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 Middle Creek 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 Middle Creek Watershed, to the bounds of the future growth limits, was delineated into 39 sub-basins with an average area of 107.2 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 Middle Creek Watershed were given a unique alphanumeric name with the format MCBBB. "MC" is the two letter code for the Middle Creek watershed. "BBB" is a three-digit sub-basin number.

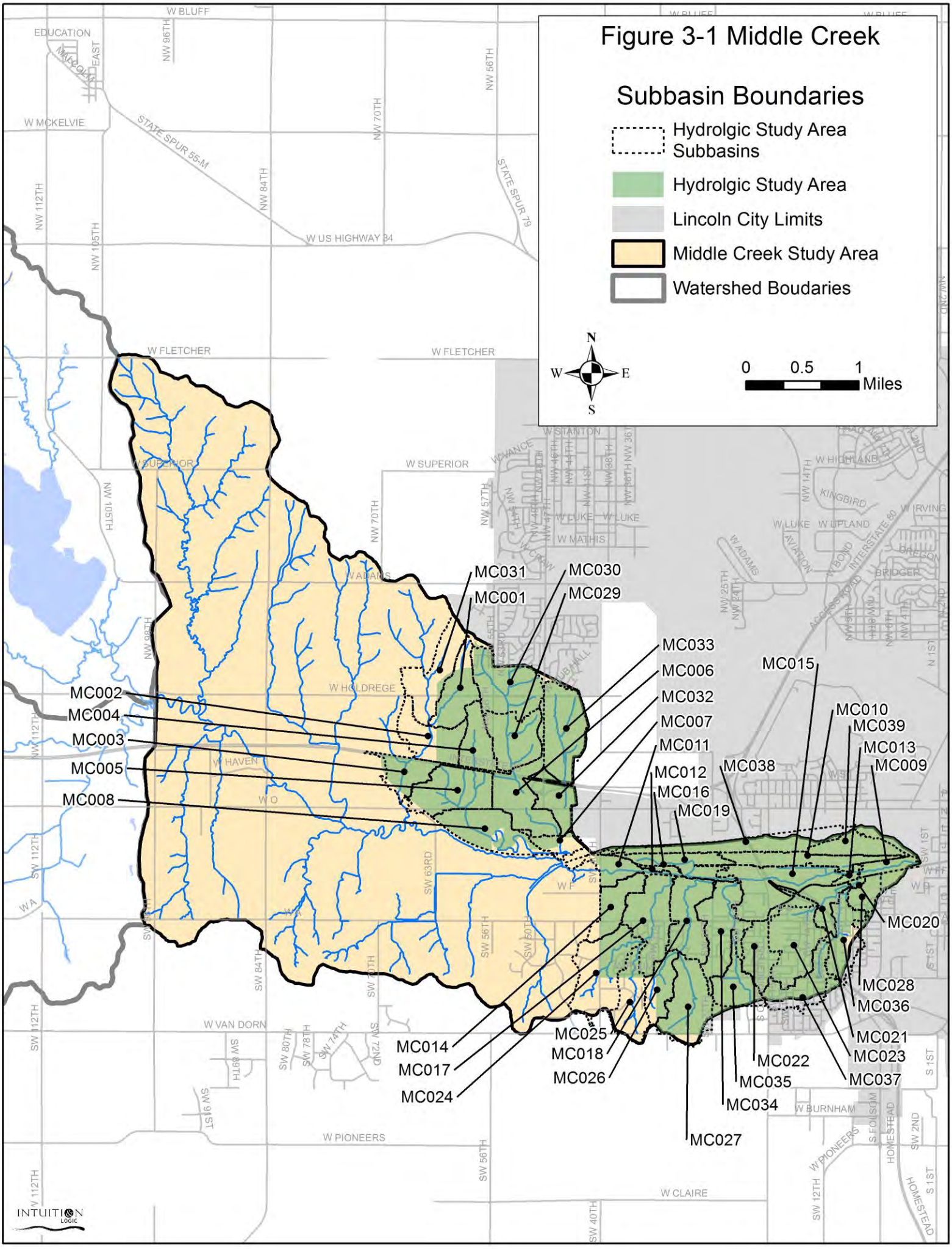
Figure 3-1 Middle Creek
Subbasin Boundaries
Hydrolgic Study Area Subbasins
Hydrolgic Study Area
Lincoln City Limits
Middle Creek Study Area
Watershed Boudaries
N
W
E
S
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0.5
1
Miles
MC001
MC002
MC003
MC004
MC005
MC006
MC007
MC008
MC009
MC010
MC011
MC012
MC013
MC014
MC015
MC016
MC017
MC018
MC019
MC020
MC021
MC022
MC023
MC024
MC025
MC026
MC027
MC028
MC029
MC030
MC031
MC032
MC033
MC034
MC035
MC036
MC037
MC038
MC039
W BLUFF
W MCKELVIE
STATE SPUR 55-M
W US HIGHWAY 34
STATE SPUR 79
W FLETCHER
W SUPERIOR
W ADAMS
W HOLDREGE
W HAVEN
W VAN DORN
W PIONEERS
W CLAIRE
W BURNHAM
W STANTON
W LUKE
W MATHIS
W HIGHLAND
W IRVING
W UPLAND
KINGBIRD
INTERSTATE 80
BRIDGEPORT
ACCESS ROAD
HOMESTEAD
NW 96TH
NW 56TH
NW 70TH
NW 84TH
NW 112TH
NW 105TH
NW 57TH
SW 63RD
SW 56TH
SW 84TH
SW 112TH
SW 91ST
SW 80TH
SW 78TH
SW 74TH
SW 72ND
SW 40TH
SW 12TH
SW 2ND
S 1ST
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

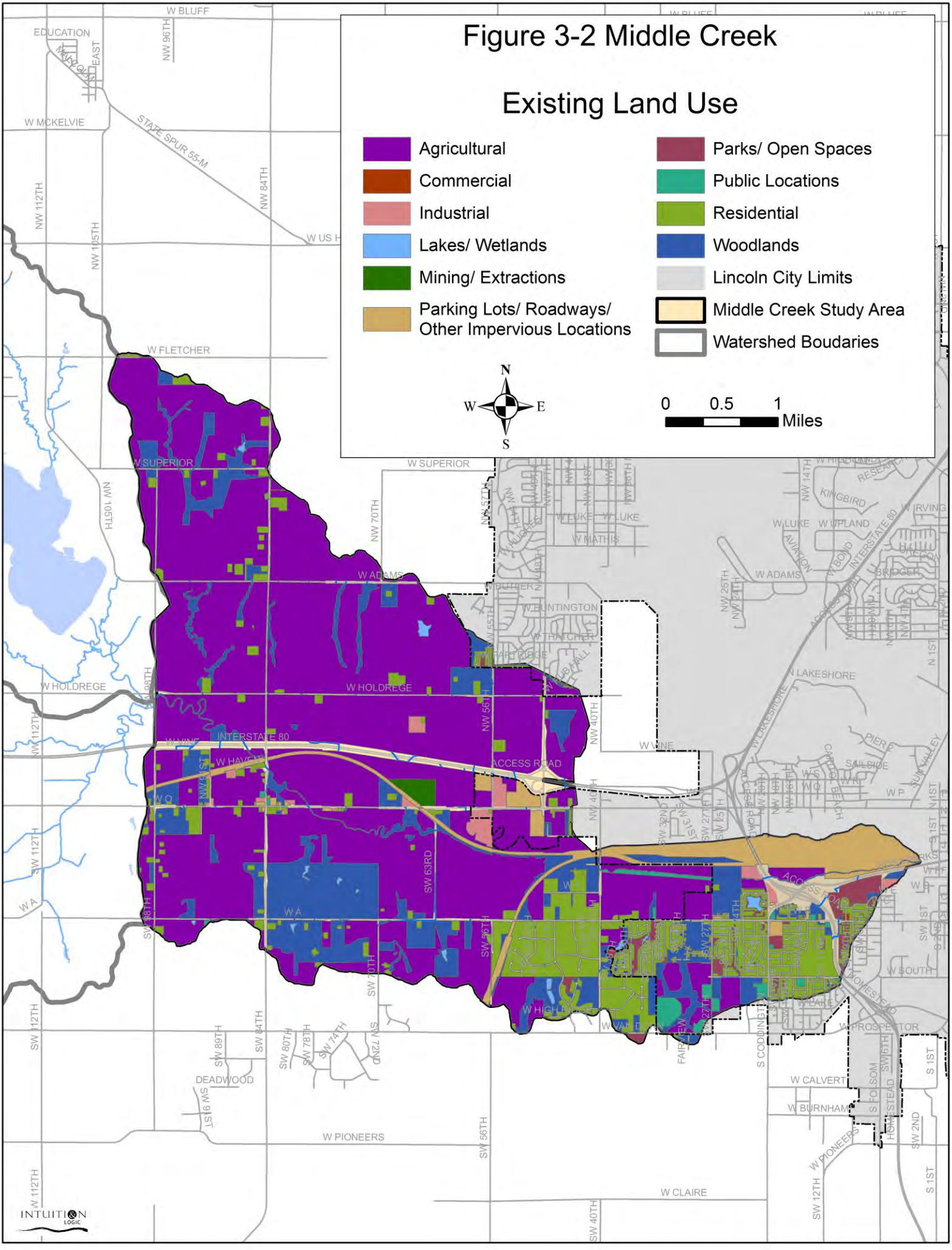
Figure 3-2 Middle Creek
Existing Land Use
Agricultural
Commercial
Industrial
Lakes/ Wetlands
Mining/ Extractions
Parking Lots/ Roadways/ Other Impervious Locations
Parks/ Open Spaces
Public Locations
Residential
Woodlands
Lincoln City Limits
Middle Creek Study Area
Watershed Boudaries
N
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0 0.5 1
Miles
W BLUFF
EDUCATION
NW 96TH
W MCKELVIE
STATE SPUR 55-M
NW 112TH
NW 105TH
NW 84TH
W US H
W FLETCHER
W SUPERIOR
NW 70TH
NW 63RD
W ADAMS
W HUNTINGTON
W HOLDREGE
NW 56TH
NW 40TH
W WINE
INTERSTATE 80
ACCESS ROAD
W HAVELOCK
SW 63RD
SW 56TH
SW 70TH
SW 84TH
SW 80TH
SW 78TH
SW 74TH
SW 72ND
SW 89TH
DEADWOOD
SW 91ST
W PIONEERS
W CLAIRE
SW 40TH
W LUKE
W MATHIS
W UPLAND
W IRVING
W BOND
W LAKESHORE
W SOUTH
W PROSPECTOR
W CALVERT
W BURNHAM
S FOLSOM
S 1ST
SW 2ND
SW 12TH
INTUITION LOGIC

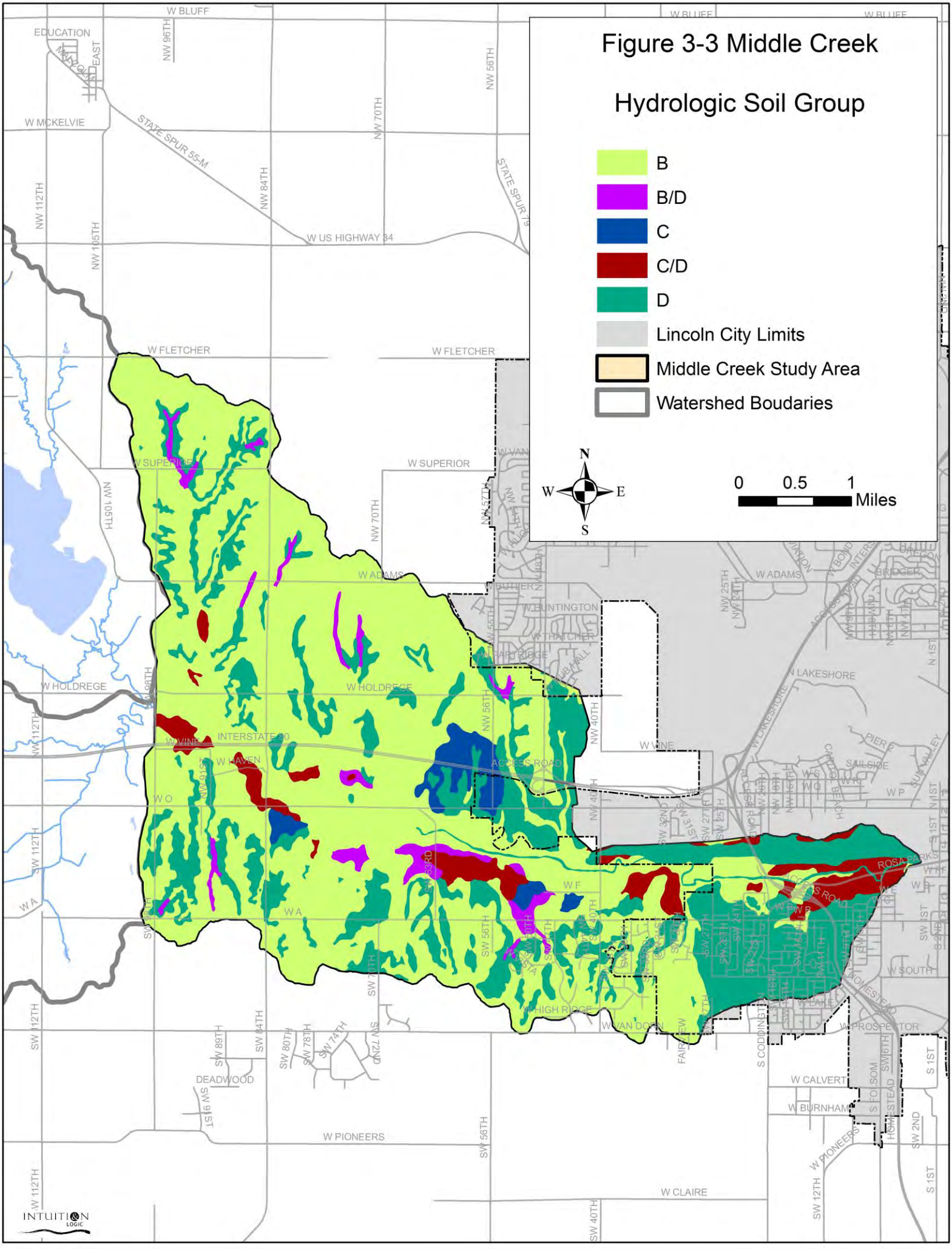
Figure 3-3 Middle Creek
Hydrologic Soil Group
B
B/D
C
C/D
D
Lincoln City Limits
Middle Creek Study Area
Watershed Boudaries
N
W
E
S
0
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1
Miles
W BLUFF
EDUCATION
NW 96TH
NW 56TH
W MCKELVIE
STATE SPUR 55-M
NW 70TH
NW 112TH
NW 84TH
NW 105TH
W US HIGHWAY 34
W FLETCHER
W SUPERIOR
NW 57TH
W ADAMS
W HUNTINGTON
W HOLDREGE
NW 40TH
W VINE
INTERSTATE 80
W HAVEN
ACCESS ROAD
W LAKESHORE
SAILSIDE
PIER
W HIGH RIDGE
W VAN DORN
W PROSPECTOR
W SOUTH
W CALVERT
W BURNHAM
W PIONEERS
W CLAIRE
DEADWOOD
SW 56TH
SW 40TH
SW 12TH
SW 2ND
S 1ST
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 Middle Creek hydrologic study area. Table 3.3 presents the results for each sub-basin. Additional hydrologic information can be found within 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)**
MC001	62.0	107.7	148.2	186.0	221.8	261.3	349.3
MC002	108.3	171.1	224.8	273.8	319.6	369.4	479.0
MC003	91.4	140.0	180.9	217.9	252.3	289.6	371.3
MC004	75.4	115.8	150.0	181.0	209.9	241.1	309.7
MC005	244.8	351.7	439.4	517.7	590.0	667.9	837.6
MC006	226.8	316.7	390.0	455.4	515.6	580.4	721.7

	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)**
MC007	63.4	95.6	122.5	146.8	169.3	193.7	247.0
MC008	133.1	208.5	272.6	331.0	385.5	444.7	575.0
MC009	100.5	141.0	174.0	203.4	230.5	259.7	323.2
MC010	143.3	201.7	249.4	291.9	331.1	373.3	465.2
MC011	55.4	89.8	119.4	146.6	172.1	200.0	261.4
MC012	14.1	21.6	27.9	33.6	39.0	44.8	57.4
MC013	34.0	46.6	56.9	66.0	74.5	83.5	103.3
MC014	63.4	101.4	134.1	164.0	192.1	222.6	290.0
MC015	186.4	280.4	358.8	429.7	495.6	566.7	722.3
MC016	13.7	21.8	28.7	35.1	41.0	47.4	61.6
MC017	112.9	181.5	240.4	294.5	345.3	400.6	522.5
MC018	130.0	204.3	267.6	325.3	379.3	437.9	566.5
MC019	69.9	110.9	146.0	178.1	208.2	240.8	312.7
MC020	13.1	20.1	26.0	31.4	36.4	41.7	53.5
MC021	127.0	176.2	216.2	251.9	284.8	320.2	397.3
MC022	140.8	201.4	251.0	295.3	336.3	380.4	476.6
MC023	189.1	277.5	350.5	416.0	476.7	542.1	684.7
MC024	97.3	172.2	239.1	301.8	361.5	427.3	574.4
MC025	49.5	94.0	134.7	173.3	210.5	251.8	345.0
MC026	33.7	64.4	92.6	119.3	145.1	173.7	238.5
MC027	93.8	164.1	226.5	284.9	340.5	401.7	538.1
MC028	49.5	79.5	105.3	129.0	151.2	175.3	228.6
MC029	130.7	207.7	273.5	333.6	389.9	451.1	585.6
MC030	143.9	237.4	318.6	393.4	463.9	541.0	711.7
MC031	92.1	153.8	207.5	257.4	304.4	355.8	469.8
MC032	153.5	218.3	271.2	318.5	362.1	409.0	511.2
MC033	206.9	311.0	397.9	476.2	549.0	627.7	799.8
MC034	141.3	215.8	278.5	335.2	388.0	445.1	570.5
MC035	99.9	151.9	195.7	235.2	272.0	311.7	398.7
MC036	151.5	220.6	277.7	328.8	376.0	427.0	538.0
MC037	138.3	199.2	249.2	293.9	335.2	379.7	476.6
MC038	160.4	225.2	278.0	325.1	368.6	415.3	517.2
MC039	113.5	158.6	195.4	228.1	258.3	290.8	361.6

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 61 stream crossing locations were identified in the Middle Creek Watershed. Of those, there were 8 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, 1 crossing had 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 M105. The As-Builts contained sufficient data for detailed analysis of the crossing. The culvert was 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 culvert location 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)
M105	Twin 10’x5’x44' CBC	3846	1231	1237.6	1232.9	4.71

Figure 3-4 illustrates the location of culvert M105.

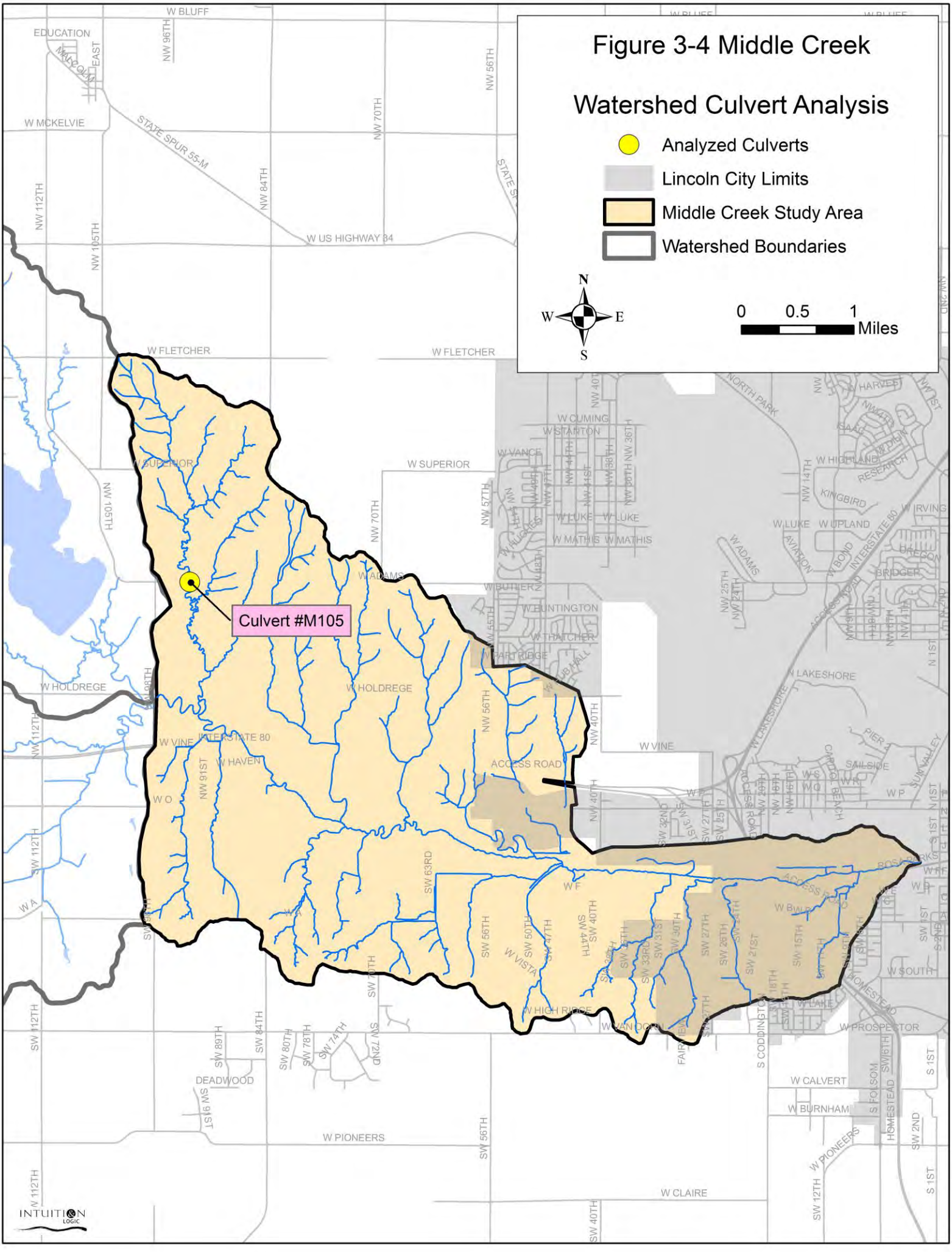
Figure 3-4 Middle Creek
Watershed Culvert Analysis
Analyzed Culverts
Lincoln City Limits
Middle Creek Study Area
Watershed Boundaries
N
W
E
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0
0.5
1
Miles
Culvert #M105
W BLUFF
EDUCATION
NW 96TH
NW 56TH
NW 70TH
W MCKELVIE
STATE SPUR 55-M
NW 84TH
NW 112TH
NW 105TH
W US HIGHWAY 34
W FLETCHER
W SUPERIOR
NW 57TH
W VANCE
W CUMING
W STANTON
W LUKE
W MATHIS
W ADAMS
W BUTLER
W HUNTINGTON
W THATCHER
W HARTRIDGE
W HOLDREGE
NW 108TH
W VINE
INTERSTATE 80
W HAVEN
NW 91ST
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W A
SW 112TH
SW 63RD
NW 40TH
ACCESS ROAD
W F
W VISTA
SW 56TH
SW 50TH
SW 47TH
SW 44TH
SW 40TH
SW 33RD
SW 31ST
SW 30TH
SW 27TH
SW 26TH
SW 21ST
SW 15TH
W HIGH RIDGE
W VAN DORN
W SOUTH
W LAKE
W PROSPECTOR
W CALVERT
W BURNHAM
W PIONEERS
W CLAIRE
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SW 78TH
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SW 72ND
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DEADWOOD
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SW 12TH
S 1ST
SW 2ND
HOMESTEAD
S FOLSOM
S CODDINGTON
FAIRVIEW
NORTH PARK
W HARVEST
W HIGHLAND
RESEARCH
KINGBIRD
W IRVING
W UPLAND
AVIATION
W BOND
BRIDGER
LAKESHORE
PIER 1
SAILSIDE
SUNNY VALLEY
BOSTWICK
INTUITION LOGIC

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