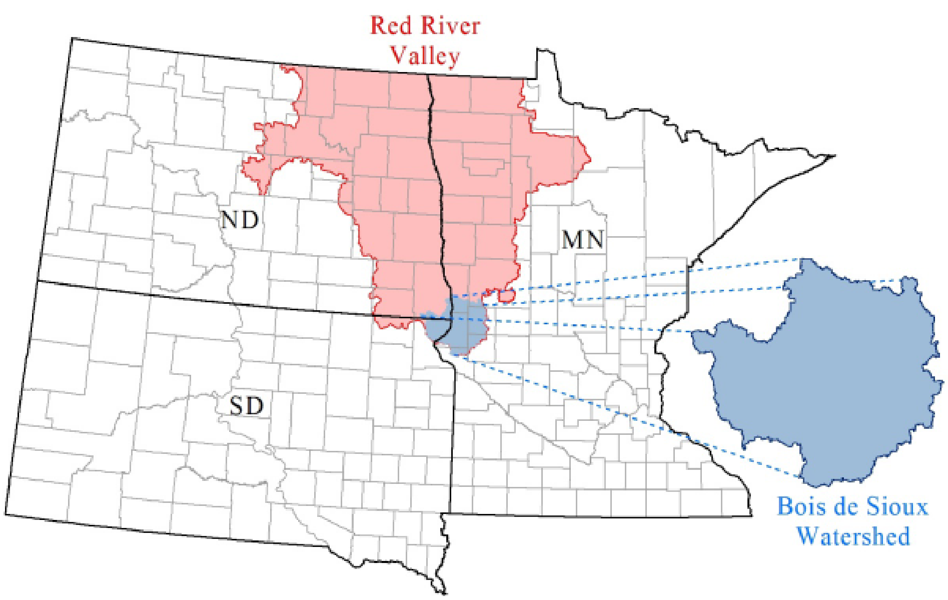
12/13/2013

Bois de Sioux Watershed

Updated Flow Reduction Strategy



Prepared for Bois de Sioux Watershed District
Red River Watershed Management Board
and Red River Basin Commission by:

Widseth Smith Nolting
610 Fillmore Street
P.O. Box 1028
Alexandria, MN 56308-1028

BOIS DE SIOUX WATERSHED
UPDATED FLOW REDUCTION STRATEGY

FOR

Bois de Sioux Watershed District
Red River Watershed Management Board
Red River Basin Commission

DECEMBER 13, 2013

Prepared By:

Widseth Smith Nolting & Associates, Inc.
610 Fillmore Street, P.O. Box 1028
Alexandria, Minnesota 56308-1028

WSN Project No.'s 409A0009, 411A0007

Certification:

I hereby certify that this 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.

Charles L. Anderson, PE	Timothy T. Ramerth, PE
12-13-13	12-13-13
Date	Date
12775	41966
License No.	License No.

Contents

Figures

Tables

1.0 Background Information

1.1 Flow Reduction Strategy Update

This report is an update of the Bois de Sioux Flow Reduction Strategy report dated June 4, 2010, which discussed the feasibility of applying sufficient flood storage within the Bois de Sioux Watershed to meet a 20% peak flow reduction goal established by the Red River Basin Commission (RRBC). Since that report, new HEC-HMS hydrologic models have been developed utilizing the recently acquired LiDAR survey data and an improved methodology for modeling the spring snowmelt. LiDAR allows for a more detailed determination of the watershed parameters that are input into the model. The meteorological event analysis has been greatly improved by incorporating a Virtual Thaw Progression (VTP) to more accurately reflect a typical spring snowmelt condition. Whereas, previous modeling efforts assumed that runoff began at the same time throughout the entire watershed, the VTP simulates a melt pattern that progresses from south to north and from lower to higher elevation.

Selection of storage sites to meet the 20% flow reduction goal has been revisited. The previous flow reduction strategy report did not identify specific detention sites in the Dakotas, but included an estimated amount of storage needed to assist in meeting the goals of the RRBC Flow Reduction Strategy. With funding from the RRBC, an objective of this strategy update is to identify specific detention site locations in the Dakota portion of the Bois de Sioux. Input was sought and received from NRCS and others in identifying potential sites. Site visits were also conducted to more accurately define conditions as they exist today and account for natural storage areas or restrictions that may currently affect flows. Several potential sites were identified and 4 have been selected for inclusion in the model, which results in more storage potential than originally assumed. As a result, the volume of distributed storage allocated in Minnesota decreased.

In Minnesota, efforts to identify suitable project sites are continuing to progress with guidance and input from Project Team work groups. Additional potential storage locations have been identified and sites needed to meet the goal were selected from the expanded list for inclusion in the model.

1.2 Red River Basin Background

Flooding has been a persistent problem within the Red River Basin. In the past, flood damage reduction strategies have often focused on protecting localized areas. Examples of these practices are urban levees, diversion channels, agricultural dikes and farmstead ring dikes. These practices provide local relief, but do not address, and often aggravate, the regional flooding issue. Approaching this issue from a basin wide perspective, the Red River Basin Commission (RRBC) developed a Flow Reduction Strategy in 2010. This strategy is to implement widely distributed detention sites to detain runoff as close to the source as practicable, with the release of detained water during non-flood periods. The overall goal is to reduce flood volume enough, by storing water throughout the basin, to reduce peak flows along the Red River by 20 percent over its entire length. The amount of flow reduction required was estimated by the Basin Commission utilizing a

Mike 11 flood routing model of the 1997 spring flood that they had developed previously. Tributary goals were then summarized in the Red River Basin Commission's Long Term Flood Solutions (RRBC LTFS) Basin Wide Flow Reduction Strategy Report. The Bois de Sioux Watershed goals identified in the report consist of three areas: the Bois de Sioux River at White Rock Dam (gaged site) with peak flow and volume reductions of 20%, the Rabbit River at TH 75 (un-gaged site) with a peak flow reduction of 35% and a volume reduction of 26% and the Bois de Sioux River (un-gaged) between White Rock Dam and Breckenridge with a peak flow reduction of 13% and a volume reduction of 9%.

Updated HEC-HMS models are currently being used throughout the Red River Basin to identify and evaluate potential storage sites. The RRWMB funded 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) funded an effort to develop comprehensive detention plans for the North Dakota portion of the Red River Basin. Development of the Updated Flow Reduction Strategy for the portion of the Bois de Sioux Watershed in the Dakotas was funded by the Red River Basin Commission.

In addition to the development of updated hydrologic models in HEC-HMS, updated hydraulic models based on HEC-RAS software are being developed by the US Army Corps of Engineers (USACE) that can be used in place of the Mike 11 model for routing flood flows along the Red River main stem.

1.3 Bois de Sioux Watershed Background

The confluence of the Bois de Sioux and Ottertail Rivers forms the headwaters of the Red River. The Bois de Sioux drainage basin includes land in Minnesota, North Dakota and South Dakota totaling 1,976 square miles. Approximately 3/4 of the basin lies within Minnesota, or roughly 1,434 square miles, and is organized as the Bois de Sioux Watershed District. There are 348 square miles in South Dakota and 194 square miles in North Dakota. **Figure 1**.illustrates the Bois de Sioux Watershed.

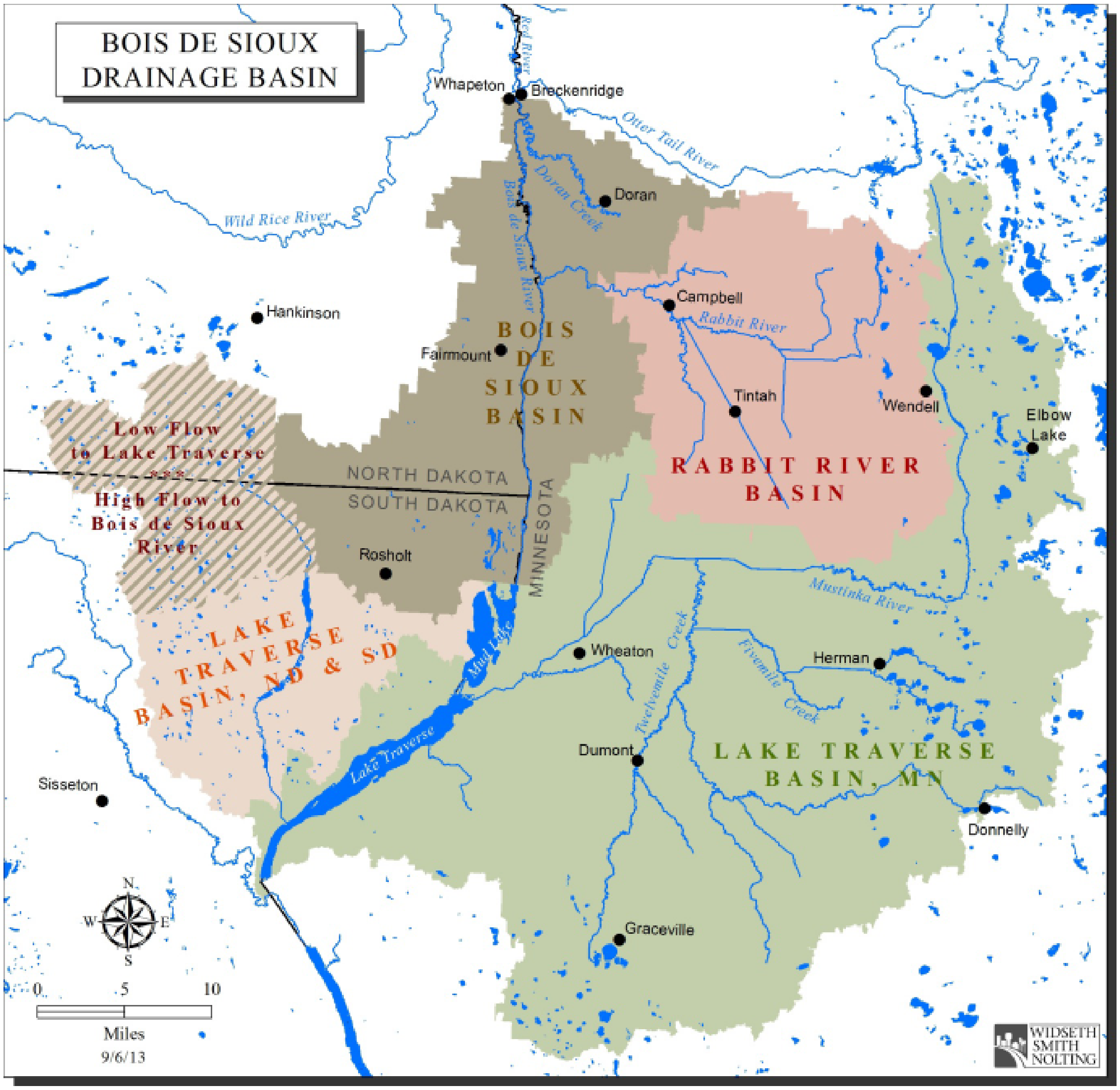


Figure 1 - Bois de Sioux Drainage Basin

At the headwaters of the Bois de Sioux River is the Lake Traverse Project that was constructed by the USACE in 1942. It includes two reservoirs, Lake Traverse and Mud Lake. These reservoirs are controlled by Reservation Dam and White Rock Dam respectively. They are operated by the USACE for recreation and flood control. The drainage area to the Lake Traverse Project is 1,325 square miles, of which approximately 986 square miles is contributed from Minnesota. During spring flood conditions, the project can hold approximately 160,000 acre-feet of water without release, and this volume represents the design gated control storage. This equates to approximately 2.3" of runoff from its contributing drainage area. Above that amount, gates are opened in an attempt to stem the rise in water levels within the reservoir. However, the discharge capacity is limited, so temporary storage of additional runoff occurs when the gate capacity is exceeded and is referred to as un-gated storage. A potential for up to 1.7" of un-gated storage is available before the dam embankment would overtop.

2.0 Distributed Detention

2.1 Existing Distributed Detention Locations

In addition to Lake Traverse and naturally occurring storage, there is one other recently constructed flood control reservoir referred to as the North Ottawa Project. This project is located in the Rabbit River Basin and was placed in service by the Bois de Sioux Watershed District since the 1997 flood. This project provides 16,000 acre-feet of gated storage, which equates to approximately 4.1" of runoff from its drainage area and 2,000 acre-feet of un-gated storage below the emergency spillway, which is equivalent to approximately an additional 0.5" of runoff. **Figure 4** highlights the drainage area from which runoff is controlled by the North Ottawa impoundment.

2.2 Potential Distributed Detention Selection Criteria

Flooding, flood water breakouts, drainage and erosion problems are widespread throughout the Bois de Sioux watershed. Selection of detention sites is primarily dictated by the need for local flood control. The storage capacity of each site is maximized to provide up to approximately 4" of gated runoff control. This amount of control is typically enough to address both local and regional flooding conditions. The 2010 Flow Reduction Strategy Report indentified sites in the Rabbit River and Lake Traverse sub-basins. In this study, sites have also been identified within the remaining area that drains directly to the Bois de Sioux River. This more closely matches the storage allocations in the RRBC LTFS report.

Regulatory permitting issues are a consideration when developing local flood detention sites. The International Water Institute (IWI) has developed a Flood Damage Reduction Planning Tool to assist local water managers in developing flood control projects. A permit complexity grid has been developed for the Minnesota portion of the Red River Basin. The grid is based on project development experience in Minnesota and North Dakota and consultation with state and federal agencies. Development of the grid incorporated several factors from three categories to comprise an overall grid for permit complexity. The categories included streams, wetlands, and biodiversity significance, with the stream index carrying a weighted factor of 2 in the overall calculations. **Figure 2** illustrates the permit complexity grid provided by the IWI for the Bois de Sioux Basin.

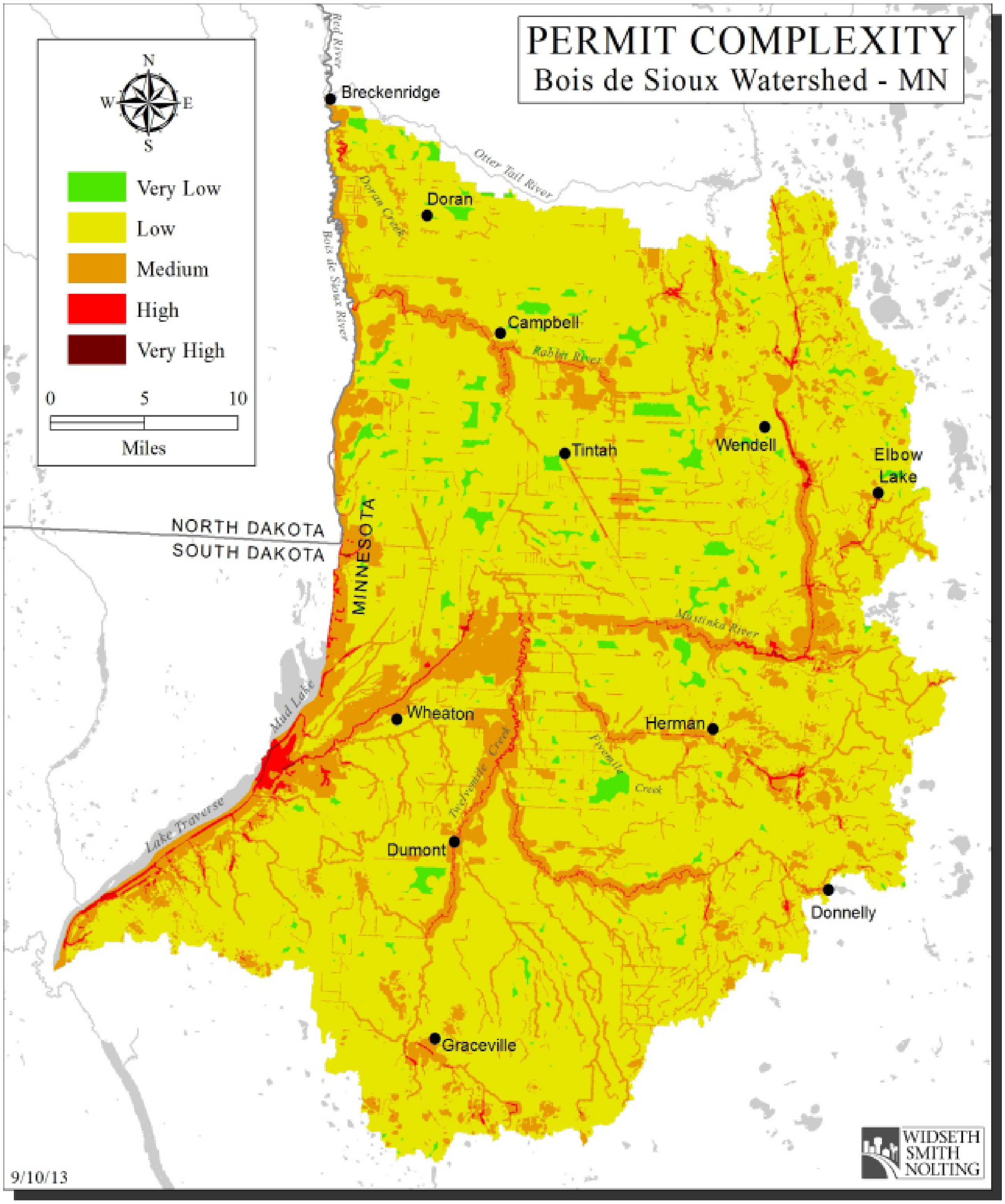


Figure 2 - International Water Institute Permit Complexity Grid

3.0 Hydrologic Analysis

3.1 Runoff Prediction and Hydrograph Development

The amount of runoff generated by a hypothetical spring snow melt event was modeled using the Hydrologic Curve Number (CN) method developed by the Soil Conservation Service (SCS). The curve number takes into account the soil type, land slope, land cover, antecedent moisture conditions, and the cultural practices of a watershed to predict runoff for a given precipitation event.

A basin wide Virtual Thaw Progression (VTP) methodology was developed to more accurately depict a typical spring snow melt event. A VTP starting date is defined as the first date of three consecutive days during which the minimum daily temperature does not fall below 32 degrees Fahrenheit. Recorded data from observation points throughout the Red River Basin was utilized in developing the VTP date. The dates for consideration at each observation location were from March 1 to May 31 for data from 1970 through 2005. A VTP date was established for each observation point and an interpolation over the observation points developed the thaw trend of the Red River Basin from south to north. **Figure 3** illustrates the VTP date established for the Bois de Sioux portion of the Red River Basin.

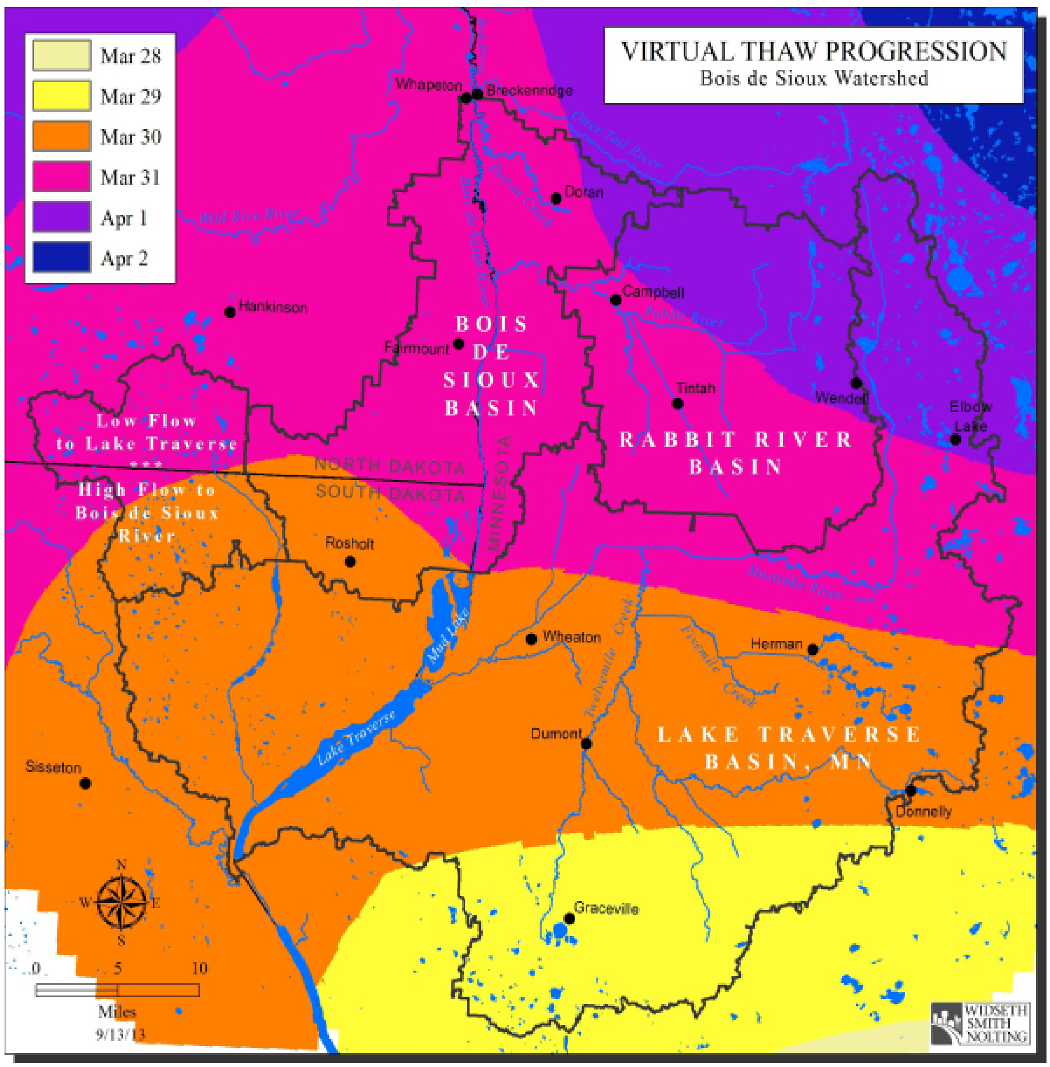


Figure 3 - Bois de Sioux Virtual Thaw Progression Start Dates

The 10 day runoff depths for a spring snow melt are based on the Natural Resources Conservation Service Technical Release 60, Earthen Dams and Reservoirs. For modeling purposes, the snow melt runoff is equated to a rainfall depth using the hydrologic curve number method. For the Bois de Sioux watershed, the average 10 day runoff depth is 5.5” with an average Runoff Curve Number of 73. This translates to a rainfall depth of

8.5” to produce this amount of runoff. These rainfall depths are distributed across the basin and correlate to the 10 day runoff depths, which increase from west to east across the Red River Basin. The timing of the runoff utilizes the VTP date as the start date and progresses over the 10 day period as described by the temporal rainfall distribution identified in the Minnesota Hydrology Guide.

The Clark Unit Hydrograph method was used in the model to transform runoff excess to outflow on a sub-basin level. GIS data inputs in the model define the hydrologic characteristics of the sub-basin, whereas the VTP data and the equivalent rainfall depths associated to the 10 day snow melt provide the rainfall hyetograph and runoff sequence information needed to complete the calculations. The resulting output is an outflow hydrograph that describes the peak discharge and volume runoff to be expected from a given watershed area.

3.2 Modifications to Existing Conditions

Since the publication of the Flow Reduction Strategy for the Bois de Sioux Watershed in 2010, new spatial information has become available in GIS format to assist in defining watershed boundaries and hydrologic characteristics. This information is considered more accurate and includes high-resolution LiDAR topographic data for the entire US portion of the Red River Basin. Conditioning of the Digital Elevation Model (DEM) continues and incorporates data from culvert inventories, corrections for vegetation obstructions and tile drainage that cannot be detected with LiDAR. This conditioning further refines the data to provide proper hydraulic connection for developing the flow network necessary to complete the GIS analysis of hydrologic characteristics. The Bois de Sioux Watershed District has an active program to inventory all culverts. Although not yet complete, this information, where available, has been very helpful in defining the hydraulic flow network. The updated information has helped to refine the sub-basin boundaries, runoff characteristics and connectivity within the HMS model improving its accuracy.

With the addition of potential storage sites, sub-basin divisions within the model were added or adjusted as necessary to define each sites contributing watershed. Hydrologic characteristics of the entire Bois de Sioux Watershed were re-evaluated. GIS routines were run to update the sub-basin parameters for drainage area, composite runoff curve number, percent impervious, time of concentration and storage coefficient.

The RRBC Long Term Flood Solutions Basin Wide Flow Reduction Strategy identifies target goals for peak flow and volume reductions based on the conditions at the time of the 1997 spring flood. Any runoff detention locations constructed after 1997 were not included in the baseline model. This baseline condition is noted as the 2000 model in the summary information.

3.3 Development of Proposed Conditions

North Ottawa Impoundment was constructed after the 1997 flood and has been incorporated into the 2010 model for illustrating the conditions as they would exist today. This can be compared with the 2000 model for demonstrating the improvements already implemented in the Bois de Sioux. This site is included in the proposed conditions model, as the storage was created after the baseline timeframe and applies toward meeting the flow reduction goal.

The proposed runoff detention sites were identified based primarily on the need for local flood control. Storage potential at each location was derived using the Natural Resources Conservation Service (NRCS) GIS Hydrologic Tools Service Pack. **Section 4.3** provides additional detail for the detention sites incorporated in the model.

4.0 Results

4.1 Estimating Effects of Proposed Storage

The effects of storage are measured by modeling a hypothetical spring flood event and comparing the peak flows and volumes to the baseline condition at critical locations throughout the basin. **Figure 5** illustrates the monitoring sites selected for comparison. The primary goal is to provide solutions for local flood damage problems that in turn will reduce peak flows and volumes along the main stem of the Red River to assist in meeting the goals established by the RRBC in its Flow Reduction Strategy.

4.2 Effects of North Ottawa

North Ottawa illustrates the effects runoff storage can have on local flooding problems. The City of Tintah had experienced frequent flood damage prior to the construction of the North Ottawa Project. As summarized in **Table 1**, North Ottawa will significantly reduce peak flows and volumes at Tintah and all downstream locations.

Bois de Sioux Reduction Summaries with North Ottawa for 100 Year Spring Flood							
	Peak Flow Reduction			Volume Reduction			
Comparison Locations	2000 Model Peak Flow	2010 Model Peak Flow	Reduction	2000 Model Volume	2010 Model Volume	Reduction	
	(cfs)	(cfs)	(%)	(ac ft)	(ac ft)	(ac ft)	(%)
JD12@Tintah (Gage 30)	2366	1121	52.6	27650	15429	12221	44.2
RabbitR@Campbell (Gage 27)	10550	10005	5.2	111616	95854	15762	14.1
RabbitR@TH75 (Gage 49)	12856	12184	5.2	131882	115732	16150	12.2
Breakout Flows to Wild Rice River	3284	2756	16.1	42632	35204	7428	17.4
Bois de Sioux @ Breckenridge	13504	13182	2.4	343743	335094	8649	2.5
Total Outflow from Bois de Sioux	16237	15395	5.2	386375	370298	16077	4.2

Table 1 - Peak Flow and Volume Reduction Summaries with North Ottawa

Comparing the results from the 2010 and 2000 models highlights that the following monitoring sites will experience a reduction in peak discharge and runoff volume: JD 12 at Tintah, Rabbit River at Campbell, Rabbit River at TH 75, Breakout Flows to Wild Rice River and Breckenridge. The effects of storage are most noticeable immediately downstream of the impoundments, as percent reductions tend to diminish as uncontrolled inflows are added downstream. Flow at Tintah will experience the largest reductions of 52.6% and 43.7% in peak discharge and volume respectively. Reductions on the Rabbit River, Breakout Flows to Wild Rice River and at Breckenridge will be less, but it is important to recognize how much impact this one detention site has on downstream flood conditions. **Figures 13-17** provide a graphical depiction of the reductions anticipated at these monitoring sites resulting from the construction of North Ottawa.

4.3 Flow Reduction Strategy

Within Minnesota, 27 potential sites were identified for storage with 19 sites being included in this strategy report. For the portion of the Bois de Sioux in the Dakotas, 16 sites were identified with 4 sites included in this report. For the purposes of this study, the intent was to model local detention sites spread throughout the basin that would provide enough downstream benefit to meet the 20 percent flow reduction strategy goals. Some sites included in the previous report have been omitted from this strategy report, as their inclusion would far exceed the 20 percent flow reduction goal. However, they are considered equally desirable to build and their omission from this report is not intended to discourage or impede their implementation in any way.

For the purposes of this report, **Figure 4** illustrates the drainage areas that runoff will be controlled by the detention sites included in the 20% flow reduction model.

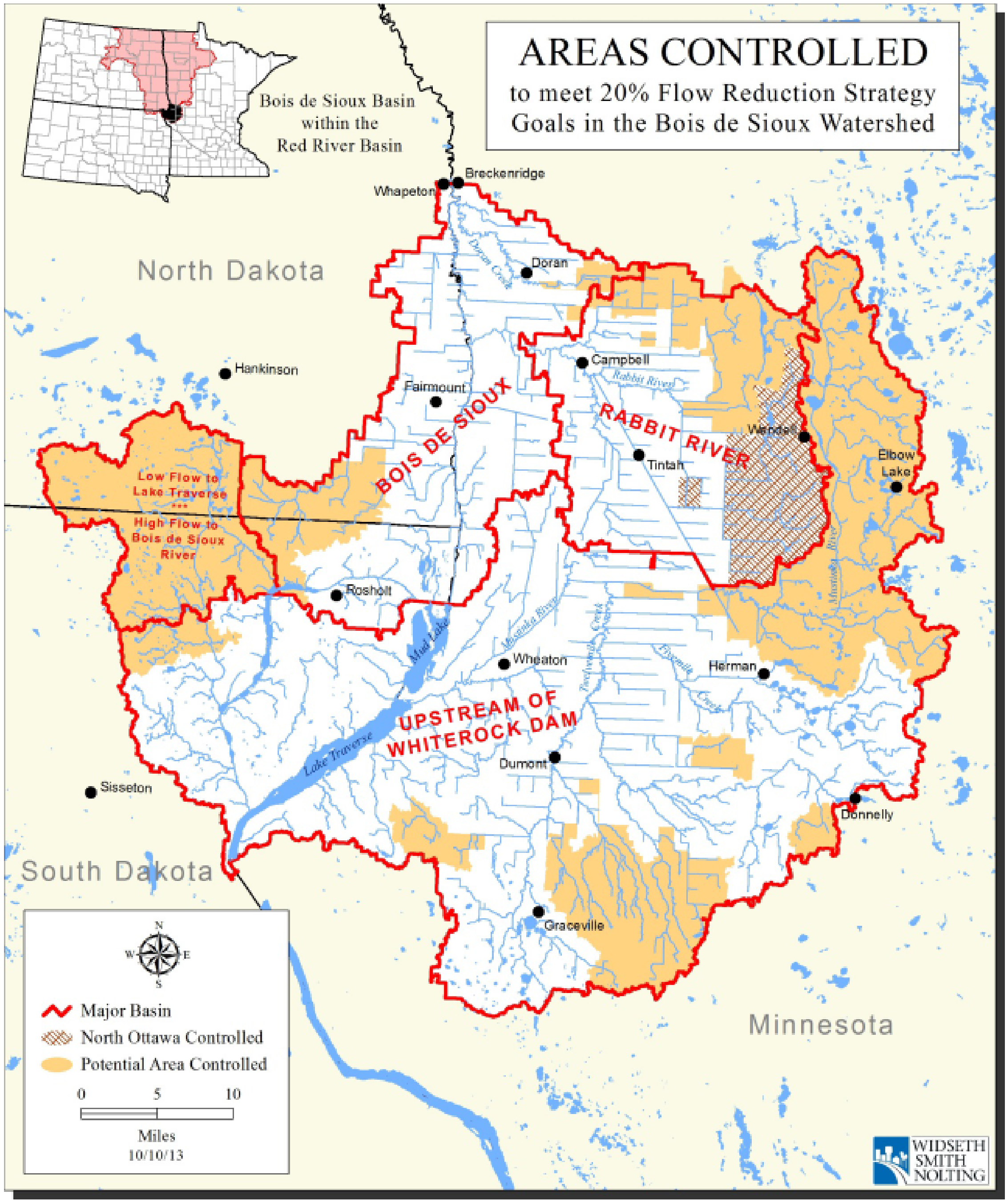


Figure 4 - Areas of Watershed Controlled with Runoff Storage

The detention sites utilized in the model represent only 23 of the total 32 local flood control sites that were identified. Additional sites have been evaluated and are still under consideration. Technical difficulties with individual sites, local support, cost, and other factors will eventually determine which projects are ultimately constructed. Having more identified sites than is necessary to meet the 20% goal is very desirable. Also, while 20% reduction is considered a reasonably achievable goal, there is no reason not to exceed it. **Table 2** provides a list of the individual sites currently in the model and summarizes the constructed storage provided. The storage has been summarized by gated and un-gated. Gated storage is the volume between the permanent pool elevation and the lowest outlet which is not gated. Gated storage removes runoff from the flood flow hydrograph and the stored water will not be released until flooding downstream has abated. The un-gated storage is the volume between the lowest un-gated outlet elevation and the emergency spillway crest. Un-gated storage delays the runoff and generally reduces peak flows, but some or all of this runoff may be released during the flood period.

Detention Site Storage Summaries							
		Storage Volume			Runoff Detention		
Site Name	Drainage Area (Mi^2)	Gated (Acre-ft)	Ungated (Acre-ft)	Total (Acre-ft)	Gated (Inches)	Ungated (Inches)	Total (Inches)
White Rock Watershed							
MN Sites							
Moonshine 4	6.28	1028.02	350.67	1378.69	3.07	1.05	4.12
Moonshine 13	6.62	1356.48	328.00	1684.47	3.84	0.93	4.77
Moonshine Lake	6.7	777.3	1753.7	2531	2.18	4.91	7.09
Leonardsville 12 *	29.89	6684.3	1029.5	7713.8	4.20	0.65	4.84
Leonardsville 31E	5.88	788	260	1048	2.52	0.83	3.34
Leonardsville 31W	3.97	1120	359	1480	5.29	1.70	6.99
Tara 12 *	8.71	1893.58	493.41	2386.99	4.08	1.06	5.14
Parnell 13	15.4	4567.8	750.3	5318.1	5.56	0.91	6.48
Moose Head	8.40	1622.32	895.31	2517.63	3.62	2.00	5.62
Eldorado 7	9.19	1699.7	304.3	2004	3.47	0.62	4.09
Dollymount 30 *	24.84	5271.47	873.20	6144.67	3.98	0.66	4.64
Big Lake	9.9	858	1215.5	2073.5	1.63	2.30	3.93
Red Path	202.72	19861.64	4505.55	24367.19	1.84	0.42	2.26
SD Sites							
Hart 2	18.2	3060.9	868.3	3929.2	3.16	0.90	4.05
Subtotal	356.70	50590.20	13986.74	64576.94			
Bois de Sioux Ungaged							
MN Sites							
Brandrup 9	8.76	1490.91	424.58	1915.49	3.19	0.91	4.10
ND Sites							
LaMars 11	46.29	8794.4	1536.2	10330.6	3.56	0.62	4.19
Elma 27	26.86	7850.6	3217.1	11067.7	5.48	2.25	7.73
SD Sites							
Victor 17	81.75	7053.8	2101.4	9155.2	1.62	0.48	2.10
Subtotal	163.66	25189.71	7279.28	32468.99			
Rabbit River Watershed							
MN Sites							
North Ottawa	71.51	16167	1486	17653	4.24	0.39	4.63
Lawrence 19	32.23	4421	919	5340	2.57	0.53	3.11
Bradford 34	11.87	3405.6	631.8	4037.4	5.38	1.00	6.38
Brandrup 23	11.77	2874.01	626.33	3500.34	4.58	1.00	5.58
Western 32	12.49	2391.46	153.16	2544.62	3.59	0.23	3.82
Subtotal	139.87	29259.27	3815.99	33075.26			
Total	**660.23**	**105039.18**	**25082.01**	**130121.19**			

* - Inches of runoff stored is based on the direct contributing area of the detention site and does not include the watershed area controlled by other upstream locations.

Table 2 - Detention Storage Summaries

Permit complexity was considered at each detention site by clipping the complexity grid at the proposed detention site boundary for calculating a weighed complexity index for the entire site. For the sites included in the model, the weighted mean permit complexity varied between low and medium. The maximum complexity value encountered should also be considered. For 6 of the 19 Minnesota sites, a maximum value of high was noted, whereas the remainder of the sites had a maximum value of medium or less. **Table 3** provides a summary of the permit complexity index for each detention site.

Permit Complexity Summaries					
	Complexity Values			Complexity Values	
Site Name	Maximum	Weighted Mean	Site Name	Maximum	Weighted Mean
White Rock Watershed			**Bois de Sioux Un-gaged**		
Moonshine 4	3	2.04	Brandrup 9	3	2.12
Moonshine 13	3	2.23			
Moonshine Lake	4	2.57	**Rabbit River Watershed**		
Leonardsville 12	3	2.05	North Ottawa	4	2.56
Leonardsville 31E	3	2.15	Lawrence 19	4	2.34
Leonardsville 31W	3	2.16	Bradford 34	3	1.88
Tara 12	3	2.04	Brandrup 23	3	2.02
Parnell 13 Opt B	3	1.93	Western 32 - Opt B	4	2.16
Moose Head	4	3.23	**Complexity Index Legend**		
Eldorado 7	2	2.00	**Very Low**	**1**	
Dollymount 30	3	2.05	**Low**	**2**	
Big Lake	3	2.67	**Medium**	**3**	
Redpath	4	2.46	**High**	**4**	
			Very High	**5**	

Table 3 - Detention Site Permit Complexity Summaries

4.4 Effects of Flow Reduction Strategy

As discussed previously in this report, the primary purpose of the sites identified herein is to provide solutions to local flooding problems. To fully assess the effects of storage on local flood conditions, hydrographs of the estimated peak discharges for the existing and proposed conditions are compared at several monitoring sites throughout the Bois de Sioux watershed. **Figure 5** illustrates the monitoring sites for which hydrographs have been included in this report.

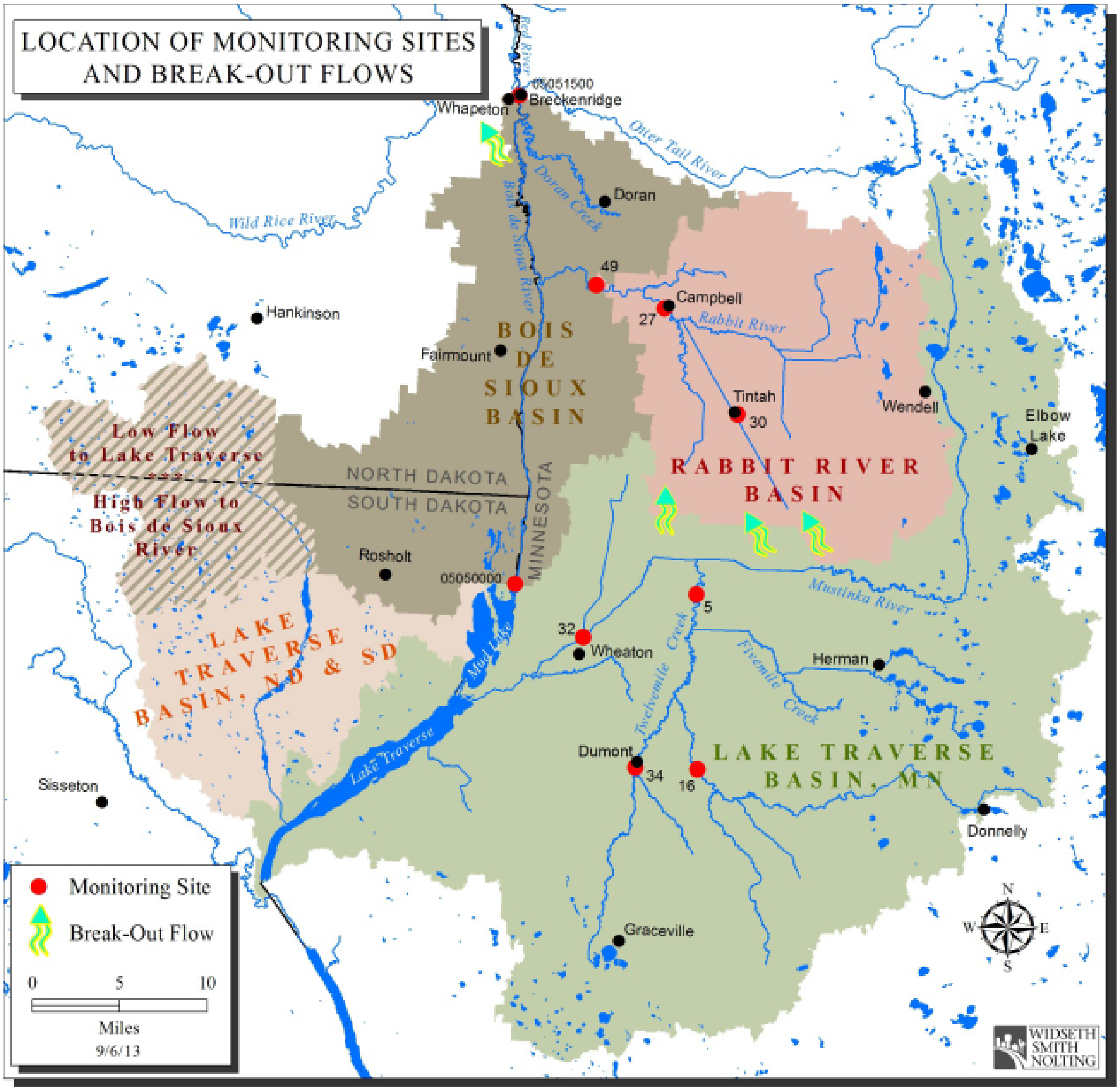


Figure 5 - Monitoring Site Locations

Following are the resulting outflow hydrographs illustrating the effects of the proposed detention sites at the various monitoring locations in the Bois de Sioux Basin. The proposed condition assumes all detention sites have been constructed.

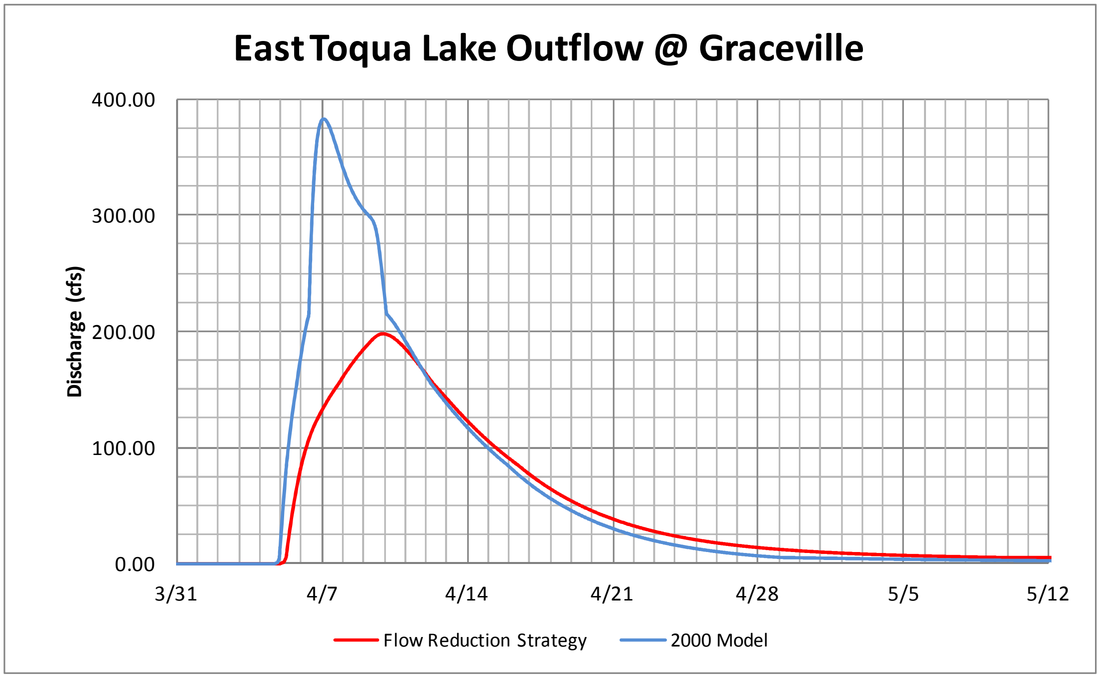


Figure 6 – East Toqua Lake Outlet

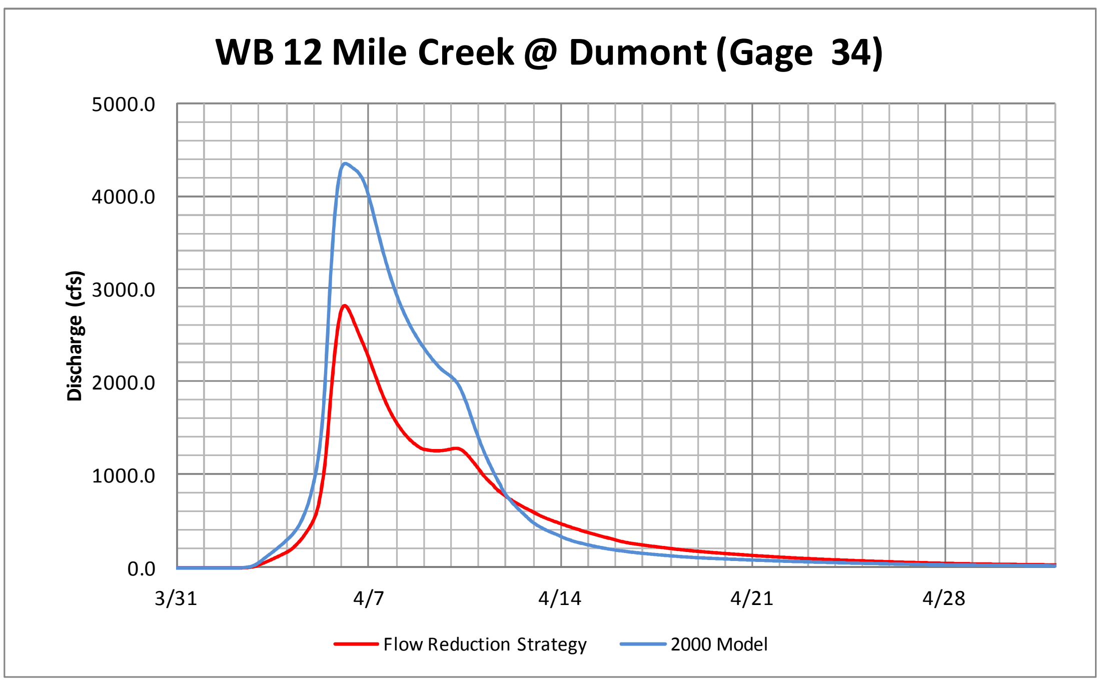


Figure 7 - West Branch of 12 Mile Creek at Dumont

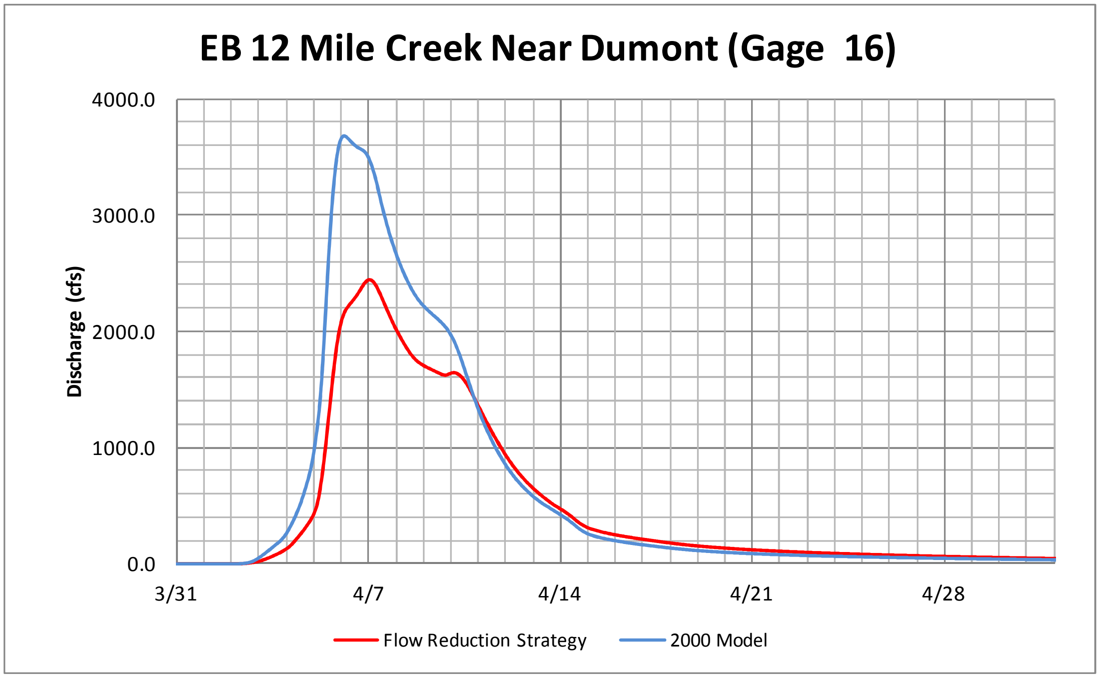


Figure 8 - East Branch 12 Mile Creek Near Dumont

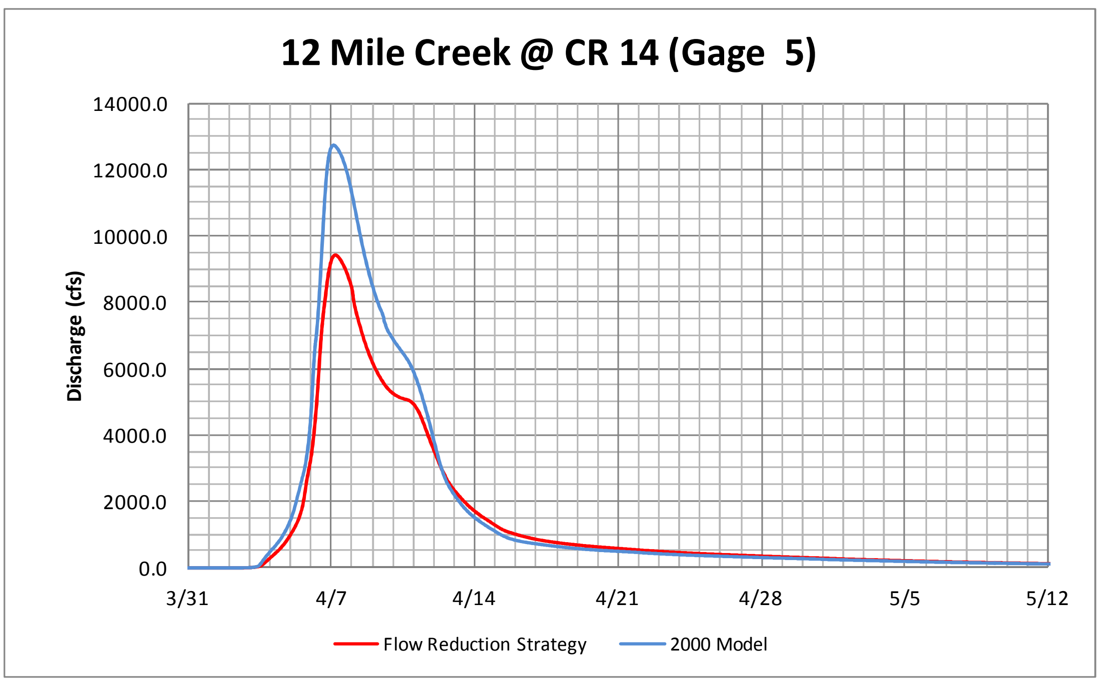


Figure 9 - 12 Mile Creek at County Road 14

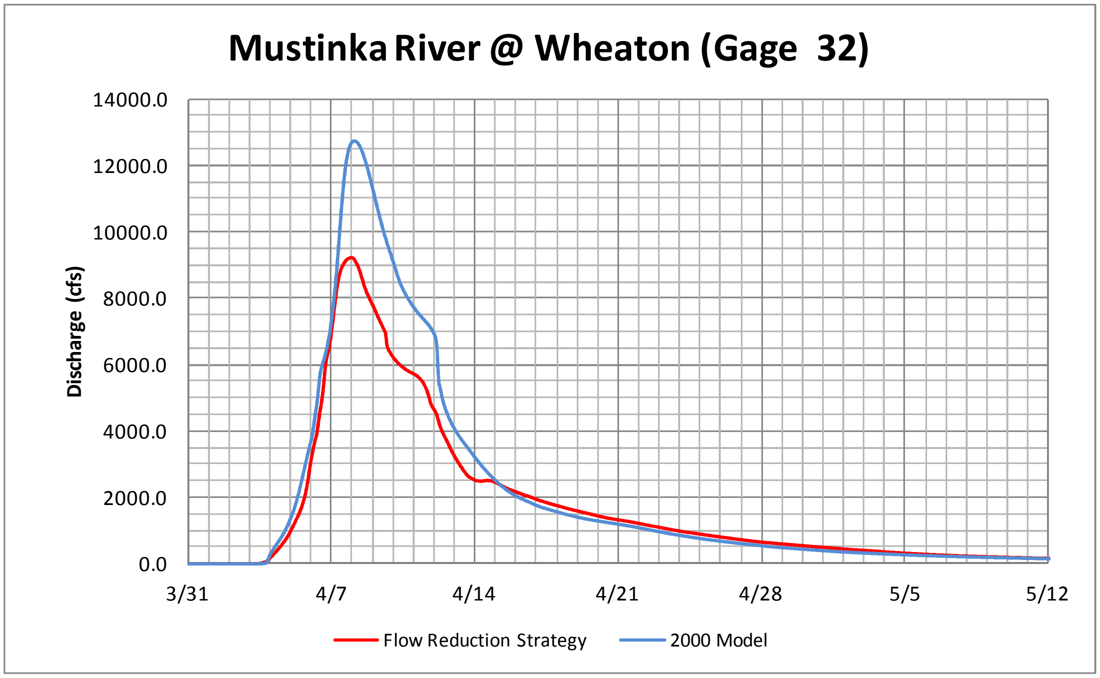


Figure 10 - Mustinka River at Wheaton

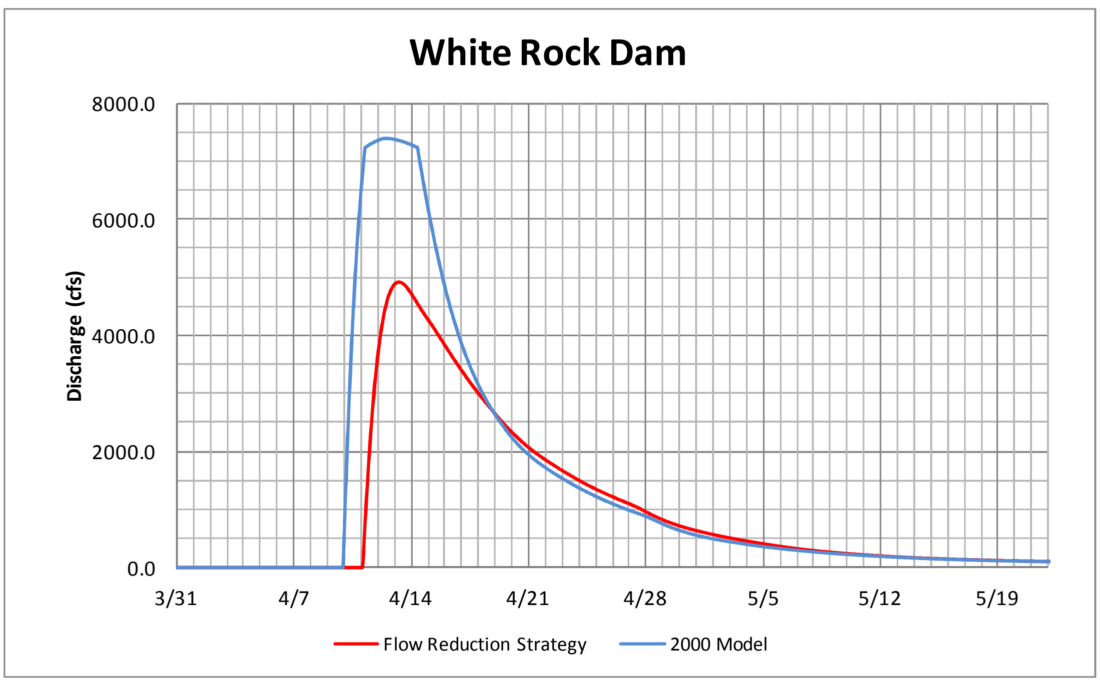


Figure 11 - White Rock Dam (Lake Traverse Outlet)

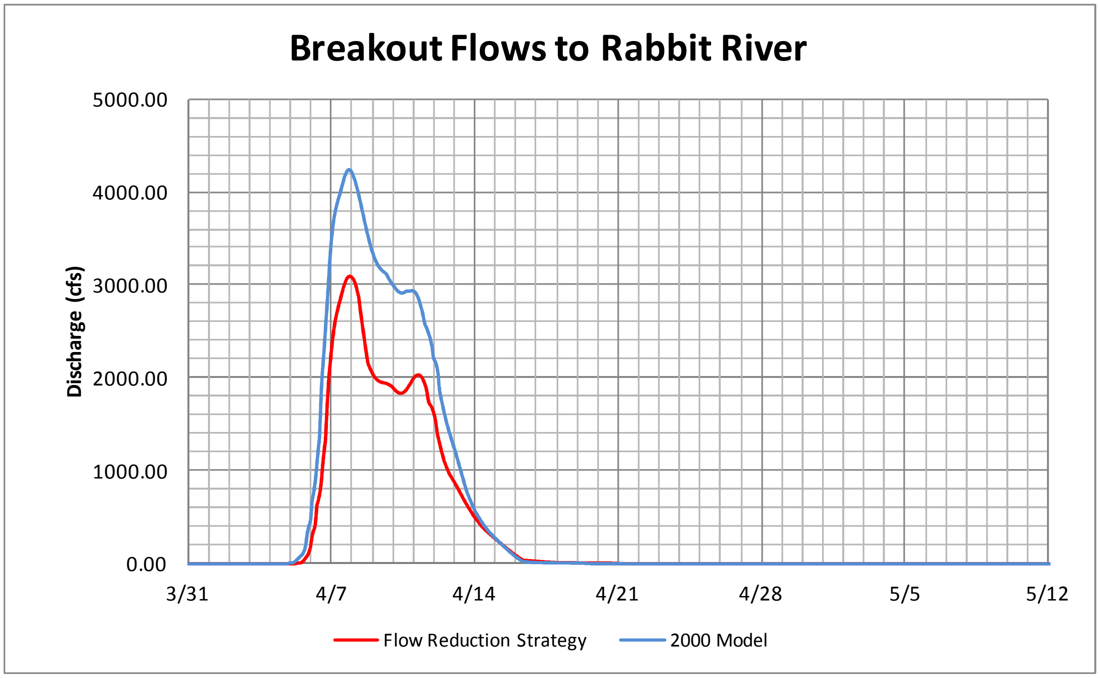


Figure 12 - Breakout Flows to Rabbit River

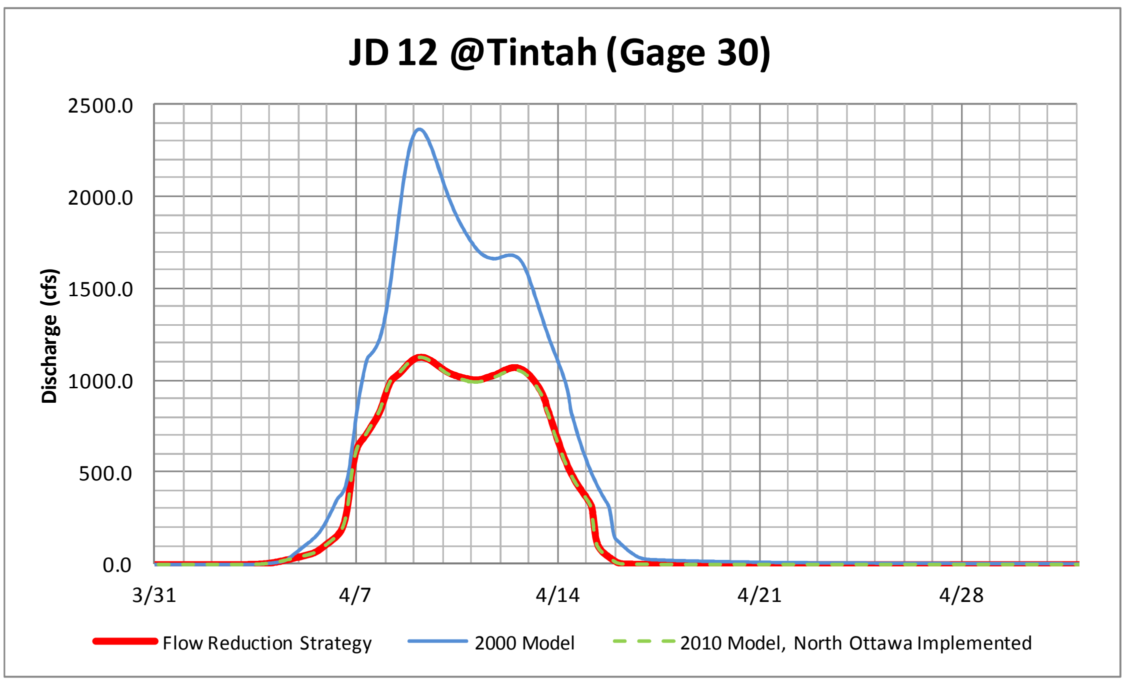


Figure 13 - Judicial Ditch 12 at Tintah

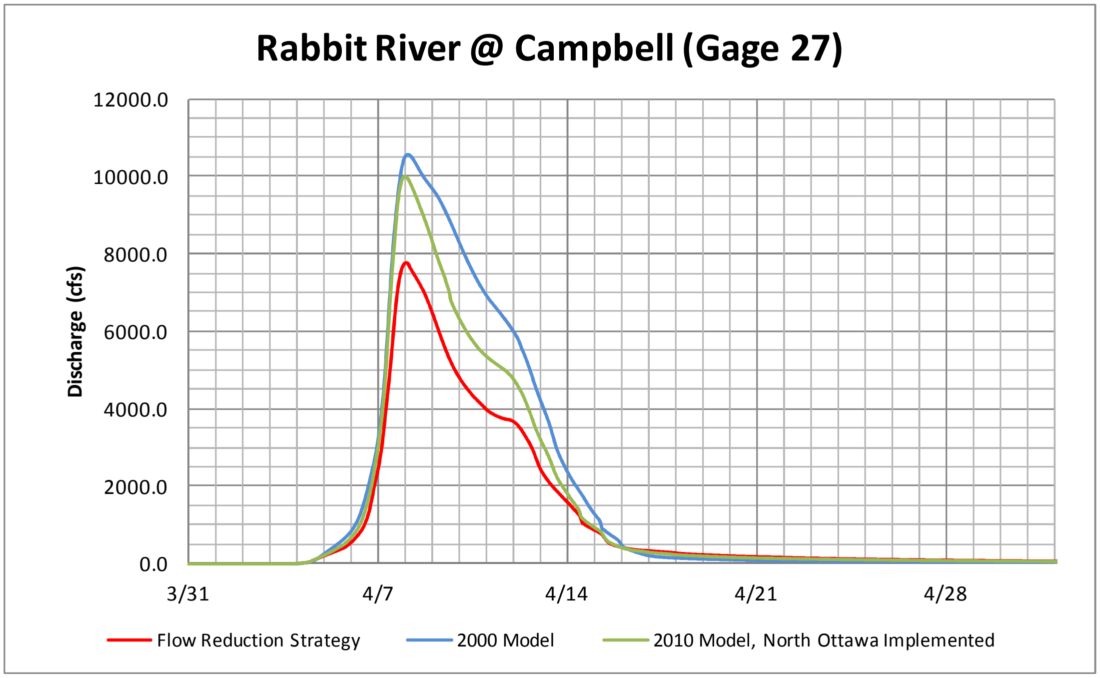


Figure 14 - Rabbit River at Campbell

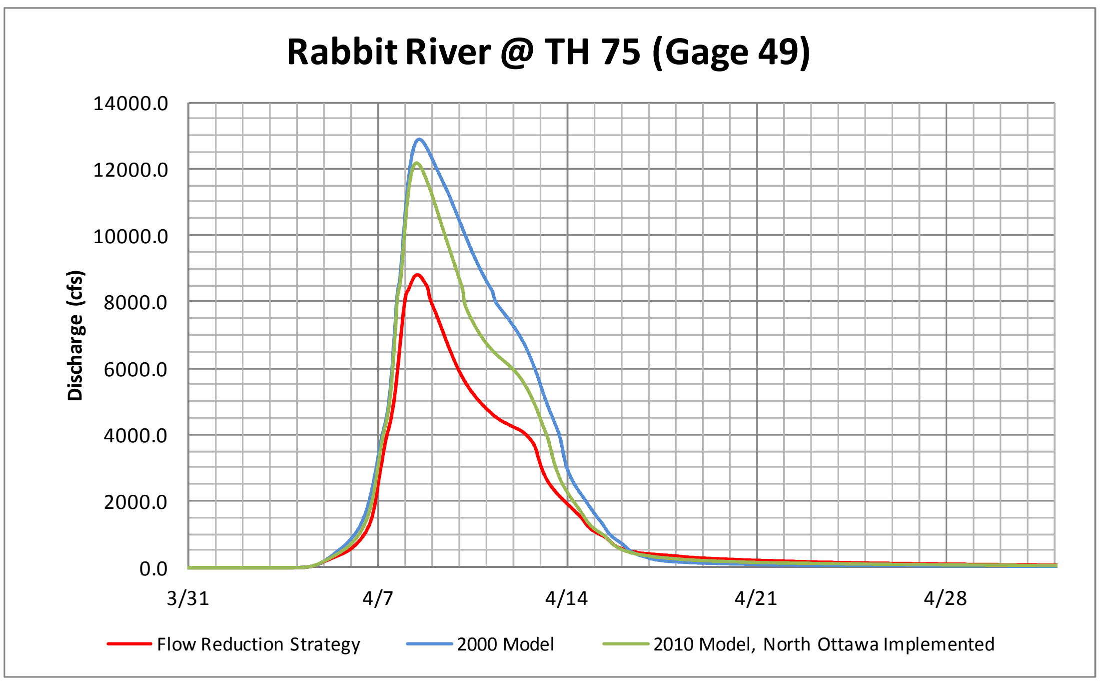


Figure 15 - Rabbit River at TH 75

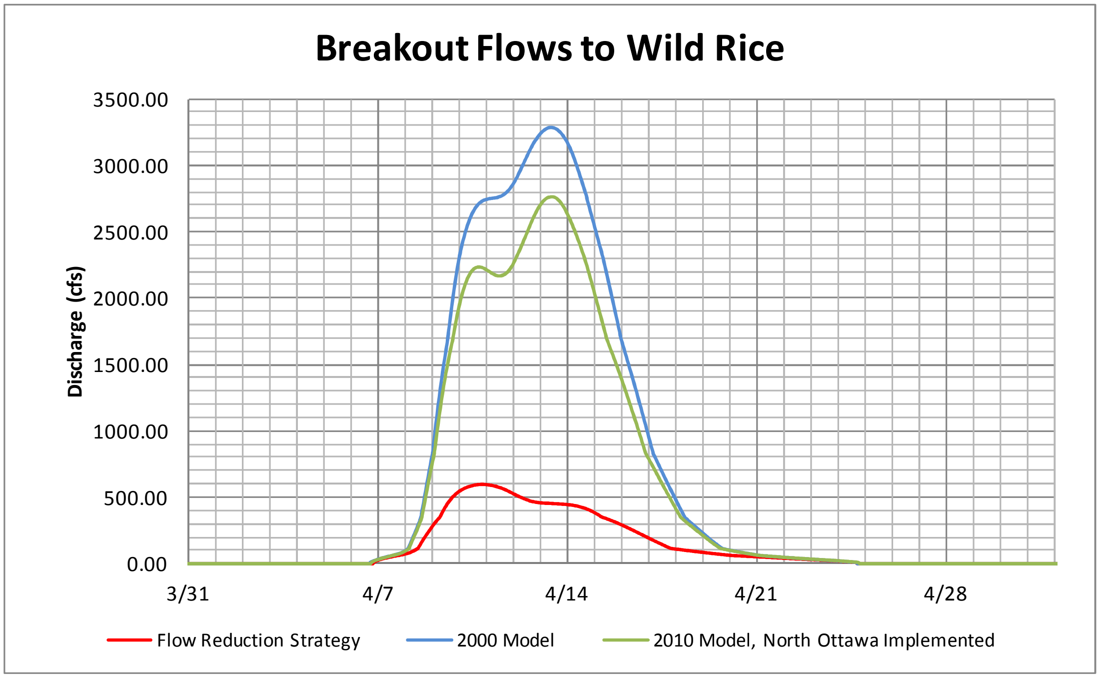


Figure 16 - Breakout Flows to Wild Rice River

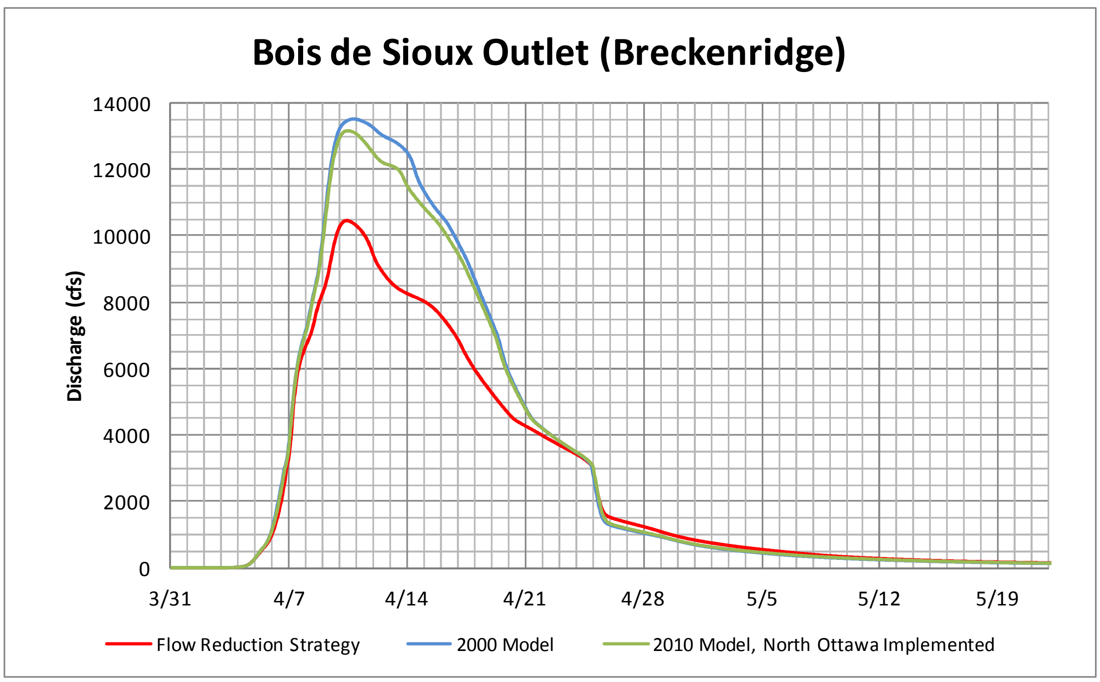


Figure 17 - Bois de Sioux Outlet at Breckenridge

Tributary goals identified by RRBC LTFS Basin Wide Flow Reduction Strategy Report include: the Bois de Sioux River at White Rock Dam (gaged site) with peak flow and volume reductions of 20%, the Rabbit River at TH 75 (un-gaged site) with a peak flow reduction of 35% and a volume reduction of 26% and the Bois de Sioux River (un-gaged) between White Rock Dam and Breckenridge with a peak flow reduction of 13% and a volume reduction of 9%.

Table 4 summarizes the anticipated flow and volume reductions for the Bois de Sioux Watershed with the corresponding RRBC Long Term Flood Solutions Basin Wide Flow Reduction Strategies goals. The goals were met or exceeded at all locations.

Bois de Sioux Flow Reduction Strategy Summaries for 100 Year Spring Flood								Red River Basin	
	Peak Flow Reduction			Volume Reduction				Goals	
Comparison Locations	2000 Model Peak Flow	FRS Model Peak Flow	Reduction	2000 Model Volume	FRS Model volume	Reduction		Flow Reduction Strategy	
	(cfs)	(cfs)	(%)	(ac ft)	(ac ft)	(ac ft)	(%)	Flow (%)	Vol. (%)
EToquaLakeOutflow@Graceville	382	198	48.2	5345	4346	999	18.7		
WB12MC@Dumont (Gage 34)	4347	2821	35.1	42806	30394	12412	29		
EB12MCNrDumont (Gage 16)	3681	2436	33.8	40489	32433	8056	19.9		
12MC@CR 14 (Gage 5)	12704	9419	25.9	140489	117884	22605	16.1		
MustinkaR@Wheaton (Gage32)	12739	9219	27.6	180033	151530	28503	15.8		
White Rock Dam	7380	4990	32.4	139508	104707	34801	24.9	20	20
Breakout Flows to Rabbit River	4229	3090	26.9	43015	29230	13785	32		
JD12@Tintah (Gage 30)	2366	1122	52.6	27650	15567	12083	43.7		
RabbitR@Campbell (Gage 27)	10550	7775	26.3	111616	76785	34831	31.2		
RabbitR@TH75 (Gage 49)	12856	8796	31.6	131882	88229	43653	33.1	35	26
Breakout Flows to Wild Rice River	3284	590	82	42632	8256	34376	80.6		
Bois de Sioux @ Breckenridge	13504	10476	22.4	343743	274853	68890	20	20	
Total Outflow from Bois de Sioux	16237	11052	31.9	386375	283109	103266	26.7		

Table 4 – Aggregate Peak Flow and Volume Reduction Summaries for BDS FRS

The total constructed storage volume in this report for the Bois de Sioux is 130,121 acre-feet, of which 105,039 acre-feet is gated and 25,082 acre-feet is un-gated, which exceeds the storage listed in the 2010 Bois de Sioux Flow Reduction Strategy report. The 23 sites reduced the downstream 100 year flood volume by 103,266 acre-feet (26.7% reduction) and peak flows by 31.9%, by controlling runoff from approximately 660 square miles of drainage area. The identified distributed detention sites meet the Bois de Sioux allocated share of the RRBC LTFS Flow Reduction Strategy requirements.

4.5 Recommendations

This study focuses on providing solutions for local flood related problems and also demonstrates that complete implementation will meet the goals of the RRBC LTFS Flow Reduction Strategy. It is anticipated this study will serve as a resource for guiding local water managers in the implementation of flood control projects. This approach will build partnering opportunities that will help solve local flooding problems in ways that will also reduce flooding along the main stem of the Red River.

References

1. Application of Flow Reduction Strategy in the Bois de Sioux Watershed, June 4, 2010.
2. Red River Basin Standardized Melt Progression Event Analysis, April 10, 2013.
3. Red River Basin Commission's Long Term Flood Solutions for the Red River Basin, Final Report, September 2011.
4. Red River Basin Wide Flood Flow Reduction Strategy, February 10, 2010.
5. U.S. Department of Agriculture, Natural Resources Conservation Service, Earth Dams and Reservoirs, Technical Release No. 60, July 2005.
6. U.S. Department of Agriculture, Natural Resources Conservation Service, Hydrology Guide for Minnesota.