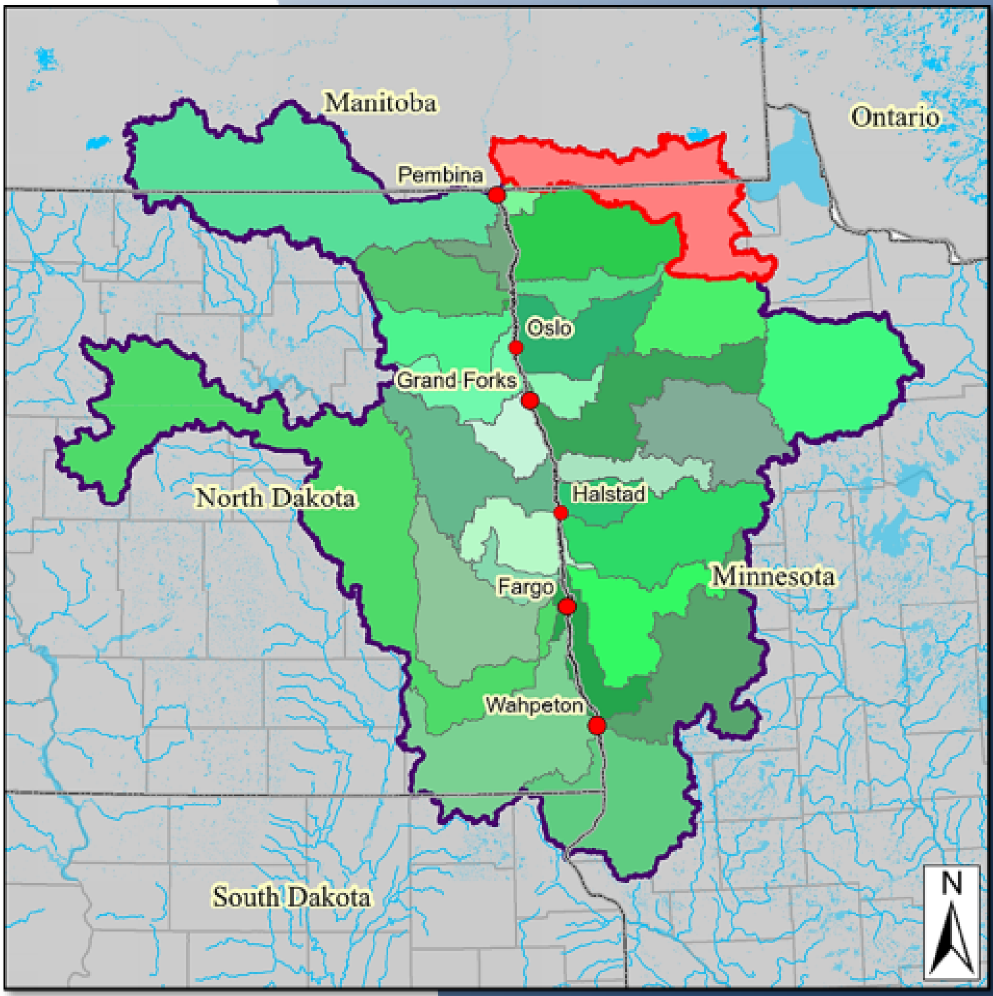
# Roseau River Watershed District

# Expanded Distributed Detention Strategy

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# ROSEAU RIVER WATERSHED DISTRICT
# EXPANDED DISTRIBUTED DETENTION STRATEGY
## for the Upper Roseau River Watershed and the Hay Creek Tributary

Prepared on behalf of:

**Roseau River Watershed District**
**Red River Watershed Management Board**

November 25, 2013

Prepared by:

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I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Jerry Bents
Jerry Bents, P.E.
License No. 42249

Date: 11/25/2013

# ROSEAU RIVER WATERSHED DISTRICT
# EXPANDED DISTRIBUTED DETENTION STRATEGY
## for the Lower Roseau River Watershed to the U.S./Canada Border

Prepared on behalf of:

**Roseau River Watershed District**
**Red River Watershed Management Board**

November 25, 2013

Prepared by:

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License No. 25309

Date: 11/25/2013

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## EXECUTIVE SUMMARY

Efforts to develop comprehensive plans for expanded distributed detention strategies are being developed throughout the United States portion of the Red River Basin. These planning efforts establish benefit to local damage centers as well as reduction in contribution to the Red River main stem. Planning efforts are largely funded through the Red River Watershed Management Board for Watershed Districts contributing to the MN portion of the Red River Basin and by the North Dakota Joint Red River Water Resource District and the North Dakota State Water Commission for subwatersheds within the ND portion of the Red River Basin. This report summarizes methodology and outcomes of the Roseau River Watershed Expanded Distributed Detention Strategy, funded by the Red River Watershed Management Board (RRWMB). Houston Engineering, Inc. (HEI) and HDR, Inc. (HDR) were tasked with the responsibility to execute the RRWMB Expanded Distributed Detention Strategy for the Roseau River Watershed District. HEI analyzed the Upper Roseau River Watershed and Hay Creek tributary, while HDR analyzed the Lower Roseau River Watershed.

The Roseau River Watershed encompasses about a 2,100 square mile area in the Unites States (U.S.) and Canada. The U.S. portion of the Roseau River Watershed, which is the jurisdictional Roseau River Watershed District, is approximately 1,200 square miles. The Roseau River Watershed Expanded Distributed Detention Strategy identifies flood water detention locations aimed at meeting peak flow and volume reduction goals similar to those specified in the RRBC's Long Term Flood Solutions (LTFS) Basinwide Flow Reduction Strategy Report. This report sets forth a strategy that would reduce flood damages throughout the basin by reducing the flood volume enough to reduce peak flows along the Red River main stem by at least 20% for the 100-year, 10-day snow melt progression runoff event.

For purposes of this report, the Upper Roseau River Watershed includes the Roseau River Watershed upstream of the community of Roseau, MN and the Hay Creek tributary (Figure 1), while the Lower Roseau River Watershed includes the portion that falls downstream of Roseau, MN and where the Hay Creek tributary intersects the Roseau River (Figure 2). While the RRWD has not implemented structures within the upper portion of the Watershed District that provide gated storage, existing structures scattered throughout the Upper Roseau River Watershed do provide approximately 3,900 acre-feet of ungated storage. Since peak flow and volume reduction goals specified in the LTFS Basinwide Flow Reduction Strategy are based on the 1997 spring flood event, storage implemented after the 1997 event is included towards meeting these goals. Of the total storage provided by existing impoundments within the Upper Roseau River Watershed, only the Palmville Fen Restoration and the Norland Impoundment Projects were implemented after 1997. The Palmville Fen Restoration Project was built primarily for natural resource enhancement purposes, but it also provides 110 acre-feet of ungated storage capacity. The Norland Impoundment Project was built primarily for flood damage reduction and natural resource enhancement purposes. The Norland Impoundment, constructed in 2009-2011, provides over 6,000 acre-feet of gated and 3,500 acre-feet of ungated storage.

This report, the Roseau River Watershed District Expanded Distributed Detention Strategy, identifies locations where runoff could be detained on the landscape in an effort to meet peak flow and volume reduction goals specified in the RRBC LTFS Basinwide Flow Reduction Strategy. Detention locations described in this report generally correlate to topography that allows three to four inches of gated runoff storage across a contributing area of twenty square miles or more. However, there were a limited number of sites that meet these criteria

throughout the entire Roseau River Watershed and this criterion was decreased in some instances to provide a greater chance of meeting storage and peak flow reduction goals, in the watershed.

The HEC-HMS models developed for the United States Army Corps of Engineers (USACE) in 2012 as part of the Red River of the North Basin-Wide Modeling Approach project have been utilized to simulate the detention sites throughout the Roseau River Watershed. A digital elevation model (DEM) created from LiDAR data was manipulated to simulate embankments, culverts, and cutoff ditches for each proposed detention site and ESRI ArcGIS™ tools were then employed to determine drainage areas and storage curves for each site. Pre-1997 conditions were developed based on the existing impoundments developed prior to Spring 1997 along with delineated drainage areas representing post-1997 and proposed sites. The proposed sites were then added to the HEC-HMS model to determine the effect that each site would have towards the peak flow reduction goals.

In the Upper Roseau River Watershed, ten proposed locations are evaluated in this analysis. Eight of the ten locations are upstream of Roseau, MN, and the remaining two locations are within the Hay Creek Watershed. Of the eight proposed detention locations upstream of Roseau, MN, four were previously identified by JOR Engineering in 2002. The current planning effort further refined these four locations with the aid of LiDAR information. The four remaining proposed locations upstream of Roseau, MN were identified during this planning effort. In total, the ten proposed detention locations provide a total gated storage capacity of approximately 55,700 acre-feet, or about 3.7 inches across 286 square miles.

In the Lower Roseau River Watershed, 11 proposed locations were identified and are evaluated in this analysis. One site, the Roseau Lakebed, was previously identified by the Roseau River Watershed District 10-Year Overall Plan. The Roseau Lakebed is a historic lake that was approximately 3.5 miles in diameter and its natural state was a shallow permanent body of water covering 2,200 acres. In its current state, the Roseau Lake is virtually non-existent, due to the construction of internal drainage ditches and channel enlargement. The 150,000 acre-feet of storage with the Roseau Lake could be better utilized to provide additional flood damage reduction benefits. The 10 remaining proposed locations downstream of Roseau, MN were identified during the current planning effort. In total, the 11 proposed detention locations provide a total gated storage capacity of approximately 233,000 acre-feet, or 3.9 inches of runoff, across 1,108 square miles. Because one of the sites is on the Roseau River, the entire drainage area upstream, including the entire Upper Roseau River Watershed, is considered.

The ten proposed detention locations in the Upper Roseau River Watershed, the 11 proposed detention locations in the Lower Roseau River Watershed, and the existing impoundments implemented after the 1997 spring flood event were incorporated into the HEC-HMS hydrologic model and compared to conditions that existed during the 1997 spring flood event. Both the 1997 conditions and the proposed conditions were analyzed using the Red River Basin Standardized Melt Progression Event, described in Section 3.3 of this report. Comparison of the analyzed detention locations with the 1997 existing conditions indicated that the proposed detention strategy exceeded peak flow and volume tributary reductions, identified in adjacent watersheds, in the RRBC LTFS Basinwide Flow Reduction Strategy. Peak flow and volume reductions in excess of the LTFS recommendations for this portion of the Roseau River Watershed were deemed acceptable due to increased flooding concern for the RRWD as a result of runoff from the Upper Roseau River Watershed.

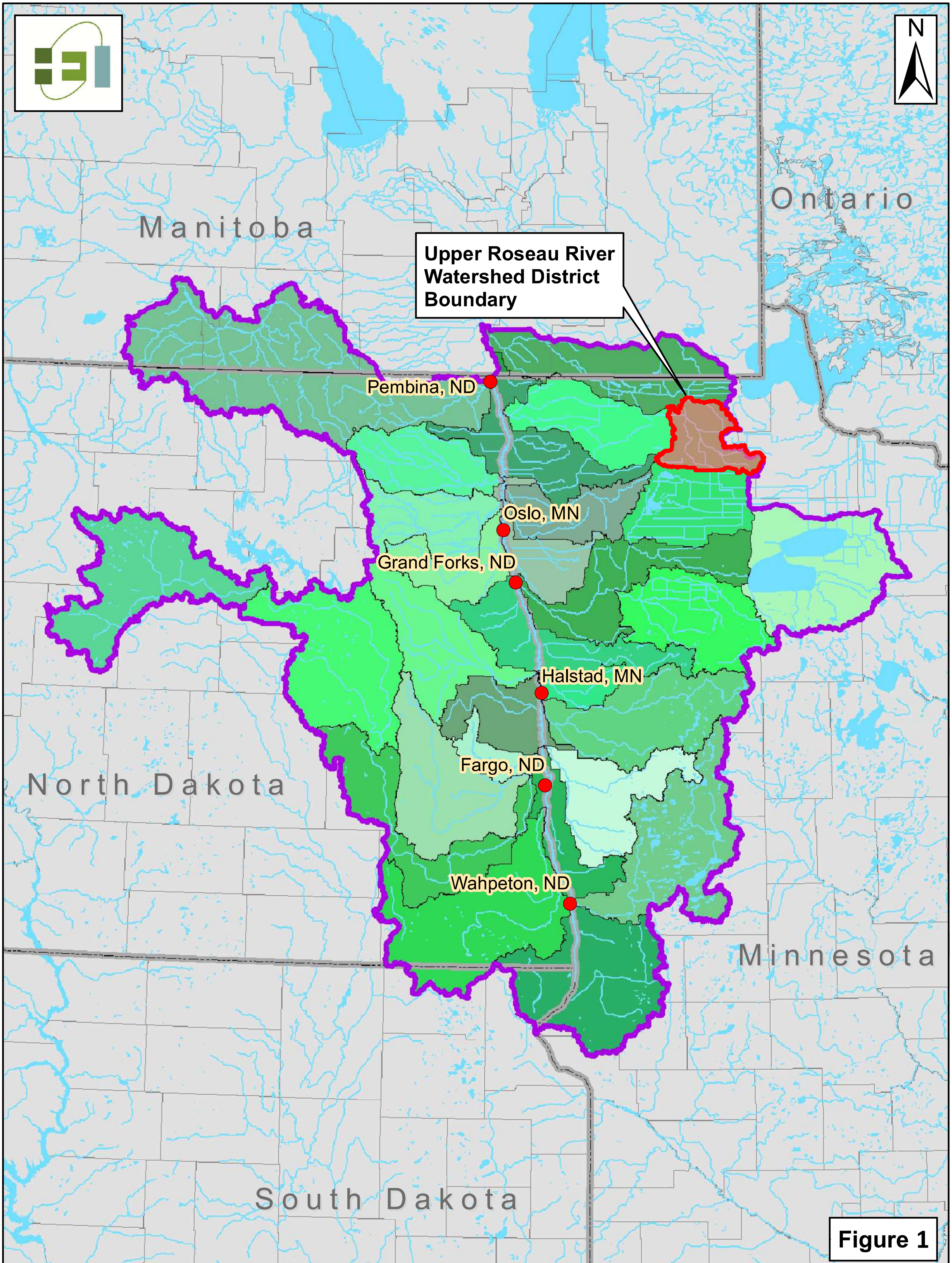
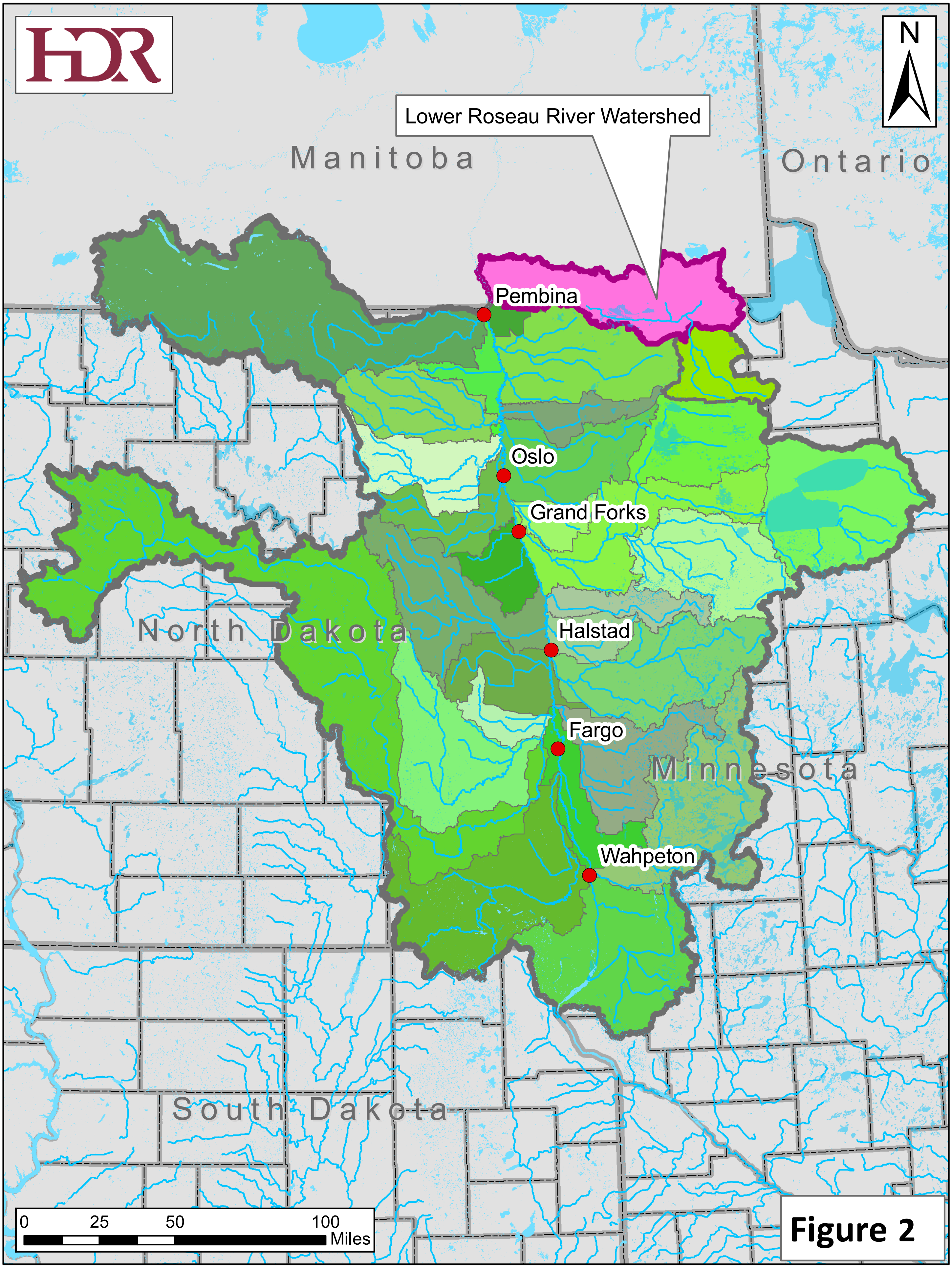

Manitoba
Ontario
Upper Roseau River Watershed District Boundary
Pembina, ND
Oslo, MN
Grand Forks, ND
Halstad, MN
Fargo, ND
Wahpeton, ND
North Dakota
Minnesota
South Dakota
N

Figure 1



HDR
N
Lower Roseau River Watershed
Manitoba
Ontario
Pembina
Oslo
Grand Forks
Halstad
Fargo
Wahpeton
North Dakota
Minnesota
South Dakota
0
25
50
100
Miles


**Figure 2**

# 1 INTRODUCTION

## 1.1 RED RIVER BASIN BACKGROUND

The Red River Basin encompasses 49,000 square miles across portions of three states (Minnesota, North Dakota and South Dakota) and one Canadian province (Manitoba). These jurisdictions are further divided into individual Watershed Districts (MN), individual Water Resource Districts (ND) and various governing bodies within Manitoba. Historically, each jurisdiction has generally focused on solving their own flooding problems with limited knowledge of the cumulative impact of their individual projects or programs. Over the years, organizations have been formed to address this issue such as the Red River Watershed Management Board in Minnesota and the Red River Joint Water Resource District in North Dakota and the Red River Basin Commission. While there have been many success stories that have had a beneficial impact to the entire basin, flooding is still a major problem. In response to a demand to reduce flood damages experienced in the Red River Basin from both MN and ND, the RRBC began the Long Term Flood Solutions report to outline recommendations to reduce the flood risk within the Red River Basin. As part of this process, peak flow and runoff volume reduction goals were established to reduce Red River main stem flooding by twenty percent. The study utilized a Mike 11 flood routing model of the 1997 flood that had been developed previously. These goals were determined by manually modifying 1997 spring flood inflow hydrographs for the Red River Main Stem Mike 11 model. Tributary goals were then summarized in the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy Report. Even though the LTFS does not specify peak flow and volume reduction goals for the Roseau River, the goals specified for similar watersheds around Roseau were established to be a 35% peak flow reduction and 20% overall volume reduction for the 100-year 10-day Standardized Melt Progression Event. Due to localized flooding concerns, these same goals for peak flow and volume reductions were assumed for the Roseau River watershed.

Since completion of the RRBC Long Term Flood Solutions report, new modeling capabilities have become available to analyze potential benefit of flood damage reduction projects within the Red River Basin. In 2012, hydrologic models were developed for the USACE across the Red River Basin utilizing HEC-HMS software. Standardized procedures for model development and calibration were developed and utilized in creating tributary hydrologic models. Consistency was also attained by utilizing the Red River Basin-wide LiDAR topography data acquired through the International Water Institute's Red River Basin Mapping Initiative. Initial hydrologic model development was funded by the USACE and the communities of Fargo, ND and Moorhead, MN.

In addition, other ongoing efforts have also led to the development of a detailed hydraulic model for the main stem of the Red River. At the time of this report, the model extends from near the White Rock Dam on the upstream end (south), to Emerson, Manitoba on the downstream end (north). This hydraulic model, developed using HEC-RAS software, utilizes unsteady flow hydraulic routing methods to account for the large amount of floodplain storage that occurs on the landscape adjacent to the Red River main stem during large flood events. A combination of field survey and bathymetry elevation information was used to derive channel geometry for the Red River, and was combined with LiDAR topography information to determine floodplain geometry and storage characteristics.

The HEC-HMS models are currently being used throughout the Red River Basin to identify and evaluate potential flood water detention locations. The Red River Watershed Management Board (RRWMB) is funding development of expanded detention strategies for the Minnesota portion of the Red River Basin. Additionally, the North Dakota Red River Joint Water Resource District (NDRRJWRD), along with cooperation from the North Dakota State Water Commission (NDSWC) and Southeast Cass Water Resource District, is funding an effort to develop Comprehensive Detention Plans for the ND portion of the Red River Basin.

## 1.2 UPPER ROSEAU RIVER WATERSHED BACKGROUND

The Upper Roseau River Watershed is located in the northern portion of the Red River Basin and is within the State of Minnesota, as illustrated in Figure 1. The Upper Roseau River Watershed consists of approximately 477 square miles of the Roseau River Watershed upstream of the community of Roseau, MN, and 102 square miles contributing to the Hay Creek. A map of this region is presented in Figure 7. Topography within the Upper Roseau River Watershed is characterized by steep slopes within the upstream (south and east) portion of the watershed and more gradual slopes further downstream towards the community of Roseau, MN. Very few rolling hills and lakes exist, creating minimal non-contributing (closed) basins. Land use in lower portions of the Upper Roseau River Watershed is dominated by agricultural activities. Southern and eastern portions of the Upper Roseau River Watershed are predominately forested lands with limited agricultural use. This portion of the watershed contains a portion of the Beltrami Island State Forest and is primarily controlled by the State for forestry and wildlife purposes.

## 1.3 LOWER ROSEAU RIVER WATERSHED BACKGROUND

The Lower Roseau River Watershed is located in the northern portion of the Red River Basin, and falls within the State of Minnesota and the Province of Manitoba (Figure 2). For the purpose of this study, however, only the portion of the watershed that falls within the State of Minnesota is included (Figure 22). The approximate 478 square mile studied portion of the Lower Roseau River Watershed is of is downstream of the community of Roseau, MN and the location where the Hay Creek tributary joins the Roseau River. Land within the Lower Roseau River Watershed has higher elevations and steeper slopes in the eastern portion of the watershed and very gradual slopes in the central and western portion of the watershed. The southern to north-central portions of the Lower Roseau River Watershed are dominated by agricultural row crops and pasture lands. The northeastern and western portions of the watershed are predominately wetlands, open water, and deciduous forest. This western portion of the Lower Roseau River Watershed contains the Roseau River Wildlife Management Area and the Big Swamp, as illustrated in Figure 23, and is controlled by the Minnesota DNR for fish and wildlife purposes.

## 1.4 SCOPE AND PURPOSE

Development of the Roseau River Watershed Expanded Distributed Detention Strategy first involved identifying areas of the watershed that are conducive to storing runoff on the landscape. This involved review of LiDAR data, the International Water Institute's Project Planning tools, and consultation with RRWD staff. Flood water detention locations previously identified and/or under investigation by the RRWD were included in the analysis. Ideal locations were generally considered to have topographic characteristics exhibiting enough storage capacity to contain gated storage for three to four inches of rainfall runoff from twenty or more square miles contributing to the impoundment. Portions of the Roseau River Watershed contained few ideal locations, so in some instances, the threshold for identifying storage locations was lowered to increase the number of available sites to meet the

RRBC Basinwide Flood Reduction Strategy goals. Runoff volumes greater than the gated storage capacity were assumed to by-pass the flood water detention location.

Identified flood water detention locations were incorporated in the HEC-HMS hydrologic model of the Roseau River Watershed. Results from the hydrologic model were used to compare volume and peak flow reduction percentages to those outlined in the RRBC LTFS Basinwide Flow Reduction Strategy. While the RRBC LTFS Strategy does not specifically define peak flow and volume reductions for the Roseau River Watershed, tributaries adjacent to the Roseau River Watershed are generally recommended to provide a 35% peak flow reduction and 20% volume reduction. For the purposes of this planning effort, these peak flow and volume reduction goals were adopted for the Roseau River Watershed. Peak flow and volume reduction goals in the LTFS Basinwide Flow Reduction Strategy were developed in comparison to the 1997 spring flood event. Runoff storage provided by both the Norland Impoundment and the Palmville Fen Restoration Project were implemented after the 1997 spring flood event, and counted towards meeting RRBC LTFS peak flow and volume reduction goals. Synthetic hydrology developed as part of the Red River Basin Commission Standardized Melt Progression Analysis was used to calculate peak flow reductions and volume reduction benefits. This event utilizes 100-year 10-day runoff depths described in NRCS's Technical Release No. 60 publication. Additional details of this hydrology are included in Section 3.3.

Potential flood water detention locations identified as part of this planning effort are not intended to dictate specific impoundment sites for development of future projects. Rather, the analysis was intended to indicate the net effect of detaining flood waters at various locations within the Roseau River Watershed. It is anticipated that the RRWD, working through the Project Team Mediation Agreement, will further pursue and optimize flood water detention in general locations outlined in this report to develop and optimize the actual impoundment site locations.

Development of the Roseau River Watershed District Expanded Distributed Detention Strategy was executed by both HEI and HDR. HEI analyzed the Upper Roseau River Watershed and the Hay Creek Tributary, while HDR analyzed the Lower Roseau River Watershed. HEI's analysis and results of the Upper Roseau River Watershed and the Hay Creek Tributary may be found in Section 4. HDR's analysis and results of the Lower Roseau River Watershed may be found in Section 5.

# 2 FLOOD WATER DETENTION LOCATION SELECTION

## 2.1 INTERNATIONAL WATER INSTITUTE – PROJECT PLANNING TOOL

To assist in identifying areas to store runoff, the International Water Institute's Project Planning Tool was used. The Project Planning Tool provided a hypothetical analysis to illustrate the runoff storage potential if all roads within the watershed were raised. Utilizing LiDAR data, the analysis indicates the resultant flood pool, the available storage, and the contributing watershed. These locations were reviewed to assist in selecting areas of the watershed conducive to detaining flood water.

The International Water Institute's Project Planning Tool was also utilized to evaluate environmental obstacles associated with flood water detention locations through the Permit Complexity layer. This GIS layer provides information on the general level of difficulty associated with regulatory permitting and review.

## 2.2 SELECTION CRITERIA

Prior to this planning effort, selection criteria were developed for locating areas to detain runoff. The primary criterion was that locations should have the ability to detain three to four inches of runoff from a minimum of twenty square miles. Due to the scarcity of potential detention sites in portions of the watershed, this threshold was reduced in order to increase the volume of storage to meet the RRBC LTFS study goal.

The International Water Institute's Project Planning Tool aided in looking for general areas that may hold enough storage to meet the desired criteria for a flood water detention site, on the landscape. Once general areas were identified, embankment alignments were developed to minimize or eliminate potential structural impacts to rural residences and farming operations based on review of aerial photography and LiDAR data. Locations of cut-off ditches for off-channel flood water detention locations were also evaluated with the aid of LiDAR data to ensure flood waters could be diverted into potential impoundments at a reasonable gradient and depth of required cut to construct.

Permit complexity and practicality were also considered in the site selection process. Areas with sensitive environmental characteristics or multiple homes and farmsteads were avoided. The overall number of detention sites selected was based on an effort to meet the volume and peak flow reduction goals identified in the LTFS Plan.

The RRWD had previously identified several potential flood water detention locations in the Roseau River Watershed. These locations were further reviewed, optimized with the aid of LiDAR information, included in the Roseau River Watershed District Expanded Distributed Detention Strategy wherever practical.

## 3 HYDROLOGIC ANALYSIS

The identified flood water detention locations were incorporated into the Roseau River Watershed USACE HEC-HMS hydrologic model. The portion upstream of the United States/Canada border encompasses approximately 1,147 square miles of contributing area to the Red River Basin, and was previously developed by the US Army Corps of Engineers.

### 3.1 MODIFICATIONS TO EXISTING CONDITIONS

The existing conditions HEC-HMS model was modified as necessary to provide a more accurate comparison between existing and proposed conditions. Subbasins were divided at critical locations such as at outlet structures and/or diversion inlet locations for off channel sites. At locations where subbasins were required to be split, HEC-HMS reach routing variables were also adjusted. The existing conditions HEC-HMS model utilized the Modified-Puls and Muskingum-Cunge routing methods for all reach routing elements. Storage/outflow relationships used for Modified-Puls routing in the baseline HEC-HMS model were assigned proportional to reach length for the split reaches. Split reaches using Muskingum-Cunge methods required slope and typical cross sections to be derived from LiDAR data. Muskingum-Cunge routing methods were utilized in instances where new reaches were required. This new modified existing conditions model was validated with the baseline calibrated model by comparing the results of the TR-60 Melt Progression scenario.

### 3.2 DEVELOPMENT OF PROPOSED CONDITIONS

Storage information for the identified flood water detention locations was derived from LiDAR data and incorporated into the HEC-HMS model to develop a proposed conditions modeling scenario. GIS Terrain Analysis techniques were used to determine alterations to subbasin boundaries and reach alignments as a result of constructing embankments and excavating diversion ditches for each of the sites. HEC-HMS model parameters for proposed conditions were derived in a consistent manner as was used for existing conditions model development in the 2012 USACE HEC-HMS Basin-Wide Model.

For simplicity, all flood water detention locations were assumed to operate with a full drawdown, or dry, initial condition. Locations where runoff is proposed to be diverted from natural water courses were assumed to allow a base flow within those systems before excess runoff was diverted out of the channel and into the impoundment locations. Runoff diverted from legal ditches and intermittent watercourses was assumed to collect all runoff reaching the cut-off channel diverted into the impoundment location. When the diverted runoff volume exceeded the available gated storage within the impoundment, additional runoff was allowed to outflow from the site and continue downstream. This same “fill and spill” methodology was assumed for the analysis of all selected detention locations.

## 3.3 RED RIVER BASIN STANDARDIZED MELT PROGRESSION EVENT

To more accurately simulate a synthetic spring melt condition within the US portion of the Red River Basin, the Red River Basin Commission completed an analysis in early 2013. This analysis utilized temperature data at observation locations throughout the Red River Basin to estimate when snowmelt conditions generally occur during a typical spring. The results of this virtual thaw progression are illustrated in Figure 3. This timing analysis was applied to a 10-day runoff scenario depth illustrated in Figure 4. Based on the 10-day runoff scenario shown in Figure 4, equivalent rainfall depths for the 10-day runoff were developed using the composite 24-hour NRCS curve number for the portion of the Red River Basin upstream of Halstad, MN. This composite 24-hour curve number was found to be approximately 73. The resultant equivalent rainfall depths are illustrated in Figure 5. This equivalent rainfall depth was then applied using the Minnesota Principal Spillway Temporal Rainfall Distribution, as defined in the Minnesota Hydrology Guide. This temporal distribution is illustrated in Figure 6. Start time for the rainfall was set by the Virtual Thaw Progression (Figure 3) at each respective location. This information was developed in a manner to allow application via the gridded precipitation meteorological option within HEC-HMS. Gridded precipitation allows for each subbasin to depict a unique temporal distribution and total depth depending on its geographic orientation in relation to the Standardized Melt Progression. The resultant Red River Basin Standardized Melt Progression Event was utilized to determine volume and peak flow reduction criteria based on the Long Term Flood Solutions recommendations. For further information regarding the Red River Basin Standardized Melt Progression Event, refer to the *Red River Basin Standardized Melt Progression Event Analysis* Report completed by the Red River Basin Commission, April 2013 (Reference No. 1).

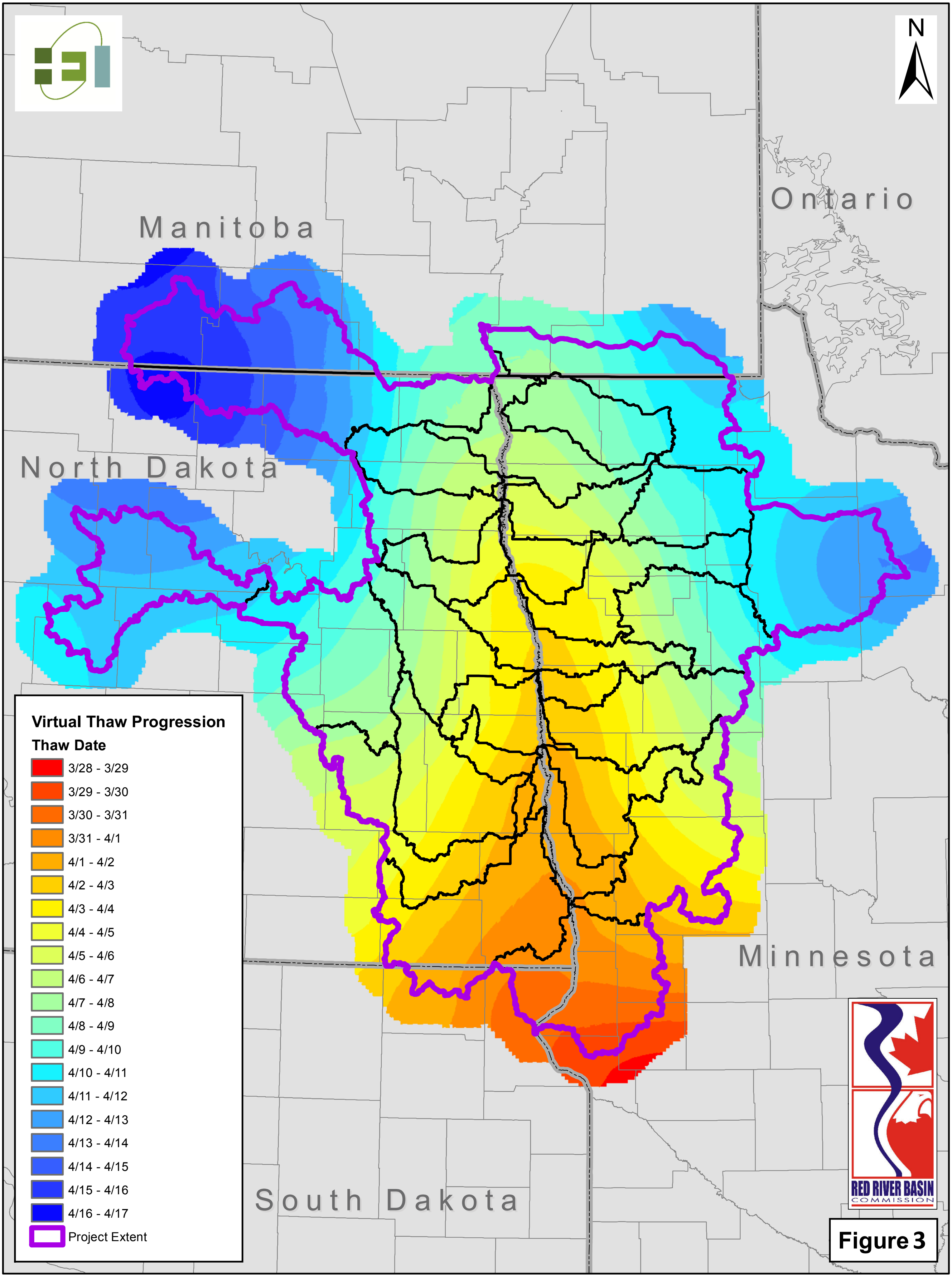
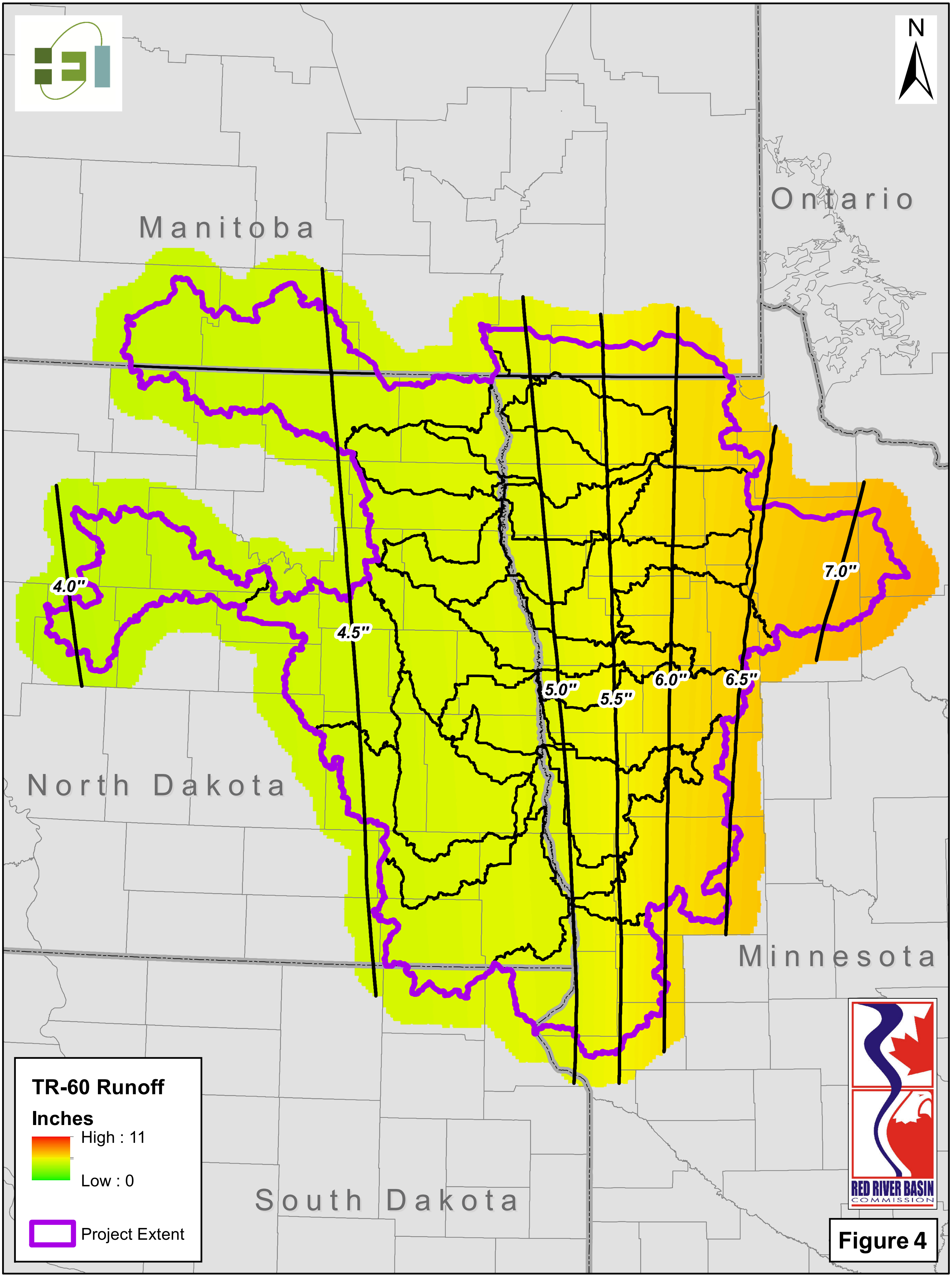
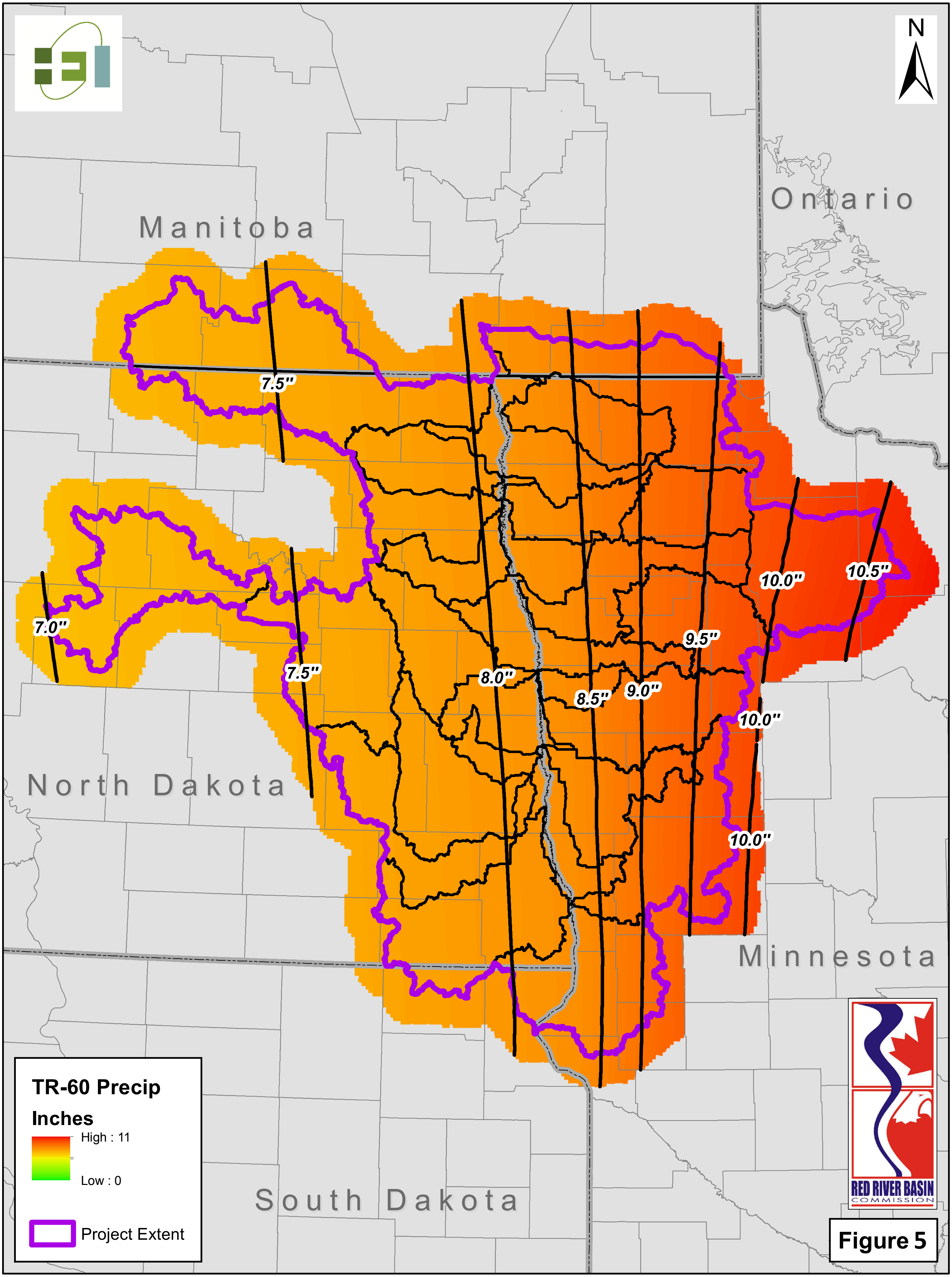

Manitoba
Ontario
North Dakota
Minnesota
South Dakota
N
Virtual Thaw Progression
Thaw Date
3/28 - 3/29
3/29 - 3/30
3/30 - 3/31
3/31 - 4/1
4/1 - 4/2
4/2 - 4/3
4/3 - 4/4
4/4 - 4/5
4/5 - 4/6
4/6 - 4/7
4/7 - 4/8
4/8 - 4/9
4/9 - 4/10
4/10 - 4/11
4/11 - 4/12
4/12 - 4/13
4/13 - 4/14
4/14 - 4/15
4/15 - 4/16
4/16 - 4/17
Project Extent
RED RIVER BASIN
COMMISSION

**Figure 3**



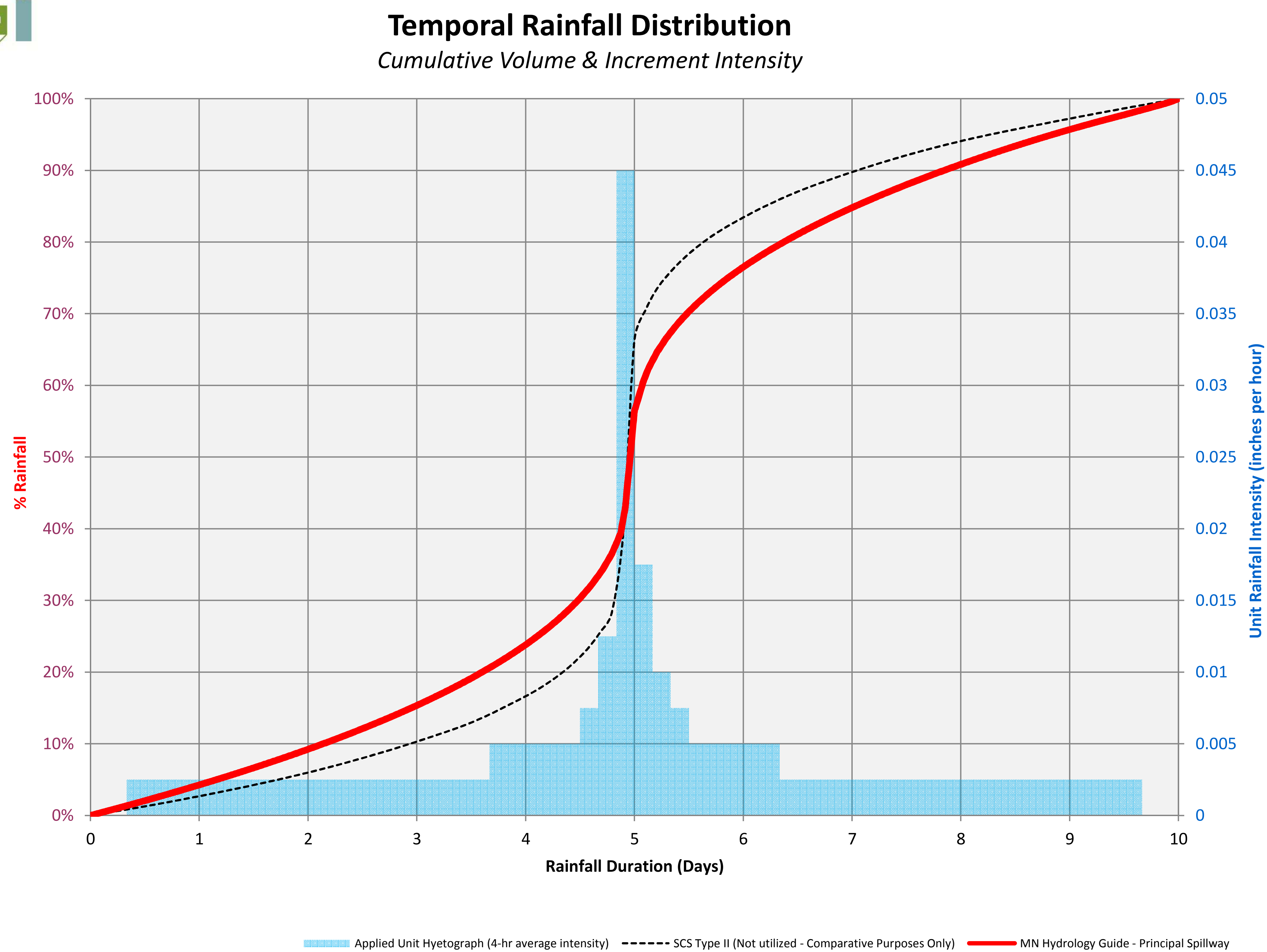
Manitoba
Ontario
North Dakota
Minnesota
South Dakota
N
4.0"
4.5"
5.0"
5.5"
6.0"
6.5"
7.0"
TR-60 Runoff
Inches
High : 11
Low : 0
Project Extent
RED RIVER BASIN
COMMISSION


Figure 4



Manitoba
Ontario
North Dakota
Minnesota
South Dakota
7.0"
7.5"
7.5"
8.0"
8.5"
9.0"
9.5"
10.0"
10.0"
10.0"
10.5"
TR-60 Precip
Inches
High : 11
Low : 0
Project Extent
N
RED RIVER BASIN
COMMISSION

Figure 5



Temporal Rainfall Distribution
Cumulative Volume & Increment Intensity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Rainfall
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Unit Rainfall Intensity (inches per hour)
0
1
2
3
4
5
6
7
8
9
10
Rainfall Duration (Days)
Applied Unit Hyetograph (4-hr average intensity)
SCS Type II (Not utilized - Comparative Purposes Only)
MN Hydrology Guide - Principal Spillway


Figure 6

# 4 UPPER ROSEAU RIVER WATERSHED EXPANDED DISTRIBUTED DETENTION STRATEGY

## 4.1 EXISTING FLOOD WATER DETENTION LOCATIONS

Several flood water impoundment locations have been implemented within the Upper Roseau River Watershed. Table 1 summarizes the available storage and drainage area characteristics of the existing impoundments within the Upper Roseau River Watershed. In total, existing detention locations (pre- and post-1997) provide approximately 3,900 acre-feet of ungated storage capacity. The majority of this existing storage capacity is located within the Beltrami Island State Forest at Hayes Lake and the Roseau River Flowage sites. These two impoundments provide approximately 3,500 acre-feet of ungated storage capacity. Figure 7 illustrates the locations and the associated drainage areas of the existing flood water impoundment locations. The Palmville Fen Restoration Project and the Norland Impoundment diversion structure at Hay Creek have been implemented after the 1997 spring flood event, and thus are included towards meeting LTFS Basinwide Flow Reduction Strategy goals. The Palmville Fen Restoration Project provides approximately 110 acre-feet of ungated storage. Benefit provided by the Norland Impoundment diversion structure to the Hay Creek watershed is dependent on downstream conditions. The focus of this planning effort is to reduce severe flooding within the Red River Basin typically associated with spring snow melt events, thus spring operation procedures were assumed for all existing impoundments.

## 4.2 SUMMARY OF SELECTED LOCATIONS

Ten locations meeting the general criteria previously described were selected during this planning effort, for the Upper Roseau River Watershed. In total, these locations would provide a gated storage capacity of approximately 55,700 acre-feet, or 3.7 inches across 286 square miles. The contributing areas to the ten selected detention locations as well as existing impoundment locations are illustrated on Figure 8. Runoff storage potential is provided on Table 2.

## 4.3 UPPER ROSEAU RIVER WATERSHED SUMMARY AND RESULTS

Because the confluence of the Roseau River with the Red River is located in Canada and the LTFS Basinwide Flow Reduction Strategy focuses on the US portion of the Red River Basin, peak flow and volume reductions for the Roseau River Watershed are not specifically defined. However, tributaries adjacent to the Roseau River Watershed are generally recommended to provide a 35% peak flow reduction and 20% volume reduction for the 100-year 10-day Standardized Melt Progression Event. For the purposes of this planning effort, these peak flow and volume reduction goals were adopted for the Roseau River Watershed. Higher levels of peak flow and volume reduction for the upper portion of the Roseau River Watershed were deemed desirable due to increased flooding concern for the RRWD as a result of runoff from the Upper Roseau River Watershed.

The ten selected detention locations and the two existing post-1997 impoundment locations provide a peak flow reduction of 60% and runoff volume reduction of 34% at the USGS Gage on the Roseau River at Malung, MN (USGS Gage 05104500) when compared with the 1997 conditions. A comparison hydrograph is provided in Figure 16. When comparing results of the Roseau River at the outlet of the Upper Roseau River Watershed, the identified locations and existing post-1997 impoundment provided a peak flow reduction of 46% and runoff volume reduction of 30% for the Standardized Melt Progression Event. Comparison hydrographs at this location are provided in Figure 21. Additionally, several other hydrograph locations were included to better illustrate benefit to Roseau River watershed. Comparison hydrographs at all locations, in order from upstream to downstream in the watershed, are provided in Figures 9-21. Specific performance statistics for each location during the Red River Basin Standardized Melt Progression Event are illustrated in Table 3. Additionally, runoff volume and peak flow reductions at various locations within the upper RRWD are presented in Table 4.

## 4.4 RECOMMENDATIONS

Potential detention locations identified as part of this effort present one possible scenario to reach runoff volume and peak flow reduction goals similar to those specified in the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy. It is anticipated that this report will serve as a framework for the RRWD to assist in providing Red River main stem benefits while pursuing projects that maximize local benefit within the RRWD.

# 5 LOWER ROSEAU RIVER WATERSHED EXPANDED DISTRIBUTED DETENTION STRATEGY

## 5.1 EXISTING FLOOD WATER DETENTION LOCATIONS

Several flood water impoundment locations have been implemented within the Lower Roseau River Watershed. Table 5 summarizes the available storage and drainage area characteristics of the existing flood storage detention locations within the Lower Roseau River Watershed. In total, existing detention locations (pre-1997 and post-1997) provide approximately 55,932 acre-feet of storage capacity during a spring snowmelt runoff event. The majority of this existing storage capacity is located within the northwestern and eastern portion of the Lower Roseau River Watershed, at the Roseau River Wildlife Management Area Pools One, Two, and Three, and the Norland Impoundment. Figure 23 illustrates the locations and the associated drainage areas of the existing flood water impoundment locations. The Norland Impoundment was implemented after the 1997 spring flood event, and thus, is included towards meeting LTFS Basinwide Flow Reduction Strategy goals. The Norland Impoundment Project provides approximately 6,000 acre-feet of gated storage and 3,500 acre-feet of ungated storage. The focus of this planning effort is to reduce severe flooding within the Red River Basin typically associated with spring snow melt events, thus spring operation procedures were assumed for all existing impoundments.

## 5.2 SUMMARY OF SELECTED LOCATIONS

Eleven flood water detention locations were identified and selected during this planning effort. In total, these proposed detention locations would provide a storage capacity of approximately 233,000 acre-feet, or 3.9 inches across 1,108 square miles. The contributing areas to the 11 selected detention locations as well as existing (pre-1997 and post-1997) impoundment locations are illustrated on Figures 24 and 25. Runoff storage potential is provided in on Table 6.

## 5.3 LOWER ROSEAU RIVER WATERSHED SUMMARY AND RESULTS

The 11 selected locations from the Lower Roseau River Watershed, in conjunction with the ten selected detention locations from the Upper Roseau River Watershed, and two existing post-1997 impoundment locations, provide peak flow reduction of 36% and runoff volume reduction of 32% at the Roseau River at the United States/Canada border for the 75-day modeling period utilized in the HEC-HMS model for the Red River Basin Standardized Melt Progression Event. A comparison hydrograph is provided in Figure 31. Additionally, several other hydrograph locations were included to better illustrate the local benefits to the Roseau River Watershed. Comparison hydrographs at all locations, in order from upstream to downstream in the Lower Roseau River watershed, are provided in Figures 26 through 31. Specific performance statistics at each location during the Red River Basin Standardized Melt Progression Event are illustrated in Table 7. The performance statistics show the volume stored using gated impoundment storage and percent reductions in peak flows and volume at the outlet of each impoundment. Additionally, runoff volume and peak flow reductions at various locations within the Lower Roseau River Watershed are presented in Table 8.

## 5.4 RECOMMENDATIONS

The proposed detention locations identified as part of this effort present one possible scenario to reach runoff volume and peak flow reduction goals similar to those specified in the Red River Basin Commission's Long Term Flood Solutions Basinwide Flow Reduction Strategy. It is anticipated that this report will serve as a framework for the RRWD to assist in providing Red River main stem benefits while pursuing projects that maximize local benefits within the RRWD.

This report is meant to serve as an illustration of potential results of identified detention sites, and does not provide a guarantee of flood damage reduction results, volume reduction, or peak flow reduction. Future analysis and optimization of proposed detention sites is required in order to determine the benefit that any individual site will provide.

## REFERENCES


1. Red River Basin Commission, *Red River Basin Standardized Melt Progression Event Analysis,* April 10, 2013.
2. JOR Engineering on behalf of Roseau River Watershed District, *Roseau River Wildlife Management Area Control Structure Improvements Preliminary Concept Report*, July 24, 2006.
3. JOR Engineering on behalf of Roseau River Watershed District, *Some Potential Impoundment Sites Upstream of Roseau,* August 5, 2002.
4. Red River Basin Commission, *LTFS Basinwide Flow Reduction Strategy,* January 20, 2010.
5. Red River Basin Commission, Long Term Flood Solutions for the Red River Basin, September 2011.
6. U.S. Department of Agriculture, Natural Resources Conservation Service, *Earth Dams and Reservoirs*, Technical Release No. 60, July 2005.
7. U.S. Department of Agriculture, Natural Resources Conservation Service, *Hydrology Guide for Minnesota.*
8. Fargo-Moorhead Metro Basin-Wide Modeling Approach – Hydrologic Modeling, *HEC-HMS Model Development for Various Tributaries above the Red River of the North at Halstad, MN*, December 23, 2011.
9. Roseau River Watershed District, *Hay Creek Setback Levees and Norland Impoundment Final Engineer's Report*, May 2009.

# Upper Roseau River Watershed Tables

HoustonEngineering Inc.

## Table 1
## Existing Conditions Flood Water Detention Location Statistics

| Site Name | Year Implemented | Drainage Area | Gated Volume | Ungated Volume** | Total Volume |
|---|---|---|---|---|---|
| ***Impoundment Locations Constructed Before the 1997 Spring Flood Event*** | | | | | |
| Roseau River Flowage | | 39.0 Mi² | 0 Ac-ft (0'') | 1,894 Ac-ft (0.9'') | 1,894 Ac-ft (0.9'') |
| Hayes Lake | | 124.5 Mi² | 0 Ac-ft (0'') | 1,614 Ac-ft (0.2'') | 1,614 Ac-ft (0.2'') |
| Unnamed Dam (T158N R38W) | | 3.1 Mi² | 0 Ac-ft (0'') | 303 Ac-ft (1.8'') | 303 Ac-ft (1.8'') |
| Subtotal *(Before 1997)* | | 127.6 Mi² | 0 Ac-ft (0'') | 3,811 Ac-ft (0.6'') | 3,811 Ac-ft (0.6'') |
| ***Impoundment Locations Constructed After the 1997 Spring Flood Event**** | | | | | |
| Palmville Fen | 2012 | 21.5 Mi² | 0 Ac-ft (0'') | 106 Ac-ft (0.1'') | 106 Ac-ft (0.1'') |
| **Total *(All Existing)*** | | 149.1 Mi² | 0 Ac-ft (0'') | 3,917 Ac-ft (0.5'') | 3,917 Ac-ft (0.5'') |

** Does not include 2009 Norland/Hay Creek Impoundment Project*

*** Data from USACE HEC-HMS model inputs*

| Table 2<br>Identified Flood Water Detention Location Statistics | | | | | |
|---|---|---|---|---|---|
| **Site Name** | **Year Implemented** | **Drainage Area*** | **Gated Volume** | **Ungated Volume** | **Total Volume** |
| ***Identified Future Detention Locations in Roseau River Subwatershed*** | | | | | |
| RR_01 | Proposed | 143.0 Mi² | 27,334 Ac-ft *(3.6")* | 21,688 Ac-ft *(2.8")* | 49,022 Ac-ft *(6.4")* |
| RR_02 | Proposed | 9.5 Mi² | 2,040 Ac-ft *(4.0")* | 4,842 Ac-ft *(9.6")* | 6,882 Ac-ft *(13.6")* |
| RR_03 | Proposed | 4.0 Mi² | 756 Ac-ft *(3.5")* | 2,781 Ac-ft *(13.0")* | 3,537 Ac-ft *(16.6")* |
| RR_04 | Proposed | 6.1 Mi² | 1,299 Ac-ft *(4.0")* | 1,764 Ac-ft *(5.4")* | 3,063 Ac-ft *(9.4")* |
| RR_05 | Proposed | 22.7 Mi² | 1,886 Ac-ft *(1.6")* | 4,295 Ac-ft *(3.5")* | 6,181 Ac-ft *(5.1")* |
| RR_06 | Proposed | 17.5 Mi² | 3,530 Ac-ft *(3.8")* | 8,732 Ac-ft *(9.4")* | 12,262 Ac-ft *(13.1")* |
| RR_07 | Proposed | 48.8 Mi² | 9,600 Ac-ft *(3.7")* | 12,996 Ac-ft *(5.0")* | 22,596 Ac-ft *(8.7")* |
| RR_08 | Proposed | 20.8 Mi² | 4,364 Ac-ft *(3.9")* | 4,066 Ac-ft *(3.7")* | 8,430 Ac-ft *(7.6")* |
| Subtotal (Roseau River Subwatershed) | | 262.3 Mi² | 50,809 Ac-ft *(3.6")* | 61,164 Ac-ft *(4.4")* | 111,973 Ac-ft *(8.0")* |
| ***Identified Future Detention Locations in Hay Creek Subwatershed*** | | | | | |
| HC_01 | Proposed | 14.7 Mi² | 3,168 Ac-ft *(4.0")* | 962 Ac-ft *(1.2")* | 4,130 Ac-ft *(5.3")* |
| HC_02 | Proposed | 8.5 Mi² | 1,759 Ac-ft *(3.9")* | 2,719 Ac-ft *(6.0")* | 4,478 Ac-ft *(9.9")* |
| Subtotal (Hay Creek Subwatershed) | | 23.2 Mi² | 4,927 Ac-ft *(4.0")* | 3,681 Ac-ft *(3.0")* | 8,608 Ac-ft *(7.0")* |
| Subtotal *(All Identified)* | | 285.5 Mi² | 55,736 Ac-ft *(3.7")* | 64,845 Ac-ft *(4.3")* | 120,581 Ac-ft *(7.9")* |
| Subtotal *(Identified and Existing Post-1997)*** | | 285.5 Mi² | 55,736 Ac-ft *(3.7")* | 64,951 Ac-ft *(4.3")* | 120,687 Ac-ft *(7.9")* |
| **Total *(Identified & All Existing)***** | | **285.5 Mi²** | **55,736 Ac-ft *(3.7")*** | **68,762 Ac-ft *(4.5")*** | **124,498 Ac-ft *(8.2")*** |

**Drainage Area inclusive of upstream detention location drainage areas*

***Existing Storage statistics summarized in Table 1*

## Table 3
## Flood Water Detention Location Performance Statistics

*Red River Basin Standardized Melt Progression Event*

| Site Name | Year Implemented | Drainage Area* | Peak Inflow | Peak Outflow | Peak Flow Reduction | Inflow Volume** | Outflow Volume** | Volume Reduction |
|---|---|---|---|---|---|---|---|---|
| ***Existing Impoundment Locations Constructed Before the 1997 Sping Flood Event*** | | | | | | | | |
| Roseau River Flowage | | 39.0 Mi² | 1,262 cfs | 1,246 cfs | -1 % | 14,235 Ac-ft *(6.8'')* | 14,234 Ac-ft *(6.8'')* | 0 % |
| Hayes Lake*** | | 124.5 Mi² | 3,917 cfs | 144 cfs | -96 % | 44,540 Ac-ft *(6.7'')* | 5.176 Ac-ft *(6.7'')* | -88 % |
| Unnamed Dam (T158N R38W) | | 3.1 Mi² | 207 cfs | 189 cfs | -9 % | 1,283 Ac-ft *(7.'')* | 1,283 Ac-ft *(7.8'')* | 0 % |
| Subtotal *(Before 1997)* | | 127.6 Mi² | | | | 60,059 Ac-ft *(8.8")* | 20,693 Ac-ft *(3.0")* | -66 % |
| ***Existing Impoundment Locations Constructed After the 1997 Sping Flood Event*** | | | | | | | | |
| Palmville Fen | 2012 | 21.5 Mi² | 863 cfs | 863 cfs | 0 % | 6,856 Ac-ft *(6.0'')* | 6,855 Ac-ft *(6.0'')* | 0 % |
| Subtotal *(All Existing)* | | 149.1 Mi² | | | | 66,914 Ac-ft *(8.4")* | 27,548 Ac-ft *(3.5'')* | -59 % |

** Drainage Area inclusive of upstream detention location drainage areas.*

*** Inches derived from Drainage Area field.*

**** Reported Statistics represent baseflow maintained in contributing waterway. Excess flood waters are diverted to the proposed detention location, RR_01.*

**Table 3 *(continued)***

**Flood Water Detention Location Performance Statistics**

*Red River Basin Standardized Melt Progression Event*

| Site Name | Year Implemented | Drainage Area* | Peak Inflow | Peak Outflow | Peak Flow Reduction | Inflow Volume** | Outflow Volume** | Volume Reduction |
|---|---|---|---|---|---|---|---|---|
| ***Identified Future Detention Locations within Roseau River Subwatershed*** | | | | | | | | |
| RR_01 | Proposed | 143.0 Mi² | 4,339 cfs | 1,408 cfs | -68 % | 44,878 Ac-ft *(5.9'')* | 17,617 Ac-ft *(2.3'')* | -61 % |
| RR_02 | Proposed | 9.5 Mi² | 228 cfs | 100 cfs | -56 % | 3,174 Ac-ft *(6.3'')* | 1,148 Ac-ft *(2.3'')* | -64 % |
| RR_03 | Proposed | 4.0 Mi² | 165 cfs | 78 cfs | -53 % | 1,332 Ac-ft *(6.2'')* | 580 Ac-ft *(2.7'')* | -56 % |
| RR_04 | Proposed | 6.1 Mi² | 284 cfs | 121 cfs | -57 % | 2,119 Ac-ft *(6.5'')* | 828 Ac-ft *(2.5'')* | -61 % |
| RR_05 | Proposed | 22.7 Mi² | 548 cfs | 391 cfs | -29 % | 5,355 Ac-ft *(4.4'')* | 3,477 Ac-ft *(2.9'')* | -35 % |
| RR_06 | Proposed | 17.5 Mi² | 789 cfs | 317 cfs | -60 % | 6,558 Ac-ft *(7.0'')* | 3,036 Ac-ft *(3.3'')* | -54 % |
| RR_07 | Proposed | 48.8 Mi² | 1,867 cfs | 631 cfs | -66 % | 16,414 Ac-ft *(6.3'')* | 6,633 Ac-ft *(2.5'')* | -60 % |
| RR_08 | Proposed | 20.8 Mi² | 1,126 cfs | 309 cfs | -73 % | 6,784 Ac-ft *(6.1'')* | 2,439 Ac-ft *(2.2'')* | -64 % |
| Subtotal *(Identified Detention within Roseau River Subwatershed)* | | 262.3 Mi² | | | | 86,614 Ac-ft *(6.2'')* | 35,758 Ac-ft *(2.6'')* | -59 % |

** Drainage Area inclusive of upstream detention location drainage areas.*

*** Inches derived from Drainage Area field.*

| Table 3 *(continued)*<br>**Flood Water Detention Location Performance Statistics**<br>*Red River Basin Standardized Melt Progression Event* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Site Name** | **Year Implemented** | **Drainage Area*** | **Peak Inflow** | **Peak Outflow** | **Peak Flow Reduction** | **Inflow Volume**** | **Outflow Volume**** | **Volume Reduction** |
| ***Identified Future Detention Locations within Hay Creek Subwatershed*** | | | | | | | | |
| HC_01 | Proposed | 14.7 Mi² | 251 cfs | 91 cfs | -64 % | 4,587 Ac-ft *(5.9'')* | 1,435 Ac-ft *(1.8'')* | -69 % |
| HC_02 | Proposed | 8.5 Mi² | 388 cfs | 155 cfs | -60 % | 2,903 Ac-ft *(6.4'')* | 1,160 Ac-ft *(2.6'')* | -60 % |
| Subtotal *(Identified Detention within Hay Creek Subwatershed)* | | 23.2 Mi² | | | | 7,490 Ac-ft *(6.1'')* | 2,596 Ac-ft *(2.1'')* | -65 % |
| Subtotal *(All Identified Future Detention Sites)* | | 285.5 Mi² | | | | 94,105 Ac-ft *(6.2'')* | 38,353 Ac-ft *(2.5'')* | -59 % |
| Subtotal *(All Identified and Existing Post-1997)* | | 285.5 Mi² | | | | 100,960 Ac-ft *(6.1'')* | 45,208 Ac-ft *(3.0'')* | -55 % |
| **Total *(All Existing & Identified)*** | | **285.5 Mi²** | | | | **161,019 Ac-ft *(10.6")*** | **65,902 Ac-ft *(4.3'')*** | **-59 %** |

** Drainage Area inclusive of upstream detention location drainage areas.*

*** Inches derived from Drainage Area field.*

## Table 4
## Performance Statistics at Monitoring Locations

*Red River Basin Standardized Melt Progression Event*

| Location | Contributing Drainage Area | Existing Conditions | | Proposed Conditions | | Percent Reductions | |
|---|---|---|---|---|---|---|---|
| | | Peak Flow | Volume | Peak Flow | Volume | Peak Flow | Volume |
| Roseau River near CR 9-B | 145.5 Mi²*<br>160.3 Mi²** | 4,434 cfs | 51,145 Ac-ft<br>*(6.6")* | 1,683 cfs | 26,278 Ac-ft<br>*(3.1")* | -62 % | -49 % |
| Roseau River at County Road 126 | 181.8 Mi² | 5,341 cfs | 62,277 Ac-ft<br>*(6.4")* | 1,778 cfs | 33,405 Ac-ft<br>*(3.4")* | -67 % | -46 % |
| Bear Creek Outlet | 25.1 Mi² | 1,089 cfs | 8,210 Ac-ft<br>*(6.1")* | 427 cfs | 4,289 Ac-ft<br>*(3.2")* | -61 % | -48 % |
| Roseau River below Bear Creek Confluence | 213.4 Mi² | 6,285 cfs | 72,544 Ac-ft<br>*(6.4")* | 2,027 cfs | 39,733 Ac-ft<br>*(3.5")* | -68 % | -45 % |
| South Fork Roseau River at County Road 12-B | 40.0 Mi² | 1,626 cfs | 14,186 Ac-ft<br>*(6.7")* | 901 cfs | 10,636 Ac-ft<br>*(5.0")* | -45 % | -25 % |
| South Fork Roseau River near Wannaska, MN | 123.9 Mi²*<br>113.5 Mi²** | 4,722 cfs | 42,190 Ac-ft<br>*(6.4")* | 1,719 cfs | 25,365 Ac-ft<br>*(4.2")* | -64 % | -40 % |
| South Fork Roseau River Outlet | 197.5 Mi² | 6,275 cfs | 73,350 Ac-ft<br>*(7.0")* | 3,531 cfs | 55,369 Ac-ft<br>*(5.3")* | -44 % | -25 % |
| USGS Gage 05104500 Roseau River near Malung, MN | 433.6 Mi² | 12,343 cfs | 147,854 Ac-ft<br>*(6.4")* | 4,883 cfs | 97,046 Ac-ft<br>*(4.2")* | -60 % | -34 % |
| Roseau River at Roseau, MN | 478.5 Mi² | 13,144 cfs | 162,569 Ac-ft<br>*(6.4")* | 5,886 cfs | 111,736 Ac-ft<br>*(4.4")* | -55 % | -31 % |
| Hay Creek near County Road 12-B | 28.7 Mi² | 1,042 cfs | 12,290 Ac-ft<br>*(8.0")* | 806 cfs | 8,953 Ac-ft<br>*(5.8")* | -23 % | -27 % |
| Hay Creek at MN Highway 11 (Upstream of Norland Impoundment Diversion Structure) | 78.6 Mi² | 2,566 cfs | 26,531 Ac-ft<br>*(6.3")* | 2,045 cfs | 21,452 Ac-ft<br>*(5.1")* | -20 % | -19 % |
| Hay Creek Outlet | 96.0 Mi² | 2,628 cfs | 32,435 Ac-ft<br>*(6.3")* | 2,118 cfs | 24,170 Ac-ft<br>*(4.7")* | -19 % | -25 % |
| Roseau River below Hay Creek Confluence near County Road 28-B | 579.2 Mi² | 10,653 cfs | 196,783 Ac-ft<br>*(6.4")* | 5,731 cfs | 137,579 Ac-ft<br>*(4.5")* | -46 % | -30 % |

**Existing Conditions Contributing Drainage Area*

***Proposed conditions contributing drainage area altered due to embankment configurations for identified impoundment locations*

# Upper Roseau River Watershed Figures

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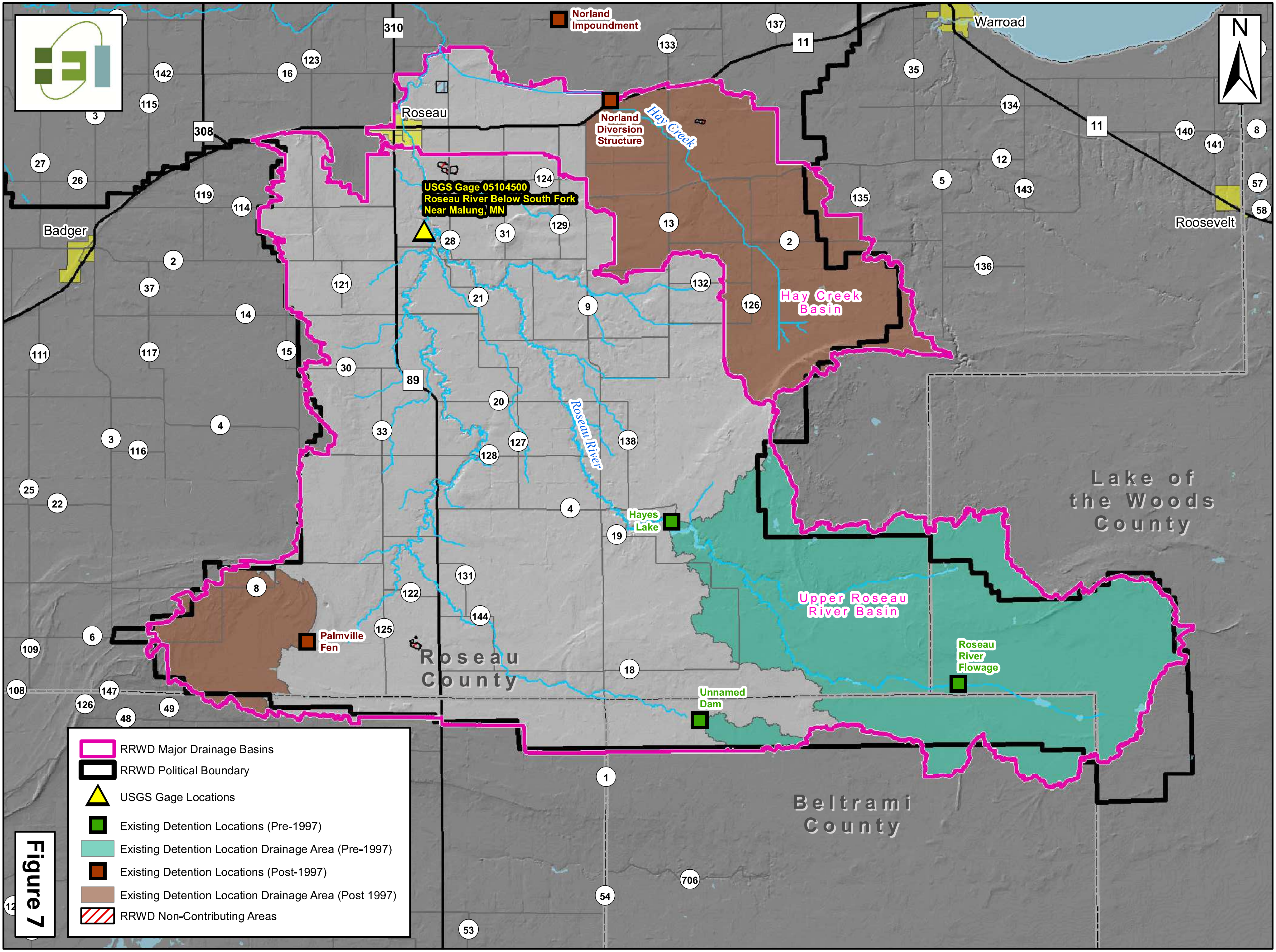
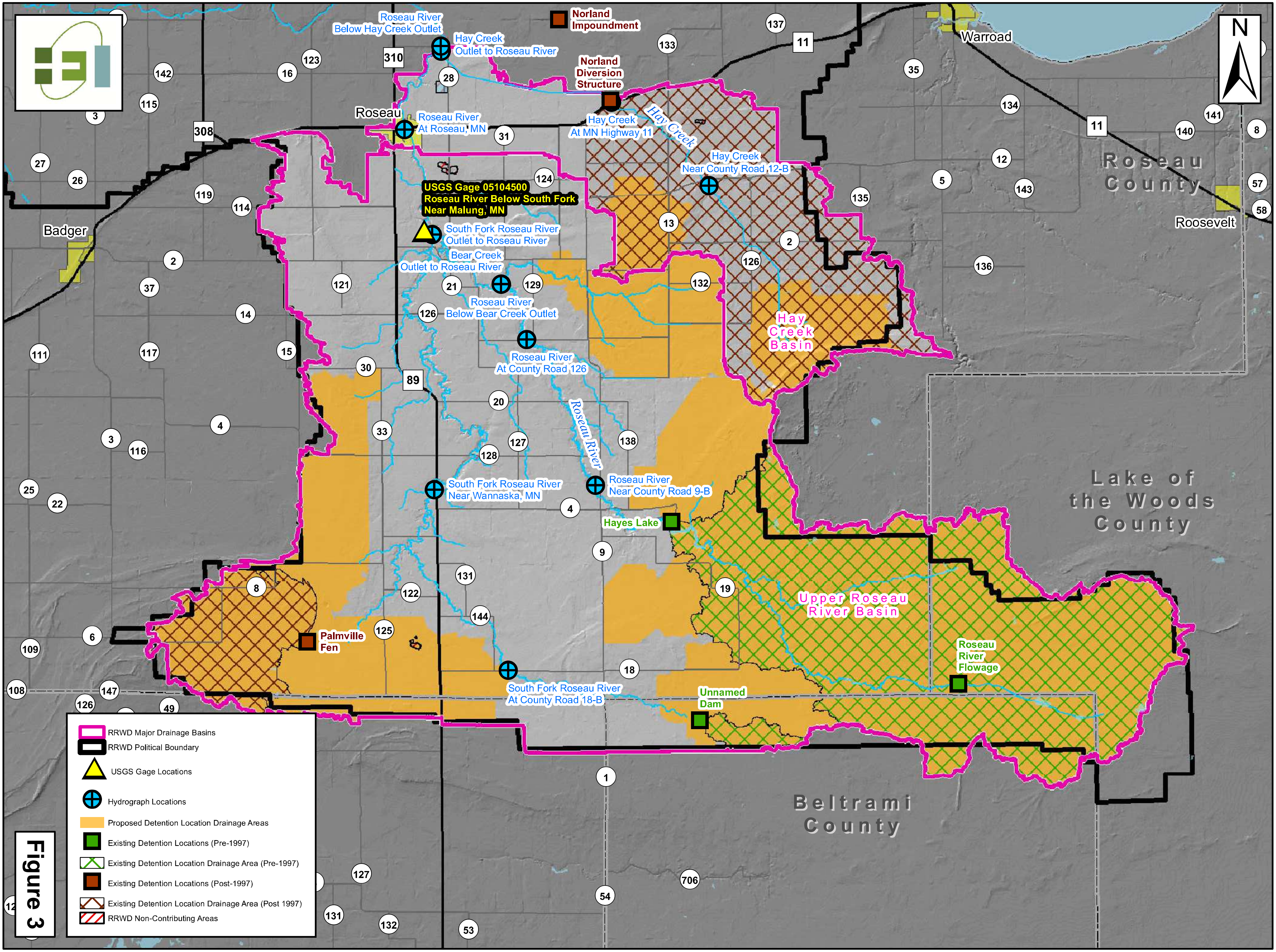


Warroad
Roosevelt
Roseau
Badger
Norland Impoundment
Norland Diversion Structure
Hay Creek
Hay Creek Basin
USGS Gage 05104500
Roseau River Below South Fork
Near Malung, MN
Roseau River
Hayes Lake
Upper Roseau River Basin
Roseau River Flowage
Unnamed Dam
Palmville Fen
Roseau County
Lake of the Woods County
Beltrami County
N
RRWD Major Drainage Basins
RRWD Political Boundary
USGS Gage Locations
Existing Detention Locations (Pre-1997)
Existing Detention Location Drainage Area (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Location Drainage Area (Post 1997)
RRWD Non-Contributing Areas


Figure 7



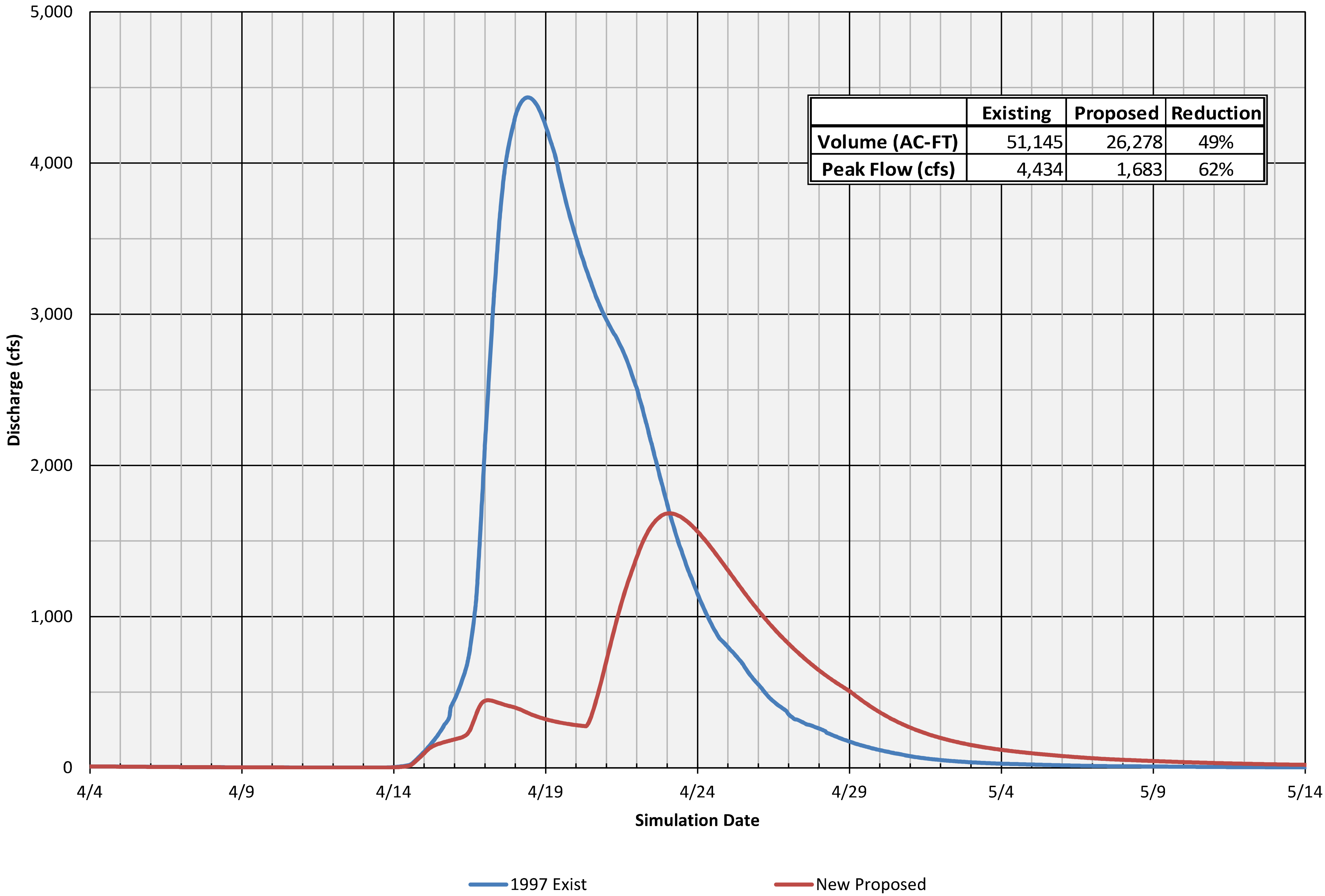
Roseau River
Below Hay Creek Outlet
Hay Creek
Outlet to Roseau River
Norland
Impoundment
Norland
Diversion
Structure
Warroad
Roseau
Roseau River
At Roseau, MN
Hay Creek
At MN Highway 11
Hay Creek
Hay Creek
Near County Road 12-B
Roseau
County
Roosevelt
Badger
USGS Gage 05104500
Roseau River Below South Fork
Near Malung, MN
South Fork Roseau River
Outlet to Roseau River
Bear Creek
Outlet to Roseau River
Roseau River
Below Bear Creek Outlet
Roseau River
At County Road 126
Hay
Creek
Basin
Roseau River
Roseau River
Near County Road 9-B
South Fork Roseau River
Near Wannaska, MN
Hayes Lake
Lake of
the Woods
County
Upper Roseau
River Basin
Palmville
Fen
Roseau
River
Flowage
South Fork Roseau River
At County Road 18-B
Unnamed
Dam
Beltrami
County
RRWD Major Drainage Basins
RRWD Political Boundary
USGS Gage Locations
Hydrograph Locations
Proposed Detention Location Drainage Areas
Existing Detention Locations (Pre-1997)
Existing Detention Location Drainage Area (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Location Drainage Area (Post 1997)
RRWD Non-Contributing Areas
N


Figure 3

## Roseau River near County Road 9-B

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

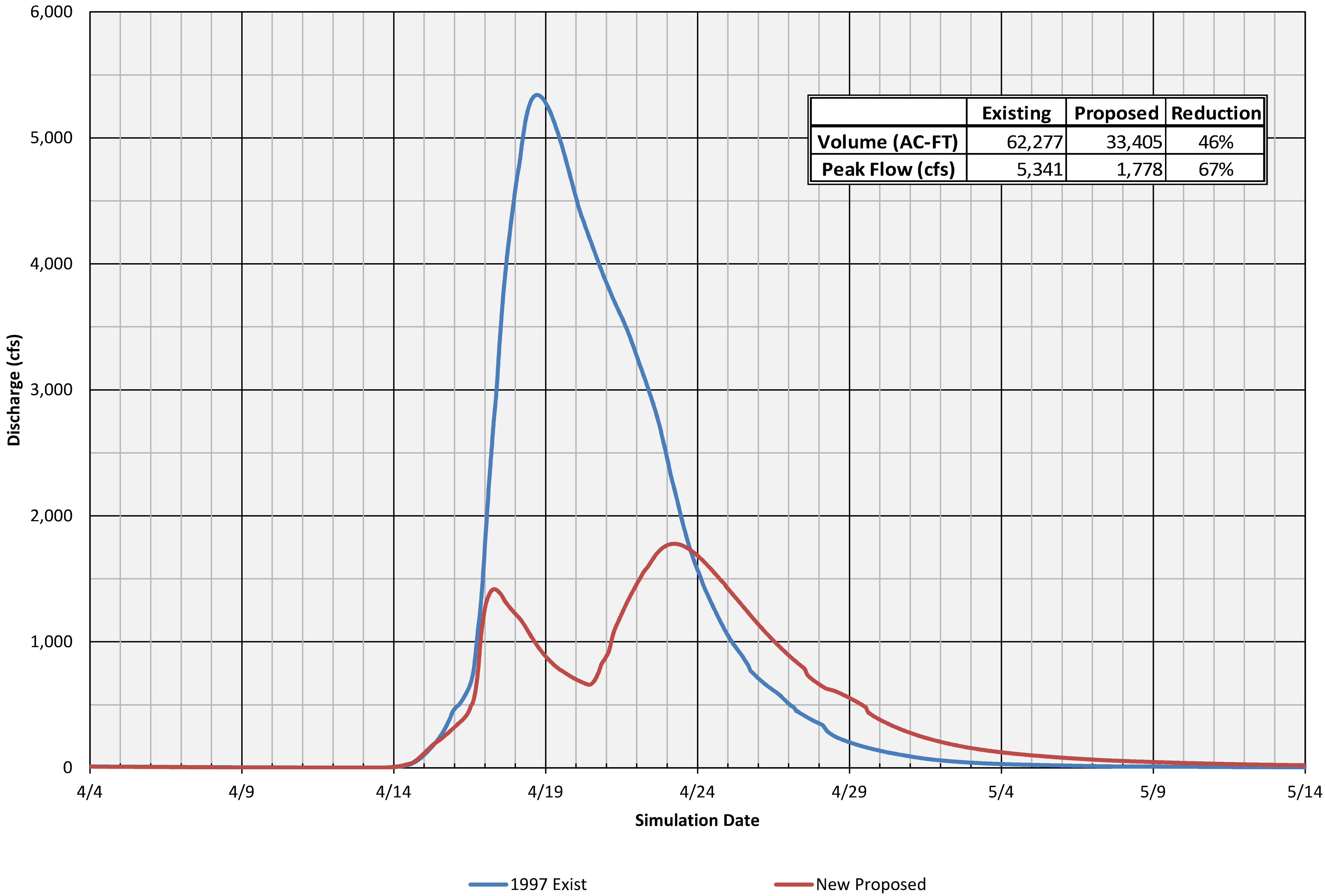
| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 51,145 | 26,278 | 49% |
| Peak Flow (cfs) | 4,434 | 1,683 | 62% |




Roseau River near County Road 9-B **- Figure 9**

# Roseau River at County Road 126

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

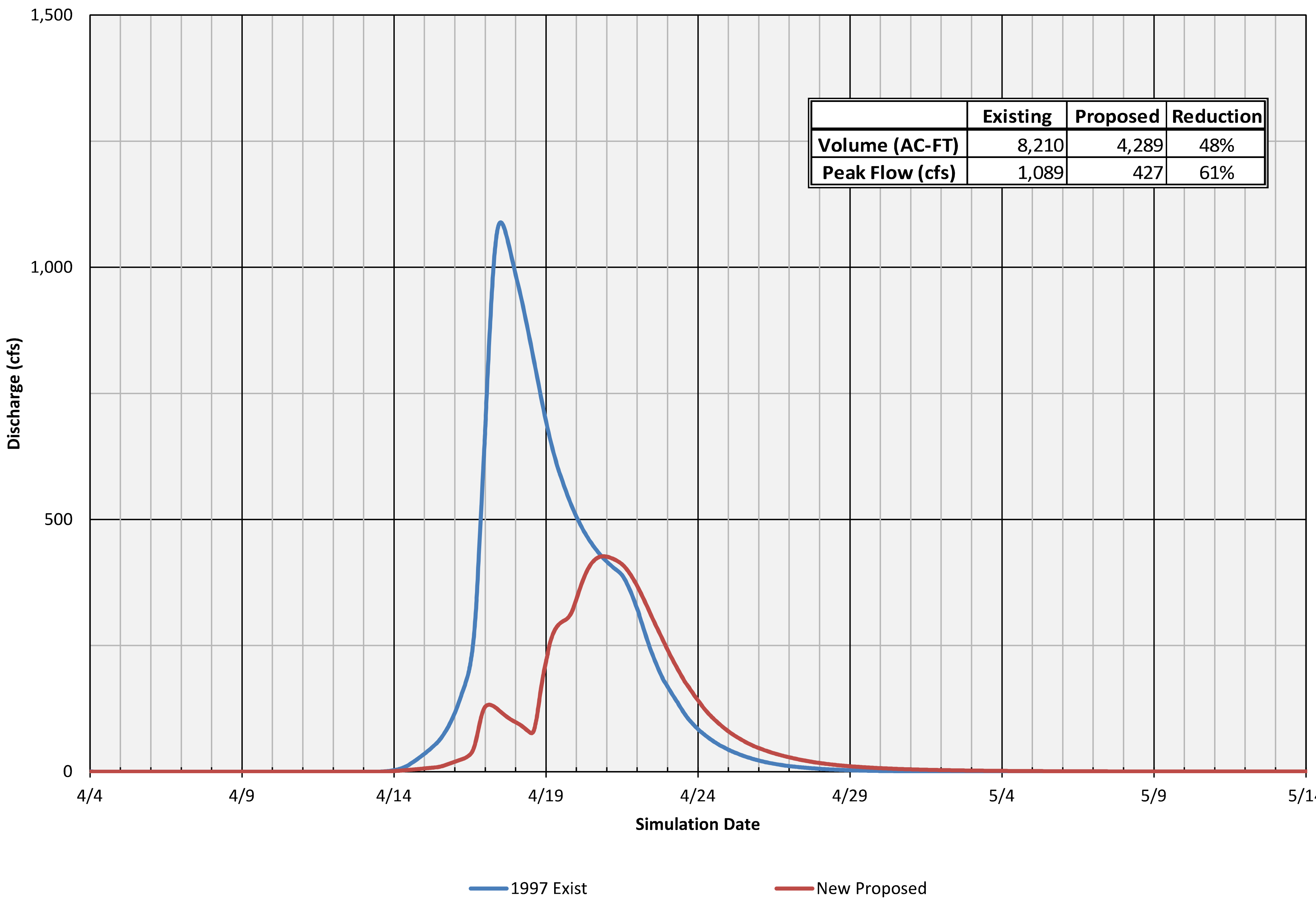



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 62,277 | 33,405 | 46% |
| **Peak Flow (cfs)** | 5,341 | 1,778 | 67% |

Roseau River at County Road 126 **- Figure10**

# Bear Creek Outlet

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

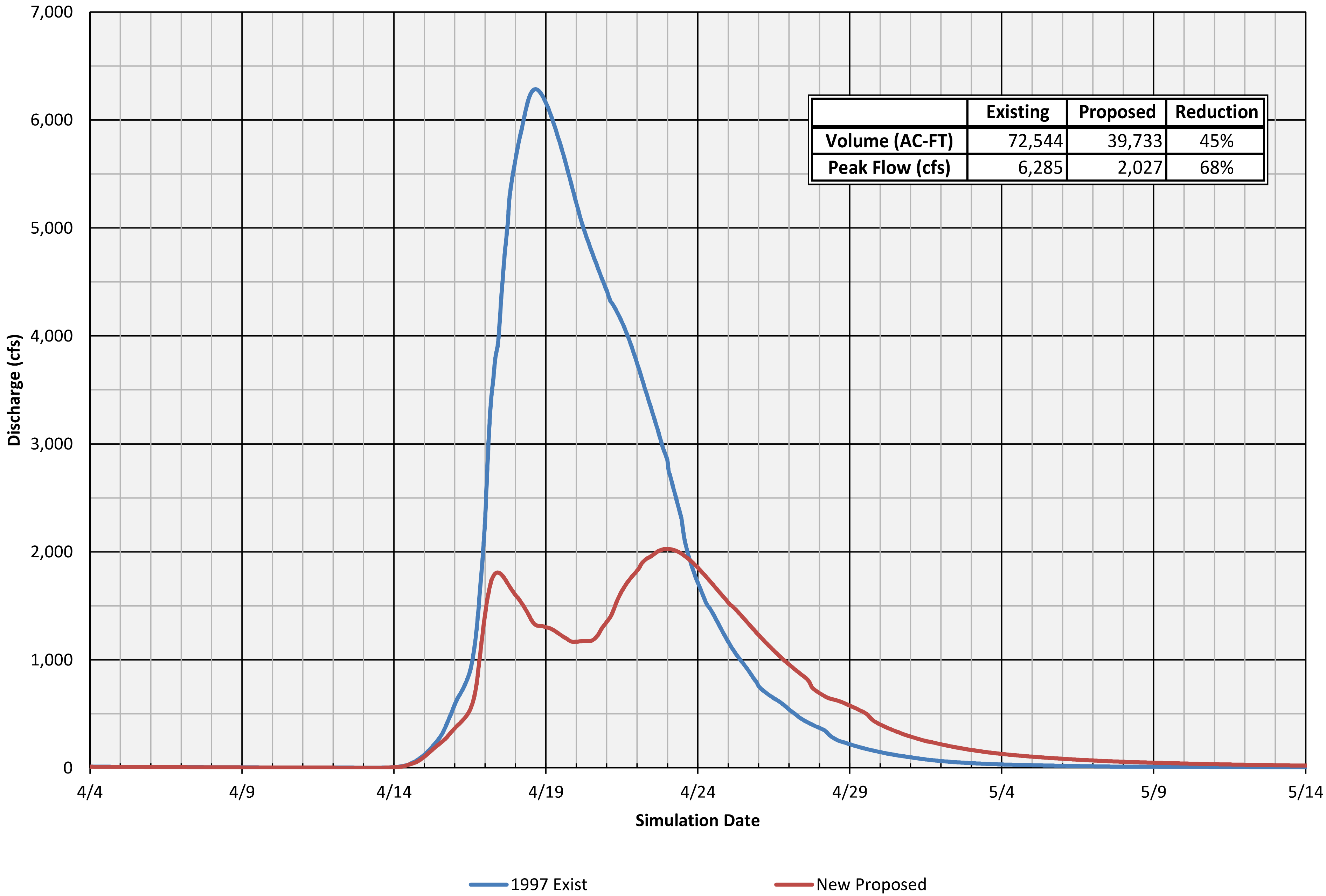



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 8,210 | 4,289 | 48% |
| **Peak Flow (cfs)** | 1,089 | 427 | 61% |

Bear Creek Outlet **- Figure 11**

# Roseau River below Bear Creek Confluence

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*



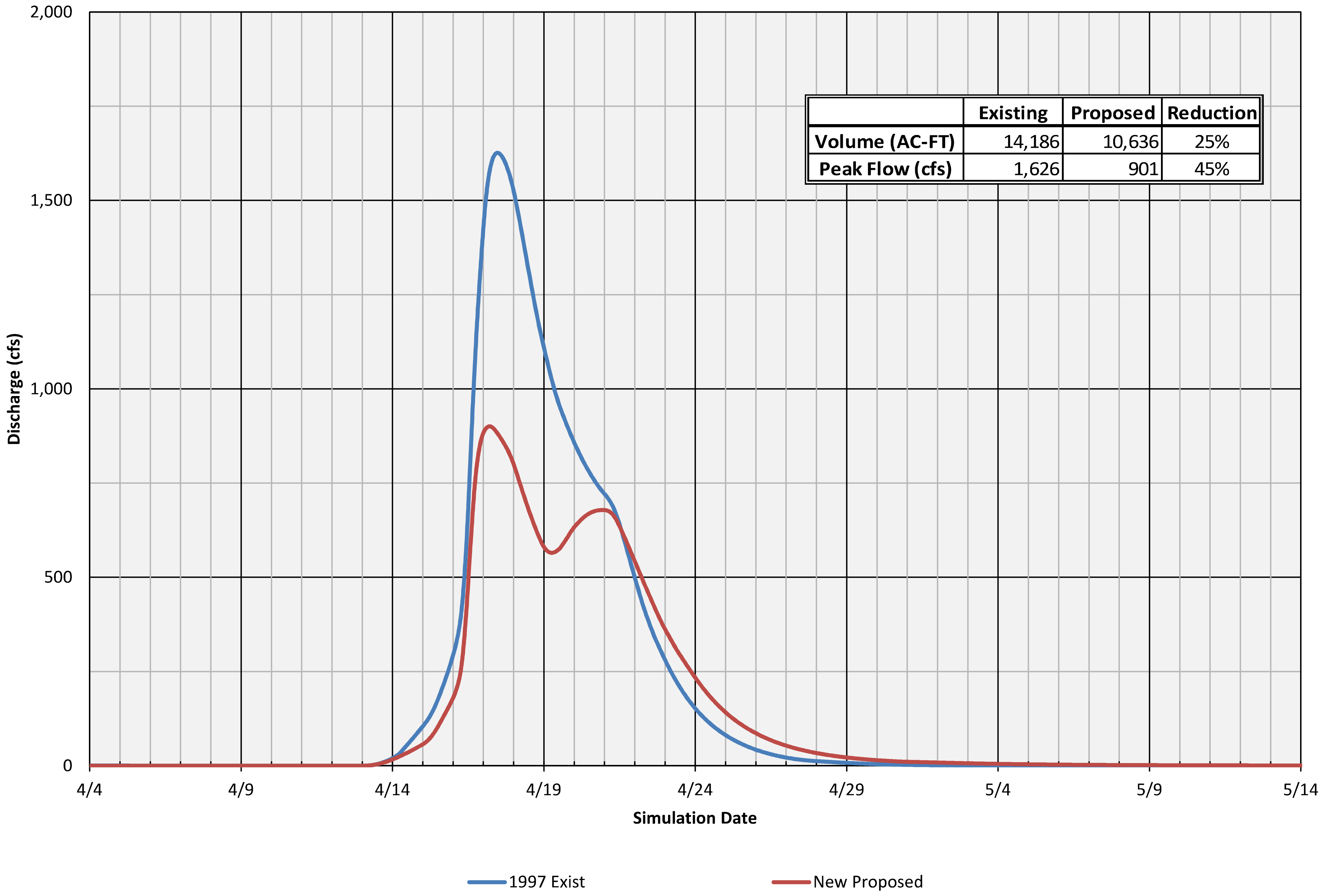

| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 72,544 | 39,733 | 45% |
| **Peak Flow (cfs)** | 6,285 | 2,027 | 68% |

Roseau River below Bear Creek Confluence **- Figure 12**

# South Fork Roseau River at County Road 12-B

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

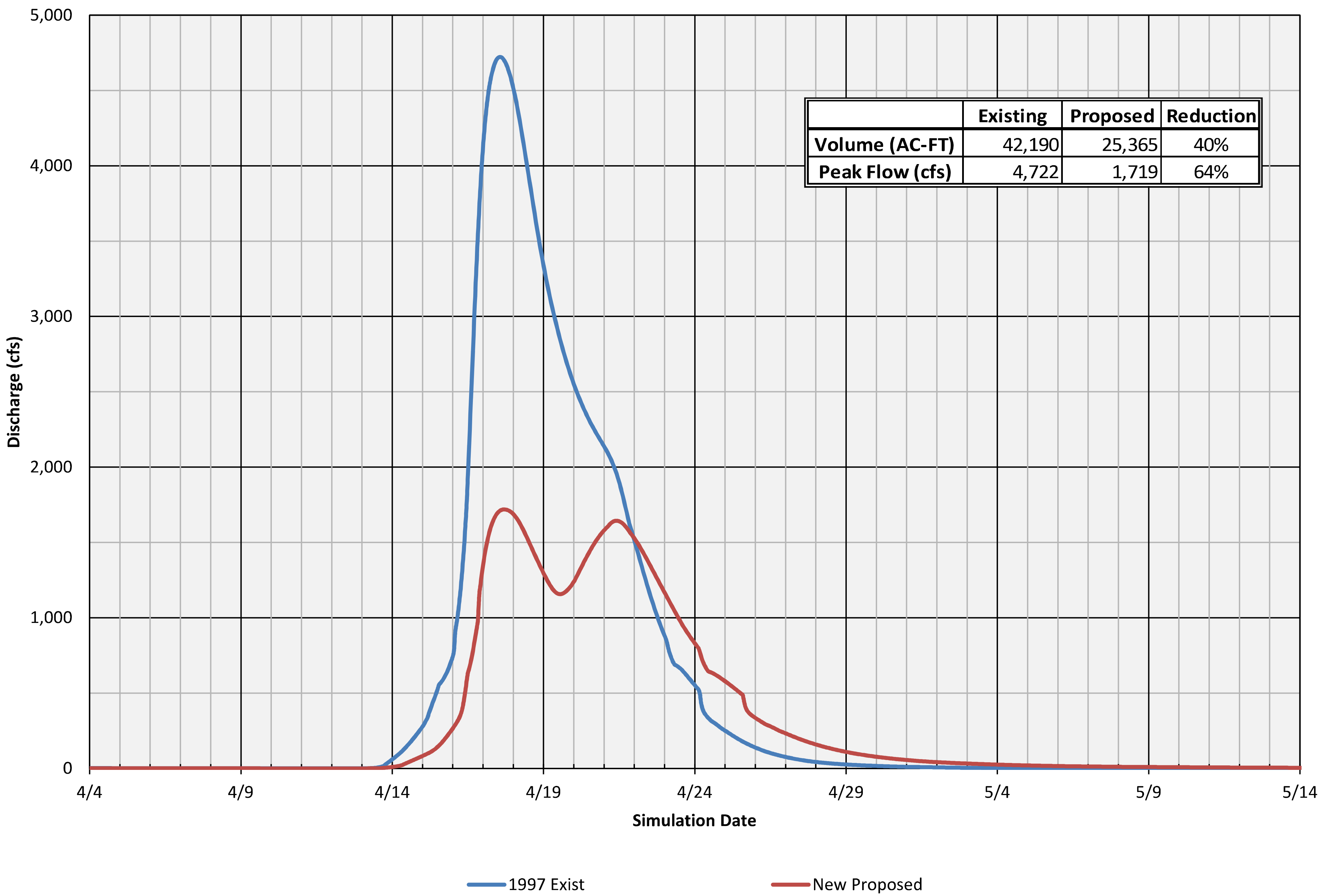
| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 14,186 | 10,636 | 25% |
| Peak Flow (cfs) | 1,626 | 901 | 45% |




South Fork Roseau River at County Road 12-B **- Figure 13**

## South Fork Roseau River near Wannaska, MN

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*



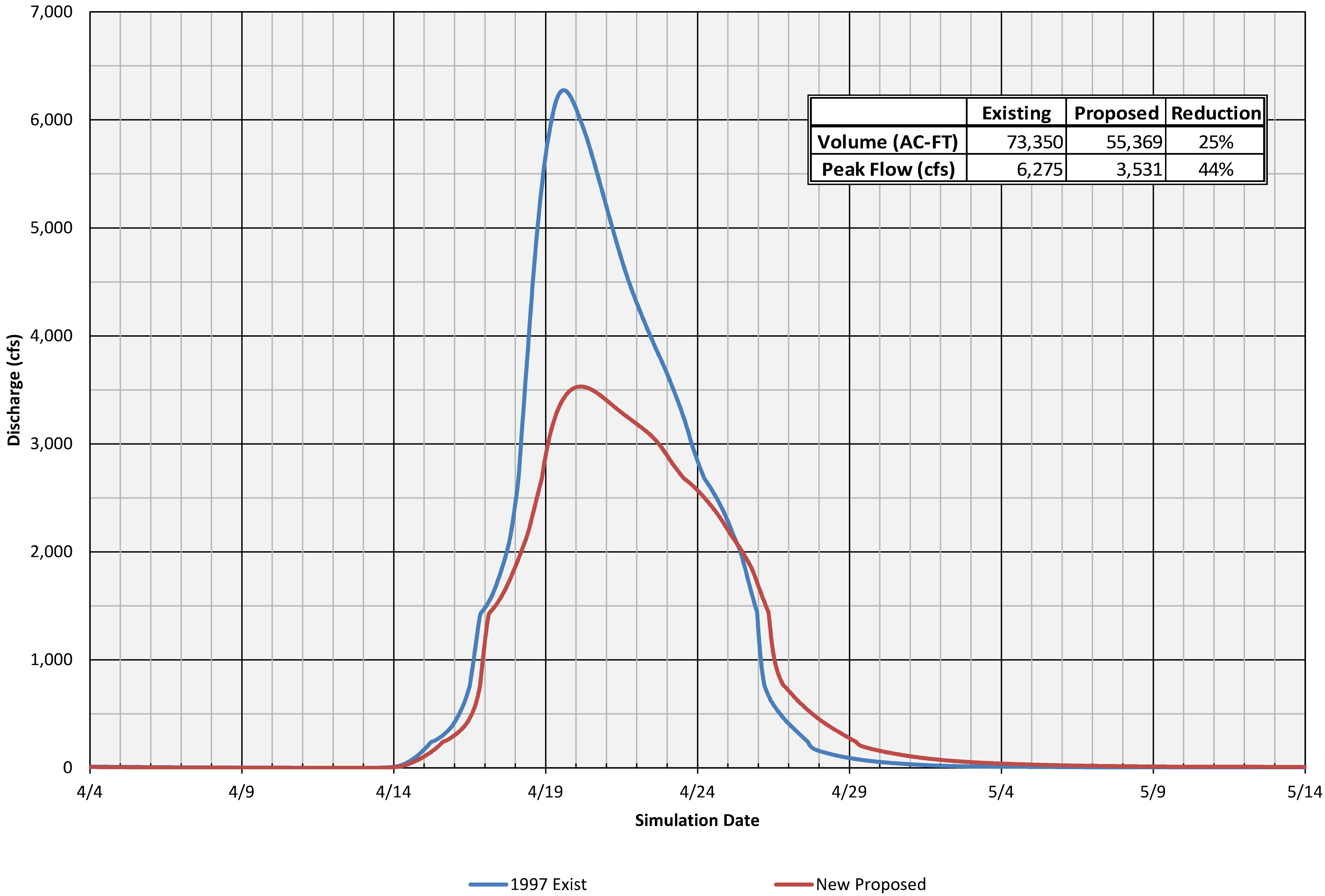

| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 42,190 | 25,365 | 40% |
| Peak Flow (cfs) | 4,722 | 1,719 | 64% |

South Fork Roseau River near Wannaska, MN **- Figure 14**

## South Fork Roseau River Outlet

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

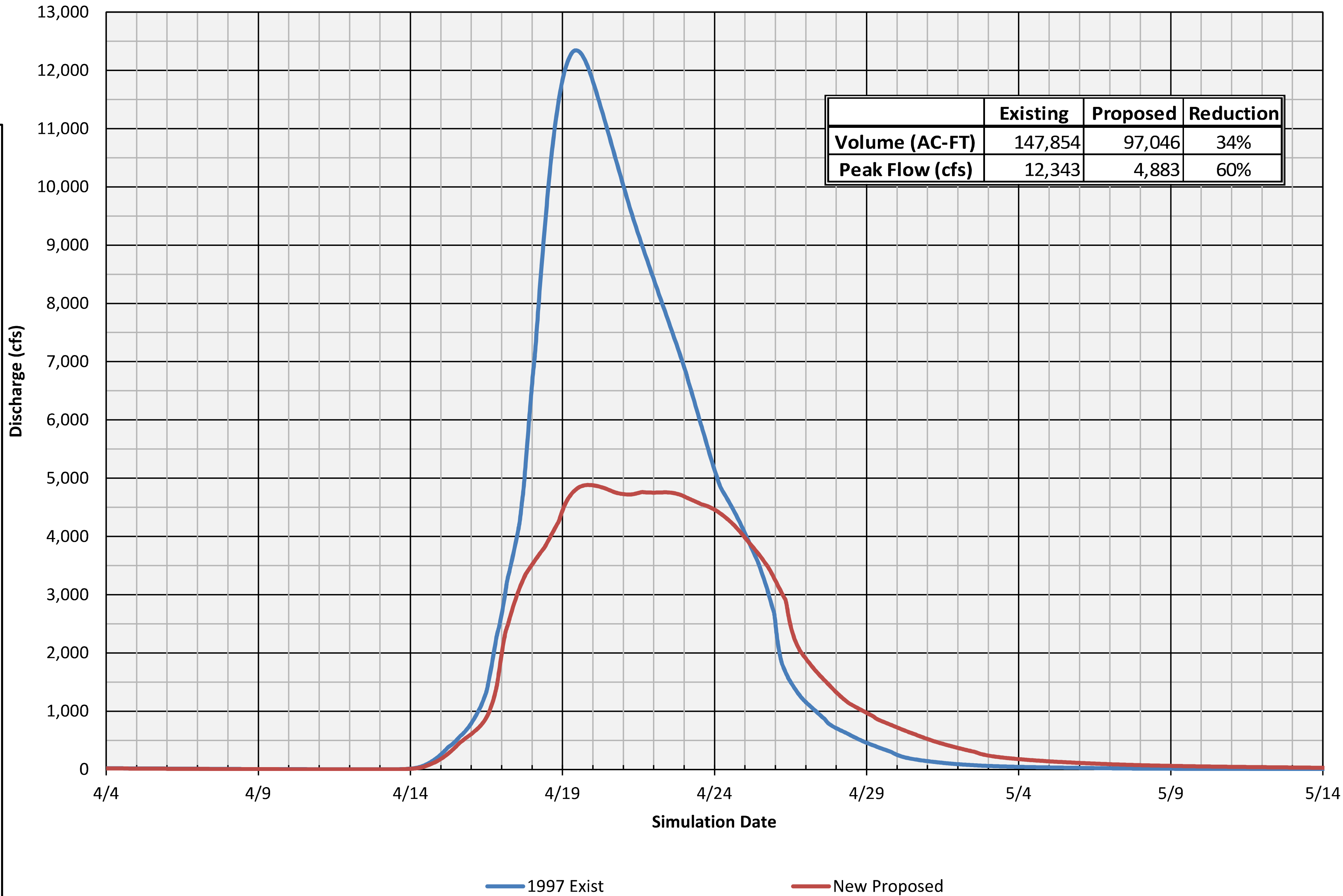
| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 73,350 | 55,369 | 25% |
| Peak Flow (cfs) | 6,275 | 3,531 | 44% |




South Fork Roseau River Outlet **- Figure 15**

# USGS Gage 05104500 Roseau River near Malung, MN

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

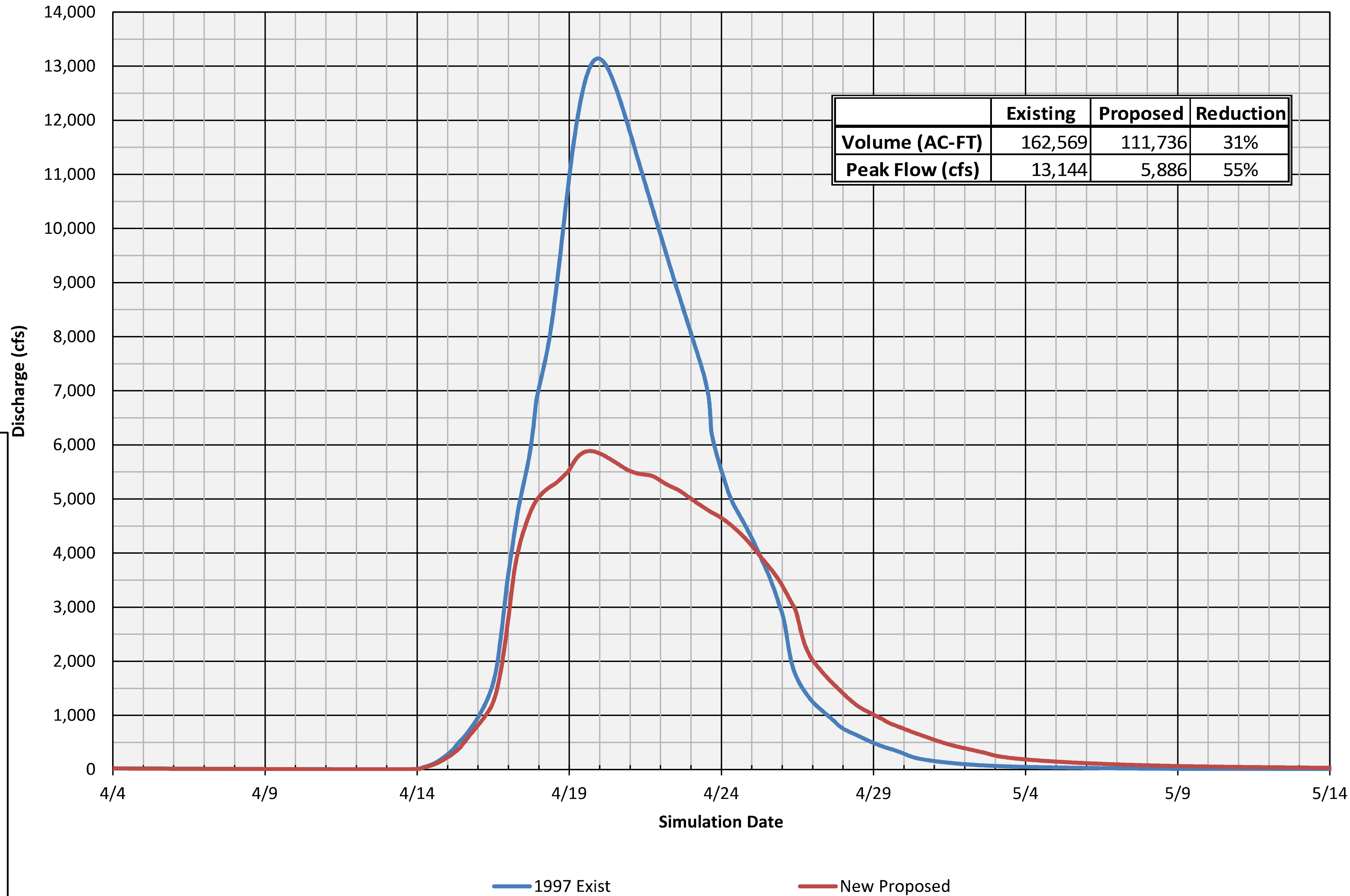



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 147,854 | 97,046 | 34% |
| **Peak Flow (cfs)** | 12,343 | 4,883 | 60% |

USGS Gage 05104500 Roseau River near Malung, MN **- Figure 16**

# Roseau River at Roseau, MN

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

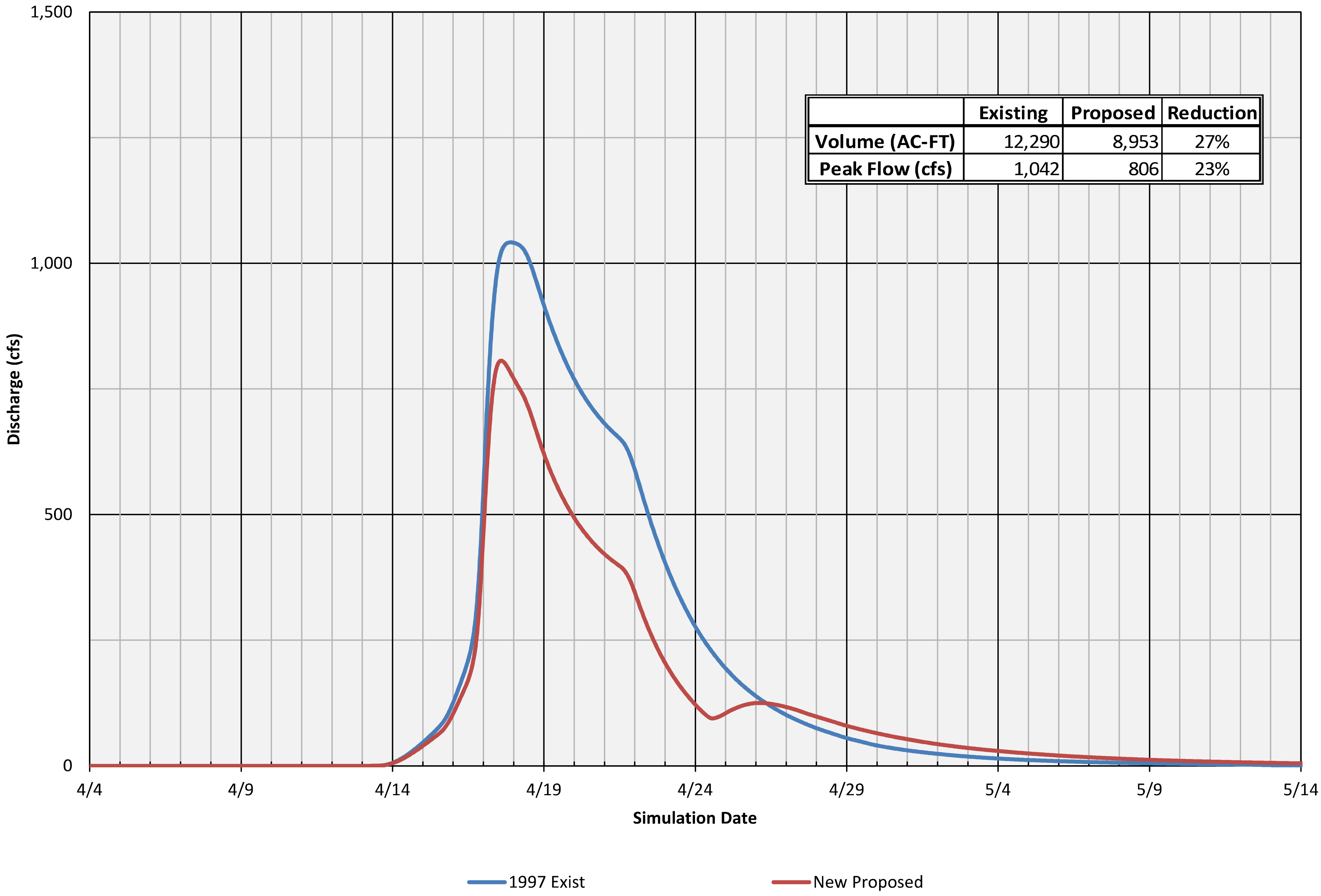



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 162,569 | 111,736 | 31% |
| **Peak Flow (cfs)** | 13,144 | 5,886 | 55% |

Roseau River at Roseau, MN **- Figure 17**

# Hay Creek near County Road 12-B

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

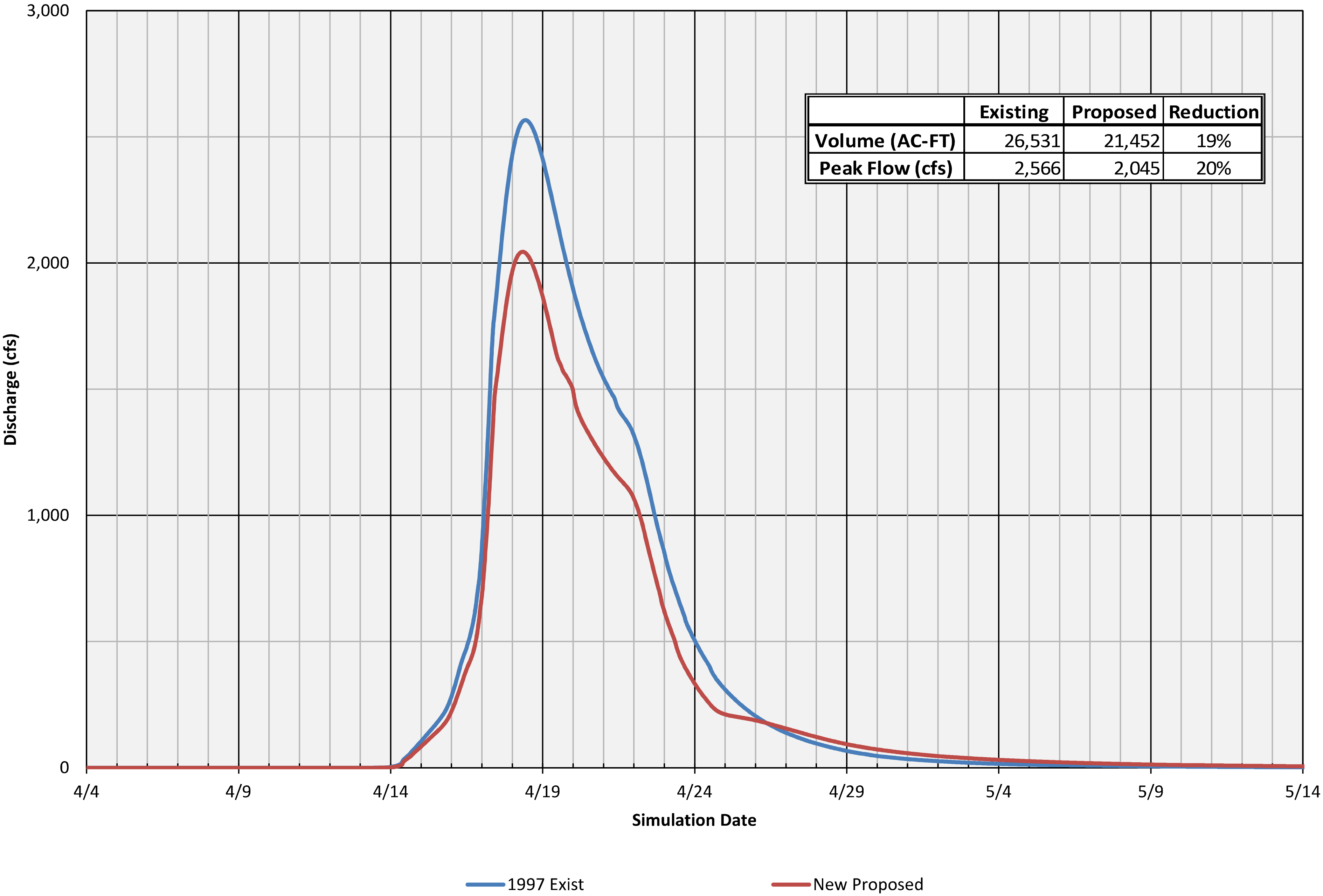



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (AC-FT)** | 12,290 | 8,953 | 27% |
| **Peak Flow (cfs)** | 1,042 | 806 | 23% |

Hay Creek near County Road 12-B **- Figure 18**

# Hay Creek at MN Highway 11

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

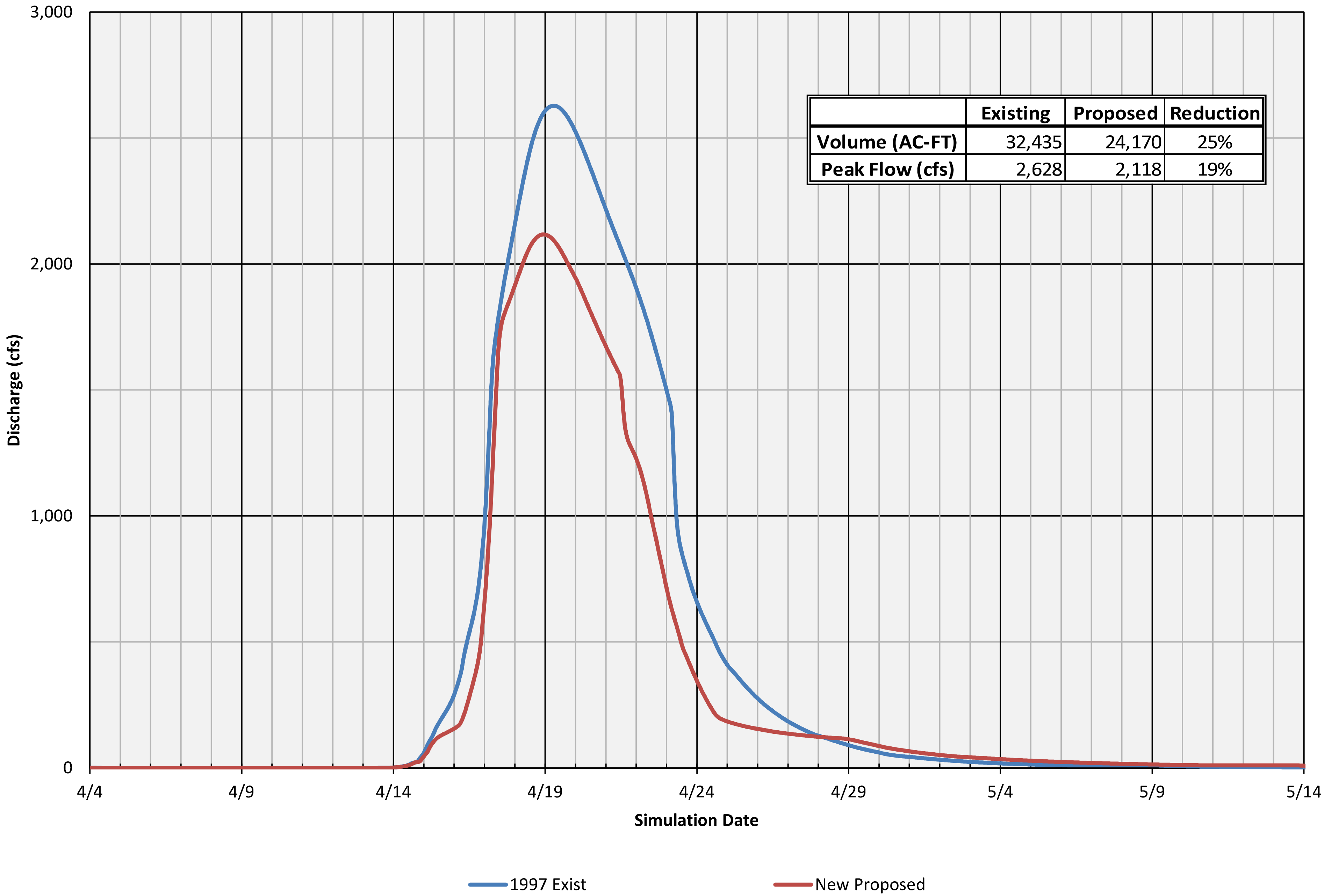



| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 26,531 | 21,452 | 19% |
| Peak Flow (cfs) | 2,566 | 2,045 | 20% |

Hay Creek at MN Highway 11 **- Figure 19**

# Hay Creek Outlet

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*



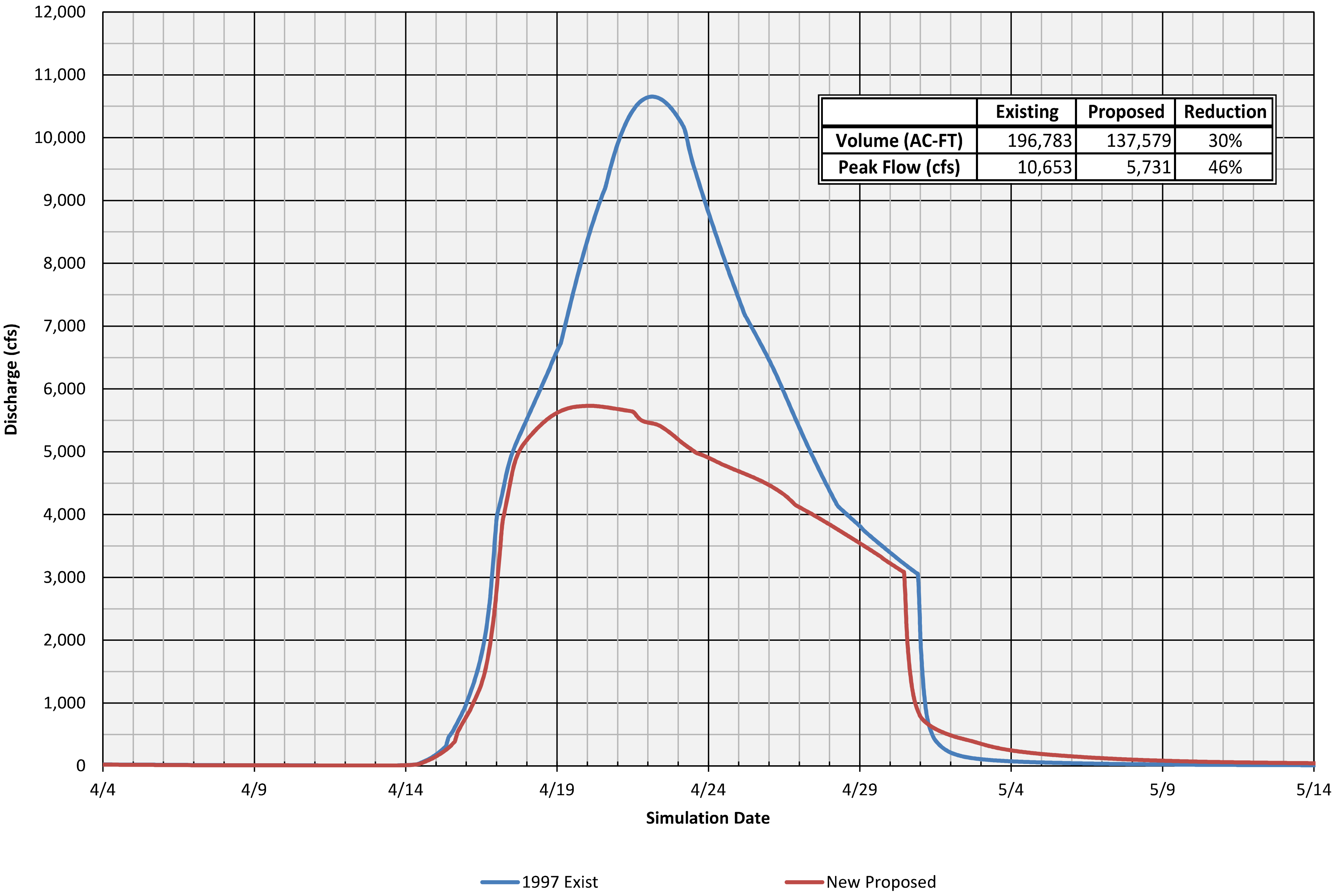

| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 32,435 | 24,170 | 25% |
| Peak Flow (cfs) | 2,628 | 2,118 | 19% |

Hay Creek Outlet **- Figure 20**

# Roseau River below Hay Creek Confluence near County Road 28-B

*Red River Basin Standardized Melt Progression*
*TR60 100-yr, 10-day Runoff Depths*

| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (AC-FT) | 196,783 | 137,579 | 30% |
| Peak Flow (cfs) | 10,653 | 5,731 | 46% |




Roseau River below Hay Creek Confluence near County Road 28-B **- Figure 21**

# Lower Roseau River Watershed Tables

| TABLE 5.<br>CURRENT CONDITIONS FLOOD WATER DETENTION LOCATION STATISTICS<br>*Red River Basin Standardized Melt Progression Event* | | |
|---|---|---|
| **Site Name** | **Drainage Area ($Mi^2$)*** | **Total Modeled Runoff Volume*** |
| ***Impoundment Locations Constructed Before the 1997 Spring Flood Event*** | | |
| Roseau River WMA Pool #1E | 2.7 $Mi^2$ | 303 Ac-ft. (2.1”) |
| Roseau River WMA Pool #1W | 77.2 $Mi^2$ | 6,749 Ac-ft. (1.6”) |
| Roseau River WMA Pool #2 | 179.9 $Mi^2$ | 16,695 Ac-ft. (1.7”) |
| Roseau River WMA Pool #3 | 202.2 $Mi^2$ | 21,886 Ac-ft. (2.0”) |
| Subtotal *(Pre-1997)* | 204.9 $Mi^2$** | 45,633 Ac-ft. (4.2”) |
| ***Impoundment Locations Constructed After the 1997 Spring Flood Event*** | | |
| Norland Impoundment | 107.8 $Mi^2$ | 10,299 Ac-ft. (1.8”) |
| Subtotal *(Post-1997)* | 107.8 $Mi^2$ | 10,299 Ac-ft. (1.8”) |
| **Total *(Current Conditions)*** | **312.7 $Mi^2$** | **55,932 Ac-ft. (3.4”)** |

*Data from USACE HEC-HMS model inputs

** Drainage Area inclusive of upstream detention location drainage areas. Drainage area subtotals or totals may not match the sum due to being upstream of, and within the same drainage area of other identified sites.

| TABLE 6.<br>IDENTIFIED FLOOD WATER DETENTION LOCATION STATISTICS<br>*Red River Basin Standardized Melt Progression Event* | | |
|---|---|---|
| **Site Name** | **Modeled Drainage Area ($Mi^2$)*** | **Total Modeled Runoff Volume (Ac-ft.)** |
| ***Identified Future Detention Locations within Lower Roseau River Watershed*** | | |
| LRR_01 | 24.2 | 13,600 (10.5”) |
| LRR_02 | 45.7 | 7,985 (3.3”) |
| LRR_03 | 65.2 | 10,465 (3.0”) |
| LRR_04 | 322.3 | 7,785 (0.5”) |
| LRR_05 | 17.1 | 4,275 (4.7”) |
| LRR_06 | 18.6 | 3,475 (3.5”) |
| LRR_07 | 5.1 | 2,950 (10.9”) |
| LRR_08 | 10.7 | 2,285 (4.0”) |
| LRR_09 | 9.8 | 7,455 (14.3”) |
| LRR_10 | 5.1 | 4,055 (14.9”) |
| Subtotal (Identified Detention within Lower Roseau River Watershed) | 388.7* | 64,330 (3.1”) |
| Subtotal (Identified and Post-1997)** | 496.5 | 74,630 (2.8”) |
| **Total (Identified, Pre-1997, and Post-1997)**** | **701.4** | **120,260 (3.2”)** |
| ***Identified Future Mainstem Detention Locations within Lower Roseau River Watershed*** | | |
| LRR_11 | 1077.1 | 168,800 (2.9”) |
| Subtotal (Identified, Identified Mainstem, and Post-1997)** | 1107.8 | 243,430 (4.1”) |
| **Total (Identified, Identified Main Stem, Pre-1997, and Post-1997)** | **1312.7** | **289,060 (4.1”)** |
| *Drainage Area inclusive of upstream detention location drainage areas. Drainage area subtotals or totals may not match the sum due to being upstream of, and within the same drainage area of other identified sites.<br>**Existing Storage statistics summarized in Table 5. | | |

**TABLE 7.**
**FLOOD WATER DETENTION LOCATION STATISTICS**
*Red River Basin Standardized Melt Progression Event*

| Site Name | | Drainage Area ($mi^2$)* | Peak Inflow (cfs) | Peak Outflow (cfs) | Peak Flow Reduction | Inflow Volume (AC-FT)** | Outflow Volume (AC-FT)** | Volume Reduction |
|---|---|---|---|---|---|---|---|---|
| ***Existing Impoundment Locations Constructed Before the 1997 Spring Flood Event*** | | | | | | | | |
| Roseau River WMA Pool #1E | | 2.7 | 182 | 96 | 47% | 1,161 | 1,151 | 1% |
| Roseau River WMA Pool #1W | | 77.2 | 680 | 330 | 52% | 10,329 | 9,650 | 7% |
| Roseau River WMA Pool #2 | | 179.9 | 1,873 | 1,707 | 9% | 44,235 | 35,707 | 19% |
| Roseau River WMA Pool #3 | | 202.2 | 1,240 | 413 | 67% | 43,574 | 31,516 | 28% |
| Subtotal *(Pre-1997)* | | 204.9 | | | | 99,298 | 78,024 | 21% |
| ***Impoundment Locations Constructed After the 1997 Spring Flood Event*** | | | | | | | | |
| Norland Impoundment | | 107.8 | 856.1 | 62 | 93% | 10,649 | 963 | 91% |
| Subtotal *(Post-1997)* | | 312.7 | | | | 109,948 | 78,987 | 39% |
| ***Identified Future Detention Locations within Lower Roseau River Watershed*** | | | | | | | | |
| **Site Name** | **Year Implemented** | **Drainage Area ($mi^2$)*** | **Peak Inflow (cfs)** | **Peak Outflow (cfs)** | **Peak Flow Reduction** | **Inflow Volume (AC-FT)**** | **Outflow Volume (AC-FT)**** | **Volume Reduction** |
| LRR_01 | Proposed | 24.2 | 818 | 333 | 59% | 9,167 | 5,141 | 44% |
| LRR_02 | Proposed | 45.7 | 679 | 679 | 0% | 11,966 | 8,758 | 27% |
| LRR_03 | Proposed | 65.2 | 1,069 | 656 | 39% | 19,140 | 13,058 | 32% |
| LRR_04 | Proposed | 322.3 | 4,628 | 4,628 | 0% | 85,844 | 81,718 | 5% |
| LRR_05 | Proposed | 17.1 | 1,075 | 1,074 | 0% | 18,962 | 16,909 | 11% |
| LRR_06 | Proposed | 18.6 | 530 | 509 | 4% | 5,406 | 3,962 | 27% |
| LRR_07 | Proposed | 5.1 | 321 | 0 | 100% | 1,601 | 0 | 100% |
| LRR_08 | Proposed | 10.7 | 405 | 390 | 4% | 3,612 | 2,871 | 21% |
| LRR_09 | Proposed | 9.8 | 404 | 0 | 100% | 3,404 | 0 | 100% |
| LRR_10 | Proposed | 5.1 | 300 | 72 | 76% | 1,842 | 571 | 69% |
| Subtotal *(Identified Detention Sites within Lower Roseau River Watershed)* | | 388.7 | | | | 160,944 | 132,988 | 17% |
| Subtotal (*Identified and Post-1997)* | | 496.5 | | | | 171,593 | 133,951 | 22% |
| Total *(Identified, Pre-1997, and Post-1997)* | | 701.4 | | | | 270,892 | 211,975 | 22% |
| ***Identified Future Mainstem Detention Locations within Lower Roseau River Watershed*** | | | | | | | | |
| LRR_11 | Proposed | 1077.1 | 11,300 | 6,019 | 47% | 285,031 | 198,527 | 30% |
| **Subtotal *(Identified, Identified Mainstem, and Post-1997)*** | | **1107.8** | | | | **456,624** | **332,478** | **27%** |
| **Total *(Identified, Identified Mainstem, Pre-1997, and Post-1997)*** | | **1312.7** | | | | **555,923** | **410,502** | **26%** |

*Drainage Area inclusive of upstream detention location drainage areas. Drainage area subtotals or totals may not match the sum due to being upstream of, and within the same drainage area of other identified sites.
**Volume based on 100-year 10-day Melt Progression Event duration of 75 days

| TABLE 8. PERFORMANCE STATISTICS AT MONITORING LOCATIONS WITH MAINSTEM DETENTION LOCATION | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Red River Basin Standardized Melt Progression Event* | | | | | | | |
| **Location** | **Contributing Drainage Area (mi$^2$)** | **Existing Conditions** | | **Proposed Conditions** | | **Percent Reductions** | |
| | | **Peak Flow (cfs)** | **Volume (ac-ft.)*** | **Peak Flow (cfs)** | **Volume (ac-ft.)*** | **Peak Flow** | **Volume** |
| Sprague Creek at Hwy 310 | 332.6 | 6,346 | 111,930 | 4,933 | 88,096 | 22% | 21% |
| Roseau River below Sprague Creek outlet | 978.4 | 17,055 | 325,391 | 11,237 | 246,676 | 34% | 24% |
| Pine Creek outlet to Roseau River | 77.3 | 838 | 20,305 | 730 | 18,244 | 13% | 10% |
| USGS Gage 05107500 Roseau River at Ross, MN | 1,085.2 | 9,959 | 372,601 | 6,024 | 202,290 | 40% | 46% |
| USGS Gage 05112000 Roseau River below State Ditch 51 nr Caribou, MN | 1,449.0 | 3,156 | 206,422 | 2,048 | 141,209 | 35% | 32% |
| Roseau River at International Border | 1,471.1 | 5,704 | 366,999 | 3,644 | 248,975 | **36%** | **32%** |

*Volume based on 100-year 10-day Melt Progression Event model duration of 75 days

# Lower Roseau River Watershed Figures

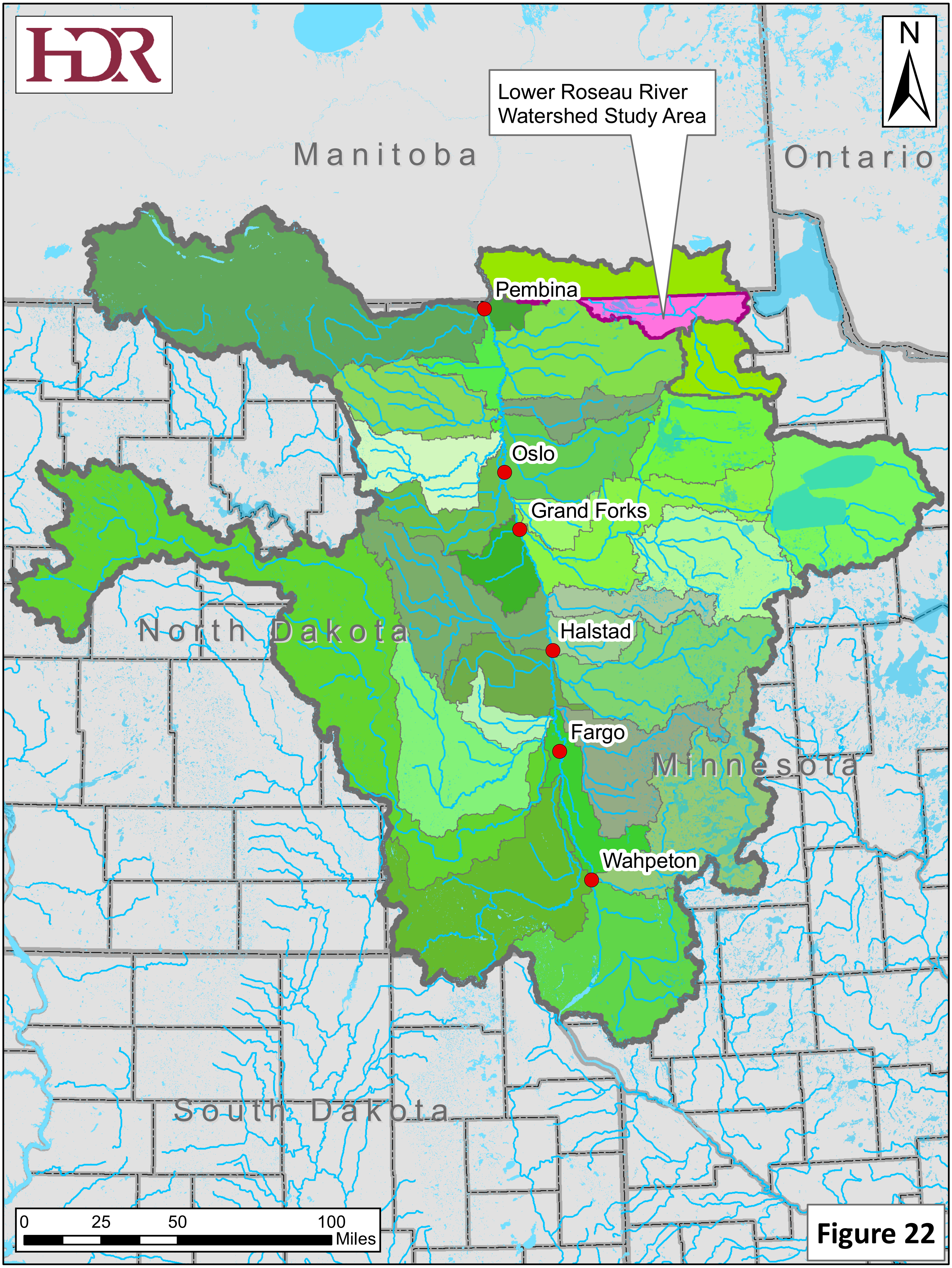
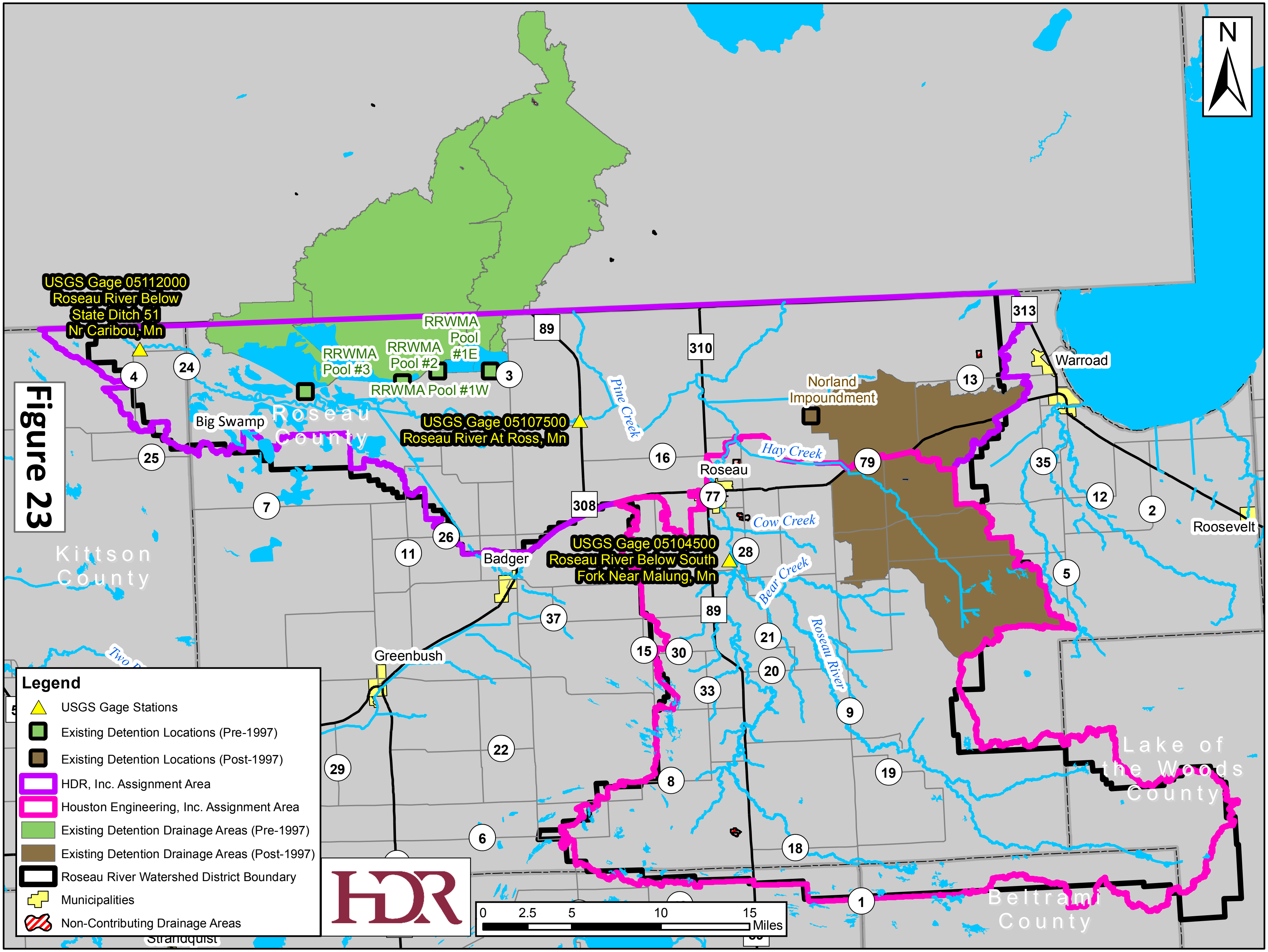

HDR
N
Lower Roseau River Watershed Study Area
Manitoba
Ontario
Pembina
Oslo
Grand Forks
North Dakota
Halstad
Fargo
Minnesota
Wahpeton
South Dakota
0 25 50 100 Miles

Figure 22



N
USGS Gage 05112000
Roseau River Below
State Ditch 51
Nr Caribou, Mn
RRWMA
Pool
#1E
RRWMA
Pool #2
RRWMA
Pool #3
RRWMA Pool #1W
Big Swamp
Roseau
County
USGS Gage 05107500
Roseau River At Ross, Mn
Pine Creek
Norland
Impoundment
Hay Creek
Roseau
Cow Creek
Warroad
Roosevelt
USGS Gage 05104500
Roseau River Below South
Fork Near Malung, Mn
Bear Creek
Roseau River
Badger
Greenbush
Kittson
County
Lake of
the Woods
County
Beltrami
County
89
310
313
308
77
79
1
2
3
4
5
6
7
8
9
11
12
13
15
16
18
19
20
21
22
24
25
26
28
29
30
33
35
37
Legend
USGS Gage Stations
Existing Detention Locations (Pre-1997)
Existing Detention Locations (Post-1997)
HDR, Inc. Assignment Area
Houston Engineering, Inc. Assignment Area
Existing Detention Drainage Areas (Pre-1997)
Existing Detention Drainage Areas (Post-1997)
Roseau River Watershed District Boundary
Municipalities
Non-Contributing Drainage Areas
HDR
0 2.5 5 10 15
Miles

Figure 23

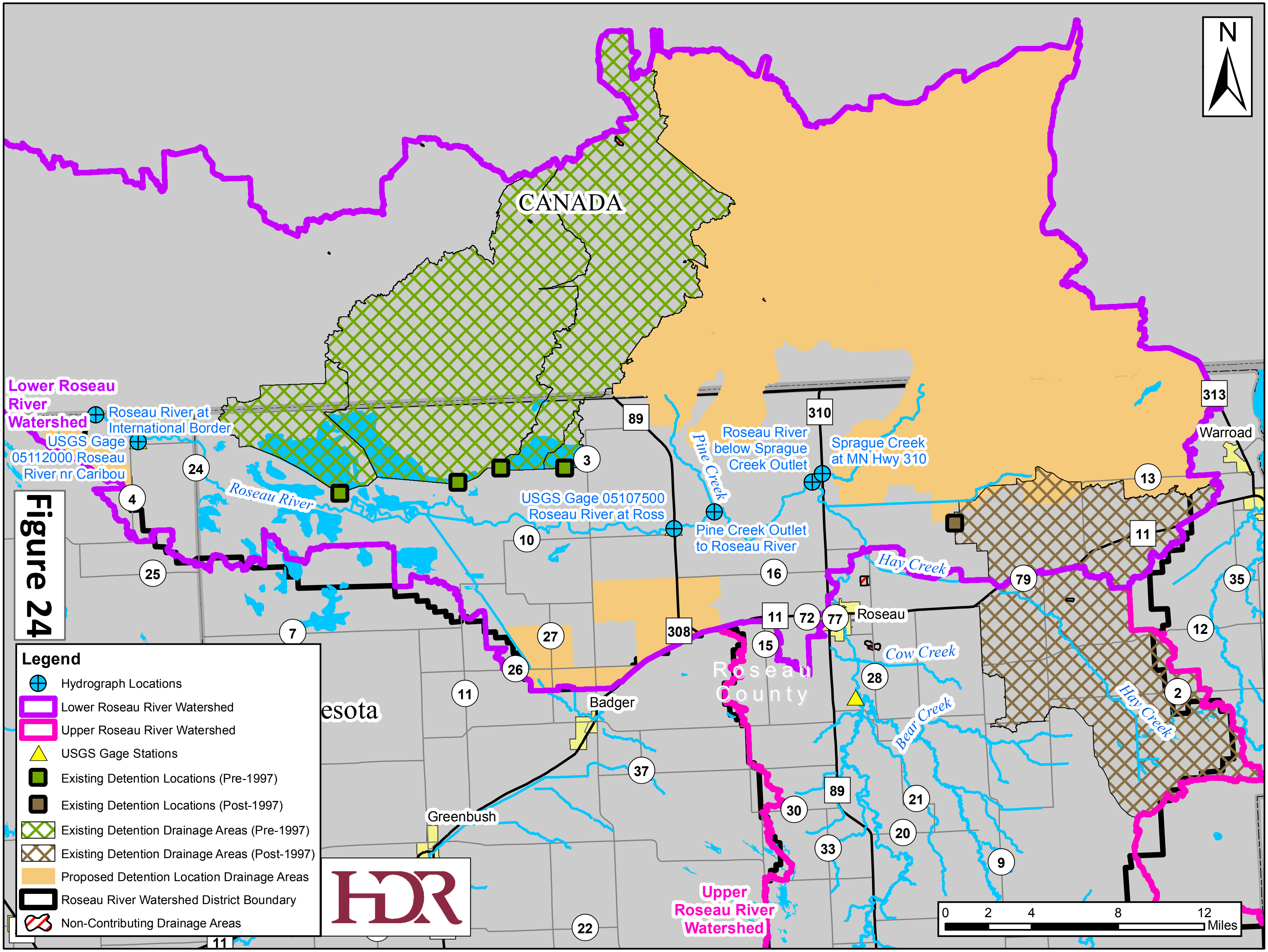
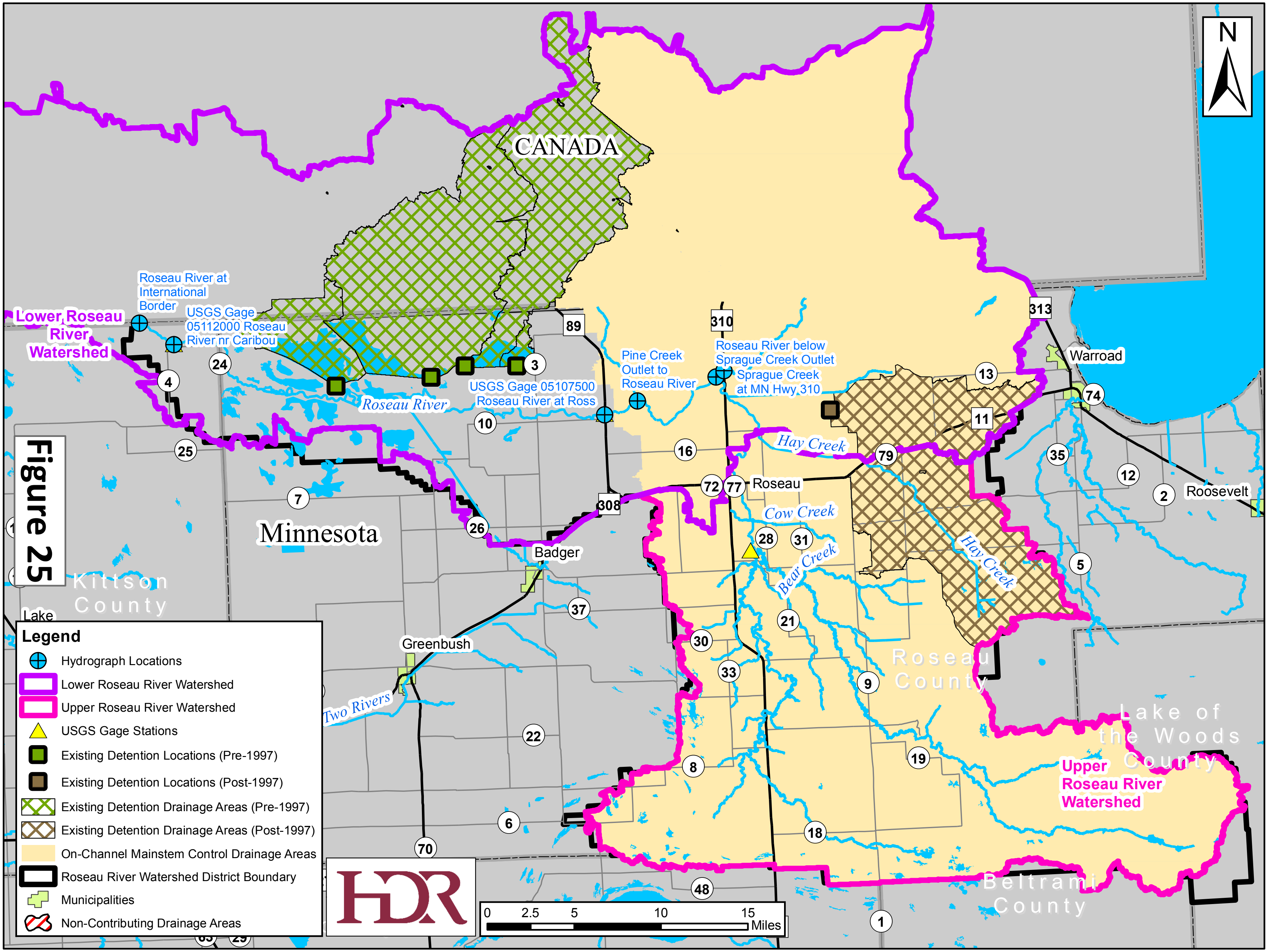
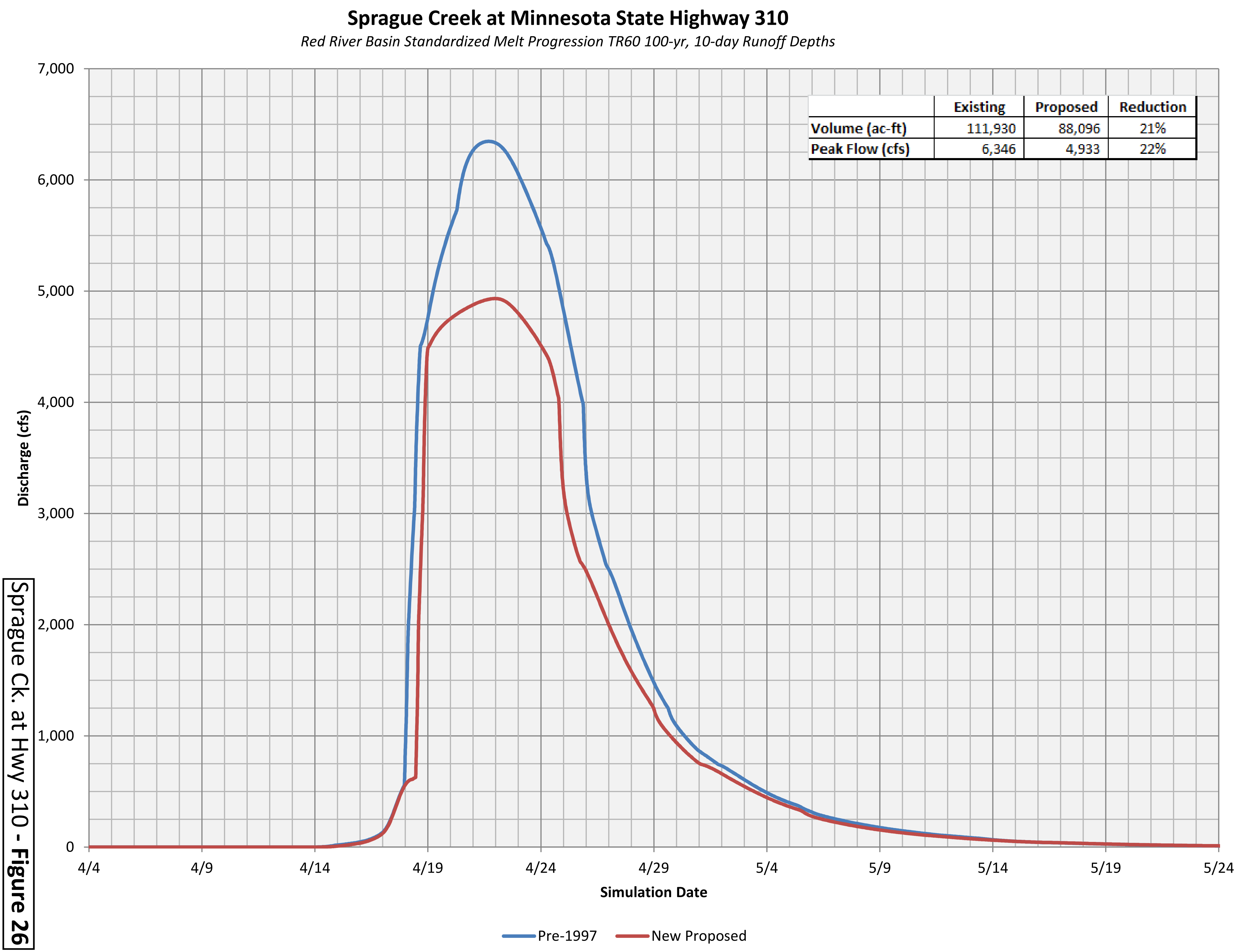


Figure 24
CANADA
Lower Roseau River Watershed
Roseau River at International Border
USGS Gage 05112000 Roseau River nr Caribou
Roseau River
USGS Gage 05107500 Roseau River at Ross
Pine Creek
Roseau River below Sprague Creek Outlet
Sprague Creek at MN Hwy 310
Pine Creek Outlet to Roseau River
Hay Creek
Cow Creek
Bear Creek
Roseau
Roseau County
Warroad
Badger
Greenbush
esota
Upper Roseau River Watershed
Legend
Hydrograph Locations
Lower Roseau River Watershed
Upper Roseau River Watershed
USGS Gage Stations
Existing Detention Locations (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Drainage Areas (Pre-1997)
Existing Detention Drainage Areas (Post-1997)
Proposed Detention Location Drainage Areas
Roseau River Watershed District Boundary
Non-Contributing Drainage Areas
HDR
N
0 2 4 8 12 Miles



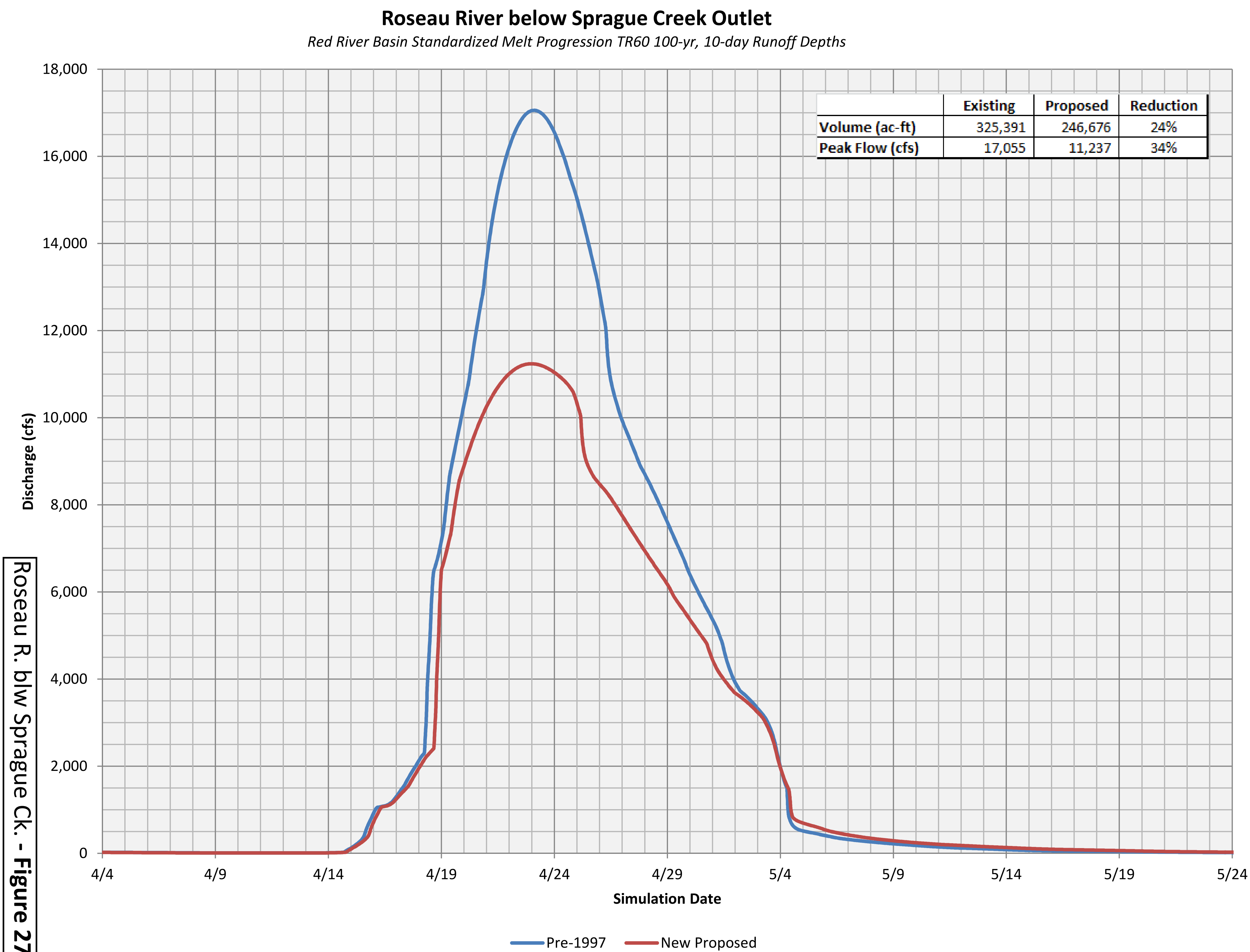
CANADA
Minnesota
Lower Roseau River Watershed
Upper Roseau River Watershed
Roseau River at International Border
USGS Gage 05112000 Roseau River nr Caribou
USGS Gage 05107500 Roseau River at Ross
Pine Creek Outlet to Roseau River
Roseau River below Sprague Creek Outlet
Sprague Creek at MN Hwy 310
Roseau River
Hay Creek
Cow Creek
Bear Creek
Two Rivers
Roseau
Warroad
Roosevelt
Badger
Greenbush
Lake
Kittson County
Roseau County
Lake of the Woods County
Beltrami County
89
310
313
308
11
72
77
Legend
Hydrograph Locations
Lower Roseau River Watershed
Upper Roseau River Watershed
USGS Gage Stations
Existing Detention Locations (Pre-1997)
Existing Detention Locations (Post-1997)
Existing Detention Drainage Areas (Pre-1997)
Existing Detention Drainage Areas (Post-1997)
On-Channel Mainstem Control Drainage Areas
Roseau River Watershed District Boundary
Municipalities
Non-Contributing Drainage Areas
HDR
0 2.5 5 10 15 Miles
N


Figure 25

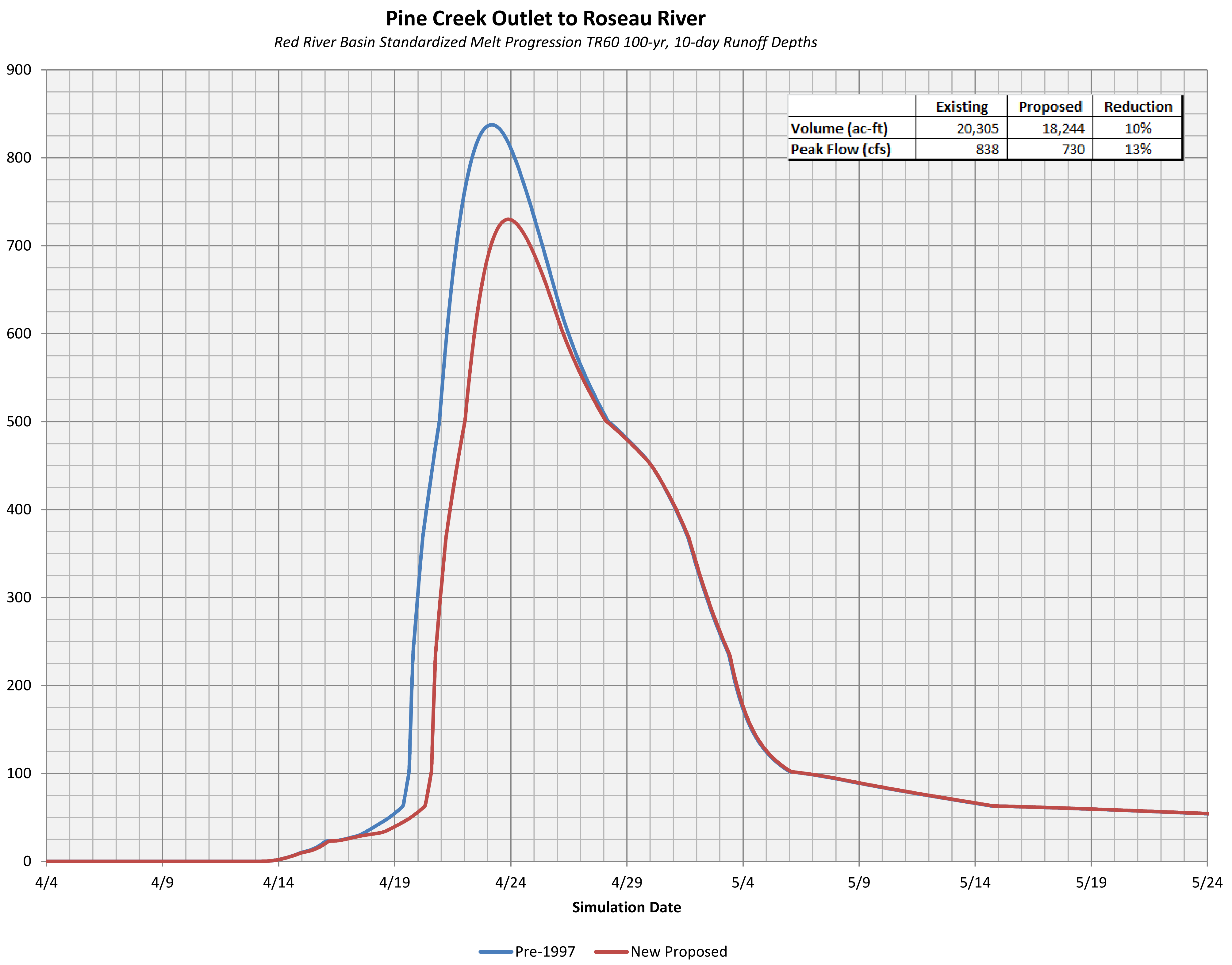



| | Existing | Proposed | Reduction |
|---|---|---|---|
| **Volume (ac-ft)** | 111,930 | 88,096 | 21% |
| **Peak Flow (cfs)** | 6,346 | 4,933 | 22% |

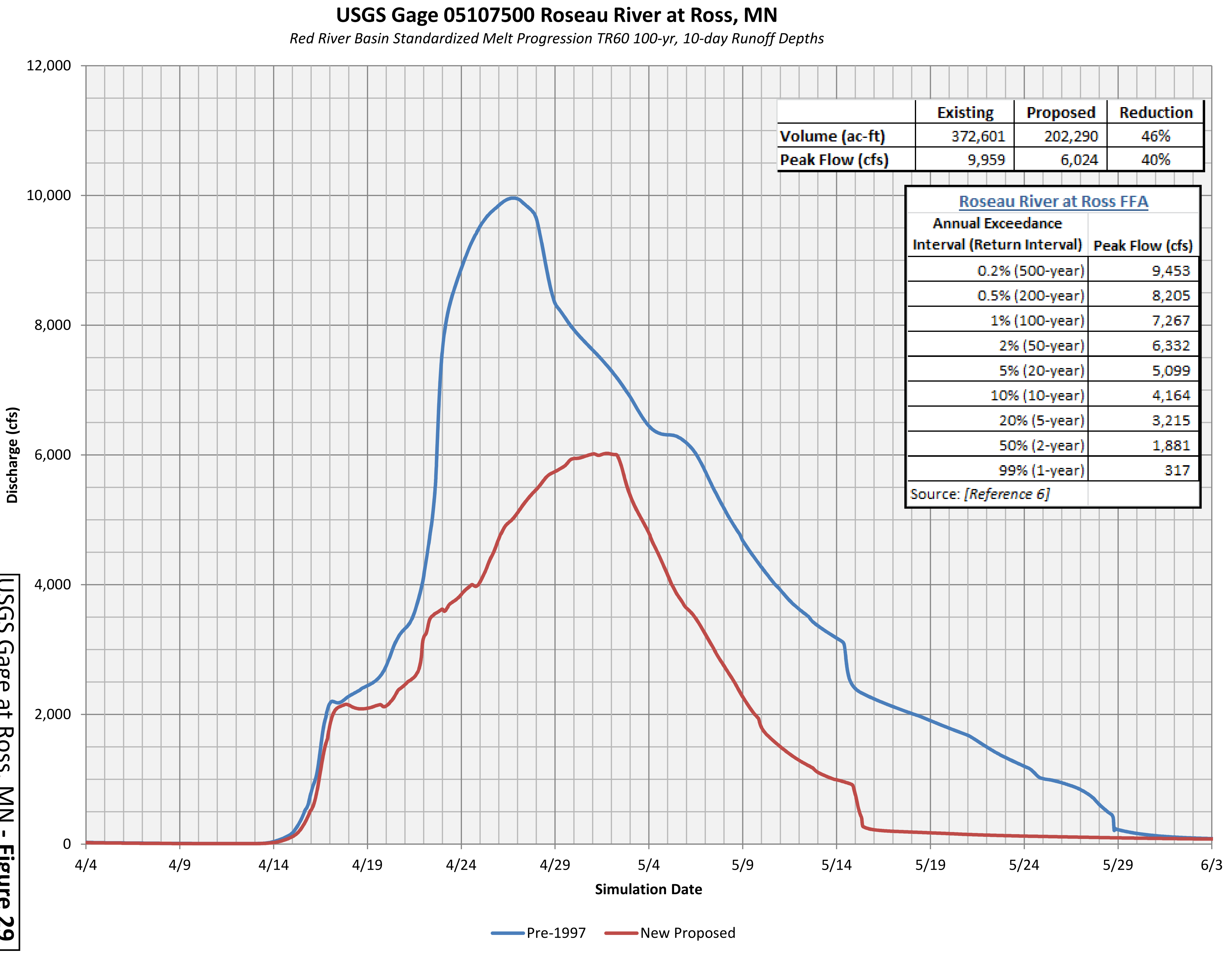
Sprague Ck. at Hwy 310 - **Figure 26**




Roseau R. blw Sprague Ck. - **Figure 27**



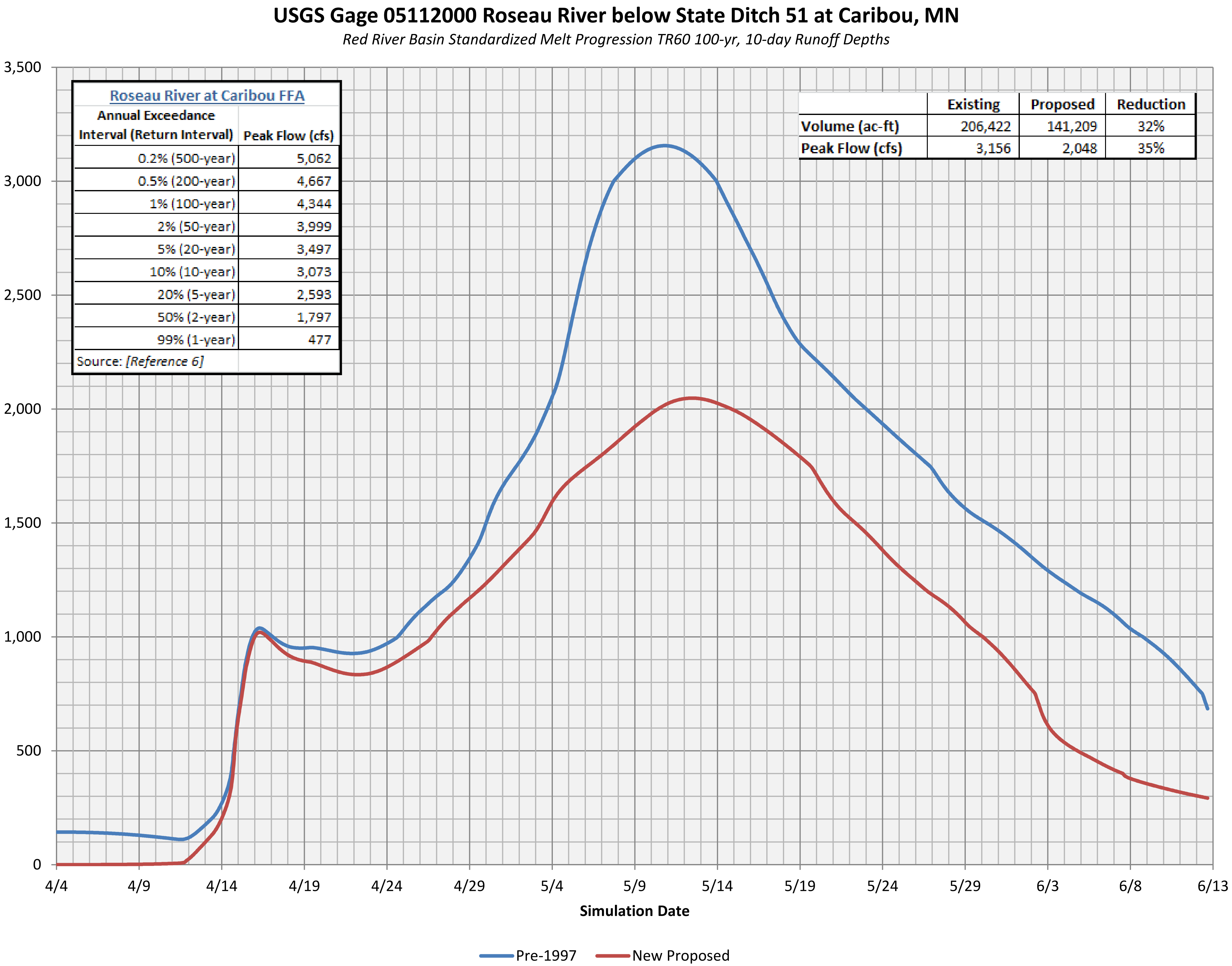

Pine Ck. outlet to Roseau R. - **Figure 28**



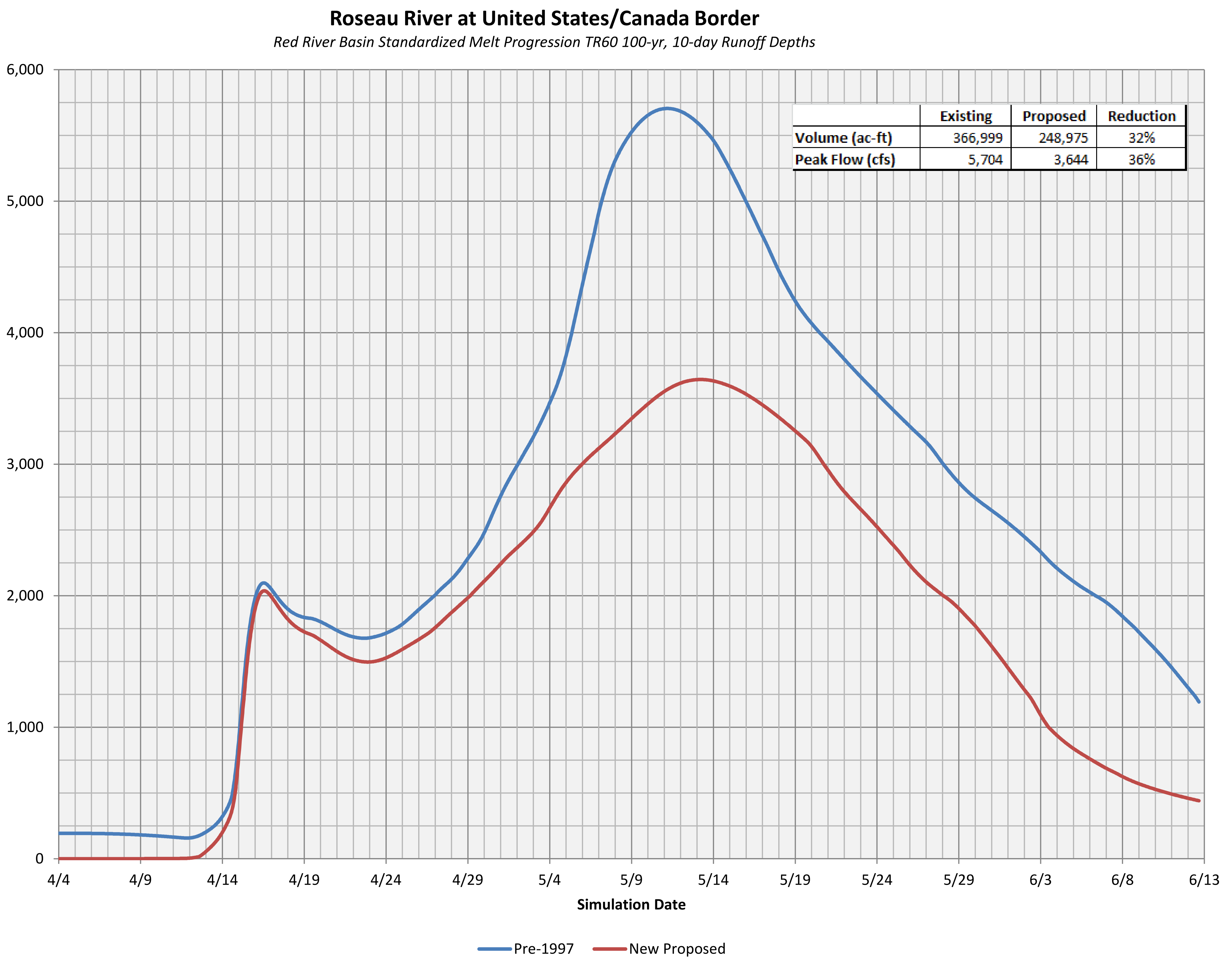

| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (ac-ft) | 372,601 | 202,290 | 46% |
| Peak Flow (cfs) | 9,959 | 6,024 | 40% |

| Roseau River at Ross FFA | |
|---|---|
| Annual Exceedance Interval (Return Interval) | Peak Flow (cfs) |
| 0.2% (500-year) | 9,453 |
| 0.5% (200-year) | 8,205 |
| 1% (100-year) | 7,267 |
| 2% (50-year) | 6,332 |
| 5% (20-year) | 5,099 |
| 10% (10-year) | 4,164 |
| 20% (5-year) | 3,215 |
| 50% (2-year) | 1,881 |
| 99% (1-year) | 317 |
| Source: *[Reference 6]* | |

USGS Gage at Ross, MN - **Figure 29**




USGS Gage at Caribou, MN - **Figure 30**




| | Existing | Proposed | Reduction |
|---|---|---|---|
| Volume (ac-ft) | 366,999 | 248,975 | 32% |
| Peak Flow (cfs) | 5,704 | 3,644 | 36% |

Roseau River at Int'l Border - **Figure 31**