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Government of Manitoba, Water Stewardship

Sturgeon Creek Hydrodynamic Model and Economic Study

Prepared by:

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Project No.: F685 003 00 (4.6.1)

Date: January, 2009

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January 16, 2009

Project No. F685 003 00 (4.6.1)

Mr. Bernie Lussier, P. Eng.
Manitoba Infrastructure and Transportation
Water Control and Structures
Box 499
Grosse Isle, Manitoba
R0C 1G0

Dear Mr. Lussier:

Re: Sturgeon Creek Hydrodynamic Model and Economic Study

AECOM Canada Ltd. is pleased to submit twenty (20) copies of our Final Report for the Sturgeon Creek Hydrodynamic Model and Economic Study.

Please distribute as required.

If you or the Technical Advisory Committee have any questions or require clarification on any aspects of this report we invite you to call Jim Friesen, Project Engineer, at (204) 284-0580.

Thank you for the opportunity to conduct this study and submit this report.

Sincerely,
AECOM Canada Ltd.

Eric Blais, B.Sc., M.A.
AECOM Water
AJF/dh

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	J. Friesen	May 12/08	Draft
2	J. Friesen	Jan. 16/09	Final

Signature Page

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List of Acronyms

Abbreviation	
AECOM	AECOM Canada Ltd.
BCR	Benefit Cost Ratio
CLI	Canada Land Inventory
CN	SCS Curve Number
DEM	Digital Elevation Model
DFO	Department of Fisheries and Oceans Canada
GIS	Geographic Information System
GPS	Global Positioning System
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HSG	Hydrologic Soil Groups
MASC	Manitoba Agriculture Services Corporation
MIT	Manitoba
MLI	Manitoba Land Inventory
MWS	Manitoba Water Stewardship
PR	Provincial Road
PTH	Provincial Trunk Highway
Qp	Stream flow at peak
RM	Rural Municipality
SCS	Soil Conservation Service
Sec	Section-Township-Range
SRTM	Shuttle Radar Topography Mission
TAC	Technical Advisory Committee
Tc	Time of Concentration
UMA	UMA Engineering Ltd
USACE	United States Army Corps of Engineers
USGS	United States Geographic Service
UTM	Universal Transverse Mercator
WSC	Water Survey of Canada

1. Project Summary

The Sturgeon Creek and Colony Creek watersheds have experienced relatively frequent flooding. The general impression held by residents is that the rural area does not have adequate drainage for the agricultural activities occurring in the catchment. There is also a perception that crossings over Sturgeon Creek are undersized and may be causing upstream flooding.

The economic consequences of flooding in the Sturgeon Creek watershed are most severe when flooding results from summer rainfall events. These include:

- Crop damage
- Loss/damage to property and infrastructure
- Socio-economic disruption
- Business disruptions due to road restrictions
- Road closures and potential basement flooding in The City of Winnipeg

It was felt that changes in regional crop practices, the increase in value-added crops and sensitivity to flooding might justify increases in the level of service to be expected from drainage infrastructure.

AECOM Canada Ltd. was engaged to perform this study under the direction of a Technical Advisory Committee (TAC). The TAC was comprised of Provincial, Municipal and City officials and local residents.

The available data, modeling assumptions, community perceptions, economic costs and benefits are examined and presented in this report. Causes of flooding were investigated and mitigation options presented in terms of hydraulic and economic benefits.

AECOM has completed this project and addressed the scope of work as follows:

1. AECOM has developed an inventory of the existing drainage system using Geographic Information System (GIS) tools. The GIS database contains the drain locations and attributes such as stream order based on the new stream mapping and classification system recently introduced by the Province of Manitoba. This database has allowed the analysis of contributing area and estimates of channel slope, time of concentration and flow rates for various return periods. GIS data is included in Appendix C.
2. A tour the watershed and a visual field inspection of the "significant drains" (as identified by TAC) was conducted soon after project award. The results of this inspection, including drain condition, were documented using field notes and digital photos. This data is available in Appendix B and with the GIS files.
3. A steady state MIKE11 model of the drainage system was used to analyse the existing hydraulic capacity of the drains and crossings along of Sturgeon Creek and Colony Creek.

Flow rates were increased until hydraulic standards were exceeded at culvert crossings or the water levels rose above prairie and affected crops, roads or other infrastructure.

Once the hydraulic capacity of various reaches had been determined, various analyses were undertaken to identify the probability or frequency with which these flows would occur. Flow frequencies were developed for stream locations in order that the critical flow could be expressed as a probability or return period in years.

Since a standard frequency analysis only uses the annual peak flow data, an additional analysis was conducted using summer data to identify the degree of risk or level of service relative to summer events.

The results of these analyses are presented in the report. This indicates the return period at which drain capacity is exceeded can be as low as the two and five-year event (annual series). This corresponds to approximately the S-Curve drainage standard which has flow values between the two and five-year frequency flows.

4. The annualized maintenance cost of the existing drainage system was estimated based on data supplied by the Rural Municipalities and Water Stewardship. The annual maintenance expenditure for ditch mowing was estimated using $162.50 per kilometre. The cost for ditch invert trimming or grade restoration was estimated as $313.33 per kilometre. Operation and maintenance estimates for the drainage basin came to $190,000 per year based on the expenditure per unit length for each drain order and total lengths in the drain inventory.
5. The relevant drainage, flooding and infrastructure issues were documented and reviewed with the TAC committee. This included mapping of the areas that are subject to flooding based on anecdotal information provided at TAC meetings.
6. An estimate of annualized flood damages to agricultural crops, provincial and municipal infrastructure, and buildings was based on limited data provided by the Rural Municipalities, Water Stewardship and The City of Winnipeg. Data received was limited in regional representation and did not warrant organization in a database. Damage estimates were computed based on flooded area and were represented in the benefit cost analysis.
7. Three alternative diversions from Sturgeon Creek to the Assiniboine River using MIKE11 were modeled to determine the capacity required to provide an agricultural drainage standard that is higher than the existing "S-Curve." Design flows were estimated using flow data from the ten-year event (annual series). Areas of recent flooding and these relative reductions were considered in the determination of the preferred Third Creek Diversion.
8. Preliminary feasibility, design and cost estimates to construct and maintain each of the diversions were made based on current construction costs and generalized maintenance cost data. The Third Creek Diversion provided the largest benefit cost ratio (BCR), even though the BCR remained below one.
9. Conceptual designs to upgrade Sturgeon and Colony Creeks were made as an alternative to a diversion. Cost estimates for bridge upgrades alone exceeded $11,000,000 and an additional $11 - $18 million would be required for culvert and channel upgrades. This was not considered economically viable as it had a lower benefit cost ratio than the diversion options. An estimate of the

capital and maintenance costs to upgrade and maintain these creeks was based on current construction costs and generalized maintenance cost data.

10. A comparison of estimated costs, benefits and benefit-cost ratio of each alternative is presented in Table 9.2.1. The benefits were primarily from reductions in agricultural flooding as data on damage to provincial & municipal infrastructure was not available or in the case of the City of Winnipeg it was indicated that Sturgeon Creek flood damages were not significant.

    High level assessment of potential impact on the aquatic habitat was performed for each mitigation alternative based on a preliminary analysis and classification of stream habitat by DFO.

11. The first, second, and third order tributary drains within the study area that require upgrading were not specifically indicated other than by indicating the typical cross section and hydraulic capacity under two areas of analysis. The first of these was the sampling of drains identified as "typical," and the determination of the existing characteristics of each drain type. Five one-mile reaches were surveyed, in each of drain orders one, two and three (15 miles in total).

    At the same time, design flows were computed for drainage areas ranging from one square mile to the largest third order tributary drain. The design flow estimates were used to compute the minimum cross section and estimate appropriate drainage structures for each contributing area. This "design cross section" and drainage structure data was compared to the sample data and a "typical upgrade" cost per unit length was estimated.

12. Preliminary cost estimates to upgrade the tributary drains were computed based on the inventory of first, second and third order tributary drains, the computed length of each type, and the "typical upgrade" cost per unit length. Cost estimates were based on current construction costs and annual maintenance costs determined as part the detailed survey of typical drains.

13. A preliminary analysis of the effect of storage on flood peaks and the potential for additional storage was conducted. This indicated that the existing drainage system, configured with dikes and control gates, already provides significant storage and attenuation of flood peaks. AECOM was not able to identify available parcels of land with large potential storage capacity.

    Grant's Lake could provide significant storage but only if it were operated for flood control rather than for wildlife benefits. The present operation of Grant's Lake provides minimal flood attenuation.

14. Environmentally sustainable features could be incorporated into the mitigation designs if any alternatives were seen to be viable.

15. A ten-year plan of prioritized construction and maintenance works can be developed based on the analysis that identified infrastructure not meeting the required hydraulic standard. Sites with below a five-year level of service would be the priority areas requiring maintenance and upgrading. Combined with the anecdotal information on flooding this can be used to achieve the flood relief in the areas that are most severely impacted. This work can be scheduled according to annual budgets or other identified funding sources.

2. Introduction

The Sturgeon Creek and Colony Creek watersheds have experienced relatively frequent flooding. The general impression held by residents is that the rural area does not have adequate drainage for the agricultural activities occurring in the catchment. There is also a perception that crossings over Sturgeon Creek are undersized and may be causing flooding upstream of road crossings.

The economic consequences of flooding in the Sturgeon Creek watershed are most severe when resulting from summer rainfall events. These include:

- Crop damage limiting crop yield
- Loss/damage of property and infrastructure
- Socio-economic disruption
- Business disruptions due to road restrictions
- Road closures and potential basement flooding in The City of Winnipeg

It was felt that changes in regional crop practices, the increase in value-added crops and sensitivity to flooding might justify increases in the level of service to be expected from drainage infrastructure.

Due to the importance of drainage to agriculture and the rural economy, the hydrologic and hydrodynamic analyses needed to be reliable and contain sufficient detail for use in accurately quantifying the cost of mitigation options.

AECOM was engaged to perform this study under the direction of a Technical Advisory Committee (TAC). The TAC was comprised of Provincial, Municipal, City officials and local residents.

The available data, modeling assumptions, community perceptions, economic costs and benefits are examined and presented in this report on hydrodynamic modeling of the Sturgeon Creek Watershed. Causes of flooding will be investigated and feasible mitigation options presented in terms of hydraulic and economic benefits.

2.1 Project Objectives

Due to the sensitivity of the flooding issue a hydrodynamic model study was commissioned by Manitoba Water Stewardship (MWS) and the municipalities in the watershed to model the hydrology and hydraulic characteristics of the Sturgeon Creek and its tributaries. The objective of the study was to identify the existing capacity in the Sturgeon Creek and its tributaries; identify flood mitigation options; and conduct an economic analysis to justify implementation of selected mitigation options.

The purpose of this report is to describe the hydrologic and hydraulic elements of the MIKE11 hydrodynamic model including its composition, limitations and analytical application. The report will:

- describe the scope and composition of the model;
- describe the observed and assumed inputs to the model;

- comment on calibration and verification of the model;
- analyze the existing capacity of Sturgeon Creek;
- compare hydraulic impacts and benefits of various flood mitigation options; and
- compare benefit-cost analyses on selected flood mitigation strategies.

2.2 Project Area

The Sturgeon Creek watershed is located between Lake Manitoba and the City of Winnipeg. The watershed (shown in Figures 2.2.1 & 3.2.1) begins in the Rural Municipality (RM) of Woodlands and flows south east through the RM of Rosser before crossing the West Perimeter highway and flowing through the City of Winnipeg. The Sturgeon Creek watershed presently has a total drainage area of approximately 598 km^2.

Colony Creek, located north of Sturgeon Creek, was formerly part of the Omand's Creek watershed, until it was diverted[1] south into Sturgeon Creek 3 km upstream of the West Perimeter Highway in the late 1960's. The Colony Creek watershed forms the northern edge of the present Sturgeon Creek basin and has a sub-drainage area of 118 km^2.

The Fourth Creek, Third Creek, Second Creek and First Creek watersheds form the south boundary of the Sturgeon Creek watershed. These narrow watersheds are in the RM of Francois-Xavier and flow southeast into the Assiniboine River. Gowler's Creek catchment in the RM of Headingley also flows southeast into the Assiniboine River and forms part of the Sturgeon Creek watershed south boundary.

Sturgeon Creek has a stream network comprised of four major branches. The Sturgeon Creek main stem starts at its confluence with Assiniboine River in the City of Winnipeg and extends upstream of the Perimeter Highway to Section-Township-Range 32-12-1W where the East and West Branches join to form the Sturgeon Creek main stem. The West Branch of Sturgeon Creek continues upstream and includes the West Branch Sturgeon Lateral Drain.

Colony Creek has three creek branches. The first branch upstream of the confluence with Sturgeon Creek is the West Colony Lateral; the second branch is called Centre Colony and the third branch is called Upper West Colony. These branches are defined in Provincial Drain drawings (with the exception of West Colony Lateral - named by AECOM) and for the purpose of the study, the naming convention has been adopted throughout this report. The East Colony Creek is not part of this study and continues through the City of Winnipeg as Omand's Creek.

[1] *Colony Creek Diversion was reported as "proposed" in S. Peterdy's Preliminary Report on Omand's Creek (Colony Creek), Manitoba Department of Agriculture and Conservation, Water Control and Conservation Division, March, 1966.*

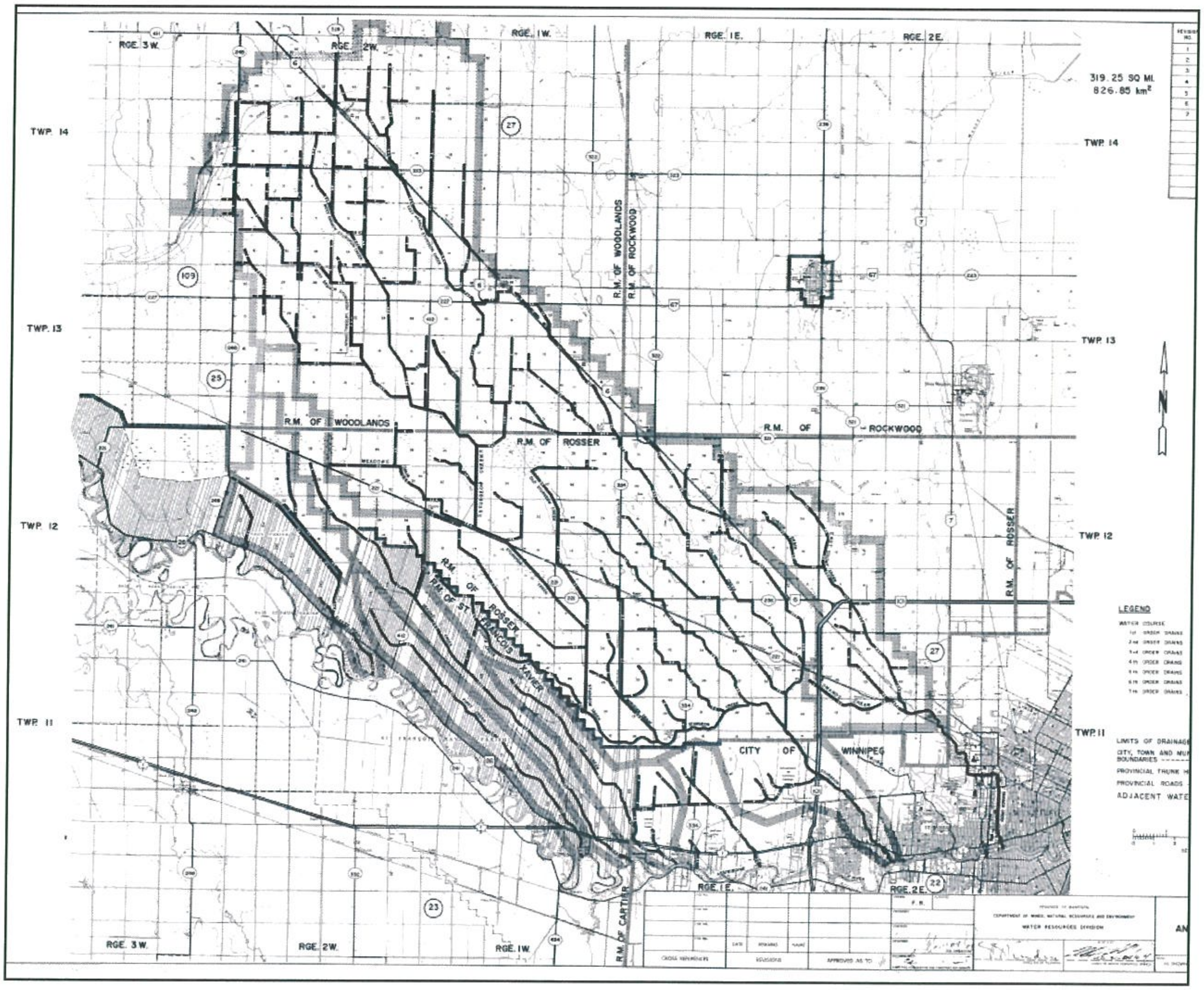


Figure 2.2.1 - Plan of Sturgeon Creek and Adjacent Watersheds

The Sturgeon Creek watershed contains nearly 286 km of drains classified as second order and greater. The watershed contains extensive areas of productive agricultural land with little natural wetland storage. The only identifiable basin storage feature is Grant's Lake in the middle reaches of the Sturgeon Creek. This marsh feature (shown in Figure 3.4.3.) is regulated with a stop-log weir structure built at the northwest end. Water levels are regulated in a range to allow for productive wetland habitat for waterfowl. The weir structure is used to control both inflow and outflow.

Significant additional storage exists in the ditches lateral to the main tributaries in the watershed. Most of these ditches flow through culverts penetrating the dikes lateral to the main channels. Flap gates (also known as "traps") and positive-control gate values (or sluice gates) on these lateral culverts are intended to prevent back flooding due to high water levels in the tributary creeks. Without these controls, local drain levels could rise to match tributary channel levels. This lateral ditch storage significantly reduces flood peaks and flow rates as demonstrated during the hydraulic analysis conducted as part of this study.

Dikes lateral to drains as shown below were noted on most provincial drain drawings.

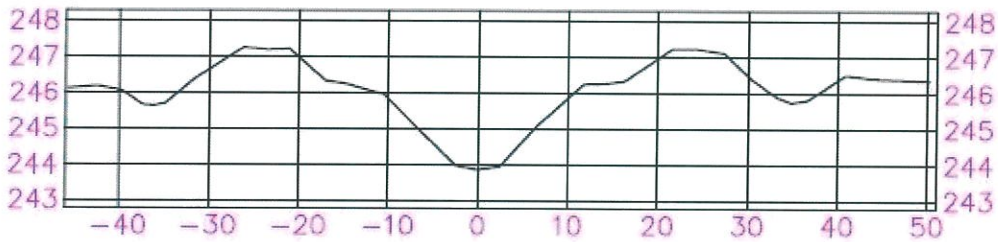


Figure 2.2.2 - Typical Channel Cross Section with Lateral Dikes
(Excerpt from Provincial Drain Drawings-metric units)

3. Data Collection and GIS Inventory

3.1 Data Collection

The collection of data for input into the watershed model involved a number of different activities including analysis and confirmation of plans produced by other agencies, data collected by the Province of Manitoba and a limited field survey programme.

The Manitoba Land Inventory (MLI) and Canada Land Inventory (CLI) provided available GIS Data on stream network, soil type, land-use, roads and air photos. Manitoba Water Stewardship defined the drainage network to model and provided information on drains, culverts and bridge crossings. Environment Canada provided rainfall records and observed peak water elevations with TAC members providing additional rainfall records. Rural Municipalities (RM's) and Communities provided data in the form of maps, property lists, anecdotal flood records and limited flood claims data for the economic analysis.

AECOM conducted a survey of selected drains in the Sturgeon Creek and Colony Creek in October 2007. This field programme collected sufficient information from the drains and road crossings to determine typical drain conditions. Drain profile and cross section information was gathered on a sample of approximately 15 miles (24 km) of drain and included photos and descriptions of culverts, crossings, dikes and ditch condition in the sampled locations. Details of the field programme are described in Appendix B.

3.2 Sturgeon Creek and Colony Creek Drainage Network

The Manitoba Water Stewardship (MWS) Department defined the extent of Sturgeon and Colony Creek stream network to be included in the model. The network extended from the Assiniboine River in Winnipeg into the upper watershed including up to the second order drains. Figure 2.2.1 shows the extents of the drainage network as presented by MWS for modeling.

The drainage network comprises approximately 400 km of stream channel in total. This included approximately 38.7 km of the Sturgeon Creek main channel, 20.0 km of the East Branch Sturgeon, 19.2 km of the West Branch Sturgeon, and 10.9 km of the West Branch Sturgeon Lateral Drain. Colony Creek is made up of three tributary branches including approximately 18.8 km of the Centre Colony Creek main channel, 27.5 km of the Upper and Lower West Colony Creek and 13.7 km of the West Colony Lateral. These branches are defined on provincial drain drawings and the naming convention has been adopted throughout this report.

The remainder of the channel length in the model is comprised of numerous lateral ditches modeled to represent the volume of storage present in the sub-catchments. An additional drain was added to the model to route inflows from Watershed 111 (shown in Figure 6.2.1).

The creeks forming the MIKE11 hydraulic network are shown in various colors in Figure 3.2.1. Additional waterways in the yellow-shaded study area and adjacent watersheds are shown as thinner blue lines.

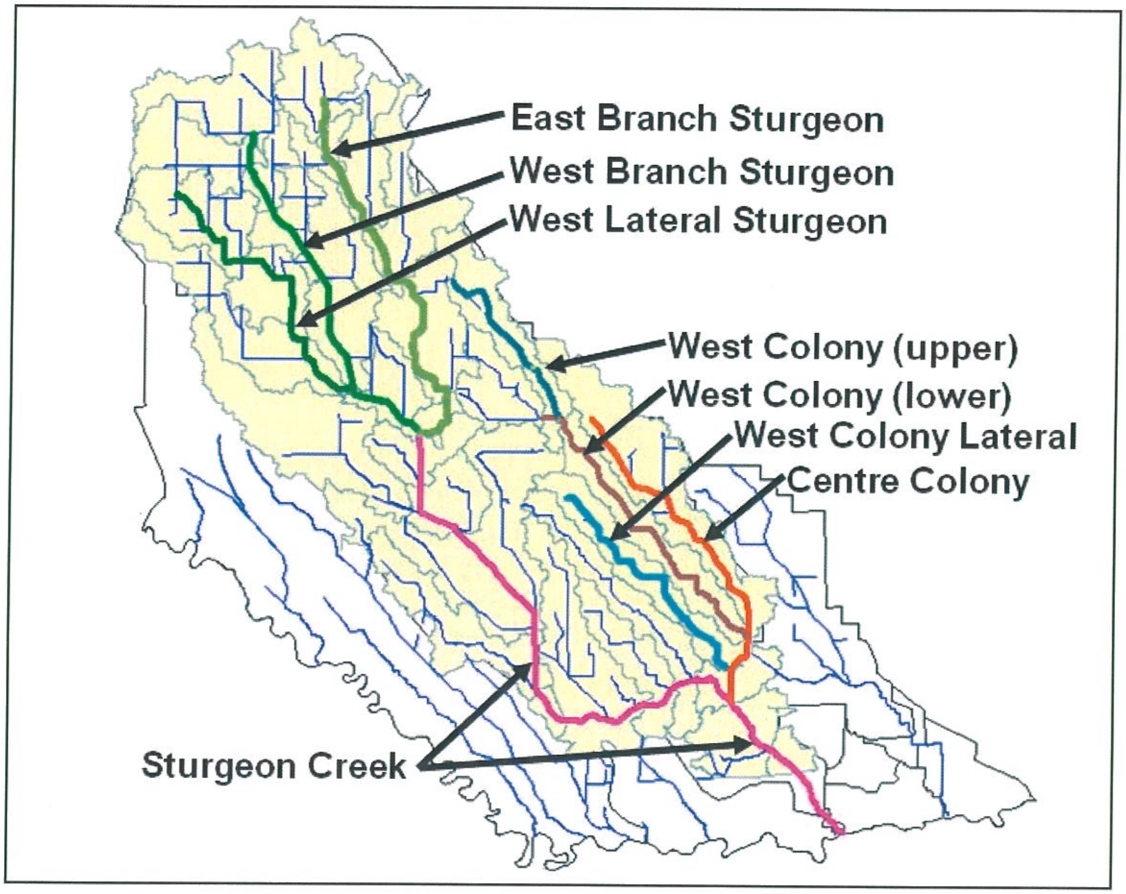


Figure 3.2.1 - Sturgeon Creek Network

MWS provided the majority of the Sturgeon Creek drainage data. The detailed infrastructure data consisted of AutoCAD drawings (version 2000 or newer), older hard copy drawings and Excel spreadsheets containing partial lists of existing hydraulic structure (bridges, culverts and weirs). Hard copy drawings of Colony Creek branches were provided, as digital AutoCAD drawings were not available.

The RM's of Headingley and St. Francois-Xavier also provided some maps and older hard copy drawings. GIS data and land ownership maps were obtained from RM of Woodlands. All relevant drawings were scanned and digital copies stored in project files.

A Geographic Information System (GIS) database was used to compile the relevant drain and hydraulic structure information including culverts, bridges and weirs.

3.3 Surface Topography

The Sturgeon Creek basin generally slopes toward the southeast where the Sturgeon Creek flows into Assiniboine River within the City of Winnipeg. The upper reaches of the watershed are more steeply sloped (up to 1.2%) with flatter slopes in the middle and lower reaches (as low as 0.05%).

A digital elevation model (DEM) of the basin topography was produced from SRTM (Shuttle Radar Topography Mission) data. This provided as a 90m grid by MLI and was processed by AECOM to define the general topography of the floodplain and re-interpolated to a 5m grid for watershed sub-catchment delineation. This grid does not have a high degree of vertical accuracy, but was considered sufficient for watershed delineation. Figure 3.3.1 shows the color-graded contours with a color-graded DEM background and stream network.

AECOM used the DEM to produce flood plain mapping and to estimate the potential decrease in water levels under various flood mitigation options.

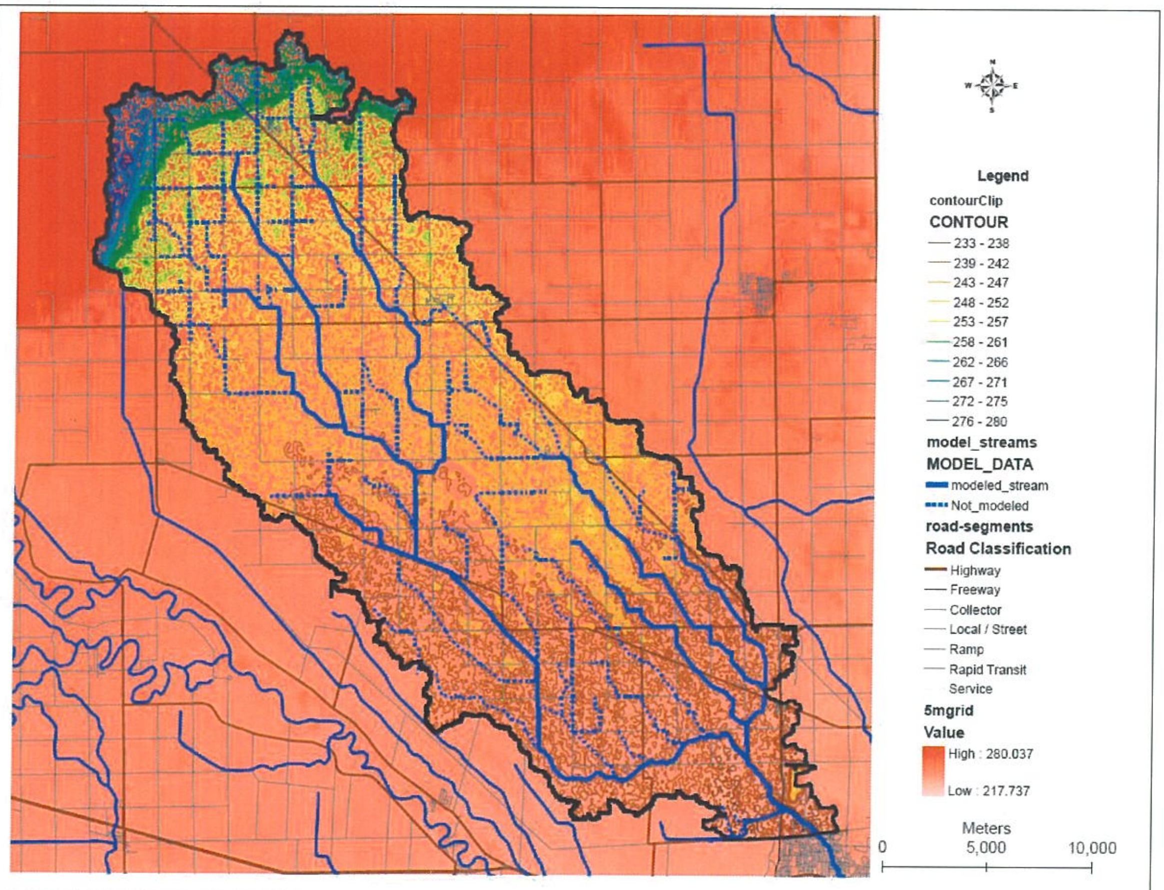


Figure 3.3.1 - Sturgeon Creek Digital Elevation Model as Contours

3.4 Soil and Land-Use

Glacial processes have influenced the basin geology. The upper watershed has sandy soils in local beach ridges while the lower watershed is primarily a lacustrine deposit and contains loamy soils and silty clay materials overlying till and deep limestone formations.

Soil information as shown in Figure 3.4.1 was downloaded from Manitoba Land Inventory (MLI) and found to be predominantly silty clay overlying till, with local sand ridges and few areas of wetland. Rich organic soils support crop-based agriculture. Metadata describing soil types and their hydrologic drainage characteristics suggested Soil Conservation Service (SCS) Hydrologic Soil Groups (HSG) "C" and "D" were predominant in the catchment. Hydrologic Soil Groups are shown in Figure 3.4.2.

Class "C" soils are shallow soils and high clay soils with below average infiltration and moderately high runoff potential. Class "D" soils are high clay soils with high shrink/swell potential and some shallow soils with impermeable horizons having the highest runoff potential.

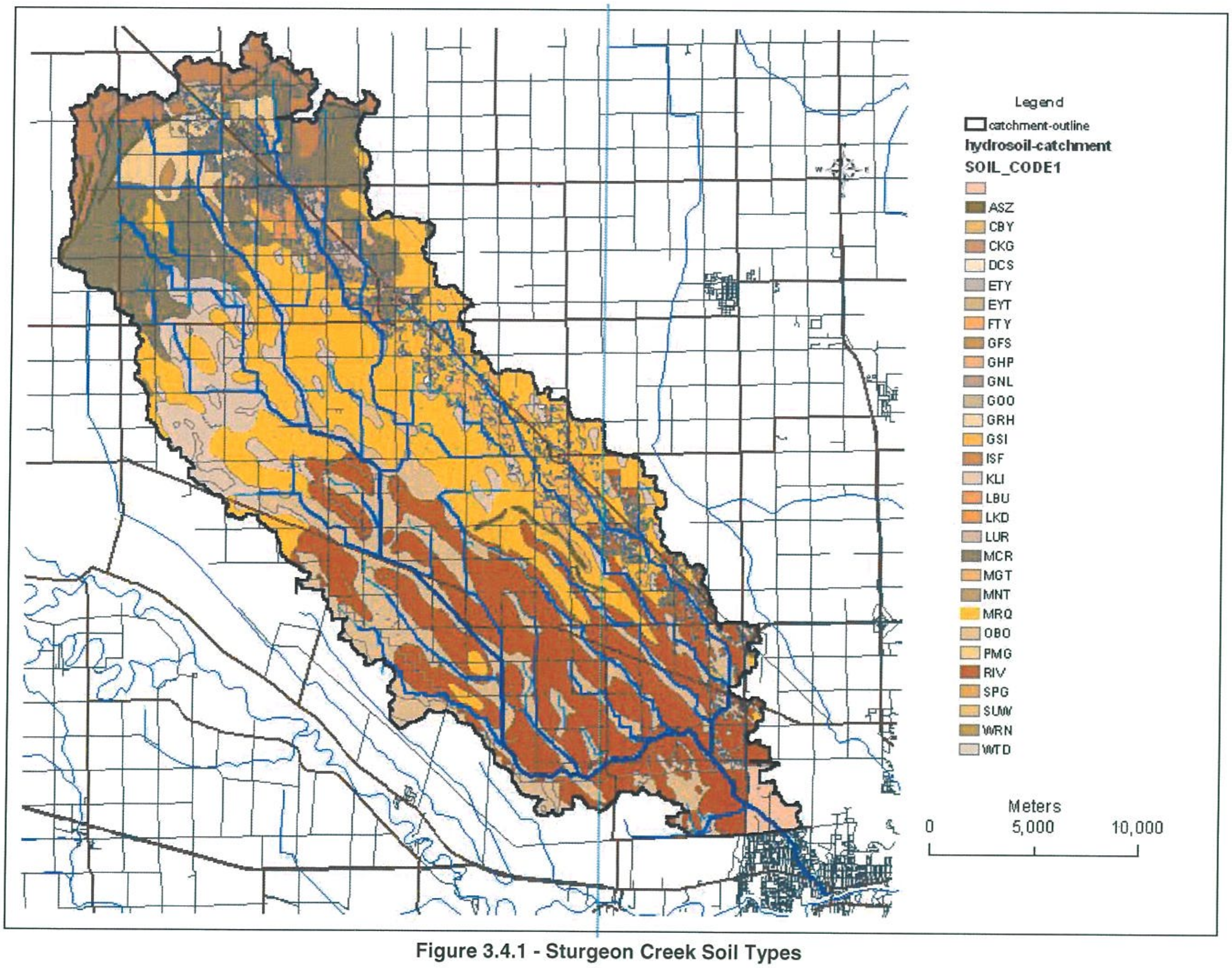


Figure 3.4.1 - Sturgeon Creek Soil Types

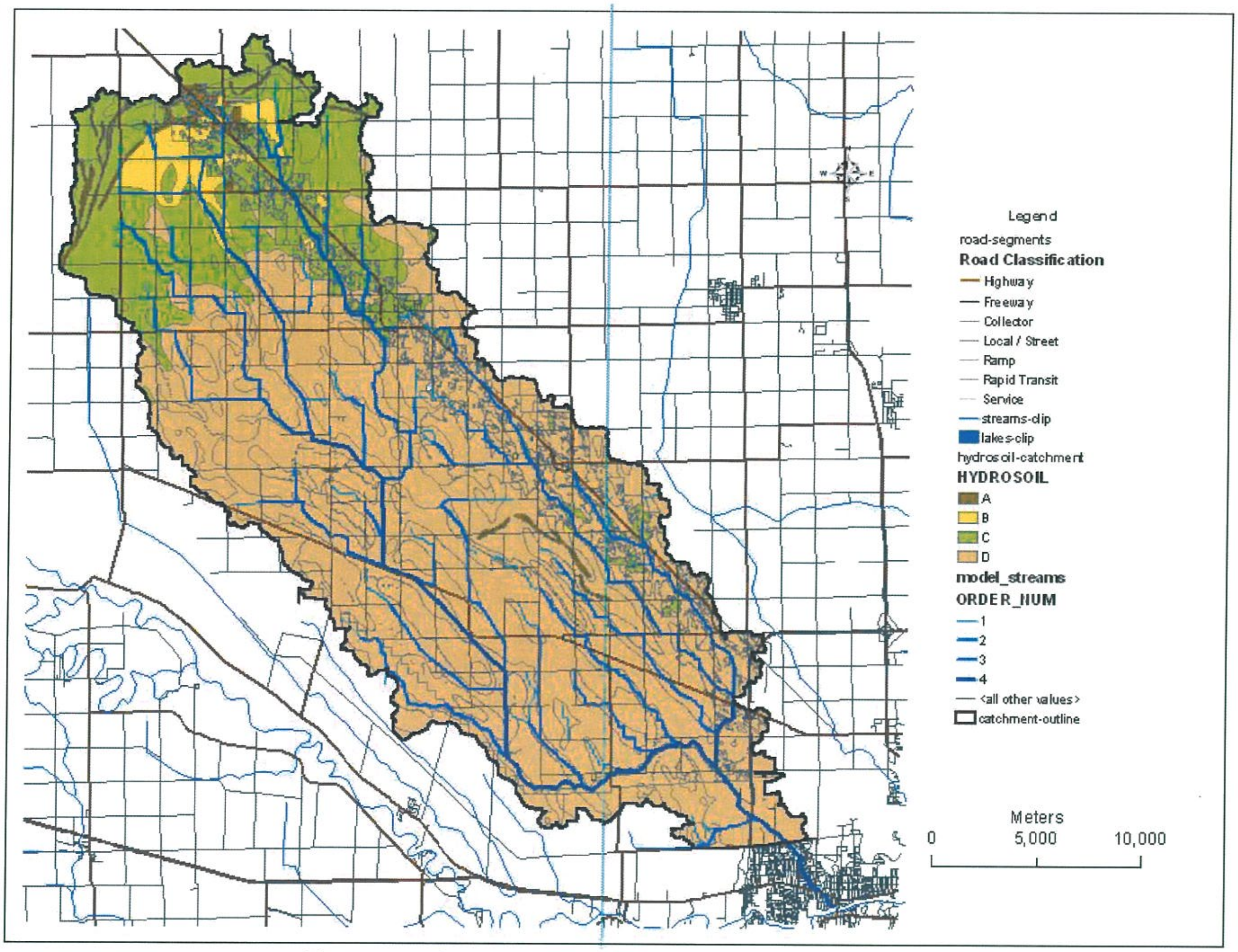


Figure 3.4.2 - Sturgeon Creek Hydrologic Soil Groups

Land use characteristics were determined from a 2002 GIS layer downloaded from MLI. Land use in the database contained 16 classifications. The 16 land uses were aggregated based on the similarity of hydrologic response into five categories to simplify the runoff analysis. Table 3.4.1 shows the aggregated areas and the percentage of each land use group.

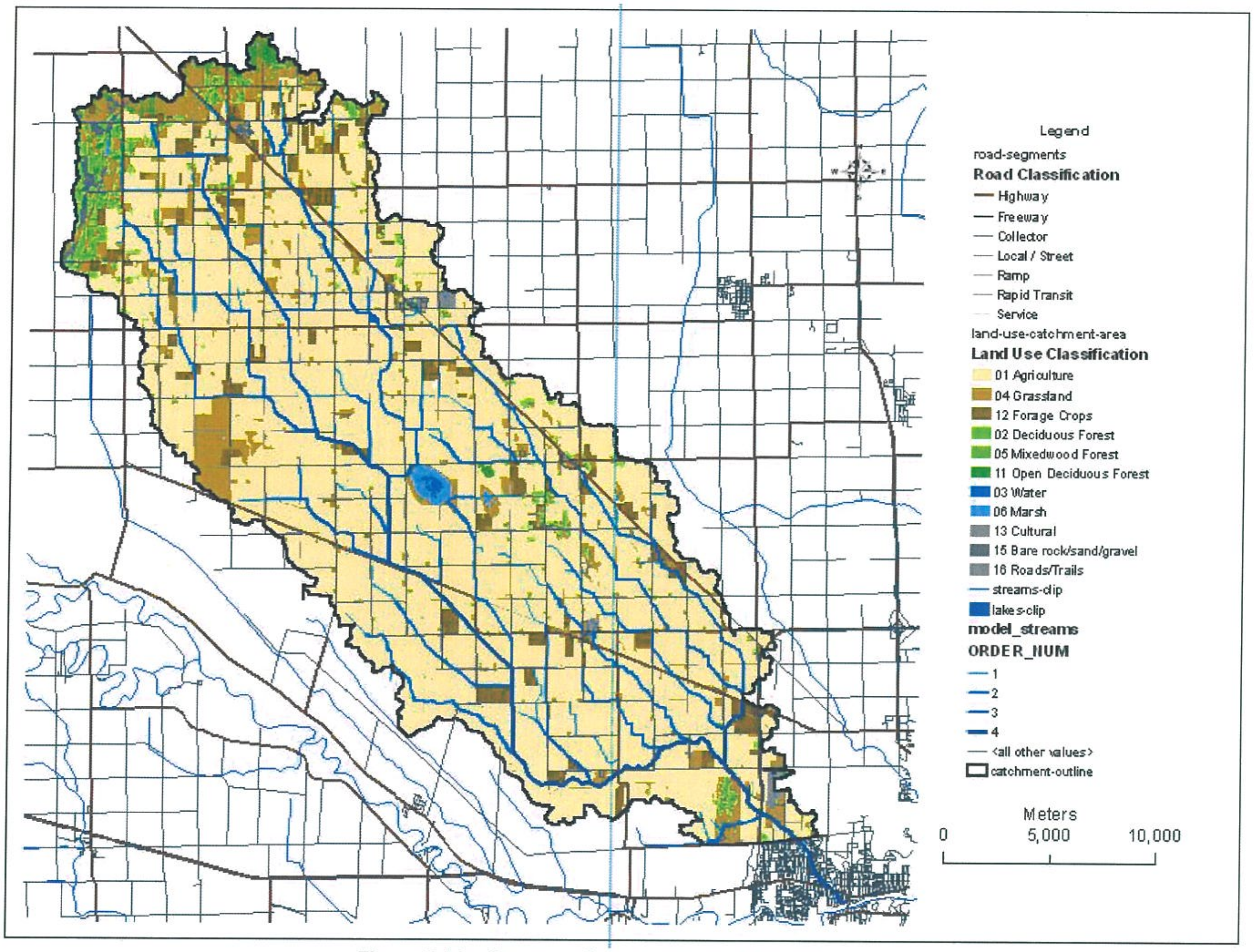


Figure 3.4.3 - Sturgeon Creek Land Use Classes

Present land use in the watershed is predominantly agricultural cultivation (75%). Forage crops and grasslands form the second largest land use (16%). Other uses such as woodlands and built-up areas form less than 5% each. Wetlands form less than 1%. The table below shows grouped land use in total area in square kilometres and percent.

Table 3.4.1 - Aggregated Land Use in Sturgeon Creek Watershed

Grouped Land Use	Land Use Area (km^2)	Land Use %
Cultivated	448.4	74.9%
Prairie	94.5	15.8%
Forest	25.1	4.2%
Wetland	3.4	0.6%
Other	27.6	4.6%

Soil type and land-use contribute to the selection of a representative SCS Curve Number (CN). The curve number generally represents the runoff characteristics of the catchment similar to a runoff coefficient. The hydrologic programme HEC-HMS[2] and the AECOM Excel model both require a curve number to estimate runoff percent, generate hydrograph time of concentration and calculate infiltration losses. Soil type and land use were considered and found to be fairly uniform. A representative CN of 80 was selected to represent each sub-catchment based on the observation that soil type was predominantly HSG Type "D" and land use was predominantly cultivated. Slope varied slightly in the sub-catchments and influenced the selection of Time of Concentration (T_c) and hydrograph timing.

3.5 Sturgeon Creek Profile

Sturgeon Creek profile and cross sections were defined from processed historical survey data, MIT and Water Stewardship bridge plans and AECOM-collected field data. Manitoba Water Stewardship supplied drawings with profile and cross section information for many of the modeled drains in the watershed. Sufficient information on the floodplain and channel was available to insert the hydraulic structures (i.e. bridges, culverts and low-level crossings) within the drains and along drains and ditches controlling flow to and from the adjacent floodplain.

The Sturgeon Creek profile is shown in Figure 3.5.1. The nominal slope of the river main stem is 0.025%. The upper reaches of the watershed have greater slopes. The East Branch Sturgeon has a slope of 0.048% from the upper reaches to the confluence with the Sturgeon main stem. The slope of the West Branch is between 0.05% to 0.044%, from the upper reaches to the confluence with the Sturgeon main stem.

[2] *Hydrologic Modeling System (HMS) software developed by the Hydrologic Engineering Center (HEC) – a branch of the United States Army Corp of Engineers (USACE).*

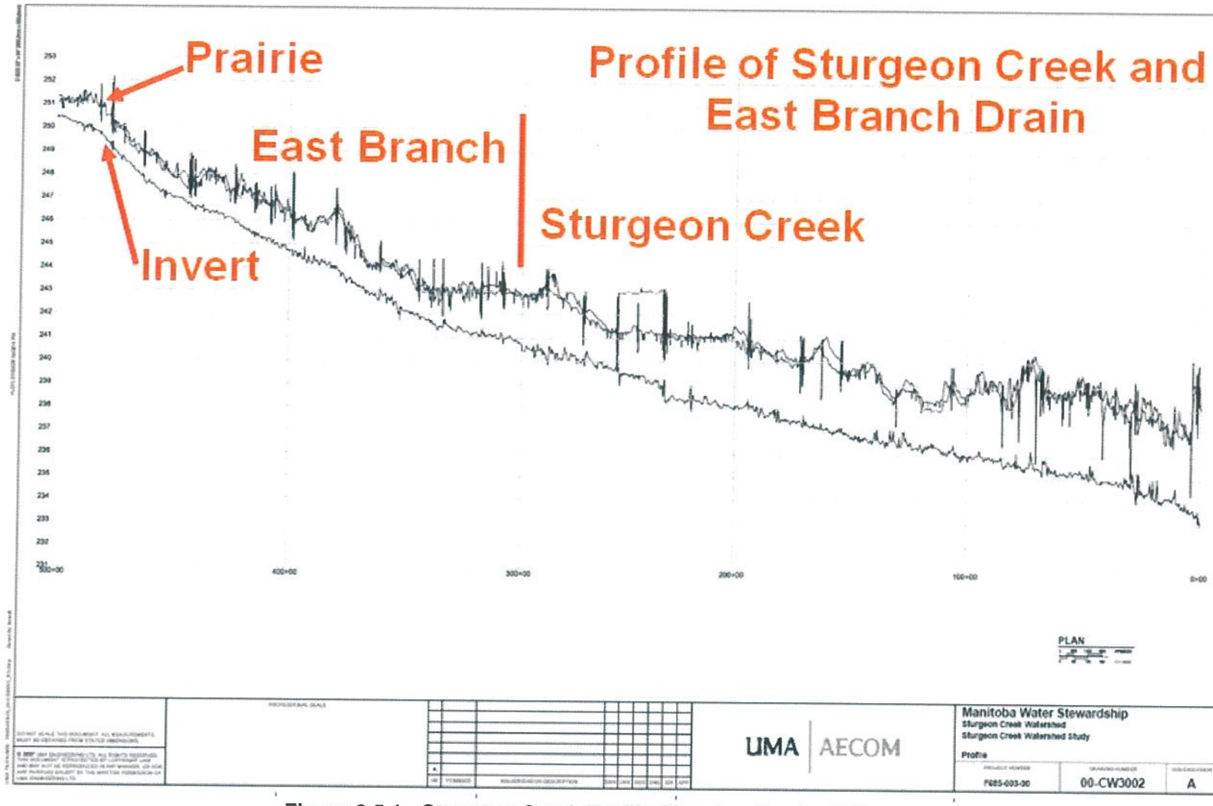


Figure 3.5.1 - Sturgeon Creek Profile Showing Nominal Slope

3.6 Cross Section and Hydraulic Structure Data

A physically realistic hydraulic model requires an accurate representation of stream cross sections and relevant crossings and restrictions. Channel cross sections were available for much of the modeled watershed. Channel constrictions within the drainage network were primarily man-made structures such as bridges, culverts, or low-level crossings constructed for the convenience of traffic crossing the channel.

Data for the hydraulic structures contained in drawings for the Sturgeon Creek watershed was used in constructing the hydraulic model. The number of structures available for each branch of the watershed is shown on Table 3.6.1. Figure 6.2.1 shows Sturgeon and Colony Creek naming convention and locations.

Table 3.6.1 - Summary of Hydraulic Structure Inventory from MWS Drawings

Branch	Upstream Location	Downstream Location	# of Hydraulic Structures
Sturgeon Creek			
Main Channel	32-12-1W	24-11-1E	96
East Branch	14-14-2W	32-12-1W	91
West Branch	16-14-2W	32-12-1W	95
West Lateral	33-13-2W	12-13-2W	46
Colony Creek			
Centre Colony	31-12-1E	32-12-1W	21
West Colony	22-13-1W	36-11-1E	44
West Colony Lateral	18-12-1E	26-11-1E	20

As the summary table indicates, based on the information provided to AECOM by MWS, Sturgeon Creek contains 328 hydraulic structures and the Colony Creek contains 85 hydraulic structures. The data was compiled and summarized on spreadsheet for model construction and organized in GIS files produced for this project. The crossing inventory is included as Table 2 in Appendix C.

The HEC-RAS models at the downstream end of Sturgeon Creek were also used to extract cross section data, as these were not available on the existing drawings.

In addition to records received from MWS, AECOM conducted a survey of various drains to collect current data from which to estimate required maintenance and typical upgrade costs to a budget level of detail.

3.7 AECOM Survey Data Collection

One of the goals of the study was to determine the condition of existing drains in the watershed. The intent was to sample five miles of typical drains in each of the first, second and third order. From this sample AECOM was to estimate the condition, conduct preliminary design and determine the estimated cost to upgrade the channels to current design standards. Information was solicited from TAC members to determine where this survey should take place so that it was representative of typical drains in each of the Rural Municipalities. MWS provided a summary of the drains to survey as shown in the figure below.

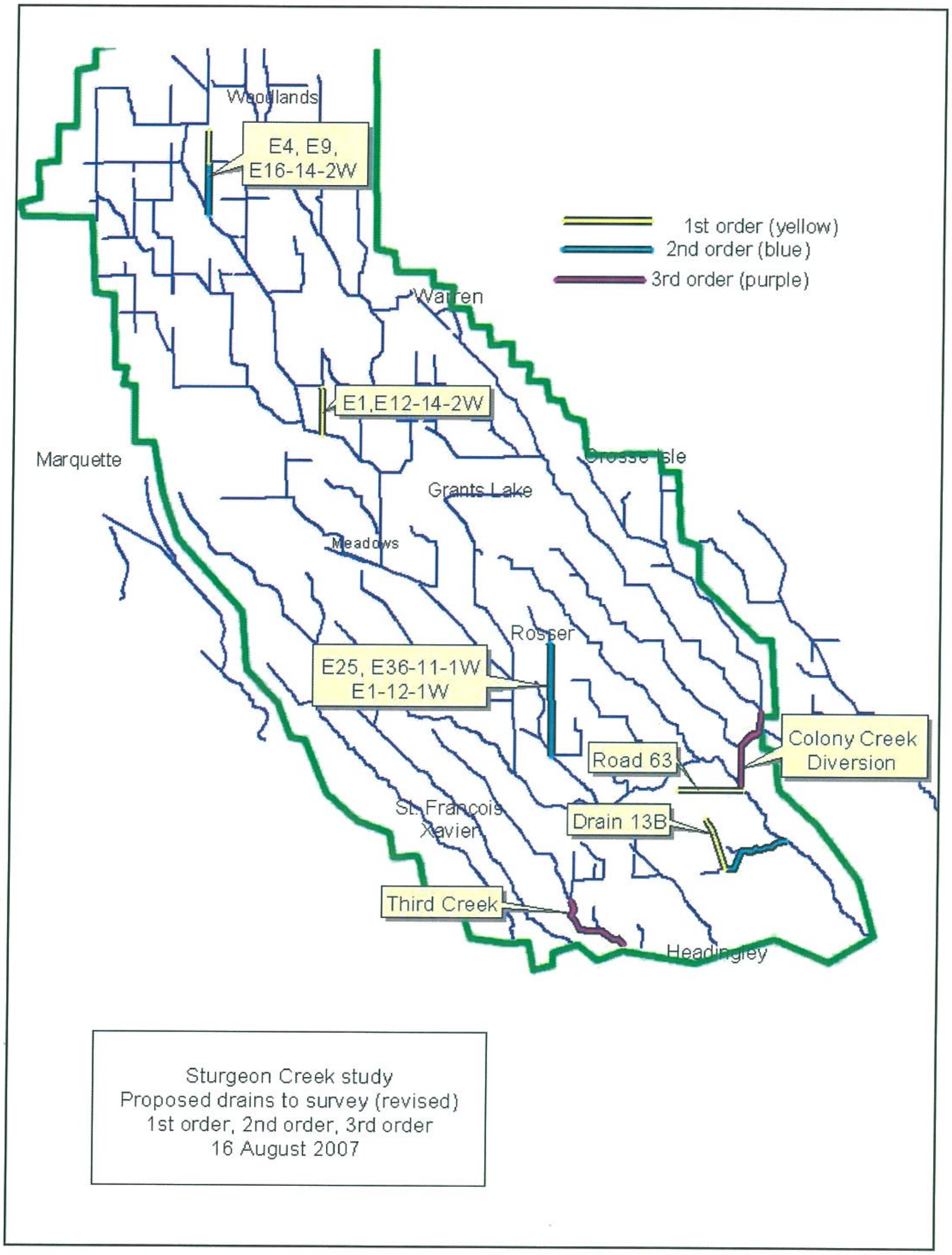


Figure 3.7.1 - MWS Selected Survey Locations (B. Lussier email October 4, 07)

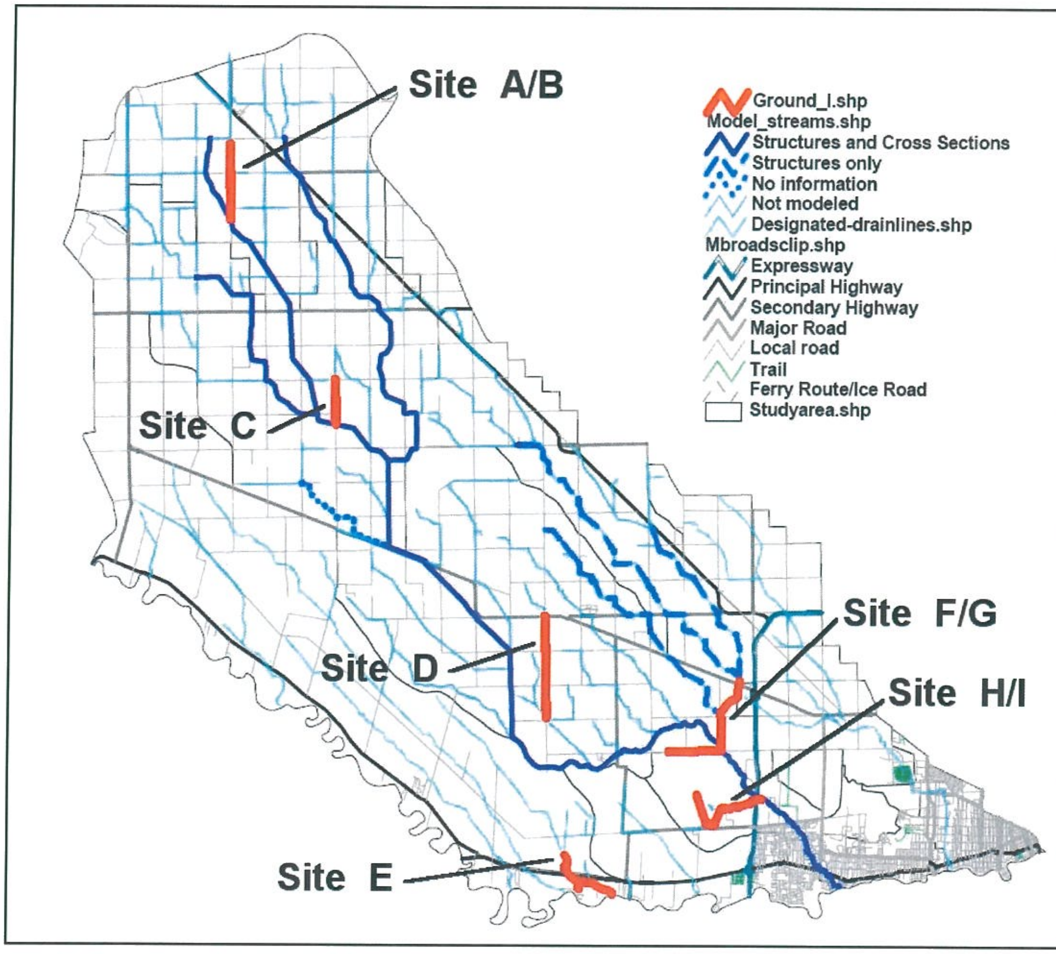


Figure 3.7.2 - AECOM Survey Locations by Site ID

AECOM modeling staff travelled to the field on three occasions to gather data from the rural municipal offices, gain familiarity with the catchment terrain and review general drain condition. Field trips were made on May 1, May 15 and October 4, 2007.

AECOM surveyed profile and cross section information for 15 miles of drain (locations shown on Figure 3.7.2). The AECOM survey team measured the profile at 100m interval, collected cross section at 400m intervals and measured culvert size and length at all culvert crossings. The ditch cross sections included lateral dike and road centreline elevation.

Hand-held Global Positioning Satellite (GPS) was used to collect plan coordinates in UTM Zone 14. Geodetic elevations were surveyed with Total Station using known culvert inverts or published benchmark information.

AECOM field records for each crossing were collected, processed and entered into a GIS model. Aerial photographs were used for visual analysis of AECOM survey locations. Photos and annotations on culvert type, end-treatment, flow obstruction by debris and other general condition comments were collected for delivery to the provincial records as part of the project.

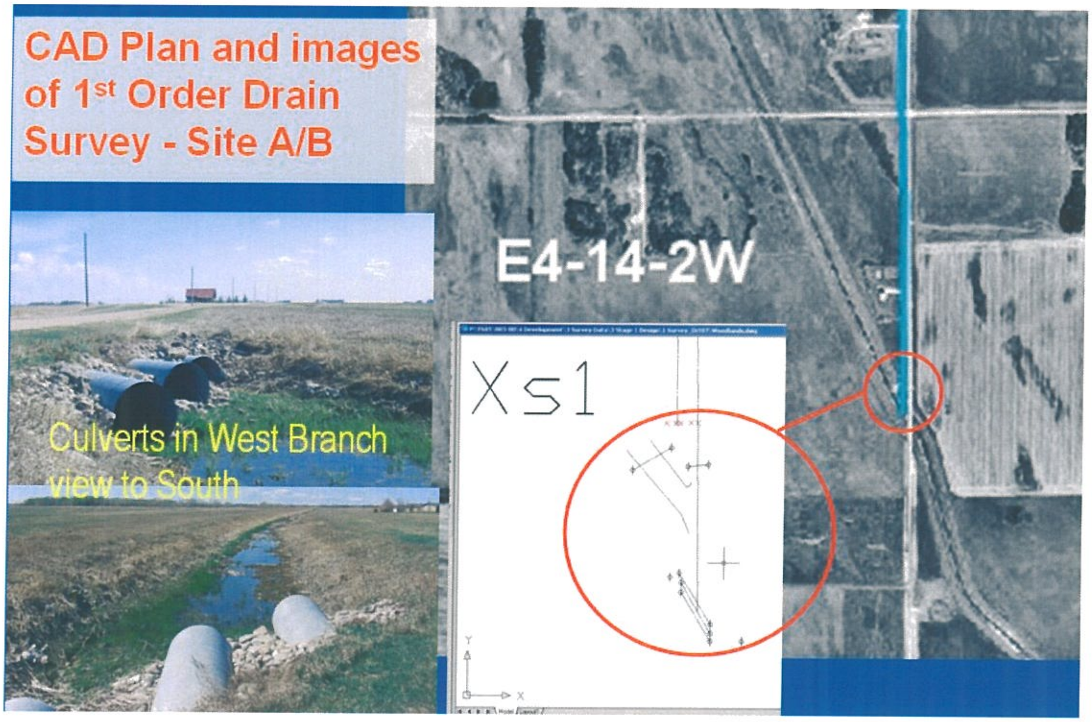


Figure 3.7.3 - AECOM Survey Sample - Site A/B

The AECOM survey data collection facilitated generation of ditch profiles and cross sections for each reach of ditch. This profile and section plotting allowed preliminary analysis of typical first, second and third Order drain condition and an estimate of maintenance required to restore drainage to the design condition. Details of this analysis and the extrapolation of these estimates into the watershed are described in Economic Analysis Section 9.0.

3.8 Historic Flooding information

Historic flood data was collected by AECOM staff at critical TAC meetings. Local members of the TAC described their recollection of historic flooding both in terms of typical and extreme events. This anecdotal information (as shown on Figure 3.8.1) was collected on large format watershed maps and scanned and processed into GIS tables for use in calibration and for archival purposes. Differences in flooded area reported and modeled may be due to observer's recollection of events, variation in rainfall event and distribution, errors in the extent of estimated flooding conditions, gaps in the geographic representation and the limitations of modeling.

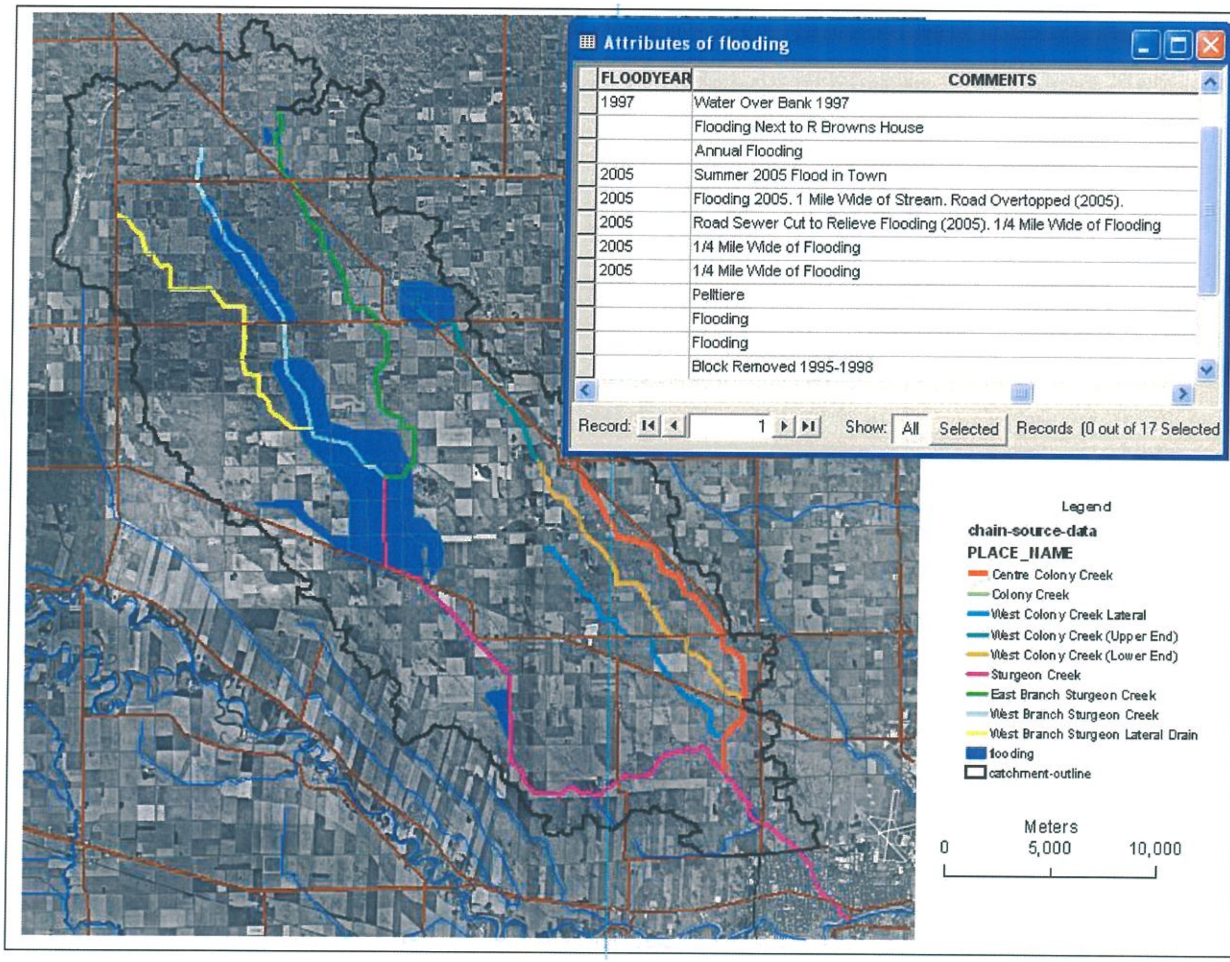


Figure 3.8.1 - Historic Flooding Anecdotal Record

3.9 GIS Data Organization

A watershed scale project requires efficient organization and distribution of data to facilitate accurate modeling and analysis. The organization of various forms of data into GIS provides efficient access to many users and allows for uncluttered updating as new or better information is made available.

AECOM GIS specialists developed spreadsheets and database files to catalogue and record all geospatial information. All geospatial information collected during the data gathering exercise was processed and compiled in GIS format using ESRI ArcView files. Figures illustrating data such as soil, land-use and contour information were shown in previous sections.

Locations of all culverts, bridges and other crossings in UTM coordinates are tabulated in Table 2 Appendix C and shown in Figure 3.9.1.

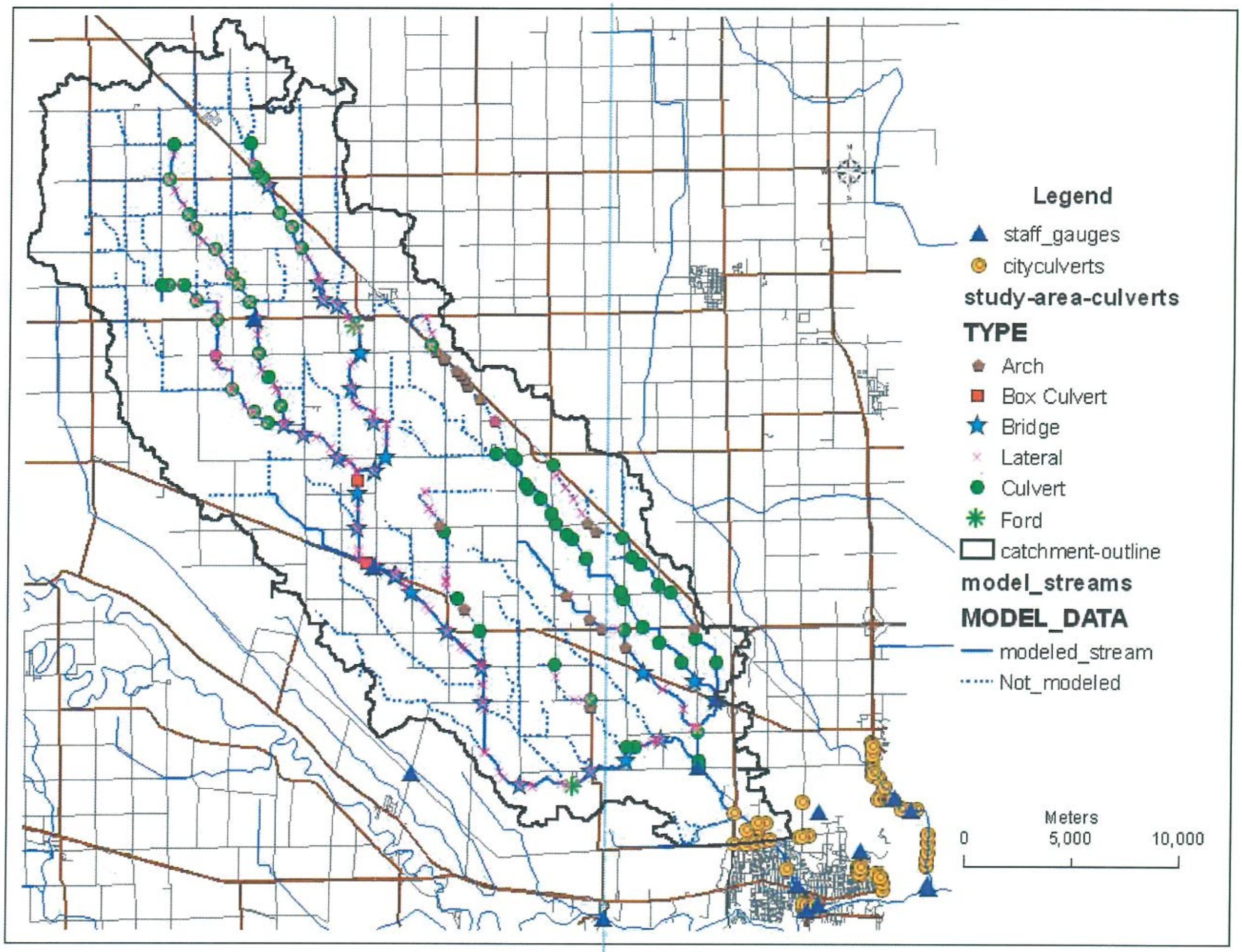


Figure 3.9.1 - GIS Record of Crossing Structures

A GIS database tool containing the inventory information including the drain locations and attributes as well as crossing and all survey data was developed by AECOM.

3.10 Hydrometric Data Sources

Sturgeon Creek hydrometric data was obtained from Environment Canada. Two sets of data were available: Sturgeon Creek at St James (#05MJ004); and Sturgeon Creek at West Perimeter Highway (#05MJ011).

Environment Canada archives provided Sturgeon Creek rainfall data. Rainfall gauges were available at Grosse Isle, Marquette, Stony Mountain, and the Winnipeg International Airport. Gauge locations are shown in Figure 3.10.1.

TAC members from the farming community delivered rainfall records collected in past years. These measurements were used to understand provide perspective on the aerial distribution of recorded events.

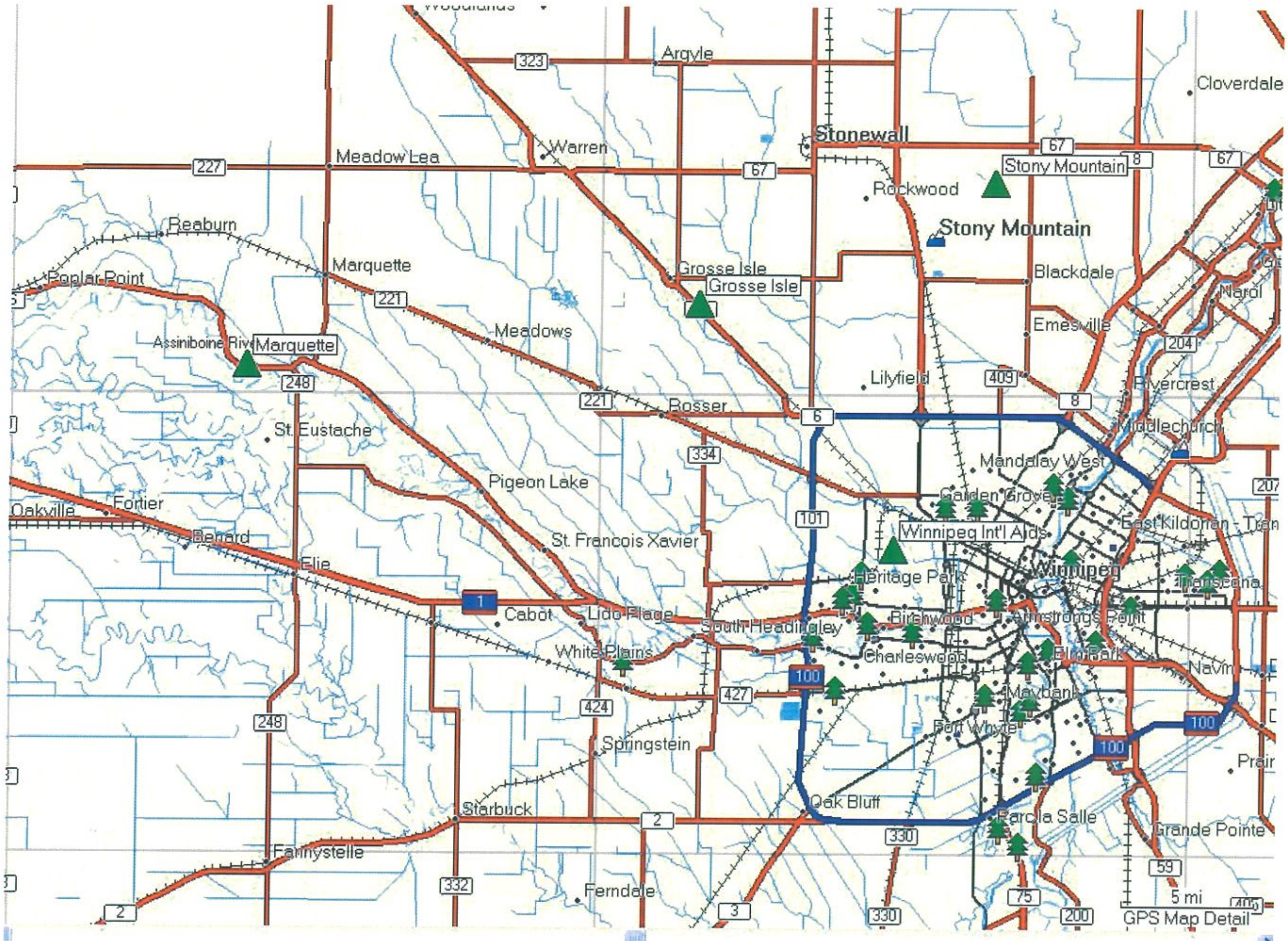


Figure 3.10.1 - Local Rainfall Gauge Locations

4. Hydrologic and Hydraulic Analysis

Due to the natural interdependence of the models to analyse an entire watershed, both the hydrologic and hydraulic models must be developed at the same time. The hydrologic inputs are modified by the hydraulic conveyance to produce an observed flow and corresponding water level at gauging locations. In addition, a significant amount of primary analysis must take place to understand the watershed before either model is developed. This includes developing an understanding of the relationship between rainfall volume and runoff volume, the observed stream flow statistics and identifying data gaps where data must be estimated.

4.1 Flow Frequencies

The frequency of flood events for the Sturgeon Creek watershed have been analysed by Manitoba Water Stewardship as part of a routine programme of developing regional runoff formula. The statistics for the Sturgeon Creek gauges computed from flow data collected by Water Survey of Canada (WSC) are presented in Table 4.1.1. The flows for the St. James station are in the process of being reviewed due to a potential inaccuracy in the computed flow rates. This did not affect the study as the data from the upstream station at the Perimeter was used for model calibration.

Table 4.1.1 - Provincial Regional Method Discharge Parameters and Flows (m^3/s)

STATION NAME	STATION NUMBER	PERIOD OF RECORD	GROSS AREA Sq. Km.	1% Q C	2% Q C	3% Q C	5% Q C	10% Q C	20% Q C	30% Q C	50% Q C
Sturgeon Creek	05MJ011	1960 - 2004	538	110.2	91.2	80.6	67.8	51.3	36.0	27.5	17.2
At Perimeter		(1960-66 Qs adjusted for diff D.A.)		0.898	0.743	0.657	0.552	0.418	0.293	0.224	0.140
Sturgeon Creek	05MJ004	1961-2003 R,2004 M 1960 U	568	124	105	94.6	81.2	63.3	45.8	35.8	23.1
At St. James		(1960-66 Qs adjusted for diff D.A.)		0.969	0.820	0.739	0.634	0.494	0.358	0.280	0.180

The stream flow statistics are computed using the largest observed flow in each year. This frequency analysis is called the annual series flow frequency and does not reflect the frequency of summer events. Table 4.1.2 lists the six largest observed flow events. These are all spring events as is common for larger watersheds in Manitoba.

Additional analyses of flow frequency were completed using stream flow data obtained from the Environment Canada web site. Two sets of data were downloaded, one for Sturgeon Creek at St James, (stream gauge #05MJ004) and the other at Sturgeon Creek at West Perimeter Highway (#05MJ011).

Data obtained for Sturgeon Creek at St James was available for 45 years from March, 1961 to October, 2005.Data for Sturgeon Creek at Perimeter Highway was only available from March 1978 to June 1994 for a total of 16 years. Both data sets consisted of daily water level and flow, with few interruptions in the record. Data was analyzed for both the annual and a partial duration summer series. Analysis results are summarized in Figures 4.1.1 and 4.1.2 respectively. Sturgeon Creek at St. James flows are the unadjusted WSC flow records.

Table 4.1.2 - Observed Storm Events at Sturgeon Creek Gauges

	Sturgeon Creek at St. James (05MJ004)		Sturgeon Creek near Perimeter Highway (05MJ011)		05MJ004 as % of 05MJ011
	Drainage Area = (km^2)	556	Drainage Area = (km^2)	524	106%
Year	Peak Flow (m^3/s)	Date	Peak Flow (m^3/s)	Date	
1974	82.7	Apr 21	-	not recorded	
1979	63.2	Apr 24	52.7	Apr 23	120%
1987	60.2	Apr 09	53.6	Apr 08	112%
1993	54.2	Aug 10	41.0	Aug 10	132%
1986	52.5	Apr 02	40.4	Apr 01	130%
1983	43.7	Apr 06	35.9	Apr 05	122%

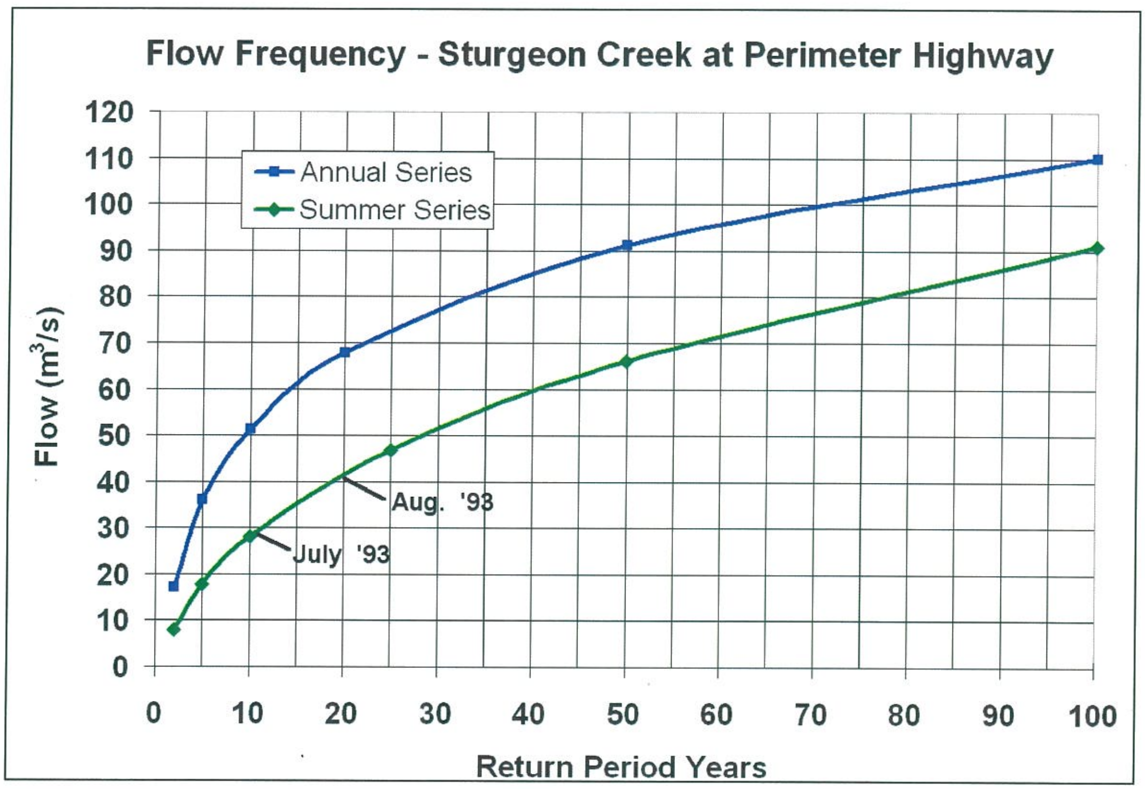


Figure 4.1.1 - Flow Frequency for Sturgeon Creek at Perimeter Highway (#05MJ011)

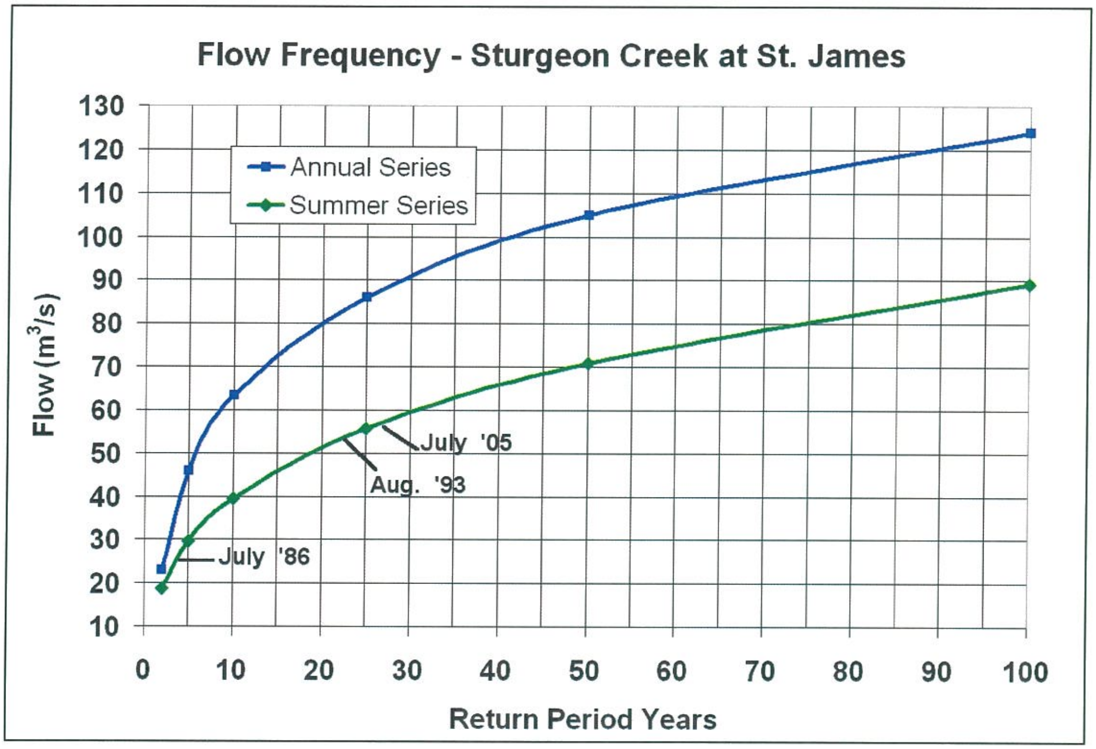


Figure 4.1.2 - Flow Frequency for Sturgeon Creek at St. James (# 05MJ004)

5. Hydrologic Model

5.1 Introduction

The goal of hydrologic modeling is to represent the precipitation and runoff from sub-catchments as point source inputs to the hydraulic model. Simulated inflow hydrographs are used as the upstream boundary conditions for the hydraulic model. The hydraulic model performs stream flow routing and the resultant modeled water levels and volumes are compared with stream gauge records collected following historic storm events to calibrate the hydrologic model output.

A watershed hydrologic model was developed to allow the response from rainfall events to be simulated and input to the hydraulic model. This required developing a conceptualization of the watershed, selection of rainfall events to be simulated and generation of inflow hydrographs.

The watershed was divided into 33 sub-catchments ranging from 2.7 km^2 to 50.5 km^2 using HEC-GeoHMS software. Estimation of inflow hydrographs for the MIKE11 hydraulic model was achieved through a combined application of AECOM-developed tools and HEC-HMS software.

The individual sub-catchment characteristics of drainage areas, slope and drainage lengths were computed and used to determine the time of concentration and the shape of the inflow hydrograph. Inflow hydrographs for the MIKE11 model input were developed by the use of the SCS Dimensionless hydrographs.

The ratio between runoff volume and observed rainfall volume was used to compute the runoff coefficient. This could be used to compute the runoff volumes as a result of a precipitation event. This was not an exact relationship as antecedent conditions play an important role in determining the runoff volume.

The influence of antecedent conditions can be demonstrated by two events in 1993. The July 1993 rainfall event recorded at Grosse Isle occurred from July 24th to 26th with daily precipitation amounts of 8mm, 63mm and 37mm. This gave a total precipitation of 108mm as rainfall depth and produced a 29.3 m^3/s flow at the Perimeter gauge. An event of this magnitude can be expected to occur once every 12 years based on the summer series flow frequency.

The August 8, 1993 event which occurred less than two weeks later fell on a wet if not saturated watershed that had not fully recovered from the July event. This had only 80 mm of precipitation but produced a flood with 41.0 m^3/s flow at the Perimeter gauge and produced a flow that would be expected to occur once every twenty years based on the summer series flow frequency.

This was evidence of how critical it is to select the right summer events for simulation to understand the watershed response. To the extent possible, the stream flow events selected were single events (even if they occurred over several days) that occurred on a dry watershed.

Inflow hydrographs were developed for the July 24th to 26th, 1993 event and July 8th to 12th, 1986 event for use in calibration of the dynamic model.

5.2 Sub-Catchment Delineation

A significant component of hydrologic model success lies in careful delineation of sub-catchments. Catchment delineation was based on the MWS drainage network definition as shown in Figure 3.2.1. The existing stream network was overlaid onto the DEM to influence the development of flow concentration to the stream network within the study area.

Sub-catchments were defined by HEC-GeoHMS based on the drainage network and available topographic data. Contour maps from a coarse provincial DEM formed the topographic basis for the catchment delineation. Figure 3.3.1 illustrates the watershed topography. Man-made structures like roads and ditches also affect sub-catchment boundaries. The HEC-GeoHMS computer model developed numerous sub-catchments which were aggregated to form the thirty three sub-catchments. Figure 5.2.1 illustrates the Sturgeon and Colony Creek sub-catchments with area expressed as square kilometres.

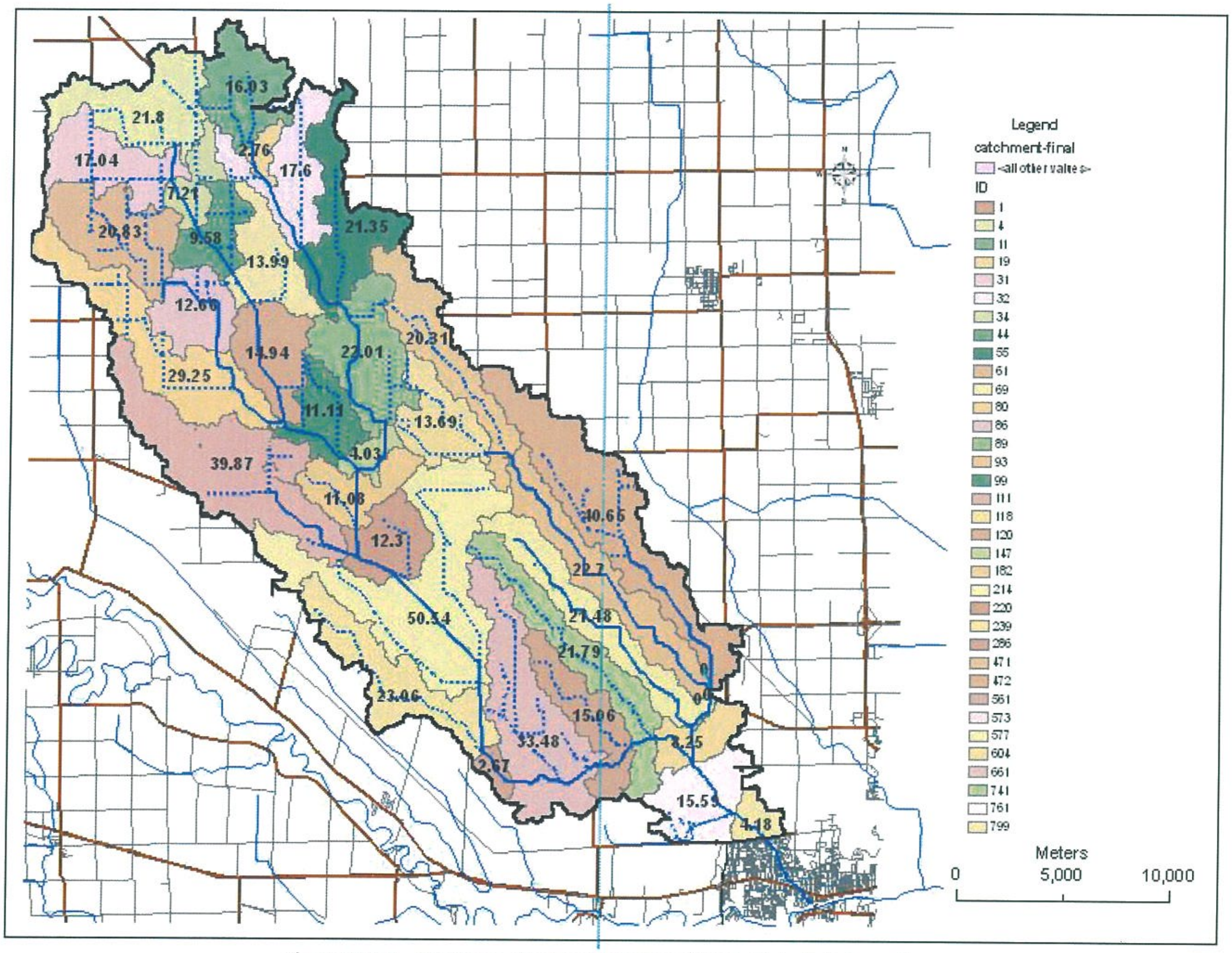


Figure 5.2.1 - Sturgeon Creek and Colony Creek Sub-Catchments

In general, one sub-catchment was developed upstream of the upper end of each tributary and a second sub-catchment was defined lateral to both sides of the tributary. These lateral catchments were bounded by the upper catchment and by the downstream confluence of the tributaries. Computerized catchment results were compared to catchments delineated by visual review of topographic data. A reasonable match was found between manual and computerized output, increasing modeler confidence in the computer output.

5.3 Sub-Catchment Hydrologic Characteristics

Hydrologic characteristics were extracted from the sub-catchments based on the GIS polygons and available geo-spatial data. Sub-catchment characteristics of: area; channel length; average basin slope; soil type; and land use were used to compute the time of concentration and SCS curve number. Sub-catchment drainage area, slope and drainage length were used to determine the time of concentration and the shape of the inflow hydrograph. Sub-catchment shape and aerial extent and location of storage also influenced timing of peak runoff.

Sub-catchment hydrographs require rainfall amounts for a known storm event. The two selected rainfall events were the July 1993 and July 1986 events. The July 1993 rainfall event recorded at Grosse Isle occurred from July 24th to 26th with daily precipitation amounts of 8mm, 63mm and 37mm on respective dates. This gave a total precipitation of 108mm as rainfall depth.

Flow observations were analyzed at the Sturgeon Creek near Perimeter gauge. Event runoff volume was computed and converted to runoff depth. This gave an equivalent net excess rainfall amount of 30.3mm which was used to generate the inflow hydrographs. The July 1993 rains produced a peak flow of 29.3 m^3/s at Sturgeon Creek at Perimeter Highway gauge.

The July 1986 event occurred from July 10th to 12th and had daily precipitation amounts of 70mm, 10mm and 4mm on respective dates. This resulted in a total precipitation of 84mm as rainfall depth. The equivalent net excess rainfall amount was 21.3mm. The July 1986 rains produced a peak flow of 26.8 m^3/s at Sturgeon Creek at Perimeter gauge.

5.4 Hydrograph Timing

Time series information was required as an input to the hydrologic model. The start of hydrograph timing was taken from precipitation data collected at local rain gauges. The duration or time base of the hydrograph was determined from catchment characteristics.

Hydrographic model processing used time of concentration developed by the USGS[3] SCS method as the basis of sub-basin timing. Sub-regional analysis considered downstream elevation, longest flow path, length of stream and SCS curve number. Verification by manual checks and equations confirmed the programme timing output was reasonable.

[3] *USGS – United States Geological Survey*

5.5 Hydrograph Calibration

Hydrologic Excel model developed by AECOM produced thirty three hydrographs representing upstream and lateral inflows which were routed through the network of tributaries in the MIKE11 model. Stream flow routing was performed in the MIKE11 hydraulic model where water levels and volumes could be compared with stream flow records from historic storms. Through this iterative process, the hydrologic model was adjusted to produce discrete sub-catchment hydrograph inputs for the modeled rainfall events.

A sample of sub-catchments were analysed using HEC-HMS to confirm that the spreadsheet-based hydrologic model was computing runoff response accurately. MIKE11 model results and observations at the Perimeter Highway stream gauge appeared reasonable.

The Sturgeon Creek watershed has stream flow records at two gauges. These gauges collect level information at Sturgeon Creek near the West Perimeter Highway (05MJ011) and at Sturgeon Creek at St. James (05MJ004). The runoff records from the 1986 and 1993 events were used in calibration of the combined hydrologic and hydraulic models.

6. Hydraulic Model

6.1 MIKE11 Introduction

The MIKE11 hydrodynamic model requires inputs representing the physical geography including the stream network complete with road crossings and natural obstructions and topography representing the floodplain under extreme events. The model used runoff hydrographs and computed downstream river levels (normal depth) as the boundary conditions. Hydrographs developed by external tools (as described in Section 5), were entered into the hydraulic model as time series files.

The development of any MIKE11 model is a multi-step process involving collecting available data, constructing a representative model, calibrating the model by running known inputs and comparing model outputs against observed measurements. Verification is accomplished in similar fashion by running an independent event and comparing modeled and observed results such as gauged river elevations. Following satisfactory model testing, selected event inputs such as the ten-year flood can be modeled to predict flooding under these conditions.

6.2 Model River Network

A physically realistic hydraulic model requires accurate representation of relevant tributaries and channel restrictions.

The Sturgeon Creek drainage network was generated from GIS shape files. The MIKE11 model extends from upstream limits to downstream of the Portage Avenue Bridge in the City of Winnipeg. The model structure is shown in Figure 6.2.1. The river network was modeled as six main streams, namely the Sturgeon Creek Main Branch, the East Branch Sturgeon, the West Branch Sturgeon, the West Lateral Sturgeon, West Colony and West Colony Lateral Creek. Additional smaller streams were also included in the model network, such as the Upper West Colony, Centre Colony, and Watershed 111.

After initial simulations, it was obvious that Sturgeon Creek has unusual hydraulic characteristics and it was thought that the presence of dikes along the main channels and flap-gated culverts on lateral drains may be part of the issue. The culverts through the dikes convey flows to the channel and may allow backup of flows into the lateral ditches and flood plain. Also during periods of high river levels, gravity drainage from lateral areas may be prevented from entering the river. High river stages would close the flap gates on culverts and temporarily force runoff into storage in lateral ditches and on fields.

Culverts lateral to the river channel on the lower half of Sturgeon Creek were modeled as flap-gated structures to prevent flow reversal from the river channel onto the flood plain. The actual number of flap gates (controls) was not provided comprehensively in drawings, so the number of flap gates was estimated based on the data available and their locations along the stream channels.

This by itself did not solve the modeling errors and numerous lateral drains were constructed in the model to represent the channels that discharge into the main channel through dikes on both sides of the main channel.

The lateral drains were constructed with length and shape characteristics representative of the storage volume available in the real ditches. Hydrographs were input to lateral ditches as distributed flows. Inflow hydrographs for each lateral drain were produced by dividing each sub-catchment runoff hydrograph by the number of lateral ditches. These could then be input as discrete point inflows.

These changes to the model allowed flood peak attenuation due to flood plain storage and a more accurate simulation of flow rates.

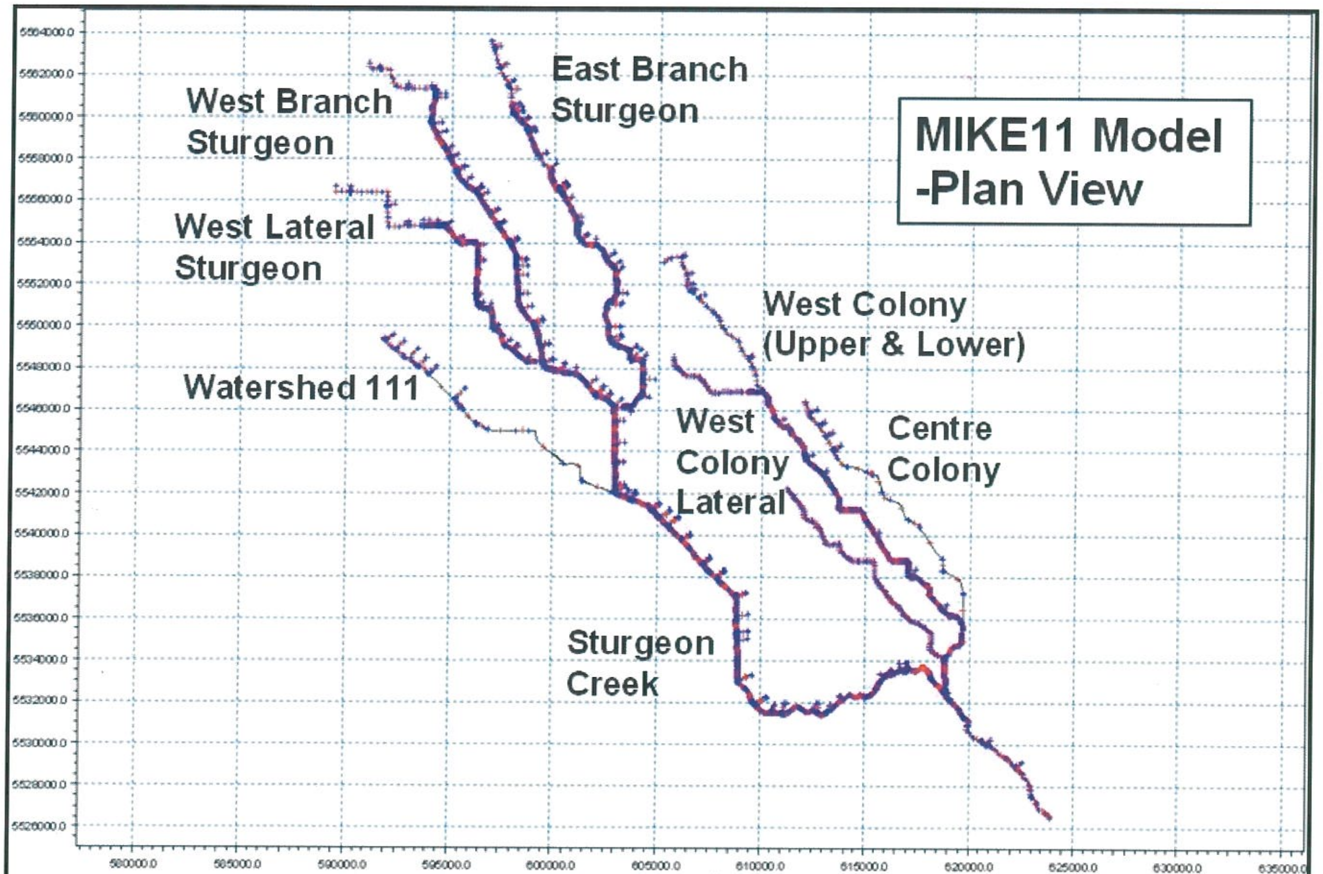


Figure 6.2.1 - Sturgeon Creek MIKE11 Model Network

The model network includes 481 culverts in total (including the laterals), 52 weirs and 33 bridges. Among the 481 culverts, 135 culvert sites are in the main channels and the remainder are in lateral ditches, West Colony Lateral, Centre Colony, Upper West Colony and Watershed 111. Roads along lateral drains may be over-topped during flood conditions. For this reason, all road crossings on the main channels (not including lateral drains) were modeled as weirs. The hydraulic flow and head relationships for all of these weir structures were calculated using the MIKE11 built-in function.

6.3 Model Cross Sections

Available cross sections for Sturgeon Creek branches were obtained from existing drawing data. The left and right levee bank levels were set to the dike elevation (when available) or to prairie level. Where a large distance existed between consecutive cross sections, additional MIKE11 cross sections were interpolated. The HEC–RAS model used by the Province and the City of Winnipeg at the downstream end of Sturgeon Creek was used to extract cross section data that were not available on the existing drawings.

Cross sections were only available for segments of Centre Colony Creek while other branches in the watershed only had elevation information presented on plans as bed profiles or culvert inverts. Cross sections considered typical of the Colony Creek topography were transposed to other Colony Creek sub-basin tributaries where no cross section data was available. Bed elevations on transposed cross sections were adjusted based on the elevation data available as either stream profiles or culvert invert elevations.

A cross section representing lateral drain characteristics was developed based on typical construction and applied in all lateral ditches. The downstream bed elevation in the lateral ditches was estimated to match culvert invert elevations and elevation changes were based on nominal basin slope and typical lateral drain length. The road elevation and associated weir crest for all main channel crossings was determined from existing maps and nearby cross sections. Bridge opening geometry was either entered from drawing data or estimated from the open-channel cross sections adjacent to bridges.

6.4 Model Boundary Conditions

The Assiniboine River water levels were found not to influence the water levels at points of interest due to the steepness of the downstream channel and the Sturgeon Creek channel characteristics downstream of Portage Avenue were used to compute the downstream boundary water levels. Flow boundaries were used for all other boundary locations.

A minimum steady state summer flow was run in the channels as an initial condition to prevent dry channel induced instabilities. The downstream flow rate for initialization was between 0.5 and 1.0 m^3/s, depending on the recorded initial condition for the calibration event.

6.5 Model Calibration

The MIKE11 model was calibrated to the 1986 and 1993 summer floods. The runoff for the 1979 spring flood was used as a proxy for the ten-year return period event. The calibration process began using steady state flows and static Assiniboine River levels for the boundary conditions. This allowed model calibration without the added complication of dry-channels potentially causing model instabilities or having to account for water leaving the channel into flood plain storage.

The Sturgeon Creek gauging stations West of the Perimeter Highway and near St. James (upstream of Sturgeon Road) were used to calibrate the model. The recorded water levels and discharges on the above stations for the July 1993 event (Q_p= 29.3 m^3/s at Perimeter) and July 1986 event (Q_p= 26.8 m^3/s at Perimeter) were selected to calibrate the model.

Figures 6.5.1 and 6.5.2 below illustrate the hydrographs simulated for the Sturgeon Creek near the Perimeter gauge compared with the 1993 observations. The simulations were within 1.0 m^3/s (3.5%) of peak flow rates and runoff volumes within 1%.

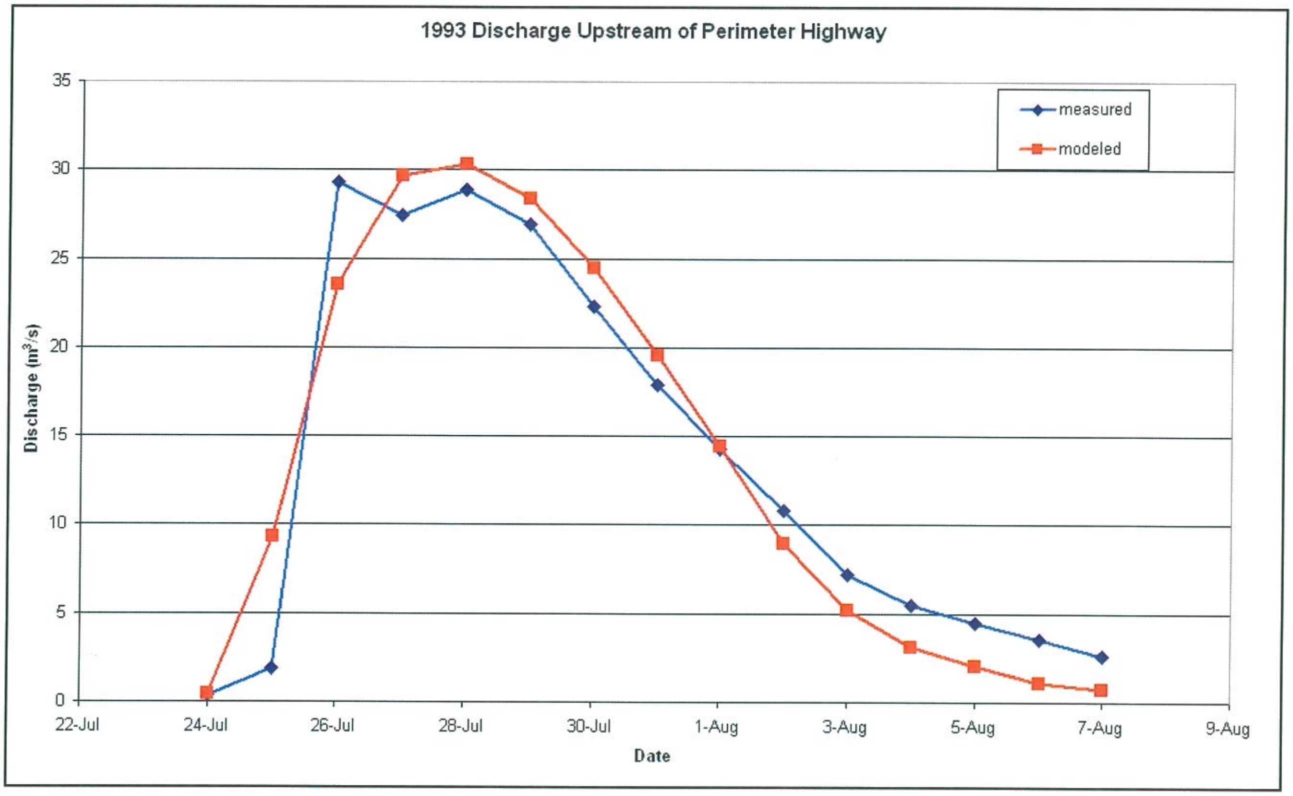


Figure 6.5.1 - Sturgeon Creek at Perimeter Hwy - 1993 Flow Hydrograph

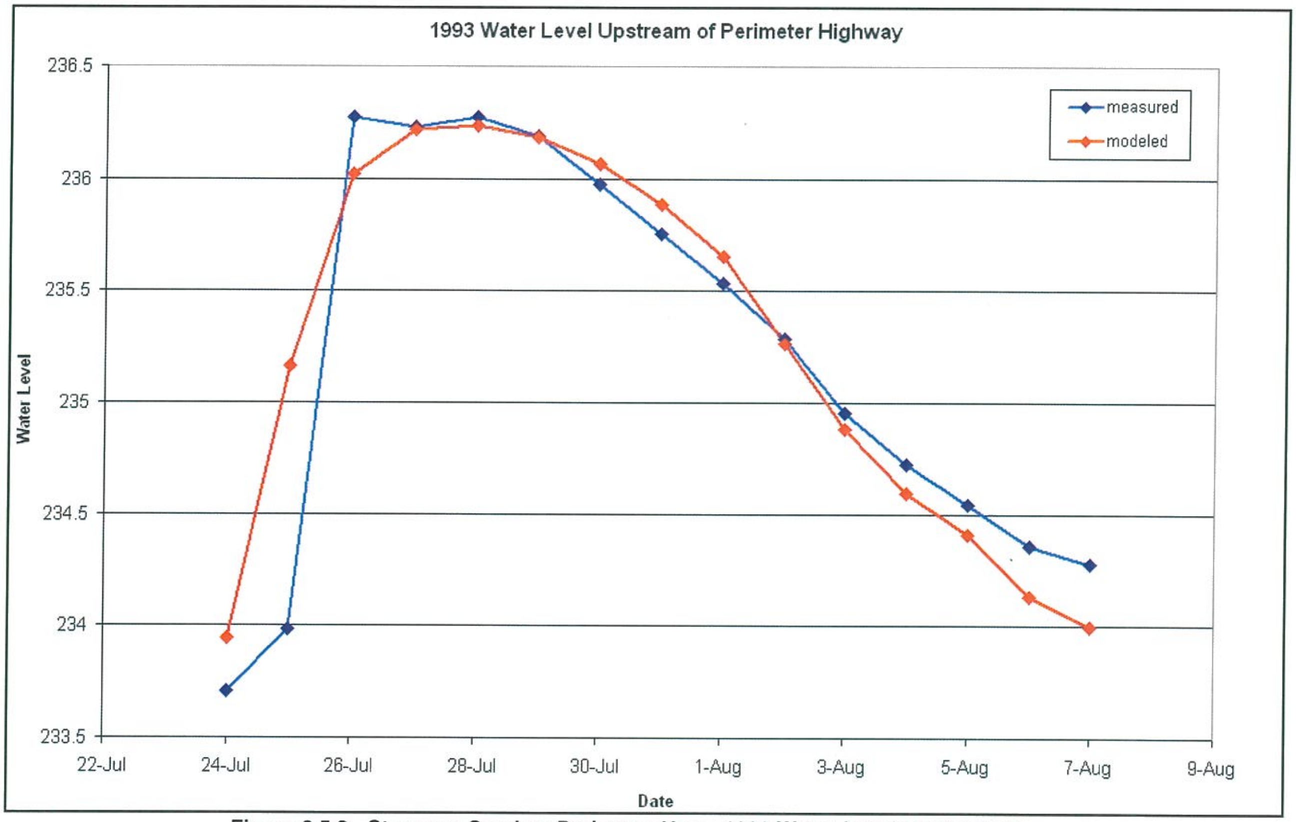


Figure 6.5.2 - Sturgeon Creek at Perimeter Hwy - 1993 Water Level Hydrograph

Sturgeon Creek flows for 1986 flows were available at both the St. James and Perimeter gauges however, water level data were not available at the Perimeter gauge for 1986. The MIKE 11 model under simulated peak flows for the Perimeter gauge by 1.8 m^3/s or almost 7% is shown in Figure 6.5.3. The MIKE11 model produced hydrographs were within 0.6 m^3/s (2.3%) of the peak flow rate and within 5.8% of the recorded runoff volumes at the St. James gauge. These results should be taken with some caution as the flow records for this gauge are under review. The model results illustrated at the St. James gauge are shown in Figures 6.5.4 and 6.5.5 below.

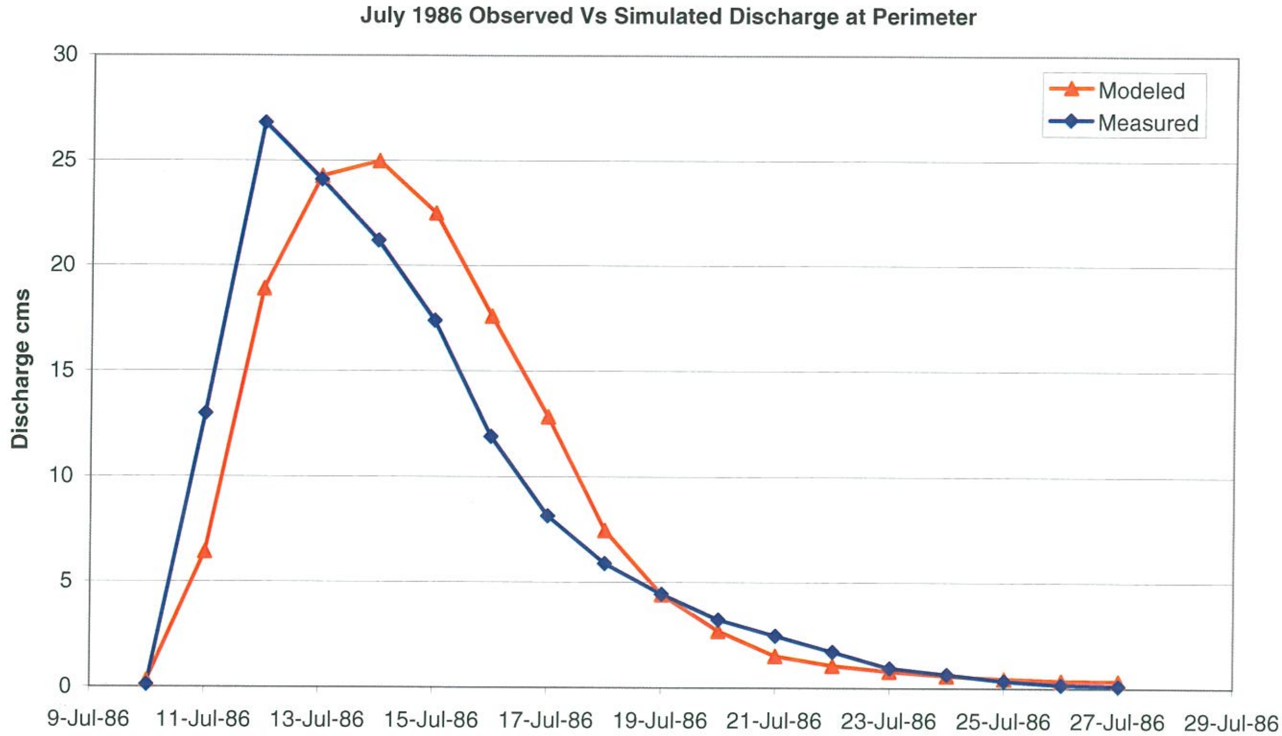


Figure 6.5.3 - Sturgeon Creek at Perimeter Hwy- 1986 Flow Hydrograph

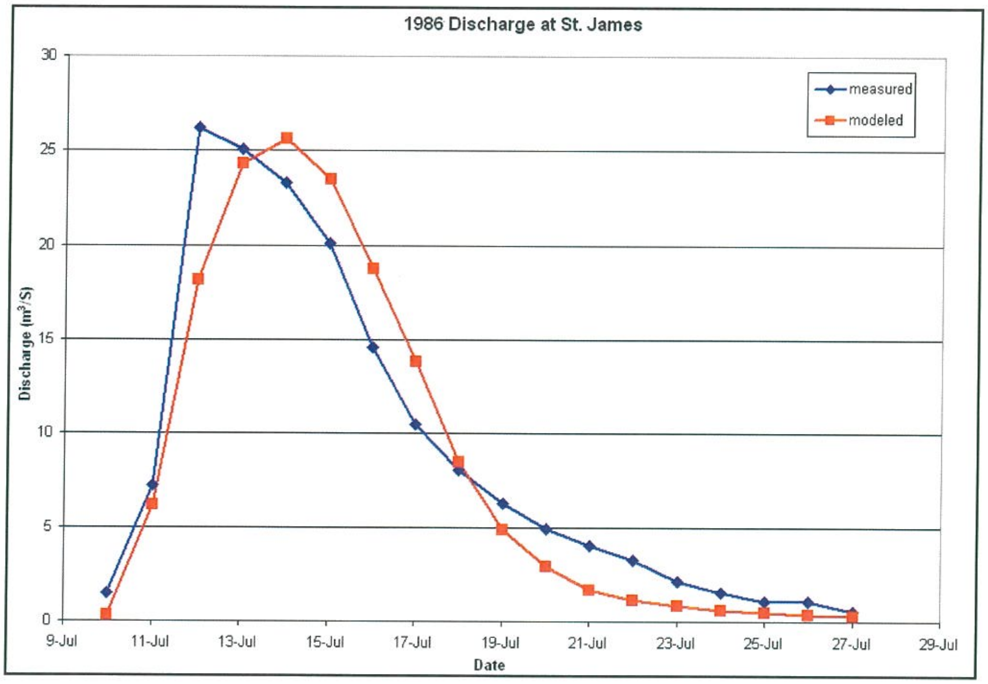


Figure 6.5.4 - Sturgeon Creek at St. James - 1986 Flow Hydrograph

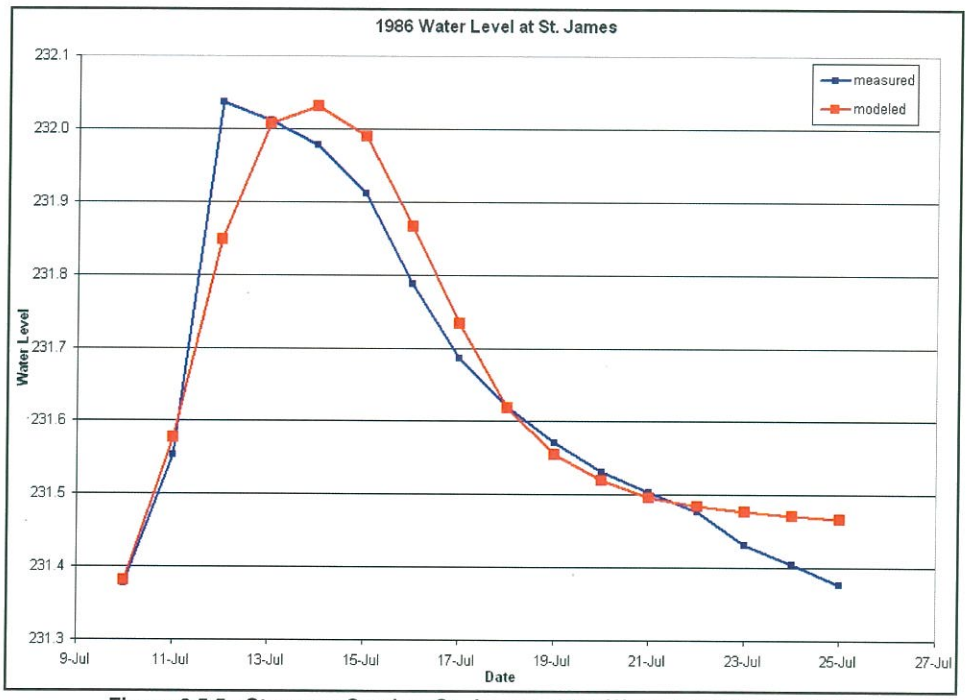


Figure 6.5.5 - Sturgeon Creek at St. James - 1986 Water Level Hydrograph

There have been questions about the accuracy of the simulations particularly with respect to the difference in timing between the observed and modeled hydrograph peaks. There are two explanations. The first is this may be partially due to the limitations of the hydrologic modeling. In both simulation years, the rainfall events simulated occurred over a few days but were input into the model as single events that must enter the streams through lateral drains. Although this is physically realistic, the estimation of this large number of structures introduces a potential inaccuracy into the model.

The second is that the hydraulics of the watershed was adjusted until the peak flows and volumes were reasonable for the intended purpose, which was to provide a tool to evaluate the relative performance of mitigation options. Changing the dimensions of all the lateral drains in the network in an attempt to get a more representative hydrograph was a very time consuming task. Modifications to the model stopped when reasonable results were achieved.

6.6 Results of Hydrologic and Hydraulic Model Calibration

The 1979 spring event was used as a proxy to find the excess net precipitation for the ten-year event. The ten-year event was chosen as the target "value-added" discharge that mitigation schemes were attempting to accommodate. The 1979 event was suitable due an observed peak that had a ten-year return period. This was a spring event and as such, the runoff depth was computed from the observed flows and used to develop inflow hydrographs for input into the MIKE11 model. The simulation produced flow peaks and volumes that were sufficiently close to observed flows that modelers were satisfied that an adequate simulation was achieved.

The 1979 flood yielded an effective rainfall depth of 105 mm and peak discharge of 52.7m^3/s. Simulated results for the 10% event are shown below. Figures 6.6.1 and 6.6.2 illustrate the 10% event (ten-year) hydrograph modeled at the Sturgeon Creek at Perimeter gauge.

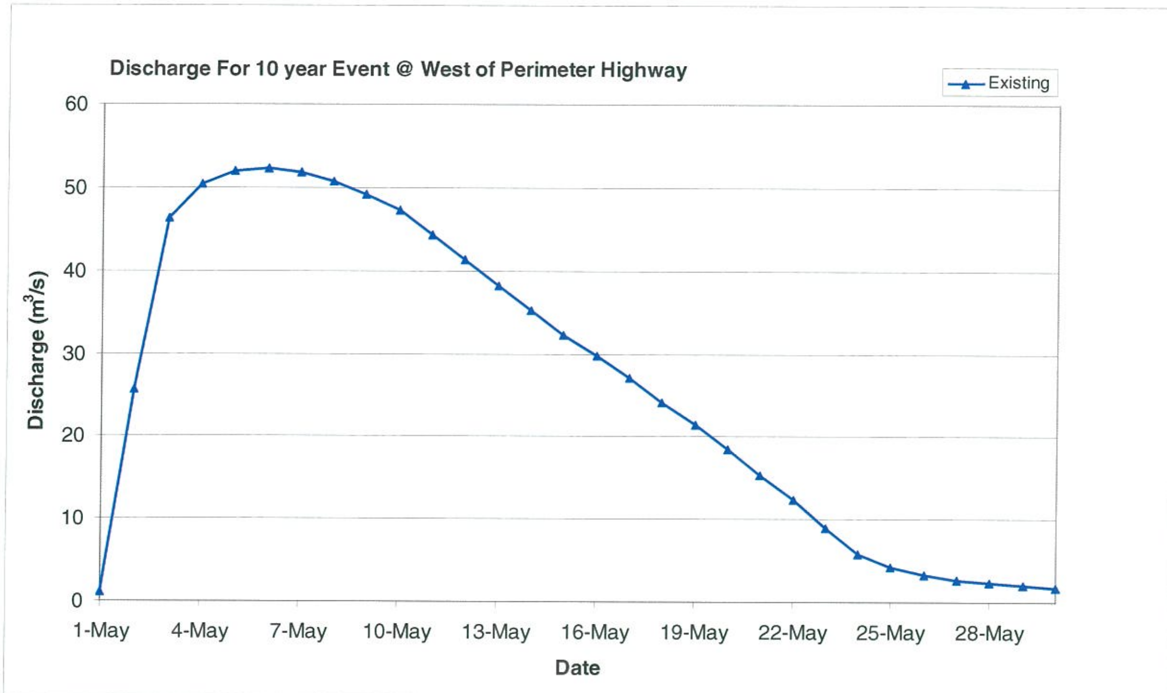


Figure 6.6.1 - Sturgeon Creek Flow Hydrograph – 10% Event

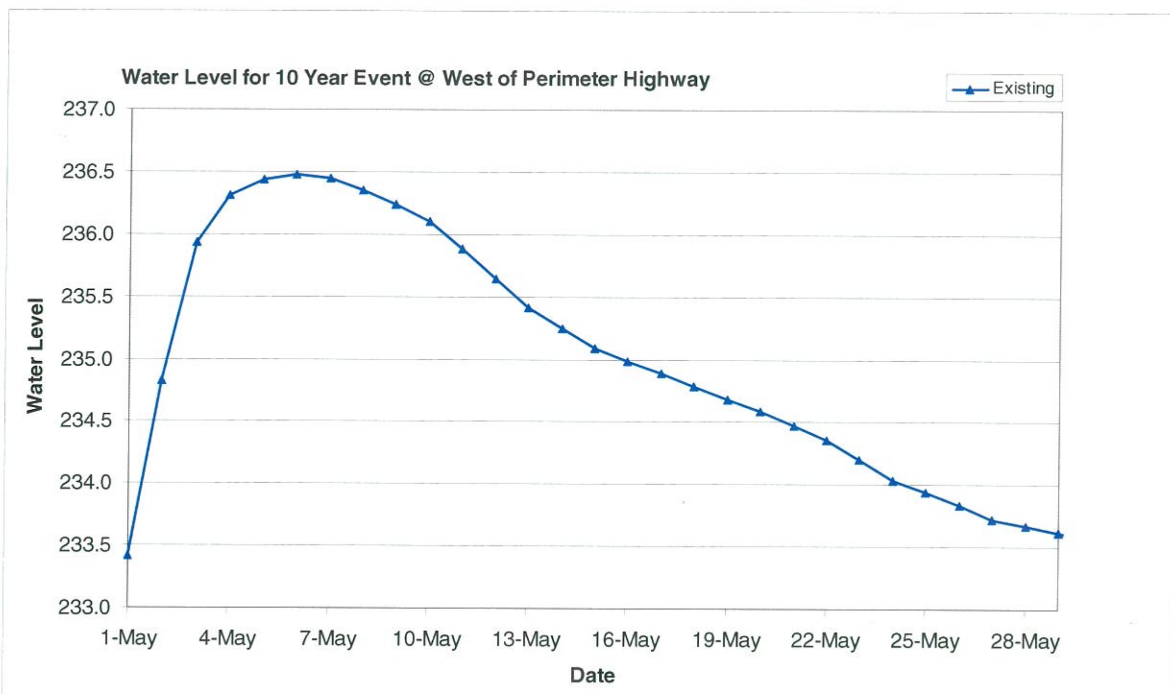


Figure 6.6.2 - Sturgeon Creek Stage Hydrograph – 10% Event

7. Flood Zone Maps

The MIKE11 model was run to simulate the flood zone for events with magnitude similar to the five-year (July 1993) and ten-year flood (spring 1979) events. The water level elevations at a given channel location or cross section were extrapolated beyond the lateral dikes onto the flood plain perpendicular to the channel to produce the inundation maps based on the available topographic information. This was considered a conservative estimate of the maximum extent of flooding. A better estimate was not possible without a more detailed land surface topography and explicit knowledge of the timing of lateral runoff peaks relative to the channel peak. A fairly course digital elevation model represented the flood plain.

Flood inundation maps were not available for the 1993 summer flood event. The anecdotal comments from Technical Advisory Council (TAC) members were considered the best records available for flood zone calibration. Figure 7.1 shows the areas of anecdotal flooding provided by TAC members at the March 2007 meeting. Many comments were related to the 2005 event, which had a recorded peak of 48.7 m^3/s at St. James, significantly larger than the 1993 event

The July 1993 flood (with a peak flow of 29.3 m^3/s at the Perimeter) is considered representative of the flood with a return period of slightly less than five years. Figure 7.2 shows the extents of flooding predicted by modeling the July 1993 event.

Flooding is only shown adjacent to modeled channels based on simulated water levels. In reality, other channels exist outside those modeled and additional flooding may be experienced which is not shown by the flooding model.

The MIKE11 Model was also run to simulate the 10% or ten-year rainfall event to estimate the extent of flooding. The existing condition model showed a maximum flooded area of 97.45 km^2 as shown on Figure 7.3.

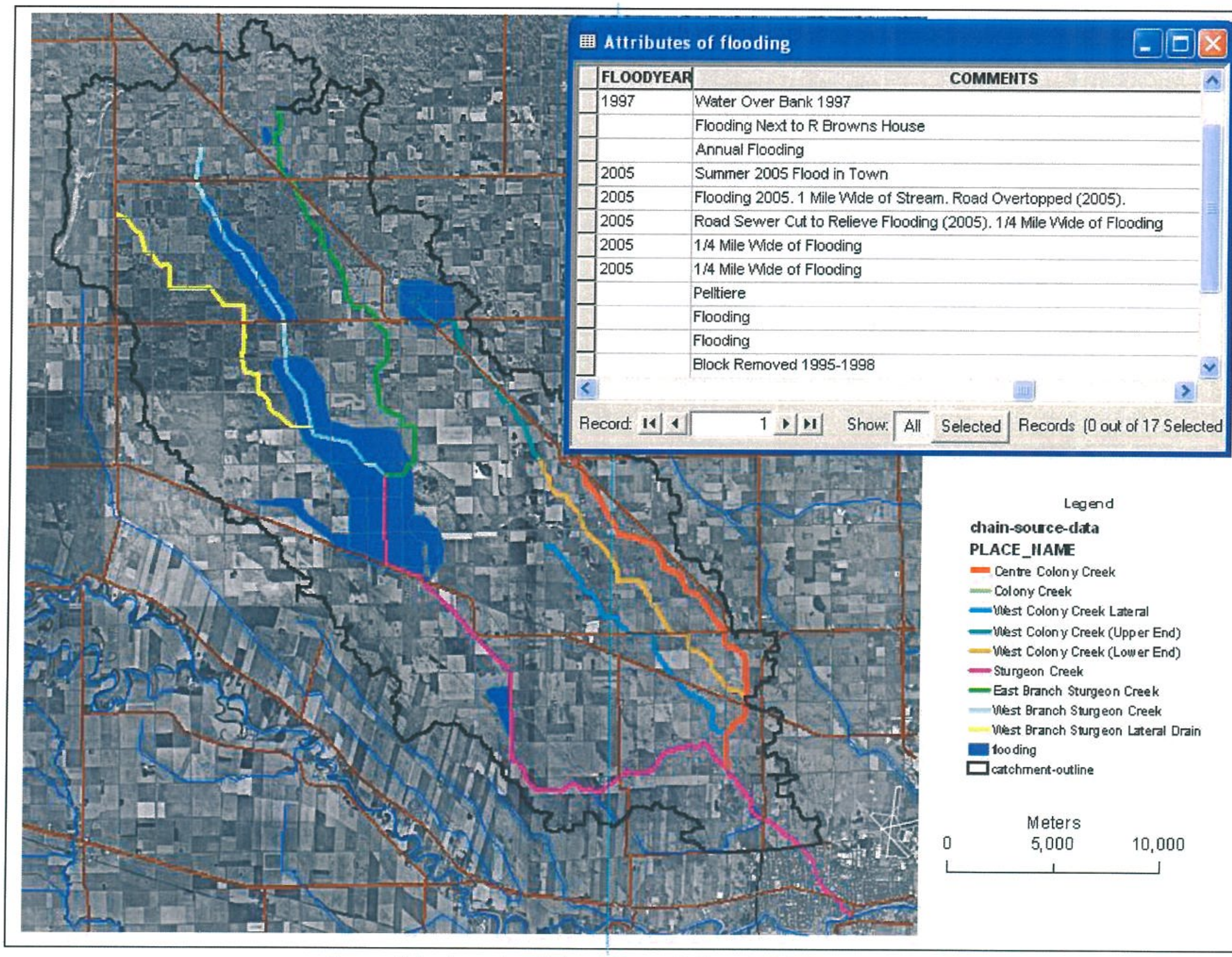


Figure 7.1 - Anecdotal Flood Record ***(from TAC Members)***

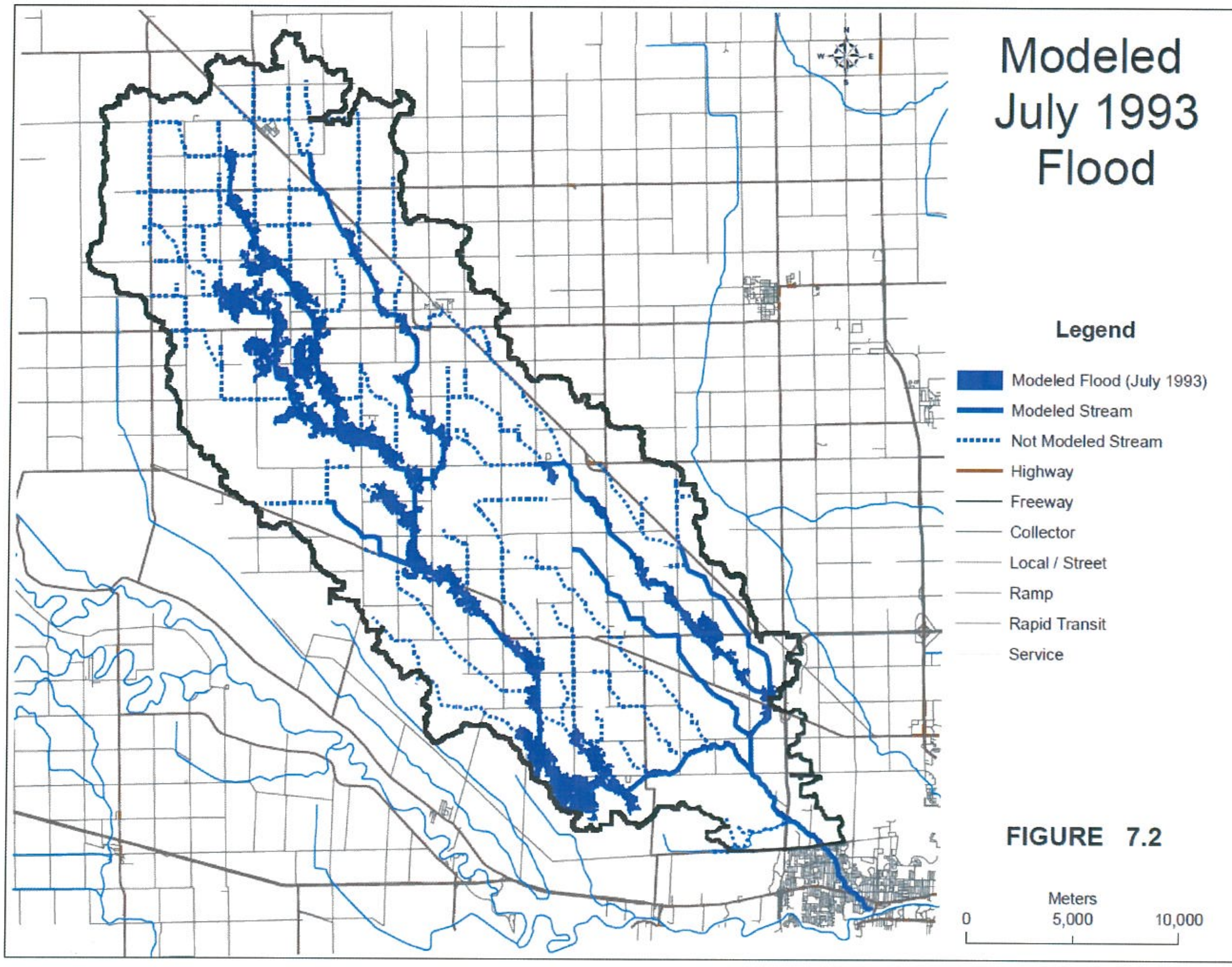


Figure 7.2 - Modeled Flood Inundation Map for 1993 (Q_p=29.3 m^3/s)

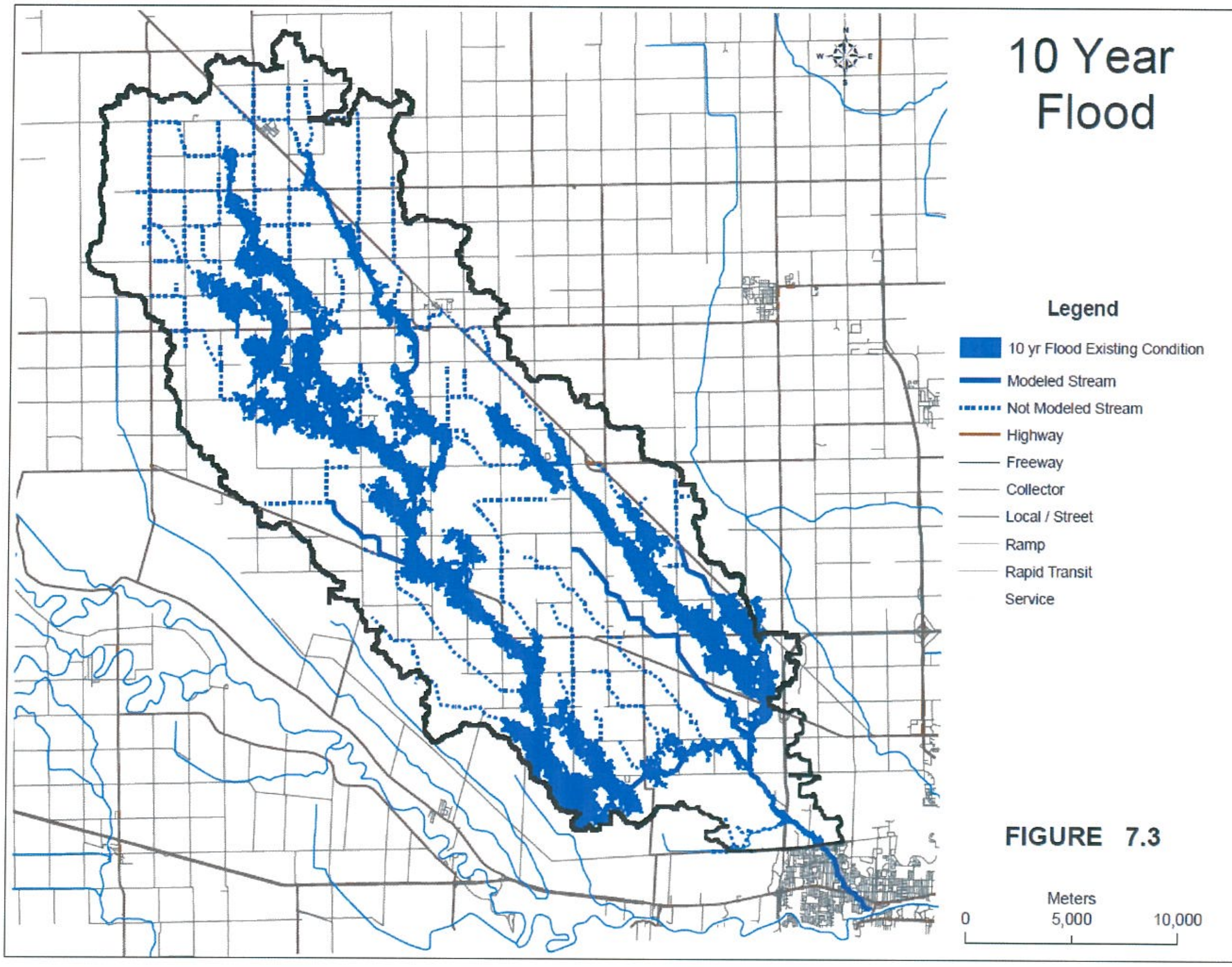


Figure 7.3 - Modeled Flood Inundation Map for 10% Event (Q_p=52.7 m^3/s)

8. Flood Mitigation Modeling

The geographic, hydrologic and hydraulic modeling tools were used to estimate the relative flood reduction from various mitigation options. Mitigation alternatives included three proposed diversion channel alignments, in-channel improvements such as upgraded hydraulic structures, and partial storage or detention of water in existing or proposed wetlands within the catchment.

Manitoba Water Stewardship suggested three diversion alignments as shown in Figure 8.1. These diversions were modeled and preliminary estimates generated for channel dimensions, excavation volume and cost of various diversion routes. Improved crossing structures (bridges and culverts) were conceptualized to determine the hydraulic improvement that could be achieved without diversion.

Preliminary cost estimates for each mitigation option are shown below with the mitigation description. Assumptions built into the estimated benefits are discussed in the Economic Analysis Section 9.

The ten-year flood was modeled with three different flood diversions and in-channel improvements in order to identify and compare the effectiveness of various flood mitigation alternatives. The concept of upstream storage was evaluated based on the available storage volumes in comparison to the required storage volume. The mitigation options included:

- Option 1 – Diversion to Assiniboine River via Fourth Creek and Halliday Road
- Option 2 – Diversion to Assiniboine River via Third Creek
- Option 3 – Diversion to Assiniboine River via the West Perimeter Highway
- Option 4 – In-Channel improvements (Bridge upgrades) – Downstream of the Perimeter Highway to Saskatchewan Avenue
- Option 5 – In-Channel improvements (Culvert and Bridge upgrades) – Upstream of the Perimeter Highway
- Option 6 – Upstream Storage

Diversions to the Assiniboine River were the mitigation option strongly favoured by local residents on the Technical Advisory Committee. The public perception was that a diversion to the Assiniboine River was the option promised by government in the 1960's and therefore considered most beneficial from an intuitive perspective.

Current opinion expressed by stakeholders, (based on what they believe were previous government commitments), suggested that a diversion should be sized to handle a flow equivalent to the Colony Creek watershed contribution for a ten-year event. This would require a hydraulic capacity in the order of 16.2 m^3/s, plus any ten-year event local flows intercepted along the diversion route to the Assiniboine River.

All diversions were modeled with capacity of 20 m^3/s to accommodate the highest of these local contributions and hydraulic structures through municipal roads were sized based on 20 m^3/s. Structures through Provincial Roads (PR) and Trunk Highways (PTH) were sized to handle the 20 m^3/s diversion plus the 50 year storm runoff from local catchments.

Diversion channels ranged in depth from 2 to 4 m below prairie to produce water levels below prairie and eliminate the need for dikes or freeboard considerations. The diversion channels were conceptualized with 15 to 20 m bases and 4:1 (H:V) side-slopes due to the nature of local soils and to facilitate maintenance of vegetated side slopes. Nominal bed slopes were 0.01 to 0.02% and produced diverted flow velocities in the range of 0.84 to 1.7 m/s.

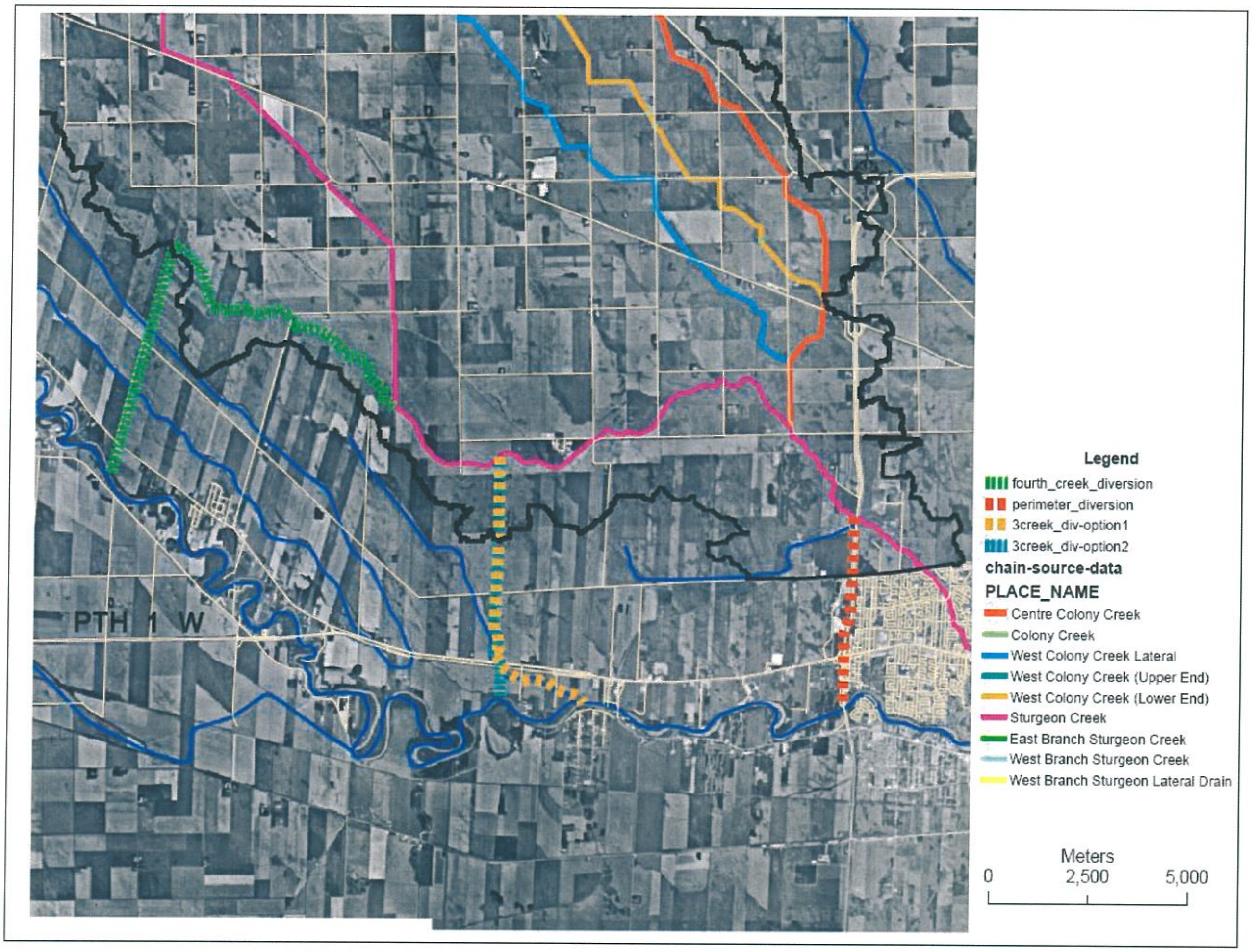


Figure 8.1 - Sturgeon Creek Diversions

8.1 Diversion via Fourth Creek

The Fourth Creek diversion would intersect the Sturgeon Creek in Section-Township-Range 24-11-1W. The total distance of Fourth Creek diversion was approximately 13 km. The Fourth Creek diversion consists of two portions. The first portion would require reverse grading Fourth Creek from the Sturgeon Creek confluence to a point 7 km upstream. The second portion runs south along the Halliday Road alignment 6 km to the Assiniboine River and intercepts both Second Creek and First Creek.

The proposed invert of the Fourth Creek diversion channel is 236.6m matching the existing elevation of Sturgeon Creek at the diversion intersection. Fourth Creek would be cut 0.8 m below existing bed inverts at the confluence and reverse graded at a 0.01% slope downstream to the Assiniboine River. This grade would cut through First and Second Creek below their existing bed elevations, so that grade control structures would be required to transition their flows into the diversion. This would also affect downstream First and Second Creek riparian flows. The proposed diversion channel bottom width is 20 m.

There are a total of 12 crossings in this proposed diversion alignment. Three of the major road / highway crossings are Rosser Road, Two Mile Road and PTH 26. The remaining nine crossings are farm access roads or driveways. Four 3.0 m diameter corrugated metal pipes (CMPs) are proposed to be placed in all crossings to convey the 19.7 m^3/s diverted flows.

This mitigation concept provides some local improvement of flooding in areas downstream of the diversion. The local benefit does not generally extended beyond 2 km upstream of the Sturgeon Creek confluence with Fourth Creek.

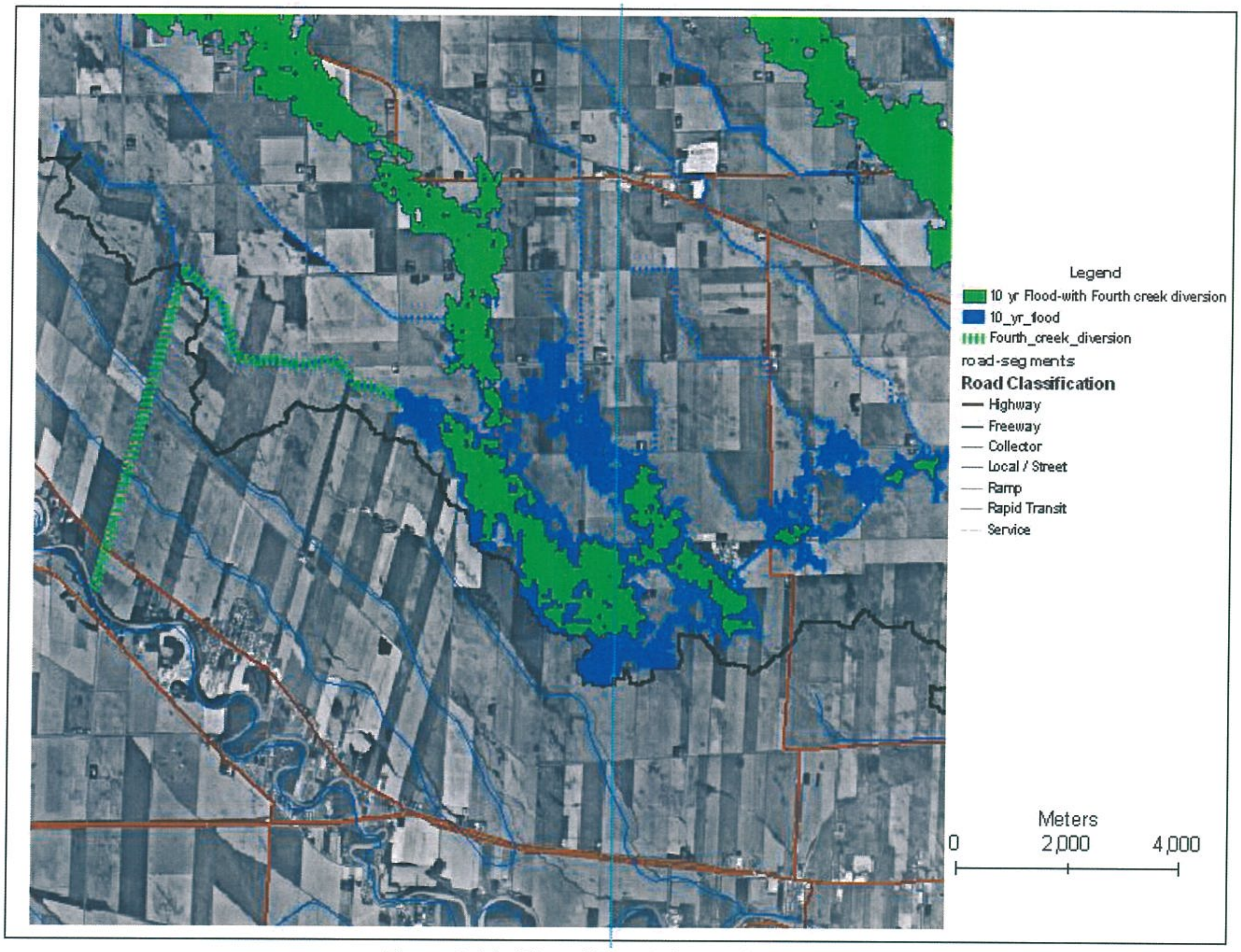


Figure 8.1.1 - Plan of Fourth Creek Diversion

The Fourth Creek diversion decreases downstream flooding due to reduced water volumes reaching lower reaches of Sturgeon Creek. Model results for the ten-year runoff event showed that the Fourth Creek diversion would reduce the flow in the downstream flow to 37 m^3/s and achieve a maximum reduction in flooded area of 13.4 km^2. There was a 0.78 m decrease in water level near the diversion and a 0.41 m decrease in the peak water level at the Perimeter Highway gauge. The hydraulic benefit (in the form of water level reduction) extended upstream of the diversion location but was less than 0.3 m at 1.5 km upstream and less than 0.15 m at 4 km upstream.

Department of Fisheries and Oceans (DFO) concerns were considered significant in this diversion concept. Water levels in the diversion channel under peak diverted flows are not elevated enough to provide for riparian flow in the upper reaches of the First and Second Creeks immediately downstream of the diversion route. Local inflows to lower reaches of these creeks would provide intermittent riparian flow. Such impacts on the fish habitat typically require compensation due to habitat alteration and destruction.

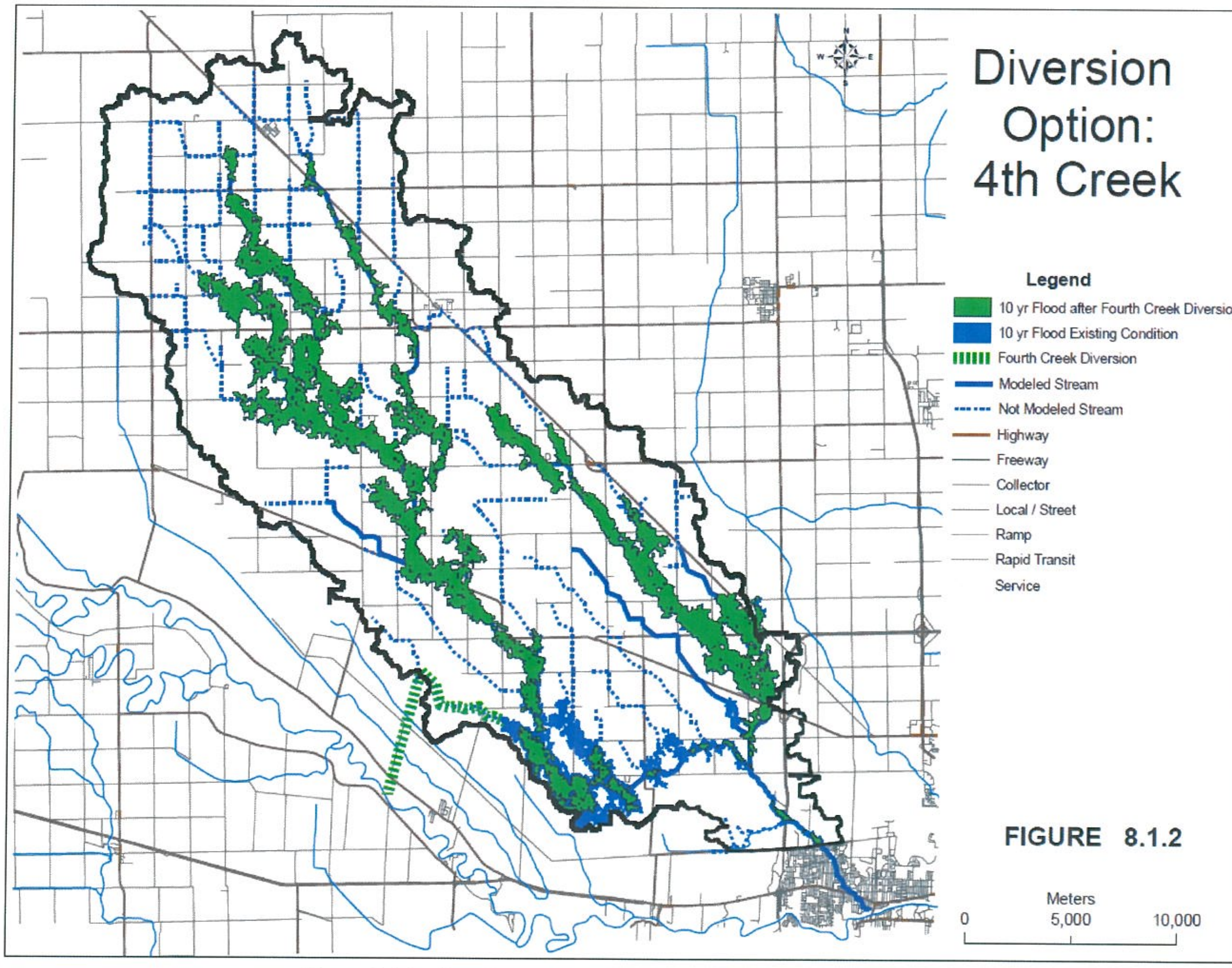


Figure 8.1.2 - Flooded Area Plan with Fourth Creek Diversion

Costs associated with the Forth Creek Diversion option were estimated as $14,759,000. Supporting assumptions are described in Section 9 Economic Analysis and are shown in Table 8.1.1.

The benefits associated with this mitigation option were based on comparing the relative reduction in flooded agricultural area. These details are explained in Section 9 Economic Analysis.

A cursory analysis of an alternate alignment of a Fourth Creek Diversion was performed late in the study. This diversion alignment was to intersect Sturgeon Creek near the CP Rail track in section 16-12-1W with intent to eliminate the need to reverse-grade Fourth Creek. The economic considerations for benefit cost analysis are presented in Section 9.2.

Table 8.1.1

Estimated Cost of Diversion
Fourth Creek / Halliday Road Diversion Channel

Station	River	Feature	Length (m)	Supply & Installed Cost	Excavation Cost	Road Works	Grade Control structure Cost	Land Acquisition
722	Fourth creek	Local Road Culvert	8	$ 62,000				
1604	Fourth creek	Farm Access Culvert	8	$ 62,000				
2637	Fourth creek	Local Road Culvert	12	$ 92,000				
3699	Fourth creek	Rosser Road Culvert	18	$ 138,000		$ 342,000		
3619	Fourth creek	Local Road Culvert	10	$ 77,000				
4165	Fourth creek	Local Road Culvert	8	$ 62,000				
4574	Fourth creek	Farm Access Culvert	8	$ 62,000				
5075	Fourth creek	Farm Access Culvert	8	$ 62,000				
5463	Fourth creek	Farm Access Culvert	8	$ 62,000				
6282	Fourth creek	Farm Access Culvert	9	$ 69,000				
7600	Fourth creek	Farm Access Culvert	9	$ 69,000				
1	Diversion channel	2 Mile Road	20	$ 154,000		$ 683,000		
2	Diversion channel	Highway 26	25	$ 192,000		$ 1,366,000		
		Excavation cost			$ 6,441,000			
	Fourth creek	Excavation cost drop structure					$ 76,000	
	Second creek	Excavation cost drop structure					$ 76,000	
	First creek	Excavation cost drop structure					$ 76,000	
	Halliday diversion	Assiniboine River drop structure					$ 169,000	
	Land acquisition							$ 148,258
	Sub total			$ 1,163,000	$ 6,441,000	$ 2,391,000	$ 397,000	$ 148,258
							Sub-total	$ 10,541,000
							Contingency 30%	$ 3,163,000
							Engineering 10%	$ 1,055,000
							Estimated Total	**$ 14,759,000**

Note:

Diverted flow from Sturgeon Creek		$20\ m^3/s$
Channel bottom width		20 m
Channel side slopes(H:V)		3:1
Culvert Diameter at each crossing		3.05 m
No. of culverts at each crossing		4
3.05 m diameter Culvert cost per metre	$	1,276.50
Land acquisition per acre	$	2,000.00
1 acre = $4047m^2$		
Estimated drainage easment width (m)		50
Approx. diversion channel length along Haliday Rd. (m)		6000
Land acquisition along Fourth Creek is not included		
Total required area (m^2)		300000
Area in acres		74.13

8.2 Diversion to Assiniboine River via Third Creek

The second diversion option to mitigate Sturgeon Creek flooding was an alignment incorporating the existing Third Creek. This alignment would divert Sturgeon Creek flood flows at Section 18-11-1E and route directly south along the east limit of River Lot 226 to intercept the existing Third Creek alignment north of the Trans-Canada Highway (PTH1W). The diversion length north of the Trans-Canada Highway would be 5.3 km. Culvert upgrades through PTH1W would be required to convey existing Third Creek runoff and diverted flow from Sturgeon Creek to the existing channel south of PTH1W and to the Assiniboine River.

Downstream of PTH1W, the diverted flow could flow through two different options.

The Third Creek alignment (Option 1) would see all flows conveyed along the existing Third Creek with channel and crossing improvements required to accommodate the increased flow rates. The total length of the Third Creek diversion alignment would be 7.9 km. Figure 8.2.1shows the Option 1 alignment.

The invert of the Third Creek Diversion channel was set to 236.26 m, or 0.34 m higher than the invert of Sturgeon Creek at the diversion location. The diversion channel was designed at 0.02% slope along its entire length to the Assiniboine River with a proposed diversion channel bottom width of 15 m.

Seven culvert crossings in the existing creek channel would require upgrading along the proposed Option 1 diversion alignment.

An alternative configuration of Third Creek Diversion (Option 2) included a flow split south of the Trans-Canada Highway. The existing ten-year flow capacity would be conveyed in the existing downstream channel (with no changes to bed profile or culvert crossings) and the surplus diversion flow would be conveyed directly south through agricultural land in a new 1 km long channel. A piped drop structure near the confluence of Assiniboine River and Second Creek (upstream of the Headingley Correctional Centre) property would provide the final outlet. The total length of this Third Creek alignment would be 6.3 km or 1.6 km shorter than Option 1. Figure 8.2.2 shows the Option 2 split alignment.

A total of five crossings would require upgrading in the proposed Option 2 diversion alignment.

Both options would require the installation of two 3 m x 2.4 m box culverts through the east and west bound lanes of PTH1W.

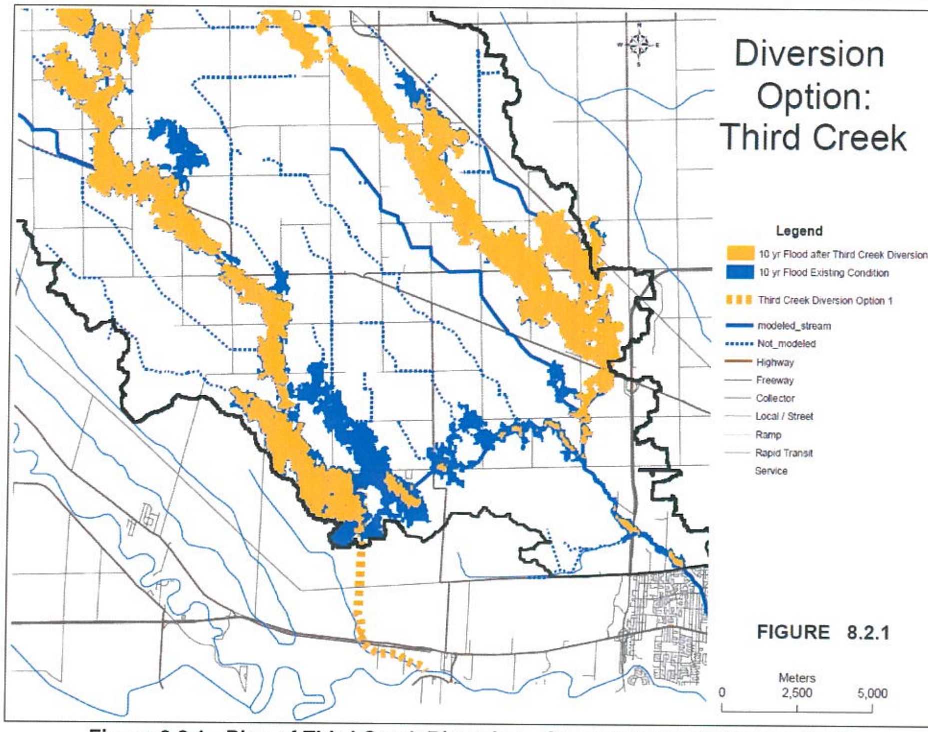


Figure 8.2.1 - Plan of Third Creek Diversion - Creek Alignment (Option One)

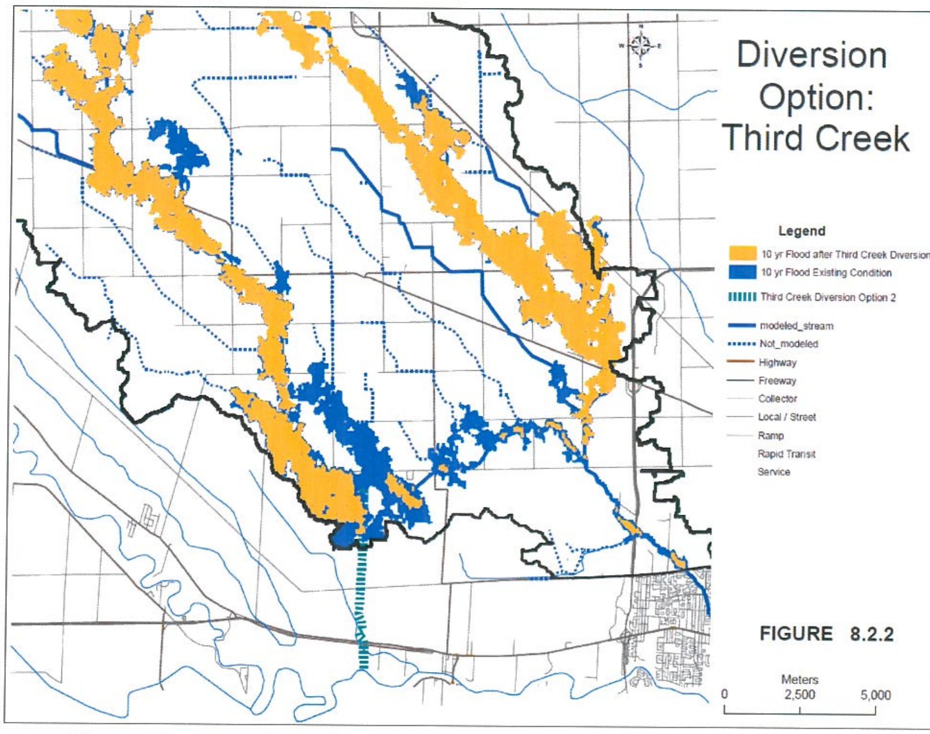


Figure 8.2.2 - Plan of Third Creek Diversion – Flow Split Alignment (Option Two)

Model results for the Third Creek diversion indicate the ten-year runoff event flow at the Perimeter Highway gauge was reduced to 32 m^3/s with a 0.55 m decrease in the peak water level. It also produced a 1.0 m decrease in water level near the diversion. A water level reduction of more than 0.3 m extended 3.0 km upstream and was less than 0.15 m at 6.2 km upstream. The maximum flooded area would be reduced by 22.5 km^2 with either of the Third Creek diversion options as shown in Figure 8.2.3.

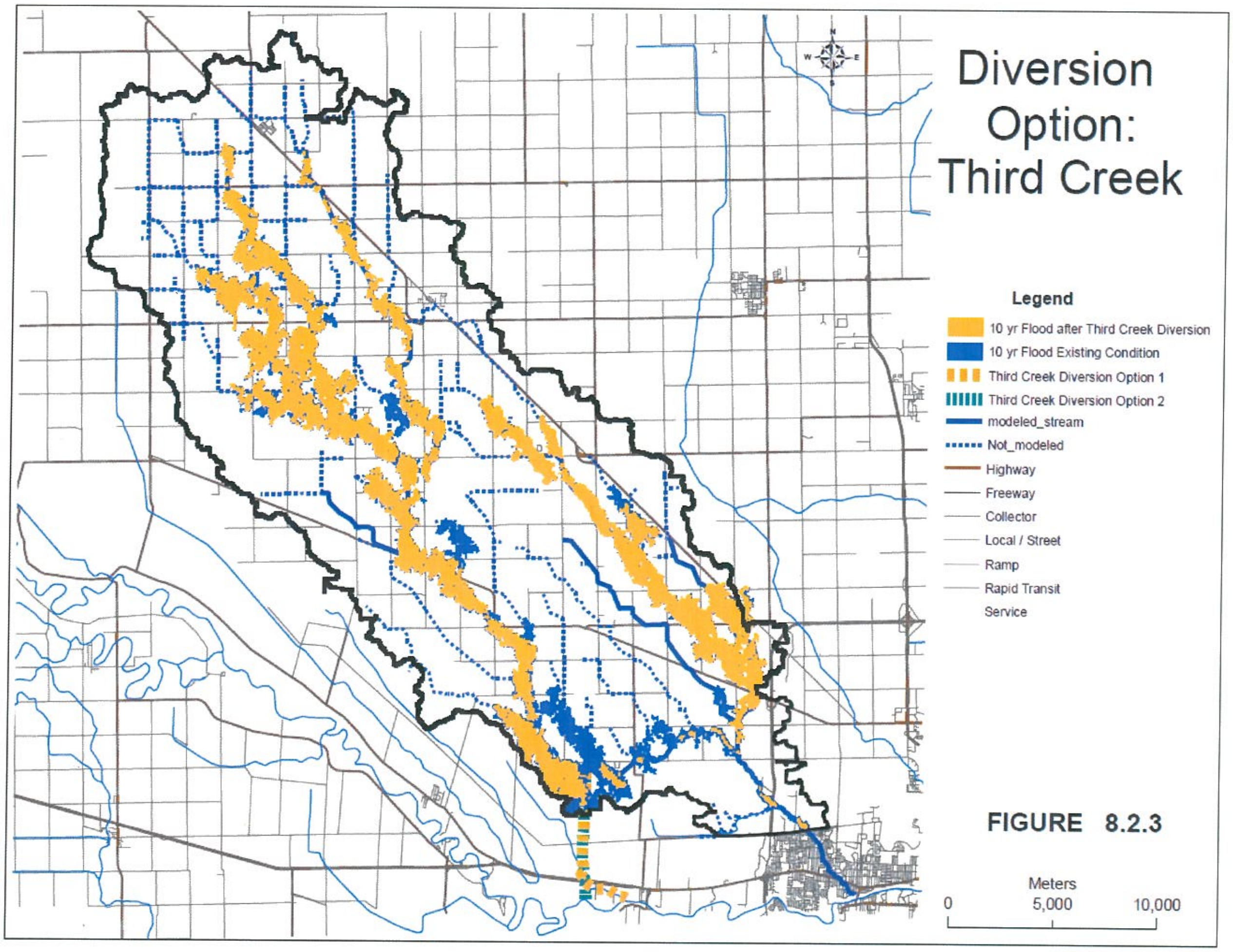


Figure 8.2.3 - Flooded Area Plan with Third Creek Diversion

Costs associated with the Third Creek diversion Option One was estimated as $12,547,000. Third Creek diversion Option Two was estimated to cost $9,471,000. Supporting assumptions are described in Section 9 Economic Analysis and are shown in Table 8.2.1 and Table 8.2.2.

Both options were equally effective at reducing flows and levels along Sturgeon Creek. Option 2 offers some advantages in reducing fisheries issues and reduced construction and maintenance costs. The benefits associated with this mitigation option were based on comparing the relative reduction in flooded agricultural area. The economic considerations for benefit cost analysis are presented in Section 9.2.

Table 8.2.1

Estimated Cost of Diversion
Third Creek Diversion Along Natural Channel (Option 1)

Station	River	Feature	No. of Culverts	Length (m)	Supply & Installed Cost	Excavation Cost	Road Works	Grade Control Structure Cost	Land Acquisition
722	Third Creek	Two Mile Road	3	25	$ 144,000		$ 683,000		
1604	Third Creek	Farm Access Culvert	3	15	$ 87,000				
2637	Third Creek	Farm Access Culvert	3	15	$ 87,000				
3699	Third Creek	PTH 1	5	32	$ 1,122,000		$ 2,732,000		
	Third Creek	Gaol Road	4	25	$ 192,000		$ 342,000		
	Third Creek	Farm Access Culvert	4	15	$ 115,000				
	Third Creek	Farm Access Culvert	4	25	$ 192,000				
	Excavation cost					$ 2,912,000			
	Sturgeon & Third Creek diversion drop structure							$ 76,000	
	Assiniboine river drop structure							$ 169,000	
	Land acquisition								$ 108,000
	Sub total				$ 1,939,000	$ 2,912,000	$ 3,757,000	$ 245,000	$ 108,000
								Sub-total	$ 8,961,000
								Contingency 30%	$ 2,689,000
								Engineering 10%	$ 897,000
								Estimated Total	**$ 12,547,000**

Note:

Diverted flow from Sturgeon Creek		20 m^3/s
Channel bottom width		15 m
Channel side slopes(H:V)		3:1
Culvert diameter		3.05 m
Box culvert dimensions		2.4m x 3.05 m
3.05 m diameter culvert cost per metre	$	1,277
3.05m x 2.4m box culvert cost per metre	$	4,673
Land acquisition per acre	$	2,000
1 acre = 4047m^2		
Estimated drainage easment width (m)		50
Approx. diversion channel length along Third Creek (m)		4370
Total required area (m^2)		218500
Area in acres		53.99

Table 8.2.2

Estimated Cost of Diversion
Third Creek Diversion Channel (Flow Split in Creek & Channel) (Option 2)

Station	River	Feature	No. of Culverts	Length (m)	Supply & Installed Cost	Excavation Cost	Road Works	Grade Control Structure Cost	Land Acquisition
722	Third Creek	Two Mile Road	3	25	$ 144,000		$ 342,000		
1604	Third Creek	Farm Access Culvert	3	15	$ 87,000				
2637	Third Creek	Farm	3	15	$ 87,000				
3699	Third Creek	PTH 1	5	32	$ 1,122,000		$ 2,732,000		
3619	Third Creek	Local Road	3	25	$ 144,000				
	Excavation cost					$ 1,730,000			
	Sturgeon & Third Creek diversion drop structure							$ 76,000	
	Assiniboine river drop structure							$ 169,000	
	Land acquisition								$ 131,000
	Sub total				$ 1,584,000	$ 1,730,000	$ 3,074,000	$ 245,000	$ 131,000
								Sub-total	$ 6,764,000
								Contingency 30%	$ 2,030,000
								Engineering 10%	$ 677,000
								Estimated Total	**$ 9,471,000**

Note:

Diverted flow from Sturgeon Creek	20 m^3/s
Channel bottom width	15 m
Channel side slopes(H:V)	3:1
Culvert diameter	3.05 m
Box culvert dimensions	:.4m x 3.05 m
3.05 m diameter Culvert cost per metre	$ 1,277
3.05m x 2.4m box Culvert cost per metre	$ 4,673
Land acquisition per acre	$ 2,000
1 acre = $4047m^2$	
Estimated drainage easment width (m)	50
Approx. diversion channel length along Third Creek (m)	5270
Total required area (m^2)	263500
Area in acres	65.11

8.3 Diversion to Assiniboine River via West Perimeter Highway

The third option to mitigate Sturgeon Creek flooding was a diversion channel alignment conceptualized as running south to the Assiniboine River along the west ditch of the Perimeter Highway, and if possible within the existing highway Right-Of-Way. This route would begin upstream of the Perimeter Highway box culvert. The total diversion length would be approximately 5 km. Although this option is feasible hydraulically, it would be difficult to construct. The high degree of development in west Winnipeg, Headingley and along the Perimeter Highway would make this route relatively complex requiring numerous large diameter long-culvert crossings to convey the diverted flows to the Assiniboine River.

The proposed invert of the diversion channel was set to 233.35 m, 0.95 m higher than the Sturgeon Creek cross section invert at the diversion location. The proposed channel had a 15 m bottom width and a uniform 0.02% for all open-channel sections.

Seven culvert crossings would require upgrading in the proposed Perimeter Highway diversion alignment. Three of the major crossings are at CP Rail North of Saskatchewan Avenue, Saskatchewan Avenue and Portage Avenue. Four parallel 2.4 m x 3.0 m box culverts were proposed in each of these crossings. The remaining four crossings were municipal roads which were modeled with four 3.0 m diameter culverts.

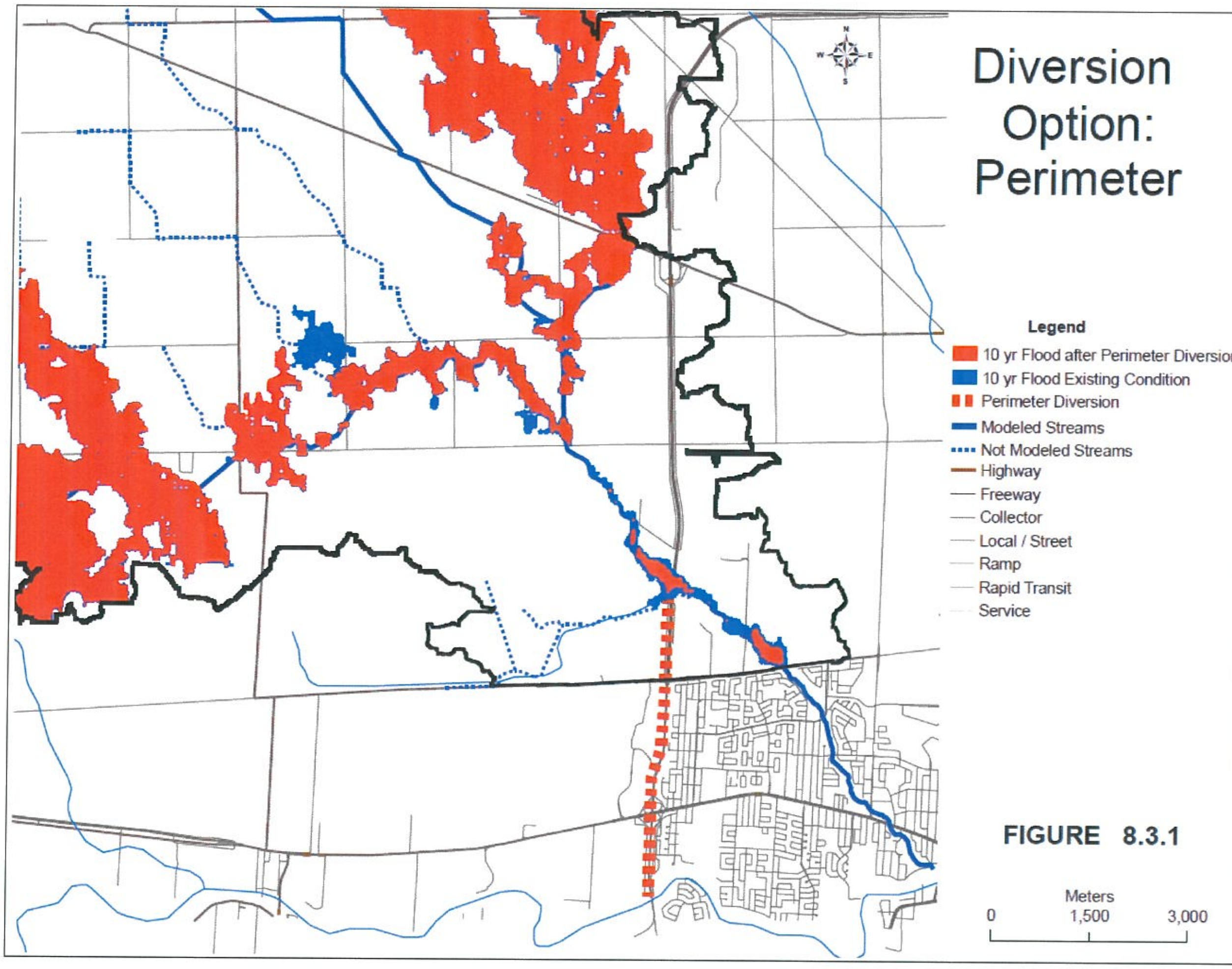


Figure 8.3.1 - Plan of Diversion Along Perimeter Highway Alignment

Model results for the ten-year runoff event showed that Perimeter Highway diversion would reduce the downstream channel flow to 33 m^3/s with a 1.1 m decrease in the peak water level at the Perimeter Highway gauge. The water level reduction was less than 0.25 m at a distance of 2.7 km upstream and less than 0.15 m at 3 km upstream.

Diversion at the downstream end of the watershed has very little benefit in reducing upstream flooding. The maximum flooded area would only be reduced by 2.3 km^2 with the Perimeter Highway diversion option.

Costs associated with the West Perimeter Diversion option were estimated as $17,383,000. Supporting assumptions are described in Section 9 Economic Analysis and are shown in Table 8.3.1.

The benefits associated with this mitigation option were based on comparing the relative reduction in flooded agricultural area. The economic considerations for benefit cost analysis are presented in Section 9.2.

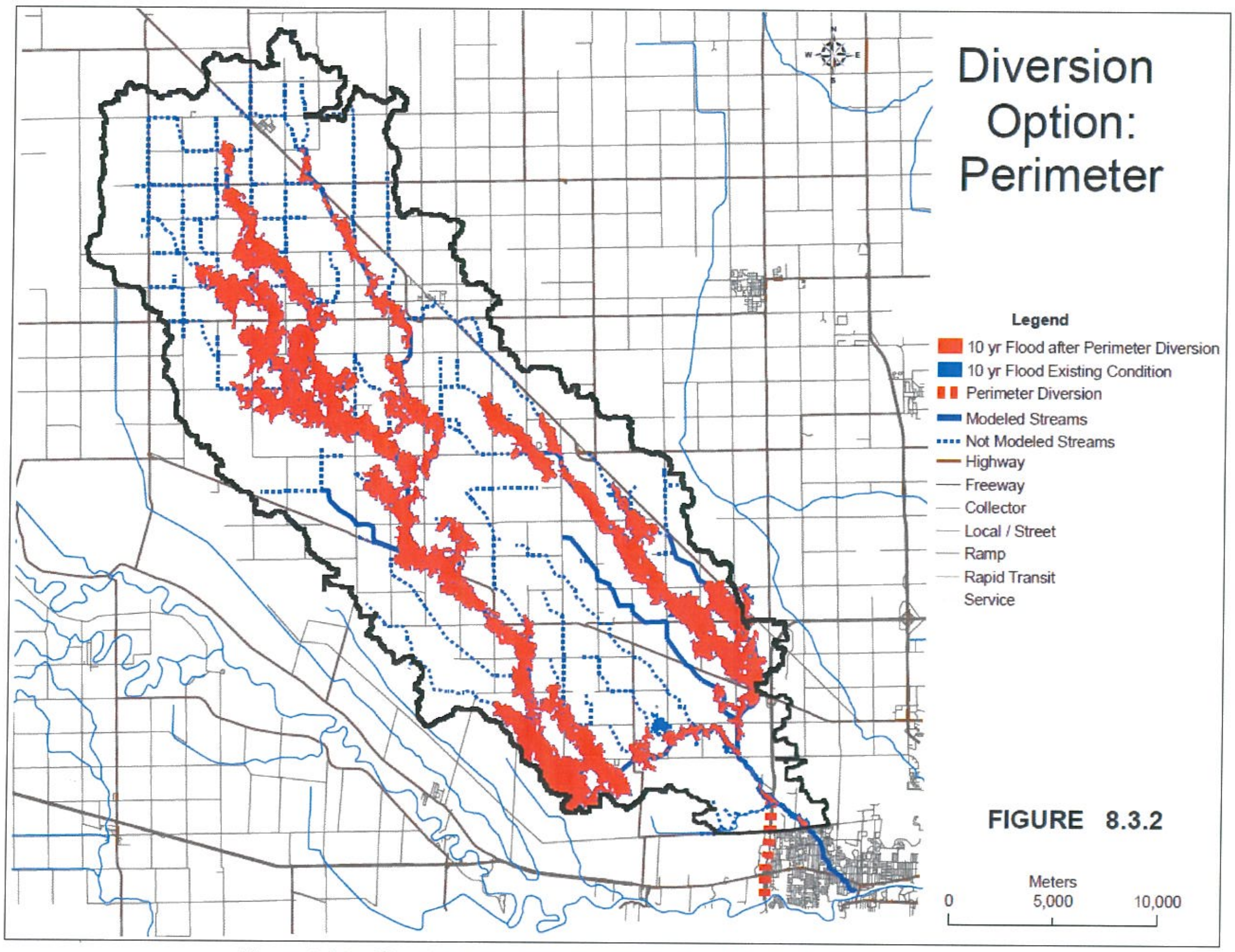


Figure 8.3.2 - Flooded Area Plan with West Perimeter Highway Diversion

Table 8.3.1

Estimated Cost of Diversion
West Perimeter Diversion

Station	River	Feature	Culvert Diameter/ Span (m)	Culvert Rise (m)	No. of Culverts	Length (m)	Supply & Installed Cost	Excavation Cost	Road Works	Grade Control Structure Cost	Land Acquisition
1	Diversion Channel	Paddock Ave.	3.05		3	25	$ 144,000		$ 683,000		
2	Diversion Channel	CP Rail	3.05	2.4	4	10	$ 281,000		$ 683,000		
3	Diversion Channel	Saskatchewan Rd.	3.05	2.4	4	70	$ 1,963,000		$ 1,025,000		
4	Diversion Channel	Race Track Rd.	3.05		3	45	$ 259,000		$ 683,000		
5	Diversion Channel	Portage Ave.	3.05	2.4	4	55	$ 1,542,000		$ 1,366,000		
6	Diversion Channel	Augier Ave.	3.05		3	25	$ 144,000		$ 683,000		
7	Diversion Channel	Oxbow Bend Rd.	3.05		3	25	$ 144,000		$ 683,000		
	Excavation cost							$ 1,769,000			
	West Perimeter Diversion drop structure									$ 76,000	
	Assiniboine River drop structure									$ 169,000	
	Land acquisition										$ 119,000
	Sub total						$ 4,477,000	$ 1,769,000	$ 5,806,000	$ 245,000	$ 119,000

Sub-total	$ 12,416,000
Contingency 30%	$ 3,725,000
Engineering 10%	$ 1,242,000
Estimated Total	**$ 17,383,000**

Note:

Diverted flow from Sturgeon Creek	20 m^3/s
Channel Bottom width	15 m
Channel side slopes(H:V)	3:1
3.05 m diameter Culvert cost per metre	$ 1,276.50
3.05m x 2.4m Box concrete	$ 4,672.55
Land acquisition per acre	$ 2,000.00
1 acre = 4047m^2	
Estimated drainage easment width (m)	50
Approx. diversion channel length along West Perimeter. (m)	4800
Total required area (m^2)	240000
Area in acres	59.30

8.4 Modeled Benefit of Diversions for 10% (Ten-Year) Flood

The relative benefit of mitigation options are shown in Appendix A. The reduction in flow rate is illustrated on Figure 8.4.1. Tables 8.4.1 and 8.4.2 document the simulated impact of the diversion options on the flows and water levels upstream of the Perimeter Highway.

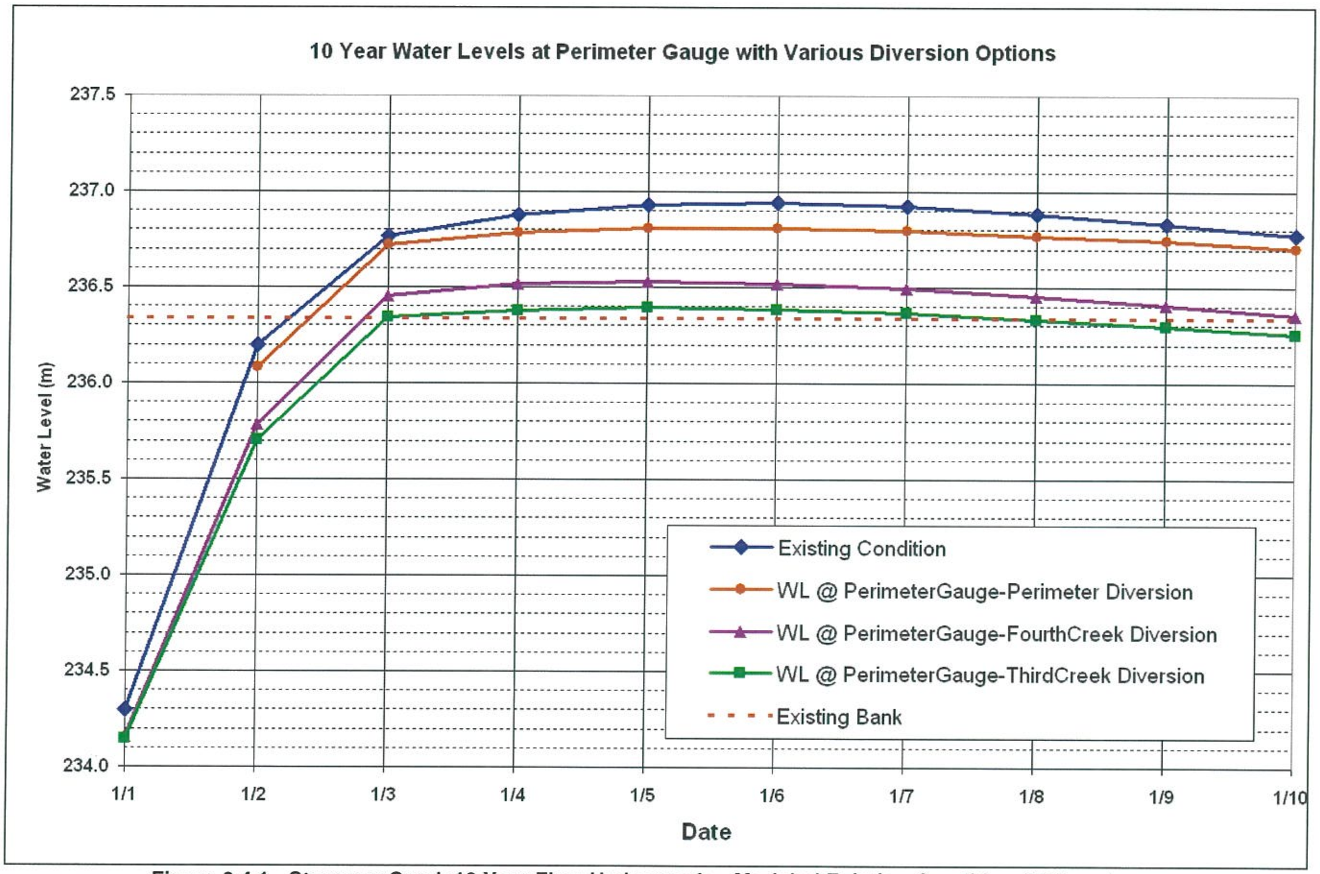


Figure 8.4.1 - Sturgeon Creek 10 Year Flow Hydrograph – Modeled Existing Condition & Diversions

Table 8.4.1 – Simulated Flow Rates near Perimeter Highway

	Existing Condition	Fourth Creek Diversion	Third Creek Diversion	Perimeter Diversion *
Diverted flow (m^3/s)		19.74	19.92	19.80
Max. flow near Perimeter Gauge (m^3/s)	52.4	37.0	32.2	32.6

Table 8.4.2 - Simulated Flow Water Levels near Perimeter Highway

	Existing Condition	Fourth Creek Diversion	Third Creek Diversion	Perimeter Diversion *
Max. water level near Perimeter Gauge (m)	236.94	236.53	236.39	235.84
Reduced water level by (m)		0.41	0.55	1.1

* The Perimeter diversion was modeled as departing the Sturgeon Creek downstream of the Perimeter gauge, thus explaining the appearance in the model of no in-stream flow reduction at the gauge.

8.5 In-Channel Improvements

Increasing the hydraulic capacity of the existing drains to convey the ten-year flow without flooding was considered as an alternative to diverting flow. The channel improvements consisting of bridge and structure upgrades were considered in two regions: downstream (involving MIT and City of Winnipeg crossing structures); and upstream (primarily in rural areas).

The viability of these options were analysed using multiple types and sources of data with the objective of estimating the upgrades required to the hydraulic structures and channels.

8.5.1 Preliminary Design of Downstream Hydraulic Structure Upgrades & Estimated Cost

The first part of in-channel improvements consisted of upgrading the provincial box-culvert crossing at the Perimeter Highway; the CP Rail bridge north of Saskatchewan Avenue; and the City of Winnipeg box-culvert crossing at Saskatchewan Avenue. There is a perception among stakeholders that existing transportation road and rail infrastructure is causing flooding in upstream reaches of Sturgeon Creek. The location of these structures is shown in Figure 8.5.1. This mitigation concept was to replace box culvert and bridge crossings with structures to convey the fifty-year discharge (the appropriate design event for transportation infrastructure).

Data on existing structures was provided by the City of Winnipeg, CP Rail and Manitoba Water Stewardship.

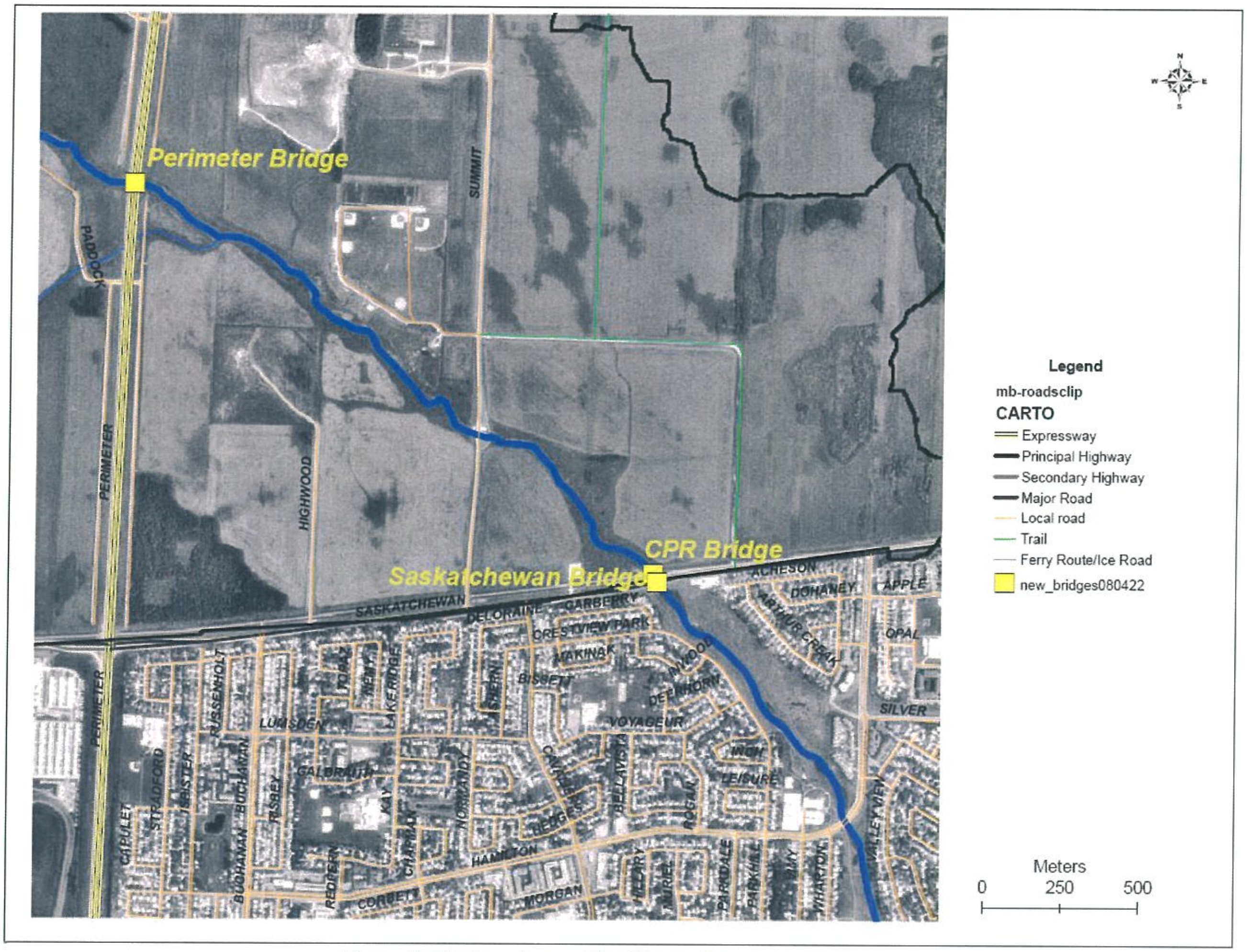


Figure 8.5.1 - Locations of In-Channel Improvements

Model results showed that for the ten-year runoff event there was a 1.1 m decrease in the peak water level at the Perimeter Highway gauge and a 1.0 m decreased water level at the CP Rail and Saskatchewan Avenue structures. However, the hydraulic benefit to upstream reaches of Sturgeon Creek is insignificant upstream of the Colony – Sturgeon Creek confluence.

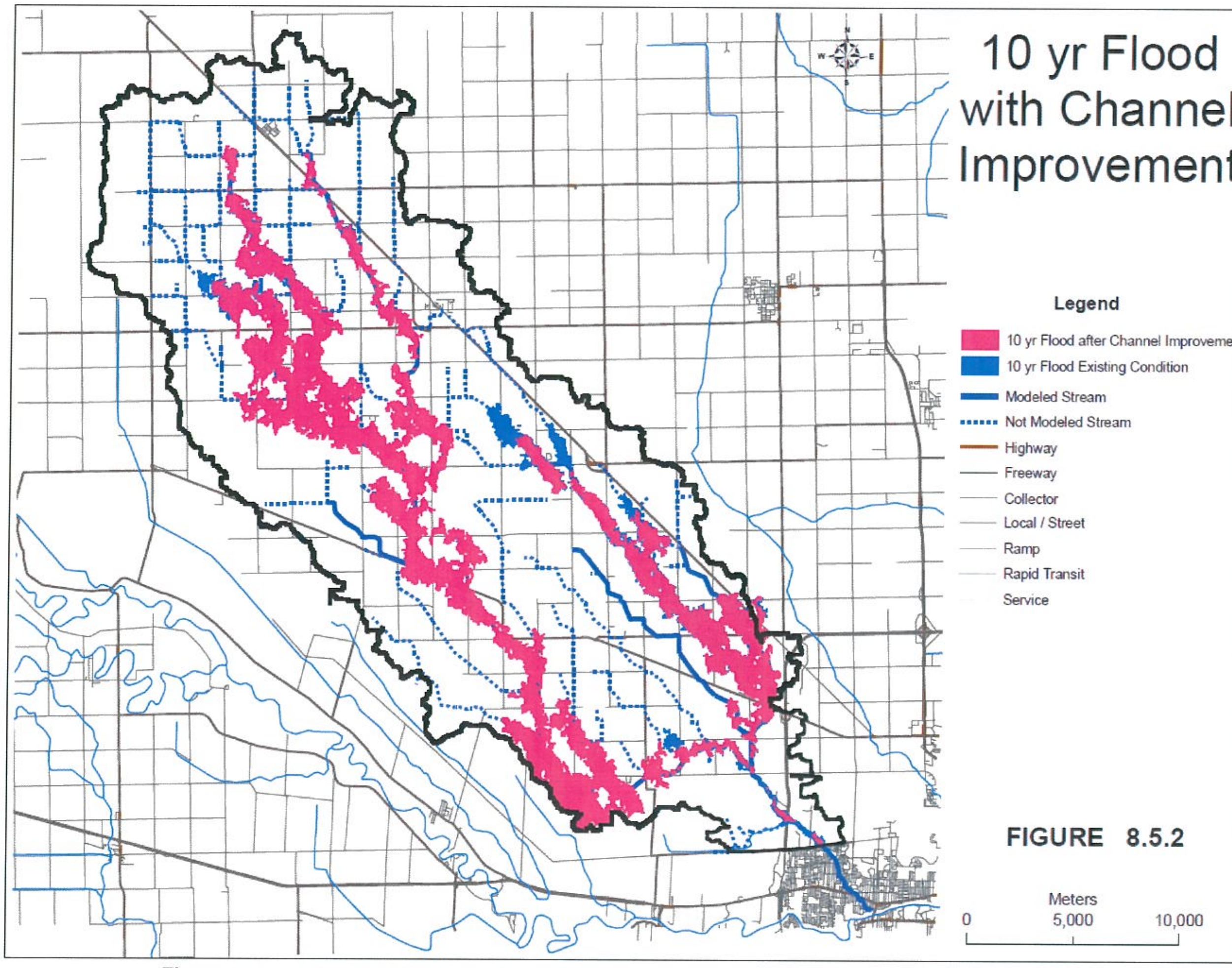


Figure 8.5.2 - Flooded Area Plan with In-Channel Improvements (Perimeter & Downstream)

The benefits achieved through in-channel improvements in the form of crossing structure upgrades downstream of the Sturgeon – Colony Creek confluence were not significant for reducing flooding in agricultural areas upstream of the confluence of Colony and Sturgeon Creeks.

Summary cost of the proposed bridge upgrades are shown on Table 8.5.1.

Table 8.5.1 - Cost Estimate for Hydraulic Structure Upgrades

Crossing	Installed Cost	Earth Works	Road Works	Total
Perimeter -Bridge	$ 3,680,000	$ 10,000	$ 1,370,000	$ 5,060,000
Saskatchewan Ave.	$ 1,160,000	$ 10,000	$ 1,370,000	$ 2,540,000
CP Rail	$ 350,000	$ 5,000	$ 40,000	$ 400,000
Sub Total	$ 5,190,000	$ 25,000	$ 2,780,000	$ 8,000,000
		30% Contingency		2,400,000
		10% Engineering		800,000
		Estimated total		**$ 11,200,000**

8.5.2 Analysis of Upstream Hydraulic Structures and Preliminary Design of Upgrades

The second analysis of in-channel improvements consisted of upgrading the hydraulic structures in portions of the Sturgeon and Colony Creek watersheds upstream of the Perimeter Highway. The completed hydraulic model was used to analyse the hydraulic capacity of the existing drainage system using steady state flows. The first objective was to determine the capacity of the existing drainage system (relative to historic standards) in order to identify sections with inadequate capacity. The second objective was to conceptually design upgrades required to provide a ten-year level of service.

Design flows for generic areas from 1 to 25 mi^2 (2.6 to 65 km^2) were calculated using typical conditions (time of concentration, site slope, soil type coefficients, etc.). Flows were calculated for two, five and ten-year design events and historic standards using provincially acceptable methods.

8.5.3 Historic Design Standards (S-Curve / M-Curve)

The S-Curve and M-Curve (shown in Figure 8.5.3.1) were developed in the early 1900's to predict runoff from prairie watersheds. These methods were considered representative for Manitoba and therefore adopted as the provincial design standard. These standards were in effect during the development of the Sturgeon Creek drainage basin and are referenced in current documents. The S-Curve and M-Curve were defined in the 1981 provincial Hydraulic Design Manual[4].

Historically, the S-Curve was applied to areas with nominal slope not greater than 13 feet per mile (0.25%) and generally associated with agricultural crop land use. The M-Curve was applied to areas with agricultural crop land and nominal slopes steeper than 0.25%. The M-Curve[5] was developed by Minnesota Department of Drainage and Water, and the S-Curve developed by John T. Stewart, U.S.D.A,

[4] *Section 1 -Agricultural Design Discharge Definitions, A. Swedlo, P.Eng., Winnipeg, February, 1981*
[5] *Ibid, Figure 1.1 Drainage Coefficients for Red River Valley, Minnesota – North Dakota.*

in 1907. Either method generates runoff estimates for a given watershed area and reflects the storage capacity in agricultural lands and local ditches.

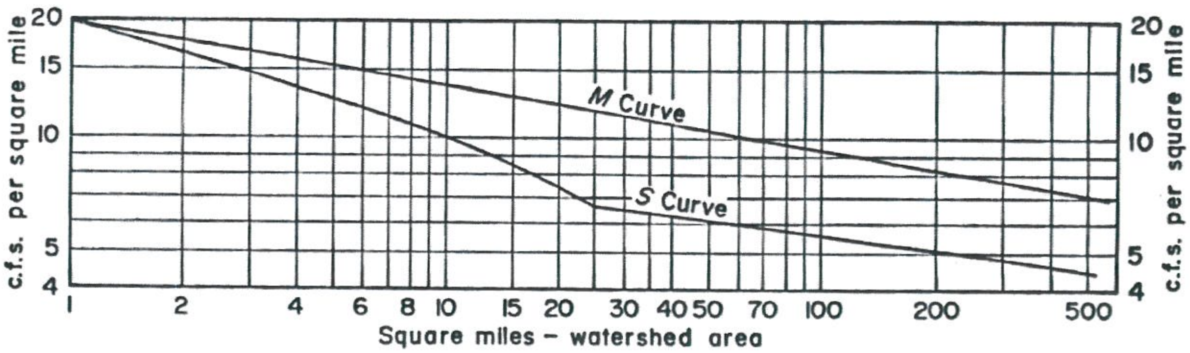


Figure 8.5.3.1 - Design Storm Flow with S-Curve and M-Curve Standards

The Sturgeon Creek - Colony Creek watershed has catchment slopes in the range of 0.05% to 1.2%.

Flows calculated by the above methods were compared to flows generated using S- and M-Curves. As indicated on Figure 8.5.3.2 the S-Curve is located between the current two and five- year runoff estimate, where as the M-curve is located between the current five and ten-year design storm estimates. The hydraulic capacity of hydraulic structures designed based on the S-Curve design storm provides below five-year and above two-year service level and the M-Curve provides service level above five-year and below ten-year storms.

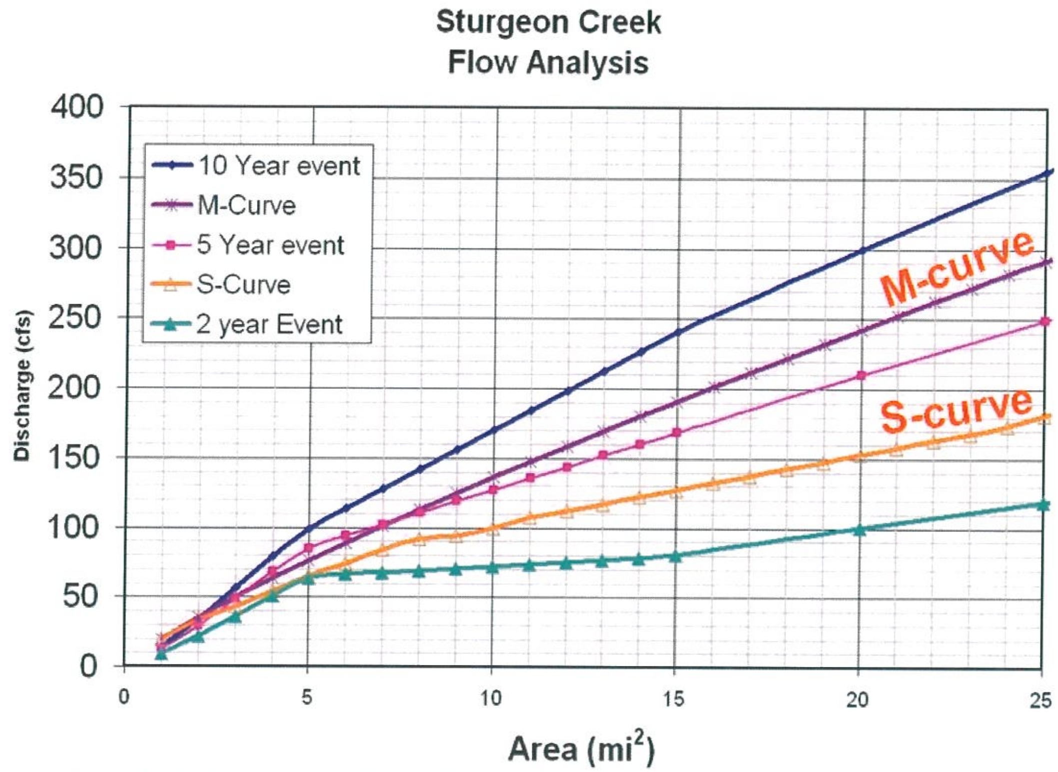


Figure 8.5.3.2 - Design Storm Flow Estimates Compared with S-Curve and M-Curve Standards

8.5.4 Current Hydrologic Methods & Existing Hydraulic Capacity

Hydrologic methods developed by the Province of Manitoba (Harden, 1983, 1986 & 1988) were used to compute mean daily flows for 50% (two-year), 20% (five-year) and 10% (ten-year) events for use in the MIKE 11 steady-state model. The instantaneous peak discharges determined by the Rational Method was used for catchment areas up to 13 km^2. Rational Method instantaneous flows were converted to the daily mean discharge by averaging flow rates over 24 hours. The Regional Method was used to estimate mean daily discharge for catchment areas larger than 38 km^2. A Transitional Method (Harden, 1986) that produces a flow estimate from an area-weighted average between the Rational and Regional Methods was used for areas ranging between 13 and 38 km^2.

Design flows were computed for catchment areas ranging from 2.7 km^2 to 50.5 km^2. Table 8.5.4.1 shows design flow calculations for each catchment area as produced for the two-year design storms. Tables 8.5.4.2 and 8.5.4.3 show design flows for each catchment for the five and ten-year design storms. The details of catchment areas were shown previously in Figure 5.2.1.

Table 8.5.4.1 Design Flow Calculations - 2 Year Storm

Watershed Number	Drainage Area (km^2)	Channel Length (m)	Channel Slope (m/m)	Corrected I (I x 0.95) (mm/hr)	Design Flow m^3/s Mean Daily (m^3/s)	Rational Method m^3/s	Transitional (m^3/s)	Regional (m^3/s)	Mean daily Design Flow (m^3/s)
4	21.8	6344	0.0005	5.8	-	-	1.99	-	**1.99**
31	17.0	6046	0.0005	5.8	-	-	1.91	-	**1.91**
61	20.8	6972	0.0005	5.8	-	-	1.97	-	**1.97**
34	7.2	4873	0.0005	5.8	0.92	5.17	-	-	**0.92**
44	9.6	4379	0.00048	5.8	1.19	7.37	-	-	**1.19**
86	12.7	4139	0.00048	5.8	1.54	10.30	-	-	**1.54**
69	14.0	5229	0.00048	5.8	-	-	1.85	-	**1.85**
120	14.9	5841	0.00044	5.8	-	-	1.87	-	**1.87**
99	11.1	5092	0.00044	6.8	1.47	7.39	-	-	**1.47**
32	17.6	7883	0.00048	5.8	-	-	1.91	-	**1.91**
55	21.4	9809	0.00048	5.8	-	-	1.98	-	**1.98**
89	22.0	6244	0.00044	5.8	-	-	1.99	-	**1.99**
472	40.7	18642	0.00032	5.8	-	-	-	2.38	**2.38**
239	23.1	11720	0.00032	5.8	-	-	2.01	-	**2.01**
214	50.5	12954	0.00032	5.8	-	-	-	2.81	**2.81**
741	21.8	12962	0.00019	5.8	-	-	1.99	-	**1.99**
706	15.1	7424	0.00019	5.8	-	-	1.87	-	**1.87**
661	33.5	11206	0.00019	5.8	-	-	2.18	-	**2.18**
604	8.3	3442	0.00019	7.1	1.07	5.73	-	-	**1.07**
577	21.5	13606	0.00019	5.8	-	-	1.98	-	**1.98**
93	20.3	11669	0.00032	5.8	-	-	1.96	-	**1.96**
118	13.7	6049	0.00032	5.8	-	-	1.85	-	**1.85**
286	2.7	2135	0.00019	11.0	0.29	2.85	-	-	**0.29**
182	11.1	4341	0.00044	7.7	1.39	8.35	-	-	**1.39**
147	4.0	2731	0.00044	11.3	0.43	4.42	-	-	**0.43**
11	16.0	5863	0.0005	5.8	-	-	1.89	-	**1.89**
19	2.8	2899	0.0005	11.1	0.30	2.98	-	-	**0.30**
220	12.3	4000	0.00044	8.3	1.50	9.88	-	-	**1.50**
111	39.9	15403	0.00044	5.8	-	-	-	2.35	**2.35**
80	29.3	14548	0.00044	5.8	-	-	2.11	-	**2.11**
471	22.7	14755	0.00032	5.8	-	-	2.00	-	**2.00**
761	15.6	4406	0.00019	5.8	-	-	2.35	-	**2.35**
799	4.2	2375	0.00019	9.9	0.48	4.03	-	-	**0.48**

Note:

Land Use & Antecedant Moisture Conditions	42	Runoff Coefficient	0.35
Soil Type	D	Rainfall Correction Factor	0.95
		Curve No.	80

Table 8.5.4.2 Design Flow Calculations - 5 Year Storm

					Design Flow m^3/s				
Watershed Number	Drainage Area (km^2)	Channel Length (m)	Channel Slope (m/m)	Corrected I (I x 0.95) (mm/hr)	Mean Daily (m^3/s)	Rational Method m^3/s	Transitional (m^3/s)	Regional (m^3/s)	Mean daily Design Flow (m^3/s)
4	21.8	6344	0.0005	7.7	-	-	3.25	-	3.25
31	17.0	6046	0.0005	7.7	-	-	2.81	-	2.81
61	20.8	6972	0.0005	7.7	-	-	3.16	-	3.16
34	7.2	4873	0.0005	9.9	1.23	6.91	-	-	1.23
44	9.6	4379	0.00048	10.6	1.59	9.85	-	-	1.59
86	12.7	4139	0.00048	11.1	2.06	13.61	-	-	2.06
69	14.0	5229	0.00048	7.7	-	-	2.53	-	2.53
120	14.9	5841	0.00044	7.7	-	-	2.62	-	2.62
99	11.1	5092	0.00044	9.1	1.95	9.88	-	-	1.95
32	17.6	7883	0.00048	7.7	-	-	2.87	-	2.87
55	21.4	9809	0.00048	7.7	-	-	3.21	-	3.21
89	22.0	6244	0.00044	7.7	-	-	3.27	-	3.27
472	40.7	18642	0.00032	7.7	-	-	-	4.99	4.99
239	23.1	11720	0.00032	7.7	-	-	3.37	-	3.37
214	50.5	12954	0.00032	7.7	-	-	-	5.89	5.89
741	21.8	12962	0.00019	7.7	-	-	3.25	-	3.25
706	15.1	7424	0.00019	7.7	-	-	2.63	-	2.63
661	33.5	11206	0.00019	7.7	-	-	4.32	-	4.32
604	8.3	3442	0.00019	9.6	1.42	7.68	-	-	1.42
577	21.5	13606	0.00019	7.7	-	-	3.22	-	3.22
93	20.3	11669	0.00032	7.7	-	-	3.11	-	3.11
118	13.7	6049	0.00032	7.7	-	-	2.51	-	2.51
286	2.7	2135	0.00019	14.8	0.39	3.83	-	-	0.39
182	11.1	4341	0.00044	10.4	1.85	11.16	-	-	1.85
147	4.0	2731	0.00044	15.1	0.58	5.93	-	-	0.58
11	16.0	5863	0.0005	7.7	-	-	2.72	-	2.72
19	2.8	2899	0.0005	14.9	0.40	4.01	-	-	0.40
220	12.3	4000	0.00044	11.1	2.00	13.23	-	-	2.00
111	39.9	15403	0.00044	7.7	-	-	-	4.91	4.91
80	29.3	14548	0.00044	7.7	-	-	3.94	-	3.94
471	22.7	14755	0.00032	7.7	-	-	3.33	-	3.33
761	15.6	4406	0.00019	7.7	-	-	2.89	-	2.89
799	4.2	2375	0.00019	13.3	0.63	5.42	-	-	0.63

Note:

Land Use & Antecedant Moisture Conditions	42	Runoff Coefficient	0.35
		Rainfall Correction Factor	0.95
Soil Type	D	Curve No.	80

Table 8.5.4.3 Design Flow Calculations - 10 Year Storm

					Design Flow m^3/s				
Watershed Number	Drainage Area (km^2)	Channel Length (m)	Channel Slope (m/m)	Corrected I (I x 0.95) (mm/hr)	Mean Daily (m^3/s)	Rational Method m^3/s	Transitional (m^3/s)	Regional (m^3/s)	Mean daily Design Flow (m^3/s)
4	21.8	6344	0.0005	9.0	-	-	4.23	-	**4.23**
31	17.0	6046	0.0005	9.0	-	-	3.48	-	**3.48**
61	20.8	6972	0.0005	9.0	-	-	4.07	-	**4.07**
34	7.2	4873	0.0005	11.5	1.43	8.07	-	-	**1.43**
44	9.6	4379	0.00048	12.4	1.85	11.52	-	-	**1.85**
86	12.7	4139	0.00048	12.9	2.40	15.92	-	-	**2.40**
69	14.0	5229	0.00048	9.0	-	-	3.00	-	**3.00**
120	14.9	5841	0.00044	9.0	-	-	3.15	-	**3.15**
99	11.1	5092	0.00044	10.7	2.27	11.54	-	-	**2.27**
32	17.6	7883	0.00048	9.0	-	-	3.57	-	**3.57**
55	21.4	9809	0.00048	9.0	-	-	4.16	-	**4.16**
89	22.0	6244	0.00044	9.0	-	-	4.26	-	**4.26**
472	40.7	18642	0.00032	9.0	-	-	-	7.11	**7.11**
239	23.1	11720	0.00032	9.0	-	-	4.42	-	**4.42**
214	50.5	12954	0.00032	9.0	-	-	-	8.40	**8.40**
741	21.8	12962	0.00019	9.0	-	-	4.22	-	**4.22**
706	15.1	7424	0.00019	9.0	-	-	3.17	-	**3.17**
661	33.5	11206	0.00019	9.0	-	-	6.05	-	**6.05**
604	8.3	3442	0.00019	11.2	1.66	8.98	-	-	**1.66**
577	21.5	13606	0.00019	9.0	-	-	4.18	-	**4.18**
93	20.3	11669	0.00032	9.0	-	-	3.99	-	**3.99**
118	13.7	6049	0.00032	9.0	-	-	2.96	-	**2.96**
286	2.7	2135	0.00019	17.3	0.45	4.50	-	-	**0.45**
182	11.1	4341	0.00044	12.1	2.16	13.05	-	-	**2.16**
147	4.0	2731	0.00044	17.7	0.67	6.95	-	-	**0.67**
11	16.0	5863	0.0005	9.0	-	-	3.32	-	**3.32**
19	2.8	2899	0.0005	17.5	0.46	4.69	-	-	**0.46**
220	12.3	4000	0.00044	12.9	2.33	15.47	-	-	**2.33**
111	39.9	15403	0.00044	9.0	-	-	-	7.01	**7.01**
80	29.3	14548	0.00044	9.0	-	-	5.39	-	**5.39**
471	22.7	14755	0.00032	9.0	-	-	4.37	-	**4.37**
761	15.6	4406	0.00019	9.0	-	-	3.25	-	**3.25**
799	4.2	2375	0.00019	15.6	0.73	6.36	-	-	**0.73**

Note:

Land Use & Antecedant Moisture Conditions	42	Runoff Coefficient	0.35
Soil Type	D	Rainfall Correction Factor	0.95
		Curve No.	80

Hydraulic capacity analysis of the existing structures in Central, West and West Colony Lateral Creek; and Main Stream, East Branch, West Branch and West Lateral Sturgeon Creek was performed for two, five and ten-year design flood using the MIKE11 hydrodynamic model run in a steady-state configuration.

Hydraulic performance was evaluated based on the provincial criterion of hydraulic head loss with hydraulic structures with head loss less than 0.21 m considered adequate for the design flow and structures with head loss greater than 0.21 m considered undersized.

Figures 8.5.4.1, 8.5.4.2 and 8.5.4.3 display the hydraulic capacity of culverts with the two, five and ten-year design flows respectively. Culvert hydraulic capacity is represented by red or green circles. Red circles indicate hydraulic head loss greater than 0.21m for the design flow; green circles indicate hydraulic head loss less than 0.21m. Structures downstream of the Sturgeon Creek - Colony Creek confluence are not displayed in these figures. Reaches where no culverts are shown either have bridges (i.e. Sturgeon Creek and lower reaches of East Branch Sturgeon Creek), or no culvert data which could be analyzed (i.e. Center Colony Creek and West Colony Lateral).

Table 8.5.4.4 contains locations, dimensions, drainage area, water level and head losses through analyzed hydraulic structure.

Table 8.5.4.4

Culvert Head Losses & Preliminary Upgrade Configuration

Branch Name	Chainage from U/S	Culvert ID	Culvert Size and Number	Contributing Area (km^2)	Chainage from D/S	2 Yr Design Flood		5 Yr Design Flood		10 Yr Design Flood		Upgraded Culvert Size and Number for 10 Year Event
						Discharge (m^3/s)	Head Loss (m)	Discharge (m^3/s)	Head Loss (m)	Discharge (m^3/s)	Head Loss (m)	
West Branch	28	191.3 W	3 x 1200mm dia x 14.3m	21.8	19156	2.00	0.09	3.25	0.06	4.23	0.11	
	1701	186.3 W	3 x 1500mm dia x 18.5m	38.8	17484	2.31	0.15	4.81	0.17	6.91	0.16	
	3586	178.3 W	3 x 1336mm dia x 18.6m	38.8	15599	2.31	0.06	4.81	0.11	6.87	0.29	3 x 1650mm dia x 18.6m
	4319	171.3 W	3 x 1336mm dia x 30.9m	40.1	14865	2.63	0.07	5.48	0.19	7.83	0.46	3 x 1650mm dia x 30.9m
	5722	166.3 W	3 x 1336mm dia x 24.8m	46.1	13462	2.63	0.07	5.48	0.18	7.83	0.44	3 x 1800mm dia x 24.8m
	7087	158.3 W	3 x 1370mm dia x 35.3m	55.6	12098	3.04	0.11	6.33	0.28	9.05	0.63	3 x 1800mm dia x 35.3m
	7669	154.3 W	3 x 1300mm dia x 23.5m	55.6	11515	3.04	0.07	6.33	0.27	9.05	0.64	3 x 1800mm dia x 23.5m
	8639	149.3 W	3 x 1335mm dia x 20.5m	69.6	10545	3.61	0.10	7.52	0.34	10.74	0.71	3 x 1800mm dia x 20.5m
	11207	135.3 W	3 x 1400mm dia x 16.4m	69.6	7977	3.61	0.05	7.52	0.17	10.74	0.47	3 x 1800mm dia x 16.4m
	12458	131.3 W	3 x 1500mm dia x 15.5m	69.6	6726	3.61	0.04	7.52	0.15	10.74	0.37	3 x 1800mm dia x 15.5m
	13971	125.3 W	3 x 1500mm dia x 15.5m	84.6	5213	3.61	0.04	7.52	0.18	10.74	0.41	3 x 1800mm dia x 15.5m
East Branch	54	328.3 E	3 x 1200mm dia x 14.2m	16.0	19980	1.89	0.19	2.74	0.13	3.37	0.14	
	1168	323.3 E	3 x 1200mm dia x 12.5m	16.0	18866	1.89	0.04	2.74	0.05	3.36	0.08	
	1524	320.3 E	3 x 1200mm dia x 12.5m	16.0	18510	1.89	0.07	2.74	0.08	3.36	0.08	
	1881	318.4 E	4 x 1200mm dia x 18.6m	16.0	18153	1.89	0.21	2.74	0.12	3.36	0.08	
	2380	313.3 E	3 x 1219mm x 1829mm x 25.5m	18.8	17654	1.94	0.10	2.99	0.13	3.79	0.16	
	3766	308.3 E	3 x 1200mm dia x 16.8m	18.8	16268	1.94	0.03	2.99	0.06	3.79	0.11	
	4659	303.3 E	3 x 1200mm dia x 16.8m	18.8	15375	1.94	0.03	2.99	0.06	3.79	0.13	
	5839	300.2 E	2 x 1500mm dia x 29.1m	20.4	14195	2.24	0.04	4.61	0.10	6.54	0.20	
Main Branch	28891	1.1 M	3 x 3450mm dia x 26.7m	579.1	133	18.20	0.09	38.06	0.26	54.30	0.51	4 x 3800mm x 3400mm x 26.7m Arch
Colony Creek	65	85.3CC	3 x 1200mm dia x 18m	13.7	21199	1.85	0.11	2.51	0.06	2.96	0.16	
	1058	84.3CC	3 x 1200mm dia x 14m	13.7	20206	1.85	0.08	2.51	0.16	2.96	0.07	
	1349	83.3CC	3 x 1200mm dia x 14m	34.0	19915	2.19	0.05	4.38	0.16	6.14	0.28	3 x 1500mm dia x 14m
	2761	82.3CC	3 x 1350mm dia x 10.5m	34.0	18503	2.19	0.01	4.38	0.07	6.14	0.16	
	3024	81.3CC	3 x 1520mm dia x 11.5m	36.3	18240	2.28	0.01	4.59	0.05	6.50	0.09	
	3840	80.3CC	3 x 1520mm dia x 11m	36.3	17424	2.28	0.01	4.59	0.04	6.50	0.09	
	4821	79.3CC	3 x 1520mm dia x 16m	36.3	16443	2.28	0.01	4.59	0.04	6.50	0.13	
	5282	78.3CC	3 x 1520mm dia x 16m	39.5	15982	2.40	0.01	4.88	0.03	6.96	0.12	
	6033	77.3CC	3 x 1520mm dia x 8m	39.5	15231	2.40	0.01	4.88	0.04	6.96	0.08	
	6395	76.3CC	3 x 1520mm dia x 12.5m	39.5	14869	2.40	0.01	4.88	0.03	6.96	0.13	
	7472	75.3CC	3 x 1520mm dia x 11.5m	41.8	13792	2.49	0.01	5.09	0.03	7.26	0.11	
	10276	74.3CC	3 x 1520mm dia x 13m	41.8	10988	2.49	0.01	5.09	0.03	7.26	0.15	
	10590	73.3CC	3 x 1520mm dia x 34m	41.8	10674	2.49	0.03	5.09	0.07	7.26	0.21	
	12213	72.3CC	3 x 1520mm dia x 12.5m	51.7	9051	2.88	0.01	6.00	0.04	8.55	0.14	
	13729	71.3CC	3 x 1600mm dia x 17m	51.7	7535	2.88	0.02	6.00	0.04	8.55	0.16	
	15264	70.3CC	3 x 1520mm dia x 13m	56.7	6000	3.07	0.07	6.44	0.11	9.18	0.23	3 x 1800mm dia x 13m
	16329	69.3CC	3 x 1800mm dia x 20.3m	56.7	4935	3.07	0.05	6.44	0.08	9.18	0.11	
	21114	1.3CC	3 x 1600mm dia x 24.5m	123.0	150	5.41	0.40	11.33	0.57	16.17	0.81	3 x 2800mm dia x 24.5m
West Lateral	10	237.2 L	2 x 1200mm dia x 15m	20.8	10898	1.97	0.09	3.16	0.17	4.07	0.32	2 x 1500mm dia x 15m
	336	234.2 L	2 x 1200mm dia x 14.9m	20.8	10572	2.01	0.15	3.16	0.20	4.07	0.30	2 x 1500mm dia x 14.9m
	1090	232.2 L	2 x 1200mm dia x 21.7m	20.8	9818	1.97	0.23	3.16	0.26	4.07	0.38	3 x 1500mm dia x 21.7m
	2029	227.2 L	2 x 1200mm dia x 23.1m	20.8	8879	1.98	0.18	3.16	0.22	4.07	0.35	3 x 1500mm dia x 23.1m
	3823	220.2 L	2 x 1800mm dia x 21.9m	20.8	7085	1.97	0.03	3.16	0.05	4.07	0.06	
	5479	213.2 L	2x1850mmx1050mmx17.4m Arch	33.5	5429	2.18	0.08	4.32	0.32	6.05	0.66	4x1850mmx1050mmx17.4m Arch
	7670	202.3 L	3 x 1350mm dia x 21.9m	53.0	3238	2.18	0.05	4.32	0.11	6.05	0.22	3 x 1500mm dia x 21.9m
	9270	197.3 L	3 x 1350mm dia x 17.5m	53.0	1638	2.18	0.03	4.32	0.11	6.05	0.22	3 x 1500mm dia x 17.5m
	10135	193.3 L	3 x 1350mm dia x 17.6m	53.0	773	2.18	0.03	4.32	0.11	6.05	0.22	3 x 1500mm dia x 17.6m

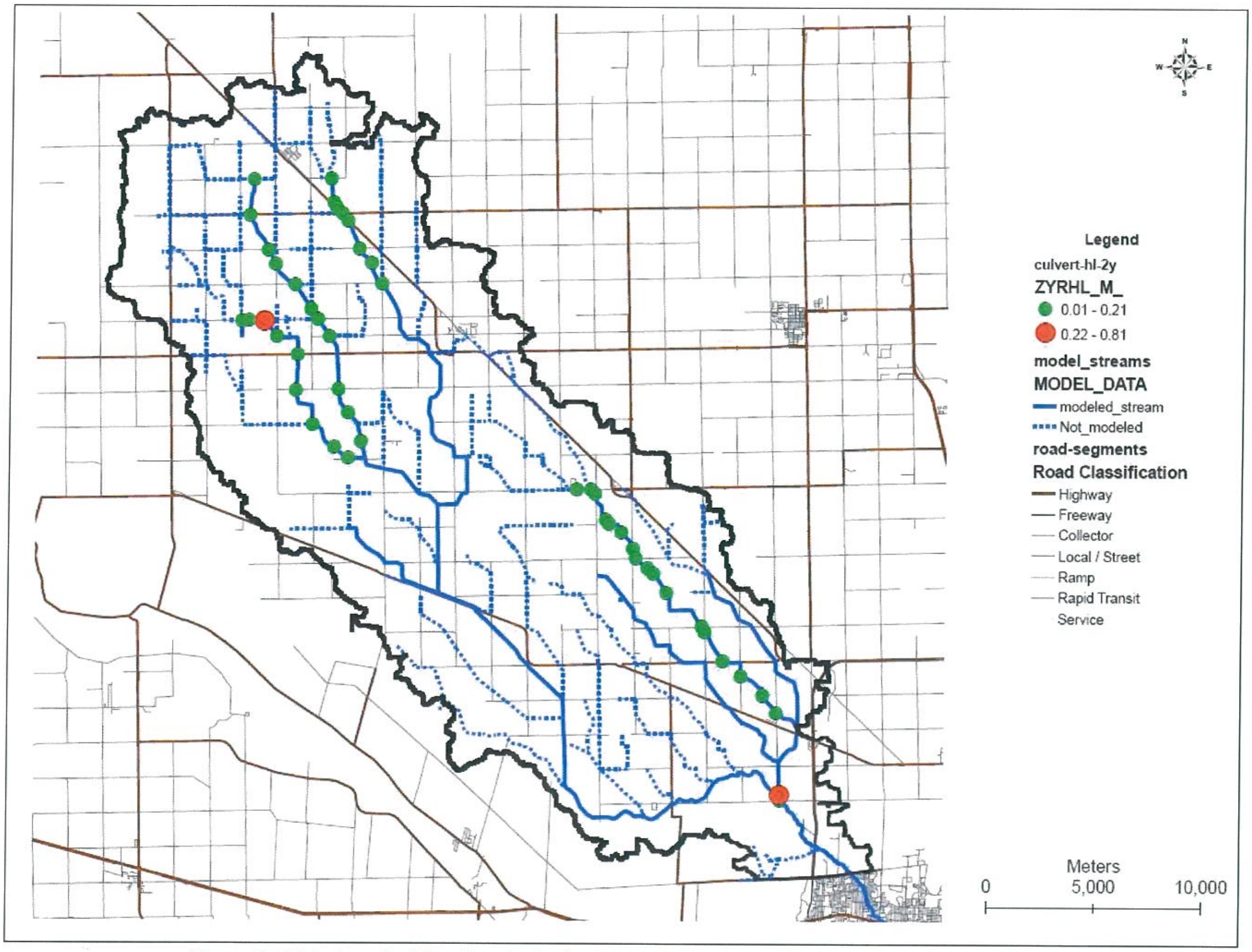


Figure 8.5.4.1 - Level of Service Analysis, 0.21m Head Loss Criteria – Two-Year Flow

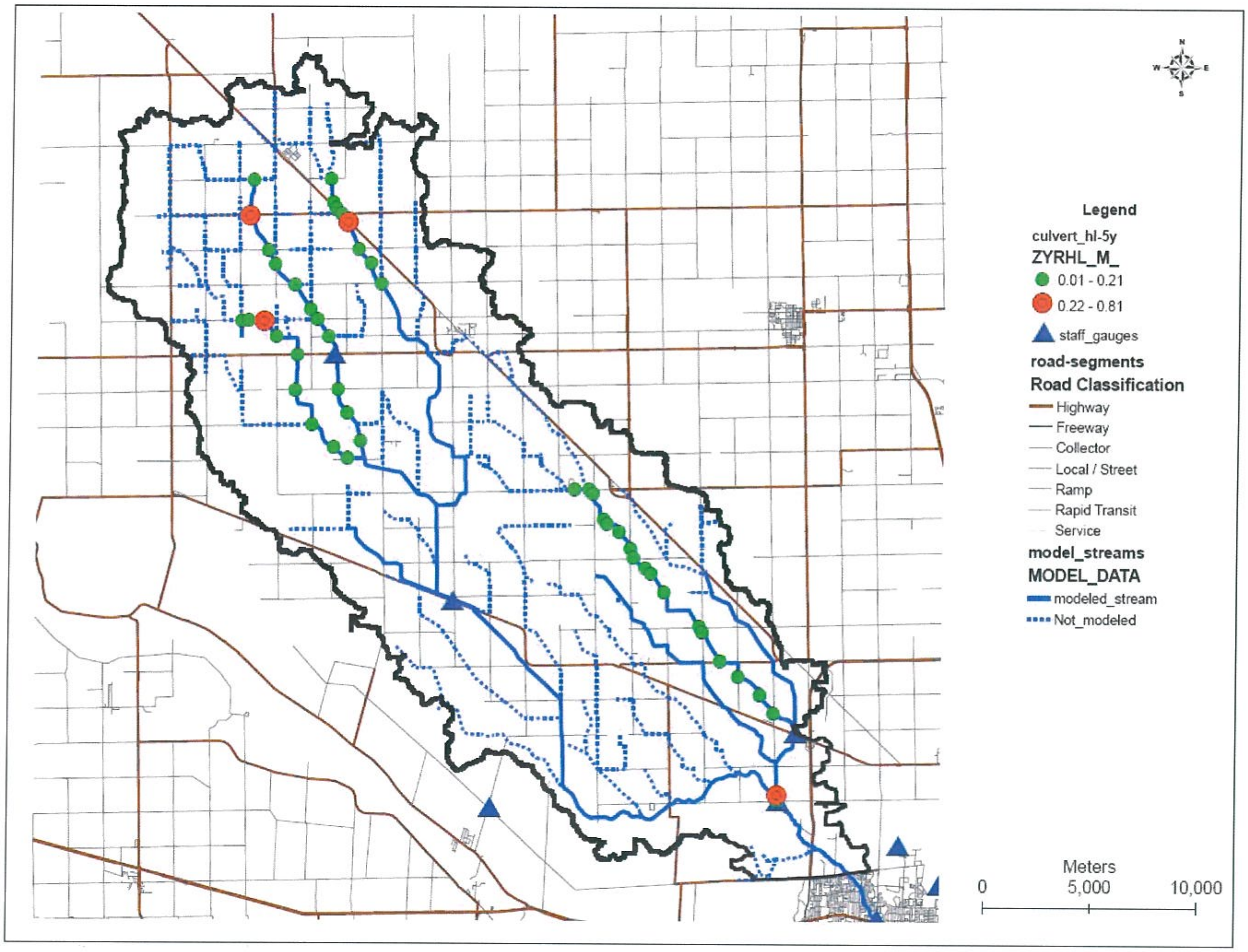


Figure 8.5.4.2 - Level of Service Analysis, 0.21m Head Loss Criteria – Five-Year Flow

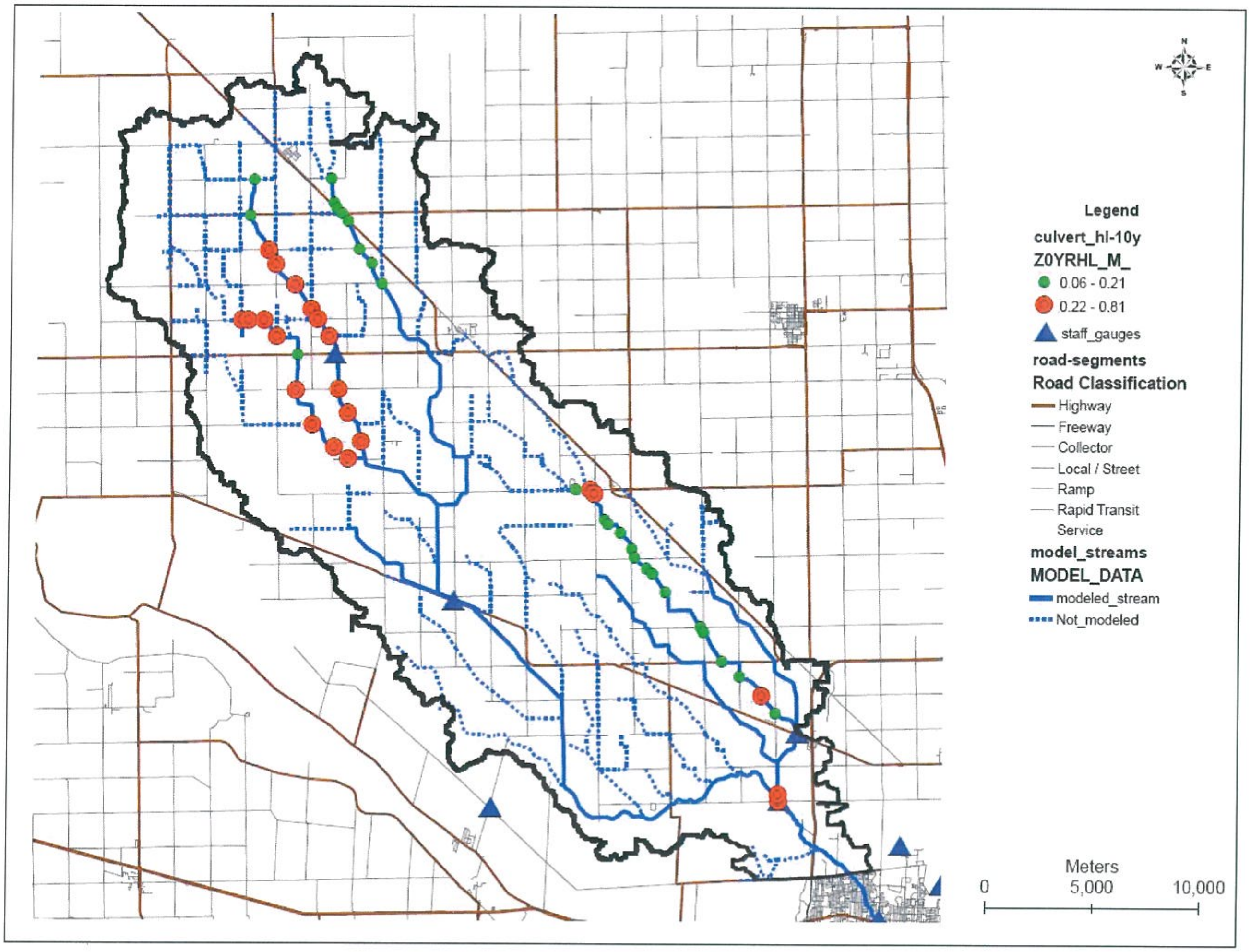


Figure 8.5.4.3 - Level of Service Analysis, 0.21m Head Loss Criteria – Ten-Year Flow

In summary, two of 47 culvert pipe structures did not have adequate capacity for the two-year design flow condition, eight culverts did not have adequate capacity for the five-year design flow condition and twenty-one of 47 culvert pipe structures failed the hydraulic head loss test in the ten-year design flow.

The modeled hydraulic capacity of the channels in this watershed is generally higher than the culvert conveyance capacity, based on modeled hydraulic profile observations.

8.5.5 Capacity Upgrades Required to Convey Ten-Year Flows

Once the existing capacity and level of service had been analyzed, AECOM estimated the cost of upgrading the existing channels and culverts to convey 10-year design flow with acceptable head loss. Since channel slopes were relatively uniform, computing replacement culvert sizing using Culvert Master software was considered adequate for this level of detail.

The design flows were computed for various contributing areas in 1 mi^2 increments. The culvert size required to convey the design flows were computed for single, double and triple culvert configurations to allow for minimum cover considerations. A summary of acceptable culvert size preliminary upgrades is shown in Table 8.5.5.1.

A conceptual culvert sizing tool was developed where flows corresponding to various agricultural areas and the appropriate culvert configurations to convey the 10-year design flows are plotted to allow consistent culvert sizing. This preliminary design chart is shown in Figure 8.5.5.1.

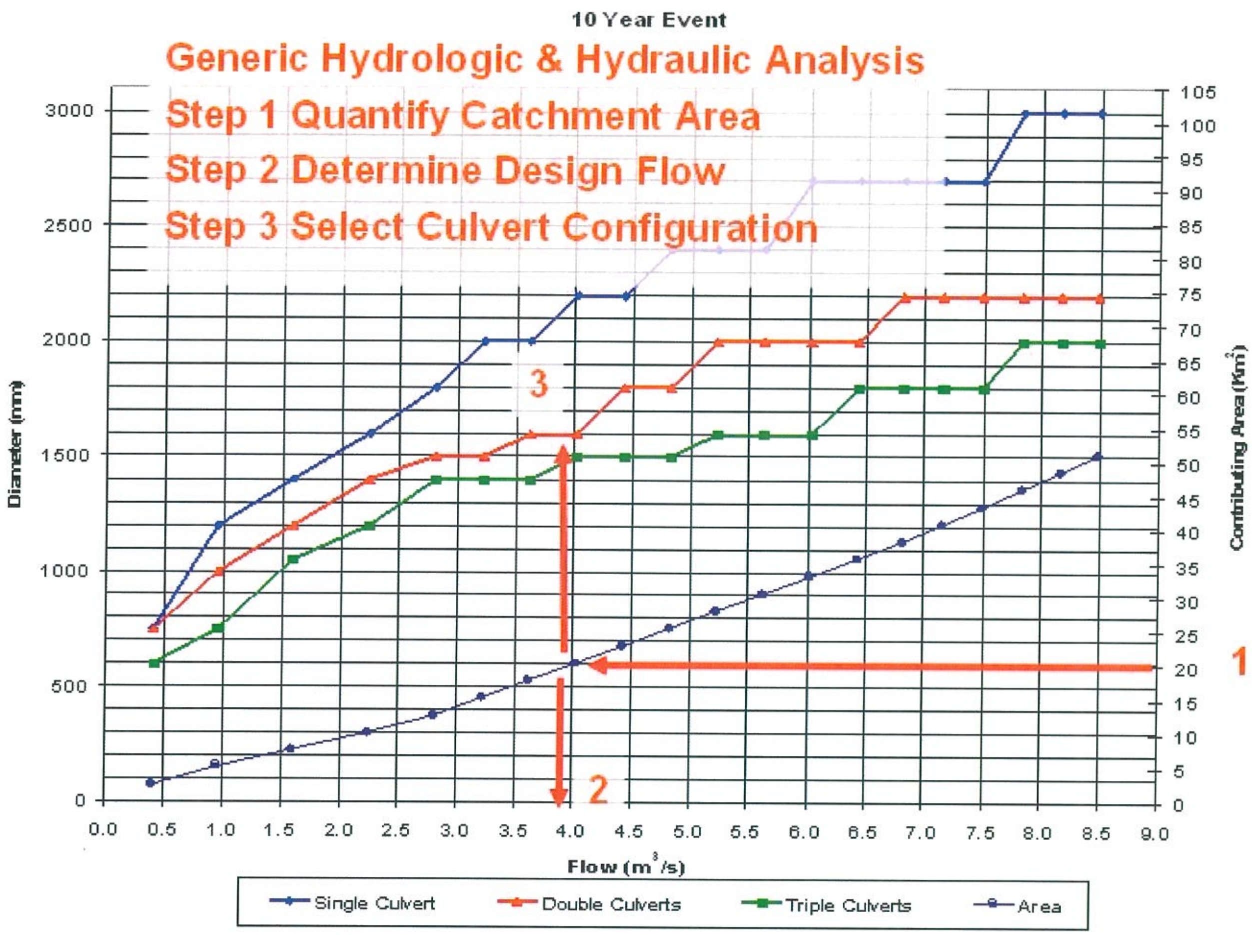


Figure 8.5.5.1 – Preliminary Culvert Configuration to Meet Design Flows

TABLE 8.5.5.1

Sturgeon Creek
Generic Drainage and Culvert Size Analysis
10 Year Design Event

Drainage Area		Mean Daily		Culvert Configuration & associated Head Loss					
		Flow	Flow	Single Culvert		Double Culverts		Triple Culverts	
Mi^2	Km^2	m^3/s	ft^3/s	Diameter (m)	Head Loss (m)	Diameter (m)	Head Loss (m)	Diameter (m)	Head Loss (m)
0.5	1.3	0.27	10	0.6	0.17	0.45	0.20	0.45	0.12
1	2.6	0.40	14	0.75	0.20	0.6	0.15	0.6	0.13
1.5	3.8	0.69	24	1.05	0.11	0.75	1.50	0.6	0.19
2	5.1	0.95	34	1.2	0.12	0.9	0.18	0.75	0.21
3	7.7	1.59	56	1.35	0.19	1.05	0.15	0.9	0.14
4	10.2	2.24	79	1.65	0.16	1.2	0.17	1.05	0.14
5	12.8	2.81	99	1.8	0.16	1.35	0.15	1.2	0.12
6	15.4	3.22	114	1.95	0.15	1.35	0.20	1.2	0.15
7	17.9	3.62	128	1.95	0.19	1.5	0.16	1.2	0.19
8	20.5	4.02	142	2.12	0.17	1.5	0.19	1.35	0.14
9	23.0	4.42	156	2.12	0.21	1.65	0.15	1.35	0.17
10	25.6	4.82	170	2.28	0.18	1.65	0.18	1.35	0.20
11	28.2	5.22	184	2.43	0.16	1.8	0.14	1.5	0.14
12	30.7	5.62	199	2.43	0.19	1.8	0.16	1.5	0.17
13	33.3	6.02	213	2.59	0.17	1.8	0.19	1.5	0.19
14	35.8	6.42	227	2.59	0.19	1.95	0.15	1.65	0.14
15	38.4	6.81	241	2.74	0.17	1.95	0.17	1.65	0.16
16	41.0	7.16	253	2.74	0.18	1.95	0.19	1.65	0.18
17	43.5	7.50	265	2.74	0.20	1.95	0.21	1.65	0.19
18	46.1	7.83	277	3.05	0.17	2.12	0.16	1.8	0.14
19	48.6	8.16	288	3.05	0.19	2.12	0.18	1.8	0.16
20	51.2	8.49	300	3.05	0.20	2.12	0.19	1.8	0.17

In addition, AECOM surveyors conducted a survey of a sample of typical drains in October 2007. The data collected from these samples allowed an estimate of the required channel and pipe conveyance and costs to upgrade the total system.

The 15-mile sample survey of typical first, second and third order drains and hydraulic structures inventory indicated the hydraulic capacity of the existing hydraulic structures and drainage channels is below the ten-year return period level of service. A summary of the hydraulic structures inventory of the AECOM-surveyed area is shown on Table 8.5.5.2.

Table 8.5.5.2

Sturgeon Creek Study
Existing Hydraulic Structure Inventory in Selected Survey Areas

Location	Estimated Drainage Area (km^2)	Existing Culvert Size (mm)			
		1st Order	2nd Order	3rd Order	4th Order
Site A&B	4	1-450mm, 2-600mm	1-450mm, 7-600mm, 1-750mm		
Site C	2.3	1-300mm, 1-450mm, 2-600mm			
Site D	8.17		3-1400mm (single), 1-1400mm (double)		
Site E	24.6			1-1100mm, 2-1200mm(double), 1-1240x2400 Box Culvert, 1-2000x2500 Box Culvert	
Site F	95.5				1-1600mm triple
Site G	2.4	4-600mm single			
Site H & I	13.3	1-400mm	1-1000mm, 1-1200mm, 1-1800mm, 1-2500mm		

Select channels were surveyed by AECOM to be considered as typical examples of channel condition in four stream orders. Two representative profiles and corresponding proposed channel bed upgrades are shown on Figures 8.5.5.2 and 8.5.5.3.

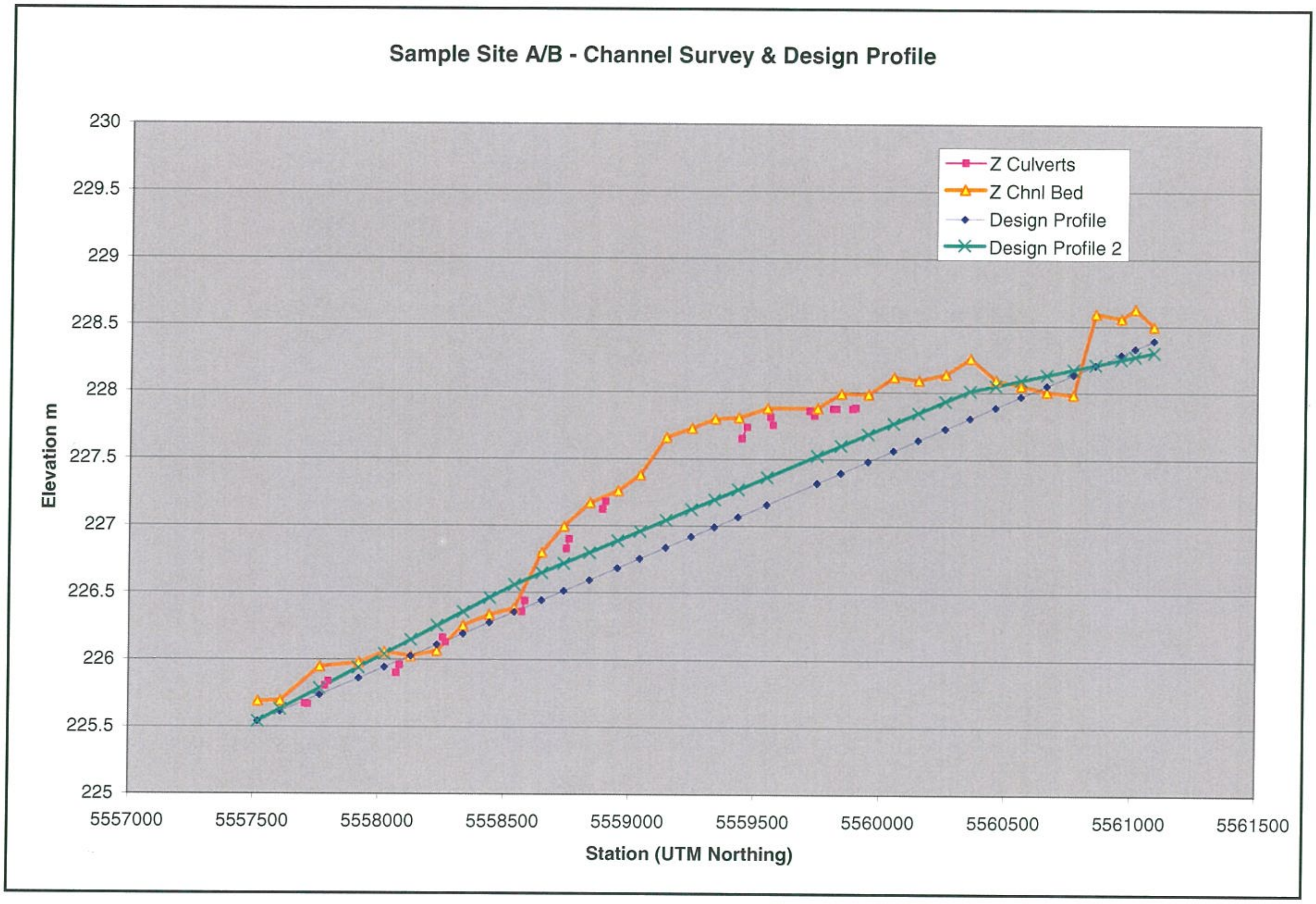


Figure 8.5.5.2 - Channel Profile Survey and Proposed Design Grade (Site A/B)

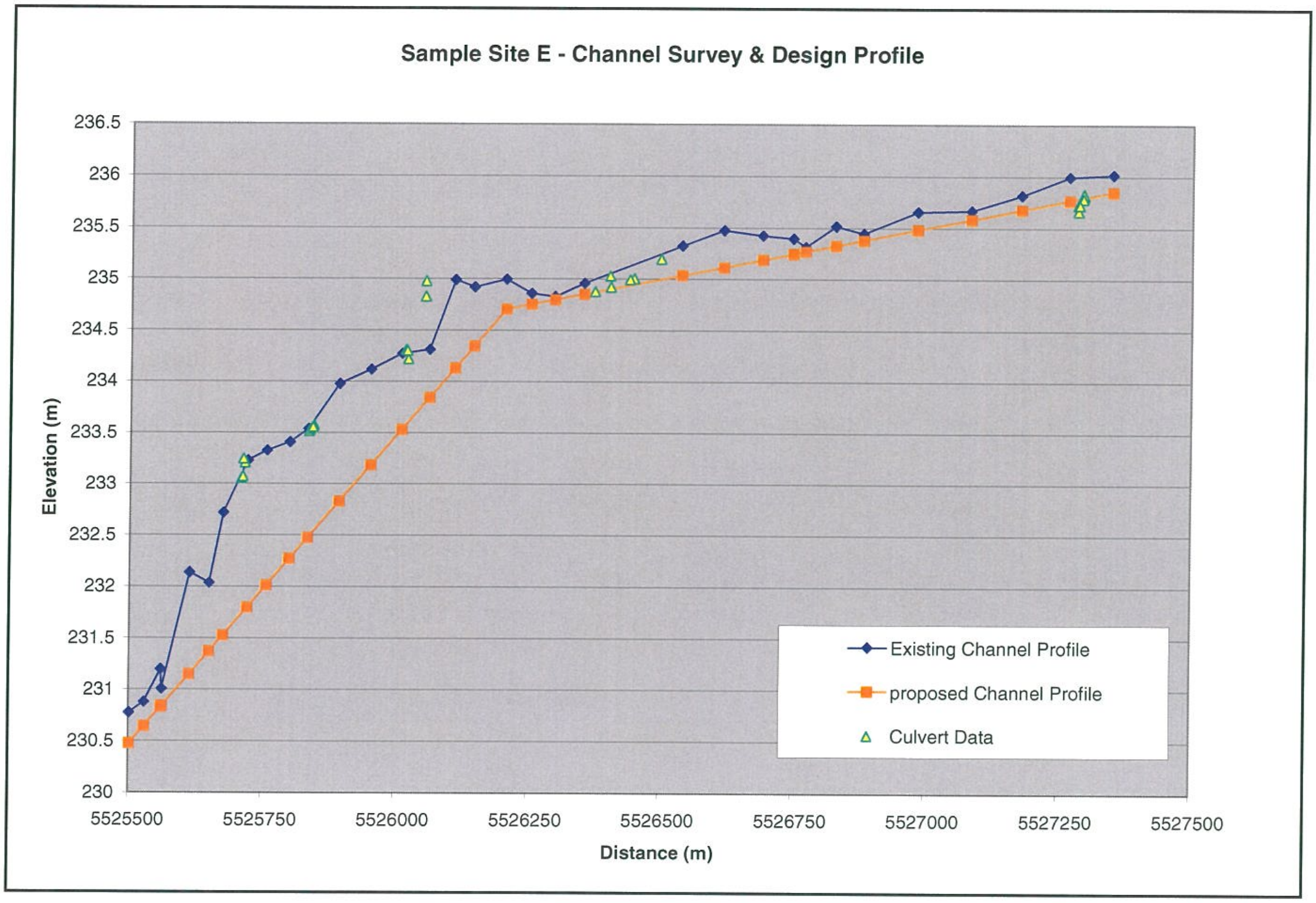


Figure 8.5.5.3 - Channel Profile Survey and Proposed Design Grade (Site E)

The cost of a watershed wide culvert and channel upgrade was estimated based on quantities determined from sample surveys and hydraulic capacity analysis. Channel grades were analysed at a preliminary level of detail that and are not optimized for quantities and cost. Hydraulic structure sizes, channel alignments and upgrade cost to upgrade Sturgeon and Colony Creek to convey the ten-year design event is summarized on Table 8.5.5.3.

Table 8.5.5.3

Sturgeon & Colony Creek - Culvert Replacement & Channel Upgrade Preliminary Cost Estimate
10 Year Design

Provincial Drain Order	Approx. Drainage Area (km²)	Calculated Flow (m³/s)	Single Culvert (mm)	Unit Price (per m)	Double Culverts (mm)	Unit Price (per m)	Triple Culverts (mm)	Unit Price (per m)	Estimated # Culvert Crossings	Average Culvert Length (m)	Estimated Drain Length (km)	Supply & Installed prices	Earth Work costs		Comment
													As Per O&M Linear Length	As Per Volumetric Rate	
1st Upper Reach	1.25	0.27	600	$ 127	450	$ 100	450	$ 100	31	25		$ 198,000 $ 312,000 $ 468,000			replace existing by single culvert, or replace existing by double culverts, or triple culvert not recommended
1st Lower Reach	2.56	0.4	750	$ 160	600	$ 127	600	$ 127	40	25	114	$ 321,000 $ 509,000 $ 763,000	$ 535,000	$ 1,397,000	replace existing by single culvert, or replace existing by double culverts, or triple culvert not recommended
2nd Order	13	2.81	1800	$ 737	1350	$ 583	1200	$ 475	98	25	158	$ 3,612,000 $ 5,714,000 $ 6,983,000	$ 742,000	$ 1,936,000	replace existing by single culvert, or replace existing by double culverts, or replace existing by triple culverts
3rd Order	25	4.82	2280	$ 706	1650	$ 528	1350	$ 583	50	25	81	$ 1,765,000 $ 2,639,000 $ 4,373,000	$ 380,000	$ 993,000	replace existing by single culvert, or replace existing by double culverts, or replace existing by triple culverts
4th Order	100	14.53	3660	$1,515	2740	$ 1,051	2440	$ 773	29	25	46	$ 2,197,000 $ 3,049,000 $ 3,361,000	$ 216,000	$ 564,000	replace existing by single culvert, or replace existing by double culverts, or replace existing by triple culverts
													$ 1,873,000	**$ 4,890,000**	
Single Culvert replacement total (Supply & Install) **Double culverts replacement total (Supply & Install)** **Triple culverts replacement total (Supply & Install)**												**$ 8,093,000** **$ 12,223,000** **$ 15,948,000**			
Single Culvert replacement total (Supply, Install & Earth work) **Double Culverts replacement total (Supply, Install & Earth work)** **Triple Culverts replacement total (Supply, Install & Earth work)**													**$ 9,966,000** **$ 14,096,000** **$ 17,821,000**	**$ 12,983,000** **$ 17,113,000** **$ 20,838,000**	
Single Culvert replacement total (Supply, Install & Earth work) plus 30% contingency and 10% engineering **Double Culverts replacement total (Supply, Install & Earth work) plus 30% contingency and 10% engineering** **Triple Culverts replacement total (Supply, Install & Earth work) plus 30% contingency and 10% engineering**													**$ 13,952,400** **$ 19,734,400** **$ 24,949,400**	**$ 18,177,000** **$ 23,959,000** **$ 29,174,000**	

Note: 1. Number of culverts was determined base on the assumption of 1 culvert crossing per mile
2. Earth works volume was calculated based on excavation depth of 0.25 m across the channel and an assumption of 70% of drain length
3. Unit cost for excavation was based on $7,500 per mile of channel alignment and maintenance cost (provided by Manitoba Water Stewardship)
4. Culvert prices obtained from Armtec on Dec. 12, 2007

Earth work costs

$ 5.00 per m³ volume work

$ 4.69 per Linear metre ($7,500 per mile O & M cost Manitoba Water Stewardship)

8.6 Upstream Storage Flood Mitigation

The effect of runoff detention in upland regions was more thoroughly understood and demonstrated with the dynamic modeling tools. Upland detention has limited benefit even for small events and potentially creates economic challenges for the owner of the flooded land on which the water is temporarily stored.

Flood mitigation by upstream detention was tested by modeling the water volume to be removed from the system to reduce the flow to within banks for the ten-year event. The model was configured to connect all input hydrographs directly to the main channels instead of the culvert-throttled lateral drains. This configuration produced the "Without Storage" hydrograph shown in Figure 8.6.1. The volume stored in existing ditches was found to be 36,700,000 m^3, which is roughly equivalent to 12 times the size of Grant's Lake. Another way to visualize this volume is 14 square miles flooded 1m deep.

Grant's Lake has a weir control structure and dikes to contain water. It is presently operated as a wetland by maintaining partially elevated water levels. In this operating scheme it provides wildlife habitat but offers limited capacity to provide flood storage. However, if the lake was emptied between runoff events the estimated volume would be in the order of 3,100,000 m^3. This estimate was generated by assuming the area defined by land use data as water body (0.49 km^2) had a nominal depth of 2 m, and the area defined as marsh (2.12 km^2) had a nominal depth of 1m.

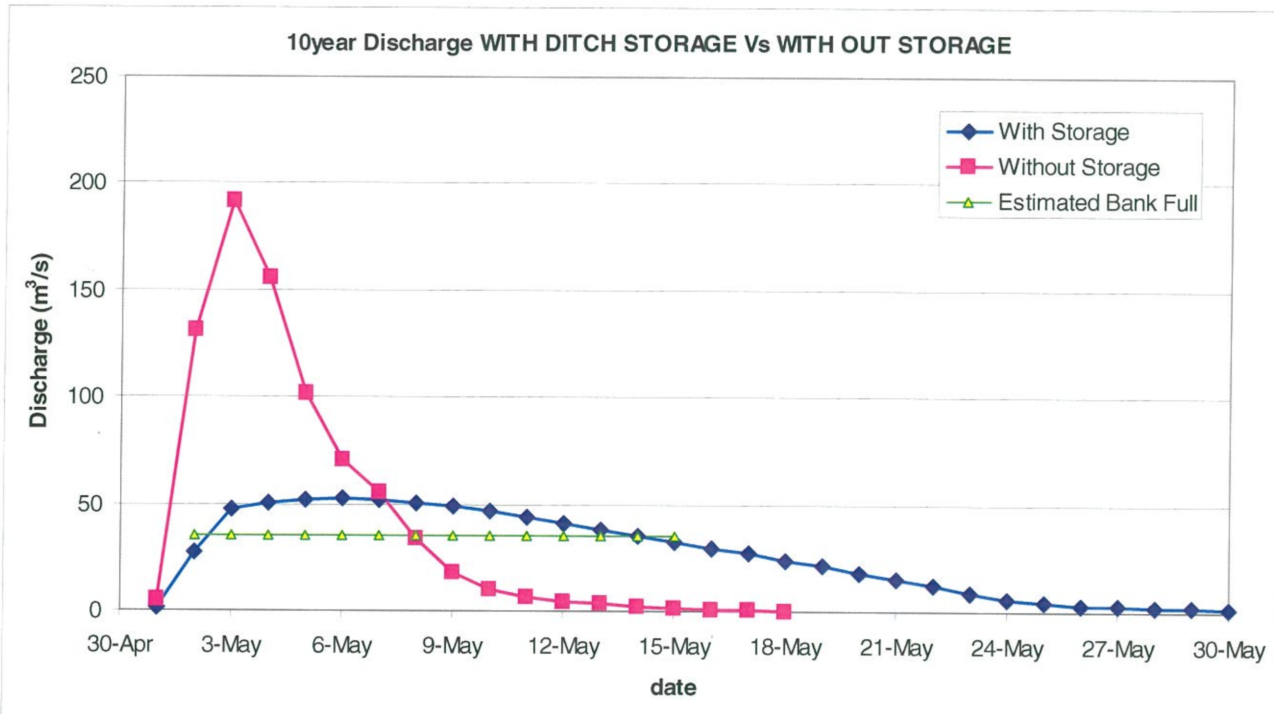


Figure 8.6.1 – Ten-Year Sturgeon Creek Hydrograph with and without Ditch Storage

Ideally, and if sufficient volume could be temporarily stored in upland regions, this would produce equivalent runoff volumes over time but would delay the peak runoff to arrive at a time when the river flow was below flood levels. However, large volumes are already temporarily stored in lateral ditches

(Figure 8.6.1). If the existing ten-year flood peak was to be reduced to a 35 m^3/s event over 10 days, this additional storage volume required would be 12,960,000 m^3 which is roughly equivalent to 4 times the assumed volume of Grant's Lake. This magnitude of additional storage would be difficult to find in this highly developed agricultural watershed. For this reason, upland detention was considered infeasible at reducing floods for this study area and no benefit-cost analysis was performed.

9. Economic Analysis

The impact of flooding on the affected communities is significantly greater than what can be measured by economics alone. The social, physiologic and psychological impacts of flooding are difficult to measure with engineering tools and outside the scope of this study. However, for the purpose of measuring the effectiveness of various mitigations, economic measures were considered a fair representation of flood damage cost.

This study focussed on defining the maximum flood inundation zone and evaluating the economic losses associated with this flooded area under existing conditions. Then the model was run with various mitigation options to compare the relative reductions of flood zone extents. Mitigation options were ranked according to evaluation of construction costs and economic benefit measured as flooding averted.

9.1 Asset Evaluation

Flooded area and a value representing crop loss payments formed the basis for economic assessment. Flood claim information was requested from the rural communities. Economic impact data was available for few flood events however varied in regional distribution such that this did not provide a comprehensive representation of the total impact of a given flood. For this reason economic evaluation was based on flooded property assumed to be agricultural land.

Damage claims to the Manitoba Emergency Measures Organization were provided for floods in 2001 and 2005 in the RM of Woodlands, but not for other regions.

A plot of post-harvest excess moisture claims (Figure 9.1.1) from Manitoba Agricultural Services Corporation (MASC) shows the pattern of claim values in the study municipalities for the years 1996 to 2005. Total claims amounted to $5,900,000 for RM Rosser and $4,200,000 for RM Woodlands. Claim amounts averaged at $52 per acre and ranged in the order of $6.83 to $90.40 per acre. We were not able to determine whether the claims submitted were equal to the payments processed. Because of ambiguity over whether these values were payouts or claims and uncertainty on regional representation, these values were not directly useful in economic evaluations.

Asset values were discussed at TAC meetings and it was suggested that a unit value of $200 per flooded acre fairly represented the cost of annual investment, and reflected flood damages paid out to farmers. A sensitivity analysis considered other damage values, but was not recommended.

The City of Winnipeg indicated that existing high water levels are within the capacity of the existing drainage and flood protection systems, so that benefits to the City would not influence the economic outcomes of mitigation efforts in the Sturgeon Creek and Colony Creek watershed.

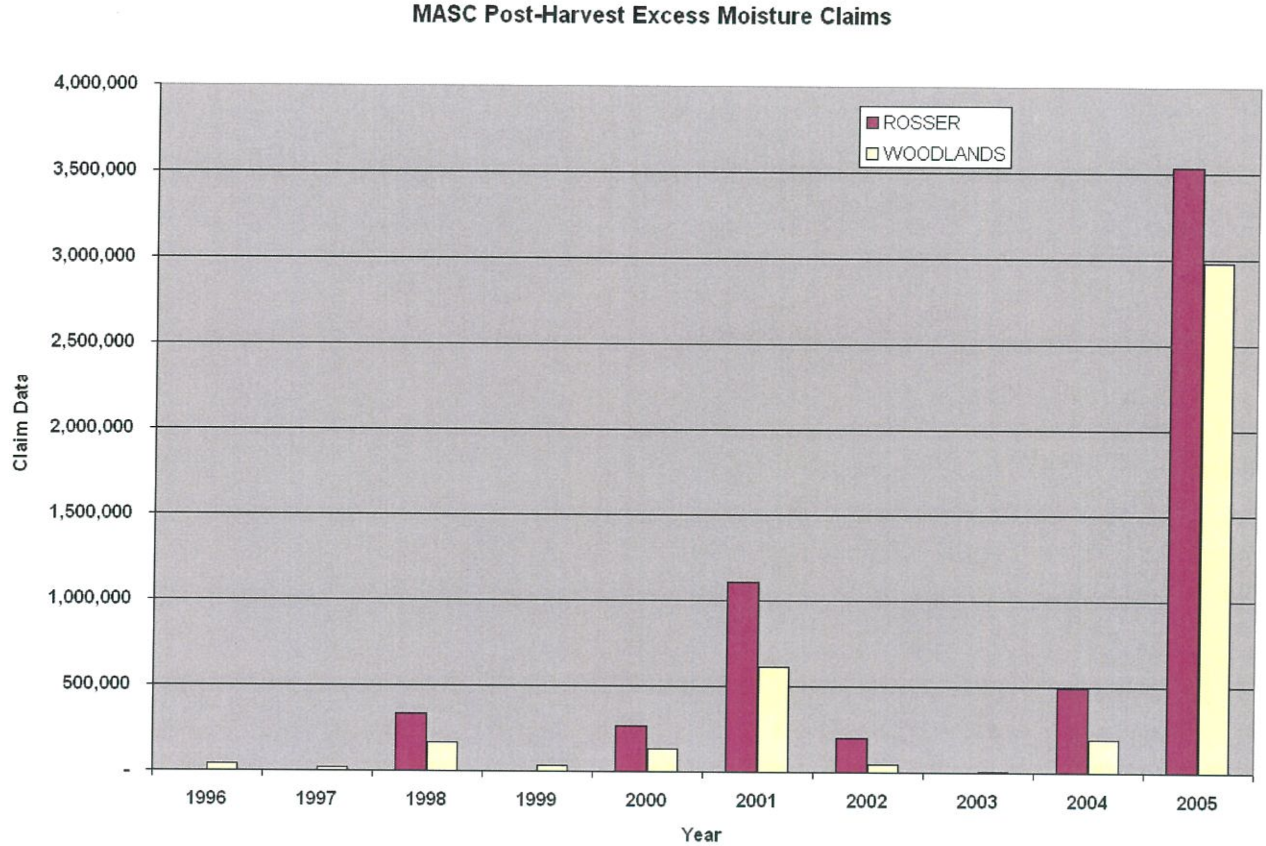


Figure 9.1.1 - MASC Post-Harvest Excess Moisture Claims

Limited data on infrastructure losses prevented analysis of damages corresponding to floods of a given magnitude. For this reason, the flood cost was attributed to cost of damage to agricultural crops only.

9.2 Economic Benefit and Cost Evaluation

The economic analysis assessed the costs and benefits of all the flood mitigation alternatives. MIKE11 simulations indicated both the aerial extent and depth of flooding. The existing flooded area corresponding to the ten-year flood were estimated under existing river conditions. Reduction in flooded area damages associated with each mitigation alternative was defined as the benefit.

A property was considered flood affected and the crop value counted as lost when a property was located within the defined flood zone for a given scenario, without regard to depth or duration. The flood zone estimate was based on the conservative assumption that flood levels outside the lateral dikes would reach the same elevation as in-channel elevations. This was considered a reasonable approach for estimating flooding when explicit knowledge of culvert flood-gate condition was not available.

The costs of the flood control alternatives were determined to a "feasibility study" level. Construction costs for alternatives were estimated based on recent tendering costs for major projects in Manitoba, standard engineering procedures for estimating earthwork or other construction activities, and land values based on recent assessments. Common earthwork was estimated costing $5/m^3 and property acquisition at $2000/acre. Temporary road works costs were from 2007 tenders supplied by MIT and scaled to suit diversion sites. Grade control structures required at existing stream intersections were conceptualized as sheet pile and rock weirs spanning the existing streams.

Capital costs for mitigation works were amortized over an estimated fifty-year lifetime using a discount rate of five percent. Cost estimates were based on quantity estimates generated from design grades and cross section templates applied to topographic information from various sources. Given the uncertainty of these volume estimates, the costs included a 30% contingency factor and engineering service estimate of 10% on the construction cost sub-total.

Annual maintenance cost estimates for each mitigation option were based on 0.5% of capital cost. Annual maintenance cost estimates for the diversions ranged from $40,000 to $90,000.

The annual benefit (or damages averted) was calculated from a damage-frequency curve. The known points on the curve were the frequency associated with no damage (roughly the four-year event) and damages associated with the ten-year and fifty-year events. Annualized benefit was the difference between frequency/damages curves representing the existing condition base case and the residual damages following mitigation.

A summary of the mitigation options hydraulic impact, construction cost estimate and associated property losses averted is presented in Table 9.2.1. The Benefit Cost Ratio (BCR) is included for reference and selection of options considered feasible based on the limited economic data analyzed in this study.

Benefit cost ratios greater than one (1) indicate that benefit – in the form of economic value gained or losses prevented, are above the value spent mitigating losses. The most optimistic benefit cost ratio in the proposed mitigation options remained less than one, indicating the protection works costs more than the protection value gained. Economic ranking was based on the highest BCR.

Table 9.2.1 - Economic Summary

	MITIGATION OPTIONS RANKED BY ECONOMICS			
Economic Effects	**FOURTH CREEK DIVERSION**	**THIRD CREEK DIVERSION (Option 2 - Split Flow)[a]**	**PERIMETER HIGHWAY DIVERSION**	**STURGEON CREEK CHANNEL IMPROVEMENTS (BRIDGES only)[b]**
Total Cost of Project [$]	**$14,759,000**	**$9,471,000**	**$17,383,000**	**$11,200,000**
Annual Cost with Maintenance	**$734,655**	**$471,435**	**$865,269**	**$557,499**
Base Case Flooding (Ex.Cond 10Yr, km^2)	97.45	97.45	97.45	97.45
Remaining Flooding (km^2)	84.09	74.95	95.11	93.14
Benefit - Flooded Area Reduction (km^2)	13.36	22.50	2.34	4.31
Benefit - Reduced Flooding (Acres)	**3,301**	**5,560**	**578**	**1,065**
Benefit - Annual Damages Averted	**$175,814**	**$296,094**	**$30,794**	**$56,718**
Benefit-Cost Ratio	**0.24**	**0.63**	**0.04**	**0.10**
Rank	**2**	**1**	**4**	**3**

Notes:

Maximum Flood (97.45 km^2 or 24,080 acres) occurs with existing condition & 10 Year flood event. Assume Worst Case -No lateral containment dikes.

Agricultural Loss considered total when flooded, regardless of depth or duration.

Agricultural Loss evaluated at $200/acre. Residential & Infrastructure losses not included.

a - Third Creek Option 1 (along existing streambed) Cost $12,550,000 (BCR 0.50)

b - In-Channel Improvements (add $29,175,000 for Triple Barrel or $18,177,000 for Single Barrel culvert configuration for upstream improvements)

Detailed summary cost for the three diversion options (Fourth Creek, Third Creek, and Perimeter Highway) including supporting assumptions were shown in the report Section 8.0 describing the mitigation options (Tables 8.1.1, 8.2.1, 8.2.2, and 8.3.1). The diversion along Third Creek was analyzed as requested in the existing channel as well as a split flow scenario with partial flow in a secondary diversion south of the Trans-Canada Highway.

Following presentation of the economic results to the Technical Advisory Committee, an additional analysis was conducted to consider whether an alternative alignment of the Fourth Creek diversion would significantly alter the benefit cost ratio. The requested additional alignment was a diversion intersecting the Sturgeon Creek in Section 20-12-1W. The incremental benefits were estimated by summing all flooded area from downstream of the CPR bridge crossing at 16-12-1W to the previous Fourth Creek diversion intersection. This additional area was summed as 6.58 km^2 and would represent an additional Annual Average Benefit of $86,600 as flooding averted for the ten-year event (Table 8.1.1). If costs for this diversion route remained the same as the previous Fourth Creek diversion, the resultant BCR would rise from 0.24 to 0.36. Cost estimates for this alignment were not updated.

9.3 Annual Operation & Maintenance Cost Estimate

Water Stewardship was consulted to determine the definition and cost estimates of annual maintenance for provincial drains. Annual maintenance was considered to include ditch mowing and a maximum of 0.3 m cut to channel inverts to restore positive drainage. The cost of cutting grass in the drains was estimated at $650 per km based on conversations with municipal maintenance supervisors. However, due to limited access in periodic wet conditions, on average a drain would see mowing once in four years.

More significant ditch maintenance was described as drainage re-alignment and grading or bed restoration. AECOM was informed[6] that maintenance cost of the existing drainage system ranges between $5,000 and $10,000 per mile, with a fifteen to twenty-year frequency. This study used the mean of $7,500 per mile ($4700/km) once in fifteen years or $313.33/km/yr.

Annual maintenance costs of the Sturgeon Creek drainage system are summarized in Table 9.3.1 below.

Table 9.3.1 - Summary of Annual Operation and Maintenance Cost

Item	Estimated Drain Length (km)	Annual Mowing Maintenance Cost ($162.50/km)	Annual Drainage Alignment and Grading Cost ($313.33/km)
First order drain	114	$18,525	$35,720
Second order drain	158	$25,675	$49,506
Third order drain	82	$13,325	$25,693
Fourth order drain	46	$7,475	$14,413
Sum	**400**	**$65,000**	**$125,332**
	Total Annual Maintenance Cost		**$190,332**

Drainage alignment and bed profile maintenance cost estimate were based on excavation depth up to 0.3 m. Excavation depth greater than 0.3 m would require volume estimates based on design section template and ditch profile selection. Due to the nature of the available data it is recommended to consider the above as a budget class estimate. It does not include engineering fees or contingency allowances.

[6] *Personal communication with Mr. B. Lussier*

10. Environmental Screening

A high-level environmental screening was performed on the proposed mitigation options. This evaluation was conducted by AECOM based on familiarity gained with the watershed during site tours and survey activities. The analysis did not include field sampling or testing. Aquatic habitat information on Sturgeon Creek had been previously collected from the Department of Fisheries and Oceans (DFO). Fish use, habitat type, sensitivity to development and classification of streams according to their capacity to sustain aquatic activities are shown in Figure 10.1 and 10.2. Habitat type is based on the species present and the stream's ability to support various fish activities. Type A is considered prime fish habitat, while Type E habitat is occasionally dry and unable to support a fishery.

Data provided by the Department of Fisheries and Oceans is provisional data subject to change due to factors including temporal and environmental influences, and is provided for discussion only.

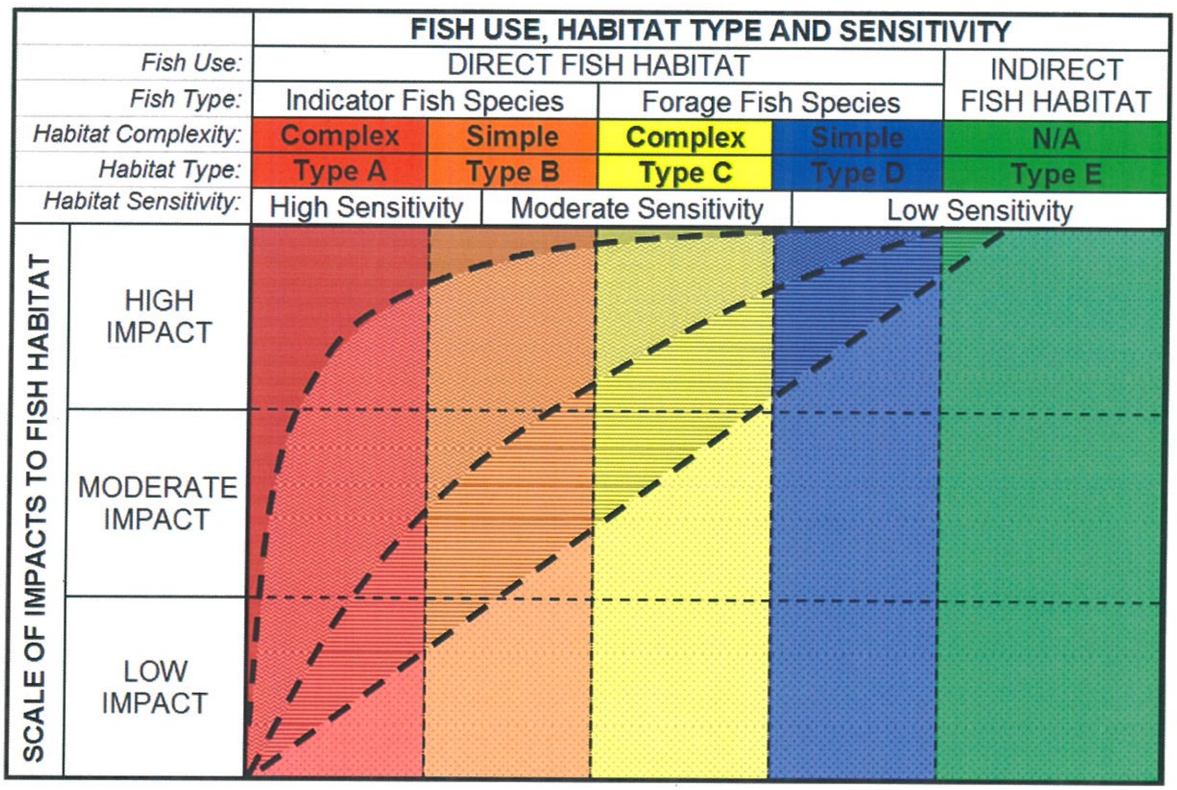


Figure 10.1 - Risk Matrix - Fish Use, Habitat Type and Sensitivity (DFO, April 2007)

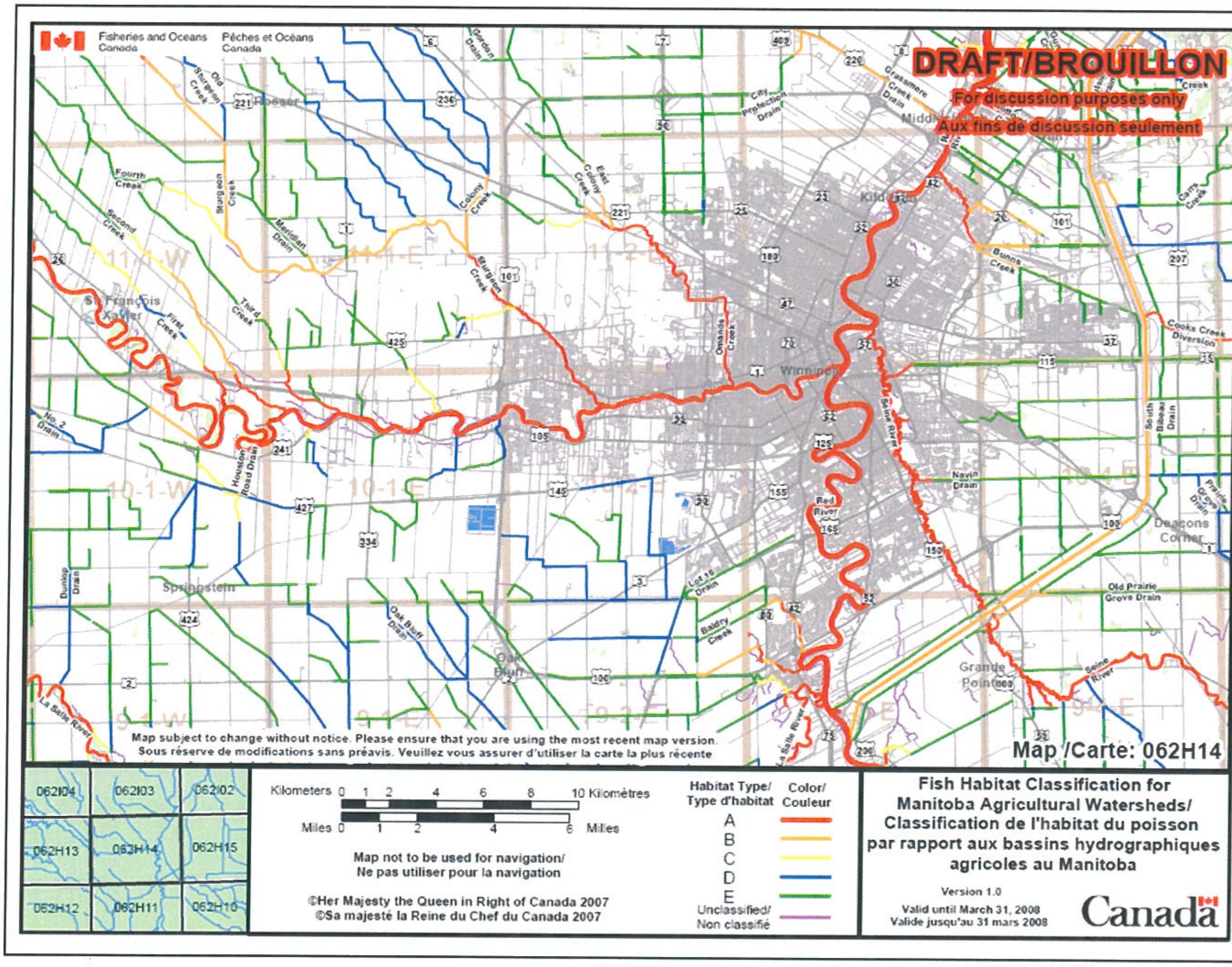


Figure 10.2 - Fish Habitat Classification (DFO, April 2007)

This Fish Habitat Classification for Manitoba Agricultural Watersheds map data was supplied as draft by DFO staff on April 27th 2007.

10.1 Environmental Screening Table

The environmental screening results table (Table 10.1.1) summarizes the values considered in the general environmental analysis. General categories included Ecological, Physical, Human Health and Socio-Economic effects.

Ecologic impacts considered impacts of the terrestrial and aquatic habitat; physical effects considered potential impacts on sub-surface and surface water flow and land use changes; and socio-economic considerations were primarily from changes to transportation routes. The impact on human health was considered equally beneficial regardless of mitigation selected, with no negative impacts known. The final score was the average of scores for all categories.

Table 10.1.1 - Environmental Screening Summary

ELEMENTS RANKED	FOURTH CREEK DIVERSION	THIRD CREEK DIVERSION	PERIMETER HIGHWAY DIVERSION	STURGEON CREEK CHANNEL IMPROVEMENTS (CULVERTS & BRIDGES)
Ecological Effects	4	2	3	1
Physical Effects	4	1	2	3
Human Health	1	1	1	1
Socio-Economic Effects	2	1	3	4
Summary (Total / 4)	**2.75**	**1.25**	**2.25**	**2.25**

RANK based on 1 being the most positive impact, 4 being the worst impact

11. Conclusions

The MIKE11 model was constructed and calibrated to successfully represent the Sturgeon Creek and Colony Creek watersheds. Watershed model analysis suggested that the most poorly serviced parts of the existing drainage network has between the two and five-year level of service as determined from head loss analysis at hydraulic crossings.

A survey of several first to third order streams indicated the watershed is maintained to an average or above average level of service. System performance appears to be typical of agricultural drains in the prairies. Upgrades to the drainage network could improve local flooding issues in some places, with a resultant transfer of flooding to other locations presently downstream of constricted crossings. Changes to the local drainage network would not totally solve the flooding issues experienced by the agricultural community at present.

Drainage system upgrade costs were estimated between $10M and $30M depending on the level of service selected. The recommended channel maintenance (mowing and grade restoration through minor invert trimming) on the drainage network was estimated at $190,000 annually.

Maintenance prioritization was conducted as a spreadsheet analysis with GIS representation of locations where culverts were unable to convey design flows within acceptable hydraulic standards.

Four mitigation options were analyzed to reduce present flooding. Three channel diversions reduced water levels at the Perimeter Highway between 0.41 and 1.0 m. These diversions reduced ten-year flooding in the model from 97.5 km^2 to 75 km^2 (23%) and estimated cost ranged from $9,500,000 to $17,400,000. Benefit Cost Ratios were all below one, ranging between 0.04 to 0.63.

In-channel improvements from the Perimeter Highway and downstream were also considered. This would result in a reduction in the water level upstream of the Perimeter Highway 1.1 m. Estimated cost for three bridges was $11,200,000. This cost would increase depending on the extent of upstream culvert replacements and channel upgrades. This option resulted a only a small reduction in water levels upstream of the Sturgeon – Colony Creek confluence. A benefit cost ratio of 0.1 did not support pursuit of this mitigation strategy.

The benefit cost ratios of the four mitigation options studied do not support implementation of the mitigation efforts from a purely economic perspective.

The analysis identified the Third Creek diversion as the most beneficial from an economic perspective. Changes to economic conditions and other factors may allow this preferred mitigation option to be considered for future development.

Appendix A
Figures and Flood Maps

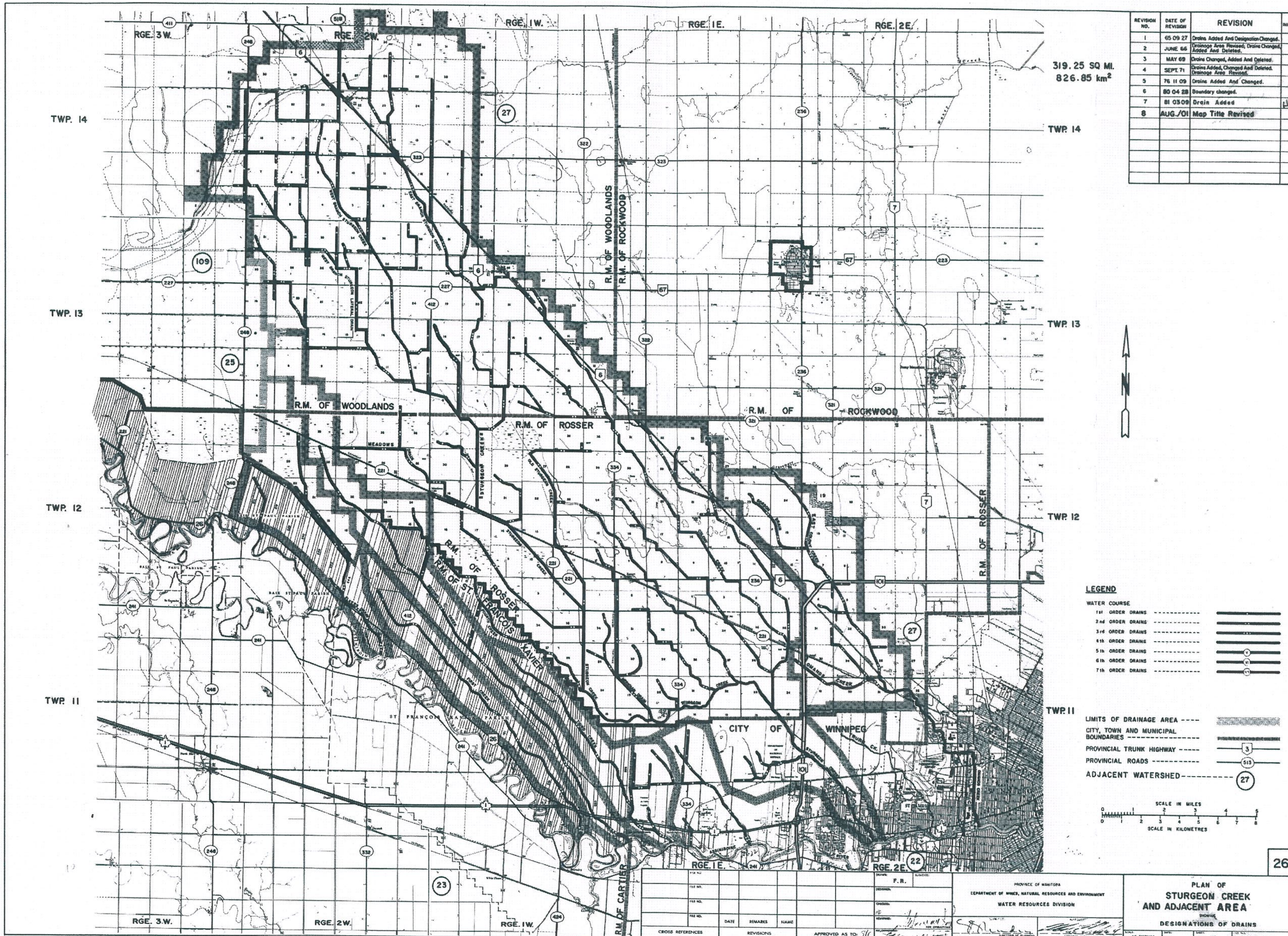

RGE. 3W.
RGE. 2W.
RGE. 1W.
RGE. 1E.
RGE. 2E.
319.25 SQ MI.
826.85 km²
REVISION NO.
DATE OF REVISION
REVISION
INITIAL
1 65 09 27 Drains Added And Designation Changed.
2 JUNE 66 Drainage Area Revised; Drains Changed, Added And Deleted.
3 MAY 69 Drains Changed, Added And Deleted.
4 SEPT. 71 Drains Added, Changed And Deleted. Drainage Area Revised.
5 76 11 09 Drains Added And Changed.
6 80 04 28 Boundary changed.
7 81 03 09 Drain Added
8 AUG./01 Map Title Revised
TWP. 14
TWP. 13
TWP. 12
TWP. 11
R.M. OF WOODLANDS
R.M. OF ROCKWOOD
R.M. OF ROSSER
R.M. OF ST. FRANCOIS XAVIER
R.M. OF CARTIER
CITY OF WINNIPEG
STURGEON CREEK
LEGEND
WATER COURSE
1st ORDER DRAINS
2nd ORDER DRAINS
3rd ORDER DRAINS
4th ORDER DRAINS
5th ORDER DRAINS
6th ORDER DRAINS
7th ORDER DRAINS
LIMITS OF DRAINAGE AREA
CITY, TOWN AND MUNICIPAL BOUNDARIES
PROVINCIAL TRUNK HIGHWAY
PROVINCIAL ROADS
ADJACENT WATERSHED
SCALE IN MILES
SCALE IN KILOMETRES
26
CROSS REFERENCES
REVISIONS
APPROVED AS TO:
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, NATURAL RESOURCES AND ENVIRONMENT
WATER RESOURCES DIVISION
DIRECTOR OF PLANNING
PLAN OF
STURGEON CREEK
AND ADJACENT AREA
SHOWING
DESIGNATIONS OF DRAINS
AS SHOWN
79 10 12
1 OF 1
92-2-1013

FIGURE 2.2.1

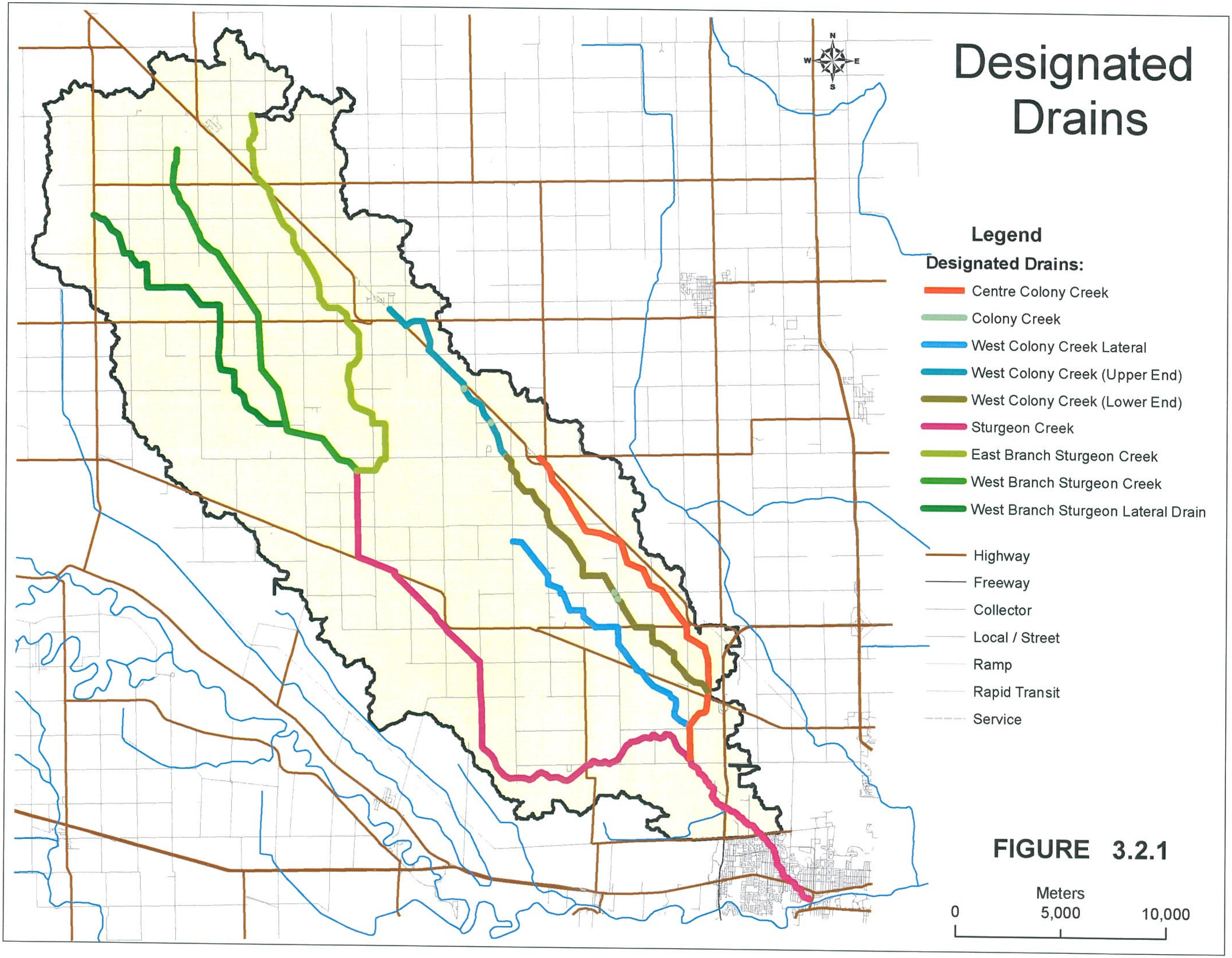

Designated Drains
N
W
E
S
Legend
Designated Drains:
Centre Colony Creek
Colony Creek
West Colony Creek Lateral
West Colony Creek (Upper End)
West Colony Creek (Lower End)
Sturgeon Creek
East Branch Sturgeon Creek
West Branch Sturgeon Creek
West Branch Sturgeon Lateral Drain
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 3.2.1

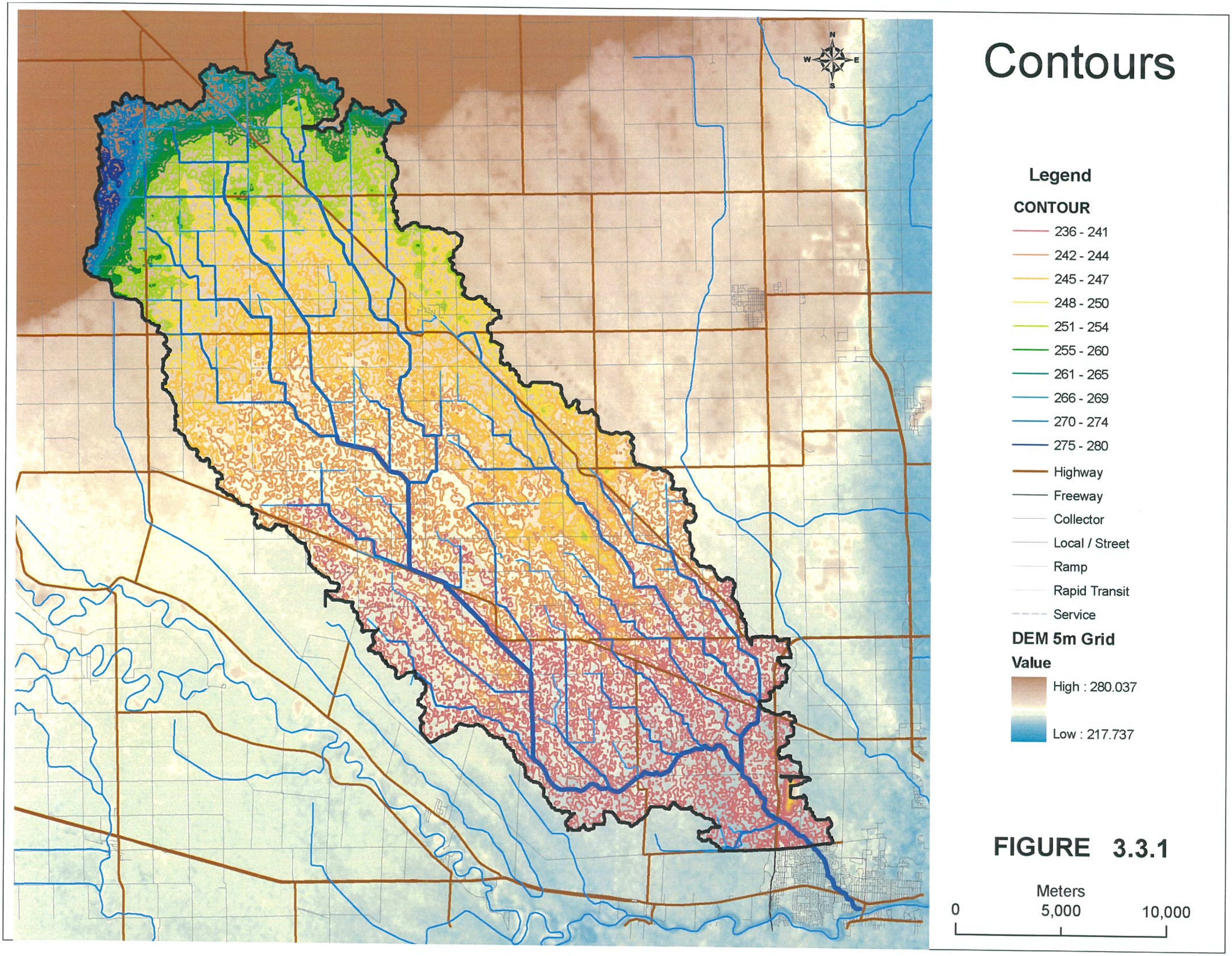

Contours
N
W
E
S
Legend
CONTOUR
236 - 241
242 - 244
245 - 247
248 - 250
251 - 254
255 - 260
261 - 265
266 - 269
270 - 274
275 - 280
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
DEM 5m Grid
Value
High : 280.037
Low : 217.737
Meters
0
5,000
10,000

FIGURE 3.3.1

Soil Types

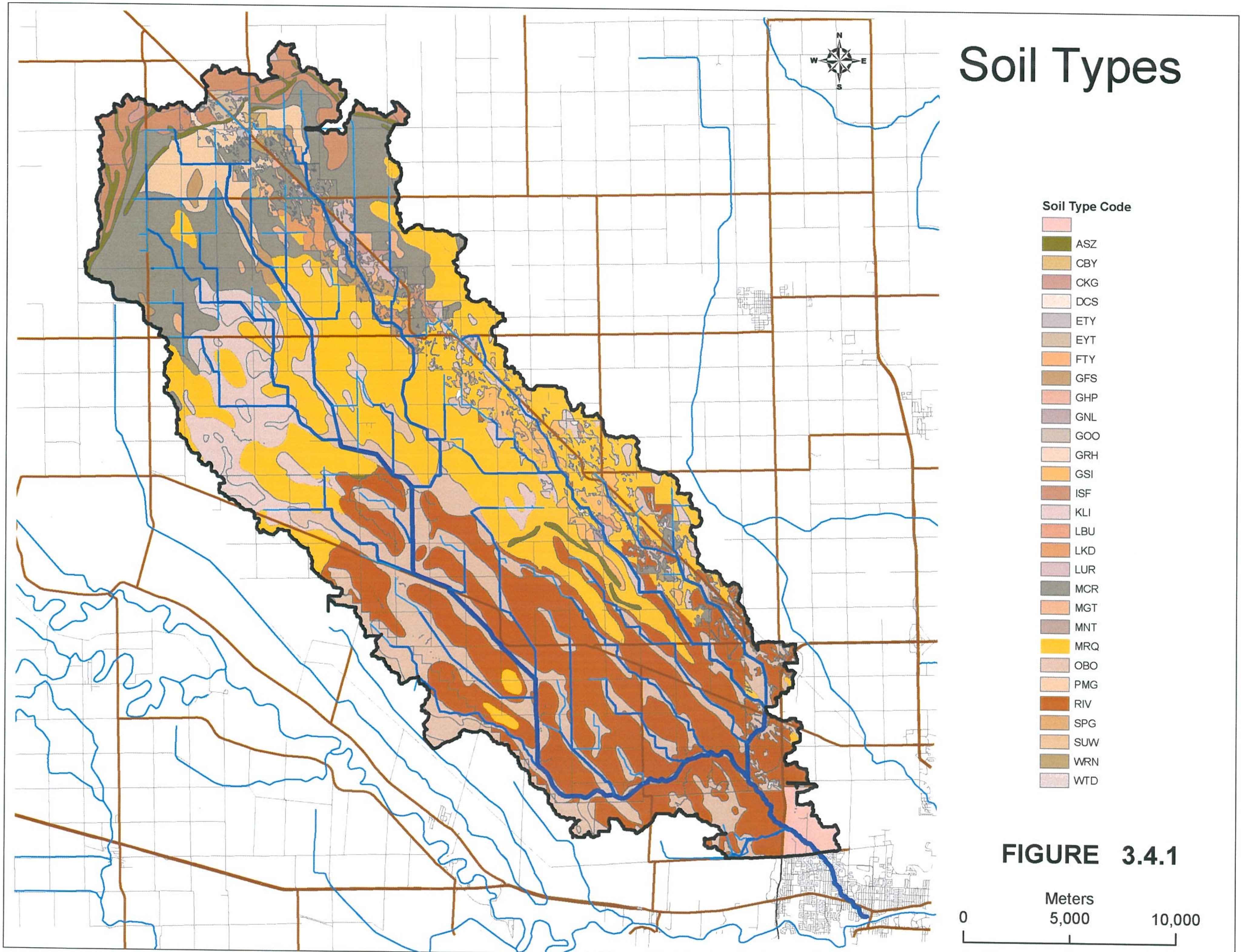


FIGURE 3.4.1

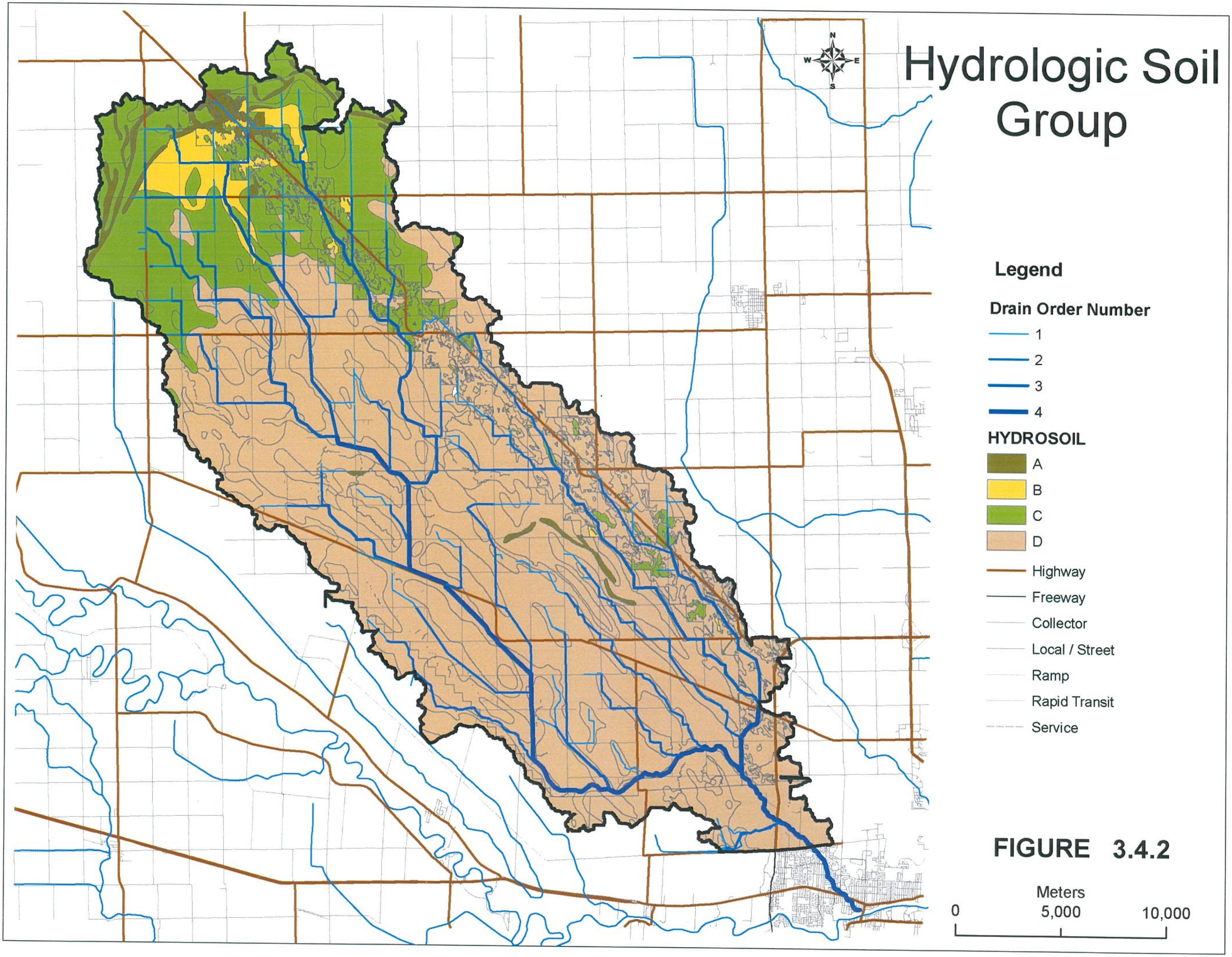

Hydrologic Soil Group
N
W
E
S
Legend
Drain Order Number
1
2
3
4
HYDROSOIL
A
B
C
D
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 3.4.2

Land Use

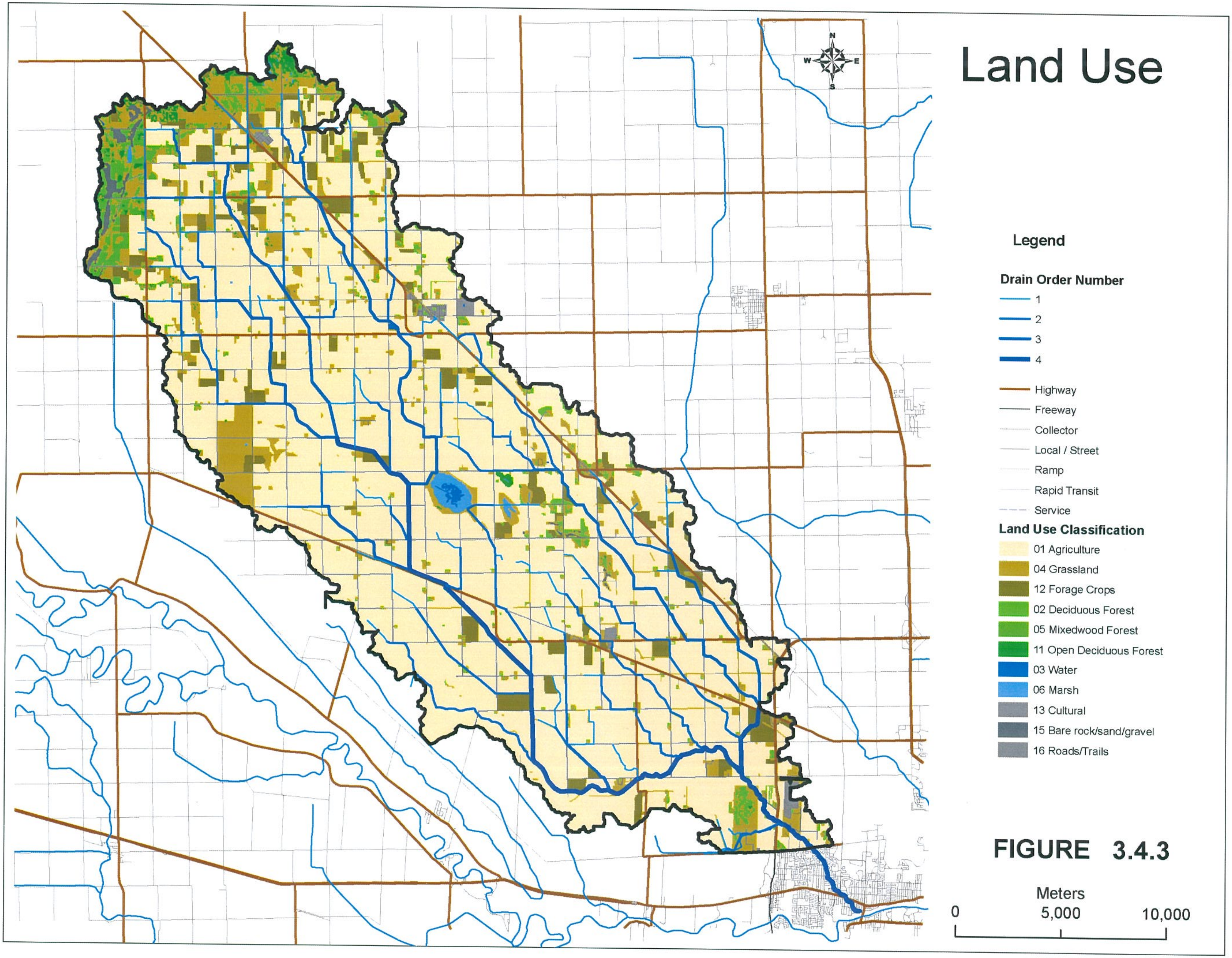


FIGURE 3.4.3

Survey Sites

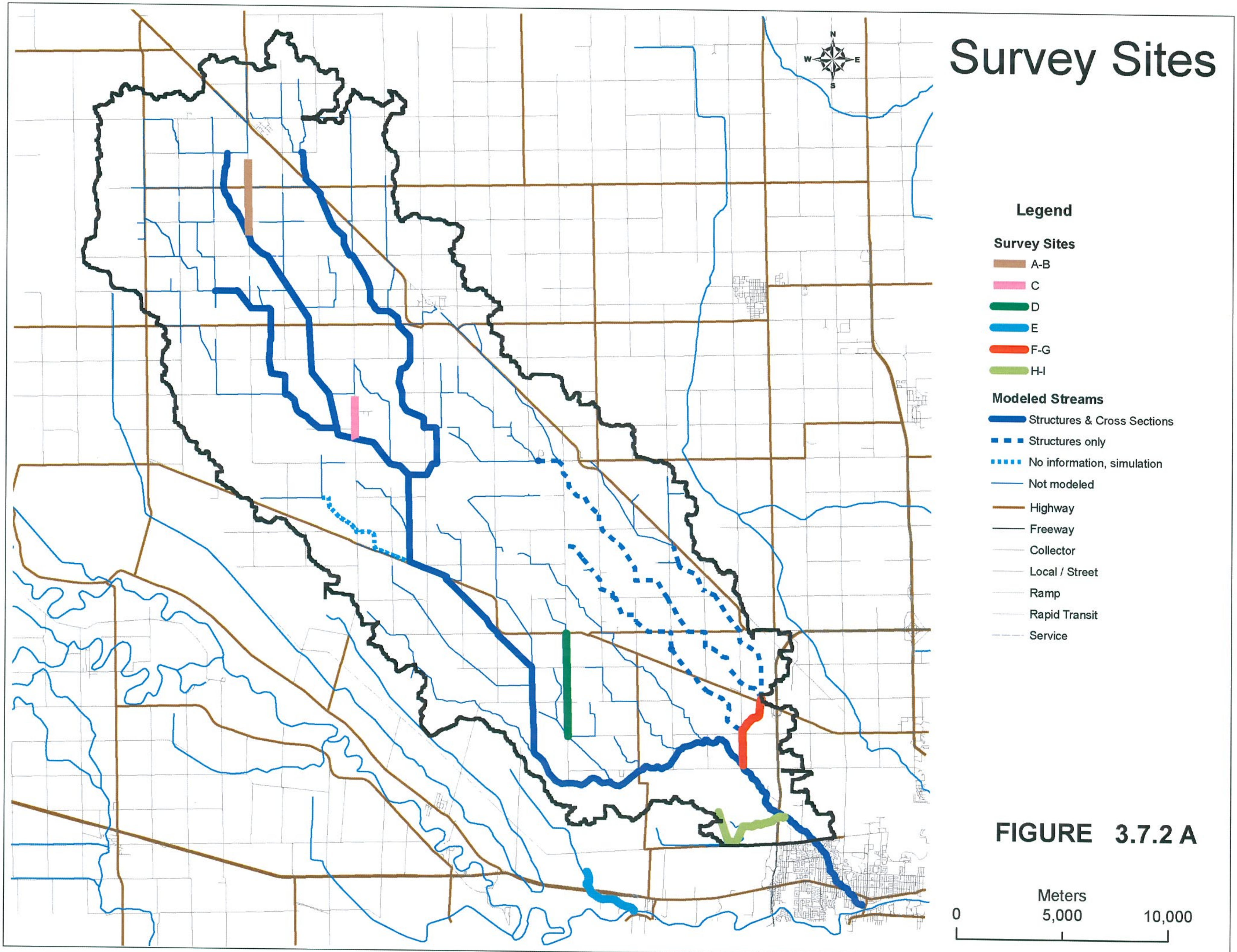
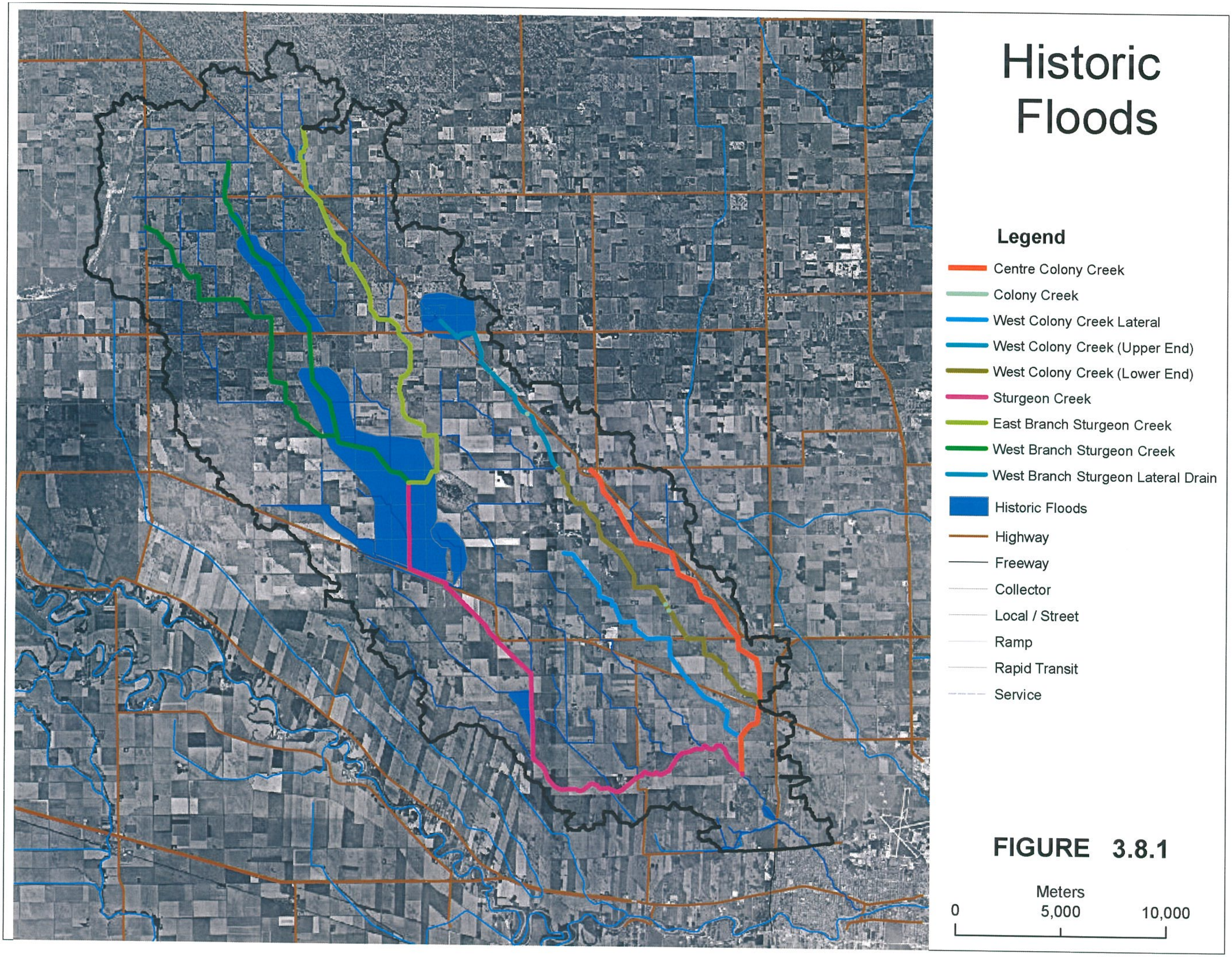
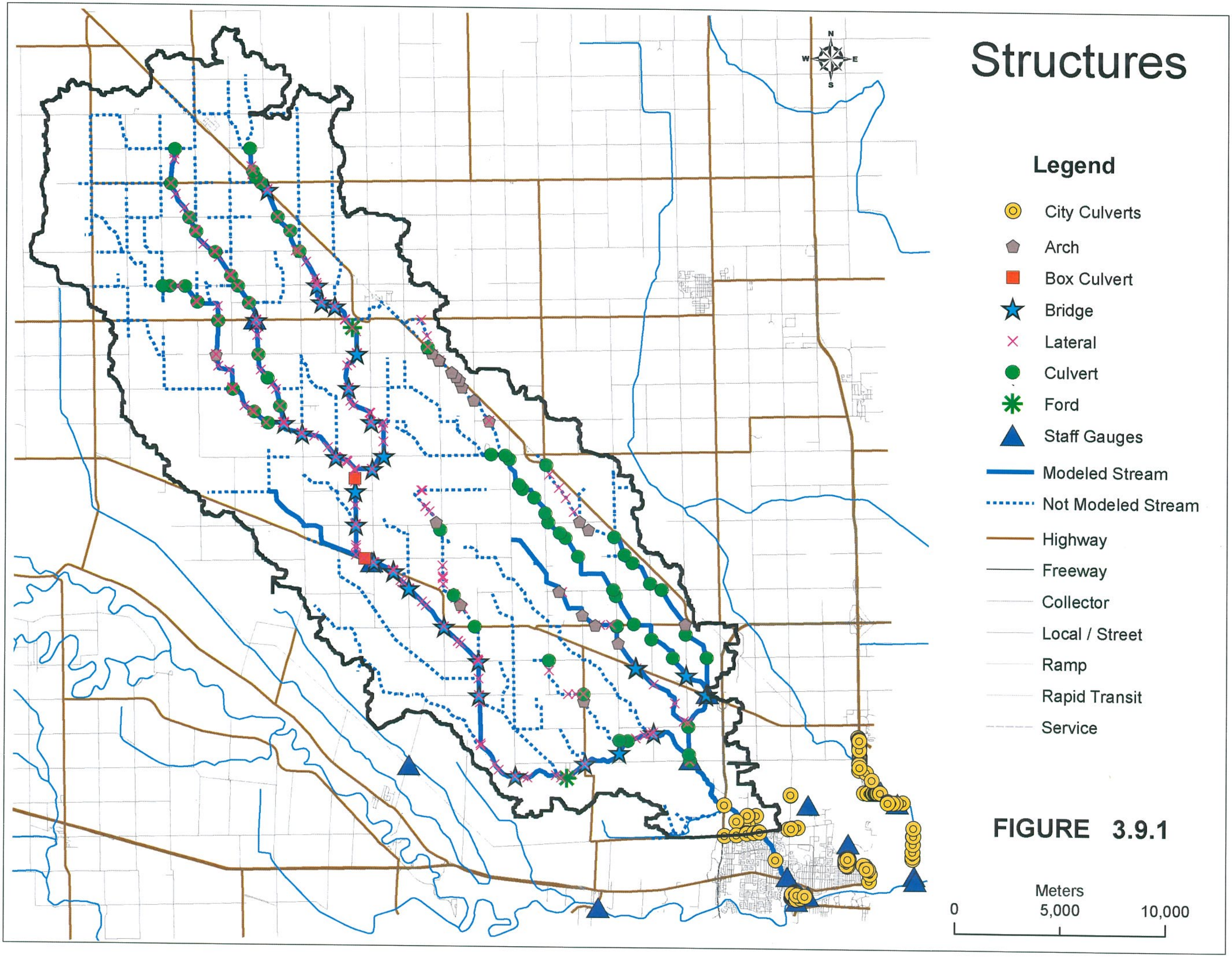


FIGURE 3.7.2 A



Historic Floods
Legend
Centre Colony Creek
Colony Creek
West Colony Creek Lateral
West Colony Creek (Upper End)
West Colony Creek (Lower End)
Sturgeon Creek
East Branch Sturgeon Creek
West Branch Sturgeon Creek
West Branch Sturgeon Lateral Drain
Historic Floods
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 3.8.1



Structures
N
S
W
E
Legend
City Culverts
Arch
Box Culvert
Bridge
Lateral
Culvert
Ford
Staff Gauges
Modeled Stream
Not Modeled Stream
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 3.9.1

Catchments

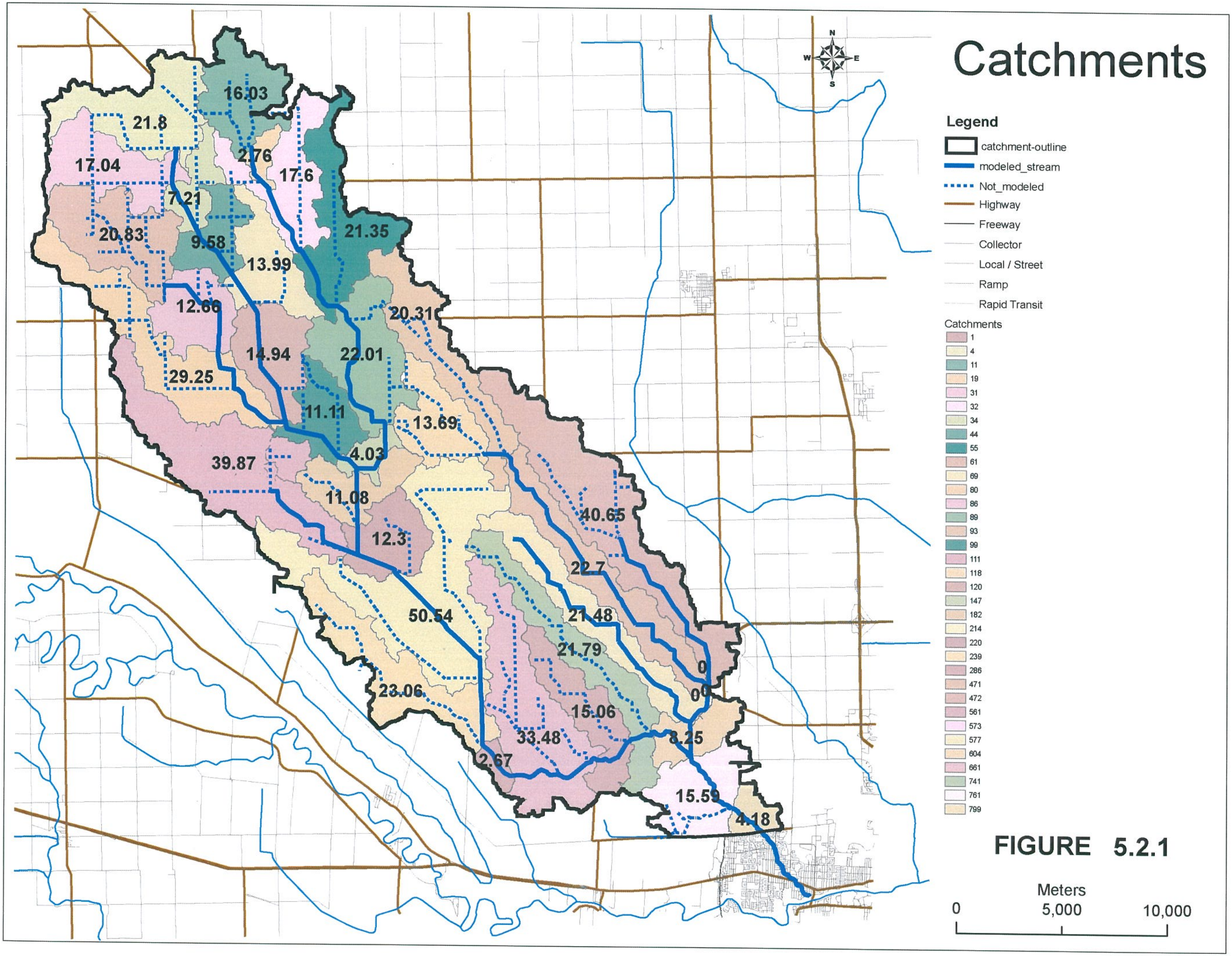


FIGURE 5.2.1

Modeled July 1993 Flood

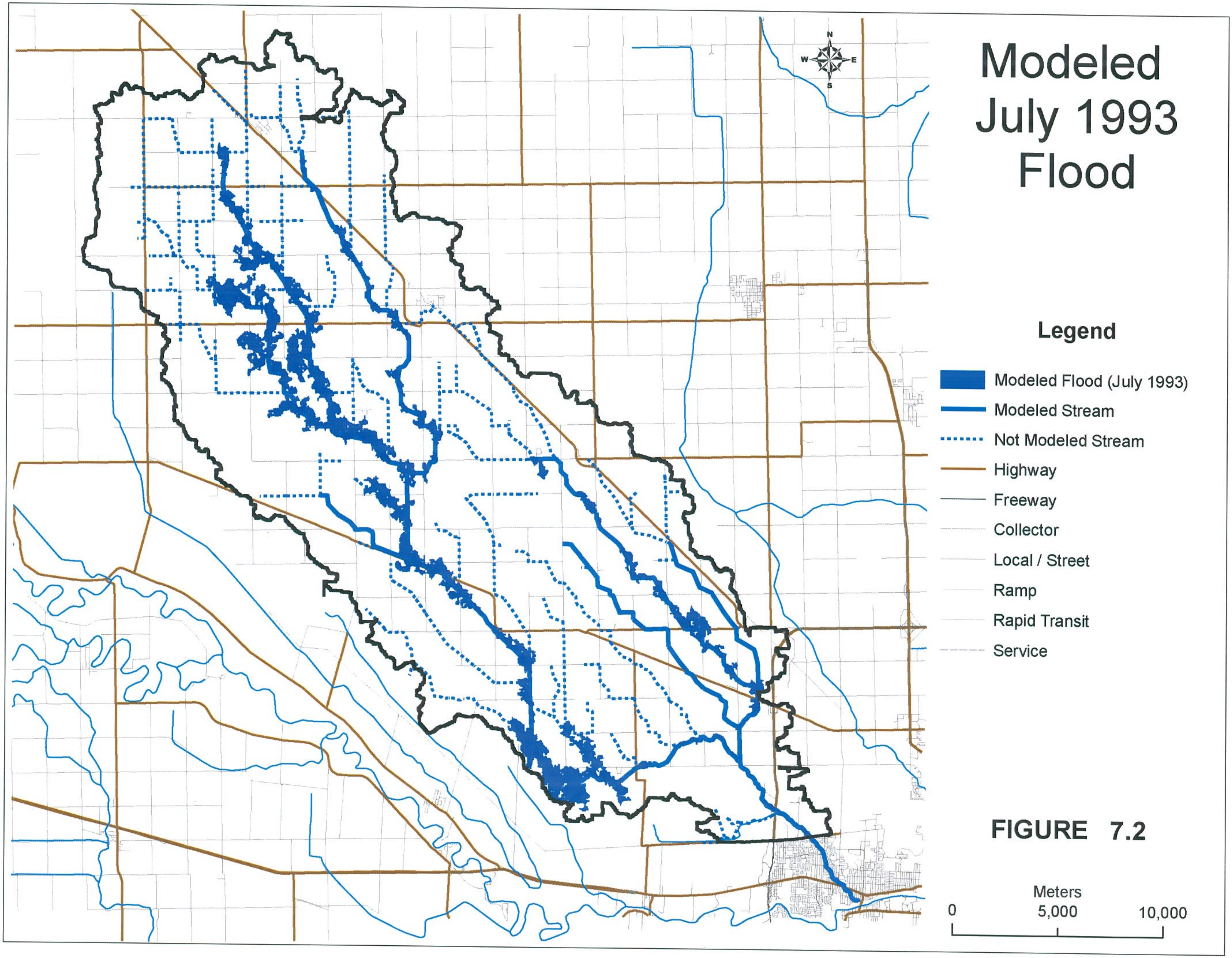
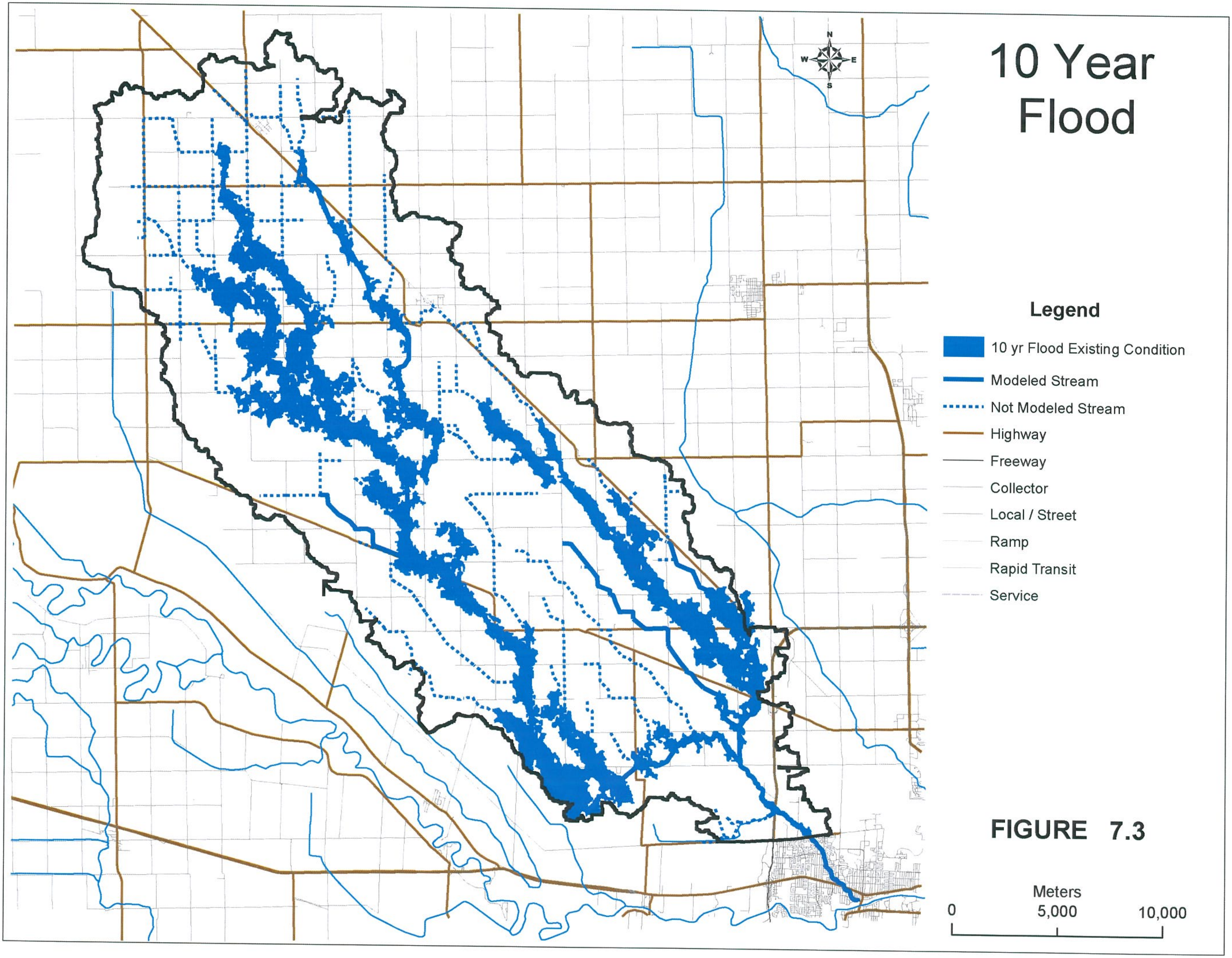
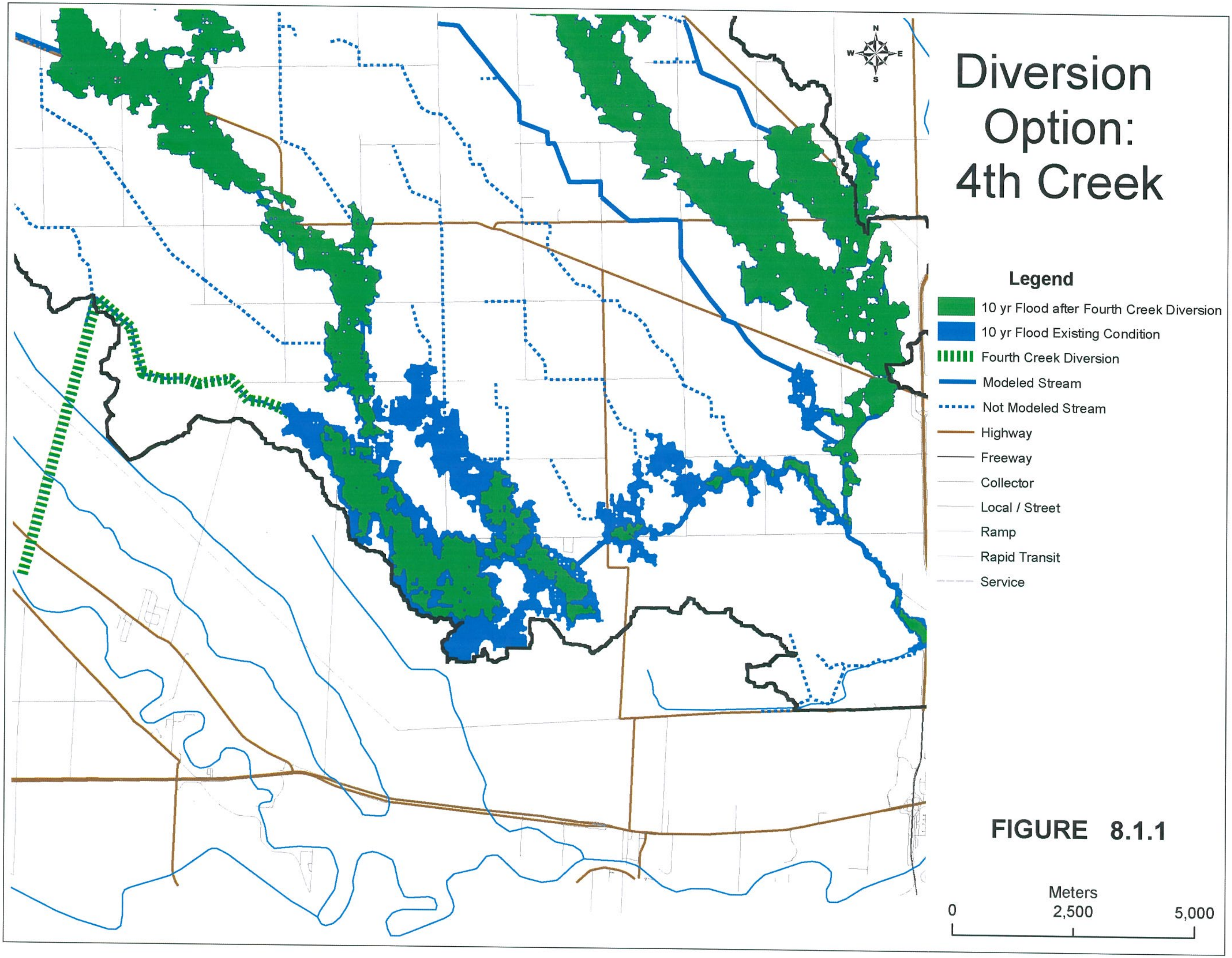
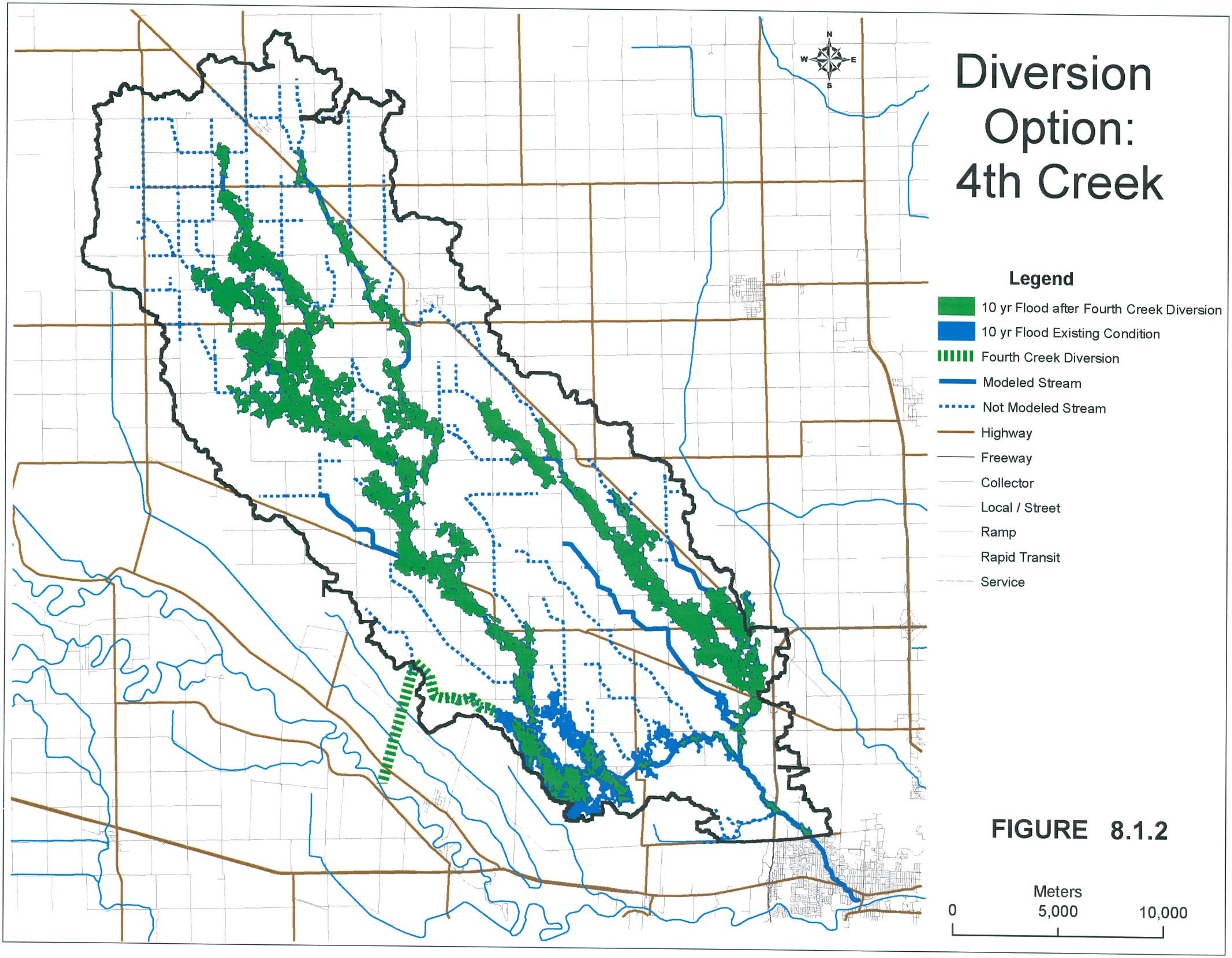


FIGURE 7.2


10 Year Flood
N
W
E
S
Legend
10 yr Flood Existing Condition
Modeled Stream
Not Modeled Stream
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
FIGURE 7.3
Meters
0
5,000
10,000


Diversion Option: 4th Creek
N
W
E
S
Legend
10 yr Flood after Fourth Creek Diversion
10 yr Flood Existing Condition
Fourth Creek Diversion
Modeled Stream
Not Modeled Stream
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
FIGURE 8.1.1
Meters
0
2,500
5,000



Diversion Option: 4th Creek
N
S
E
W
Legend
10 yr Flood after Fourth Creek Diversion
10 yr Flood Existing Condition
Fourth Creek Diversion
Modeled Stream
Not Modeled Stream
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 8.1.2

Diversion Option: Third Creek

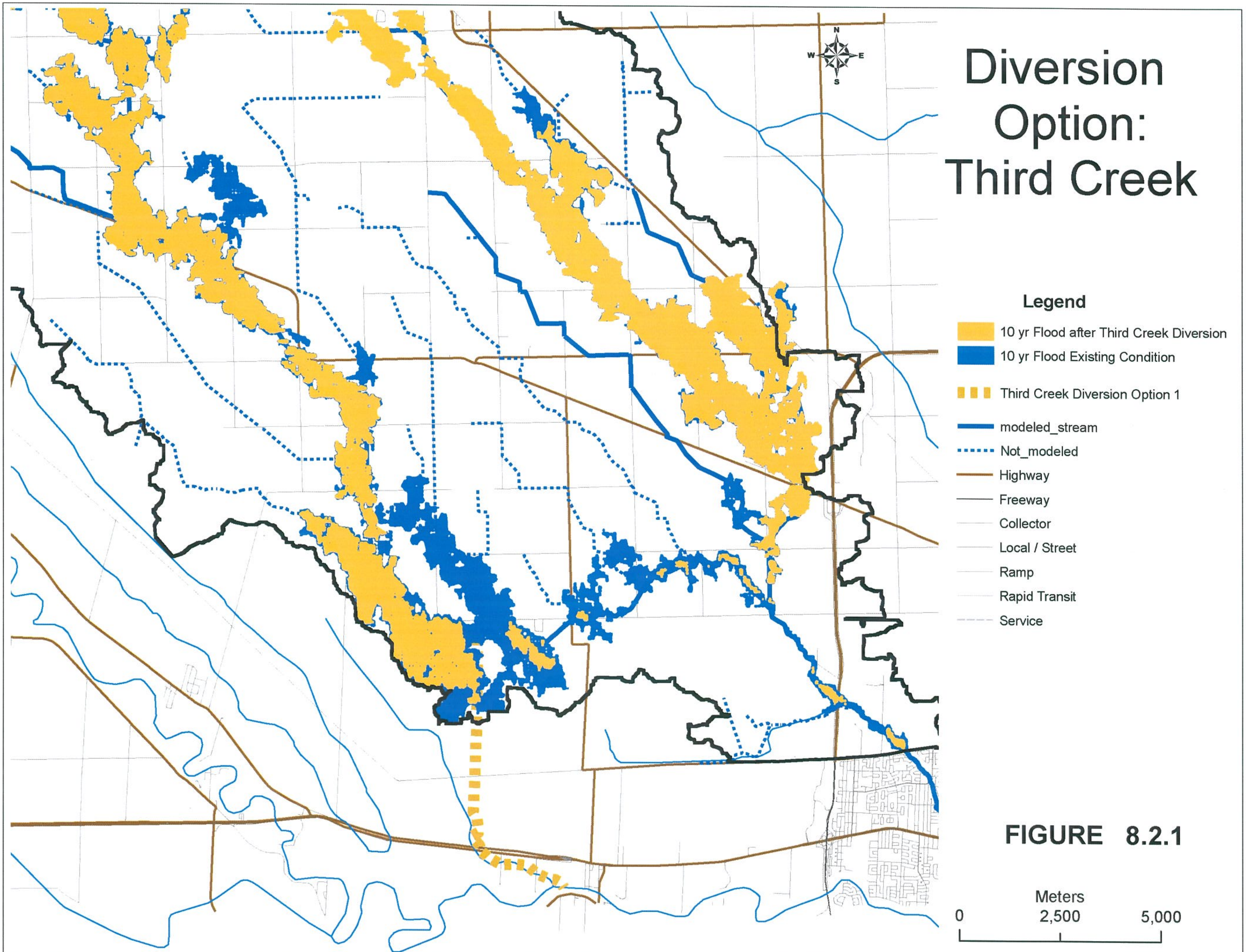
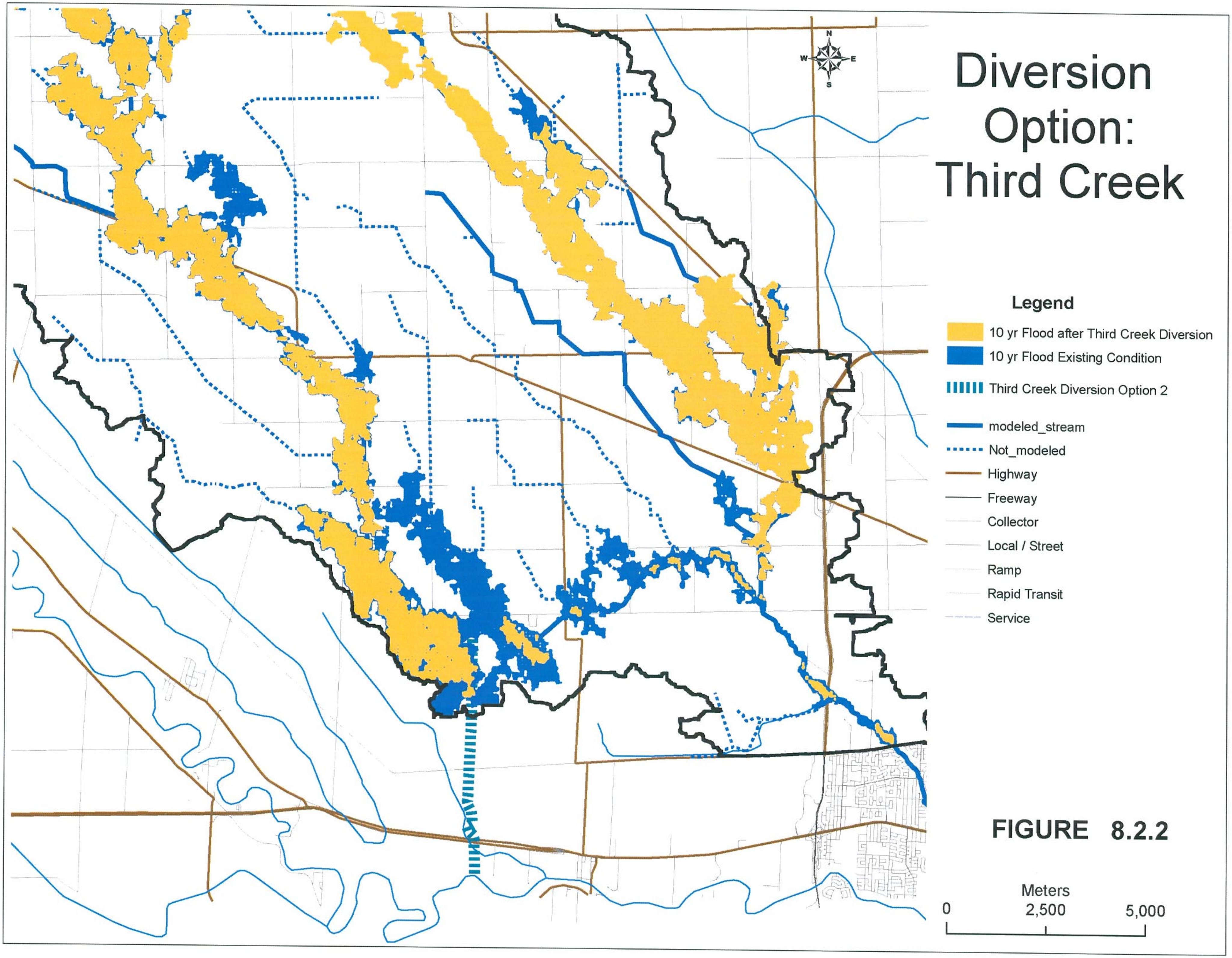


FIGURE 8.2.1



N
W
E
S
Diversion Option: Third Creek
Legend
10 yr Flood after Third Creek Diversion
10 yr Flood Existing Condition
Third Creek Diversion Option 2
modeled_stream
Not_modeled
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
2,500
5,000

FIGURE 8.2.2

Diversion Option: Third Creek

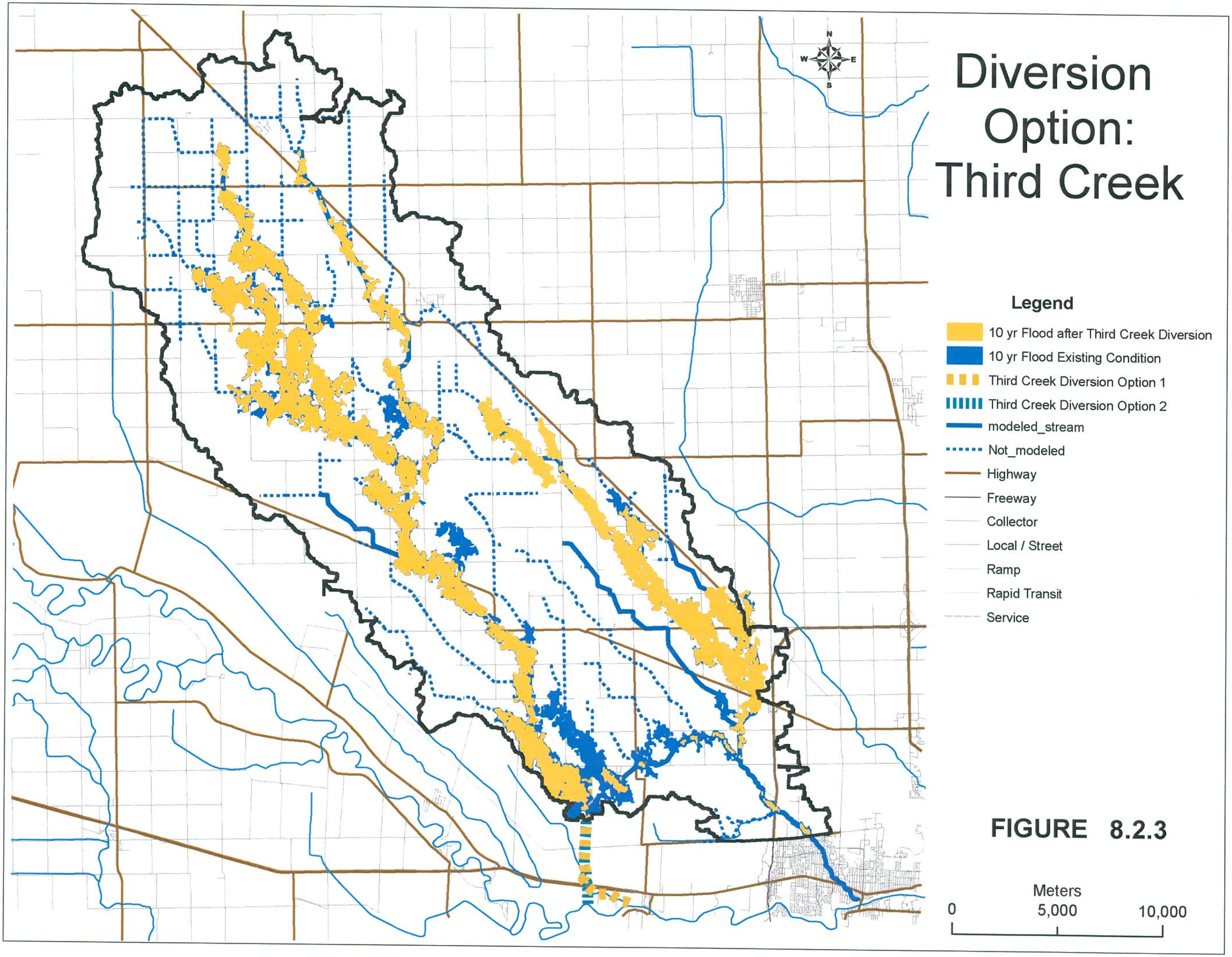
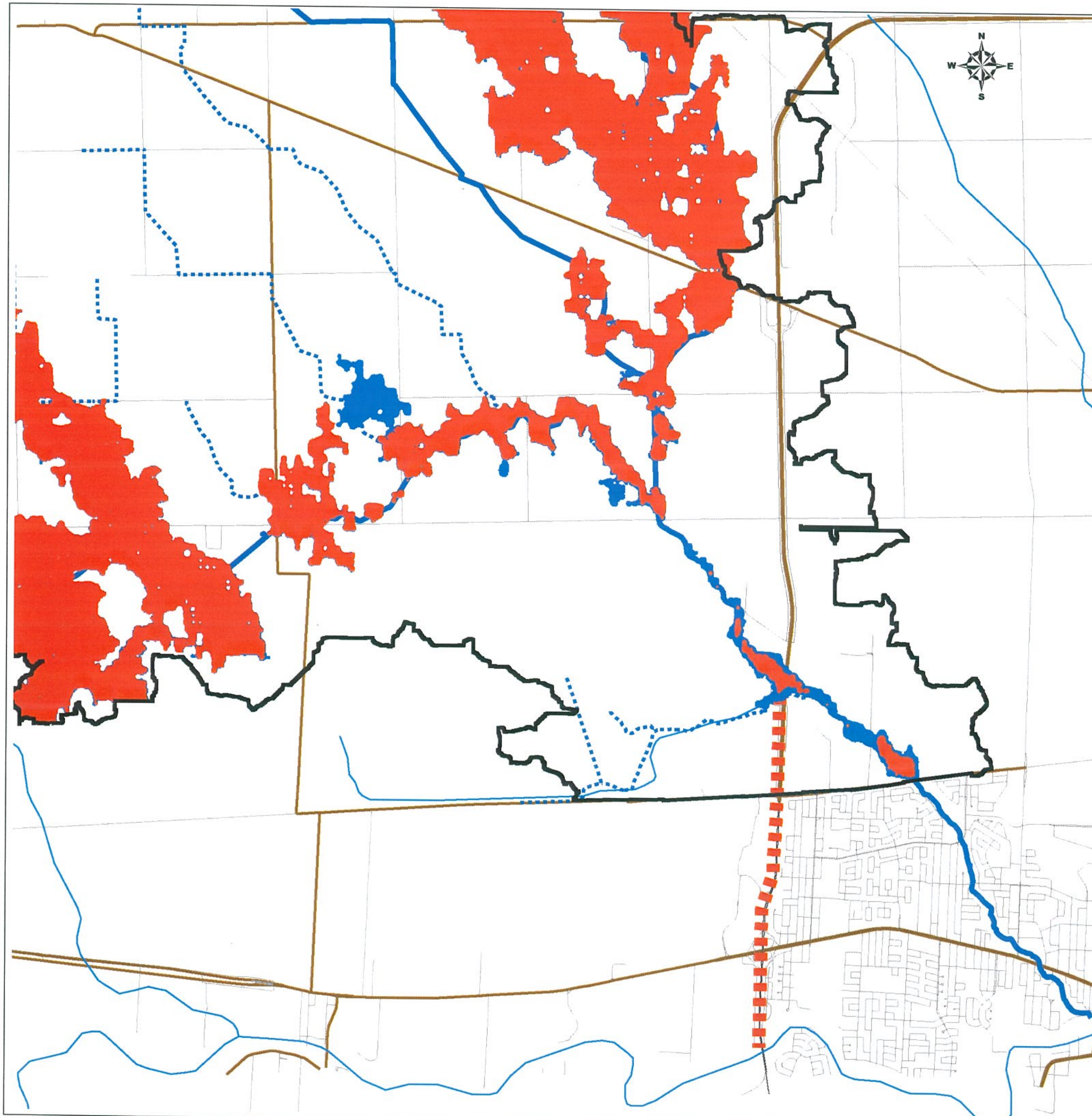


FIGURE 8.2.3



Diversion Option: Perimeter

Legend

- 10 yr Flood after Perimeter Diversion
- 10 yr Flood Existing Condition
- Perimeter Diversion
- Modeled Streams
- Not Modeled Streams
- Highway
- Freeway
- Collector
- Local / Street
- Ramp
- Rapid Transit
- Service

FIGURE 8.3.1

Meters

0 1,500 3,000

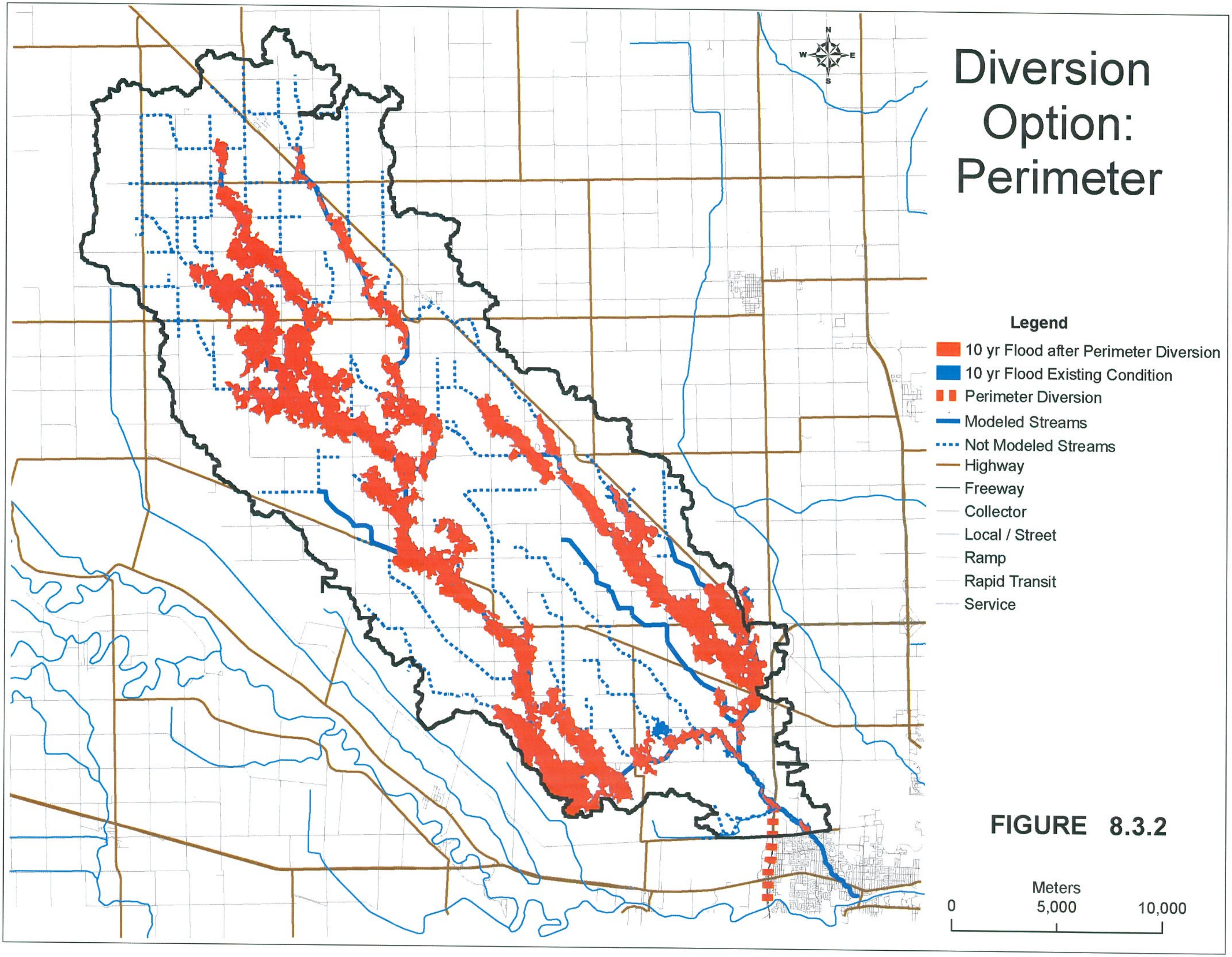

N
W
E
S
Diversion Option: Perimeter
Legend
10 yr Flood after Perimeter Diversion
10 yr Flood Existing Condition
Perimeter Diversion
Modeled Streams
Not Modeled Streams
Highway
Freeway
Collector
Local / Street
Ramp
Rapid Transit
Service
Meters
0
5,000
10,000

FIGURE 8.3.2

Proposed Bridges

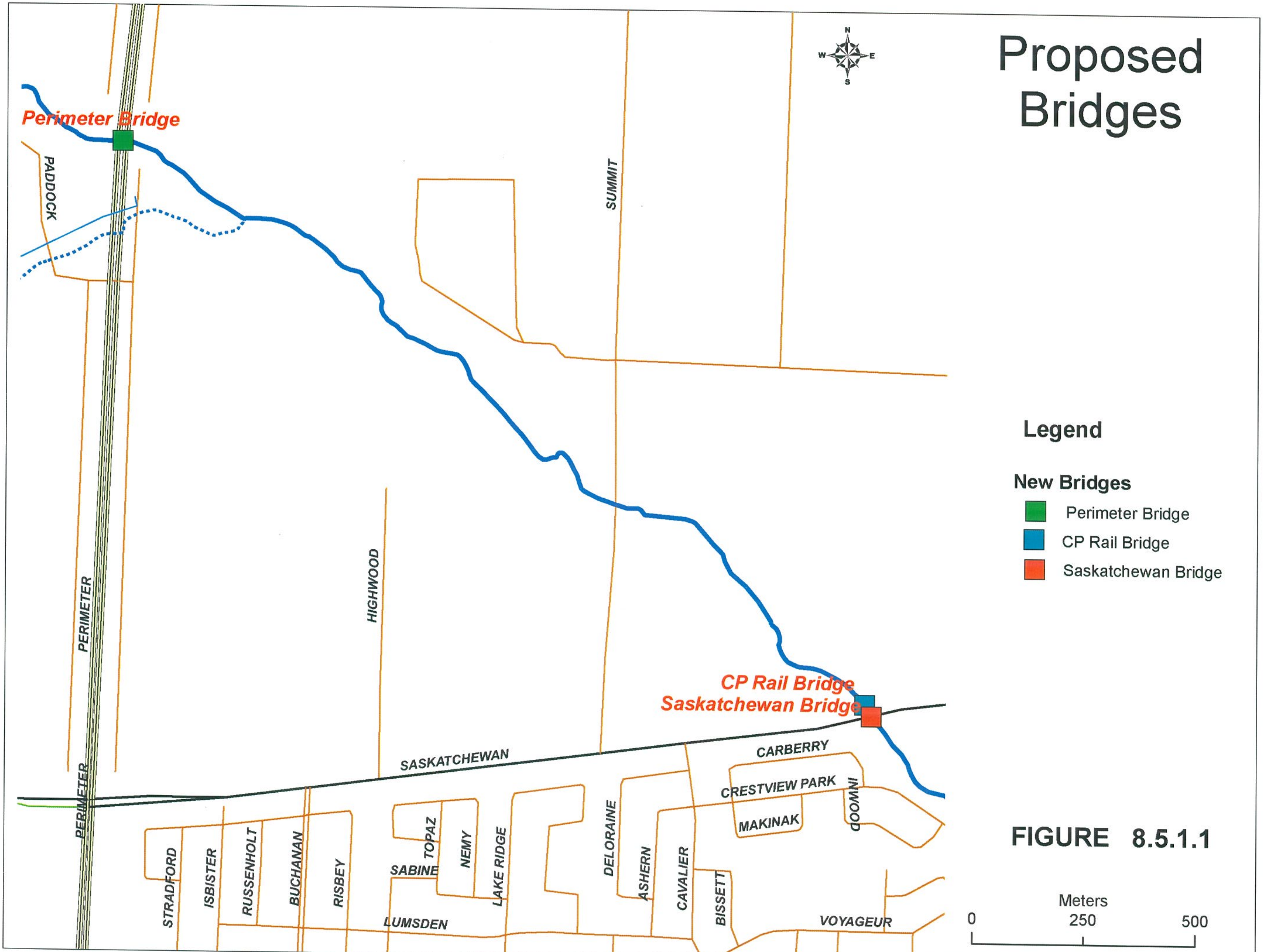


FIGURE 8.5.1.1

10 yr Flood with Channel Improvement

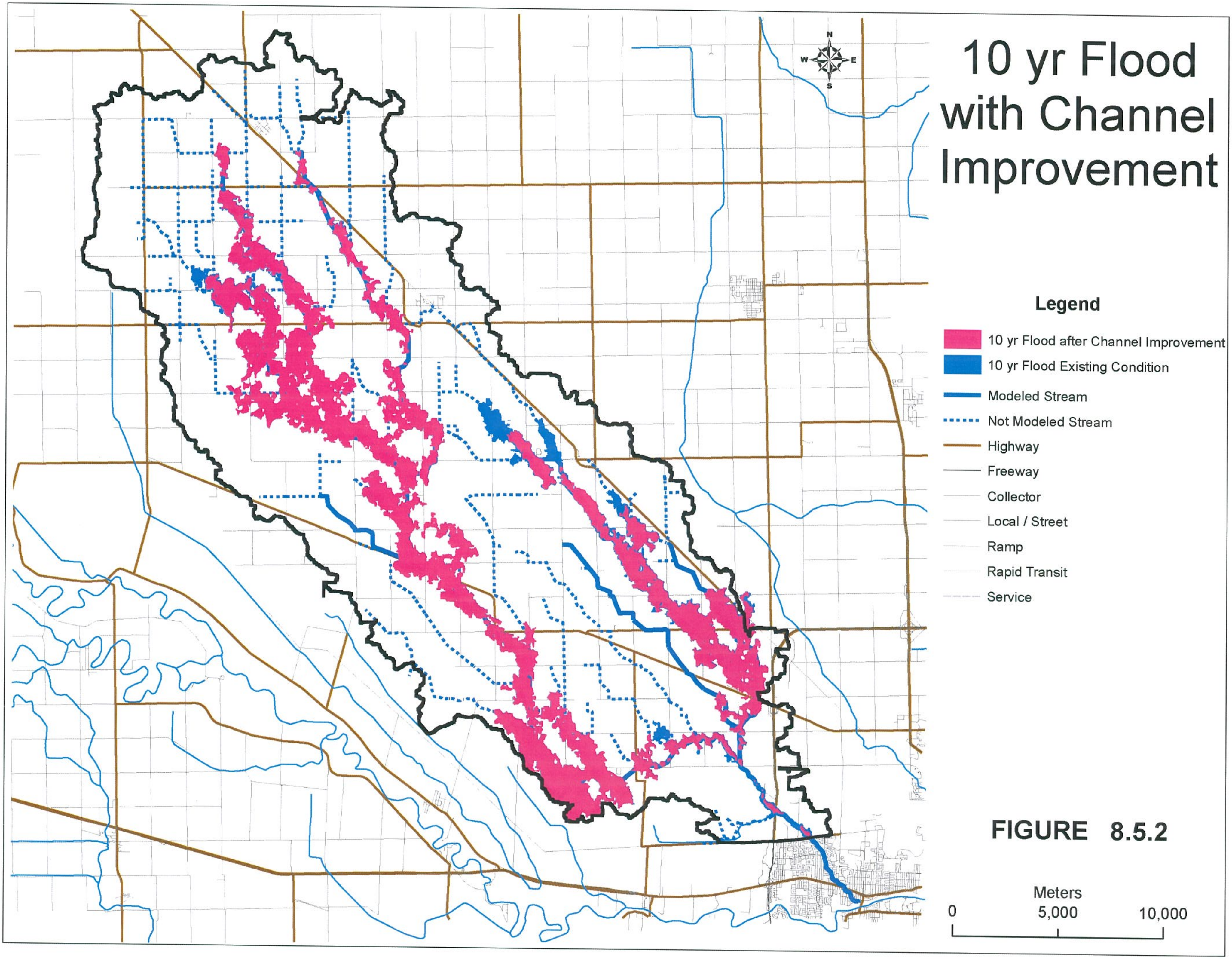
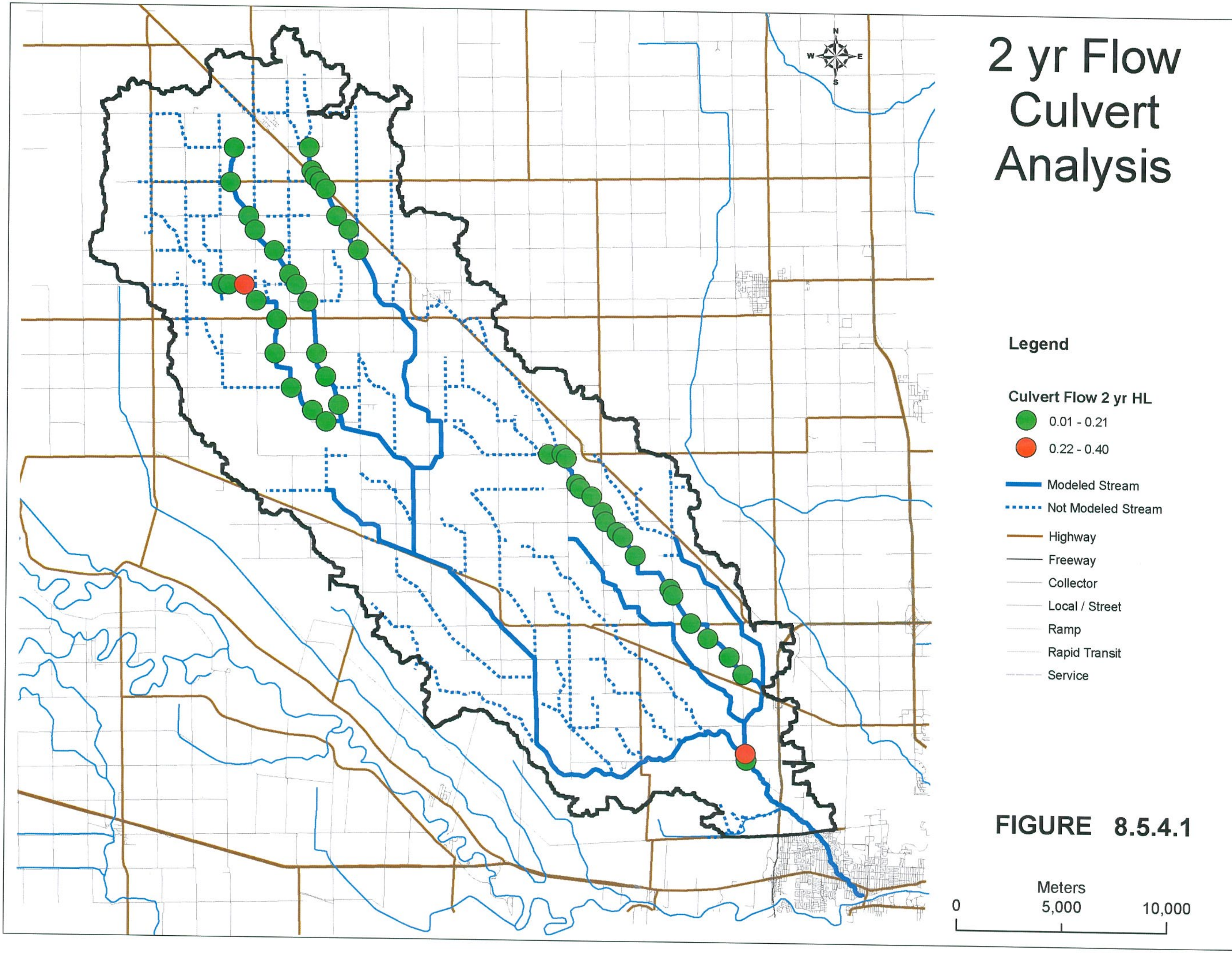


FIGURE 8.5.2



2 yr Flow Culvert Analysis

FIGURE 8.5.4.1

5 yr Flow Culvert Analysis

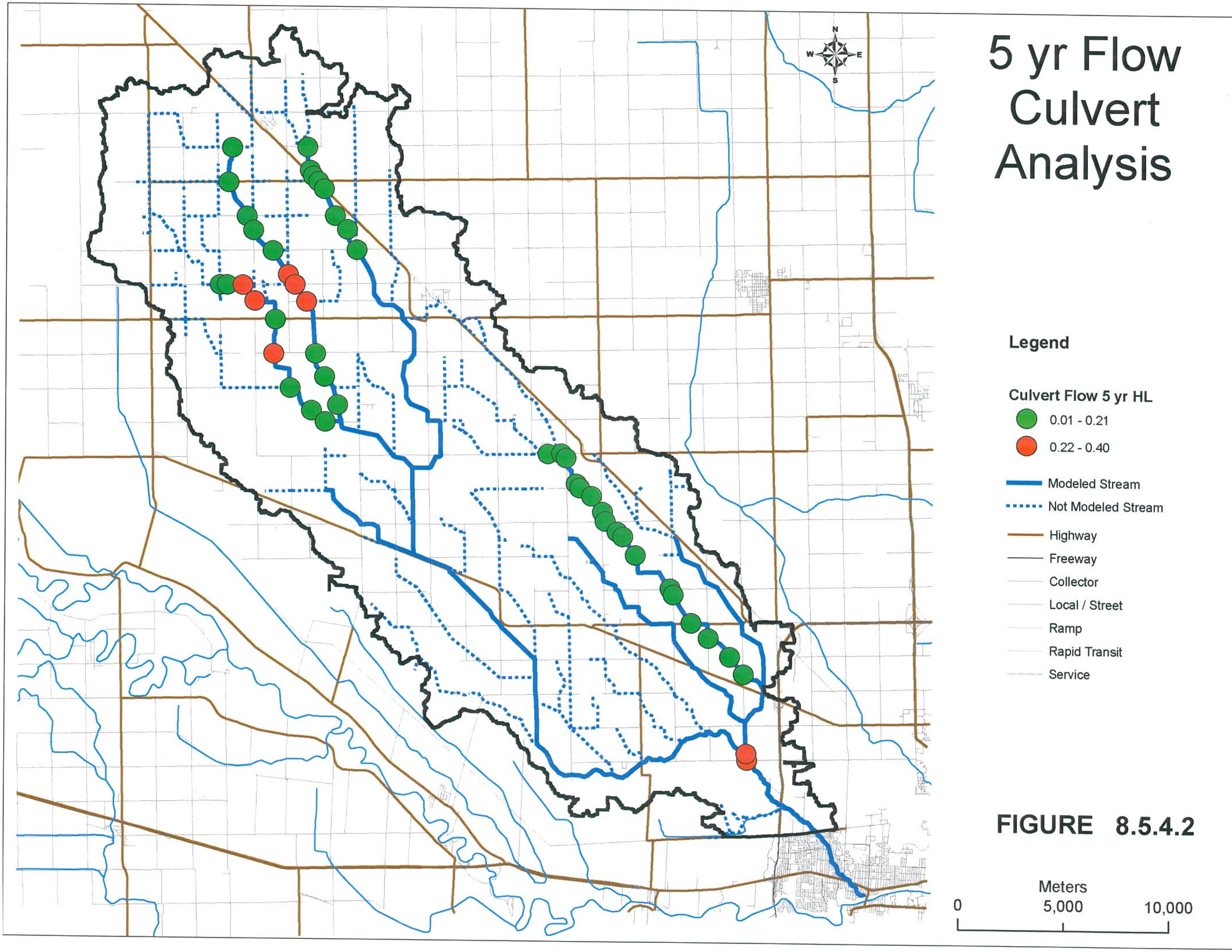
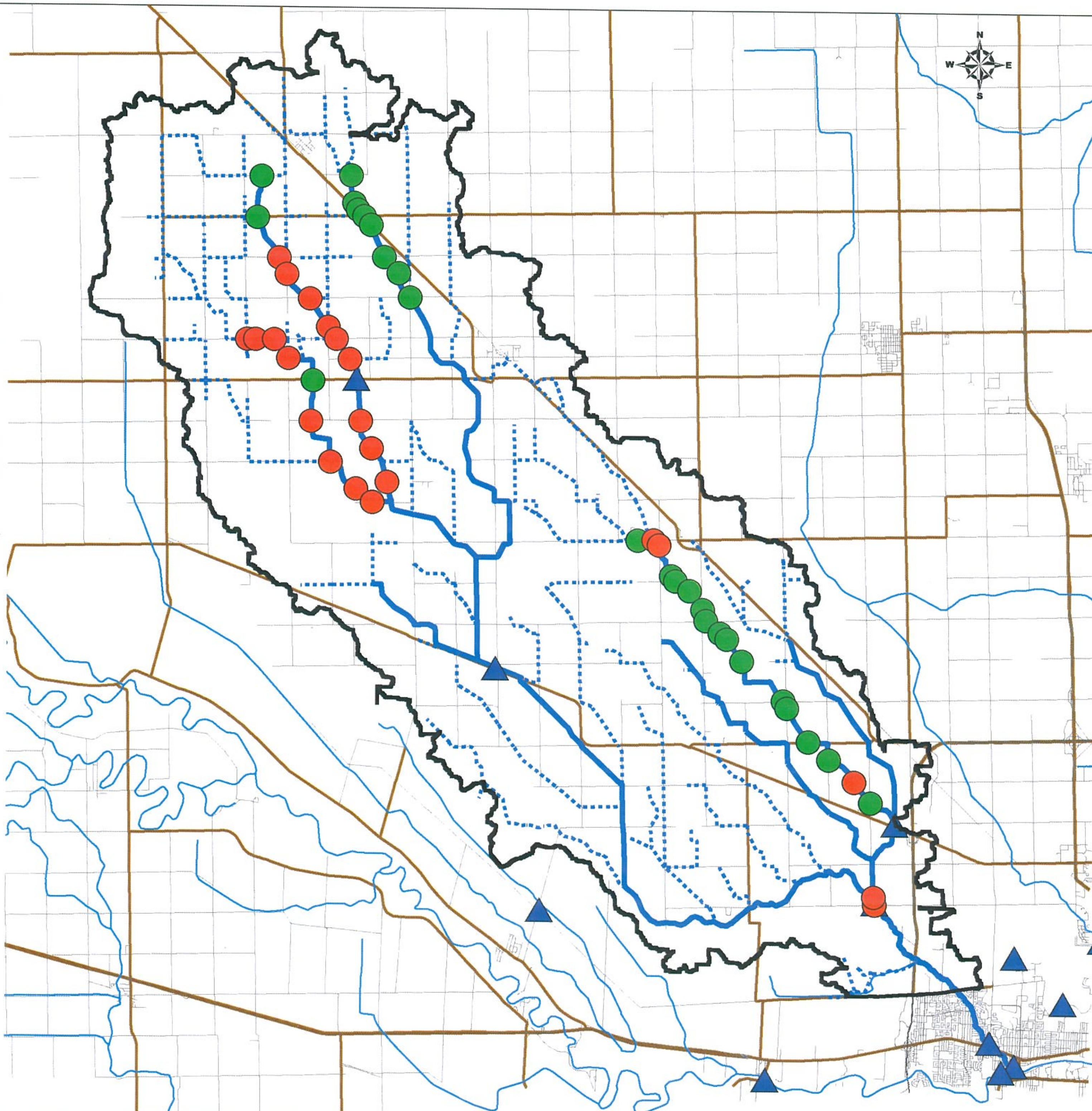


FIGURE 8.5.4.2

10 yr Flow Culvert Analysis



Legend

Culvert Flow 10 yr HL

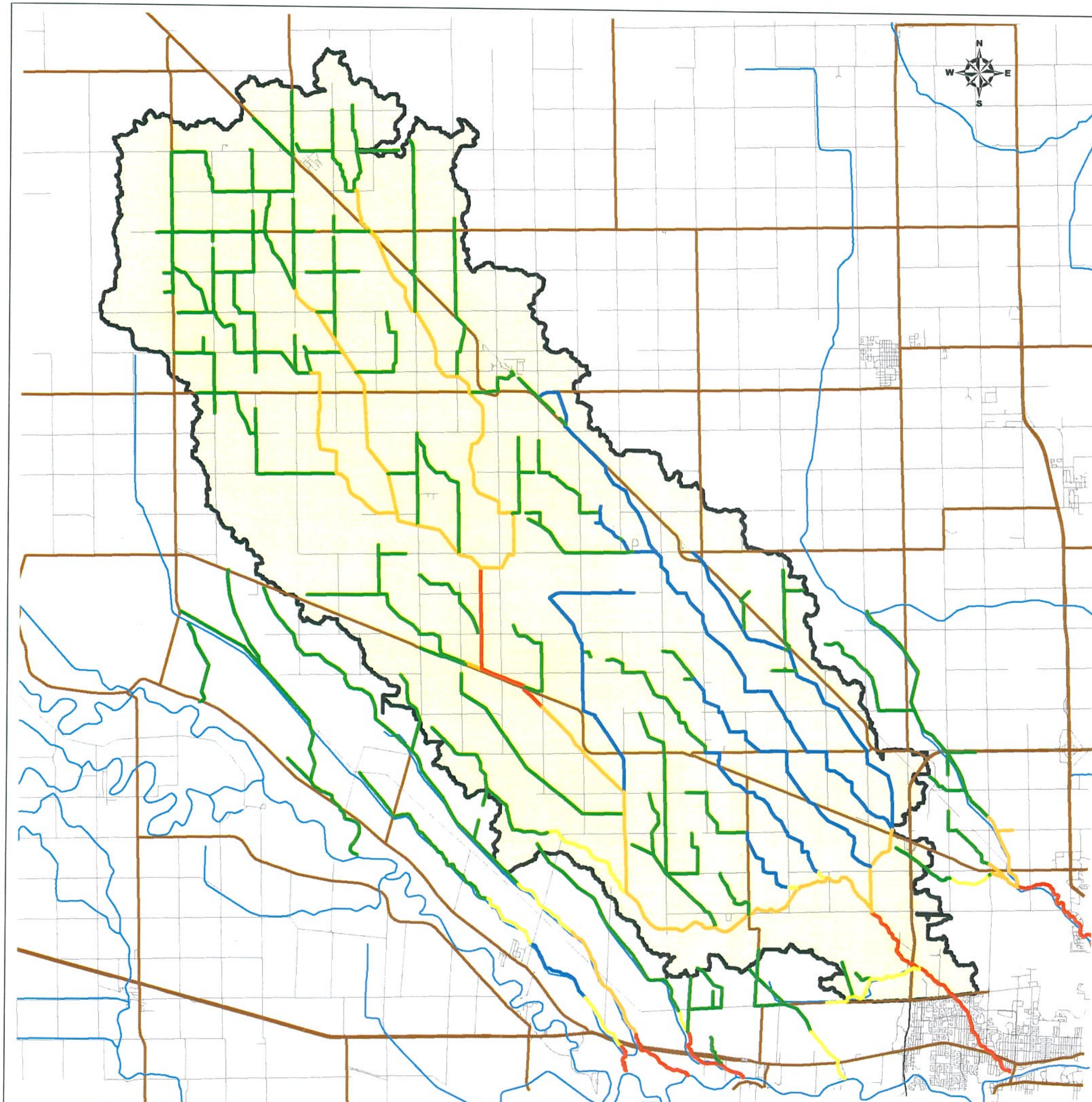
- 0.01 - 0.21
- 0.22 - 0.40
- Modeled Stream
- Not Modeled Stream
- Highway
- Freeway
- Collector
- Local / Street
- Ramp
- Rapid Transit
- Service

FIGURE 8.5.4.3

Meters

0 5,000 10,000

Fish Habitat



Legend

Fish Habitat (DFO)

- Complex Indicator Fish Species
- Simple Indicator Fish Species
- Complex Forage Fish Species
- Simple Forage Fish Species
- Indirect Fish Habitat

- Highway
- Freeway
- Collector
- Local / Street
- Ramp
- Rapid Transit
- Service

FIGURE 10.2 A

Meters
0 5,000 10,000

AECOM

AECOM Canada Ltd.
1479 Buffalo Place
Winnipeg, Manitoba R3T 1L7
T 204.284.0580 F 204.475.3646 www.aecom.com

Memorandum

Date:	March 26, 2009
To:	Bernie Lussier, P.Eng. (Manitoba Water Stewardship)
From:	Jim Friesen, P.Eng. (AECOM Canada Ltd.)
Project Number:	41 0302 F685 003 00 (4)
Subject:	Sturgeon Creek Benefit Cost Analysis
Distribution:	Eric Blais

Benefit Cost Analysis Recalculation with $345/acre for Sturgeon Creek Study.

AECOM conducted economic analysis for the Sturgeon Creek Study with values available at the time of the study. The Technical Advisory Committee (TAC) provided $200/acre as the value of property losses incurred due to crop flooding. The Benefit Cost Ratios for various mitigation options were shown in Table 9.2.1 of the report and the essential values are repeated in Table 1 (attached). The highest BCR was 0.63 for the Third Creek Diversion.

At the recent request of the TAC, recalculation of Benefit Cost Analysis was conducted using $345/acre as the assessed value of property damages due to flooding. The Benefit Cost Ratios for the same mitigation options are also shown in Table 1. The highest BCR was 1.08 for the Third Creek Diversion.

Loss of residential and business property, lost opportunity and intangibles were not included in the economic assessment due to the sporadic availability of data and variable nature of these assets.

Table 1

	Benefit Cost Ratio based on $200/Acre				BCR with $345/Acre all else equal	
Mitigation Option	**Capital Cost**	**Annual Cost with Maintenence**	**Annual Damages Averted (Benefit)**	**B/C Ratio**	**Annual Damages Averted (Benefit)**	**B/C Ratio**
Fourth Creek Diversion	$14,759,000	$734,655	$ 175,814	0.24	$ 303,279	0.41
Third Creek Diversion (Existing Channel)	$12,547,000	$624,549	$ 296,094	0.47	$ 510,762	0.82
Third Creek Diversion (Flow Split)	$9,471,000	$471,435	$ 296,094	0.63	$ 510,762	1.08
Perimeter Highway Diversion	$17,383,000	$865,269	$ 30,794	0.04	$ 53,119	0.06
In-Channel Improvements (Bridges only)	$11,200,000	$557,499	$ 56,718	0.10	$ 97,839	0.18
In-Channel Improvements (Bridges & Upstream Culverts)	$40,374,000	$2,009,686	$ 56,718	0.03	$ 97,839	0.05

Contingency 30%
Engineering 10%

Jim Friesen, P.Eng.
Project Engineer
AJF/dh

MEM-F685-003-00-Lussier-BCR-090326.doc

Manitoba

Memorandum

DATE : 21 December 2009

TO: Steven Topping, P.Eng.
Executive Director
Regulatory & Operational Services
Manitoba Water Stewardship

FROM: Bernie Lussier, P.Eng.
Water Control Operations Engineer
Water Control and Structures
Manitoba Infrastructure & Transportation

SUBJECT : Benefit-Cost Analysis Recalculation for AECOM Sturgeon Creek Watershed Study

I have estimated the estimated benefit-cost ratios for the mitigations options based on $300/acre for property losses due to crop flooding.

AECOM had initially calculated the benefit-cost ratios based on $200/acre in the Sturgeon Creek Hydrodynamic Model Economic Study report of January 2009.

At the request of the Technical Advisory Committee, AECOM had recalculated the benefit-cost ratios based on $345/acre in a memo dated March 26, 2009.

Since then, the Technical Advisory Committee has agreed to recommend the value of $300/acre at its meeting on June 30, 2009.

The calculation is based on a linear interpolation between the figures calculated by AECOM.

The table below summarizes the results :

value/acre	$ 200.00	$ 300.00	$ 345.00
Mitigation Option	B/C ratio (AECOM)	B/C ratio (estimated)	B/C ratio (AECOM)
Fourth Creek Diversion	0.24	0.36	0.41
Third Creek Diversion (Existing Channel)	0.47	0.71	0.82
Third Creek Diversion (Flow Split)	0.63	0.94	1.08
Perimeter Highway Diversion	0.04	0.05	0.06
In-Channel Improvements (Bridges Only)	0.10	0.16	0.18
In-Channel Improvements (Bridges & upstream culverts)	0.03	0.04	0.05

Bernie Lussier, P.Eng.