silty clay, moderate fine and medium subgranular blocky structure, hard	Dark brown to brown clay loam moderate medium prismatic structure, hard	Very dark grayish brown silt loam, massive, slightly hard	Black silty clay loam, weak medium prismatic structure, hard	Very dark gray silt loam, weak fine and medium granular structure, hard, friable
	Middle	Dark grayish, moderate medium prismatic structure, very hard	Dark grayish brown silty clay, moderate medium prismatic structure, hard	Grayish brown clay loam, moderate medium prismatic structure, hard	Very dark grayish brown silt loam, massive, slightly hard	Black silty clay, moderate medium prismatic structure, very hard	Black silty clay loam, moderate medium subangular blocky structure, slightly hard
	Lower	Olive brown clay, moderate medium prismatic structure, very hard	Olive brown silty clay loam, weak medium prismatic structure, hard	Grayish brown clay loam, moderate medium prismatic structure, hard	Very dark grayish brown silt loam, massive, slightly hard	Black silty clay, moderate medium prismatic structure, very hard	Very dark gray silty clay loam, moderate coarse and medium subangular blocky structure, slightly hard
Underlying Material		Olive clay loam, weak coarse prismatic structure, slightly hard	Olive gray silty clay loam, slightly hard	Light brownish gray clay loam, weak coarse prismatic structure, hard	Very dark grayish brown silt loam, massive, slightly hard	Very dark gray silty clay, moderate medium prismatic structure, hard	Very dark silty clay loam, moderate coarse and medium subangular blocky structure.

Table I-5

Soil Legend and Hydrologic Soil Group (HSG)

Symbol	Description	HSG
BpF	Burchard-Nodaway complex, 2 to 30% slopes	B
BrD	Burchard clay loam, 6 to 11% slopes	B
Bu	Butler silt loam, 0 to 1% slopes	D
Co	Colo silty clay loam, 0 to 2% slopes	B/D
Cp	Cold-Nodaway silty clay loams, 0 to 2% slopes	B/D
Cr	Crete silt loam, terrace, 0 to 1% slopes	D
CrB	Crete silty clay loam, terrace, 1 to 3% slopes	D
CrC	Crete silty clay loam, terrace, 3 to 6% slopes	D
DcD	Dickinson fine sandy loam, 6 to 11% slopes	A
Fm	Fillmore silt loam, 0 to 1% slopes	D
GeD	Geary silty clay loam, 6 to 11% slopes	B
HeF	Hedville sandy loam, 6 to 30% slopes	D
JuC	Judson silt loam, 2 to 6% slopes	B
Ke	Kennebec silt loam, 0 to 2% slopes	B
Lm	Lamo silty clay loam, 0 to 2% slopes	C
MeC2	Mayberry silty clay loam, 2 to 7% slopes, eroded	D
MrD	Morrill clay loam, 6 to 11% slopes	B

Table I-5 (continued)

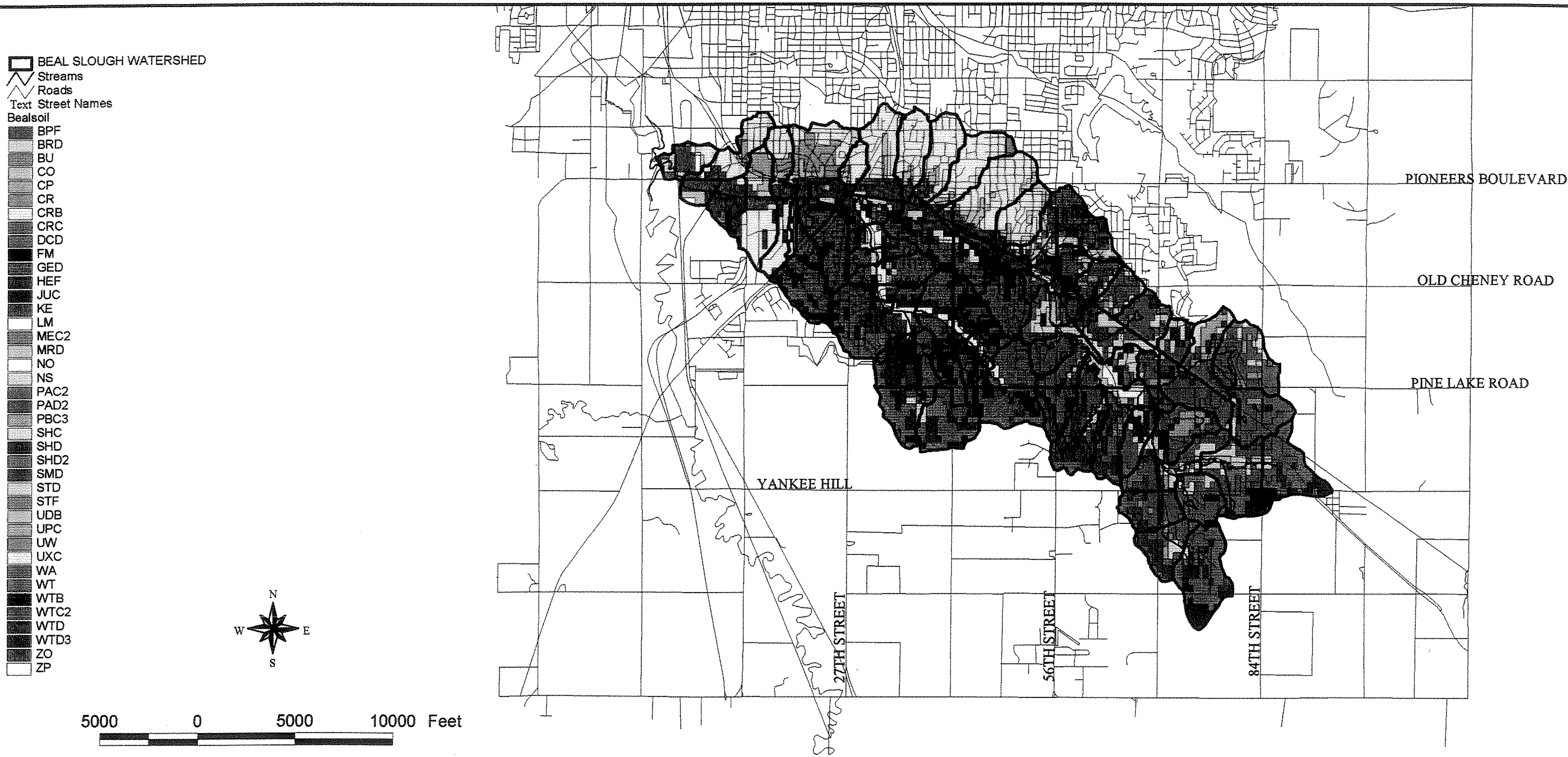
Soil Legend and Hydrologic Soil Group (HSG)

Symbol	Description	HSG
No	Nodaway silt loam, 0 to 2% slopes	B
Ns	Nodaway silt loam, channeled	B
PaC2	Pawnee clay loam, 2 to 7% slopes, eroded	D
PaD2	Pawnee clay loam, 7 to 11% slopes, eroded	D
PbC3	Pawnee clay, 2 to 7% slopes, severely eroded	D
ShC	Sharpsburg silty clay loam, 2 to 5% slopes	B
ShD	Sharpsburg silty clay loam, 5 to 9% slopes	B
ShD2	Sharpsburg silty clay loam, 5 to 9% slopes, eroded	B
SmD	Shelby clay loam, 6 to 11% slopes	B
StD	Steinauer loam, 6 to 11% slopes	B
StF	Steinauer loam, 11 to 30% slopes	B
UdB	Urban land-Judson complex, 1 to 3% slopes	B
UpC	Urban land-Pawnee-Mayberry complex, 2 to 7% slopes	D
Uw	Urban land-Wymore complex, 0 to 2% slopes	D
UxC	Urban land-Wymore-Sharpsburg complex, 2 to 7% slopes	D
Wb	Wabash silty clay, 0 to 1% slopes	D
Wt	Wymore silty clay loam, 0 to 1% slopes	D

Table I-5 (continued)

Soil Legend and Hydrologic Soil Group (HSG)

Symbol	Description	HSG
WtB	Wymore silty clay loam, 1 to 3% slopes	D
WtC2	Wymore silty clay loam, 3 to 7% slopes, eroded	D
WtD	Wymore silty clay loam, 7 to 11% slopes	D
WtD3	Wymore silty clay, 5 to 9% slopes, severely eroded	D
Zo	Zook silt loam, 0 to 2% slopes	C/D
Zp	Zook silty clay loam, 0 to 2% slopes	C/D

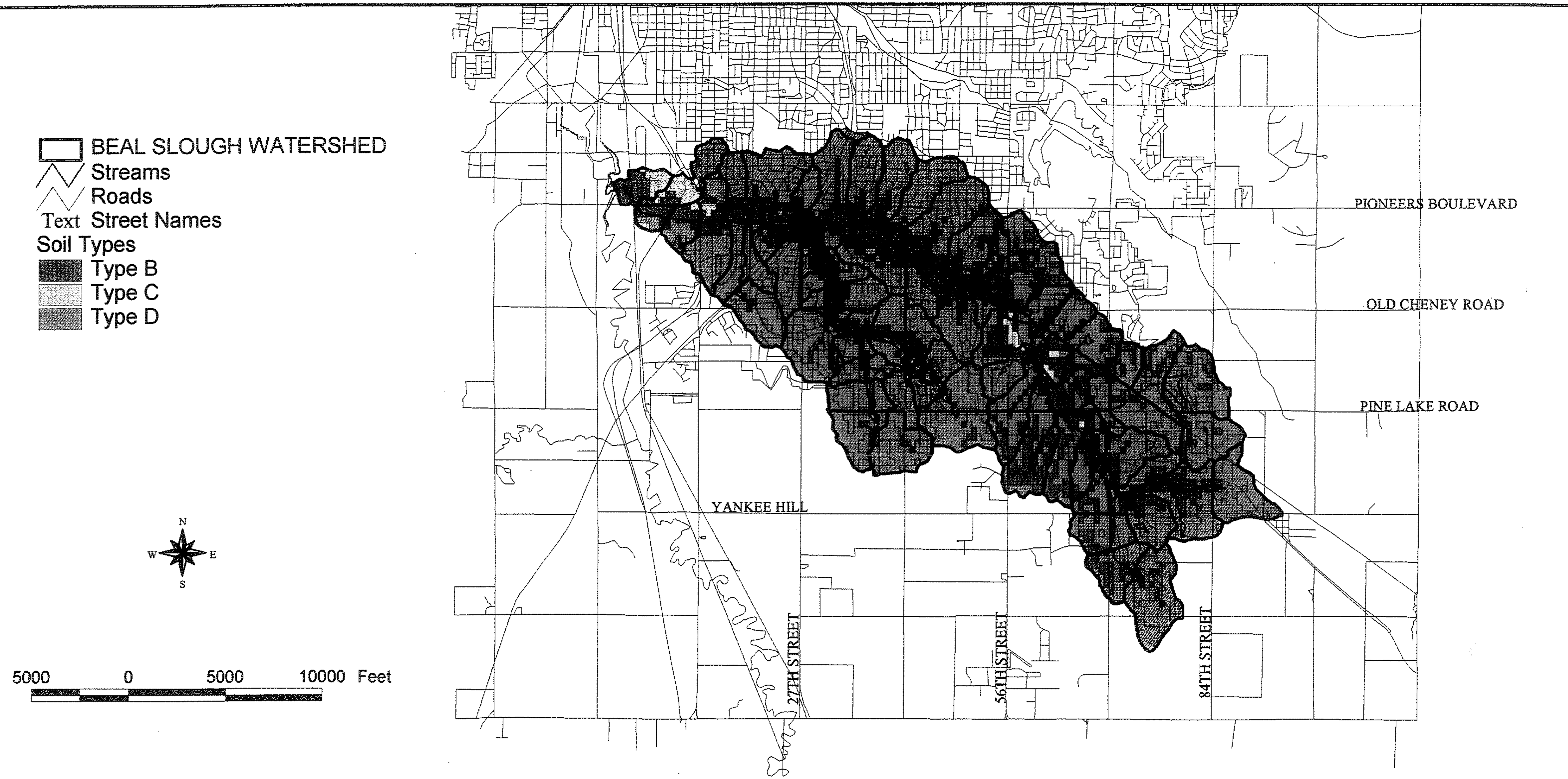


Existing Soil Types in the Beal Slough Watershed
Lincoln, Nebraska

Source: Nebraska Natural Resources Commission

Wright Water Engineers, Inc.

FIGURE I-5 EXISTING SOIL TYPES



SCS Hydrologic Soil Groups in the Beal Slough Watershed
Lincoln, Nebraska

Source: Nebraska Natural Resources Commission
Wright Water Engineers, Inc.

PONDS

There are 21 existing reservoirs in the watershed. Six of these are designed for stormwater management purposes. The Pine Lake dam and the Boone Trace pond do not have sufficient flood storage to significantly affect downstream peak flow rates for larger storms. Characteristics of each stormwater management pond are presented in Table I-6. For purposes of hydrologic modeling, the full flood storage volume was assumed to be available in each of the ponds at the beginning of the storm. The Mulberry Hill facility provides for detention of the runoff from a significant drainage area. However, because of its relative location in the basin and need to limit areal variability between basins for modeling purposes, the facility was not selected as a basin terminus. Peak reduction effects of the Mulberry Hill detention site were analyzed in the minor storm drain system analysis prepared for the Interim Beal Slough Basin Stormwater Planning Report 1997.

Table I-6

Pond Characteristics

Pond	Master Plan Element Number	Storage Volume at Spillway (acre-feet)	Spillway/ Overflow Elevation (M.S.L.)	Ownership and Uses
Pine Lake	N12	288.2	1334.9	Private aesthetics/recreation
Williamsburg Retention at Browning Street	N43	58.6	1123.1	Private[1] stormwater runoff storage facility
Williamsburg Retention at 34th Street	N49	15.8	1214.7	Private[1] stormwater runoff storage facility
Pine Lake Heights Retention, north side Pine Lake Road	N41	29.3	1235.8	Private stormwater runoff storage facility
Pine Lake Heights Retention, south side Pine Lake Road	N40	32.8	1242.3	Private stormwater runoff storage facility
King Arthur Court Detention	N61	78.9	1228.0	Private incidental stormwater runoff detention/recreation
Eagle Ridge Circle Detention	N44	11.3	1282.0	Private stormwater runoff storage facility
Pond 5 in §27-T9N-R7E	N5	26.2	1346.0	Private grade stabilization
Boone Trail Pond	N2	21.5	1334.0	Private grade stabilization

[1] Public Works &Utilities is responsible for maintenance for another one to three years, dependant on extensions granted

QUALIFICATIONS AND LIMITATIONS

Hydrologic and hydraulic procedures used for this Master Plan are consistent with procedures outlined in publications of the Water Environmental Federation and the American Society of Civil Engineers.

Municipal stormwater management practices are typically designed for a range of design storms with average return periods of 2 years through 100 years. No analysis of storms larger than the 100-year event was done. Regional stormwater storage facilities, a widely used stormwater management practice will be required to meet Nebraska Department of Water Resources design standards for flood storage structures.

This study does not address the effects of urbanization on ground water.

The stormwater management measures described in Section II MASTER PLAN of this report are based on conceptual-level engineering.

The Public Works and Utility Department has recently installed staff gages in the watershed and have recorded several minor storm events. The hydrology in this report was not calibrated to the measured flows because no stream flows of sufficient magnitude were recorded prior to completion of the Master Plan analysis.

The assumptions and projections of the Master Plan were based on information available at the time of investigation.

HYDROLOGY

PREVIOUS STUDIES

The City and the District have previously completed several reports on Beal Slough. The Flood Insurance Study (FIS), City of Lincoln, Nebraska, Lancaster County, revised June 19, 1997 contains data on Beal Slough although the information has not been updated since the original data were gathered for the in 1978 FIS. The Reconnaissance Level Study, Beal Slough Watershed, 1990 was prepared to estimate the effect of different development scenarios on stormwater potential, to develop criteria for evaluating runoff and flooding potential, and to provide recommendations for stormwater management practices to be followed in future developments (the current detention ordinance was adopted as a result of that report). The Reconnaissance Level Report, Off-Channel Detention, Beal Slough Watershed (1994) was prepared to evaluate the flood management capabilities of five proposed side-channel detention facilities along Beal Slough; however none of the proposed ponds have been built. Flow rates provided in the FIS for Beal Slough are used for comparison to1997 and future flow rates generated for this study.

DESCRIPTION OF MODEL

Delineation of the study area boundary was accomplished using topographic contour mapping derived from digital aerial photography and refined using supplemental data such as storm drain system plat maps and field verification. Subbasins were delineated in keeping with the points of interest with respect to master planning efforts, hydrologic characteristics, and HEC-1 model areal variability requirements. The hydrologic characteristics of each subbasin are represented in the model by area in square miles, runoff curve number, and the lag time in hours.

Segmentation of the watershed into subbasins determines the number and type of stream network components. Reach lengths vary from 300 feet to 3700 feet. In lower Beal Slough the majority of the stream segments have modified cross-sections. Generally, reaches above Pine Lake Road are nearly natural and undisturbed. Reaches in lower and middle Beal Slough have become incised due to bed degradation and bank sloughing.

HEC-1 uses the model components described below to represent the precipitation-runoff process.

Precipitation -	is the amount of rainfall that occurs during a storm event.
Watershed -	is the natural unit of land upon which water from direct precipitation, snow melt, and other storage collects in a channel and flows downhill to a common outlet.
Area -	is an essential consideration in the initial evaluation of watershed hydrologic behavior.
Runoff Curve - Number	is a measure of the watershed soil and cover conditions that affect runoff potential.
Lag -	is the time between the center of mass of the rainfall excess and the peak of the unit hydrograph, a value equal to 60% of the time of concentration is used in HEC-1.
Tc -	time of concentration is the time it takes for water to travel from some specified point on watershed to the basin outlet.
Antecedent Moisture Condition -	is the amount of water stored in the soil, in small depressions, and on vegetation at the start of an hydrologic events
Initial Abstraction -	is the amount of precipitation that is absorbed or adsorbed by the soil and vegetation, respectively, before runoff occurs.

PRECIPITATION DATA

The use of design storms is a widely utilized and accepted practice for stormwater management. They provide a sound basis for comparison of stormwater management practices and assist in predicting the conditions under which flooding and other problems may occur. Two types of design storms are recognized, synthetic and historic. The first are derived by synthesis and generalization of a large number of actual storms. The second are events that occurred in the past and for which the impacts on the watershed may be well documented. Both types of design storms were utilized in this report. Historic storms and observed high water marks that occurred in 1996 and 1997 were used to calibrate the watershed model reactions to closely reflect the observed response of the actual watershed. Synthetic storms were used to develop hydrographs, peak flow rates, and runoff volumes to be used for comparison of stormwater management practices. The Soil Conservation Service (now called Natural Resources Conservation Service or NRCS) developed rainfall distributions for regions of the United States. Lincoln is in the region where a Type II distribution is appropriate. The National Weather Bureau compiled Technical Paper No. 40, Rainfall Frequency Atlas of the United States, for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. The point precipitation values for synthetic storms used in this report were based on information obtained from those two sources. The Public Works and Utilities Department maintains eight weather recording stations, two of which are located in the Beal Slough watershed: one at the Lincoln Country Club, and one near 27th Street and Old Cheney.

Precipitation hyetographs are used to represent average precipitation over a computation interval. The historic design storm distributions given in Table I-7 ere used for calibration of the Tierra Branch. Synthetic design storm distributions given in Table I-8 were used to develop runoff hydrographs for 1997 and future projected conditions.

Table I-7
Beal Slough Historic Storm Distribution [a]

Time (min)	July 1996 (inches)	Cumul-ative (inches)	August 1996 (inches)	Cumul-ative (inches)	June 1997 (inches)	Cumul-ative (inches)
0	0.00	0.00	0.00	0.00	0.00	0.00
60	0.98	0.98	0.05	0.05	0.06	0.06
120	0.57	1.55	0.56	0.61	1.06	1.12
180	0.00	1.55	1.93	2.54	0.19	1.31
240	0.00	1.55	0.06	2.60	0.11	1.42
300	0.00	1.55	0.01	2.61	0.03	1.45
360	0.01	1.56			0.03	1.48
420	0.00	1.56			0.01	1.49
480	0.02	1.58				
540	0.17	1.75				
600	0.28	2.03				
660	0.61	2.64				
720	1.60	4.24				
780	0.47	4.71				
840	0.15	4.86				
900	0.36	5.22				
960	0.05	5.27				

[a] Hourly Precipitation Data recorded at the 27th Street and Old Cheney Weather Station

Table I-8
Beal Slough 24-hour Type II Storm Distribution [a]

Time (minutes)	2-Year (inches)	5-Year (inches)	10-Year (inches)	25-Year (inches)	50-Year (inches)	100-Year (inches)
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
60	0.0324	0.0424	0.0507	0.0580	0.0648	0.0721
120	0.0345	0.0452	0.0539	0.0618	0.0690	0.0768
180	0.0372	0.0487	0.0582	0.0666	0.0744	0.0828
240	0.0408	0.0534	0.0638	0.0730	0.0816	0.0908
300	0.0447	0.0586	0.0699	0.0800	0.0894	0.0995
360	0.0495	0.0648	0.0774	0.0886	0.0990	0.1102
420	0.0561	0.0735	0.0877	0.1004	0.1122	0.1249
480	0.0657	0.0861	0.1027	0.1176	0.1314	0.1463
540	0.0792	0.1038	0.1238	0.1418	0.1584	0.1764
600	0.1023	0.1340	0.1599	0.1831	0.2046	0.2278
660	0.1629	0.2134	0.2547	0.2916	0.3258	0.3627
720	1.2843	1.6824	2.0078	2.2989	2.5686	2.8597
780	0.3276	0.4292	0.5121	0.5864	0.6552	0.7295
840	0.1419	0.1859	0.2218	0.2540	0.2838	0.3160
900	0.1023	0.1340	0.1599	0.1831	0.2046	0.2278
960	0.0789	0.1034	0.1233	0.1412	0.1578	0.1757
1020	0.0654	0.0857	0.1022	0.1171	0.1308	0.1456
1080	0.0561	0.0735	0.0877	0.1004	0.1122	0.1249
1140	0.0495	0.0648	0.0774	0.0886	0.0990	0.1102
1200	0.0444	0.0582	0.0694	0.0795	0.0888	0.0989
1260	0.0402	0.0527	0.0628	0.0720	0.0804	0.0895
1320	0.0372	0.0487	0.0582	0.0666	0.0744	0.0828
1380	0.0345	0.0452	0.0539	0.0618	0.0690	0.0768
1440	0.0324	0.0424	0.0507	0.0580	0.0648	0.0721
Sum	**3.00**	**3.93**	**4.69**	**5.37**	**6.00**	**6.68**

[a] Derived from SCS Type II Rainfall Distribution and TP-40

RUNOFF PARAMETERS

The amount of rainfall on a watershed that becomes runoff is dependant on many factors including: the interval since the last rain, land use, the capacity of the soil and vegetation to absorb and hold water, the type of vegetation, the percent of the area covered by pavement and rooftops, the type and condition of drainage paths (swales, channels, pipe, etc.), the rainfall duration and intensity, land slope, and watershed shape. These characteristics can be approximated using the following parameters.

Area - The size of the contributing area is directly correlated to the amount of runoff that reaches a point. Drainage subbasins delineated for the Beal Slough watershed are shown on Figure I-5.

Runoff Curve Number - In simplistic terms, the runoff curve number is a measure of the amount of precipitation that becomes runoff. The major factors that determine runoff curve number (CN) are the hydrologic soil group, cover type (land use), treatment, hydrologic condition, and antecedent runoff condition. Another factor considered is whether impervious areas outlet directly to the drainage system. Values of CN for average hydrologic runoff conditions for urban, cultivated agricultural, other agricultural, and arid and semi-arid range land uses are published by the SCS in “Urban Hydrology for Small Watersheds,” TR-55, 1986, pp 2-1 to 2-9.

Time of Concentration - Runoff curve numbers alone do not adequately reflect the effect of urbanization on stormwater systems. Runoff volume is the same for a field of small grain crops planted in straight rows in good condition as for the same field developed into 1/4 acre lot residential units for hydrologic soil groups B, C, and D. Urban land use provides a more efficient flow pattern, i.e., the runoff arrives at the outlet quicker. Time of concentration (Tc) for each subbasin was estimated using the procedure provided in SCS TR-55. Time of concentration was converted to lag-time for use in HEC-1.

A compilation of the watershed parameters described above is given in Table I-9.

The runoff from each subbasin is represented by a unit hydrograph. “A unit hydrograph is the direct runoff from a unit depth of excess rainfall produced by a storm of uniform intensity and specified duration” (from Handbook of Hydrology, by David R. Maidment, pg 9.26). The unit hydrograph and excess rainfall are combined to form a runoff hydrograph and the runoff hydrographs from each subbasin are routed through the reaches and combined to form a complex hydrograph at each point of interest. The complex hydrographs for 1997 and projected future conditions can then be compared and used to evaluate the effectiveness of proposed stormwater management practices. A schematic outline of model components shows the sequence in which components are combined, see Figure I-6.

CALIBRATION

After the model components were connected and continuity was confirmed, the historic storm hyetographs were applied. The results were compared to observed conditions and the appropriate hydrologic parameters were adjusted, based on sound engineering judgement. Only high water mark elevations were available for the historic storms, not time of occurrence. Estimated channel flow rates were calculated for comparison to flow rates generated by Visual HEC-1. The estimated flow rates from the July 1996 storm were within 5% of the Visual HEC-1 flow rates, an acceptable match. Modifying the CNs to reflect the saturated soil conditions preceding the August 1996 storm also resulted in an acceptable flow rate comparison. Similar comparison at other locations within the watershed also provided acceptable results. Lag-time was not adjusted because temporal information on the peak time was not available.

FUTURE BASIN HYDROLOGY

For the purposes of stormwater master planning in the Beal Slough Basin, the projected land uses provided in the Lincoln Lancaster County Comprehensive Plan (LLCCP) for 2015, were used to determine future hydrologic characteristics.

Area - Urbanization occasionally results in minor changes to the subbasin shape as a result of grading operations. Of course the adjacent subbasin shape also changes, however, it is impossible to predict the location and amount of area involved. Therefore, it was assumed for the purposes of this report that the areas of urbanized subbasins did not change.

Runoff Curve Number - Changes in cover type (land use) can affect the runoff curve number. Values of CN for average hydrologic runoff conditions for urban land uses published by the SCS in "Urban Hydrology for Small Watersheds", TR-55, 1986, pp 2-1 to 2-9 were used to determine runoff curve numbers for the projected land uses. Figure I-6 shows future land use for 2105 as projected in the Lincoln/Lancaster County Comprehensive Plan. Table I-9 also displays the runoff curve numbers used for projected future land use conditions.

Time of Concentration - The alignment of streets and storm drains greatly effects the time of concentration. Studies have shown that the reduction in travel time can be estimated using the future CN, the percent impervious area, and the percent of the hydraulic length that is modified by development. Impervious area percentages provided in TR-55 Table 2-2a were used for future urban residential and commercial development land uses. For future commercial development it was assumed that 80 percent of the hydraulic length would be modified and that 50 percent of the hydraulic length would be modified in residential developments. Refer back to Table I-9 for the values of time of concentration for projected future conditions. Appendix C contains a complete runoff summary for the 2-, 5-, 10-, 25-, 50-, and 100-year storms for projected future land use conditions.

EVALUATION

Future development in Beal Slough is projected to occur almost exclusively in the Upper Beal Slough drainage area. Rural residential land use is the predominant category type in Upper Beal Slough except for commercial development projected to occur near 84th Street and Highway 2. Industrial development is projected to occur along Pioneers Boulevard near the outlet of the watershed.

Rural residential lots average 3 acres, less than 12% of the area is impervious pavement or roof top, and runoff from impervious areas flows overland through swales before entering the storm drain system. The lot area not paved or built upon is covered with grass or other permanent vegetative cover. The runoff curve number value for a subbasin with rural residential land use is less than the value for most cultivated agricultural land uses.

Commercial development is characterized by large expanses of impervious area that are directly connected to the storm drain system. More precipitation becomes runoff and, because the storm drain system efficiently transports water, it arrives at the channel sooner.

As shown in Table I-10 the peak flow rates have increased substantially since the data were gathered for the 1978 FIS. There is a significant increase in peak flow rates when values generated for 1997 conditions are compared to those used in the FIS. Master Plan alternatives will need to address the problems created as a result of the increased peak flow rates. These include higher water surface elevations in many areas and increased velocities in the channels and on the overbanks.

FIGURE I-7 VISUAL HEC1 SCHEMATIC OF BEAL SLOUGH MASTER PLAN MODEL

Table I-9
Drainage Subbasin Characteristics

Basin Designation	Basin Area (sm)	1997 Runoff Curve Number	1997 T_c (hours)	LLCCP[1] Runoff Curve Number	LLCCP[1] T_c (hours)
Upper Beal					
1	0.28	81	0.56	87	0.25
2	0.35	77	0.96	77	0.96
3	0.20	75	0.49	75	0.49
4	0.19	76	0.88	80	0.88
5	0.37	79	0.62	85	0.62
6	0.20	77	0.23	80	0.23
7	0.20	80	0.34	79	0.34
8	0.31	80	0.54	77	0.54
9	0.15	74	0.24	73	0.09
10	0.26	75	0.52	73	0.18
11	0.26	81	0.49	83	0.18
12	0.33	83	0.16	82	0.16
13	0.20	78	0.31	77	0.18
14	0.11	76	0.41	75	0.24
15	0.23	82	0.47	80	0.29
16	0.10	82	0.17	82	0.17
17	0.29	74	0.46	72	0.16
18	0.18	72	0.55	72	0.55
19	0.14	82	0.67	76	0.26
20	0.13	79	0.36	79	0.15
21	0.17	82	0.12	82	0.06
22	0.13	80	0.21	80	0.09
23	0.20	74	0.28	73	0.05
24	0.15	81	0.27	80	0.12
Subtotal	5.13				
Tierra Branch					
40	0.26	80	0.39	84	0.19
41	0.20	82	0.55	83	0.26
42	0.12	82	0.99	87	0.99
43	0.12	85	0.19	86	0.19
44	0.12	80	0.31	83	0.31
45	0.23	83	0.18	84	0.09
46	0.19	84	0.34	84	0.34
47	0.07	83	0.43	83	0.43
48	0.13	81	0.38	81	0.38
49	0.15	80	0.60	80	0.60
50	0.19	88	0.58	88	0.58
51	0.14	80	0.41	80	0.41
52	0.32	83	0.48	83	0.48

LLCCP[1] = Lincoln Lancaster County Comprehensive Plan for Projected 2015 Land Uses

Table I-9, (continued)
Drainage Subbasin Characteristics

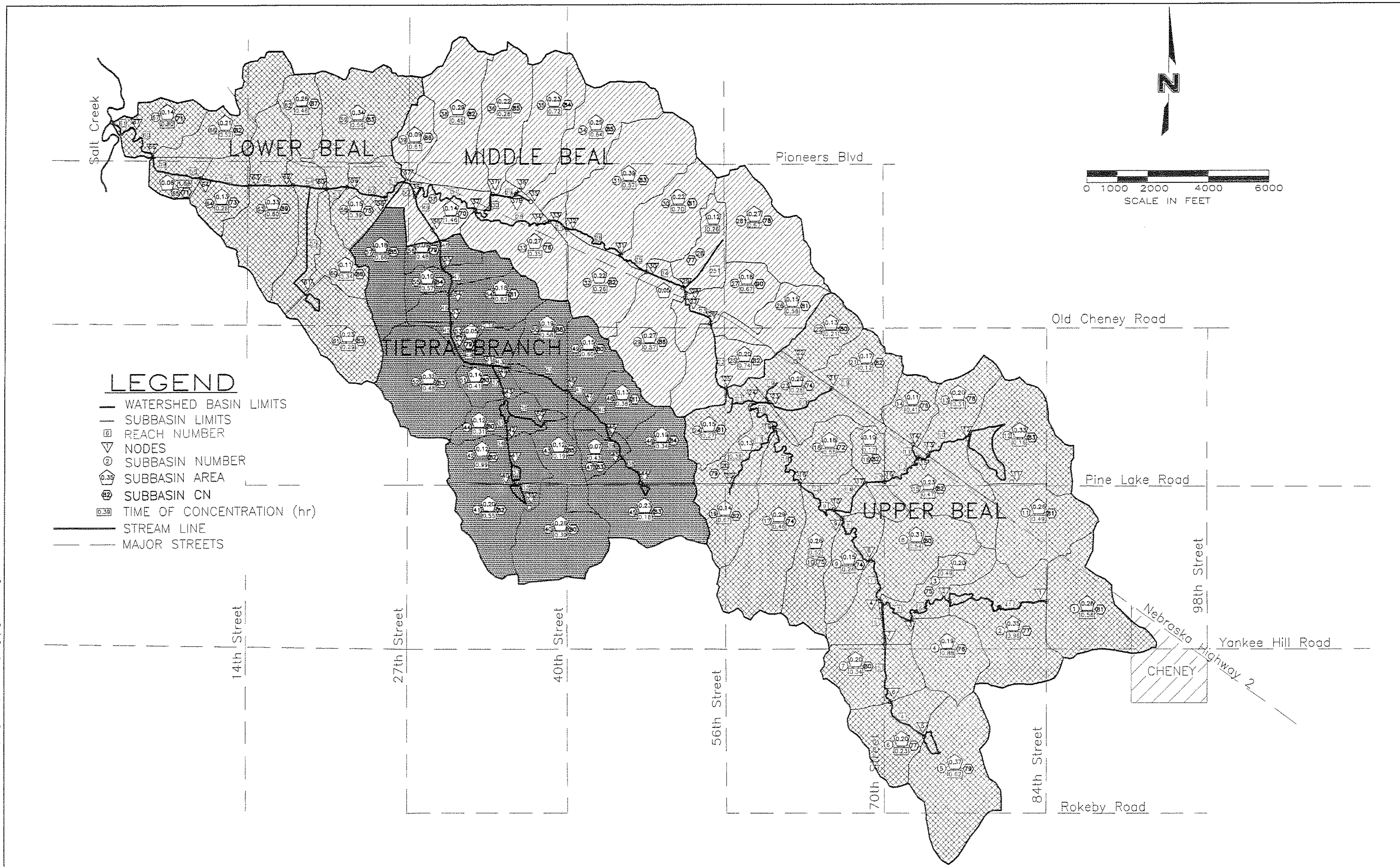
Basin Designation	Basin Area (sm)	1997 Runoff Curve Number	1997 T_c (hours)	LLCCP[1] Runoff Curve Number	LLCCP[1] T_c (hours)
Tierra Branch					
53	0.05	79	0.14	79	0.14
54	0.18	81	0.82	81	0.82
55	0.10	84	0.57	84	0.57
56	0.09	79	0.48	79	0.48
57	0.18	85	0.68	85	0.68
Subtotal	2.84				
Middle Beal					
25	0.20	82	0.74	82	0.74
26	0.15	81	0.58	81	0.58
27	0.18	90	0.67	90	0.67
28	0.12	77	0.26	77	0.26
281	0.27	78	0.67	78	0.67
29	0.27	86	0.57	86	0.57
30	0.22	81	0.70	81	0.70
31	0.39	83	0.57	83	0.57
32	0.22	82	0.26	82	0.26
33	0.27	76	0.35	76	0.35
34	0.25	85	0.64	85	0.64
35	0.23	84	0.72	84	0.72
36	0.22	85	0.28	85	0.28
37	0.14	70	1.46	70	1.46
38	0.29	82	0.45	82	0.45
39	0.09	86	0.61	86	0.61
Subtotal	3.51				
Lower Beal					
58	0.15	75	0.39	75	0.39
59	0.34	83	0.56	83	0.56
60	0.11	86	0.34	86	0.34
61	0.23	83	0.29	83	0.29
62	0.26	87	0.46	87	0.46
63	0.33	89	0.60	89	0.60
64	0.13	73	0.26	73	0.26
65	0.08	71	1.06	73	0.20
66	0.21	82	0.52	82	0.52
67	0.14	71	0.90	79	0.21
Subtotal	1.98				
Total	13.51				

Table I-10a
Peak Flow Rate Values for 2-, 10- ,and 100-year Average Return Frequency Floods at Selected Locations on the Mainstem

Location	HEC-1 Model Element	2-year 1997	10-year 1997	50-year 1997	100-year 1997	100-year FIS
84th Street	84th	260	530	740	870	N/A
70th Street	N4	540	1300	2000	2400	1860
BNSFRR	BNSF64	930	2200	3300	3900	2700
Pine Lake Road	N18	1000	2300	3500	4200	3010
56th Street	N25	1200	2800	4200	4800	2990
Old Cheney Road	N26	1300	3100	4600	5400	3900
BNSF/Hwy2 Bridge	N26	1300	3100	4600	5400	4010
48th Street	N29	1500	3600	4600	6300	4130
40th Street	N32	1800	4200	5400	7500	5000
Hwy2/BNSF Bridge	N33	1900	4300	6400	7500	5000
Beal Slough reach	N37	2100	4300	6500	7600	4500
27th Street	N57	3000	6000	8800	10000	6020
Southwood Drive	N59	3100	6000	8900	11000	6290
Highway 77 (14th)	N63	3300	6400	9200	11000	6590
Penitentiary Bridges	N64	3200	6400	9200	11000	6500
Pioneers/BNSF Br.	N66	3300	6500	9300	11000	6310
Mouth at Salt Creek	N67	3200	6500	9100	11000	6220

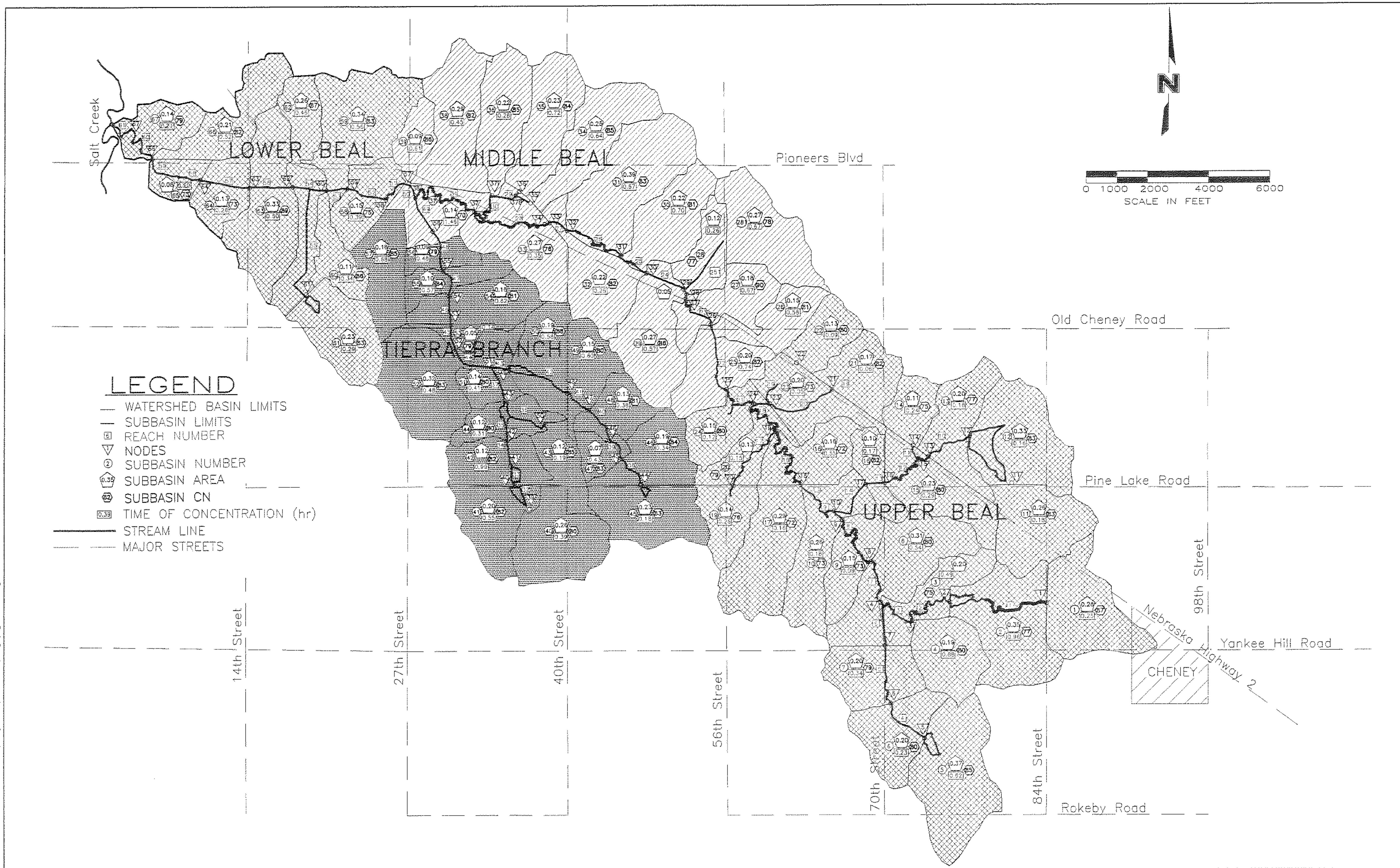
Table I-10b
Peak Flow Rate Values for 2-, 10- ,and 100-year Average Return Frequency Floods at Selected Locations on Basin Tributaries

Location	HEC-1 Model Element	2-year 1997	10-year 1997	50-year 1997	100-year 1997	100-year FIS
Yankee Hill Road	Yankee	310	740	1000	1000	N/A
70th Street	N16	460	1000	1400	1400	N/A
Pine Lake Road	N17	520	1100	1600	1600	N/A
Highway 2	22Box	130	260	390	390	N/A
Highway 2	21Box	190	400	570	570	N/A
Pine Lake Road	Pinels	150	150	230	230	N/A
Pine Lake Road	Pineln	90	230	370	370	N/A
Browning Street	Browng	70	230	390	390	N/A
Pine Lake Road	EagleC	180	300	380	380	N/A
Fox Hollow Drive	Fhollo	360	680	870	870	N/A
Cripple Creek Raod	CrplCr	400	760	990	990	N/A
40th Street	40th	550	1100	1500	1500	N/A
34th Street	Will34	660	1300	1800	2000	N/A
Jane Lane	JaneLn	860	1800	2500	3000	N/A
Old Cheney Road	OldChn	850	1800	2500	3000	N/A
Sequoia Drive	Sequoi	970	2000	2900	3500	N/A
Tierra Drive	Tierra	890	2000	3000	3500	N/A



DRAWN BY: JJM DATE: JUNE 99 REVISIONS:	BEAL SLOUGH MASTER PLAN LINCOLN, NEBRASKA	1997 HYDROLOGIC CONDITIONS	FIGURE I-8

6/30/1999 4:21 P.M. FILE: F:\Projects\960280\dwg\fig-1-7.dwg SCALE: 3000



	DRAWN BY: JJM DATE: JUNE 1999 REVISIONS:	BEAL SLOUGH MASTER PLAN LINCOLN, NEBRASKA	**FULLY URBANIZED HYDROLOGIC CONDITIONS**	**FIGURE I–9**

6/30/1999 4:26 P.M. FILE: F:\Projects\960280\dwg\fig-1-8.dwg SCALE: 3000

HYDRAULICS

Channel and valley hydraulic characteristics determine the water depth generated by a given flow rate. Characteristics such as slope, available flow area, cross-section shape, degree of meander, overbank conditions, and the presence of bridges, culverts, or other crossings all affect the flow depth in a channel or flood corridor. Experience has shown that channel modifications built with the intent of increasing flow capacity, such as channel straightening or construction of levees, often have unforeseen side-effects, such as channel degradation or accelerated bank sloughing. Increasing the duration, frequency, or peak rate of flow will likely result in similar undesirable changes to the channel. Natural streams in natural (i.e., unmodified) watersheds tend to reach an equilibrium condition determined by vegetation, runoff, and geology. Studies have shown that stream channels generally have a bank-full capacity equal to the 2-year to 5-year flood. Changes in the watershed or stream characteristics can cause a reaction upsetting equilibrium. For example, increased peak flow rates can result in greater depths of flow. HEC-RAS can be used to analyze the impacts of projected watershed parameters on the hydraulic characteristics of the stream channel. The mitigating characteristics of proposed master plan components can be compared using HEC-RAS analysis.

STREAM AND TRIBUTARY MODELING

HEC-RAS allows the analysis of one-dimensional steady flow hydraulics and calculates water surface profiles. To perform these calculations the program requires channel geometric and flow data. A stream system schematic can be helpful to organize the data into a useable form and define how a stream system is connected. The watershed basin schematic generated for the Visual HEC-1 model, Figure I-9, was used to establish connectivity for HEC-RAS.

Cross-section Geometry - Cross-section geometry and cross-section properties are located along the stream at sufficient intervals to accurately represent the channel and overbank geometry. Cross-section data were extracted from the Triangular Irregular Network (TIN) generated by computer from the aerial photography. Locations near bridges and culverts were selected to define the structure geometry. Other data for bridges and culverts was collected from digital topographic mapping, the City, previous studies, and through field visits. Stream cross-sections were located perpendicular to anticipated flow lines.

Energy Loss Coefficients - Energy loss coefficients are used to evaluate hydraulic energy losses. These include Manning's n values for channel and overbank flow, contraction and expansion coefficients for evaluation of transition losses at beginning and ending of "bottlenecks," and bridge and culvert loss coefficients to evaluate hydraulic energy losses related to bridge and culvert characteristics. The model also evaluates the hydraulic energy losses associated with stream tributary junctions.

Calibration - To verify the "repeatability" of the flood profiles, published flow values from the Lincoln FIS for the 10-year and 100-year floods were entered into the HEC-RAS model to generate flood profiles and compared to the published FIS flood profiles. They very closely matched the published FIS profiles. The one notable exception was in the area upstream of 27th Street. The flood profile was lower due to the added capacity provided by the supplemental culvert recently constructed under 27th Street and the removal of the MoPac railroad overpass involving substantial amounts of the embankment removal. Those changes were made subsequent to the 1978 FIS study.

Flow Data - Values for the peak flow rates generated by Visual HEC-1 for each of the design storms were entered into the HEC-RAS model. The analysis was carried out with 1997 channel characteristics for the 2-, 5-, 10-, 25-, 50-, and 100-year average return frequency storms for 1997 and projected future land use conditions. Refer to Tables I-12 and I-13 for a comparison of 100-year peak flow rates for FIS Report, 1997, and Master Plan conditions.

The main channel was modeled starting at the confluence with Salt Creek near First Street and Pioneers Boulevard upstream to the bottom of the subbasin delineated at 84th Street. Tributaries were modeled from their confluence with Beal Slough to the bottom of the uppermost 150-acre subbasin of the tributary.

HEC-RAS RESULTS

The output from the HEC-RAS model includes the water surface elevation, width of flow, flow velocity, and scour energy at each cross-section. All computed flow velocities in channel reaches are sub-critical with the Froude number (NF) ranging from about 0.01 to 0.80, well within the acceptable boundaries. Supercritical velocities are indicated through several bridges/culverts, and immediately downstream in some instances. Scour likely occurs in the stream bed at the bridges during passage of runoff from larger storms. The FEMA FIS floodplain and the floodplain as modeled based on 1997 Basin conditions are shown on Figures SG1-FP through SG16-FP. More detailed 100-year plan and profile sheets from the December 1997 Interim Basin Report are included in Appendix "A". Plan and profile sheets showing FIS and the 100-year flood with all Master Plan improvements completed are included in Section II Master Plan.

FLOOD PRONE AREAS

HEC-RAS provides a graphical interface that displays the extent of the reach subject to flooding. The information for the 100-year event was transferred to the digital topographic mapping. Straight-line interpolation was used to determine the water surface elevations for the areas between cross-sections. The water surface profile was projected to the valley land surface represented in the digital topographic map.

WATER QUALITY

The Nebraska 1990 Water Quality Report, which includes the most recent published data, identified known or suspected water quality impacts on Beal Slough (NDEQ Segment LP2-21500) that need additional control action to meet Section 304(i) requirements. This study identified a point source with effluent flow to stream flow dilution ratio greater than one percent as a key water quality impact. This point source was likely the Pine Lake wastewater treatment plant. The report further states the watershed supports a Warm Water Class B Fishery in the stream.

Municipal Separate Storm Sewer System NPDES Data

Water quality data were collected by the City of Lincoln for inclusion in their Municipal Separate Storm Sewer System (MS4) NPDES Permit Application. Information on annual loading for specified pollutants was completed using the “simplified method” (EPA ,1992 page 5-14). Information from Table 4-7 pertaining to Beal Slough is repeated here for convenience.

Table I-11
Annual Pollutant Loads for Beal Slough, Estimated from 1992 Monitoring Results

BOD_5 (lbs)	COD (lbs*10^3)	TSS (lbs*10^3)	TDS (lbs*10^3)	TKN (lbs)	NH_4 (lbs)	Total P (lbs)	Dslvd P (lbs)	Cd (lbs)	Cu (lbs)	Pb (lbs)	Zn (lbs)
435633	1264	7711	6788	360494	151138	5019	4589	12	160	137	408

A Water Quality Memorandum prepared by Wright Water Engineers is included as Appendix “C”.

For a complete description of the characterization data, see the Municipal - Part 2 Application on file at Lincoln Public Works and Utilities Department or at the Nebraska Department of Environmental Quality.

The system was evaluated for potential non-stormwater connections this information was also included in the MS4 NPDES Permit Application. None of the known potential illicit connections identified are located in Beal Slough. No industries covered by current environmental regulations, other than construction activities, were identified in the watershed according to the Municipal - Part 2 Application. Other industries located in the watershed include those identified in Table I-12.

Sanitary Improvement District #2 Pine Lake operates a wastewater treatment plant that discharges into the tributary below the dam. This is a limitation to on-line stormwater retention sites downstream. The rural residential developments along Beal Slough upstream of Pine Lake Road use small total retention lagoons to handle domestic wastewater needs.

Table I-12
Inventory of Industrial Facilities

Names	Mailing Address	Reg	SIC	Description
Flemming Foods of Nebraska	1601 Pioneers Blvd	xi	4222	Food Processing
Kennedy Enterprises Inc.	4910 Rentworth Blvd	xi	3556	Food Processing Equip.
Lincoln Laminating Inc.	5601 S. 50th St.	xi	2434	Cabinets
Lincoln Snack Co.	P.O. Box 81721	i	2064	Food Processing
Nebraska State Penitentiary	14th & Pioneers Blvd	i	9000	Prison, Coal Pile Runoff
Pepsi-Cola Bottling Co of Lincoln	1901 Windhoek St.	xi	2086	Bottler
Ready Mixed Concrete Co.	P.O. Box 29288	ii	3273	Ready-Mixed Concrete
Royal Linens	5500 Old Cheney Rd.	xi	2392	Bedding
Small Sewage Treatment Plant	5000 Rentfro Dr.	i	4952	Small Treatment Works
Speidel Applicator Inc.	7800 S. 40th St.	xi	3523	Farm Equip. Assembler
Square D Company	1717 Center Park Rd.	i	3613	Manufacturer
United Micrographic Systems	Box 6729	iv	3999	Microfilm Services
Vanguard Industries	3330 Prescott Ave.	i	3743	Railroad Equipment
Weaver Potato Chip Co. Inc.	P.O. Box 83208	xi	2096	Food Processing

Field screening of stormwater runoff performed by the City has not identified a serious chemical or nutrient pollution problem in the watershed. The Mayor’s Stormwater Task Force Report identified the pollutant of concern in the watershed is sediment. The main sources of sediment are land disturbance activities that accelerate the natural rate of erosion such as land grading, utility and building construction associated with new developments and stream bed and bank erosion.

Information for the two outfall monitoring sites located in Beal Slough was given in the NPDES Storm Water Permit Municipal - Part Two Permit Application, Table 4-1 has been repeated in Table I-13 for convenience.

Table I-13
Monitoring Site Description

Site	Site 2 - Tipperary Trail	Site 4 - Center Park Road
Land Use	Urban Residential	Industrial
Drainage area, acres	130	95
Sampling Site	60" RCP	42" RCP [1]
Slope (ft/ft)	0.015	0.013
Receiving Stream	Beal Slough	Beal Slough
Rain Gage	Fire Station #8, 2760 S. 17th St.	Fire Station #8, 2760 S. 17th St.

[1] Drainage at the sampling site is through twin 42" RCPs. Sample collected from the west 42" RCP

A biological assessment report of Beal Slough was completed by Wright Water Engineers in March 1997. It recommended that master planning goals include components targeted at maintenance of the substrate conditions upstream of 48th Street because the "upstream areas have the potential for supporting a reasonably dense macrobenthic community."

During the filed investigation eight sites were chosen for stream sampling. Detailed cross-sections were obtained, reference points were established, and permanent staff gauges were installed at each site. During 1997 several samples at each site were obtained for "wet" conditions and "dry" conditions. Wet conditions are defined as samples obtained during a significant rain event or during the first three hours following a significant rain event. Dry conditions are defined as samples obtained after at least 3 days without measurable rainfall. Flow depths were recorded during each sampling event. Four staff gauges, located in the downstream half of the channel, were destroyed on 27 June 1997 during a rain event. Only water quality data were obtained for subsequent sampling events at those locations. Nine sampling events occurred in 1997, three during dry conditions and six during wet conditions. Samples from eight events were analyzed and the results of oil and grease, Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) analyzes are provided in Table I-14. Only flow depth data was collected during one significant rain event.

Table I-14
Results of Chemical Analysis

Test	Limit of detection	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Blank	Spike
16 June 97 - Dry											
Oil and Grease	0.4 mg/l	<	<	<	0.4	<	<	<	<	3.6	60%
TDS	29 mg/l	600	433	800	133	233	433	500	33	767	-
TSS	29 mg/l	100	234	200	234	100	534	767	134	533	-

Table I-14 continued
Results of Chemical Analysis

Test	Limit of detection	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Blank	Spike
21 June 97 - Wet											
Oil and Grease	0.4 mg/l	1.2	4	4	<	5.2	2	4.4	1.6	2	60%
TDS	3mg/l	733	700	633	933	233	133	367	467	200	-
TSS	3 mg/l	433	366	300	300	133	166	600	333	267	-
24 June 97 - Wet											
Oil and Grease	0.4 mg/l	2.94	0.8	<	4	<	1.2	<	2.8	2	60%
TDS	3 mg/l	442	315	498	475	352	565	495	165	15	-
TSS	3 mg/l	298	1096	611	415	325	385	458	475	52	-
07 July 97 - Dry											
Oil and Grease	0.4 mg/l	<	2.6	1.4	2.4	3.6	4.8	1.2	<	2	85%
TDS	3 mg/l	716	739	672	749	49	582	447	294	51	-
TSS	3 mg/l	345	415	605	908	395	392	498	345	16	-
10 July 97 - Wet											
Oil and Grease	0.4 mg/l	1.1	2.9	0.7	4.1	2	1.2	2	4.8	<	88%
TDS	3 mg/l	596	623	566	606	460	420	400	483	37	-
TSS	3 mg/l	223	160	253	246	130	86	316	580	107	-
18 July 97 - Dry											
Oil and Grease	0.4 mg/l	2.1	1.7	2	0.8	1.2	1.6	1.2	0.8	0.4	103%
TDS	3 mg/l	530	697	630	680	577	480	483	343	63	-
TSS	3 mg/l	260	193	283	190	523	280	207	130	40	-
27 July 97 - Wet											
Oil and Grease	0.4 mg/l	<	2	1.2	4.4	2	5.2	8.8	0.8	0.8	84%
TDS	3 mg/l	633	667	703	420	220	177	277	217	7	-
TSS	3 mg/l	397	1057	447	460	477	357	390	383	10	-
11 Aug 97 - Wet											
Oil and Grease	0.4 mg/l	1.2	3.8	3.5	2.6	2.4	5.4	4.8	7.1	0.8	53%
TDS	3 mg/l	61	424	311	477	274	354	574	301	26	-
TSS	3 mg/l	100	797	2157	453	214	110	1427	917	13	-

The Comparison of the chemical analysis of the Beal Slough samples for oil and grease and Total Suspended Solids (TSS) for the eight event sampled is provide in the following table. TDS data was not provided in the NURP report. The Beal Slough samples are within the range of NURP values for oil and grease and TSS.

The sample averages for oil and grease are significantly below the national average. The range of values increases as the contributing drainage area increases. The average values also tend to increase as the drainage are increases. There also appears to be a correlation with the presence of commercial and industrial land uses (i.e., parking lots).

The average TSS values are greater than the national average but the analysis report indicates the sample collection method during dry conditions may have resulted in an exaggerated effect on sample values. The largest single event values were recorded in areas of the watershed that have both active agricultural land use and land disturbance activities associated with land development. The average values are higher in those areas and in stream reaches with active channel bed and bank erosion in the form of aggressive headcuts.

Table I-15
Comparison of Beal Slough Sampled Data to NURP data

Constituent		Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	NURP
Oil and Grease	Range	< to 2.9	< to 4.0	< to 4.0	< to 4.4	< to 5.2	< to 5.4	< to 8.8	< to 7.1	Up to 35.7
	Average	1.1	2.2	1.6	2.3	2.1	2.7	2.8	2.2	7.8
TSS	Range	100 - 433	160 - 1096	200 - 2157	190 - 908	100 - 523	86 - 534	207 - 1427	130 - 917	2 - 2890
	Average	270	540	607	401	287	289	583	412	150

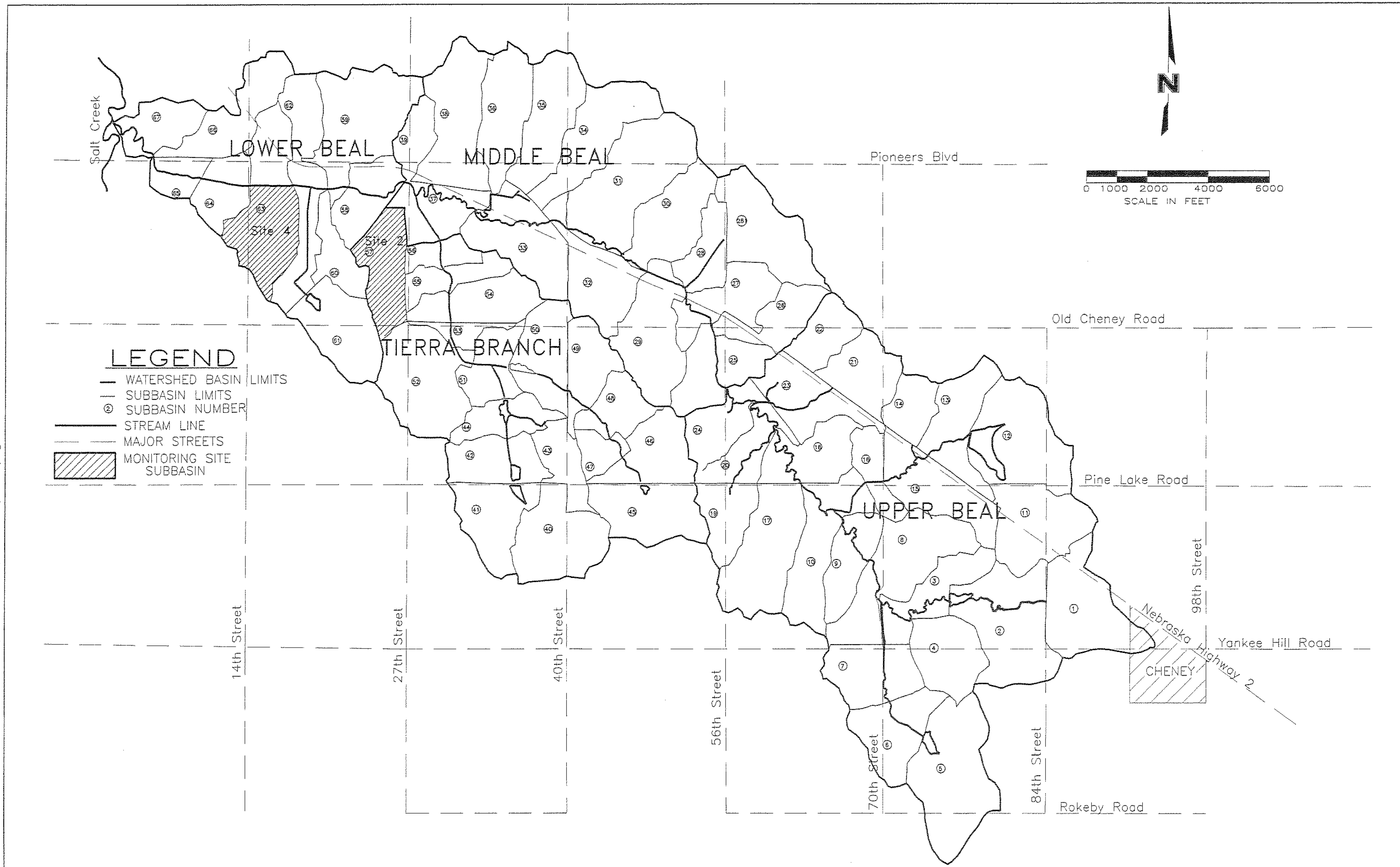
Application of erosion and sediment control measures during land disturbance activities and BMPs to improve bed and bank stability are recommended to reduce Total Suspended Solids in Beal Slough. Incorporating permanent BMPs into new developments will reduce oil and grease (and other pollutants) contained in runoff from paved areas.

Stormwater Quality Model

The project team has developed a stormwater runoff quality computer model as part of the Beal Slough Master Plan scope of work. The simple spreadsheet-based water quality model contains the available stormwater monitoring data collected by the City. Future data collection efforts can be incorporated into the model .

The primary purpose of this model will be to provide rough projections of pollutant loads for various types of land use. Using these loads and estimated pollutant removal efficiencies for various BMPs. It will be feasible to project the water quality benefit that can be provided by various stormwater management plans. It is important to remember that it would be premature to carry this spreadsheet model to the stage of projecting receiving water impacts because there are not currently defensible, scientifically-based, wet weather water quality criteria/standards. This is consistent with the EPA NPDES regulations and the EPA position that the “state of the science” of wet weather receiving water impacts is not sufficiently advanced to propose wet weather water quality standards.

The model will prompt user input such as subbasin acreage, runoff volume, land use makeup, and BMP type. Untreated stormwater pollutant concentrations for specific parameters (i.e, copper, lead, zinc, etc.) can be selected along with anticipated removal efficiency of the proposed/existing BMP. Using these input data, the model will calculate untreated stormwater pollutant loads in addition to projected treated pollutant loads. The model is user-friendly and designed with an interactive interface with “pull-down” menu options. A user’s manual has been prepared that provides the necessary guidance to navigate and effectively use the model.



DRAWN BY: JJM DATE: JUNE 1999 REVISIONS:	BEAL SLOUGH MASTER PLAN LINCOLN, NEBRASKA	NPDES STORMWATER MONITORING SITE LOCATION MAP	FIGURE I–10

06/30/1999 11:10 A.M. FILE: F:\PROJECTS\960280\DWG\FigVII1.DWG SCALE: 3000

STREAM SEGMENT EVALUATION

Stormwater management involves evaluation of the channels and crossing structures in the watershed. If not anticipated, modifications to the hydrologic and hydraulic conditions may adversely effect the performance of the channels and structures.

Reach stability analysis was perform utilizing the following factors: predominant stream slope versus distance from the mouth, sediment transport based on bed material data, and tractive force evaluation. When channel forming flows increase, stream forces will attempt to maintain a stable bed slope either by lengthening the flow path or reducing the elevation difference. In the Beal Slough channel both actions exist. The meanders are migrating outward and head cutting is reducing channel slope. The stable stream bed slope was estimated to be 0.0014 foot per foot for Beal Slough, about half of the current slope for many reaches.

The water surface profile and peak flow rates for 1997 conditions are generally greater than those determined for the FIS 100-year flood due to the effects of subsequent urbanization since 1978 (see discussion in the Hydrology Section). Increased peak flow rates and flow depths mean bank-full, bridge, and culvert capacities will be reached more frequently. To illustrate, consider the 40th Street culvert. The culvert can pass 3600 cfs without overtopping the roadway. In 1978 that flow rate corresponded to the flow generated by a 50-year average return frequency storm. Today that flow rate corresponds to a 7-year average return frequency storm. Bridge or culvert overtopping results in public hazards, traffic detours, increased maintenance and potential damage to the structure and roadway approaches. Typically, minimum highway design standards for major stream crossings require the roadway not be overtopped more often than the 50-year or 100-year average return frequency flood. This is based on evaluation of maintenance, detour, and bridge replacement costs in addition to the level of service expected by the public. Refer to Table I-16 for a bridge capacity summary.

Unless anticipated, increased recurrence of bank full conditions will adversely effects channel stability. In the FIS, the channel immediately upstream of 40th Street has a bank-full capacity of about 1100 cfs, sufficient to contain a 5-year average return frequency storm. Today it has capacity to contain a 2-year average return frequency storm. Refer to Table I-17 for a stream reach capacity summary. Table I-18 provides a cross-reference between the Visual HEC-1 model reach identifiers and the cross-section identifiers used by HEC-RAS to represent the main channel and tributaries.

Stream characteristics were determined for segments of the mainstem channel and for Tierra Branch. Reach stability, flood hazard, potential threats to bridges & utilities, land use & ownership, multipurpose use potential, and water quality issues were used to evaluate each stream segment. Photographs of channel characteristics are provided to illustrate the evaluation of each segment on the following pages.

Table I-16a
Comparison of Bridge Capacity Mainstem Channel

Bridge	Capacity [1] cfs	Average Return Frequency [2] 1978	Average Return Frequency [2] 1997
84th Street (6900 S)	700	N/A	25
70th Street (7900 S)	2500	N/A	>100
Pine Lake Road ((6300 E)	4200	>100	100
56th Street (6200 S)	2100	20	6
Old Cheney Road (5500 E)	5400	>100	100
BNSFRR (5200 E)	4400	100	10
Highway 2 (5200 E)	4400	100	10
48th Street (5000 S)	6300	>100	>100
40th Street (4900 S)	3600	50	7
Highway 2 (3800 E)	6300	>100	50
BNSFRR (3800 E)	4000	80	10
27th Street (4400 S)	8000	>100	33
Southwood Drive (4400 S)	6400	>100	14
Railroad spur (4400 S)	11000	>100	>100
Highway 77 (1400 E)	6000	83	8
Penitentiary Bridges	8400	>100	35
Pioneers Boulevard (100 E)	8400	>100	30
BNSFRR (100 E)	8400	>100	30

Table I-16b
Comparison of Bridge Capacity Tributary Channels

Bridge	Capacity [1] cfs	Average Return Frequency [2] 1978	Average Return Frequency [2] 1997
Yankee Hill Road (7000 E)	650	N/A	6
70th Street (6900 S)	1570	N/A	56
Pine Lake Road (3600 E)	510	N/A	60
Williamsburg Drive (3500 E)	1500	N/A	20
Browning Street (3600 E)	950	N/A	90
Old Cheney Road (3000 E)	2750	N/A	>50
Sequoia Drive (2900 E)	2500	N/A	20
Tierra Drive (2900 E)	1750	N/A	6

1. Capacity is defined as the flow rate that occurs prior to roadway overtopping.
2. Number of years (on average) that can be expected between overtopping events. For example, the Highway 77 bridge has a capacity before overtopping the road of 6000 cfs. In the FIS the 1% return frequency storm (100-year) flow rate is listed as 6590 cfs and the 2% return frequency storm (50-year) flow rate is 5350 cfs. By interpolation on probability paper, the bridge capacity would be equivalent to the 1.2% return frequency storm or on average the bridge can be expected to be overtopped every 83 years based on FIS flow rates. Based on our analysis of 1997 conditions 6000 cfs can be expected to occur, on average, every 8 years.

Table I-17a
Comparison of Stream Reach Capacity
Mainstem Channel

Reach	Capacity cfs	Depth feet	Average Return Frequency 1978	1997
1	320	2	N/A	4
2	290	2	N/A	2
3	600	7	N/A	5
7	1400	9	40	13
8	450	4	5	2
9	1350	8	8	4
15	600	6	3	2
16	1050	8	5	2
17	2300	10	20	10
18	3200	10	>100	15
19	4300	6	>100	36
20	4200	9	40	10
21	4300	10	>100	18
22	5300	9	>100	44
26	1500	8	6	2
27	1100	5	5	2
28	3400	9	36	6
29	# not used			
30	# not used			
31	1150	10	5	2
50	4500	9	35	4
51	2800	10	10	2
52	2800	10	10	2
53	3000	9	12	2
54	7600	14	>100	20
56	8400	14	>100	33

Table I-17a (Continued)
Comparison of Stream Reach Capacity
Mainstem Channels

Reach	Capacity cfs	Depth feet	Average Return Frequency 1978	1997
57	5500	10	50	5
58	7400	17	>100	20
59	8300	16	>100	30
60	9600	11	>100	50
61	9600	11	>100	50

Table I-17b
Comparison of Stream Reach Capacity
Tributary Channels

Reach	Capacity cfs	Depth feet	Average Return Frequency 1978	1997
32	250	8	N/A	100
33	470	6	N/A	50
34	230	4	N/A	10
35	500	2	N/A	25
36	150	1	N/A	2
37	320	2.5	N/A	10
38	180	1.5	N/A	2
39	360	3	N/A	2
40	400	4	N/A	2
41	1000	4	N/A	35
42	2150	4	N/A	100
43	680	4	N/A	>100
44	2100	3	N/A	60
45	1200	4	N/A	7

Table I-17b (continued)
Comparison of Stream Reach Capacity
Tributary Channels

Reach	Capacity cfs	Depth feet	Average Return Frequency 1978	1997
4	180	3	N/A	2
5	160	2	N/A	2
6	760	4	N/A	11
10	40	1.5	N/A	2
11	# not used		N/A	
12	300	4	N/A	3
13	600	4	N/A	3
14	500	4	N/A	2
17	140	1.5	N/A	2
19	# not used		N/A	
20	200	1.5	N/A	2
46	1200	4	N/A	7
47	2000	6	N/A	12
48	1500	7	N/A	5
49	2500	7	N/A	20
55	60	2	N/A	2

Table I-18

Visual HEC-1 Reach and HEC-RAS Cross-section Labeling Key

Segment Number	Reach Number	Cross Section
8	1	Sta. 472+50 to Sta. 514+50
8	2	Sta. 448+50 to Sta. 472+50
8	3	Sta. 432+00 to Sta. 448+50
16	4	Sta. 34+00 to Sta. 53+00
16	5	Sta. 13+50 to Sta. 34+00
16	6	Sta. 0+00 to Sta. 13+50
7	7	Sta. 416+50 to Sta. 432+00
7	8	Sta. 388+00 to Sta. 416+50
7	9	Sta. 378+00 to Sta. 383+50
15	10	Sta. 47+00 to Sta. 62+50
15	11	# not used
15	12	Sta. 23+00 to 43+00
15	13	Sta. 16+50 to Sta. 23+00
15	14	Sta. 0+00 to Sta. 16+50
7	15	Sta. 367+50 to Sta. 378+00
6	16	Sta. 329+50 to Sta. 367+50
14	17	Sta. 0+00 to Sta. 26+50
6	18	Sta. 307+00 to Sta. 330+00
14	19	Sta. 30+00 to Sta. 35+50
14	20	Sta. 5+50 to Sta. 30+00
6	21	Sta. 291+50 to Sta. 307+00

Table I-18 (continued)

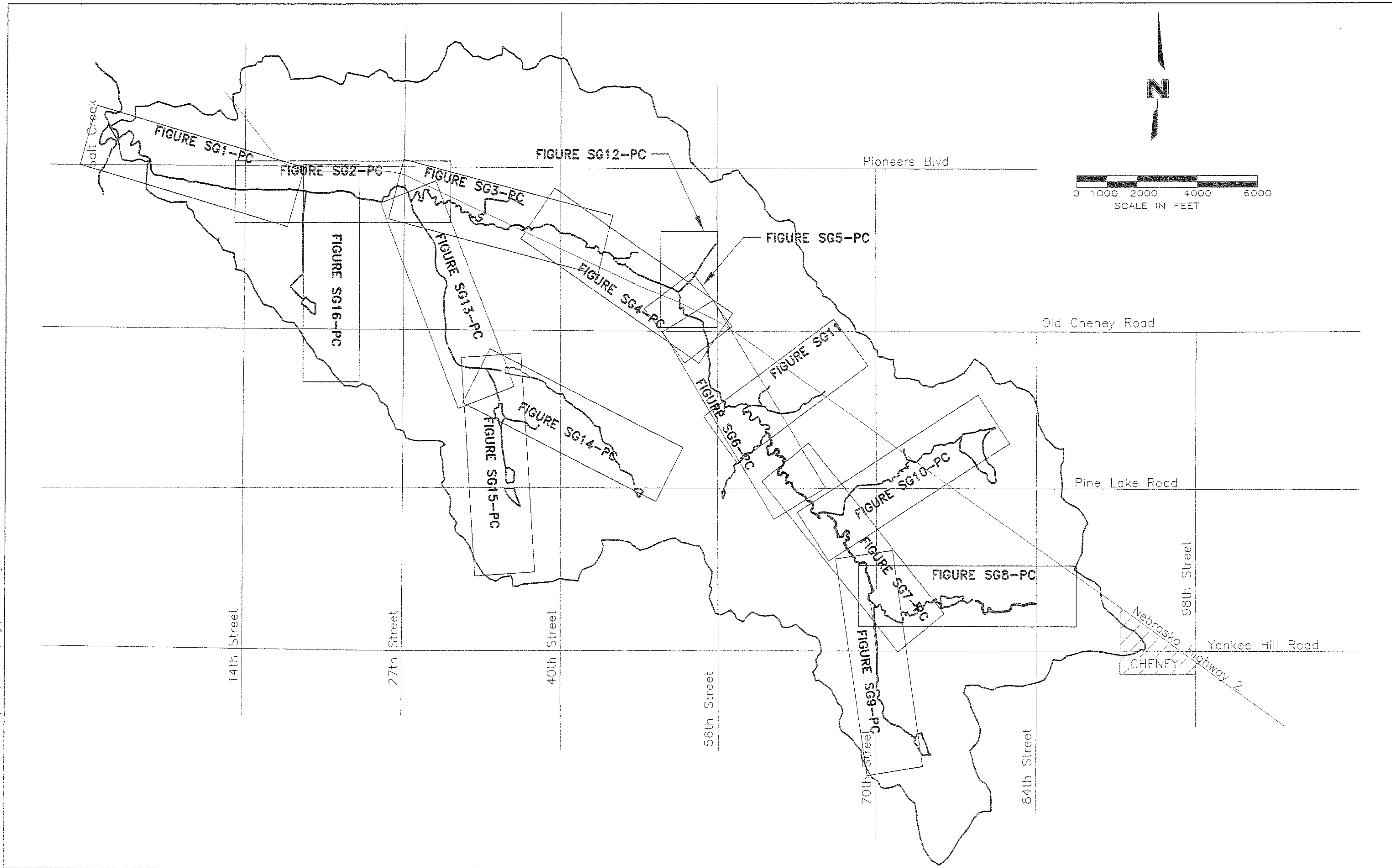
Visual HEC-1 Reach and HEC-RAS Cross-section Labeling Key

Segment Number	Reach Number	Cross Section
6	22	Sta. 268+00 to Sta. 291+50
5	23	Sta. 249+50 to Sta. 268+00
4	24	Sta. 236+50 to Sta. 249+50
4	25	Sta. 225+00 to Sta. 236+50
4	26	Sta. 201+50 to Sta. 225+50
3	27	Sta. 192+50 to Sta. 201+50
3	28	Sta. 163+00 to Sta. 192+50
3	29	# not used
3	30	# not used
3	31	Sta. 126+50 to Sta. 163+00
10	32	Sta. 23+00 to Sta. 33+00
10	33	Sta. 17+00 to Sta. 23+00
10	34	Sta. 8+00 to Sta. 16+00
10	35	Sta. 8+00 to Sta. 16+00
10	36	Sta. 0+00 to Sta. 15+50
10	37	Sta. 0+00 to Sta. 12+00
11	38	Sta. 58+00 to Sta. 69+50
11	39	Sta. 49+50 to Sta. 58+00
11	40	Sta. 36+50 to Sta. 49+50
11	41	Sta. 27+00 to Sta. 36+50
11	42	Sta. 5+50 to Sta. 27+00
11	43	Sta. 0+00 to Sta. 5+50

Table I-18 (continued)

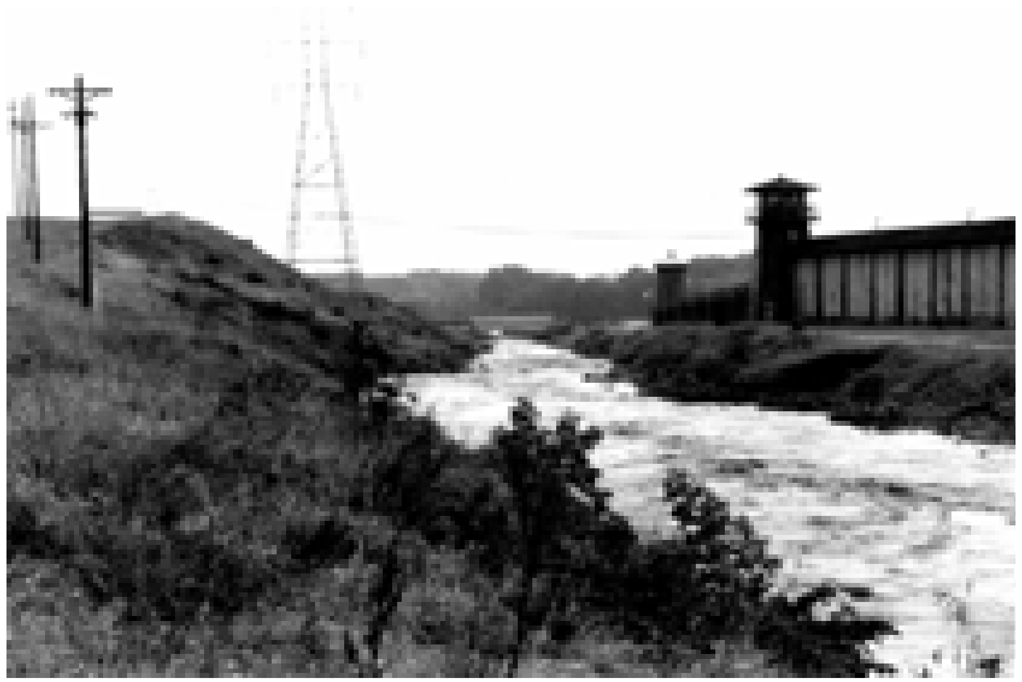
Visual HEC-1 Reach and HEC-RAS Cross-section Labeling Key

Segment Number	Reach Number	Cross Section
9	44	Sta. 53+50 to Sta. 68+50
9	45	Sta. 45+50 to Sta. 53+50
9	46	Sta. 36+00 to Sta. 45+50
9	47	Sta. 26+50 to Sta. 36+00
9	48	Sta. 12+50 to Sta. 26+50
9	49	Sta. 0+00 to Sta. 12+50
3	50	Sta. 121+50 to Sta. 126+50
2	51	Sta. 111+00 to Sta. 121+50
2	52	Sta. 97+00 to Sta. 111+00
2	53	Sta. 90+00 to Sta. 97+00
2	54	Sta.79+00 to Sta. 90+00
12	55	Sta. 0+00 to Sta. 36+00
2	56	Sta. 64+50 to Sta. 79+00
1	57	Sta. 48+00 to Sta. 64+50
1	58	Sta. 39+00 to Sta. 48+00
1	59	Sta. 27+50 to Sta. 39+00
1	60	Sta. 9+00 to Sta. 27+00
1	61	Sta. 0+00 to Sta. 9+00



6/30/1999 11:58 A.M. FILE: F:\Projects\960280\dwg\FIGI-12.dwg SCALE: 3000

DRAWN BY: JJM DATE: JUNE 1999 REVISIONS:	BEAL SLOUGH MASTER PLAN LINCOLN, NEBRASKA	STREAM SEGMENT FIGURE KEY MAP	FIGURE I-11



Photograph 1. Looking downstream from Highway 77.

Photograph 2. Looking upstream from the BNSF railroad bridge toward Pioneers Boulevard.

Stream Segment Evaluation

Stream Segment 1

Stream Segment 1 includes the reach of Beal Slough from its mouth at Salt Creek in Wilderness Park to Highway 77.

- Reach Stability - The reach from the mouth to the Union Pacific Railroad (UPRR) and Burlington Northern Santa Fe Railroad (BNSFRR) bridges has experienced 2 to 3 feet of bed degradation since 1978. From Pioneers Boulevard bridge to 500 feet upstream, the channel banks have migrated between 10 and 20 feet on the outside radius due to sloughing. The banks are steep and unstable, most likely due to the bed degradation. Near the mouth, a meander on Salt Creek and a meander on Beal Slough are moving toward each other. Salt Creek has migrated and taken over the last 500 feet of the Beal Slough channel.

- Flood Hazard Potential - The Salt Creek floodplain controls the floodplain water surface elevation from the mouth to the railroad bridges. Between Pioneers Boulevard and Highway 77 water surface elevations have increased due to the increased flow rate conveyed by the stream.

- Threats to Bridges and Utilities - Unstable banks due to a scour hole near station 55+00 threaten an electrical transmission tower. Channel degradation has exposed the timber piling supporting the Pioneers Boulevard bridge, which is listed as an historic structure.

- Land Use Ownership - Public lands lie on either side of the channel downstream of the railroad bridges. Between the railroad bridges and Highway 77 there is one residence. The remainder of the land use is identified as industrial and commercial.

- Multipurpose Potential - Multipurpose use potential is limited outside the boundaries of Wilderness Park.

- Water Quality - Parking lot and roof top runoff from adjoining industrial and commercial land use is the dominant characteristic affecting runoff water quality and environmental issues. Bank sloughing is a significant source of sediment in this reach. Bars formed in the channel are the result of sediment deposition from upstream sources. In 1997, a stream water quality monitoring location was established near the mouth. Water samples in this reach have been collected and analyzed, but evaluation by the City is not complete.

Photograph 3. Looking Upstream from Highway 77.

Photograph 4. Looking downstream from the 27th Street box culvert.

Stream Segment Evaluation
Stream Segment 2

Stream Segment 2 includes the reach from the Highway 77 bridge to the box culvert at 27th Street and is crossed by a railroad spur and Southwood Drive.

- Reach Stability - Erosive velocities are evident at the end of the 27th Street box culvert outlet channel. Head cutting is occurring at the railroad spur bridge near Station 90+00. The stream bed grade between Highway 77 and the railroad spur bridge is approximately equal to the stable slope determined for Beal Slough. The Southwood Drive culvert flow line elevation is currently 3 feet above the stream bed elevation for the same point on the FIS stream bed profile, indicating that the stream bed has degraded at this location. The channel slope from Southwood Drive to 27th Street is at or flatter than the stable slope. The box culverts serve as control points for this reach at the upstream and downstream ends. Channel banks are sloughing on the outside radii of meanders due to toe cutting.

- Flood Hazard Potential - Buildings constructed in the floodplain prior to the FIS are subject to flooding. Buildings constructed after adoption of the FIS may also be subject to flooding from the increased water surface elevation.

- Threats to Bridges & Utilities - A sanitary sewer crossing was exposed near station 66+00 upstream of Highway 77 (It was repaired at a cost of $60,000 in 1999). The head cut moving upstream from Station 90+00 will likely result in 3 to 4 feet of additional bed degradation threatening the railroad spur bridge. (If allowed to move beyond the railroad spur, it may eventually reach Southwood Drive cut nearly 10 feet deep at the culvert.)

- Land Use and Ownership - Commercial and industrial land uses occur along the downstream portion of this segment. The upstream portion of this segment is bordered on both sides by a public park.

- Multipurpose Potential - Unstable banks present safety concerns to users of the park. The encroachment of development in the downstream portion restricts additional multi-use potential of this segment.

- Water Quality - Parking lot and roof top runoff from adjoining industrial and commercial land use is the dominant characteristic effecting water quality and environmental issues. Bank sloughing is a source of sediment in this reach. Refer to the Water Quality Section for data collected at the NPDES monitoring sites discharging into this stream segment.

Photograph 5. Looking downstream from a bike path bridge near Station 160+00.

Photograph 6. Looking downstream from the 40th Street box culvert prior to the bioengineered project completed by the LPSNRD.

Stream Segment Evaluation
Stream Segment 3

Stream Segment 3 includes the reach from 27th Street to 40th Street. It passes through Tierra Park. It is bounded on the north by the BNSFRR track. On the south side near Station 148+00, multifamily housing developments have been built along the floodway limit. Three pedestrian bridges cross the channel as the bike path wanders through Tierra Park. BNSFRR and Highway 2 both cross the channel near Station 200+00.

- Reach Stability - Box culverts at 27th Street and 40th Street provide stream bed control points at the upstream and downstream ends of the segment. Head cutting has lowered the stream bed between 2 to 4 feet from station 130+00 to 200+00. A bioengineered channel improvement project built by the LPSNRD stabilizes the channel between Highway 2 and 40th Street. Near Station 149+00 bank migration of up to 20 feet has been observed.
- Flood Hazard Potential - In comparison to the FIS profile, there is almost no increase in the 100-year water surface profile for this reach between 27th Street and Highway 2. The removal of the Missouri Pacific Railroad embankment crossing the valley and construction of a supplemental culvert under 27th Street have significantly increased the capacity and prevented significant raising of the 100-year flood profile due to development activities. Public ownership of the park has preserved open space along the overbanks for storage of flood flows.
- Threats to Bridges & Utilities - Stream meanders are migrating toward the bike path and adjacent town homes near station 148+00 and threatening utilities at Stations 160+00 and 178+00. Growth of the channel width is threatening the bike path bridges near Stations 163+00 and 180+00. Shallow buried electrical lines at the 40th Street box culvert outlet restrict the culvert outlet channel shape resulting in a restriction of culvert capacity.
- Land Use and Ownership - Park land with extensive timbered areas borders both sides of the segment
- Multipurpose Potential - Existing fitness trails and bike path through the park provide multipurpose use potential.
- Water Quality - The LPSNRD bioengineering project created a stable channel between Highway 2 and 40th Street reducing the sediment load generated by bank sloughing and bed degradation. Although bank sloughing and bed degradation continue to be a significant sediment source between 27th Street and Highway 2, runoff from residential and commercial land uses in the basin likely effect water quality in this reach. In 1997, stream water quality monitoring locations were established near Station 130+00, Station 165+00, and Station 199+00. Water samples in this reach have been collected and analyzed but evaluation by the City is not complete.

Photograph 7, Looking downstream at the 40th Street box culvert.

Photograph 8, Looking downstream in the vicinity of Sutter Place Mall

Stream Segment Evaluation

Stream Segment 4

Stream Segment 4 includes the reach of Beal Slough from 40th Street to the Highway 2 and BNSFRR bridges.

- Reach Stability - The channel has degraded 1 to 2 feet on average between 40th Street and 48th Street and 1 foot between 48th Street and the BNSFRR bridge. Bank sloughing due to toe erosion is occurring near 40th Street.

- Flood Hazard Potential - The open space along the south side of the channel between 40th Street and the Highway 2 bridge provides storage for flood flows. The FIS floodplain extends into the residential development on the north side, east of 40th Street. Backwater effects from the Highway 2 bridge west of 40th Street for the 1997 conditions 100-year flood increases the water surface profile by 3 feet at 40th Street and effects the profile for an additional 2000 feet upstream. Increased water surface profile elevations at 48th Street and at Highway 2 and BNSFRR bridges, due to increased peak flow rates, have increased the flood hazard potential in those areas.

- Threats to Bridges & Utilities - Increased peak flow rates result in more frequent overtopping of the 40th Street culvert.

- Land Use and Ownership - Residential land use occurs along the north side of the reach, with park land occurring along the south side of the reach.

- Multipurpose Potential - A ball diamond, bike path, and park land currently provide multipurpose use in this stream segment.

- Water Quality - Runoff from residential and commercial land uses in the basin also effect water quality in this reach. In 1997, a stream water quality monitoring location was established near 232+00. Water samples in this reach have been collected and analyzed but evaluation by the City is not complete.

Photograph 9. Looking downstream at the reach between the Lincoln Racquet Club and Cheney Pace Mall.

Photograph 10. Looking upstream at the box culvert under Old Cheney Road near 55th Street.

Stream Segment Evaluation

Stream Segment 5

Stream Segment 5 includes the reach from BNSFRR bridge to the box culvert at 55th and Old Cheney.

- Reach Stability - The general stream slope is approximately equal to the stable stream slope. Parking lot runoff, the sharp bend at Station 266+00, and floodplain encroachment likely contribute to bank instability. Isolated toe erosion occurs in this reach. Random concrete rubble has been placed in an effort to stabilize the channel. Construction of parking lots in close proximity to the channel has resulted in steep side slopes.
- Flood Hazard Potential - Repeated flooding of the mall has been experienced.
- Threats to Bridges & Utilities - A sharp bend is located downstream of Old Cheney Road. It is stabilized with concrete rubble to protect the parking lot. However, the stream velocity is reduced sufficiently at the bend to allow deposition of sediment forming a vegetated bar that restricts the upstream box culvert capacity.
- Land Use and Ownership - Both sides of the stream are in private ownership. Development has encroached on the stream, limiting available options for channel improvement.
- Multipurpose Potential - Private ownership and tight confines limit the potential for multipurpose use. An existing bike path is located along the north side of Highway 2 and a future bike path is planned for the south side of Old Cheney Road. Space limitations and land owner willingness likely limit potential for a connecting bike path.
- Water Quality - Parking lot and roof top runoff from adjoining industrial and commercial land use is the dominant characteristic effecting water quality and environmental issues.

Photograph 11. Looking downstream at the reach from the 56th Street bridge.

Photograph 12. Looking downstream from Pine Lake Road.

Stream Segment Evaluation

Stream Segment 6

Stream Segment 6 includes the reach from Old Cheney near 55th Street to Pine Lake Road. The stream is crossed by 56th Street.

- Reach Stability - Severe head cutting has occurred from Old Cheney Road to a tributary confluence near Station 291+00. This is likely a result of replacement of the Old Cheney box culvert at a lower flowline than the previous structure. Stream bed degradation averages 3 feet in this reach. Upstream of 56th Street to Station 310+00, the channel slope is significantly greater than the stable slope. Upstream of Station 310+00 side slopes appear to be stable with isolated bank sloughing associated with meanders.

- Flood Hazard Potential - Replacement of the Old Cheney box culvert mitigated the increase in water surface elevations that would have resulted from the larger peak flow rates for 1997 conditions.

- Threats to Bridges & Utilities - Continued migration of the head cut upstream to the 56th Street bridge may threaten buried utilities and the bridge foundation.

- Land Use and Ownership - A miniature golf course and batting cage complex occupies the middle of the floodplain near Old Cheney Road. Potential for additional commercial development of the property fronting 56th Street exists, however, the open space along the west side of the channel is likely to remain. The portion of Beal Slough between 56th Street and Pine Lake Road is anchored at each end by public park land. The land between the parks is privately held.

- Multipurpose Potential - The Lincoln Lancaster County Comprehensive Plan identifies a future bike path extending from Old Cheney Road to Pine Lake Road. An extension of the sanitary trunk sewer is also identified.

- Water Quality - Parking lot and roof top runoff from adjoining industrial and commercial land use is the dominant characteristic effecting water quality and environmental issues in the downstream portion of the segment. Runoff from rural residential development and agricultural land is the dominant characteristic effecting water quality on the upstream portion of the segment. Extensive riparian vegetation is associated with the entire length of the segment. In 1997, a stream water quality monitoring location was established near 280+00. Water samples in this reach have been collected and analyzed but evaluation by the City is not complete.

Photograph 13. Looking upstream from Pine Lake Road at staff gage.

Photograph 14. Looking downstream from 70th Street.

Stream Segment Evaluation

Stream Segment 7

Stream Segment 7 includes the reaches between Pine Lake Road and 70th Street. Two private driveways and two railroad bridges cross the channel.

- Reach Stability - Comparative analysis of FIS and 1997 stream profiles reveals little channel degradation except near Station 400+00. Concrete rubble that has been placed at that location appears to have arrested the migration of severe headcuts downstream of each private driveway.
- Flood Hazard Potential - A rural residence is located in the floodplain between Pine Lake Road and the downstream BNSFRR bridge.
- Threats to Bridges & Utilities - The private driveway bridges are subject to frequent overtopping.
- Land Use and Ownership - The land is privately held on both sides of the stream for the entire length.
- Multipurpose Potential - The Lincoln Lancaster County Comprehensive Plan identifies a future bike path extending from Pine Lake Road to 70th Street. An extension of the sanitary trunk sewer is also identified.
- Water Quality - Runoff from rural residential development and agricultural land is the dominant characteristic effecting water quality of the segment. Extensive riparian vegetation is associated with the entire length of the segment.

Photograph 15, Looking at outlet of the 84th Street Box Culvert.

Stream Segment Evaluation

Stream Segment 8

Stream Segment 8 includes the reach between 70th Street and 84th Street. One private driveway crosses the channel and a private grade stabilization structure has been built near the middle of the reach.

- Reach Stability - The grade stabilization structure and associated lake located near Station 473+00 provides stream stabilization of the reach upstream of the facility. The 70th Street and 84th Street culverts provide control points at each end of the reach. The stream bed slope is comparatively steep and would be susceptible to head cutting if increased or prolonged runoff and scour are allowed to occur.
- Flood Hazard Potential - Rural acreages have been developed along the south side of the channel, but the homes and associated sanitary sewage lagoons appear to be located above the 100-year flood water surface profile.
- Threats to Bridges & Utilities - The private driveway near Station 443+00 is subject to periodic flooding. Sediment accumulated downstream of 84th Street reduces culvert capacity.
- Land Use and Ownership - The land is privately held on both sides of the stream for the entire length.
- Multipurpose Potential - Private ownership limits the potential for multipurpose use.
- Water Quality - Runoff from rural residential development and agricultural land is the dominant characteristic effecting water quality of the segment. Extensive riparian vegetation is associated with the entire length of the segment.

Photograph 16. Looking downstream at the reach below Tierra Drive.

Photograph 17. Looking at the box culvert inlet under Tierra Drive.

Stream Segment Evaluation

Stream Segment 9

Stream Segment 9 includes the reaches along Tierra Branch between the mouth at Beal Slough near 27th Street. Tierra Drive, Sequoia Drive, Old Cheney Road, and Jane Lane cross the channel.

- Reach Stability - The channel flowline is concrete-lined between the mouth at Beal Slough near 27th Street and the confluence with Tierra Branch South near 34th Street and Browning Street. This provides stream bed stability. Local scour occurs periodically behind the channel liner curb.
- Flood Hazard Potential - Many houses are subject to flooding from the 100-year storm due to proximity to the channel or constructing building openings below the 100-year water surface elevation.
- Threats to Bridges & Utilities - Head cutting at the mouth near Beal Slough has resulted in failure of 150 feet of channel liner. The remainder of the channel appears to be stable and currently poses no threat to utilities. The Tierra Drive bridge is undersized: construction of a replacement structure (completed in 1999 at a cost of $200,000) was funded through the storm sewer bond issue approved in 1997.
- Land Use and Ownership - Tierra Park at the downstream end of the segment is the only public property adjoining the channel.
- Multipurpose Potential - The existing park provides substantial multipurpose use. Lack of maintenance easements along the channel from Tierra Drive upstream to Old Cheney Road all but eliminates development of further multipurpose use along that portion of the stream segment. Construction of a bike path is planned from Old Cheney Road upstream to the existing path at the top of the segment.
- Water Quality - Runoff from residential and commercial land uses in the basin also effect water quality in this reach. Lack of vegetative overstory and the concrete channel liner constrain water quality issues.

Photograph 18. Looking downstream from Browning Street in Williamsburg.

Photograph 19. Looking upstream from Williamsburg Drive.

Stream Segment Evaluation

Stream Segment 10

Stream Segment 10 includes tributary reaches from the vicinity of 34th Street and Browning Street to the 3600 block of Pine Lake Road. Browning Street and Williamsburg Drive cross the channel. The Browning Street detention facility is located “on-line” and provides peak reduction for the 2- though 100-year storm, although the 100-year event does overtop the roadway.

- Reach Stability - The channel flowline is concrete-lined between the mouth near Browning Street and the sediment pond north of Pine Lake. This provides stream bed stability, although local scour occurs periodically behind the channel liner curb. A short segment of the channel between Pine Lake Road and the sediment pond does not have a concrete low flow liner. The stream bed slope is constrained by culverts at either end of this reach, supports riparian vegetation, and appears to be stable.

- Flood Hazard Potential - The water surface elevation of the detention pond and open channel for the 100-year flood was provided for the abutting lots and included in the subdivision covenants. No residential flooding along the channel or adjoining the detention facility is known to have occurred during the intense 1996 storm events.

- Threats to Bridges & Utilities - Erosion on upstream developments necessitated the dredging of accumulated sediment from the sediment pond at the upstream end of this segment.

- Land Use and Ownership - The park at the downstream end of the segment is the only public property. The remainder of the land along this segment is privately held.

- Multipurpose Potential - A bike path currently follows the channel from the confluence below Browning Street to the sediment pond near the upstream end of the segment.

- Water Quality - In the short term, ongoing construction upstream of this reach will continue to be a significant source of sediment, unless more stringent erosion and sediment controls are implemented. Runoff from residential land use in the basin effects water quality in this reach. Lack of vegetative overstory along the downstream portion of this segment and the concrete low flow liner constrain water quality issues.

Photograph 20. Looking downstream of 34th Street toward confluence with Segment 10 and Segment 9.

Photograph 21. Looking upstream from 40th Street.

Stream Segment Evaluation

Stream Segment 11

Stream Segment 11 includes tributary reaches from the vicinity of 34th Street and Browning Street to the 4700 block of Pine Lake Road. The channel is crossed by 34th Street, Faulkner Street, 40th Street, Cripple Creek Road, and Fir Hollow Lane. The 34th Street detention facility is located “on-line” and provides peak reduction for the 2- though 100-year storm, although flows greater than the 25-year event do overtop the roadway.

- Reach Stability - The channel flowline is concrete-lined between the confluence near Browning Street to 40th Street and unlined from 40th Street to Cripple Creek Road. The channel flowline is concrete-lined between Cripple Creek Road and Pine Lake Road. The concrete channel liner provides stream bed stability, although local scour occurs periodically behind the channel liner curb.

- Flood Hazard Potential - The water surface elevation of the detention pond and open channel for the 100-year flood was provided for the abutting lots and included in the Williamsburg Subdivision covenants. No residential flooding along the channel or adjoining the detention facility is known to have occurred during the intense 1996 storm events.

- Threats to Bridges & Utilities - Accelerated erosion from upstream development activities has filled all but the upper 4 feet of the 34th Street detention pond permanent pool volume.

- Land Use and Ownership - The park at the downstream end of the segment is the only public property. The remainder of the land along this segment is privately held. The outlot along the channel between 40th Street and Pine Lake Road is not publicly held.

- Multipurpose Potential - The multipurpose use potential for this segment seems limited to the open space in the outlot through which the channel flows between 40th Street and Pine Lake Road.

- Water Quality - In the short term, ongoing construction upstream of this reach will continue to be a significant source of sediment unless more stringent erosion and sediment controls are implemented. Runoff from residential land use in the basin effects water quality in this reach. Lack of vegetative overstory along the downstream portion of this segment and the concrete low flow liner constrain water quality issues. Extensive riparian vegetation has become established between 40th street and Cripple Creek Road.


Photograph 22. Looking west at King Arthur Court open space.


Photograph 23. Looking south at Dakota sandstone outcrop.

Stream Segment Evaluation

Stream Segment 12

Stream Segment 12 includes the tributary reach from Beal Slough along the Southwood and Lincoln Industrial Park South developments to Old Cheney Road. The channel is crossed by the Rock Island Hiker/Biker Trail near Old Cheney Road.

- Reach Stability- Head cutting has occurred near the confluence but an outcropping of Dakota sandstone provides a grade check about 1000 feet from the mouth. Steep banks along the residential development are generally stable due to home owner efforts.
- Flood Hazard - Potential The old railroad embankment temporarily impounds runoff during heavy rainfall events resulting in localized flooding of open space and recreational facilities. FEMA Floodplain limits have not been delineated on this tributary.
- Threats to Bridges and Utilities A railroad spur runs parallel to the channel from Beal Slough to the Rock Island Hiker/Biker Path. The roadbed serves to stabilize the west bank of the channel. Underground utilities along the top of the east bank rely on continued bank stabilization efforts by adjacent homeowners.
- Land use and ownership Verify with Mark Stark that City Parks and Recreation Department has ownership of the railroad spur row for a connecting bike path.
- Multipurpose Potential The channel corridor has a high potential for development of multipurpose activities resulting from the public ownership of the adjacent bike path
- Water Quality Parking lot and roof top runoff from adjoining industrial and commercial land use and runoff from adjoining residential land use are likely the determinants of water quality of this intermittent stream. Water quality samples have been collected from the adjoining subbasin.

Photograph 24. Looking southwest at terminus of concrete low flow liner.

Photograph 25. Looking upstream near Quail Ridge Road at low flow liner.

Stream Segment Evaluation

Stream Segment 13

Stream Segment 13 includes the reach from Beal Slough near the 5200 block east to 56th Street and Elkcrest Drive.

- Reach Stability - The channel has a concrete low flow liner for its entire length. Several locations in the lower portion of the reach are severely eroded behind the liner.
- Flood Hazard Potential - FEMA Floodplain limits have not been delineated on this tributary. Adjacent buildings appear to be elevated above the 100-year flood.
- Threats to Bridges and Utilities - Erosion behind the concrete channel liner threatens its integrity. Repairs should be completed before the liner fails.
- Land use and Ownership - The channel is contained in the open space provided during design of the adjoining residential and multifamily developments. The homeowners association(s) is responsible for maintenance of the channel.
- Multipurpose Potential - Open space on either side of the channel encourages recreational and aesthetic uses of this reach.
- Water Quality - Runoff from residential and multifamily land uses in the basin likely effect the water quality this reach. Increased water temperature are also likely due to the lack of tree canopy overstory and the thermal influence of the concrete liner.

Photograph 26. Looking north at riparian vegetation along tributary channel near BNSFRR.

Photograph 27. Looking northerly at upper grade stabilization pond.

Stream Segment Evaluation

Stream Segment 14

Stream Segment 14 includes the reach from Beal slough near the Trade Center business park northeast ward to Highway 2. The upper part of the basin is developed into large acreages. The lower part of the basin is currently undeveloped but is commercial land use. The channel reach is crossed by The BNSF railroad near Beal Slough and bound at the top by Highway 2. Two grade stabilization structure have been built downstream of the highway.

- Reach Stability - The grade stabilization structure appear to be performing adequately. Head cutting is occurring neat the confluence with Beal Slough.

- Flood Hazard Potential - FEMA Floodplain limits have not been delineated on this tributary. The flood prone area is wide near the railroad and includes the grade stabilization structures. There are no structures immediately adjoining the channel.

- Threats to Bridges and Utilities - A sanitary sewer line is located in the flood prone area, the manholes may be subjected to periodic inundation.

- Land use and Ownership - Adjoining property is privately held.

- Multipurpose Potential - Multipurpose use potential should be encouraged as part of open space when property is developed along this reach.

- Water Quality - Runoff from low density residential development and agricultural land is the dominant characteristic effecting water quality of the segment. Riparian vegetation is found along most of the reach.

Photograph 28. Looking downstream from Pine Lake at riparian vegetation along channel.

Photograph 29. Looking upstream from 70th Street at channel and riparian vegetation.

Stream Segment Evaluation

Stream Segment 15

Stream Segment 15 includes the reach from Beal Slough to Pine Lake Development. Pine Lake Road, 70th Street and Highway 2 cross the channel.

- Reach Stability — Box culverts at each roadway crossing provide control points in the middle of the reach. Pine Lake Dam controls frequently occurring storms enhancing stream stability.
- Flood Hazard Potential — FEMA Floodplain limits have not been delineated on this tributary. Rural acreages have been developed on the north and south side of Pine Lake Road but appear to be located above the flood prone areas.
- Threats to Bridges and Utilities — Pine Lake Road frequently floods west of 70th Street. The 70th Street box culvert and Pine Lake Road box culvert will be replaced as part the 70th Street widening project.
- Land use and ownership — The land is privately held on both sides of the stream for the entire length.
- Multipurpose Potential — Private ownership limits the potential for multipurpose use.
- Water Quality — Runoff from residential and agricultural land use is the dominant characteristic effecting water quality of the segment. Extensive riparian vegetation is associated with the entire length.

Photograph 30. Looking north from Yankee Hill Road at regraded channel along 70th Street.

Photograph 31. Looking southeast from 70th Street at riparian vegetation along channel.

Stream Segment Evaluation

Stream Segment 16

Stream segment 16 includes the reach from Beal Slough immediately upstream of 70th Street, parallel with 70th Street, under Yankee Hill Road up to a grade stabilization structure.

- Reach Stability — The lower portion of the channel was regraded as part of the 70th Street realignment project. The Yankee Hill Road culvert provides a control point near the middle of the reach.
- Flood Hazard Potential — A farmstead in the southwest corner of 70th Street and Yankee Hill Road and the intersection may be exposed to flood hazard during heavy rainfall events.
- Threats to Bridges and Utilities — The box culvert under Yankee Hill Road appears to have sufficient capacity to pass the at least the 50-year flood with out overtopping the roadway.
- Land use and ownership — The land is privately held on both sides of the stream for the entire length of this reach.
- Multipurpose Potential — Private ownership limits the potential for multipurpose use.
- Water Quality — Runoff from residential and agricultural land is the dominate characteristic effecting water quality of the segment. Extensive riparian vegetation is associated with the upper half of the segment.

EVALUATION SUMMARY

STORMWATER QUALITY

Urban Runoff

Evaluation of water quality samples collected by the City at five Lincoln sites indicates that stormwater quality within the City appears to be relatively good compared to national runoff quality data. The five monitoring sites are located in basins selected by the Public Works Department to collect runoff data from typical watersheds. Two sites are in predominately residential watersheds, two are in watersheds with predominately industrial land use, and one is in a predominantly commercial watershed. The commercial site and one of the residential sites are located in Beal Slough. There does not appear to be any trend indicating an improvement or impairment of stormwater quality. Available data indicates the parameters most frequently observed at elevated concentrations include TSS, COD, oil and grease, and nutrients. The high concentrations observed for several parameters in 1993, may in part, be explained by the heavy rains and local flooding that occurred at that time in the region. See Appendix C - Comparison of Lincoln Stormwater Quality with National Urban and Denver Metropolitan Data.

Erosion and Sedimentation in Streams

In 1997, storm runoff samples from eight locations along Beal Slough were evaluated by the City for Oil and Grease, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). National average values for TDS were not available from the National Urban Runoff Pollutants (NURP) study. Values for Oil and Grease found in stream flows in Beal Slough were below the national average, but values for TSS found on stream flows in Beal Slough are greater than the national average. TSS is indicative of the sediment load in streams. Sources for suspended solids include tire rubber and winter sanding operations, but the largest source is eroded soil. Based on field observations, stream bank and bed erosion contributes a substantial amount of suspended solids in Beal Slough. Improving bed and bank stability would reduce the amount of soil eroding and entering the stream. Reducing the amount of soil entering the stream would improve the quality of water conveyed downstream by Beal Slough.

The Beal Slough channel continues to grow wider and deeper as the watershed urbanizes. As stormwater rushes through the channel, it takes with it soil from along the banks which adds to the suspended solids problem. This erosion has led to a dramatic increase in channel width and depth that is evident when comparing aerial photographs from 1940 to those flown in 1997. In 1940, the channel widths in the lower reaches of Beal Slough were between 6 and 9 feet compared to widths between 45 and 65 feet wide today.

It is estimated that approximately 200,000 cubic yards of soil have eroded from the Beal Slough channel reach between Salt Creek and Old Cheney Road in the past 25 years -- the equivalent of 12,000 dump truck loads. This information was based on a comparison of channel cross-sections surveyed for the 1978 FIS with surveys conducted at the same locations in 1997, see Figure I-12. The comparison revealed the following:

- Between Salt Creek and Highway 77, an average of two dump truck loads of soil has eroded from each foot of channel.
- Between 27th Street and Highway 2 near 38th Street nearly 10 cubic yards of soil has eroded from each foot of channel.

Evaluation of original and current ground lines at a sanitary sewer crossing installed in 1966 downstream of Highway 77, near the Penitentiary, indicates substantial channel degradation. Originally there was 6 feet of cover above the pipe. In January 1997 the Public Works and Utilities Department spent $100,000 to repair the sewer crossing because 20 feet of pipe was exposed and the streambed was 2 feet below the sewer.

The deeply incised channel in the lower and middle reaches of Beal Slough today stems from changes to the Beal Slough channel alignment made in the 1930s as a result of Salt Creek channel degradation induced by channel straightening, and increased flow rates from urbanization since the mid-1960s. Channel banks must be stabilized and flow rates controlled in the upper reaches of Beal Slough or the banks will resemble the deeply incised channel found in the lower and middle reaches of Beal Slough.

Erosion and Sediment from Land Disturbance Activities

Construction sites in the basin are another significant source of erosion and sediment. Even though management of construction site erosion and sediment is currently required by City, State, and Federal law, erosion and transfer of sediment and related pollution to downstream properties and receiving waters is largely uncontrolled. Eroded material also carries other pollutants which attach to soil particles. This stormwater issue can best be addressed through implementation of city and NRD standards outlined in the Lincoln Stormwater Drainage Criteria Manual.

STORMWATER QUANTITY

Localized Flooding

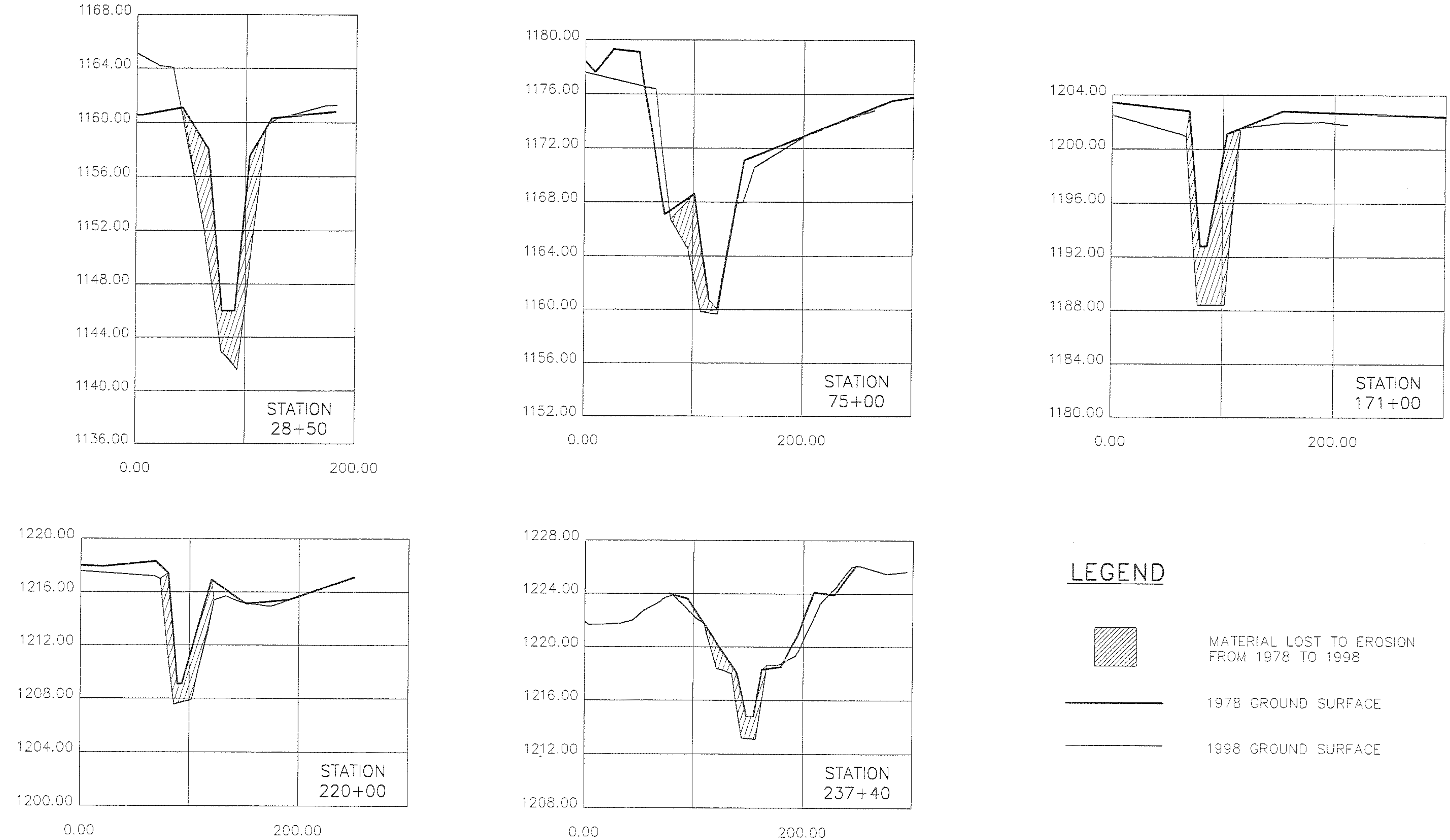
Localized flooding problems within the basin are mostly due to increased runoff from urbanization that causes damage because overflow routes to channels and streams are inadequate in capacity. Planning, implementing and protecting major storm overflow routes can prevent a majority of future localized flooding problems in new developments. The Lincoln Stormwater Advisory Committee recommended changes to stormwater policies and ordinances to require determination of overland flow routes through new developments and preservation of those routes with easements if they are not along public right-of-way. Improved public awareness of stormwater issues will also be beneficial.

Flooding Along Streams and Channels

Beal Slough basin was approximately 40% urbanized in 1978, today the urbanized area is nearly double the size it was then. Peak rates of flow along Beal Slough are 30% to 80% greater than FIS values based on 1978 conditions. The growth in peak flow rates results in more frequent bridge and channel overtopping. Overloading of these stormwater facilities necessitates premature replacement or augmentation with additional capacity. Enforcement of regulations for development in the FEMA 100-year flood plain has prevented flood damage to buildings constructed along Beal Slough after 1978, but development has occurred along tributaries to Beal Slough that were not included in the FEMA 100-year flood plain. Many homes and businesses constructed along tributary channels are exposed to flood hazards. Refer to Table I-13, 100-year Peak Flow Rate Comparision. Refer to Table I-10, 100-year

Based on hydrology and hydraulics analyses performed for this Master Plan, flood prone areas along tributaries to Beal Slough have been mapped and are shown on Figures SG1-FP through SG16-FP. Any future development along the tributaries should be done in a manner to avoid encroachment of and damage from these flood hazards.

Measures to reduce 2-year flow rates to historic values in the mainstem channel downstream of developed areas and to preserve existing 2-year flow rates in the mainstem downstream of undeveloped areas would reduce the erosive forces improving stability of the channel bed and banks.



DRAWN BY: JJM
DATE: JUNE 1999
REVISIONS:

BEAL SLOUGH MASTER PLAN

LINCOLN, NEBRASKA

CHANNEL CROSS-SECTION COMPARISON BETWEEN FIS 1978 AND 1998

FIGURE I-12

6/8/1999 8:57 P.M. FILE: F:\Projects\960280\dwg\jssec.dwg SCALE: 100