Status Summary of Follow up Items tasked to USACE from December 10, 2012 Geomorphology Technical Meeting for the Fargo Moorhead Metro Flood Risk Management Project EIS Meeting

INTRODUCTION:

USACE has been working on the items identified for follow up from the December 10th meeting. While we have not yet been able to fully address all of the follow up items, we do have a plan for items that need further analysis.

UPSTREAM IMPACTS:

We have grouped bank stability, sedimentation, and reservoir drawdown tasks together as they are related. Sediment deposition at the top of the channel bank adds weight and can cause bank failure. Also, changes in water levels in the channel will affect pore water pressures in the banks and could lead to bank failure.

1. Bank Stability
    a. Rosgen Analysis and Recommendations

    The MN DNR has expressed their concern that the Rosgen Level III Analysis was incomplete, specifically worksheets 3-14, 3-18 & 3-19. WEST did not find any bars when they did their fieldwork and the USGS did not notice bars in the Red River when they complete their 2012 sediment sampling when water levels were very low. The DNR suggested the COE contact Dave Rosgen directly for his perspective on the appropriate use and application of the Level III analysis and required data sampling due to the fine grained character of the Red River of the North sediments.

    USACE and Barr Engineering had a teleconference with Dave Rosgen on 1/18/13. During this teleconference Dave spent a few hours looking at the data and provided his viewpoint on the appropriateness of his methods and tools for the Red River. His views are listed below.

    - POWERSED does not apply for colloidal sediments
    - Bar samples represent an alternative to sub-pavement samples, but do not apply in absence of bedload
    - Dimensionless rating curve tends to over-predict suspended sediment for flood flows, and under-predict suspended sediment for lower flows. (See Graph on Page6.)
    - Dave felt that the previous operational plan of using the diversion channel every 3 to 5 years would have caused detrimental impacts to the channel and staging area. He was glad to hear that our current operational plan of the diversion only being used for a 10-yr and larger flood is a significant improvement. Dave doesn't expect that we'd see large amounts of deposition in the staging area give the colloidal sediments and relative short

detention durations (10-15 days on the floodplain). He felt the project wouldn't have significant impacts especially downstream of the diversion channel.

Dave Rosgen suggested some tasks that should be done to further evaluate stream stability. The recession limb of the flood hydrograph will be critical for bank stability.

- Look at failure mechanics under existing and proposed conditions – identify priority areas that are particularly susceptible. A Geotechnical analysis could be done to model the worst case scenario (banks completely saturated with added maximum sediment to banks, and water level at normal height) to see what the factors of safety would be under these conditions. This worst case should be qualified with a probability of occurrence, so the risk associated with this worst case is considered. At the very least, we should have Geotech confirm that the reservoir drawdown rates are acceptable (will not result in bank sloughing) and if not, determine appropriate drawdown rates to minimize drastic changes in pore water pressure of the streambanks.
- Look at the inflow from Red and Wild Rice Rivers in the staging area (affected by backwater)and consider the recession of the hydrograph from the staging
- Look at nature of banks including riparian vegetation on banks and degree of incision. If channel is incised then the influence of contained flow may increase channel erosion.
- Find a similar situation to assess potential failure mechanisms (Horace Diversion)
- Talk to Andy Simon or Eddy Langendoen – BSTEM and changes in pore water pressure leading to streambank failure. BSTEM has been applied widely to silt and cohesive systems.

b. Sedimentation

The MN DNR has expressed their concern regarding sedimentation in the staging area post-project, specifically the thickness of the sediment deposits at the banks (which could possibly lead to rotational failure) and the effect of sedimentation on and around riparian vegetation. To guide the future monitoring plan for the staging area, USACE has attempted to roughly estimate the thickness and nature of deposition for a given event. To reduce the uncertainty of this estimate, measurements from the 2010 and 2011 high flow events were used to predict the sediment deposition if an event of similar magnitude were to occur after the construction of the project. Future changes to sediment supply and frequency of high-flow events were not considered in this analysis. Even using a conservative approach (assuming 100% deposited, limiting deposition to low-lying areas, etc), the thickness of deposition estimated was relatively small (~ 0.2 in). This is not to say that thicker deposits will not be found following a flood event, although they are likely to be uncommon. Possible locations of thicker deposits could be on the crests of natural levees. Levee accretion could possibly explain the thick deposits found near the banks of the Maple River near the downstream confluence with the Sheyenne following the 2011 event. A higher

concentration of sand is found on the Maple and Sheyenne Rivers compared to the Red and Wild Rice Rivers within the staging area. Deposits at this location were approximately 6 inches thick which would correlate to a ~10% change in slope height assuming the original slope was approximately 1-2%. We would recommend identifying areas where non-uniform deposition could possibly occur, specifically areas where there is an identifiable natural levee or areas where higher concentration of course-grained sediment is found. (See the more complete explanation of the rough estimate of sedimentation starting on Page 7.)

2. Reservoir Drawdown
   The length of inundation of the staging area has been a concern expressed by the MN DNR. Increased inundation duration can cause tree mortality and causes bank saturation.

   a. Hydrographs and Inundation Mapping
      The Red River at Oxbow stage hydrographs with and without project for the 20-yr and 100-yr events are included in this packet. The stage hydrograph is plotted on top of the river cross section at Oxbow to illustrate the length of time the river will be above the channel banks and floodplain.

   b. Drawdown Rates and Proposed Geotech Analysis
      Dave Rosgen emphasized the importance of the role that the rate of water level drawdown in the staging area on the recession limb of the hydrograph plays in bank stability. The rate of water level drop has to be slow enough that the groundwater level in the streambank is dropping at a rate similar to the water level drop in the channel. If the water level in the channel is low, the unsupported saturated channel banks can have a rotational failure. The rotational failure is also a function of the streambank slope.
      A geotechnical stability analysis is proposed to examine rotational failure at different combinations of water levels and groundwater levels. Appropriate drawdown rates will need to prevent bank failures due to rapid changes in water levels. The operational plan may need to be adjusted based on results of the geotechnical stability analysis.

ENERGY GRADIENTS:

Small tributaries and ditches flowing into the Red River of the North within the protected area are not expected to have significant changes in energy gradients or velocity changes resulting from the construction of the project. Due to their small drainage basins, major flood peaks will flow into the RRN before the RRN reaches peak flows. This point is summarized in the MN DNR's technical report, *Procedures and Requirements for Flood Hazard Evaluation* (1980):

> *The probability of major flood peaks (such as the regional flood) occurring simultaneously at the confluence of a minor tributary and a large main-stem stream is considerably less than one percent.*

Furthermore, the project will not be affecting flows smaller than a 10-year flood event because the diversion channel will not be in flood operation mode.

See Page 16.

Energy gradients were looked at in terms of shear stress and erosion potential.

1. Rush River Upstream of the Diversion
    a. The tailwater on the diversion may be lower than existing conditions provided for tributaries such as the Rush River.
    b. Measures are being taken to raise the stage in the Rush River and reduce the drawdown effect.
    c. More analysis will have to be performed to ensure the higher shear and velocity will not downcut the tributaries.

2. Red River at Oxbow
    a. The project will tend to reduce velocities and shear stresses in the Red River channel due to the increase in water surface from the control structure.
    b. The energy slope/water surface slope of the with project model is never steeper than the slope of the existing conditions model. The water is regulated too slowly to have a rapid drawdown of the pool that would increase the chance for erosion.

OPERATIONAL PLAN:

1. Proposed Operational Plan from EAW

    The project would go into operation when it becomes necessary to lower the Red River and Wild Rice River control structure gates so that a stage of 35.0 is not exceeded at the USGS gage in Fargo. At this stage, the flow through Fargo will be approximately 17,000 cubic feet per second, or cfs. A flow of 17,000 cfs at the Fargo gage is approximately a 10% chance or 10-year flood event. Once the gates are lowered, water would begin to inundate the upstream staging area and would begin to flow into the diversion. A stage of 35.0 would be maintained at the Fargo gage until the upstream staging elevation reaches 922.2 NAVD 88 (the staging elevation would just reach elevation 922.2 for the 1% (100-year) event). Once the upstream staging elevation reaches 922.2, the Red and Wild Rice River control structures would be opened as necessary to maintain the upstream staging elevation of 922.2 while not exceeding a stage of 40.0 at the Fargo gage (a stage of 40.0 would occur for the expected 0.2% (500-yr) event). Once a stage of 40.0 is achieved at the Fargo gage, a stage of 40.0 would be maintained by allowing flow to exit the upstream staging area over the overflow embankment at elevation 922.2 until the upstream staging water surface rises to an elevation that provides a minimum acceptable height of freeboard on the tie-back embankments. The expectation is that emergency measures would be employed within the risk reduction area to reduce flood damages when the stage is between 35.0 and 40.0. If the upstream staging water surface elevation is forecasted to reach the point of minimum acceptable freeboard, an evacuation order would be issued for the Fargo-

Moorhead metro area. Once the upstream staging elevation reaches the point of minimum acceptable freeboard, the Red and Wild Rice River control structures would be opened further to maintain the minimum freeboard, and stages would rise above 40.0 at the Fargo gage.

See Page 32.

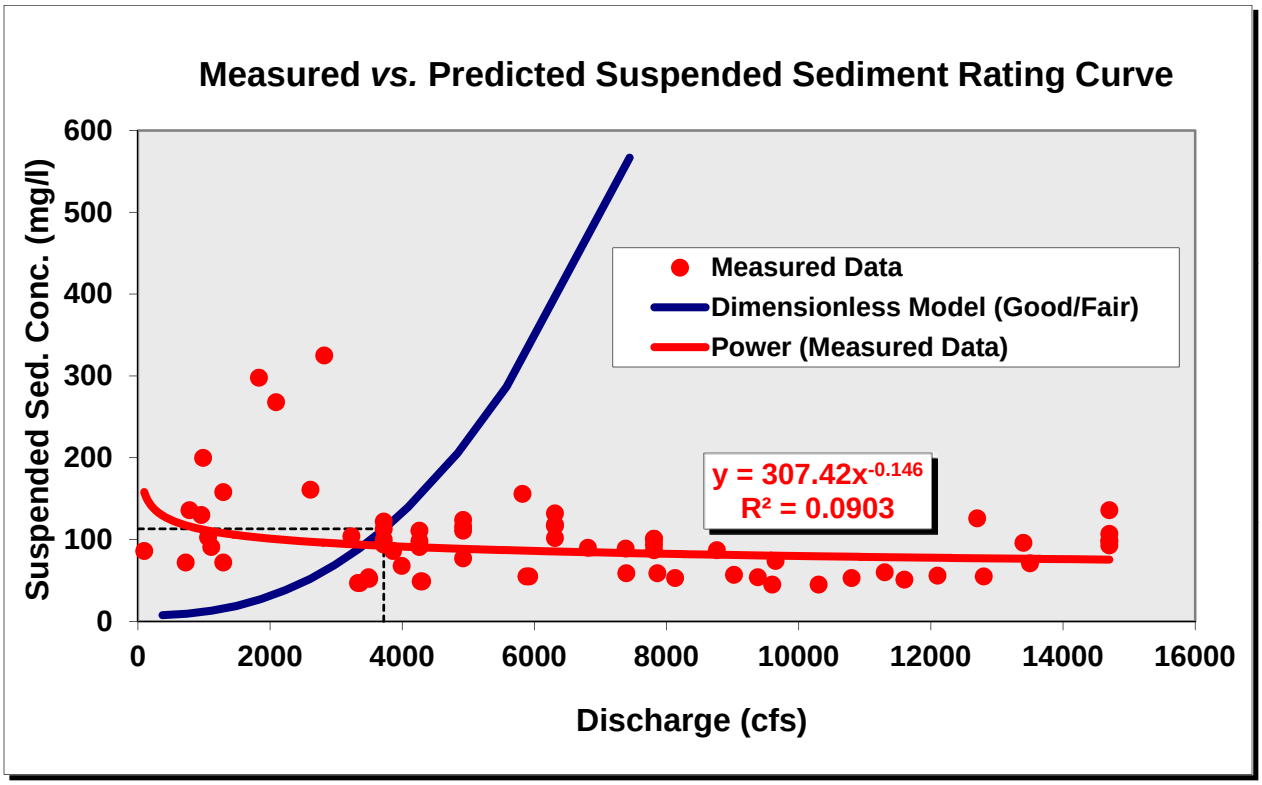
2. Possible Operational Plan Adjustments based on reservoir drawdown rate analysis

The geotechnical analysis may show that the reservoir drawdown needs to happen more gradually to avoid bank failures. However, we realize that if reservoir drawdown happens more slowly this would increase the duration of floodplain inundation which would further increase concerns of tree mortality. The bank failure issue is only a concern for steeper slopes and would not apply to the overall floodplain. One possible drawdown scenario could entail a more rapid drawdown over the flat floodplain, but have the drawdown slower in the near channel area. This would be an issue both USACE and environmental agencies would want to work together to resolve.

MONITORING PLAN:
We think locations with natural levees should be specifically monitored, but want assistance identifying the locations. Items will need to be added to the monitoring plan as we proceed and DNR input will be very important to the final monitoring plan.

Rosgen Analysis and Recommendations

Dave Rosgen expected the sediment rating curve of the measured data to be similar to the dimensionless model line shown below. He had never seen a flat sediment rating curve before. Dave felt that the models he usually uses do not apply to our streams.



Rough Estimation of Sedimentation in the Staging Area Post-Project

Background

The MN DNR has expressed their concern regarding sedimentation in the staging area post-project, specifically the thickness of the sediment deposits at the banks (which could possibly lead to rotational failure) and the effect of sedimentation on and around riparian vegetation. To guide the future monitoring plan for the staging area, USACE has attempted to roughly estimate the thickness and nature of deposition for a given event. To reduce the uncertainty of this rough estimate, measurements from the 2010 and 2011 high flow events were used to predict the sediment deposition if an event of similar magnitude were to occur after the construction of the project. Future changes to sediment supply and frequency of high-flow events were not considered in this analysis.

Several factors control the nature of deposition on a floodplain, specifically the suspended sediment concentration in the channel, the grain-size distribution of the sediment supply, and the floodplain vegetation and topography. The USGS conducted a study in the spring of 2010 and 2011 and measured the suspended sediment concentrations (SSC), loads, and particle-size distributions in the Red River of the North and the surrounding tributaries during the high-flow events. The measurements taken at the Fargo gage (USGS station number 05054000) were used in this analysis because it is the first sediment sampling site downstream of the staging area on the RRN and should be fairly representative of the sediment and flow through the staging area. There are no major tributaries between the Wild Rice-Red River confluence and the Fargo gage, and the Red and Wild Rice Rivers have similar sediment concentrations, so the sediment measurements at the Fargo gage are assumed to be representative of the Red and Wild Rice Rivers within the staging area.

The peak flows measured at the Fargo gage for the 2010 and 2011 high-flow events were 21,000 and 27,200 cfs, respectively; the peak flow for a 20-yr event at the Fargo gage is approximately 22,000 cfs. The suspended sediment samples at the Fargo gage show that greater than 90% of the suspended material are finer than sand and that the suspended sediment accounts for over 99% of the total sediment. Additional information from the USGS 2010 and 2011 reports is given in Table 1.

Table 1: USGS Measurements for the 2010 and 2011 High Flow Events

	2010 High-Flow Event	2011 High-Flow Event
Peak Flow (cfs)	21,200	27,200
Duration (days)	15	42
Total Sediment Load (tons)	76,300	110,000
Median Streamflow (cfs)	16,500	17,400
Median SSC (mg/L)	116	92

Suspended sediment concentration (SSC) and particle size distribution are two controlling factors in lateral and vertical floodplain accretion. Typically, large grain sediment (sands and gravels) tend to drop out very close to channel banks contributing to vertical accretion (Ritter et. al, 2002); deposits become finer and thinner at greater lateral distances from channel banks (Kessel, et. al, 1974). Near-bank vertical accretion leads to natural levee growth. When sediment supply is predominantly fine-grained material, the degree of fining from the banks is lessened and natural levees have greater widths and shallower slopes, deposits are thinner and dispersed farther from the channel bank (Hudson and Heitmuller, 2003; Asselman and Middlekoop, 1995).

Procedure

Several cross-sections were analyzed along the RRN within the staging area. Many of the cross-sections analyzed had very little change in topography (flat lateral slopes) as shown at STA 2599647 (Fig 2). The staging area has been an active floodplain. The nature of the flat slopes suggests that overbank deposition is predominantly thin and laterally dispersed. Near bank depressions were also common in the staging area- these depressions represent sloughs, abandon channels or oxbow lakes (Fig 3). Natural levees were fairly difficult to identify given their shallow slopes. STA 2619494's right bank had the most pronounced natural levee of the cross-sections analyzed (Fig 4 and 5). Given the natural topography in the staging area, the USGS measurements and the research available on the subject, the following assumptions were made regarding how sediment would deposit in the staging area for a flood similar to the 2010 or 2011 event:

1. The majority of the sediment will settle out uniformly along the floodplain due to the fine grained nature of the suspended sediment load. For an event similar in size to the 2010 or 2011 flood, most of the deposition would be contained within low-lying areas surrounding the channel. Low-lying areas were identified as areas that are inundated for a 10-yr event with the project (see Figure 1). The total area of inundation is approximately 7000 acres (compared to ~17,000 acres that are inundated for a 20 yr event).

2. As stated above, local non-uniform deposition is more likely where natural levees are present.

To estimate uniform deposit on the floodplain, the total sediment load was divided by the event duration. The time the water is retained in the staging area was estimated to be 30 days and during this period 100% of the sediment was assumed to deposit within the low-lying area. The dry unit weight of the deposited material was assumed to be 1.5 tons/m^3(85 lbs/ft^3). Given these assumptions, the total thickness of a uniform deposition for the 2010 event would be 0.22 in and 0.11 in for the 2011 event.

STA 2619494 right levee slope was adjusted by 0%, 10%, and 20% to estimate deposit thickness resulting from levee slope steepening. This levee was chosen because its slope is representative of the other levee slopes that were identified in cross-section (Table 2). The maximum deposition

resulting from levee accretion for these four scenarios are given in Table 3 and shown in Fig 5; for slope to change, deposition will be thickest at the channel banks. Given the grain size distribution of the sediment supply, the estimated range of slope change is between 0 and 20% (Smith, et. al, 2008). This exercise was only done for the 2010 event.

Table 2: Levee Slopes in Staging Area

Stations with identifiable Levees	Left Bank (ft/ft)	Right Bank (ft/ft)
STA 2619494	0.012	0.014
STA 2568232	0.003	0.015
STA 2557350	0.010	0.01

Table 3: Maximum Deposition at channel banks resulting from Levee Accretion

	Levee Slope Change (%)		
	0	10	20
Deposit Thickness at Channel Bank (in)	0.22	5.4	10.9

Conclusions

The purpose of this exercise was to provide a rough estimate of sediment deposition on the staging area for an event similar to the 2010 or 2011 high-flow events. This should be considered a rough estimate because many factors were not or could not be accounted for without using more involved process (such as a numerical model). Even using a conservative approach (assuming 100% deposited, limiting deposition to low-lying areas, etc), the estimated thickness of deposition is relatively small. This is not to say that thicker deposits will not be found, although they are likely to be uncommon. Possible locations of thicker deposits could be on the crests of natural levees. Levee accretion could possibly explain the thick deposits found near the Maple River banks (near the downstream confluence with the Sheyenne) following the 2011 event (Fig 6). A higher concentration of sand is found on the Maple and Sheyenne Rivers compared to the Red and Wild Rice Rivers within the staging area. Deposits at this location were approximately 6 in thick which would correlate to a ~10% change in slope height assuming the original slope was approximately 1-2%.

From the results of this analysis, we would recommend identifying areas where non-uniform deposition could possibly occur, specifically areas where there is an identifiable natural levee or areas where higher concentration of coarse-grained sediment is found.

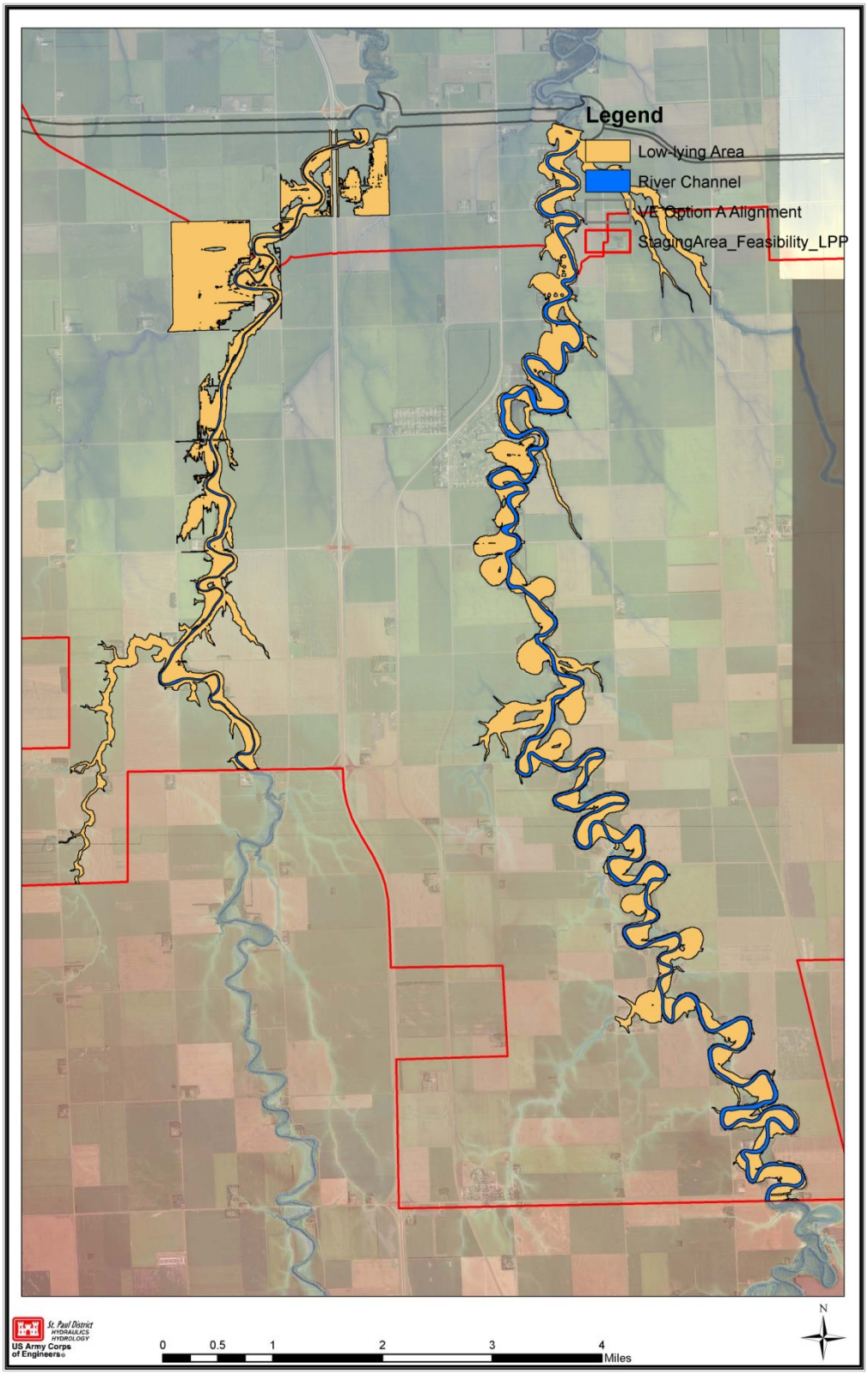


Figure 1: Channel Banks and low-lying area in the staging area

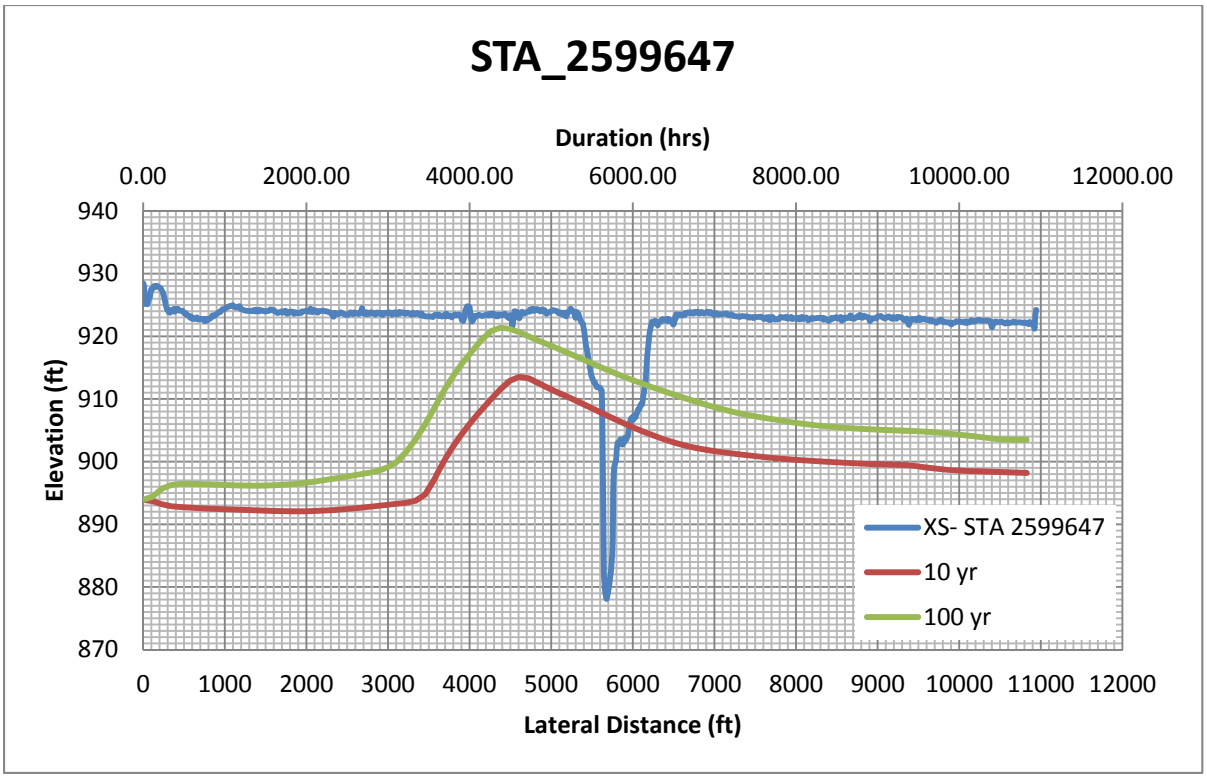


Figure 2: Sta 2599647- Typical flat topography

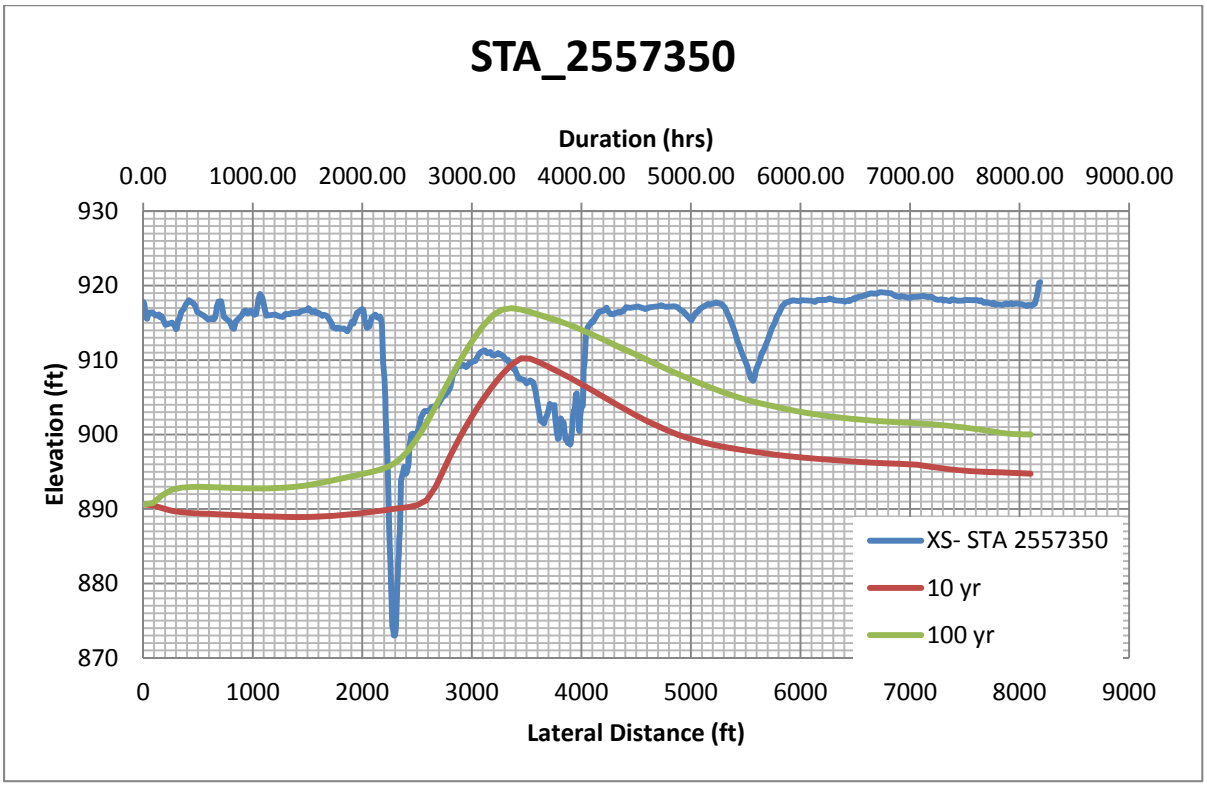


Figure 3: STA 2557350- channel with nearby low-lying area

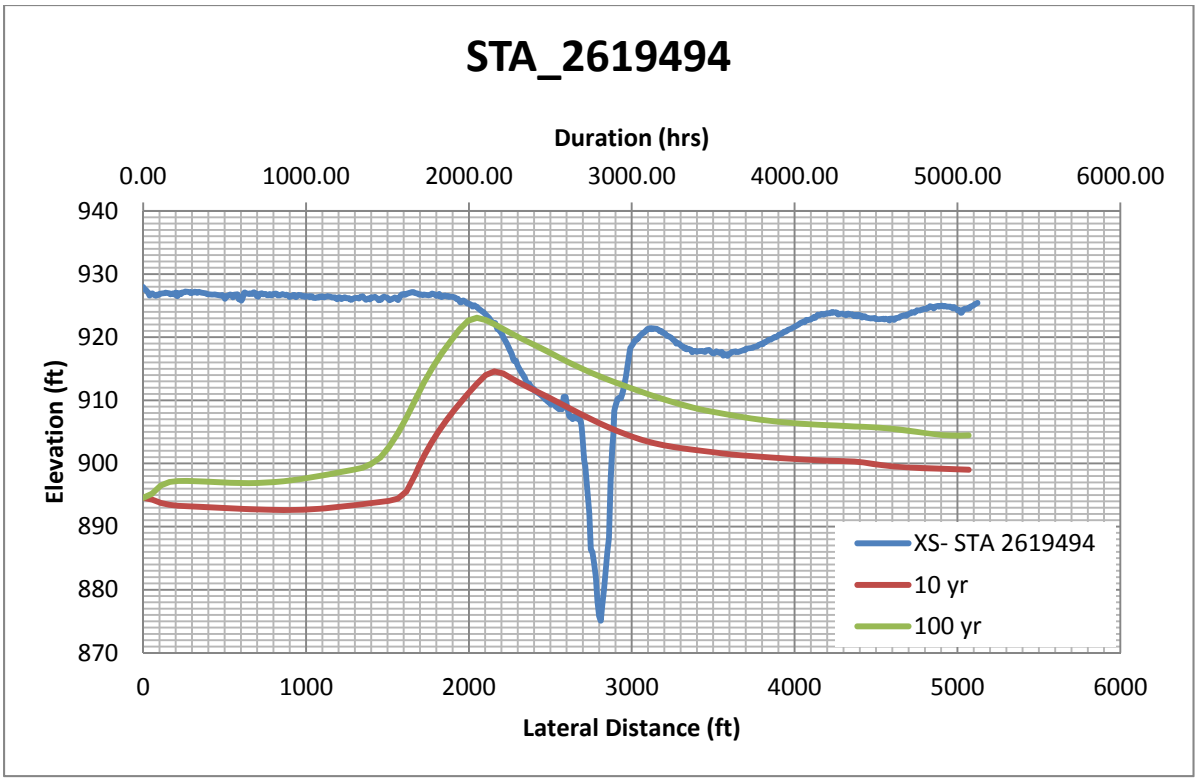


Figure 4: STA 2619494- cross section with natural levee (right bank)

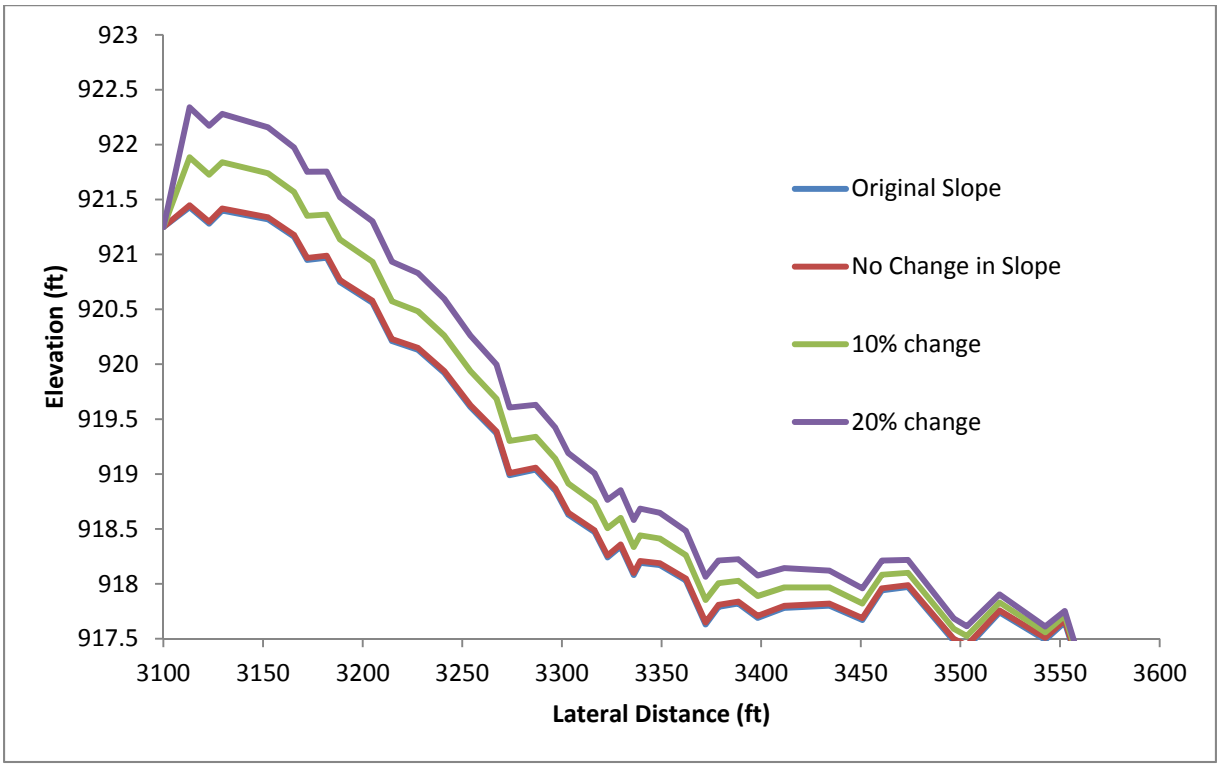


Figure 5: Levee Accretion for Right Levee at STA 2619494

Figure 6: Overbank Deposits on the Maple River Banks following the 2011 high-flow event

Works Cited

Asselman, N.E.M., Middlekoop H. "Floodplain sedimentation: quantities, patterns and processes." *Earth Surface Proceses and Landforms* (1995): 481-499.

Dale F. Ritter, R Craig Kochel, Jerry R. Miller. *Process Geomorphology*. Long Grove, Illinois: Waveland Press, Inc, 2002.

Joel M. Galloway, Robert A. Blanchard, Christopher A. Elison. "Sediment Concentrations, Loads, and Particle-Size Distributions in the Red River of the North and Selected Tributaries near Fargo, North Dakota, during the 2011 Spring High-Flow Event." 2011.

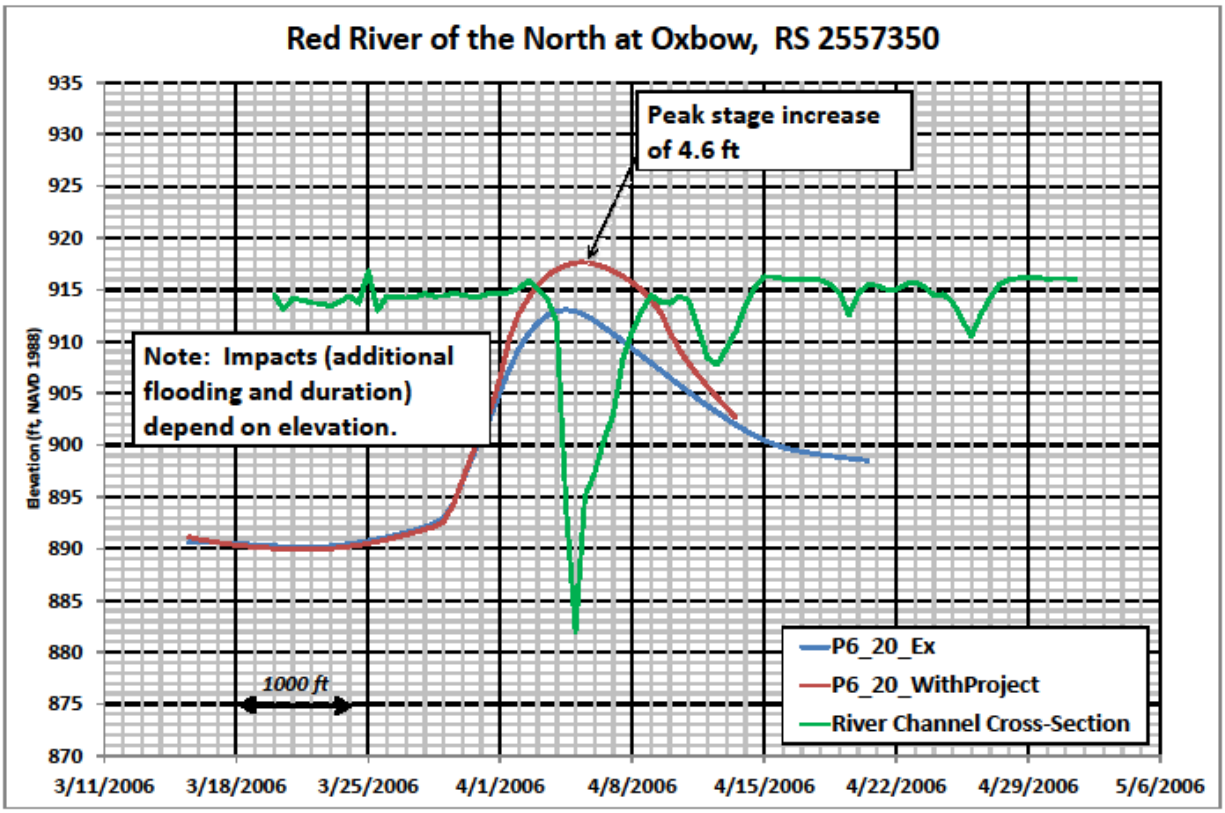
Kesel, R.H., Dunne, K.C., McDonald, R.C., Allison, K.R., Spicer, B.E. "Lateral erosion and overbank deposition on the Mississippi River in Louisiana caused by 1973 flooding." *Geology* (1974): 461-464.

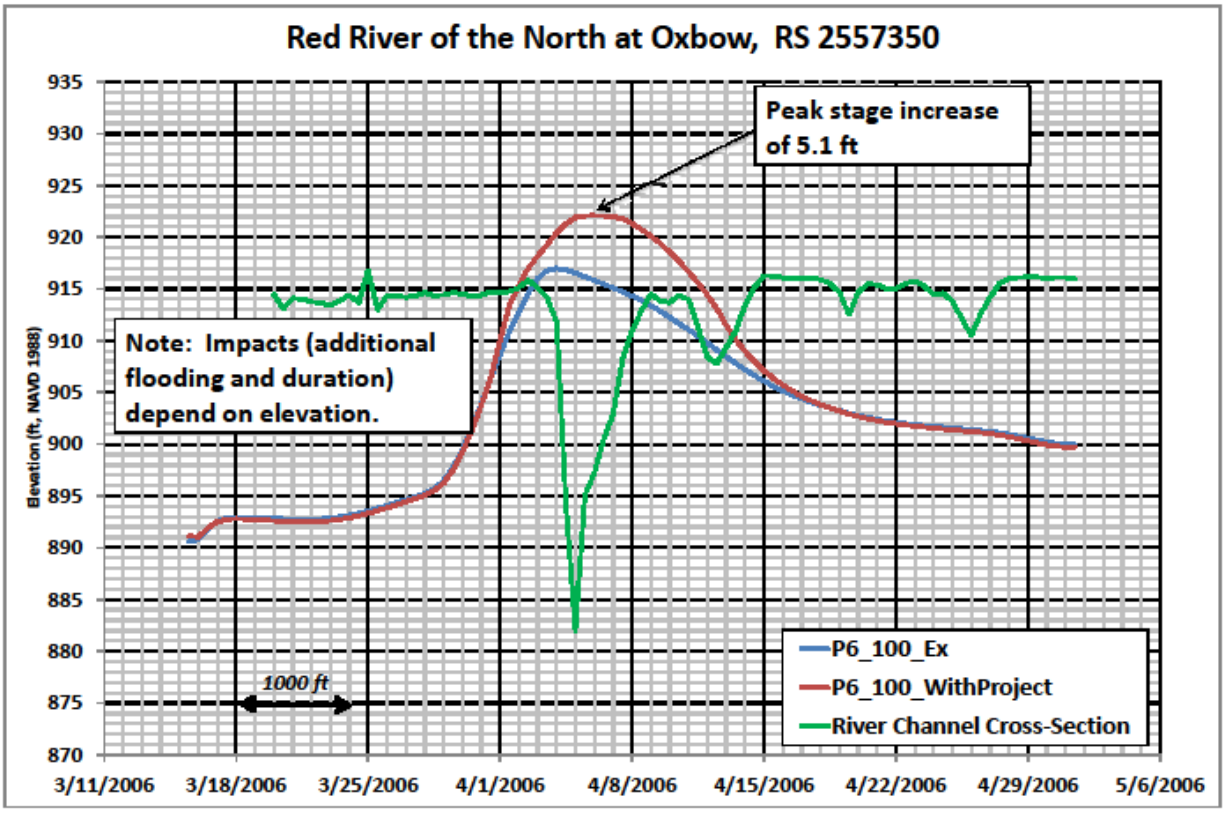
Norman D. Smith, Marta Preez-Arlucea. "Natural levee deposition during the 2005 flood of the Saskatchewan River." *Geomorphology* (2008): 583-594.

Paul F. Hudson, Franklin T. Heitmuller. "Local- and watershed-scale controls on the spatial variablility of natural levee deposits in a large fine-grained floodplain: Lower Panuco Basin Mexico." *Geomorphology* (2003): 255-269.

Robert A. Blanchard, Christopher A. Elison, Joel M. Galloway, Dennis A. Evans. "Sediment Concentrations, Loads, and Particle-Size Distributions in the Red River of the North and Selected Tributaries near Fargo, North Dakota, during the 2010 Spring High-Flow Event." 2011.

Reservoir Drawdown in Staging Area





ENERGY GRADIENTS

Allowable Velocities

Table 2-5
Suggested Maximum Permissible Mean Channel Velocities

Channel Material	Mean Channel Velocity, fps
Fine Sand	2.0
Coarse Sand	4.0
Fine Gravel[1]	6.0
Earth	
Sandy Silt	2.0
Silt Clay	3.5
Clay	6.0
Grass-lined Earth (slopes less than 5%)[2]	
Bermuda Grass	
Sandy Silt	6.0
Silt Clay	8.0
Kentucky Blue Grass	
Sandy Silt	5.0
Silt Clay	7.0
Poor Rock (usually sedimentary)	10.0
Soft Sandstone	8.0
Soft Shale	3.5
Good Rock (usually igneous or hard metamorphic)	20.0

Notes:
1. For particles larger than fine gravel (about 20 millimetres (mm) = 3/4 in.), see Plates 29 and 30.
2. Keep velocities less than 5.0 fps unless good cover and prope maintenance can be obtained.

Table 8–4 Allowable velocities

Channel material	Mean channel velocity (ft/s)	(m/s)
Fine sand	2.0	0.61
Coarse sand	4.0	1.22
Fine gravel	6.0	1.83
Earth		
Sandy silt	2.0	0.61
Silt clay	3.5	1.07
Clay	6.0	1.83
Grass-lined earth (slopes <5%)		
Bermudagrass		
Sandy silt	6.0	1.83
Silt clay	8.0	2.44
Kentucky bluegrass		
Sandy silt	5.0	1.52
Silt clay	7.0	2.13
Poor rock (usually sedimentary)	10.0	3.05
Soft sandstone	8.0	2.44
Soft shale	3.5	1.07
Good rock (usually igneous or hard metamorphic)	20.0	6.08

- U.S. Army Corps of Engineers. 1994. “Hydraulic Design of Flood Control Channels”. Engineer Manual 1110-2-1601, U.S. Army Corps of Engineers, Washington, D.C.
- Natural Resource Conservation Service. 2007. “Part 654 Stream Restoration Design National Engineering Handbook”. U.S. Department of Agriculture, Washington, D.C.

Permissible Shear Stress in the Manitoba Floodway Design

TABLE3-2
PRELIMINARY DESIGN CRITERIA FOR MAXIMUM
PERMISSIBLE SHEAR STRESS IN EXPANDED FLOODWAY
CHANNEL

Bed Material	Maximum Shear Stress (Pascals)	Source
Bare Clay	0.17 psf	Calculated from stress in Low Flow Channel that caused erosion
Bare Sand/Gravel	6 to 8	Ven te Chow[1]/ USDT
Bare Glacial Till	29	Ven te Chow[1]/ USDT
Grass-Covered Clay[3]	0.35 psf	USDT[4]
Grass-Covered Sand/Gravel[3]	17	USDT[4]
Grass-Covered Glacial Till[3]	29	USDT[4]

NOTES:
1. "Open-Channel Hydraulics", by Ven te Chow, 1959
2. "Design of Roadside Channels with Flexible Linings", U.S. Department of Transportation, 1988.
3. Coverage by grass or equivalent vegetation that is suitable for protection against erosion.
4. The USDT criteria depend on the vegetative type and do not refer to soil characteristic.

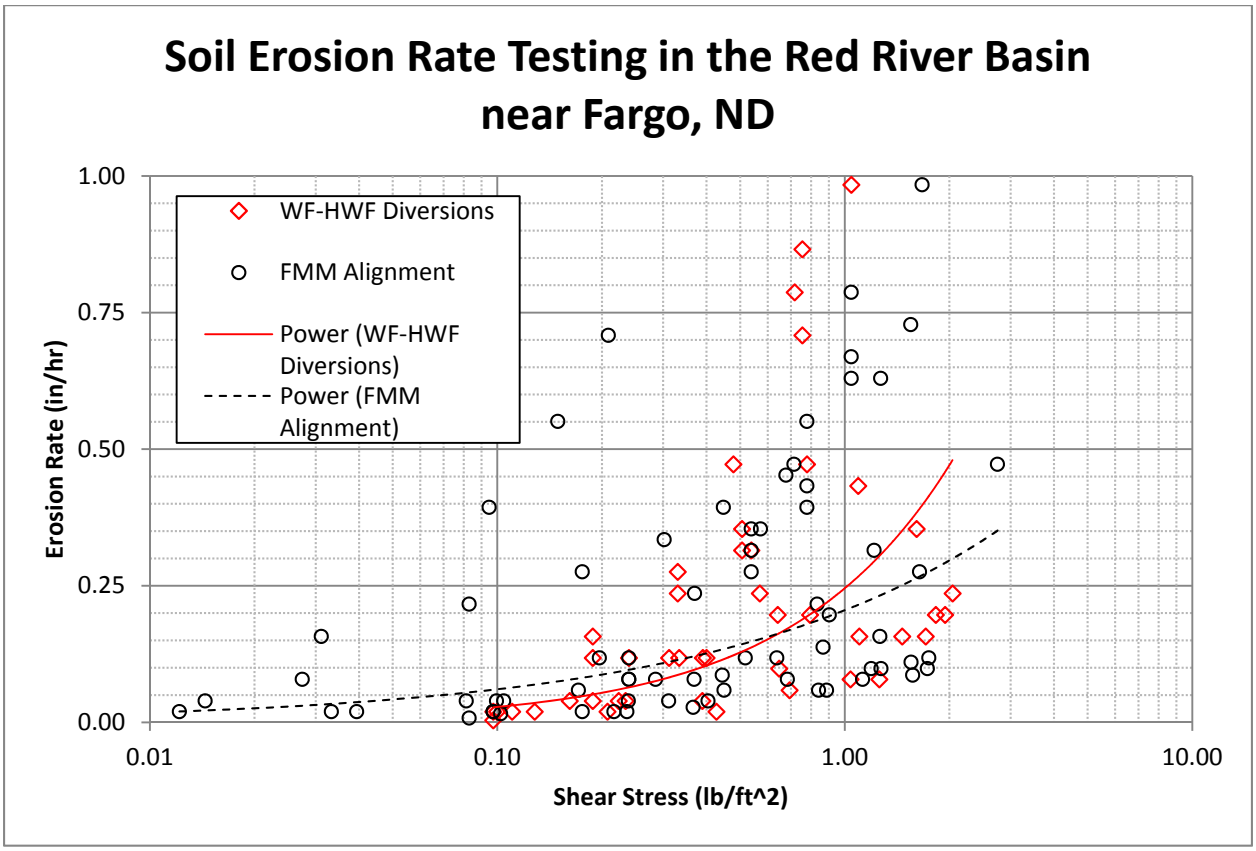
- KGS Group. 2003. "Preliminary Engineering Report for the Manitoba Floodway Expansion".

Permissible Shear Stress and Velocity

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N

- Fischenich, C. (2001). "Stability Thresholds for Stream Restoration Materials," EMRRP Technical Notes Collection (ERDC TNEMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

FMM Erosion Rate Testing



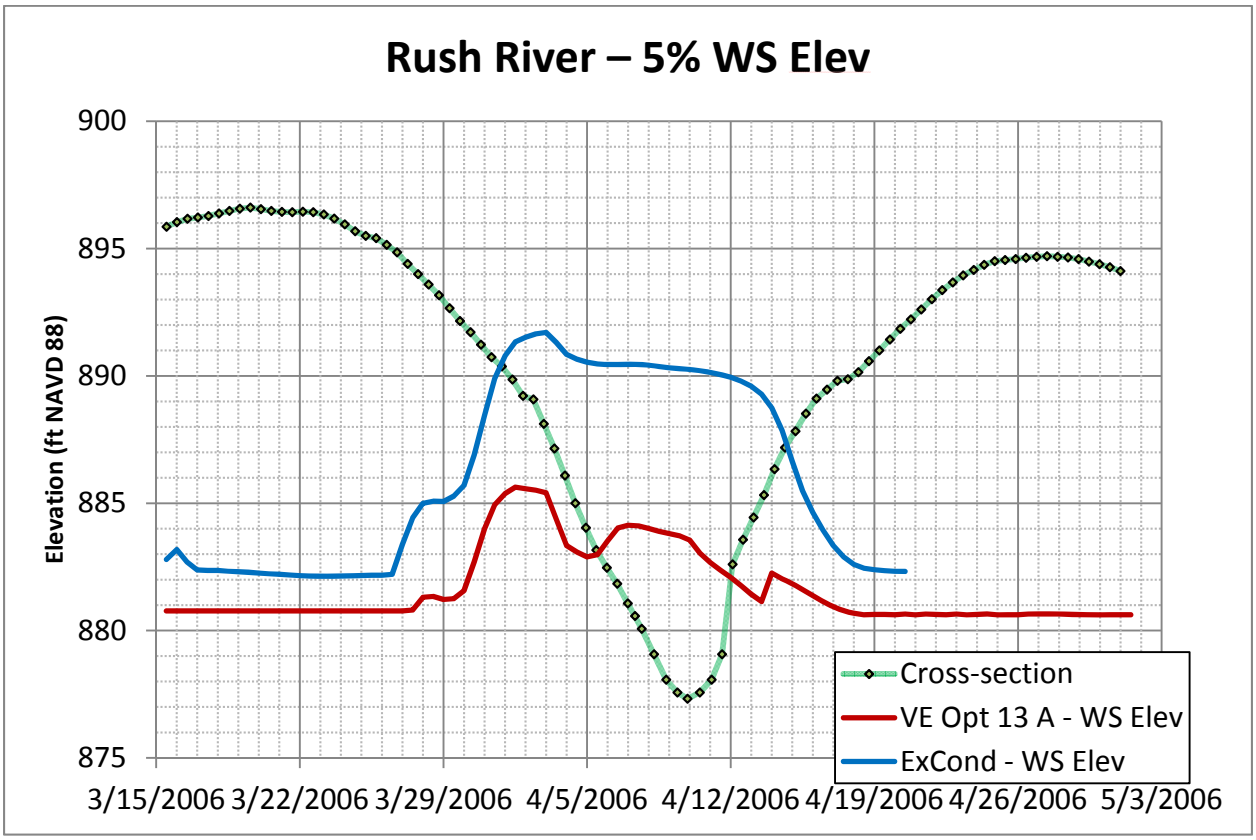
Summary of Shear Stress and Erosion Potential

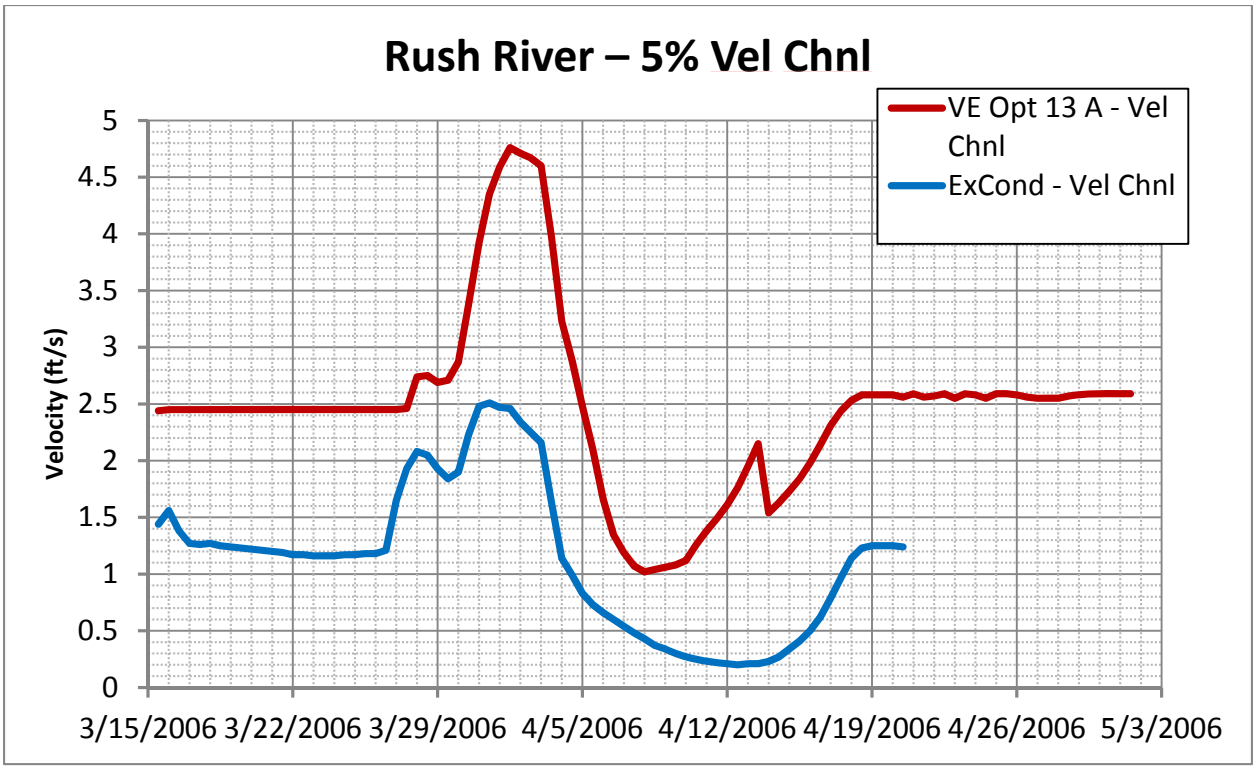
- Shear Thresholds

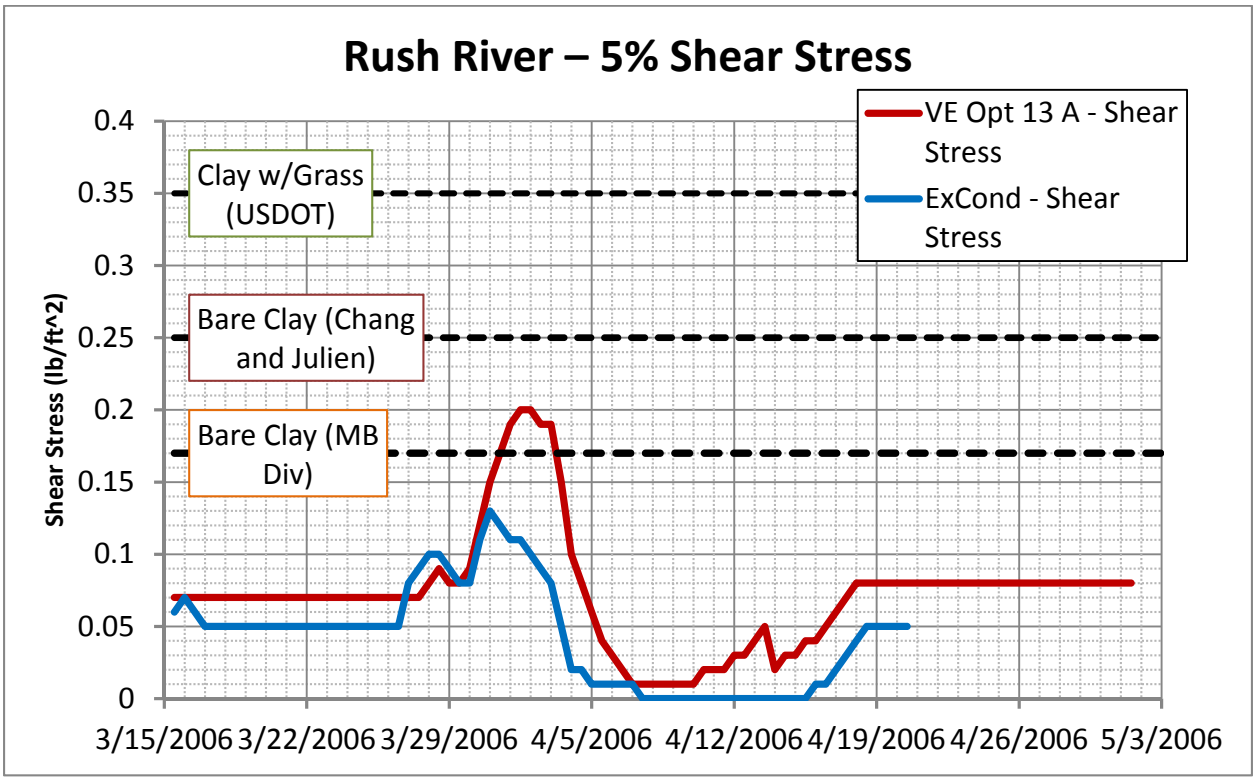
Shear (lb/ft^2)	Material	Source
0.17	Bare clay	Estimated based on performance of Manitoba Floodway
0.26	Bare clay	Chang (1988) and Julien (2001)
0.35	Grass-covered clay	USDOT (1988)

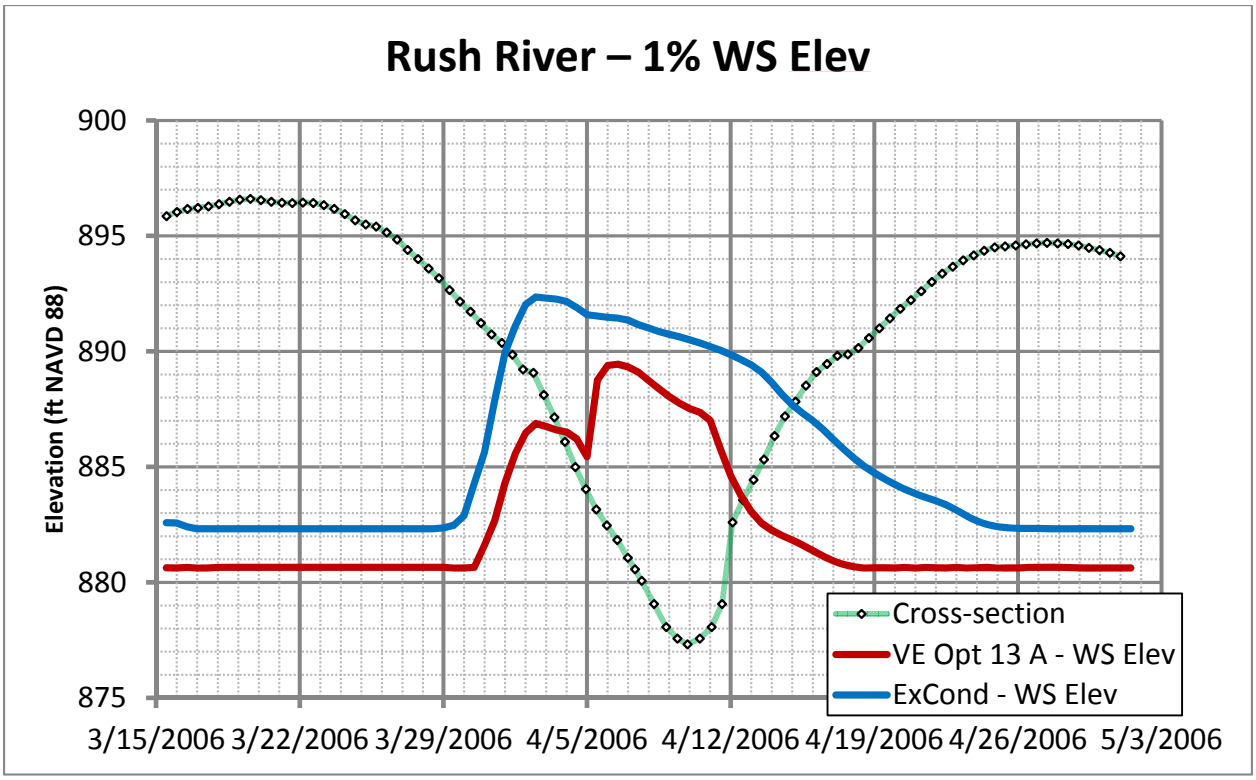
- Erosion rates are low even for shear stresses experienced during floods, and this shear stress would only be experienced for a short duration (a few days).

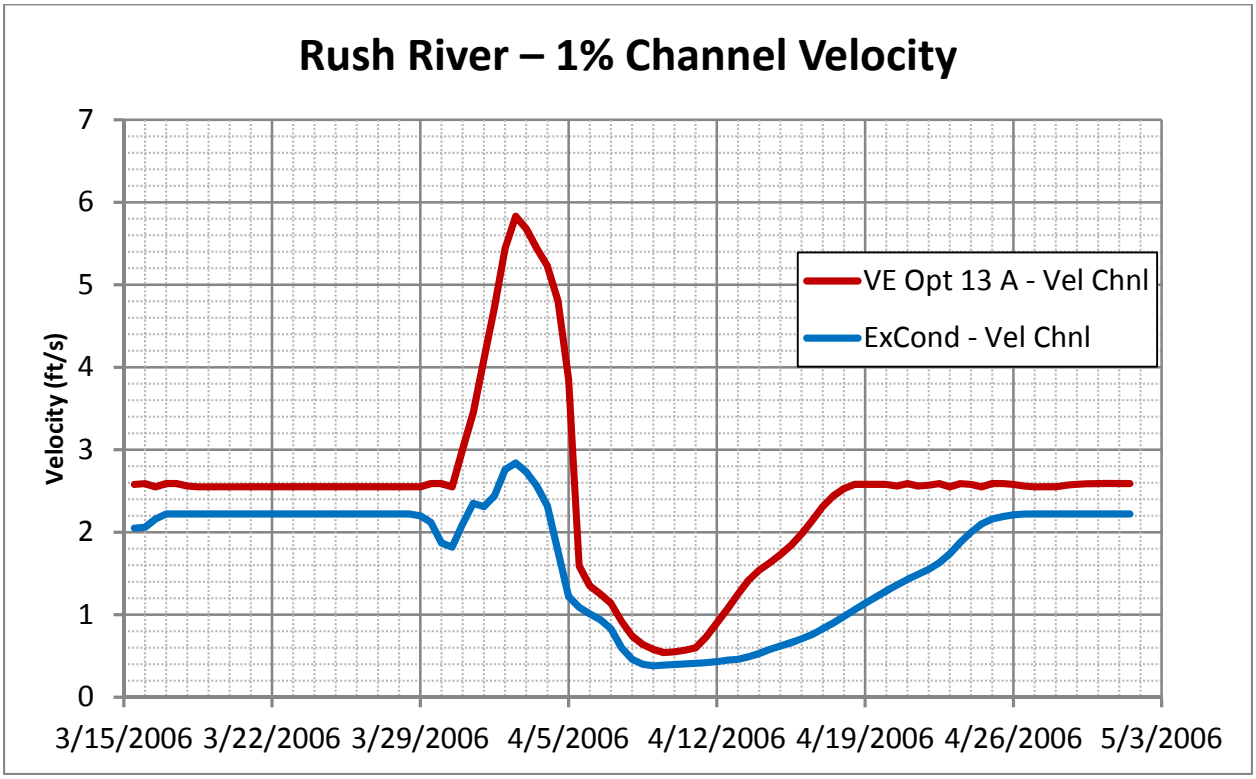
Tributaries Emptying into the Diversion - Rush River upstream of the Diversion

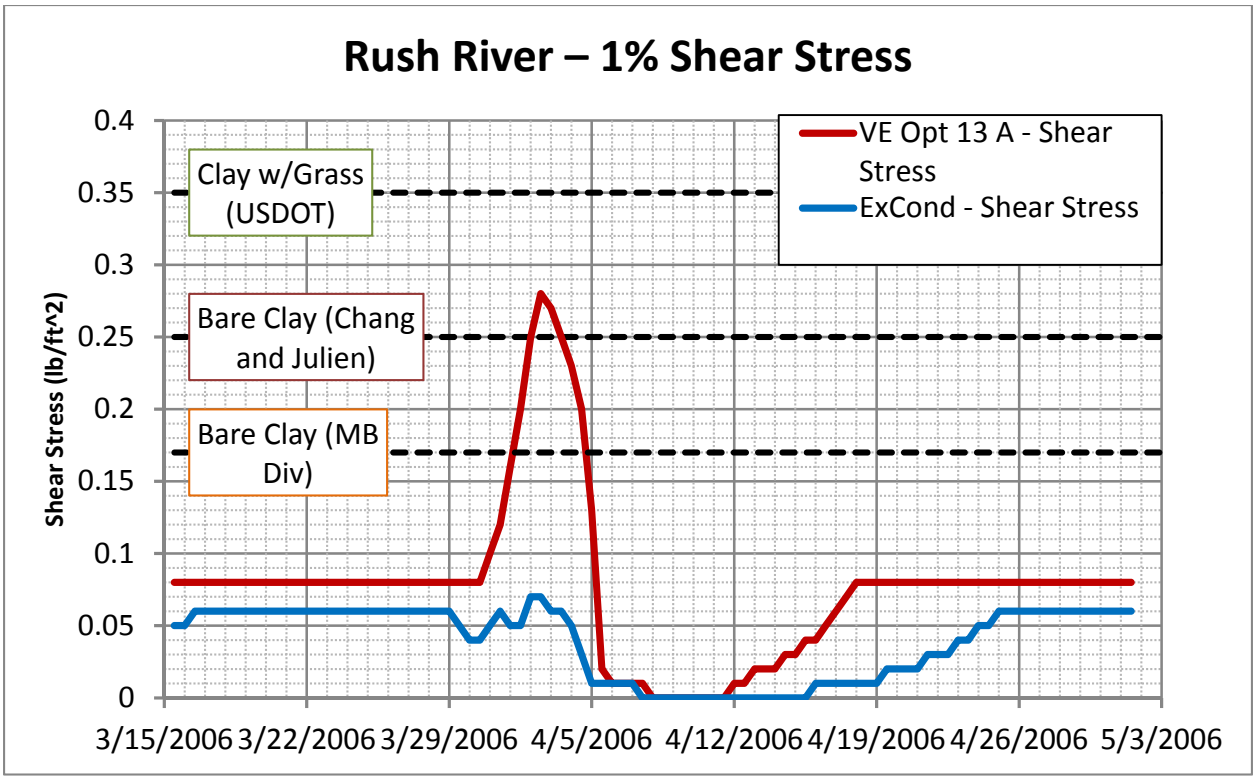



Rush River – 5% Vel Chnl
VE Opt 13 A - Vel Chnl
ExCond - Vel Chnl
Velocity (ft/s)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006


Rush River – 5% Shear Stress
VE Opt 13 A - Shear Stress
ExCond - Shear Stress
Clay w/Grass (USDOT)
Bare Clay (Chang and Julien)
Bare Clay (MB Div)
Shear Stress (lb/ft^2)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006


Rush River – 1% WS Elev
Elevation (ft NAVD 88)
900
895
890
885
880
875
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
Cross-section
VE Opt 13 A - WS Elev
ExCond - WS Elev


Rush River – 1% Channel Velocity
Velocity (ft/s)
7
6
5
4
3
2
1
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
VE Opt 13 A - Vel Chnl
ExCond - Vel Chnl



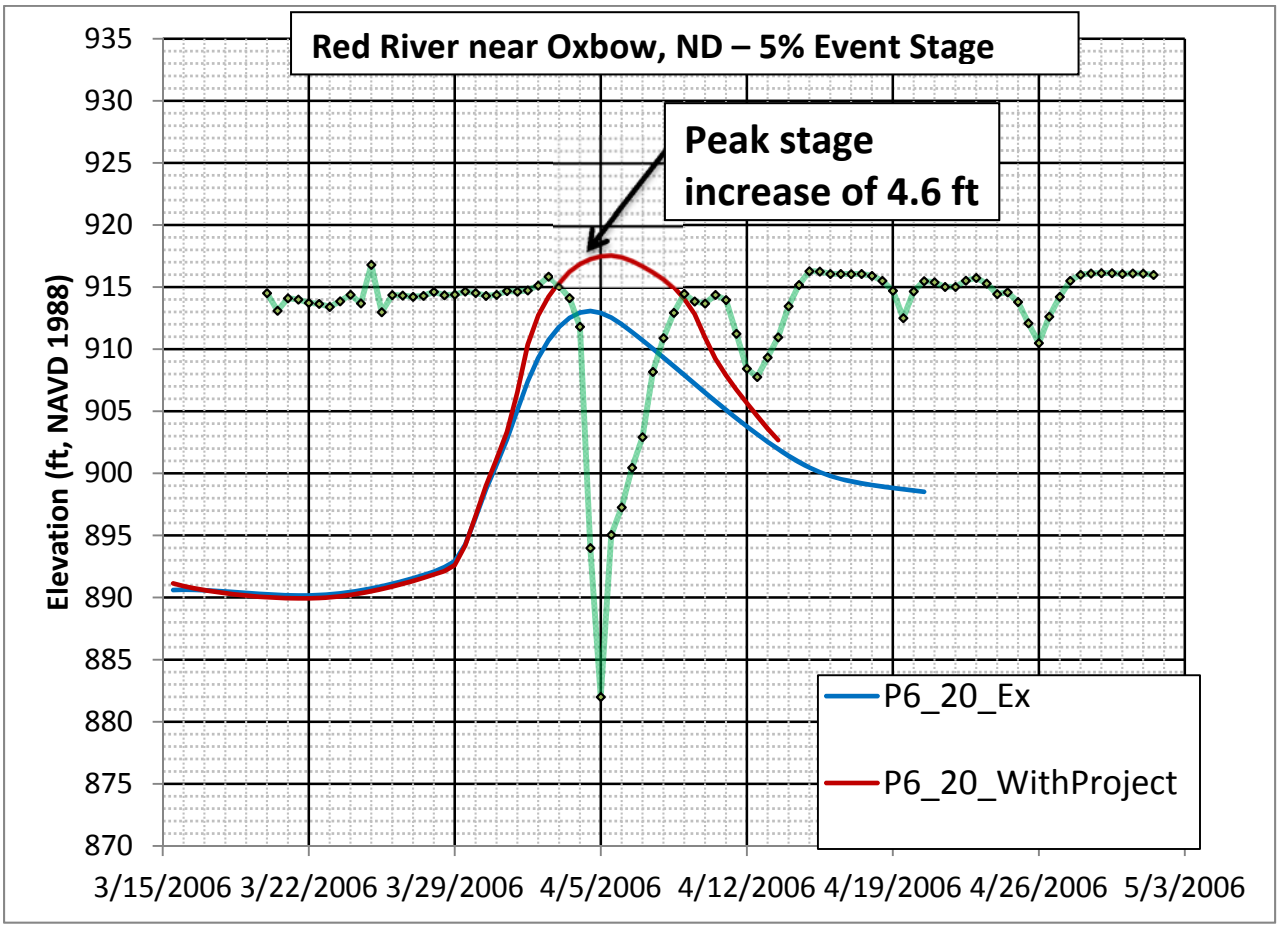
Summary of Tributaries Emptying into the Diversion

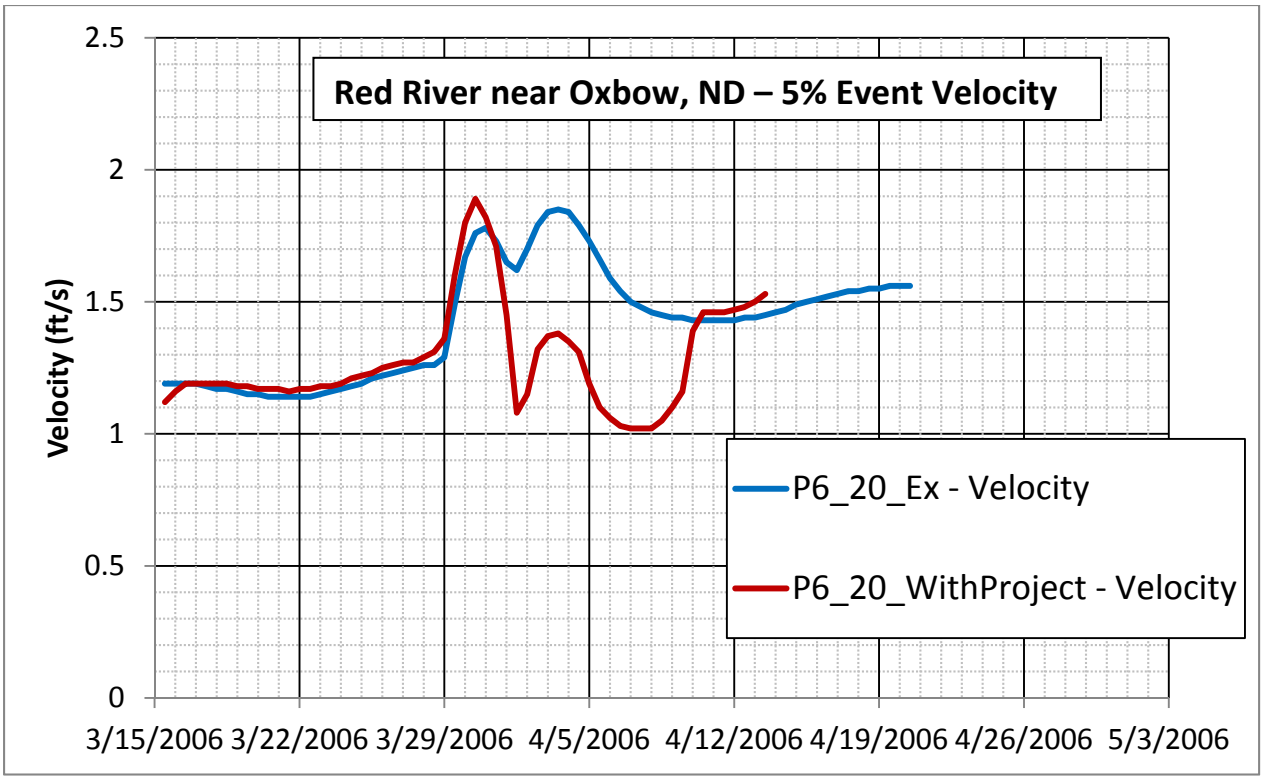
- The tailwater on the diversion may be lower than existing conditions provided for tributaries such as the Rush River.

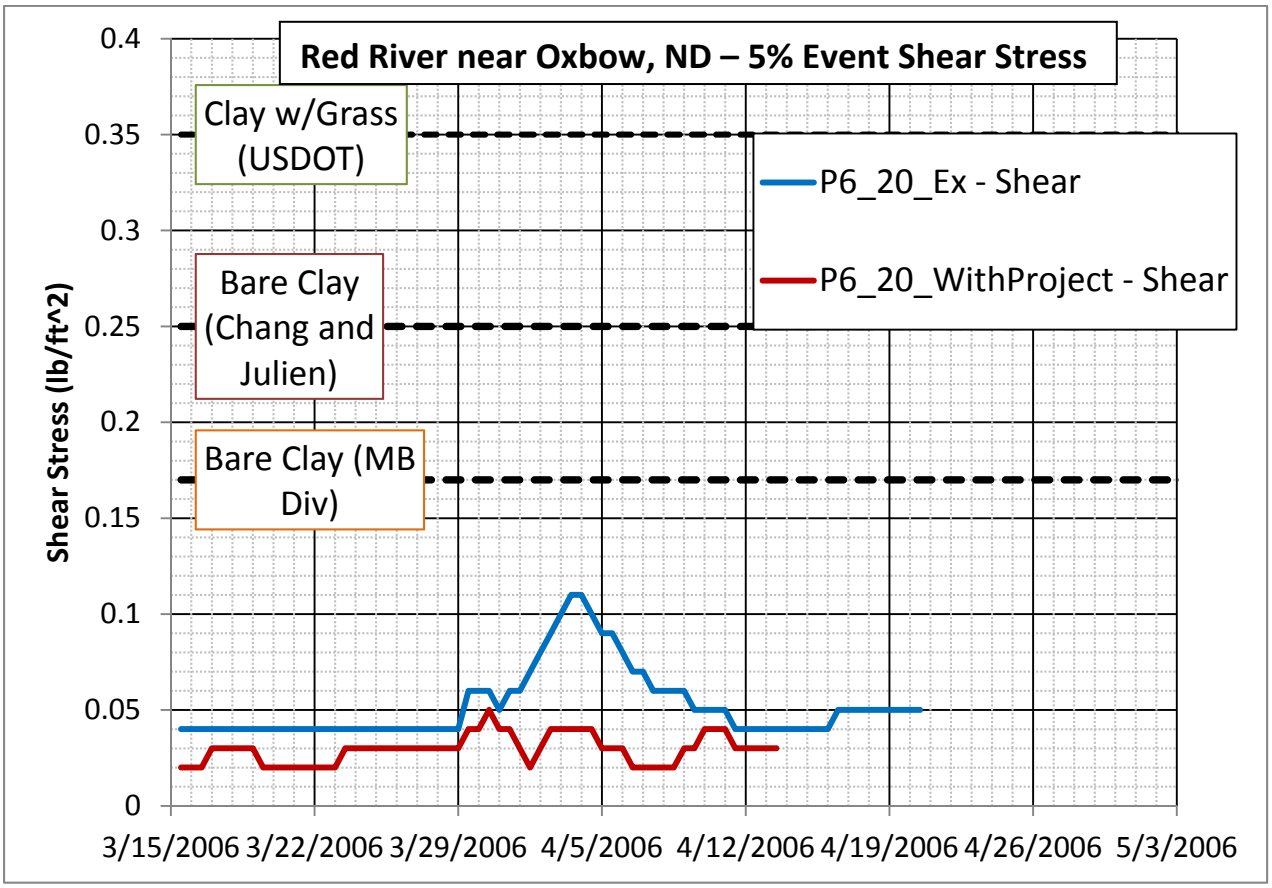
- Measures are being taken to raise the stage in the Rush River and reduce the drawdown effect.

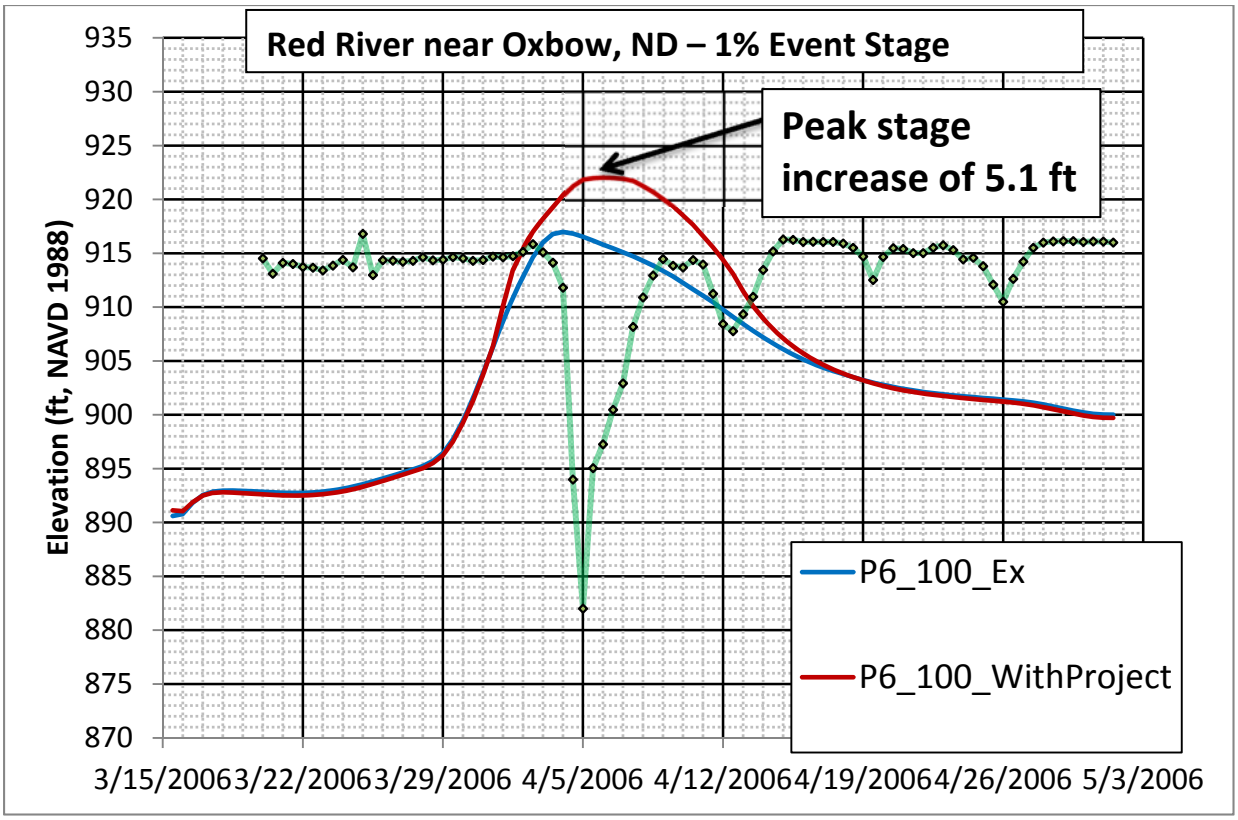
- More analysis will have to be performed to ensure the higher shear and velocity will not downcut the tributaries.

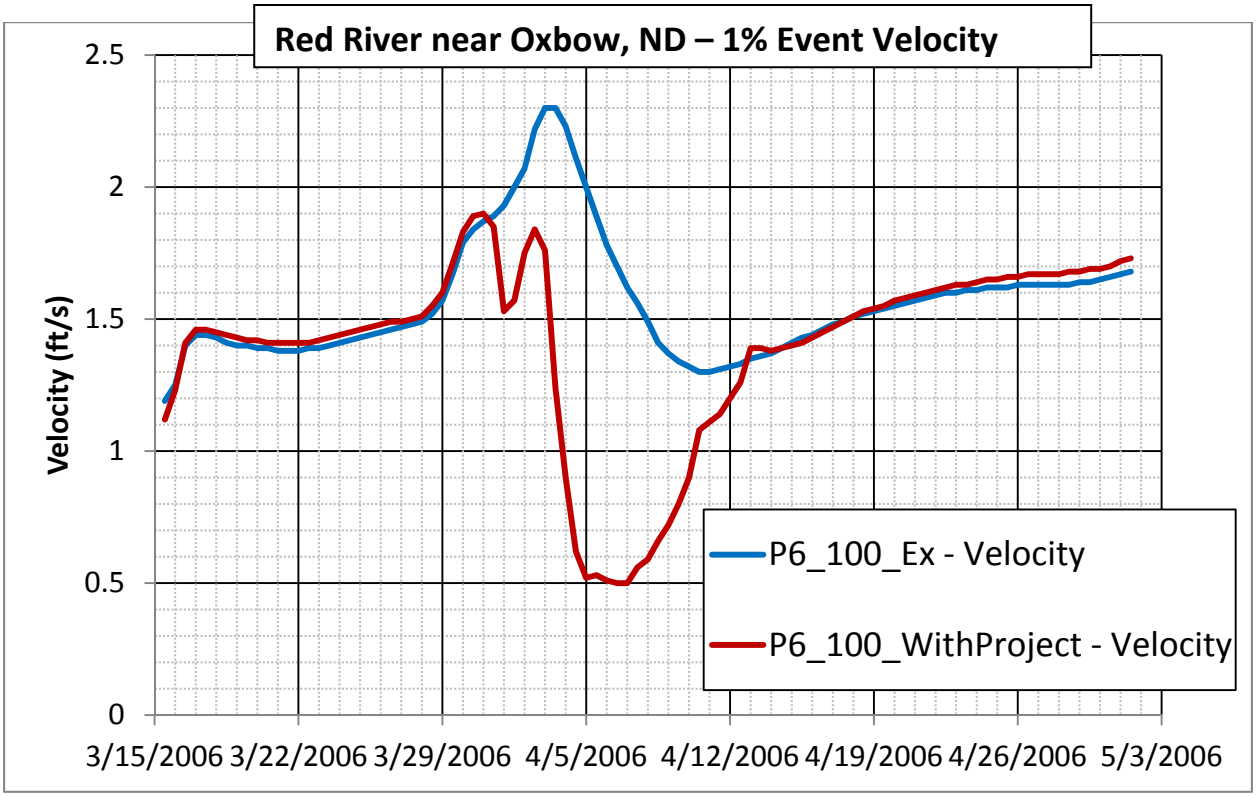
Red River in the Staging Area – Oxbow, ND

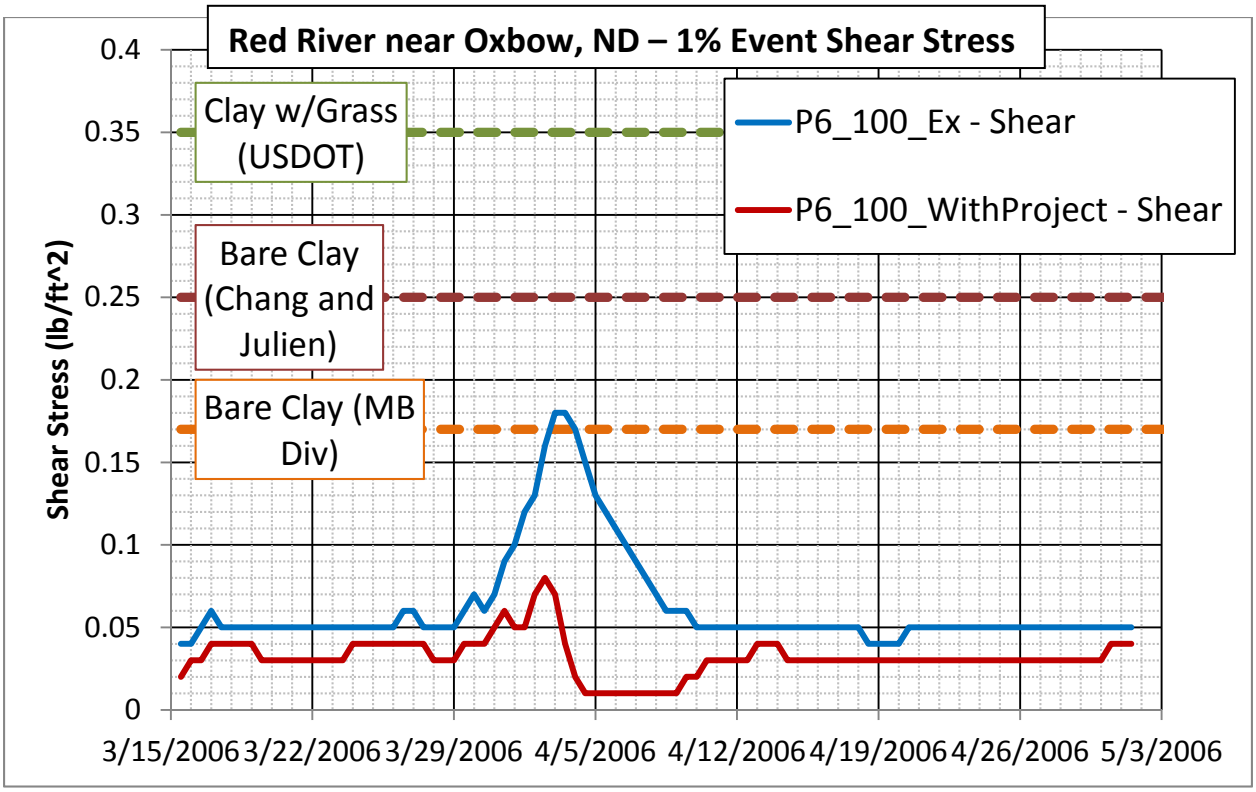


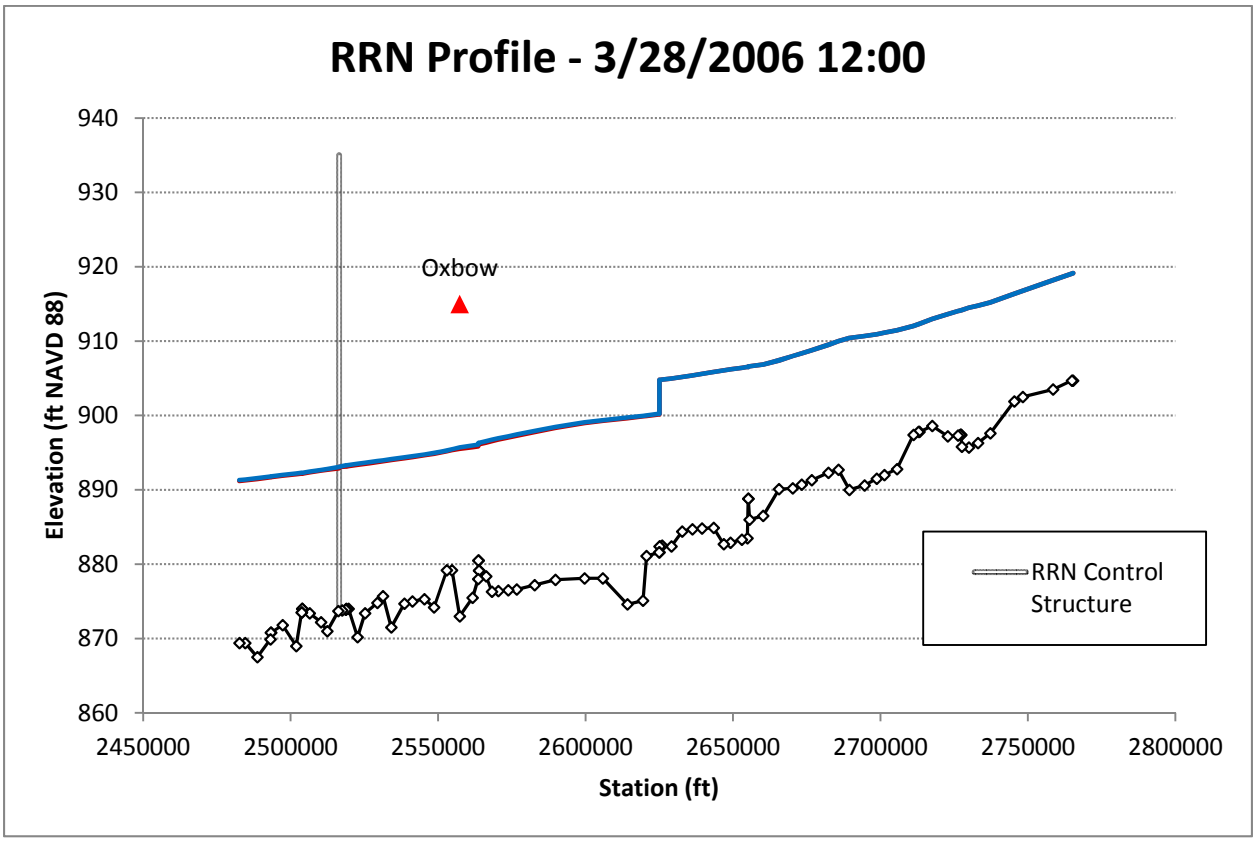

Red River near Oxbow, ND – 5% Event Velocity
Velocity (ft/s)
2.5
2
1.5
1
0.5
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
P6_20_Ex - Velocity
P6_20_WithProject - Velocity

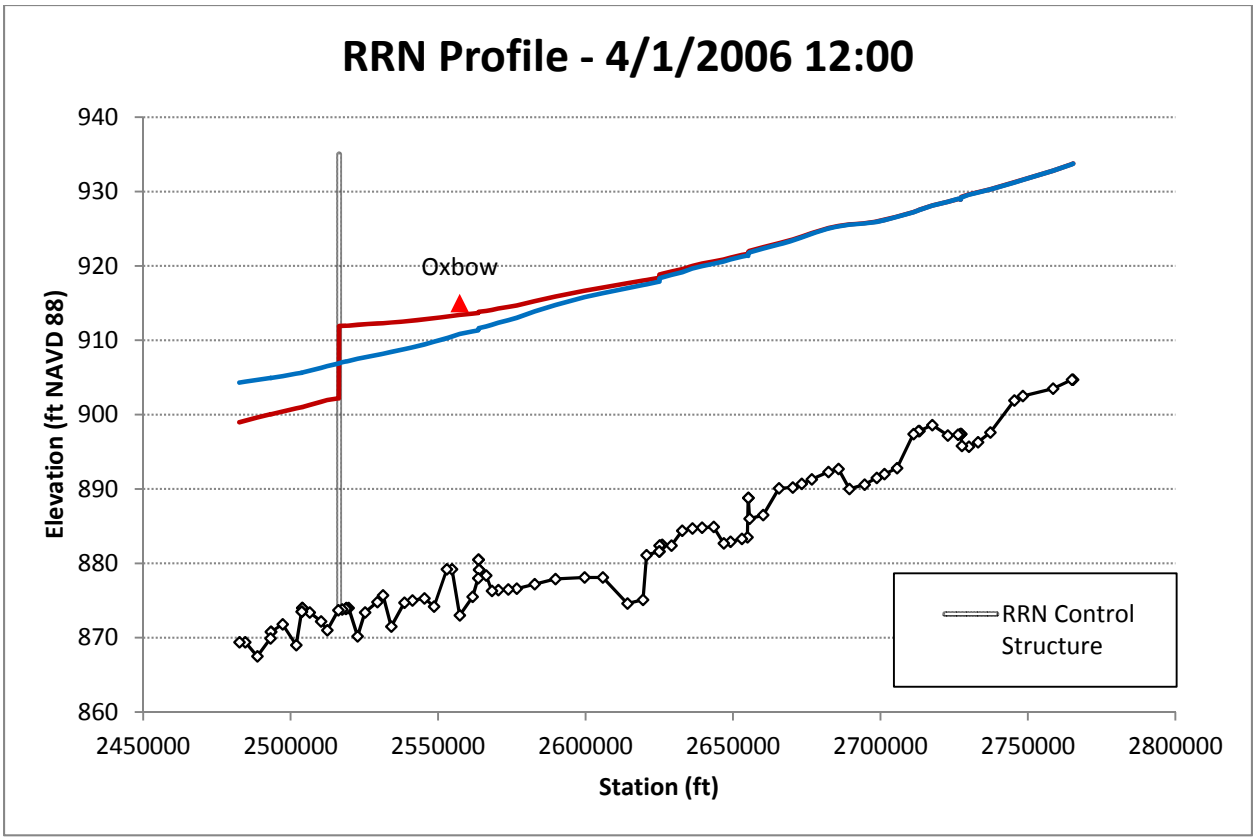

Red River near Oxbow, ND – 5% Event Shear Stress
Shear Stress (lb/ft^2)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Clay w/Grass (USDOT)
Bare Clay (Chang and Julien)
Bare Clay (MB Div)
P6_20_Ex - Shear
P6_20_WithProject - Shear
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006

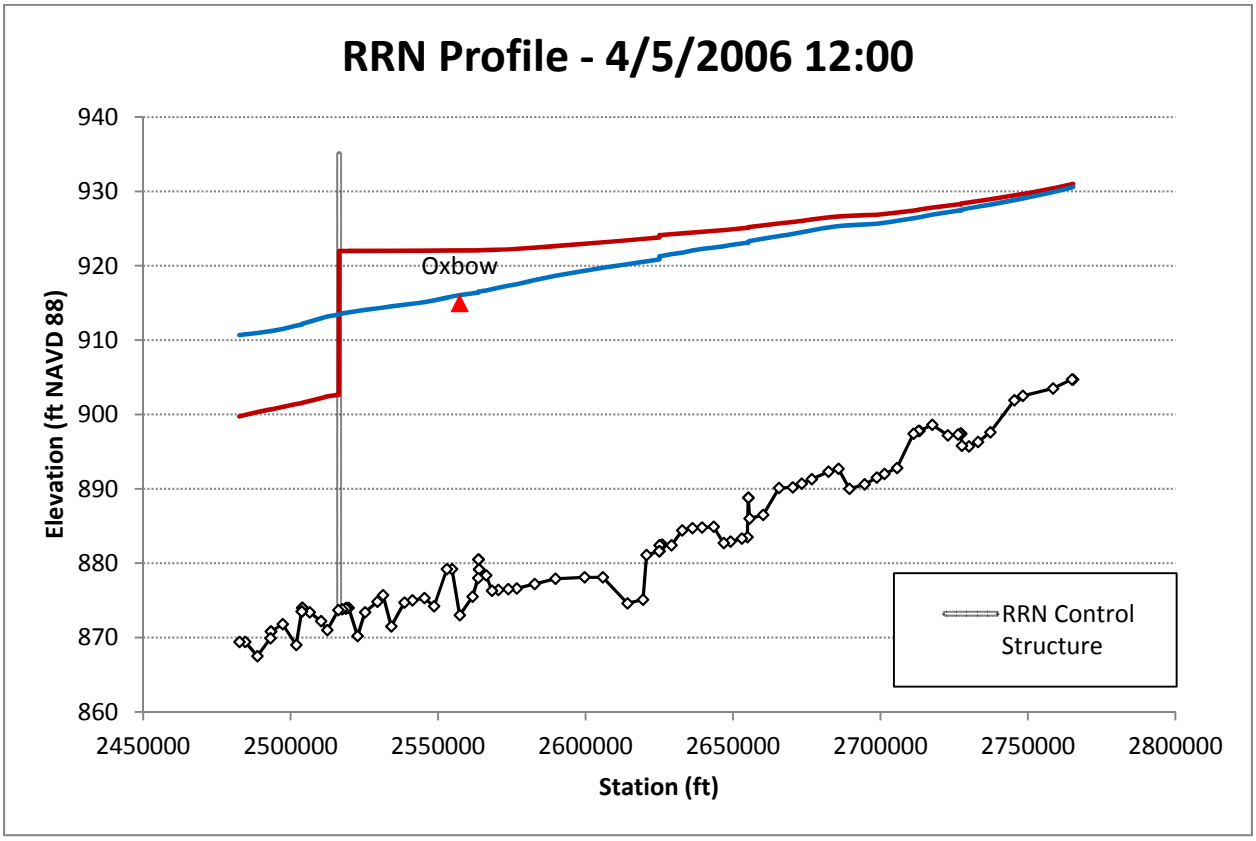

Red River near Oxbow, ND – 1% Event Stage
Peak stage increase of 5.1 ft
Elevation (ft, NAVD 1988)
935
930
925
920
915
910
905
900
895
890
885
880
875
870
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
P6_100_Ex
P6_100_WithProject

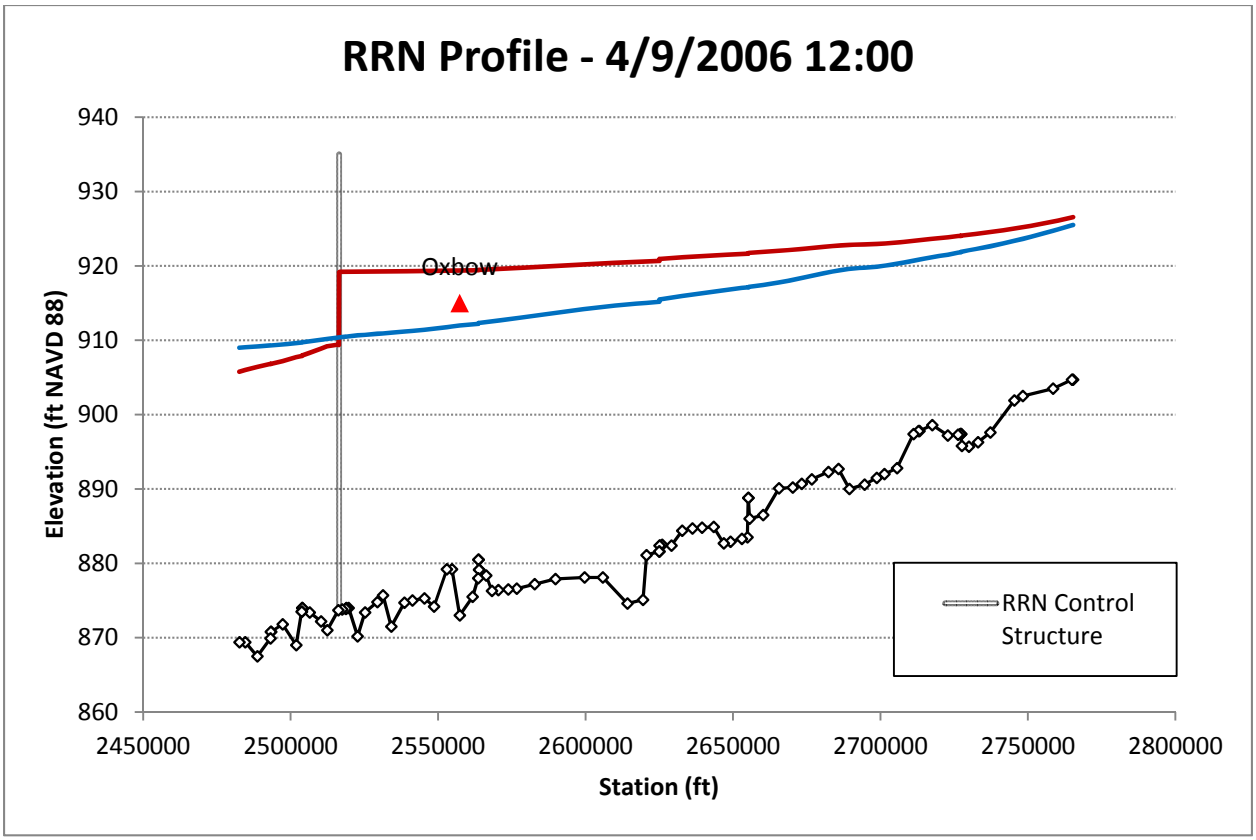

Red River near Oxbow, ND – 1% Event Velocity
Velocity (ft/s)
2.5
2
1.5
1
0.5
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
P6_100_Ex - Velocity
P6_100_WithProject - Velocity

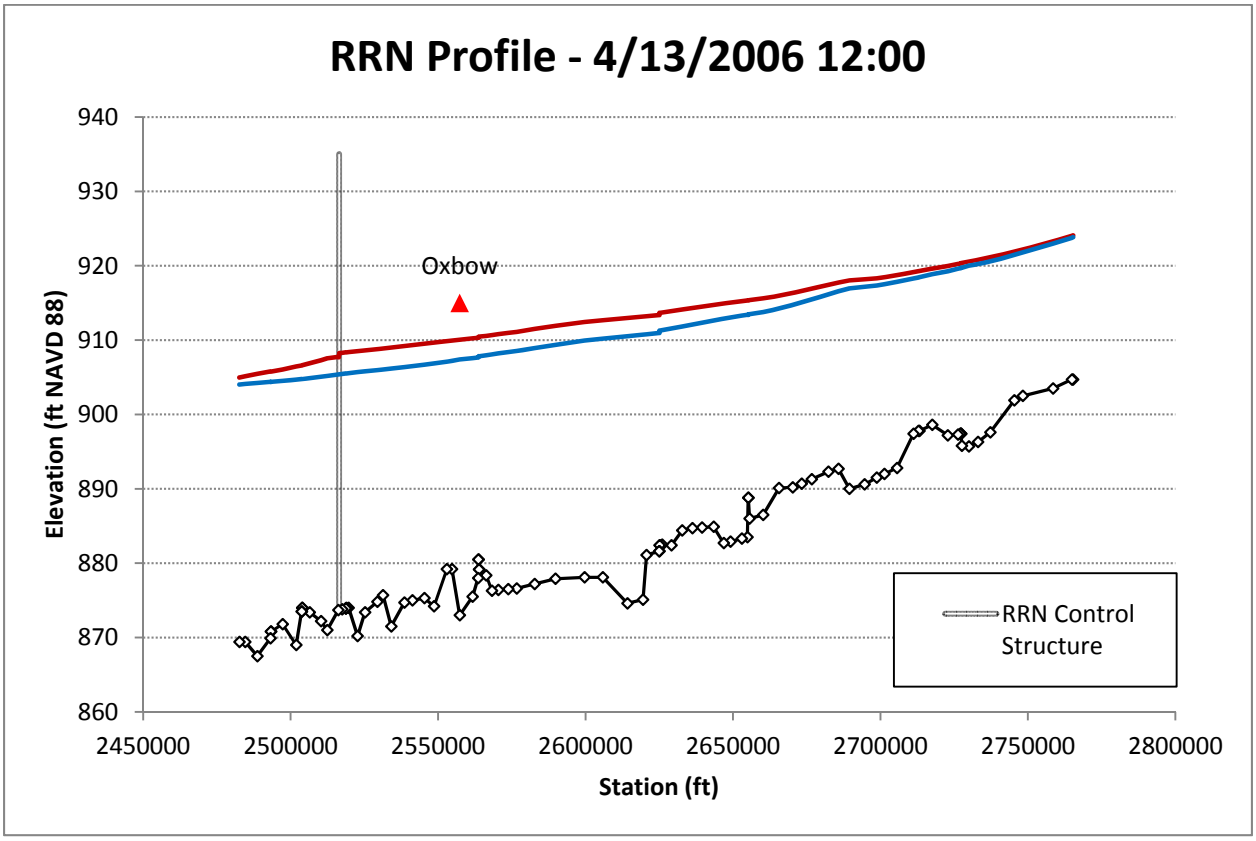

Red River near Oxbow, ND – 1% Event Shear Stress
Clay w/Grass (USDOT)
Bare Clay (Chang and Julien)
Bare Clay (MB Div)
P6_100_Ex - Shear
P6_100_WithProject - Shear
Shear Stress (lb/ft^2)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3/15/2006
3/22/2006
3/29/2006
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006

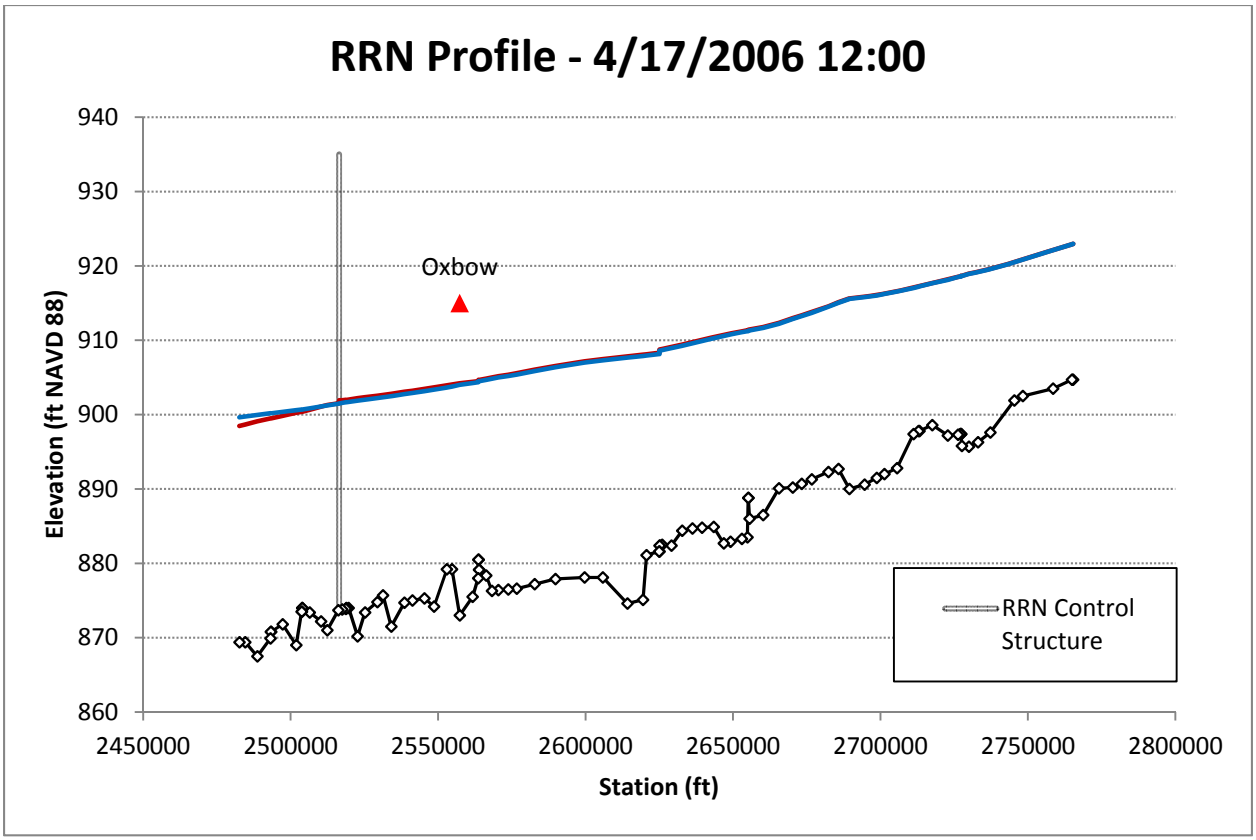

RRN Profile - 3/28/2006 12:00
Oxbow
RRN Control Structure
Elevation (ft NAVD 88)
940
930
920
910
900
890
880
870
860
2450000
2500000
2550000
2600000
2650000
2700000
2750000
2800000
Station (ft)


RRN Profile - 4/1/2006 12:00
Elevation (ft NAVD 88)
940
930
920
910
900
890
880
870
860
Oxbow
RRN Control Structure
2450000
2500000
2550000
2600000
2650000
2700000
2750000
2800000
Station (ft)


RRN Profile - 4/5/2006 12:00
Elevation (ft NAVD 88)
940
930
920
910
900
890
880
870
860
Oxbow
RRN Control Structure
2450000
2500000
2550000
2600000
2650000
2700000
2750000
2800000
Station (ft)


RRN Profile - 4/9/2006 12:00
Elevation (ft NAVD 88)
940
930
920
910
900
890
880
870
860
Oxbow
RRN Control Structure
2450000
2500000
2550000
2600000
2650000
2700000
2750000
2800000
Station (ft)


RRN Profile - 4/13/2006 12:00
Elevation (ft NAVD 88)
940
930
920
910
900
890
880
870
860
Oxbow
RRN Control Structure
2450000
2500000
2550000
2600000
2650000
2700000
2750000
2800000
Station (ft)

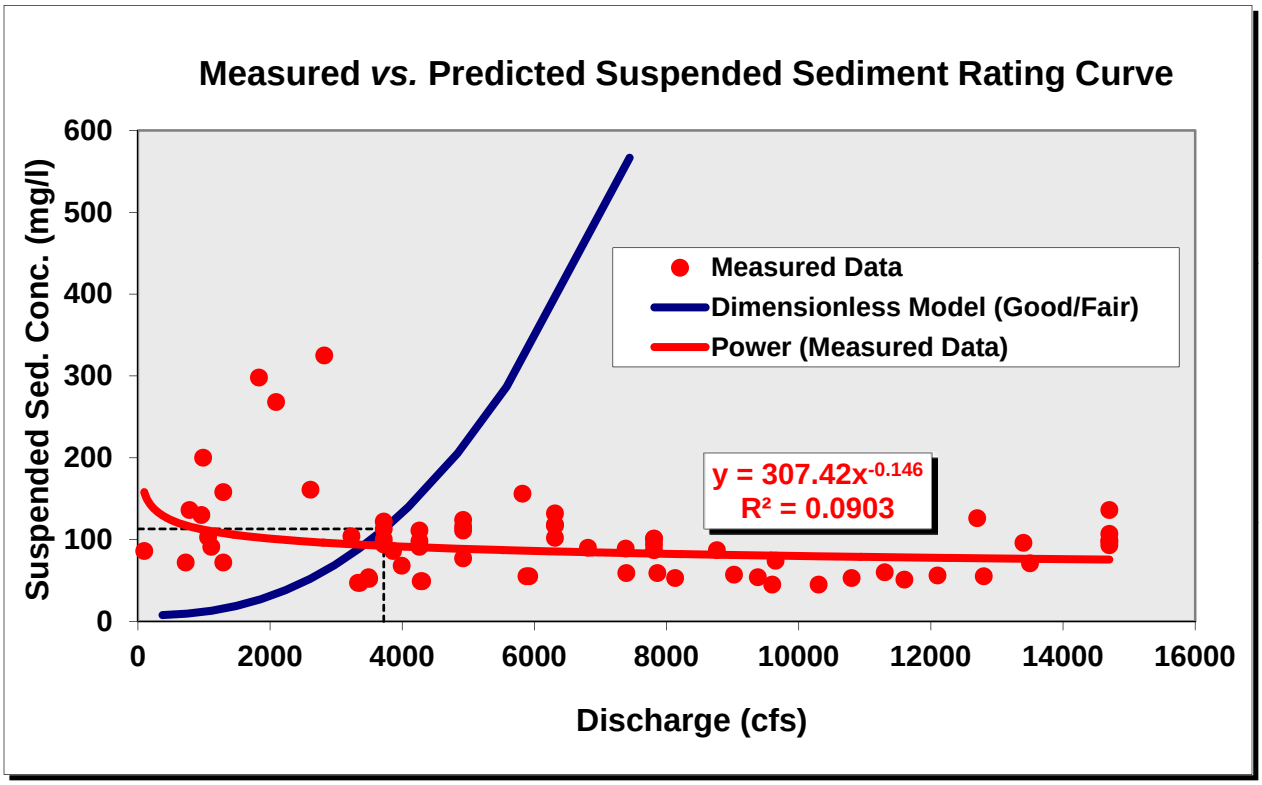


Summary of the Red River in the Staging Area

- **The project will tend to reduce velocities and shear stresses in the Red River channel due to the increase in water surface from the control structure.**

- **The energy slope/water surface slope of the with project model is never steeper than the slope of the existing conditions model. The water is regulated too slowly to have a rapid drawdown of the pool that would increase the chance for erosion.**

Suspended Sediment Rating Curve for the Red River



Predicted is Rosgen's Dimensionless Model curve

General Operating Plan

- ✓ **Project begins operating when Fargo gage reaches a stage of 35.0, storage of water begins**
- ✓ **Fargo stage of 35.0 maintained until pool reaches 922.2**
  - ✓ **1% event would result in a pool at 922.2**
  - ✓ **Spillway set at 922.2 to 923.0**
- ✓ **Pool of 922.2 maintained while Fargo stage is allowed to rise to 40.0**
  - ✓ **0.2% event would result in Fargo stage of 40.0**
  - ✓ **Flood fighting occurs when Fargo stage is between 35.0 and 40.0**
- ✓ **Fargo stage of 40.0 maintained while pool is allowed to rise, spillway flow begins**
- ✓ **Once minimum freeboard is achieved due to rising pool, control gates are opened and Fargo stage rises above 40.0, flood fighting stops and city is allowed to flood**
  - ✓ **Evacuation order given in advance of exceeding Fargo stage of 40.0**
- ✓ **Operating plan will be clearly documented in the O&M manual**

Flow Information

- ✓ **Peak Flows at Fargo**
  - ✓ **50% = 5,600 cfs**
  - ✓ **20% = 12,150 cfs**
  - ✓ **10% = 17,000 cfs**
  - ✓ **2% = 29,300 cfs**
  - ✓ **1% = 34,700 cfs**
  - ✓ **0.2% = 61,700 cfs**
  - ✓ **SPF = ½ PMF = 103,000 cfs**
  - ✓ **PMF = 205,000 cfs**
- ✓ **<10% chance of forcing flow down diversion in any given year**
- ✓ **20,000 cfs into diversion at inlet for 1% and 0.2% chance events**
- ✓ **32,000 cfs at outlet for 1% event, 35,000 cfs at outlet for 0.2% event**
- ✓ **17,000 cfs into city for 1%**
- ✓ **30,000 cfs into city for 0.2%**