Section 3
Hydrologic Model Development

3.1 Introduction

The Hydrologic Investigation presents the methodology used to develop peak runoff rates for sub-basins within the City of Lincoln, Nebraska's (the City) future growth limits. For the Haines Branch Watershed, the City's future growth limits were used to define the outer boundary of the hydrologic study area. The runoff rates developed are intended to provide developers with the pre-development flowrates. This section provides a brief description of the basin, the methodology used to determine the peak flowrate for each sub-basin, followed by the model results. The methodology section also presents the process used for basin delineation, the design rainfall and the determination of rainfall excess (runoff).

This section also presents the methodology and findings of a culvert analysis for selected culverts located within the Watershed. More information on the Hydrologic Model and culvert analysis is found in Appendix C.

3.2 Methodology

3.2.1 Sub-basin Delineation

The Haines Branch Watershed, to the bounds of the future growth limits, was delineated into 9 sub-basins with an average area of 92.1 acres. A map showing the sub-basin boundaries is shown in Figure 3-1. The sub-basin delineation was performed using ArcView, HEC-GeoHMS, and the digital elevation model (DEM) provided by the City. The HEC-GeoHMS tool is an extension within ArcView and uses the DEM to delineate sub-basins and to determine the overland flow path for each sub-basin.

Using the HEC-GeoHMS tool, the approximate locations for sub-basin outlets such as stream crossings, tributaries, and major lakes/ ponds were located using ArcView and available GIS data. The HEC-GeoHMS tool uses these points to automatically delineate the sub-basin boundaries based on the DEM. The automated process was then checked against contours and drainage structure locations.

Sub-basins within the Haines Branch Watershed were given a unique alphanumeric name with the format HBBBB. "HB" is the two letter code for the Haines Branch Watershed. "BBB" is a three-digit sub-basin number.

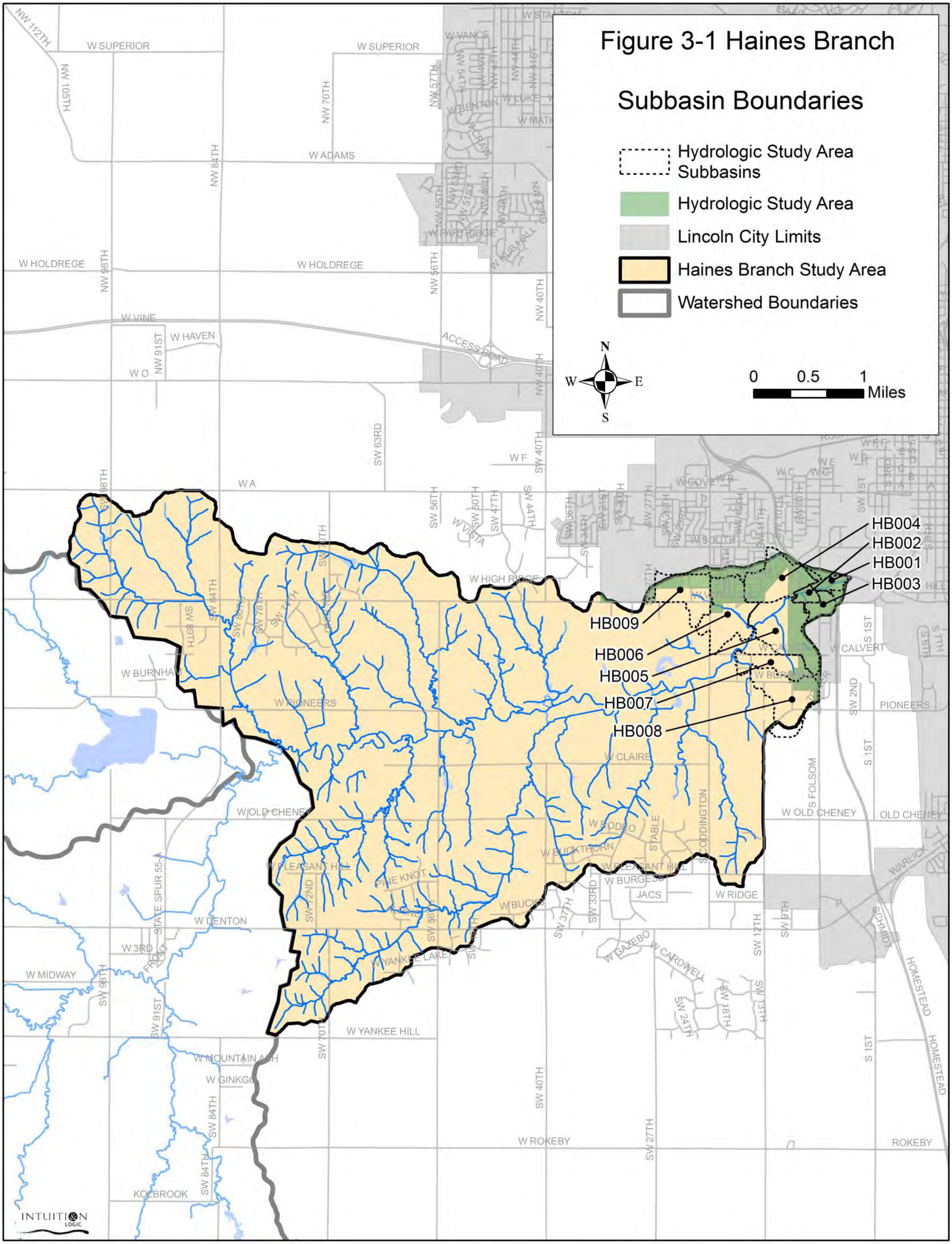
Figure 3-1 Haines Branch
Subbasin Boundaries
Hydrologic Study Area Subbasins
Hydrologic Study Area
Lincoln City Limits
Haines Branch Study Area
Watershed Boundaries
N
W
E
S
0
0.5
1
Miles
HB004
HB002
HB001
HB003
HB009
HB006
HB005
HB007
HB008
W SUPERIOR
W ADAMS
W HOLDREGE
W VINE
W HAVEN
W O
ACCESS ROAD
W A
W F
W HIGH RIDGE
W BURNHAM
W PIONEERS
W CALVERT
PIONEERS
W CLAIRE
W OLD CHENEY
OLD CHENEY
W RODEO
W BUCKTHORN
W PLEASANT HILL
W BURGESS
JACS
W RIDGE
PINE KNOT
W DENTON
W 3RD
W MIDWAY
W YANKEE LAKE
W YANKEE HILL
W MOUNTAIN ASH
W GINKGO
W ROKEBY
ROKEBY
KOLBROOK
W GAZEBO
W CARDWELL
WARLICK
SCHMIDT
HOMESTEAD
STATE SPUR 55-A
FRONT
S FOLSOM
S CODDINGTON
STABLE
NW 112TH
NW 105TH
NW 98TH
NW 84TH
NW 70TH
NW 56TH
NW 40TH
SW 63RD
SW 56TH
SW 40TH
SW 27TH
SW 12TH
SW 9TH
SW 1ST
S 1ST
SW 2ND
SW 98TH
SW 91ST
SW 84TH
SW 70TH
SW 72ND
SW 33RD
SW 37TH
SW 24TH
SW 18TH
SW 13TH
INTUITION LOGIC

3.2.2 Rainfall

The SCS Type II storm distribution was used to develop the 24-hr events of the 2-, 5-, 10-, 25-, 50-, 100-, and 500-yr storm events. Rainfall depths corresponding to these return periods were taken from the City's Drainage Criteria Manual (Rev May 10, 2004 edition) and are listed in Table 3.1 below. The 500 year rainfall depth is interpolated.

Table 3.1 Rainfall Depths

Return Period	Depth (in)
2-yr	3.00
5-yr	3.93
10-yr	4.69
25-yr	5.37
50-yr	6.00
100-yr	6.68
500-yr	8.17

3.2.3 Runoff Volume

The SCS Curve Number Loss method was used to calculate the volume of the runoff resulting from the corresponding design storms. The major factors that determine the runoff curve number (CN) are the hydrologic soil group, land cover type, and antecedent moisture condition.

The composite curve number for each basin was calculated using digitized maps of the existing land use and hydrologic soil group. The land use information describing the vegetation and use (agricultural, urban, etc.) of the Watershed was obtained from the City and is displayed in Figure 3-2. The Soil Survey Geographic (SSURGO) soil data was obtained from the Natural Resources Conservation Service (NRCS) and classifies the hydrologic soil groups found within the Watershed. The soil layer is displayed in Figure 3-3. Overlaying the land use and soil group information resulted in areas that represented a specific combination of one land use and one soil group. Using this combination and assuming a normal antecedent moisture condition (AMC II) a CN value was assigned using tables published by the NRCS. A lookup table defining the CNs used for each land use/soil group combination is displayed in Table 3.2. After assigning the CN values to each combination, the CN for each basin was calculated using an area-weighted average for each basin.

The SCS Method uses an initial abstraction value and composite curve number to estimate runoff volumes from each sub-basin for a particular design rainfall event.

Initial abstraction is defined as losses from rainfall before runoff begins. Initial abstraction is a function of the composite CN and is commonly calculated using Equation 3.1.

$$I_a = 0.2S \qquad \text{(Eq.3.1)}$$

Where the maximum retention, S is computed as follows:

$$S = \frac{1000}{CN} - 10 \qquad \text{(Eq. 3.2)}$$

Table 3.2 Lookup table used to define the curve number for each land use/soil group combination

Land Use Description	Details	Hydrologic Soil Group		
		B	C	D
Commercial and Business Areas	85% IMP	92	94	95
Industrial Areas	72% IMP	88	91	93
Farmsteads		74	82	86
Lakes		100	100	100
Parking lots, Roofs, and other impervious areas	Paved Streets with Curbs and Inlets	98	98	98
	Paved with open ditches	89	92	93
	Gravel	85	89	91
Parks, Golf Courses, and other Open Areas	Fair	69	79	84
	Good	61	74	80
Soil Mining	Treated as Newly Graded Area	86	91	94
Brush	Poor	67	77	83
	Good	48	65	73
Row Crops, Straight	Good	78	85	89
Schools	38% IMP	75	83	87
Wetlands		98	98	98
Woods	Fair	60	73	79
	Good	55	70	77
Residential	1/8 acre-65% IMP	85	90	92
	1/4 acre-38% IMP	75	83	87
	1/3 acre-30% IMP	72	81	86
	1/2 acre-25% IMP	70	80	85
	1 acre-20% IMP	68	79	84
	2 acre-12% IMP	65	77	82

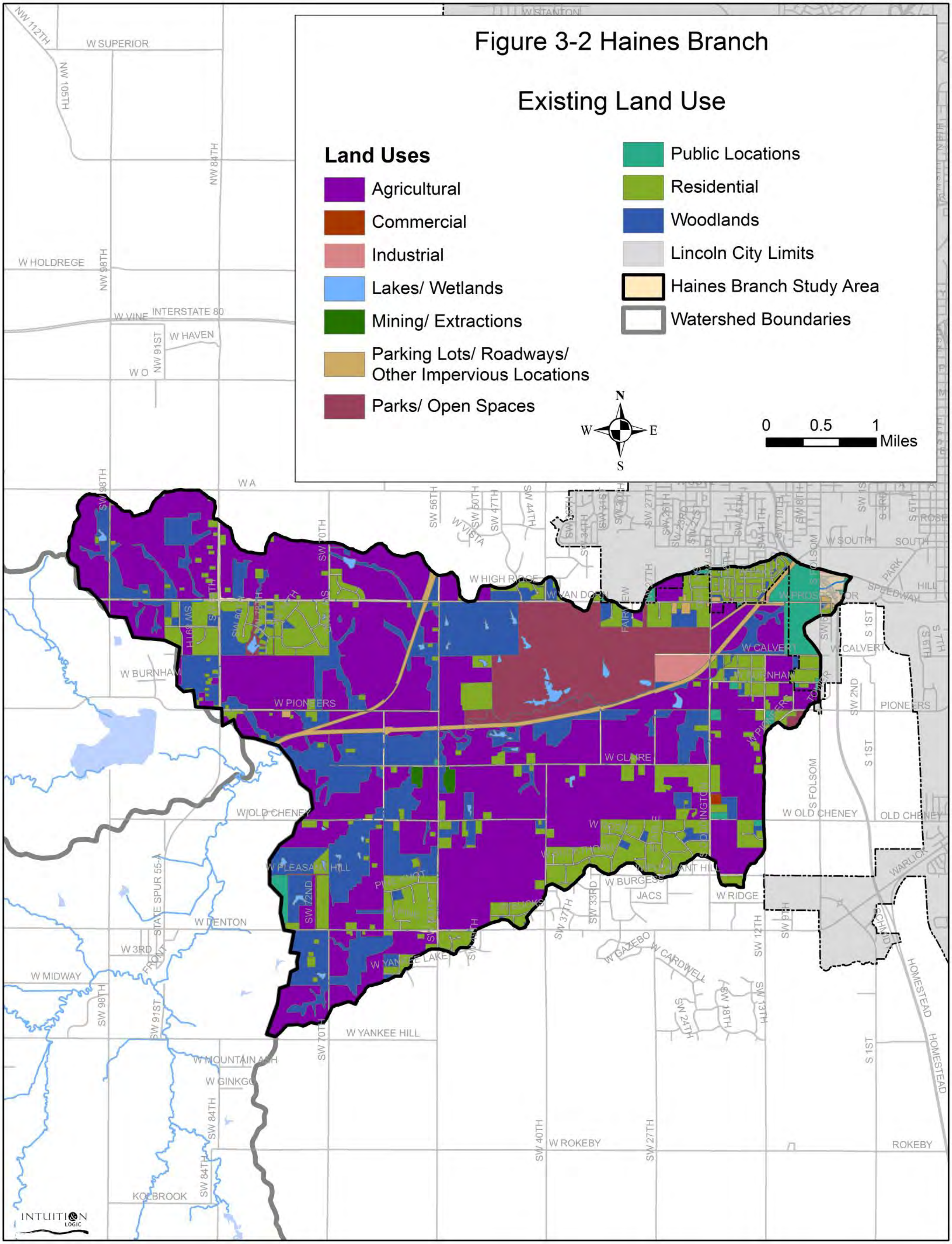

Figure 3-2 Haines Branch

Existing Land Use

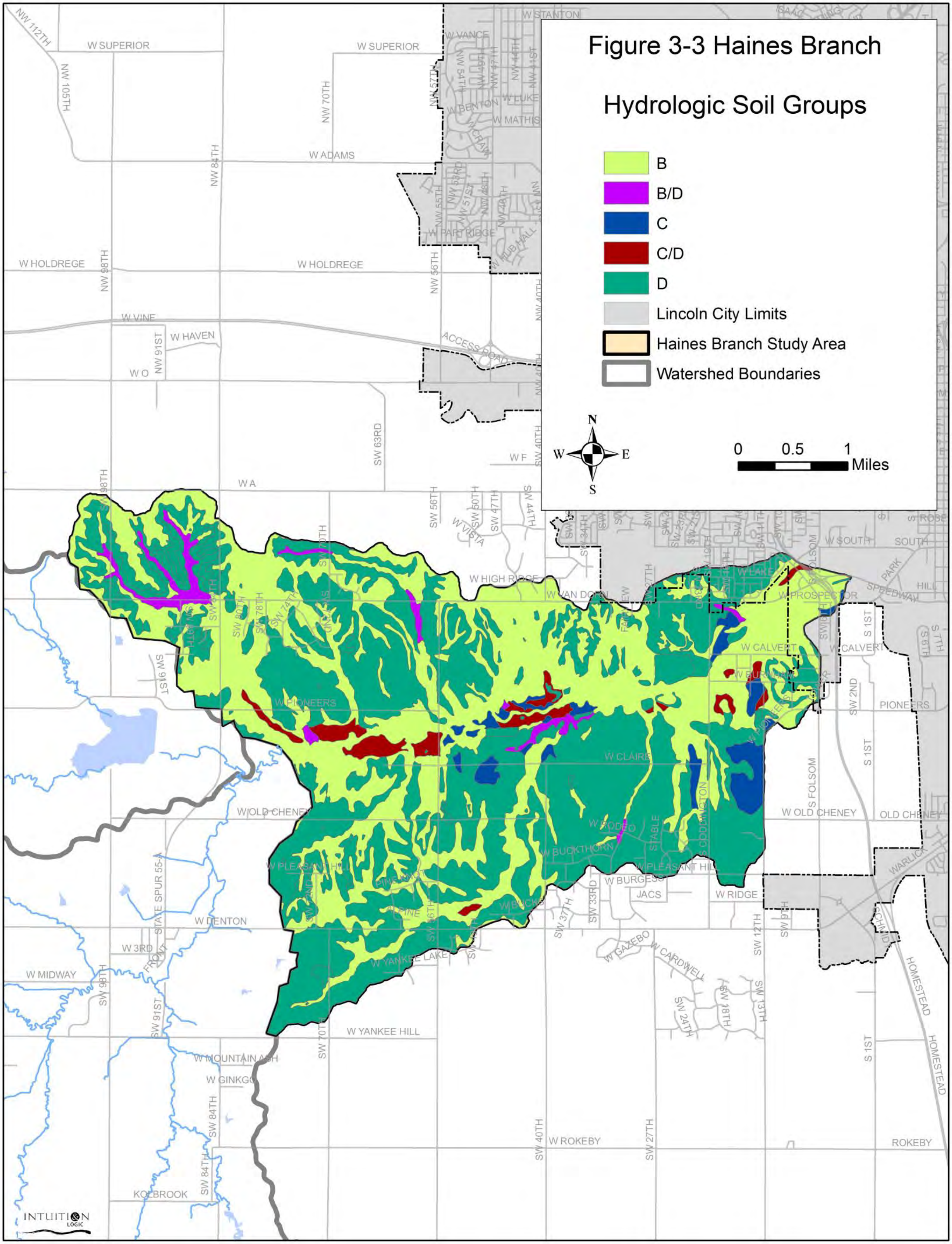
Figure 3-3 Haines Branch
Hydrologic Soil Groups
B
B/D
C
C/D
D
Lincoln City Limits
Haines Branch Study Area
Watershed Boundaries
N
S
E
W
0
0.5
1
Miles
INTUITION LOGIC

3.2.4 Runoff Hydrographs

The SCS Dimensionless Unit Hydrograph method was employed within HMS in order to distribute the runoff volume for each basin. This method requires the SCS lag time to be calculated. The lag time for each basin was calculated using the Curve Number Lag Method described in "National Engineering Handbook, Section 4" (Natural resources Conservation Service, 2001). This calculation was performed using an automated process available within HEC-GeoHMS. To calculate the lag time, HEC-GeoHMS employs a DEM to estimate the hydraulic length and average land slope of each basin. The lag time for each catchment was calculated using the following equation:

$$L = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}} \qquad \text{(Eq. 3.3)}$$

in which L equals the lag time in hours, l is defined as the hydraulic length of the catchment in feet, Y represents the average Watershed slope in percent, and S represents maximum retention and can be determined using Equation 3.2, defined previously.

HMS then uses the lag time parameter to internally calculate the time of concentration (t_c) for each basin using the equation:

$$t_c = \frac{5}{3}L \qquad \text{(Eq. 3.4)}$$

The time of concentration represents the time it takes for a drop of water to travel from the hydraulically most remote point of the catchment to the outlet.

3.3 Modeling Results

Peak runoff rates were developed for each sub-basin within the Haines Branch hydrologic study area. Table 3.3 presents the results for each sub-basin. Additional Hydrologic information can be found in Appendix C.

Table 3.3 Peak Flow Rates

	Peak flow Rate (cfs) with respect to Return Frequency (yr)						
Basin Name	**Q, 2yr (cfs)**	**Q, 5yr (cfs)**	**Q, 10yr (cfs)**	**Q, 25yr (cfs)**	**Q, 50yr (cfs)**	**Q, 100yr (cfs)**	**Q, 500yr (cfs)**
HB001	77.7	105.6	128.2	148.3	166.9	186.8	230.4
HB002	35.6	52.4	66.8	79.7	91.7	104.6	132.7
HB003	74.0	103.3	127.0	148.2	167.7	188.7	234.5
HB004	150.2	226.0	289.4	346.5	399.6	456.8	582.1
HB005	131.4	206.7	270.8	329.2	383.7	443.0	573.1
HB006	167.3	254.9	328.3	394.7	456.4	523.1	669.2
HB007	46.4	76.1	101.8	125.5	148.0	172.7	227.3
HB008	60.8	99.2	132.5	163.2	192.0	223.4	293.0
HB009	121.5	186.5	241.1	290.6	336.7	386.5	495.7

3.4 Culvert Analysis

The Nebraska Department of Natural Resources has prepared hydrologic and hydraulic data for the Haines Branch Study Area. This information was used to delineate the Zone A Special Flood Areas. The Zone A areas illustrate a floodplain boundary based on normal flow depths, but do not provide corresponding water surface elevations and do not consider the effect of culverts.

Many older culverts in the Watershed were designed to convey a 10 to 25 year storm event and possibly overtop the roadway during larger storm events. The Culvert Analysis is intended to evaluate culverts where sufficient flow rates and culvert as-built information is available to determine if the roadway is overtopped during a 100 year, 24 hour storm event due to the presence of the culvert.

3.4.1 Flowrates

The analysis is based on available discharge and depth data from the Nebraska Department of Natural Resources. NDNR developed flowrate and depth estimates for delineating the FEMA Zone A special flood hazard areas in the tributaries. The available data was provided in a GIS shape file for use in the Culvert Analysis. The data consists of the 1% annual occurrence discharge, the flood depth, the flood elevation, and the cross section location where each flood depth and elevation were determined.

3.4.2 Culvert Identification

The culvert identification process consisted of identifying all stream crossing locations, intersecting with the limits of DNR data, estimating the roadway elevation from GIS contours, and estimating the local flood elevation from the DNR depth data. A total of 33 stream crossing locations were identified in the Haines Branch Watershed. Of those, there were 11 crossing locations that had sufficient hydrologic data for the analysis.

The evaluation list of culverts was further refined by identifying where the existing flood depth was below the roadway elevation, i.e. under normal channel flow conditions the roadway is not overtopped. Locations where the normal channel depth is greater than the roadway would require more extensive road and culvert modifications to eliminate roadway overtopping. The refinement led to 7 culvert crossing locations that were sent to the County to obtain As-Built records for further analysis (no survey data was obtained for this analysis).

Of the 7 culvert crossings, 2 crossings have As-Built records. For more information on culvert crossing locations, refer to Appendix C.

3.4.3 HY-8 Analysis

The County provided As-Builts for culvert ID number O125 and N129. The As-Builts contained sufficient data for detailed analysis of the 2 crossings. The culverts were modeled in HY-8 to determine if the current culvert configuration causes the roadway to overtop for the 1% annual occurrence discharge.

3.4.4 Results

Table 3.4 summarizes the two known culvert locations where the existing culvert capacity is insufficient to convey the 1% annual occurrence discharge without overtopping the roadway.

Table 3.4 Culvert Overtopping Analysis

County ID	Description	Q100 year flow (cfs)	Normal Depth Elev (ft)	Headwater Elev (ft)	Roadway Elev (ft)	Overtopping Depth (ft)
O125	Triple 10’x8’x45’ CBC	3950	1181.5	1195.0	1192.9	2.12
N129	Single 8’x8’x56’ CBC	3950	88.1	106.8	99.9	6.89

Figure 3-4 illustrates the location of crossing O125 and N129.

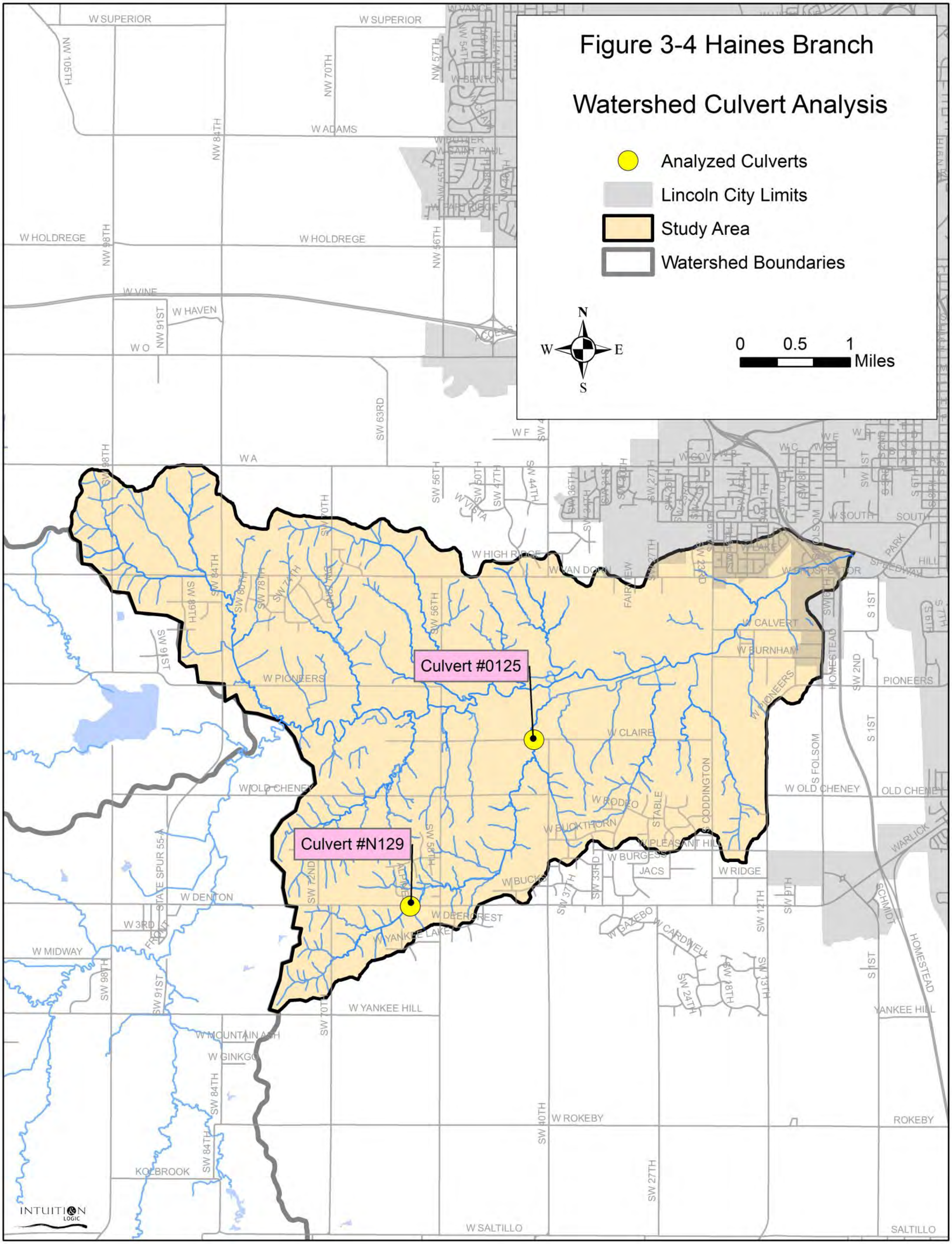
Figure 3-4 Haines Branch
Watershed Culvert Analysis
Analyzed Culverts
Lincoln City Limits
Study Area
Watershed Boundaries
N
W
E
S
0
0.5
1
Miles
Culvert #0125
Culvert #N129
W SUPERIOR
W ADAMS
W HOLDREGE
W VINE
W HAVEN
W O
W A
W F
W HIGH RIDGE
W VAN DORN
W CALVERT
W BURNHAM
W PIONEERS
W CLAIRE
W OLD CHENEY
W RODEO
W BUCKTHORN
W PLEASANT HILL
W BURGESS
JACS
W RIDGE
W DENTON
W DEERCREST
W YANKEE LAKE
W 3RD
W MIDWAY
W YANKEE HILL
W MOUNTAIN ASH
W GINKGO
W ROKEBY
KOLBROOK
W SALTILLO
SALTILLO
ROKEBY
YANKEE HILL
OLD CHENEY
PIONEERS
W SOUTH
SOUTH
HOMESTEAD
SCHMIDT
WARLICK
W GAZEBO
W CARDWELL
CODDINGTON
STABLE
FAIRVIEW
STATE SPUR 55-A
S FOLSOM
NW 105TH
NW 84TH
NW 70TH
NW 98TH
NW 91ST
NW 56TH
SW 98TH
SW 84TH
SW 91ST
SW 70TH
SW 72ND
SW 63RD
SW 56TH
SW 44TH
SW 40TH
SW 27TH
SW 12TH
S 1ST
S 2ND
INTUITION LOGIC