DRAFT

# MEMORANDUM

**DATE:** January 21, 2015 **ACE PROJECT NO.:** NEHEADWATERS04-04

**TO:** Jerry Kenny, Headwaters Corporation

**FROM:** Michelle Martin, P.E., Anderson Consulting Engineers, Inc.

Brad Anderson, P.E., Anderson Consulting Engineers, Inc.

**SUBJECT:** North Platte Choke Point: Investigation of Channel Modifications Upstream of Highway 83

The Executive Director's Office (EDO) of the Platte River Recovery Implementation Program (PRRIP) requested assistance from Anderson Consulting Engineers, Inc. (ACE) to evaluate methods to improve flood conveyance through the Choke Point on the North Platte River in order to accommodate short duration high flows. A preliminary analyses of alternatives, supported by sediment transport analyses and modeling, was completed by ACE in 2012.

Sediment deposition historically occurring along the North Platte River has diminished hydraulic capacity at the Highway 83 gage. To accommodate the conveyance of short duration high flows (SDHF) in this reach of the North Platte River, it is necessary to achieve 3,000 cfs capacity at or below minor flood stage, which is currently defined by the NWS at 6.0 feet. Presently, the hydraulic capacity at Highway 83 at the 6-foot flood stage is approximately 1,500 cfs. Dredging alternatives downstream of Highway 83 to increase hydraulic capacity were evaluated by ACE and summarized in a June 5, 2012 memo. It was determined that dredging ranging from 1.25 ft to 3 ft in the reach downstream of Highway 83 will initially achieve the targeted capacity of 3,000 cfs; however long-term sediment modeling indicates that the targeted hydraulic capacity will be diminished within 3 to 5 years after initial dredging. A supplemental investigation to increase transport capacity through construction of jetties/bendway weirs in combination with dredging downstream of Highway 83 was conducted by ACE and summarized in a July 17, 2012 memo. The July 2012 memo concluded that the addition of jetties/bendway weirs to dredging alternatives downstream of Highway 83 did not sustain the targeted hydraulic capacity relative to the 6-foot flood stage and recurring maintenance obligations would be necessary to achieve the desired capacity. All work conducted and summarized in the 2012 memos focused on channel improvements downstream of Highway 83.

Additional data was collected to describe the sediment deposition in the vicinity of Highway 83 during and following the peak flows of 2011. Using the additional data for calibration, detailed modeling was conducted to confirm the sediment transport conditions and extend the alternative evaluation to include reaches upstream of Highway 83. The additional data provided insight and a better understanding of how sediment movement is diminishing hydraulic capacity through the Choke Point. The results of the calibration modeling reflecting existing channel conditions were used to provide insight into potential solutions to problems related to the limited hydraulic capacity. Influence of the Highway 83 Bridge on sediment transport and hydraulic capacity was analyzed to determine if bridge modification was a feasible solution. Channel modifications upstream of Highway 83 were analyzed with and without the channel improvements previously identified for the reaches downstream of Highway 83 (dredging, channel widening, and the use of jetties/bendway weirs). The upstream channel improvements were investigated while considering historic flood hydrology, SDHFs, and long-term hydrology simulation integrating both historic flooding and SDHFs. This memo summarizes the sediment transport analyses and the subsequent results.

**Methods**

The Sediment Impact Analysis Method (SIAM) within HEC-RAS was used to compute reach-averaged sediment transport potential to aid in interpretation of the 1D sediment transport modeling. SIAM results were used to evaluate sediment transport potential of existing conditions and various alternatives.

The North Platte River HEC-RAS hydraulic model developed by HDR (Tetra Tech) was used to conduct steady state and 1D sediment transport analyses of existing and alternative conditions. This is the same model used in 2012 analyses. The model reach for this effort includes approximately 11 miles of the North Platte River upstream of the Tri County Diversion Structure, see Figure 1. The sediment transport models simulated periods between five and sixteen years in order to evaluate long-term channel response.

**Performance Metric**

The hydraulic capacity at 6-foot flood stage at the gage located downstream of Highway 83 was computed throughout each simulation period and used as the performance metric by which alternatives are evaluated. The objective is to achieve and maintain 3,000 cfs capacity at or below the minor flood stage of 6 feet.

**Hydrology**

Three different hydrographs were used in the sediment transport simulations. Hydrographs used in the modeling are summarized below.

- *March 2009 – May 2014 Historic Hydrograph* – This hydrograph includes 5-years of daily average gage data from March of 2009 through May of 2014, including the 2011 flood. The start date of March 2009 was selected to coincide with the March 2009 LiDAR data that the model geometry is based upon. This data was not available in the 2012 analyses.
- *16-Year Hydrograph w/2011 Flood and SDHFs* – This hydrograph consists of a combination of the 2002 to 2014 historic hydrology embedded with SDHFs. This simulated hydrology data is intended to reflect the impact of SDHFs along with the occurrence of a peak flow significantly exceeding 3,000 cfs. The hydrograph includes the following sequence of data: (a) 2002 to 2005 historic hydrology embedded with SDHFs followed by, (b) 5-year historic hydrology reflecting the time period between 2009 and 2014 (including the 2011 flood), followed by (c) 2003 to 2009 historic hydrology embedded with SDHFs. SDHFs occur eleven times in the 16-year period. The 2011 flood occurs during year six. This hydrograph was developed to evaluate alternatives on a long-term basis with embedded SDHFs prior to and following the 2011 flood. It was important to consider flooding in combination with SDHFs on a long-term basis in order to determine sediment transport conditions and channel response under varying hydrologic conditions.

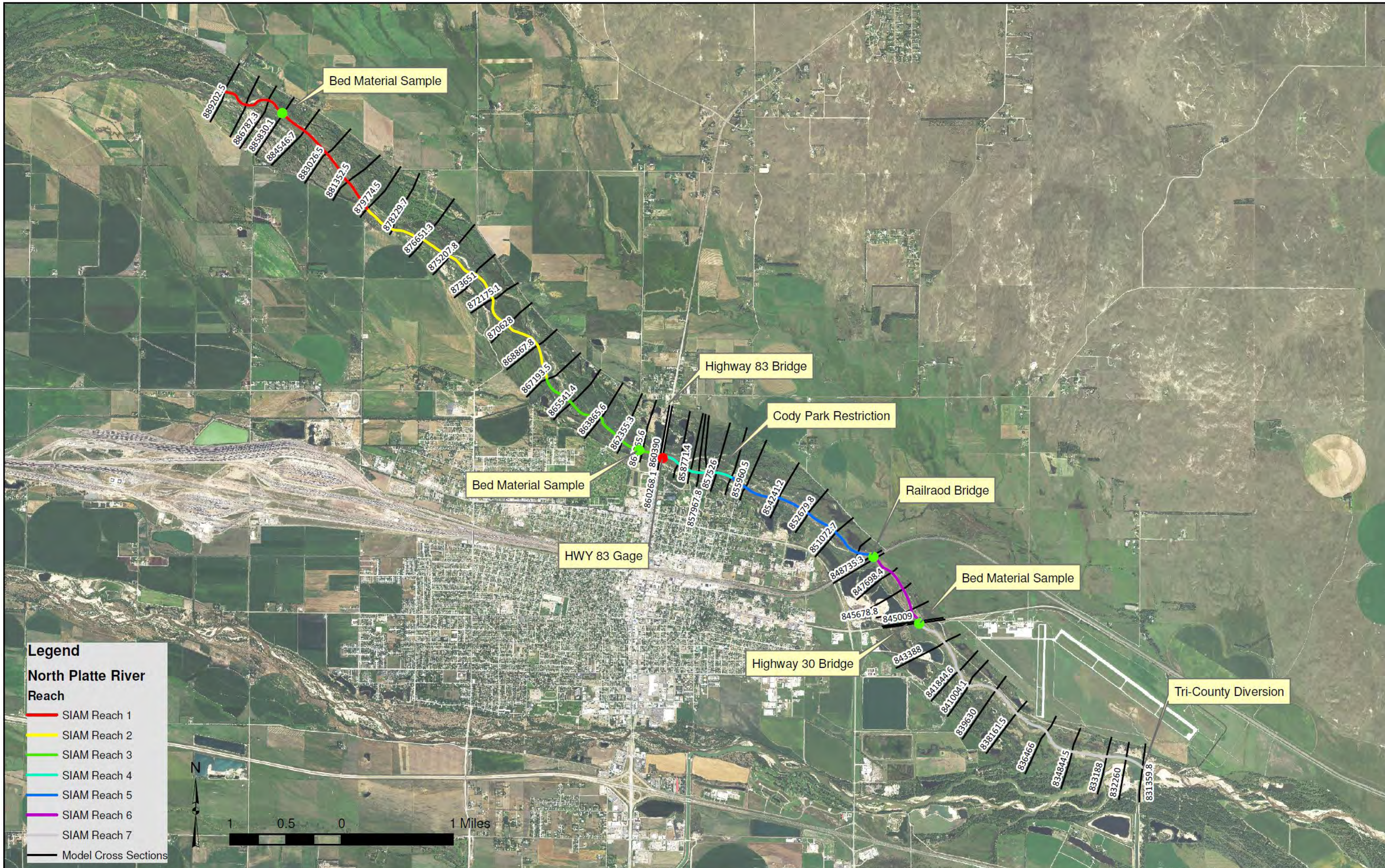



**Figure 1. North Platte River Choke Point Reach**

**Alternatives**
Five alternative channel conditions were developed for investigation. Sediment transport modeling was conducted for various scenarios which include either an individual alternative or a combination of alternatives. The five alternative used in the analyses are described below.

A. *Existing Conditions* – Existing condition model geometry is based upon LiDAR data collected in March of 2009 and developed by Tetra Tech.
B. *Highway 83 Bridge Removed* – This alternative simulated the removal of the Highway 83 Bridge on sediment transport conditions.
C. *Channel Widening Upstream of Highway 83* – This alternative includes widening of the channel to 350 feet along a 3 mile reach upstream of Highway 83. Modification to the channel slope is also included.
D. *Dredging Downstream of Highway 83* – This alternative combines the improvements in Alternative C with channel widening to a minimum of 300 feet along with dredging in the reach between Highway 83 and the Railroad Bridge. (More information regarding the details of the improvements downstream of Highway 83 can be found in the June 5th, 2012 memo).
E. *Jetties/Bendway Weirs and Dredging Downstream of Highway 83* – This alternative combines the improvements in Alternative C with widening of the channel a minimum of 300 feet in the reach downstream of Highway 83 to the Railroad Bridge, dredging to lower the thalweg 1.25 to 3 feet, and the addition of 2-foot high jetties/bendway weirs to constrict the low flow channel to a width of 150 feet (more information regarding the details of the improvements downstream of Highway 83 can be found in the July 17th, 2012).

**Alternatives and Model Simulations**
A total of six model simulations were conducted to investigate the five alternatives identified above. Model simulations reflect a combination of a selected alternative and various streamflow hydrographs. Table 1 summarizes the alternative and hydrologic combination of each model run. The purpose of each simulation will be discussed in the following text.

**Table 1. Choke Point 1D Sediment Transport Model Simulations**

| Run # | Alternative | Alternative Description | Hydrology Data |
|---|---|---|---|
| 1 | A | Existing Conditions | 2009 to 2014 Historic Hydrograph |
| 2 | B | Highway 83 Bridge Removed | 2009 to 2014 Historic Hydrograph |
| 3 | C | Channel Widening Upstream of Highway 83 | 2009 to 2014 Historic Hydrograph |
| 4 | D | Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 | 2009 to 2014 Historic Hydrograph |
| 5 | D | Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 | 16-Year Hydrograph w/ 2011 Flood & SDHFs |
| 6 | E | Channel Widening Upstream of Highway 83 + Jetties/Bendway Weirs and Dredging Downstream of Highway 83. | 16-Year Hydrograph w/ 2011 Flood & SDHFs |

**Scenario A - Existing Conditions**

It is important to conduct an initial evaluation to determine if the modeling results reasonably reflect the historic data. Existing condition sediment transport analyses were conducted for two reasons: 1) to determine how well the model can reproduce historic observations and 2) to gain more insight into the movement of sediment through the existing system and provide insight into the reduction of hydraulic capacity. Existing condition model results are also useful for relative comparisons to alternative conditions.

**Run 1 – Existing Conditions with 2009 to 2014 Historic Hydrograph**

Historic field observations and measurements indicate that the hydraulic capacity at Highway 83 at 6.0 foot flood stage was approximately 1,500 to 1,600 cfs prior to the 2011 flood event. Just after the 2011 flood event, capacity at flood stage increased to approximately 2,600 cfs. However, within a few months of the 2011 flood, hydraulic capacity at the Highway 83 gage was diminished to 1,500 to 1,600 cfs.

Figure 2 compares the computed water surface elevation with measured data at the HWY 83 gage, along with the 2009 to 2014 historic hydrograph, and a plot of hydraulic capacity at flood stage also compared with gage data. More detailed model results are provided in Figures A-1 through A-3 provided in Attachment A. Results of the sediment transport modeling for Run 1 indicate that the model provides a reasonably accurate simulation of changes in water surface elevation and hydraulic capacity at the HWY 83 gage.

At the start of the simulation, hydraulic capacity (at 6-foot flood stage) is approximately 1,500 cfs, increasing to 2,300 cfs at the start of the 2011 flood. At the peak of the 2011 flood, sediment deposition reduces flood capacity to 1,600 cfs. On the receding limb of the 2011 flood hydrograph, hydraulic capacity increases to a high of 2,750 cfs. This compares well with gage data and observation of 2,600 cfs. Following the flood, model results show that the hydraulic capacity is steadily reduced to 1,500 cfs over a 2-year period. Gage data indicates that the capacity was diminished to approximately 1,100 cfs within one year of the 2011 flood. The model is able to reproduce changes in hydraulic capacity with reasonable accuracy, however, the temporal rate of change is noticeably different than the field observations. Channel response in the model appears to occur at a slower rate than what has been observed in the field. This could be attributed to use of a standard sediment transport equation, coarsening of the bed material, changes in upstream sediment sources, or changes in channel geometry that may have occurred after the 2009 LiDAR was collected.

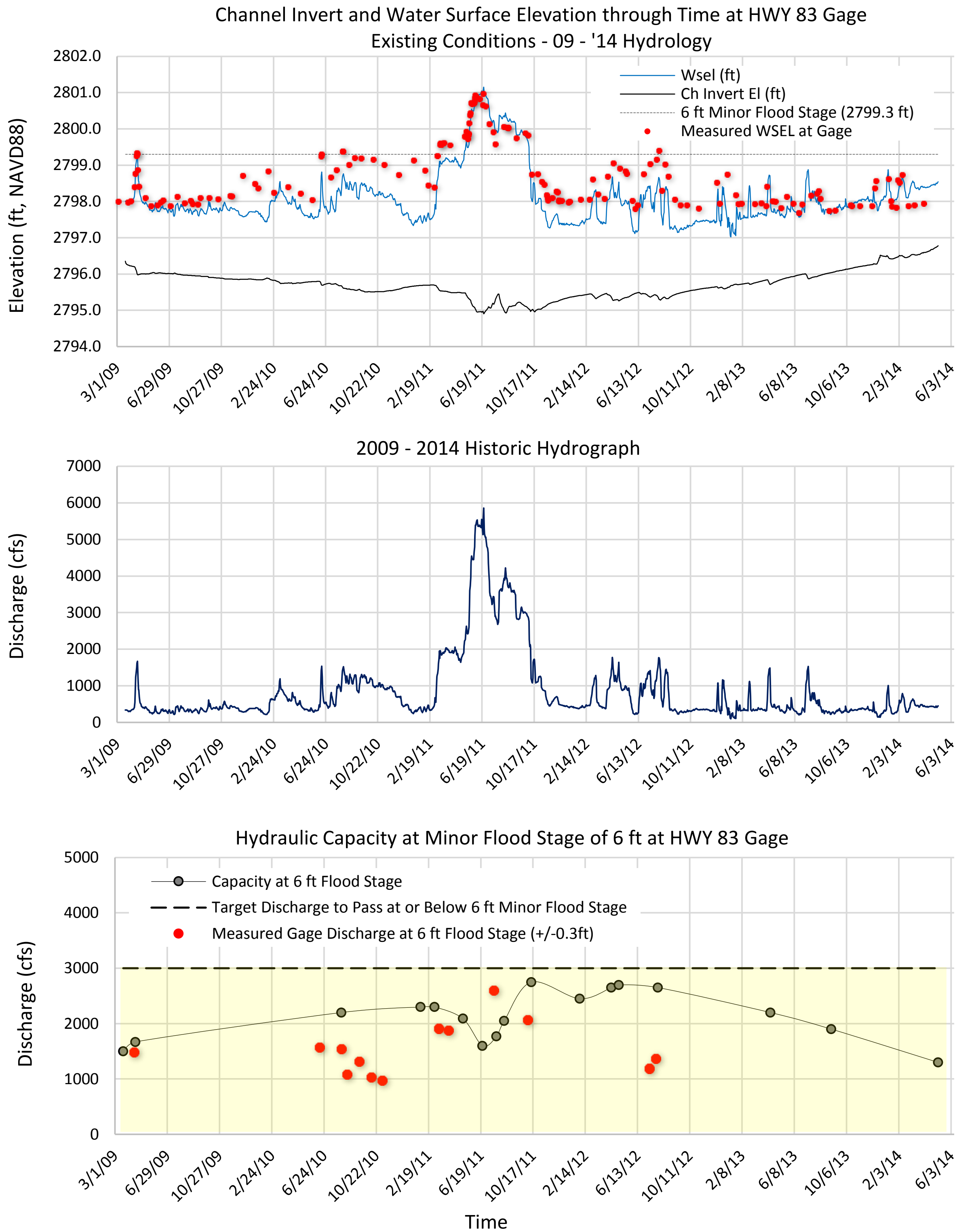



**Figure 2. Run 1-Existing Condition 2009 to 2014 Hydrology, 2009 to 2014 Historic Hydrograph (top), Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

**Existing Conditions SIAM Reach Average Sediment Transport Potential**

Reach-averaged sediment transport potential was computed for existing conditions using the Sediment Impact Analysis Method (SIAM) within HEC-RAS. This analysis was conducted to gain a better understanding of reaches within the Choke Point area that are contributing to the loss of channel capacity. The SIAM model combines reach-averaged hydraulics, hydrologic regime, and bed material gradations to formulate transport potential. The SIAM model is a useful tool to predict trends in transport potential on a reach-by-reach basis.

The Choke Point study reach was split into seven SIAM reaches based upon planform geometry, location of hydraulic structures, and changes in hydraulic parameters (e.g., streampower, shear stress, velocity, etc.). Choke Point SIAM reaches are summarized in Table 2 and illustrated in Figure 1. A plan view map of each reach is provided in Figures B-1 through B-7 in Attachment B. During review of hydraulic parameters and plan view geometry, it was noted that SIAM Reach 2 seemed to stand out when compared against other reaches. In particular, SIAM Reach 2 has an extremely narrow, single-threaded channel with an average width of 170 feet. This is distinctly different from other reaches in that SIAM Reach 2 does not have any mid-channel bars or braiding and is almost half as narrow as all other reaches, see Figure 3.

**Table 2 Choke Point SIAM Reaches**

| SIAM Reach | From Station to Station (HEC-RAS XSECs) | Description of Reach Limits | Reach Length | | Notes |
|---|---|---|---|---|---|
| | | | (ft) | (miles) | |
| 1 | 889202 - 879774 | | 9,428 | 1.79 | Braided reach with some mid-channel bars. Average channel width is approx. 350 ft. |
| 2 | 878229 - 867193 | | 11,036 | 2.09 | Narrow single thread channel approx. 170 ft in width with some small side channels. Channel width is generally half as narrow when compared to all other reaches. |
| 3 | 865541 - 860390 | Above HWY 83 | 5,151 | 0.98 | Large mid-channel bars. Average channel width, with channel bars included, is approx. 540 ft. |
| 4 | 860268 - 856779 | HWY 83 to Cody Park Restriction | 3,489 | 0.66 | Single thread channel. Channel narrows from approx. 350 ft down to 150 ft at the Cody Park restriction, with a reach average width of 270 ft. |
| 5 | 855960 - 848912 | Cody Park Restriction to Railroad Bridge | 7,048 | 1.33 | Single thread channel with one mid-channel bar just upstream of RR Bridge. Average channel width is 270 ft. |
| 6 | 848735 - 845009 | Railroad Bridge to HWY 30 Bridge | 3,726 | 0.71 | Braided channel with average width of 390 ft. |
| 7 | 844919 - 831359 | HWY 30 Bridge to Tri County Diversion | 13,560 | 2.57 | Braided reach with some mid channel bars and an average channel width of approx. 430 ft. |

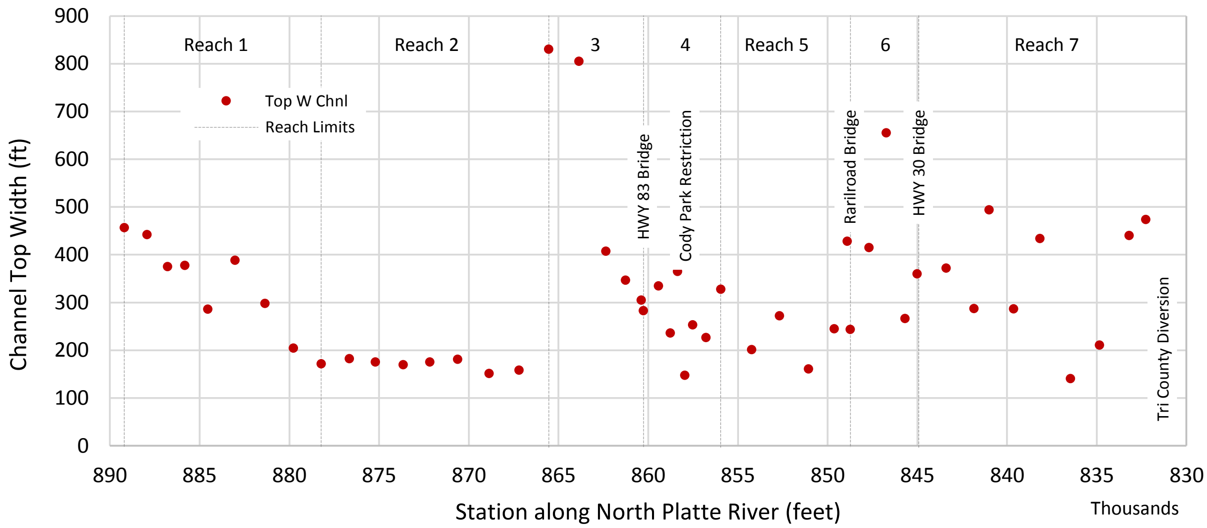



**Figure 3. North Platte River Channel Top Width through Choke Point Study Reaches**

Estimated reach-average sediment transport capacity computed using SIAM is shown graphically in Figure 4. The transport capacity of SIAM Reach 2 is extremely high when compared with surrounding reaches (it is 5.5 times higher than SIAM Reach 1, 20 times higher than SIAM Reach 3, and 3 times higher than SIAM Reach 4). Assuming an availability of sediment supply, SIAM Reach 2 is acting as a transport and supply reach to depositional reaches located both upstream and downstream of Highway 83. The imbalance of transport capacity is likely contributing to deposition occurring through the Highway 83 Bridge and downstream through the Cody Park Restriction. The transport capacity imbalance can explain why channel improvement alternatives downstream of Highway 83 were ineffective at maintaining long-term hydraulic capacity. Previous analyses conducted in 2012 attempted to increase the transport capacity between Highway 83 and the Cody Park Restriction, however increases were not enough to overcome the large amounts of sediment that Reach 2 is capable of moving. It is evident that reduction in the transport capacity in Reach 2 would need to be achieved in order to maintain hydraulic capacity at flood stage downstream of Highway 83. Furthermore, reduced transport capacity in Reach 2 would likely need to be coupled with improvements downstream of Highway 83.

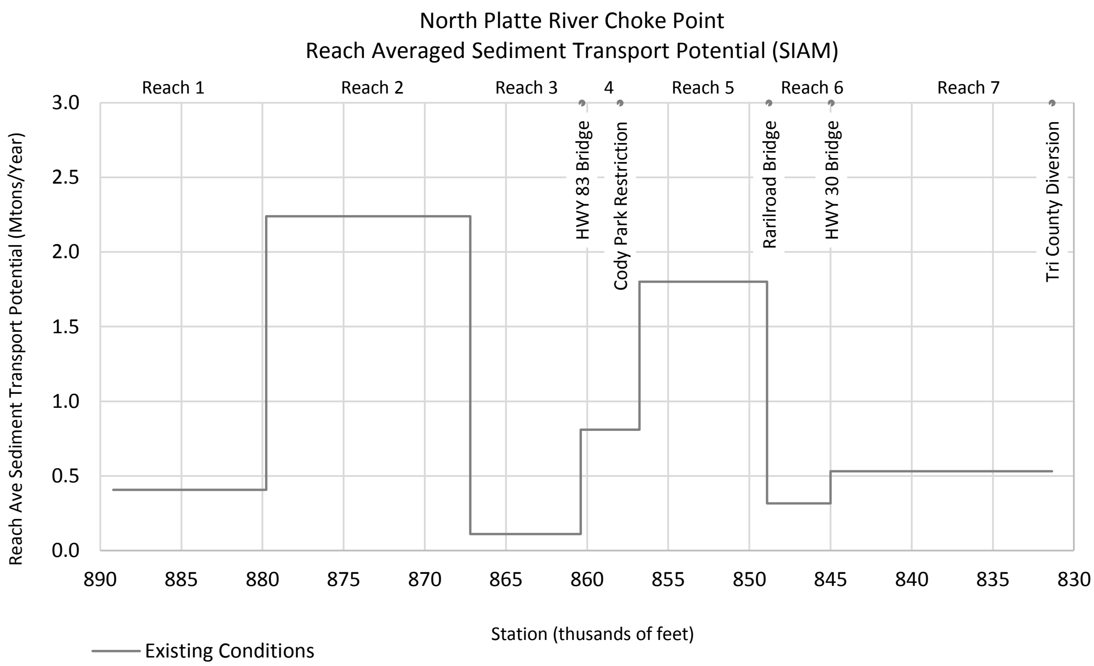



**Figure 4. North Platte River Choke Point Reach-Averaged Sediment Transport Potential**

In summary, the results of the sediment transport modeling for the existing conditions indicate the following:

- Degradation in Reach 2 upstream of Highway 83 creates a supply of sediment that cannot be transported through Reach 3 (at and immediately upstream of the bridge).
- The aggradation in Reach 3 transitions to an environment of slight degradation in Reach 4 with localized areas of aggradation. Specifically, the gage at the Highway 83 bridge reflects aggradation associated with the deposition of sediment immediately upstream.
- Reach 5 exhibits slight degradation within the channel with localized areas of aggradation.
- Reach 6 reflects aggradational trends throughout the channel.
- Reach 7 demonstrates a balance of sediment supply compared to sediment transport.

**Run 2 – Alternative B, Removal of Highway 83 Bridge (2009 to 2014 Historic Hydrograph)**

There has been uncertainty about the impact of the Highway 83 Bridge on the sediment transport and the diminishing of hydraulic capacity. Consequently, the Highway 83 Bridge was removed from the model geometry and a simulation conducted with the 2009 to 2014 historic hydrograph. Figure 5 shows the 2009 - 2014 hydrograph along with a comparison of the computed hydraulic capacity at minor flood stage for existing conditions and removal of the Highway 83 Bridge. More detailed model results are provided in Figures A-4 through A-6 provided in Attachment A. Results indicate that removal of the bridge does not improve hydraulic capacity relative to existing conditions. The bridge provides some constriction of flow which actually increases sediment transport allowing for some scour through the bridge near the gage during the 2011 flood. Removal of the bridge would reduce transport capacity and would not improve hydraulic capacity at minor flood stage. Removal or modification to the Highway 83 bridge is not a feasible solution to hydraulic capacity issues, therefore further modeling of Highway 83 Bridge removal was not pursued.

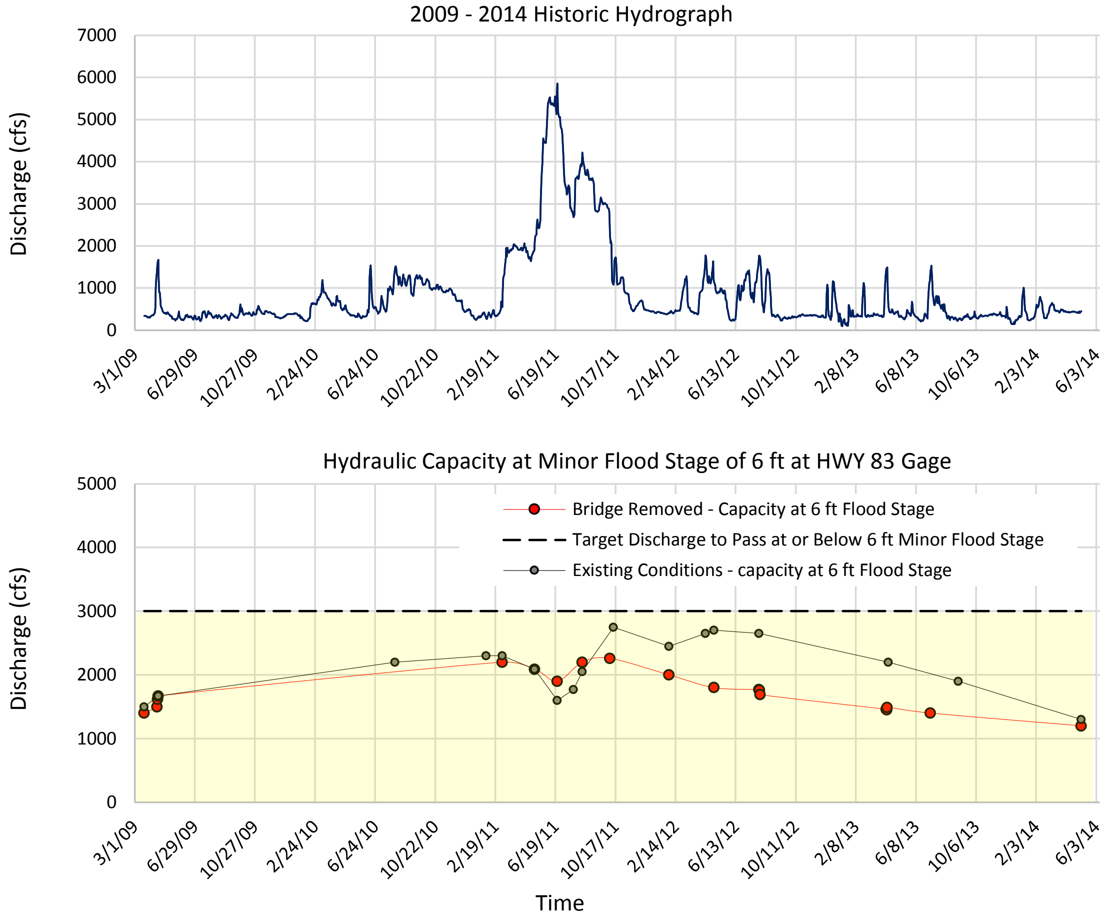



**Figure 5. Run 2 HWY 83 Bridge Removed - 2009 to 2014 Historic Hydrograph (top) and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage for Existing Conditions and Removal of the Highway 83 Bridge (bottom).**

## Alternative C - Channel Widening Upstream of Highway 83

Channel modifications along SIAM Reach 2, located upstream of Highway 83, are proposed in order to reduce sediment transport capacity of the reach. Channel modifications include widening of the channel to 350 feet along with some channel excavation to create a more constant channel slope. Channel widening was simulated between stations 878229 to 867193, see Figure 6. Modification to the channel slope is shown graphically in Figure 7. Reach-average sediment transport capacity for the channel modification was computed using SIAM and compared with existing conditions, see Figure 8. Proposed channel modifications upstream of Highway 83 reflect a reduction in transport potential in Reach 2 of approximately 75%. To further evaluate the effect of channel modification upstream of Highway 83 on hydraulic capacity, a 1D sediment transport model simulation was conducted and the results presented in the following section.


**Figure 6. Limits of Channel Widening upstream of Highway 83. Channel would be widened to 350 feet.**

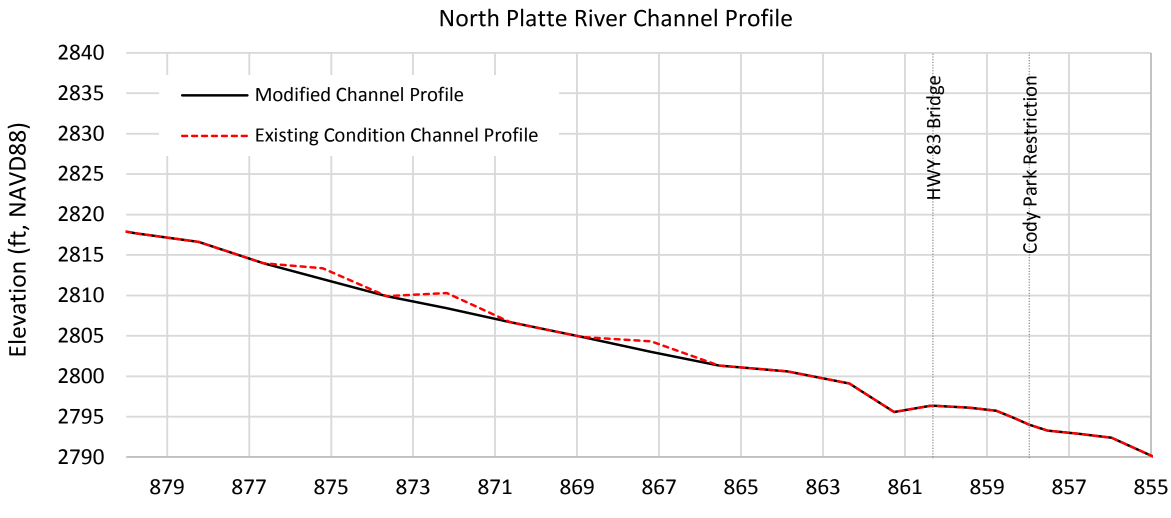



**Figure 7. North Platte River Channel Profile – Existing and Modified Conditions Upstream of Highway 83**

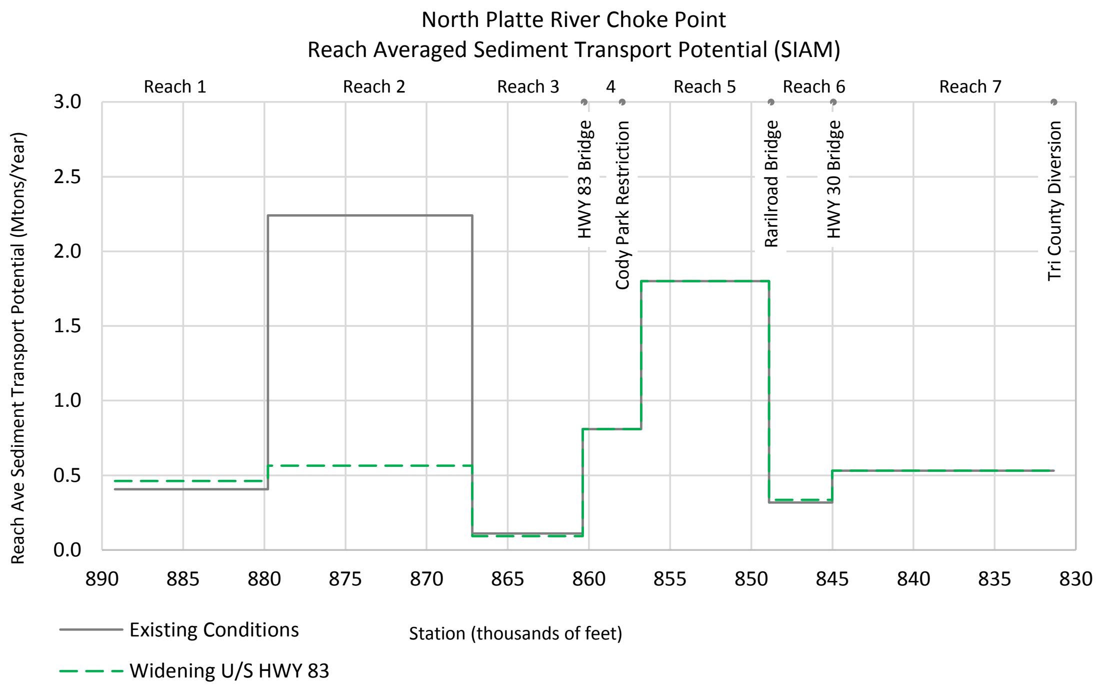



**Figure 8. North Platte River Choke Point Reach-Averaged Sediment Transport Potential, Existing vs Channel Widening Upstream of HWY 83.**

**Run 3 – Alternative C, Channel Widening Upstream of Highway 83 (2009 to 2014 Historic Hydrograph)**

Run 3 was conducted to determine if channel modifications upstream of Highway 83 were capable of reducing the transport capacity upstream of Highway 83 and thus decreasing the sediment load to reaches downstream of Highway 83 under 2009 to 2014 hydrologic conditions. Figure 9 shows the 2009 to 2014 historic hydrograph along with a comparison of the computed hydraulic capacity at minor flood stage for existing conditions and channel widening upstream of Highway 83. More detailed model results are provided in Figures A-7 through A-9 provided in Attachment A. Results show that hydraulic capacity is increased to 3,450 cfs prior to the 2011 flood event. At the peak of the flood, capacity is reduced to 2,000 cfs but recovers back to 3,000 cfs within a year after the flood. Hydraulic capacity then dips below 3,000 cfs for the remainder of the simulation. Reduction in the transport capacity of the reach upstream of Highway 83 where channel modifications are made results in deposition occurring in that reach by the end of the 5-year simulation. Figure 10 shows the cumulative mass bed change over the simulation period for existing conditions and Alternative C. The reach upstream of Highway 83 is generally degradational (indicated on the figure by a negative number). The results reflect that reaches upstream have become generally aggradational, indicating that there has been a reduction in transport capacity in Reach 2. Channel improvements upstream of Highway 83 alone will not meet the target objective. However, channel improvements upstream of Highway 83 combined with alternatives downstream of Highway 83 may be able to achieve long-term hydraulic capacity objectives.

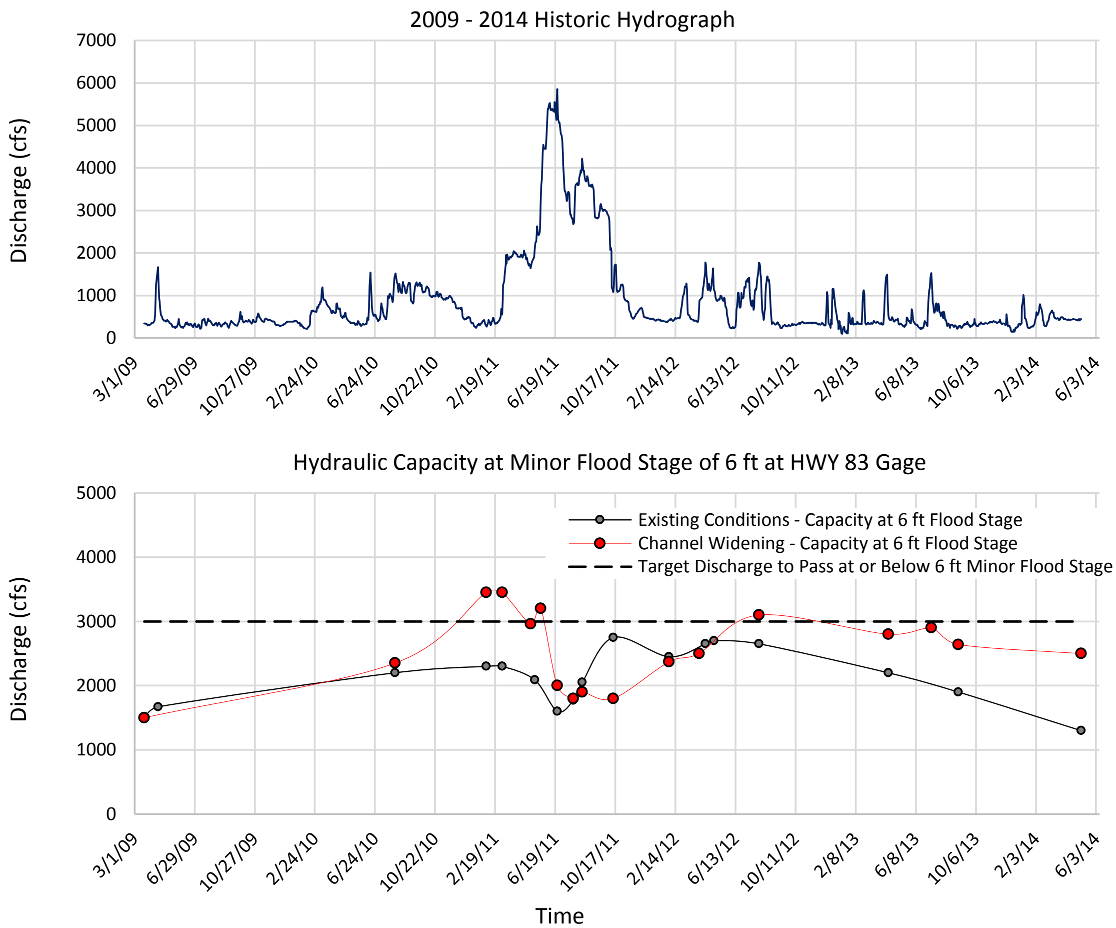



**Figure 9. Run 3-Alternative C, Channel Widening Upstream of Highway 83 - 2009 to 2014 Historic Hydrograph (top) and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage for Existing Conditions and Channel Widening Upstream of Highway 83 (bottom).**

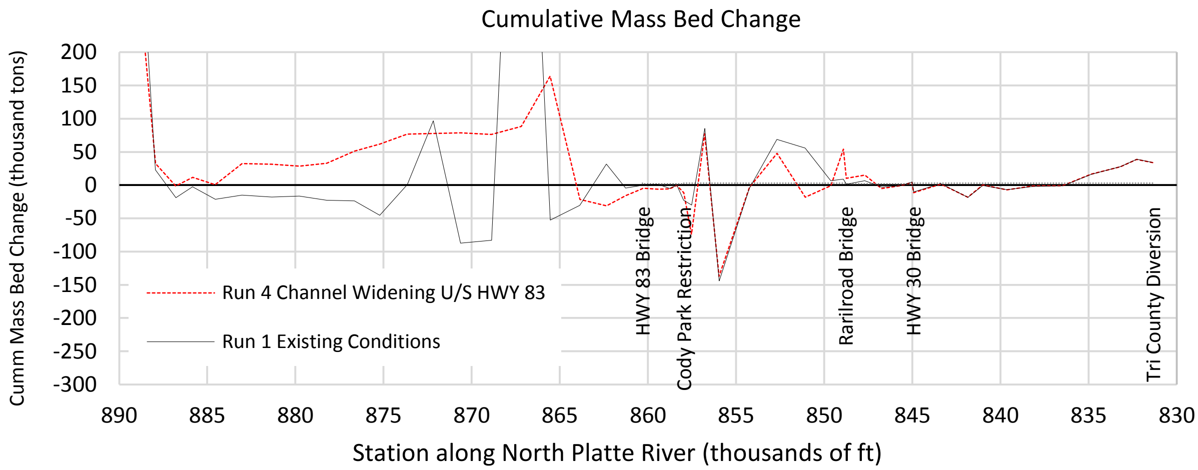



**Figure 10. Cumulative Mass Bed Change 2009 – 2014 Hydrograph, Existing Conditions vs Alternative C-Channel Widening**

In summary, the results of the sediment transport modeling for the Alternative C compared to the existing conditions indicate the following:

- The modifications associated with this alternative do not meet the target hydraulic capacity.
- The sediment supply from Reach 2 is greatly reduced but is insufficient to meet the flood stage requirements.
- Degradation immediately upstream of the Highway 83 bridge is apparent but insufficient to meet the flood stage requirements.
- An environment of slight degradation in Reach 4 with localized areas of aggradation continues to occur. The gage at the Highway 83 bridge reflects the benefit of the slightly degradational reach upstream of the bridge.
- Reach 5 continues to exhibit slight degradation within the channel with localized areas of aggradation.
- Reach 6 continues to reflect aggradational trends throughout the channel.
- Reach 7 continues to demonstrate a balance of sediment supply compared to sediment transport.

## Alternative D - Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83

The results of Run 3 show that Alternative C, involving channel modifications upstream of Highway 83, reduces transport capacity in SIAM Reach 2. However, channel work upstream of Highway 83 alone will not meet hydraulic capacity objectives. Further analyses were conducted to determine if the combination of channel widening upstream of Highway 83 with downstream improvements can meet hydraulic capacity objectives.

Alternative D combines channel widening upstream of Highway 83 with dredging and widening improvements downstream of Highway 83 that were presented in the June 5th, 2012 memo. These improvements include channel widening to 300 feet with 1.25 feet of dredging between Highway 83 and the Railroad Bridge. Two 1D sediment transport runs (Run 4 and 5) were conducted to determine if this combination of channel improvements upstream and downstream of Highway 83 can sustain desired hydraulic capacity under a 6-foot flood stage for two hydrologic conditions.

Reach-average sediment transport capacity for the channel modifications associated with Alternative D was computed using SIAM and compared with existing conditions, see Figure 11. Proposed channel modifications upstream of Highway 83 reflect a reduction in transport potential in Reach 2 of approximately 75%, a negligible increase in Reach 3, a decrease of approximately 55% in Reach 4, and a decrease of approximately 50% in Reach 5.

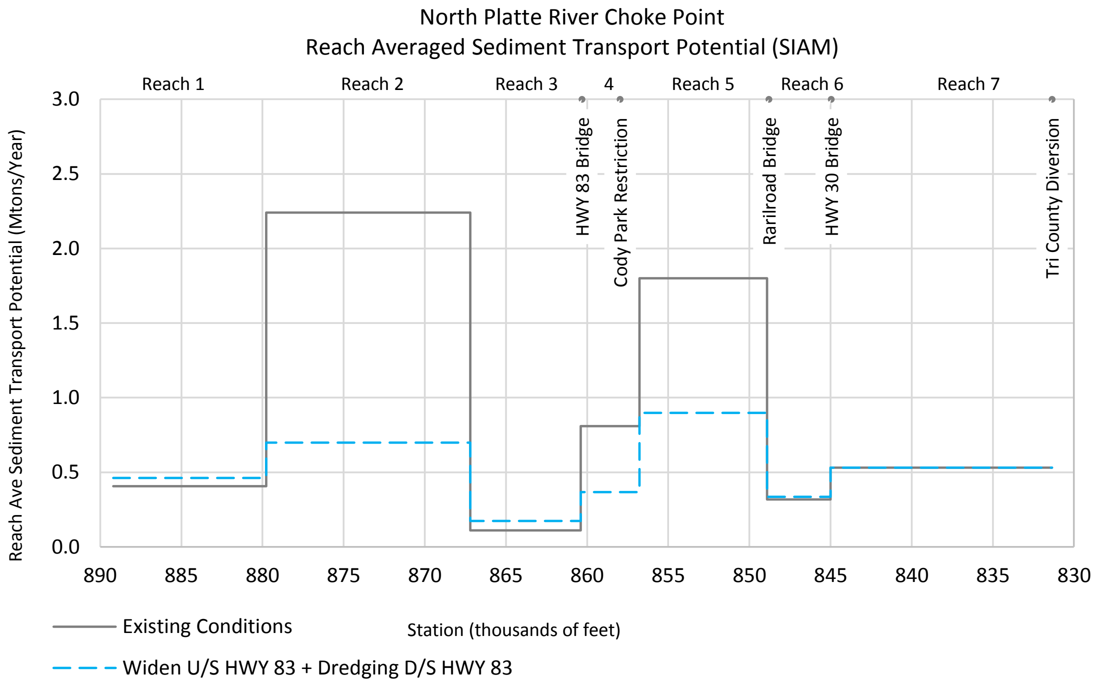
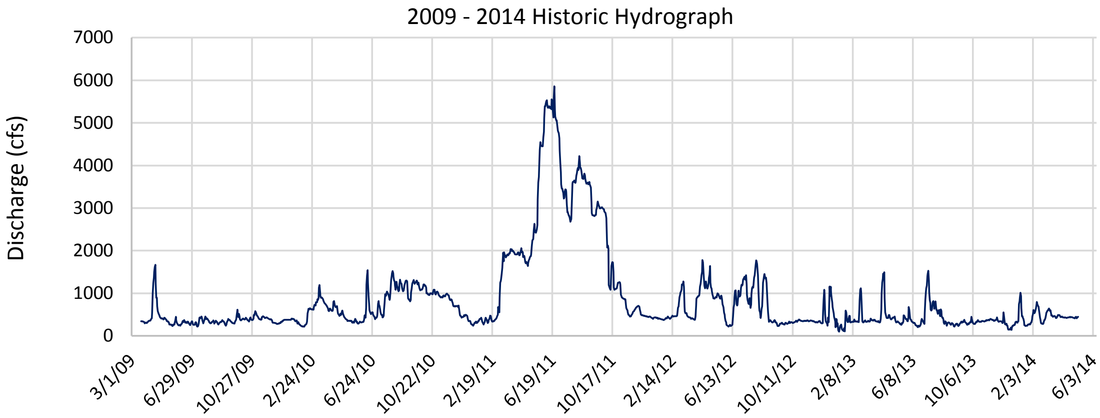



**Figure 11. North Platte River Choke Point Reach-Averaged Sediment Transport Potential, Existing vs Alternative D (Widening U/S HWY 83 + Dredging D/S HWY 83).**

### Run 4 – Alternative D, Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 (2009 to 2014 Historic Hydrograph)

This run was conducted to determine the effectiveness of this combination of channel improvements under the 2009 to 2014 hydrologic conditions. Figure 12 shows the 2009 to 2014 historic hydrograph along with a comparison of the hydraulic capacity at minor flood stage computed by the 1D sediment transport model. More detailed model results are provided in Figures A-10 through A-12 provided in Attachment A. Initial hydraulic capacity is 4,200 cfs due to dredging and channel widening associated with Alternative D downstream of Highway 83. Hydraulic capacity is increased to 4,500 cfs at the start of the 2011 flood. At the peak of the flood capacity is reduced to 3,000 cfs and decreases to 2,600 cfs during the receding limb of the flood. However, hydraulic capacity recovers to 3,000 cfs approximately 2 years after the flood event.



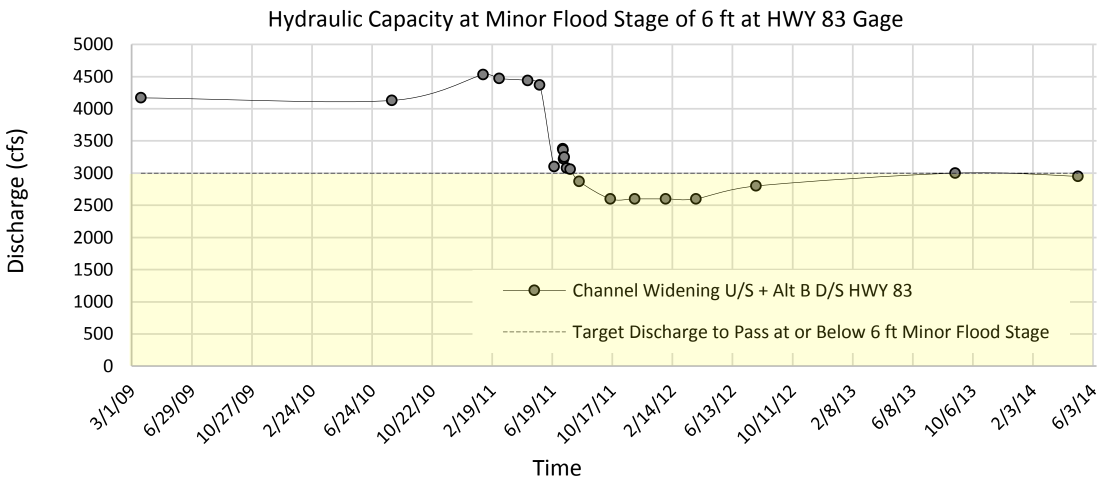




**Figure 12. Run 4-Alternative D, Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 (2009 to 2014 Historic Hydrograph) (top) and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

Figure 13 shows the cumulative mass bed change over the simulation period for existing conditions and Alternative D. Reduction in transport capacity of SIAM Reach 2 upstream of Highway 83 where channel modifications are made results in deposition occurring in that reach by the end of the 5-year simulation. The reach upstream of Highway 83 is generally degradational (indicated on the figure by a negative number). The results reflect that reaches upstream have become generally aggradational, indicating that there has been a reduction in transport capacity in Reach 2. Figure 13 also indicates that downstream of Highway 83 deposition is occurring where dredging improvements are located. Even though upstream sediment supply from Reach 2 has been reduced aggradation is still occurring in the reaches downstream of Highway 83 which result in a loss of hydraulic capacity after the 2011 flood event, as shown in Figure 12 above. Deposition occurring downstream of Highway 83 in Reaches 4 and 5 can be attributed to the reduction in sediment transport potential due to dredging, as shown by the SIAM analyses presented in Figure 11.

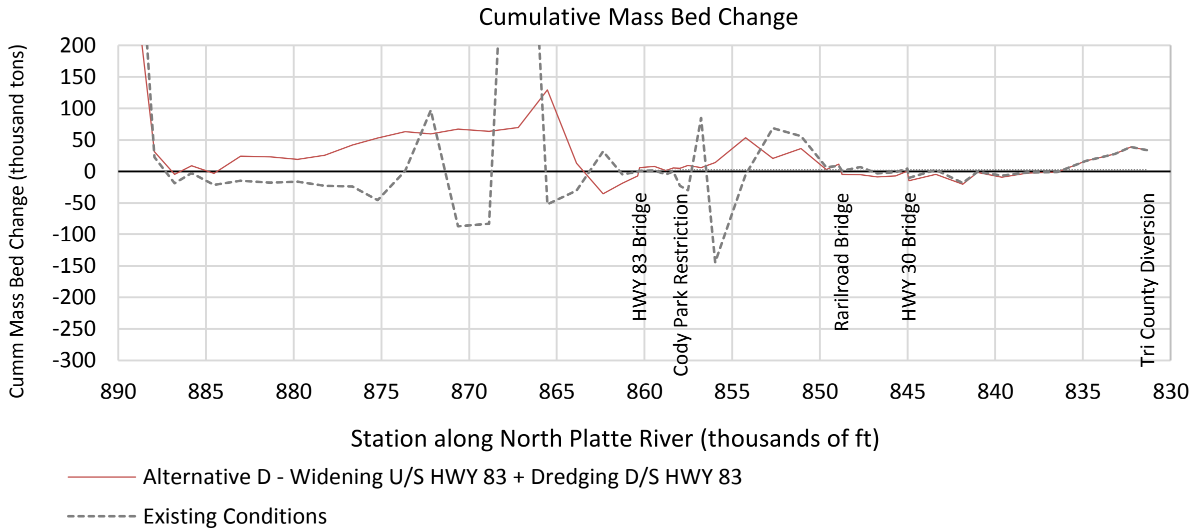



**Figure 13 Cumulative Mass Bed Change – Existing Conditions vs Alternative D 2009 – 2014 Historic Hydrograph**

In summary, the results of the sediment transport modeling for the Alternative D compared to the existing conditions indicate the following:

- The modifications associated with this alternative can meet long-term target hydraulic capacity prior to flooding. However, hydraulic capacity is diminished during and after the flood event due to a reduction in transport potential downstream of Highway 83.
- Reach 2 has become aggradational reducing the sediment supply to downstream reaches.
- The sediment supply from Reach 2 is greatly reduced but the reduction is insufficient to meet the flood stage requirements.
- Degradation immediately upstream of the Highway 83 bridge is apparent but insufficient to meet the flood stage requirements.
- Reach 4 appears to have achieved a sediment balance due to a decrease in transport capacity.
- Reach 5 is generally aggradational within the channel.
- Reach 6 continues to reflect marginally aggradational trends throughout the channel.
- Reach 7 continues to demonstrate a balance of sediment supply compared to sediment transport, with the exception of the area approaching the Tri-County Diversion.

**Run 5 – Alternative D, Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 for 16-Year Hydrograph with 2009 - 2013 Historic Hydrograph (2011 Flood) and SDHFs.**
This simulation was conducted to determine the long-term performance of combined improvements under hydrologic conditions that consider both SDHFs and flood conditions. Figure 14 shows the 16-year hydrograph with the 2011 flood and SDHFs along with the computed hydraulic capacity at minor flood stage for channel widening upstream of Highway 83 and dredging downstream of Highway 83. More detailed model results are provided in Figures A-13 – A-16 provided in Attachment A. Initial hydraulic capacity is 4,200 cfs due to dredging and channel widening downstream of Highway 83. Hydraulic capacity is increased to 4,500 cfs by year five prior to the flood. At the peak of the flood, occurring around year

six, hydraulic capacity is reduced to approximately 2,000 cfs. After the flood, hydraulic capacity steadily increases to 3,000 cfs by year thirteen. This scenario is not able to maintain the hydraulic capacity objective after the occurrence of 2011 flooding. This would mean that additional channel maintenance would be required after significant flood events.

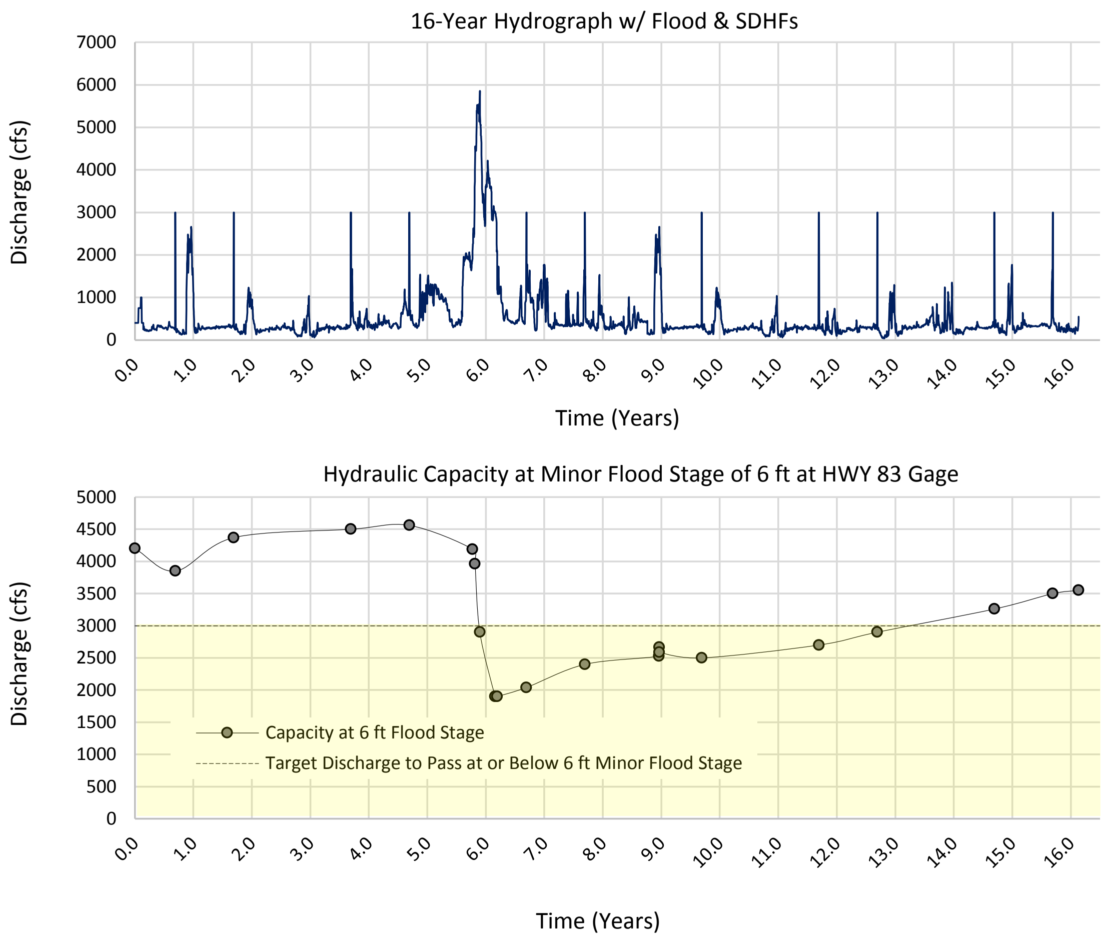



**Figure 14. Run 5-Alternative D, Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 - 16-Year Hydrograph with Flood and SDHFs (top) and Hydraulic Capacity at Minor Flood Stage for Channel Widening Upstream of Highway 83 + Dredging Downstream of Highway 83 (bottom).**

Figure 15 shows the cumulative mass bed change over the simulation period for Alternative D. Reduction in transport capacity of SIAM Reach 2 upstream of Highway 83 where channel modifications are made results in deposition occurring in that reach by the end of the 16-year simulation. The reach upstream of Highway 83 is degradational (indicated on the figure by a negative number). The results reflect that reaches upstream have become generally aggradational, indicating that there has been a reduction in transport capacity in Reach 2. Figure 15 also indicates that downstream of Highway 83 deposition is occurring where dredging improvements are located. Even though upstream sediment supply from Reach 2 has been reduced aggradation is still occurring in the reaches downstream of Highway 83 which result in a loss of hydraulic capacity after a flood event, as shown in Figure 14 above. Deposition occurring downstream of Highway 83 in Reaches 4 and 5 can be attributed to the reduction in sediment transport potential due to dredging, as shown by the SIAM analyses presented in Figure 11.

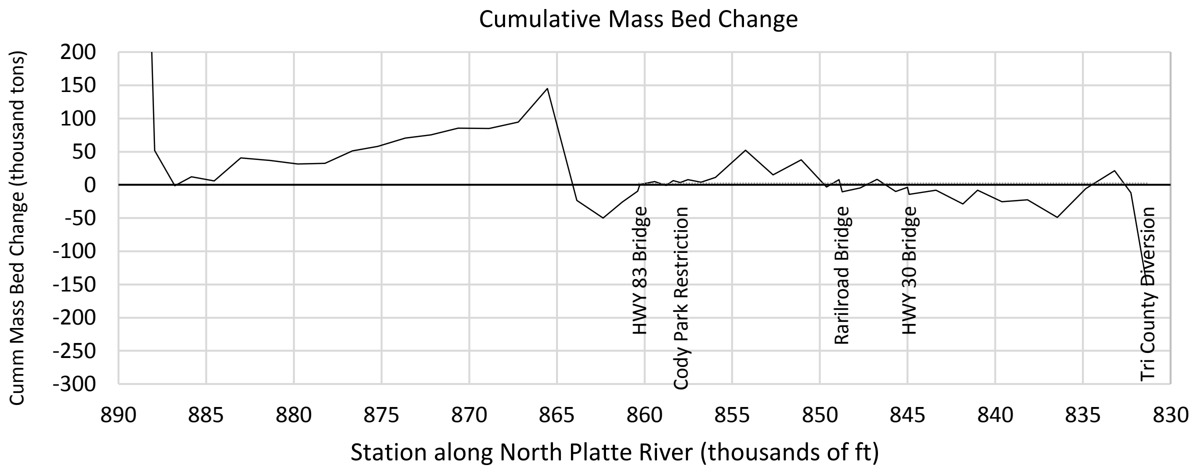



**Figure 15. Cumulative Mass Bed Change – Run 5 Alternative D 16-Year Hydrograph w/ SDHFs**

In summary, the results of the sediment transport modeling for the Alternative D (16-year hydrograph) compared to the existing conditions indicate the following:

- The modifications associated with this alternative do not meet the target hydraulic capacity.
- The sediment supply from Reach 2 is greatly reduced but the reduction is insufficient to meet the flood stage requirements.
- Degradation immediately upstream of the Highway 83 bridge is apparent but insufficient to meet the flood stage requirements.
- An environment of slight degradation in Reach 4 with localized areas of aggradation continues to occur. The gage at the Highway 83 bridge reflects the benefit of the slightly degradational reach upstream of the bridge.
- Reach 5 continues to exhibit slight aggradation within the channel with localized areas of degradation.
- Reach 6 reflects a sediment balance with localized areas of aggradation and degradation.
- Reach 7 reflects a trend toward aggradation.

## Alternative E - Channel Widening Upstream of Highway 83 + Jetties/Bendway Weirs and Dredging Downstream of Highway 83

Channel widening upstream of Highway 83 coupled with dredging and widening downstream of Highway 83 (Alternative D) cannot meet hydraulic capacity objectives over the 16-year long-term simulation with historic flooding and SDHFs. The addition of jetties/bendway weirs downstream of Highway 83 was explored to determine if the structures could increase transport capacity in order to maintain long-term hydraulic capacity.

Alternative E includes channel widening upstream of Highway 83 coupled with jetties/bendway weirs and dredging downstream of Highway 83. This alternative includes widening of the channel to a minimum of

300 feet, dredging to lower the thalweg 1.25 to 3 feet, and the addition of 2-foot high jetties/bendway weirs that constrict the low flow channel to a width of 150 feet downstream of Highway 83 (see the July 17th, 2012 memo for more information). Figure 16 shows a conceptual layout of jetties/bendway weirs downstream of Highway 83.

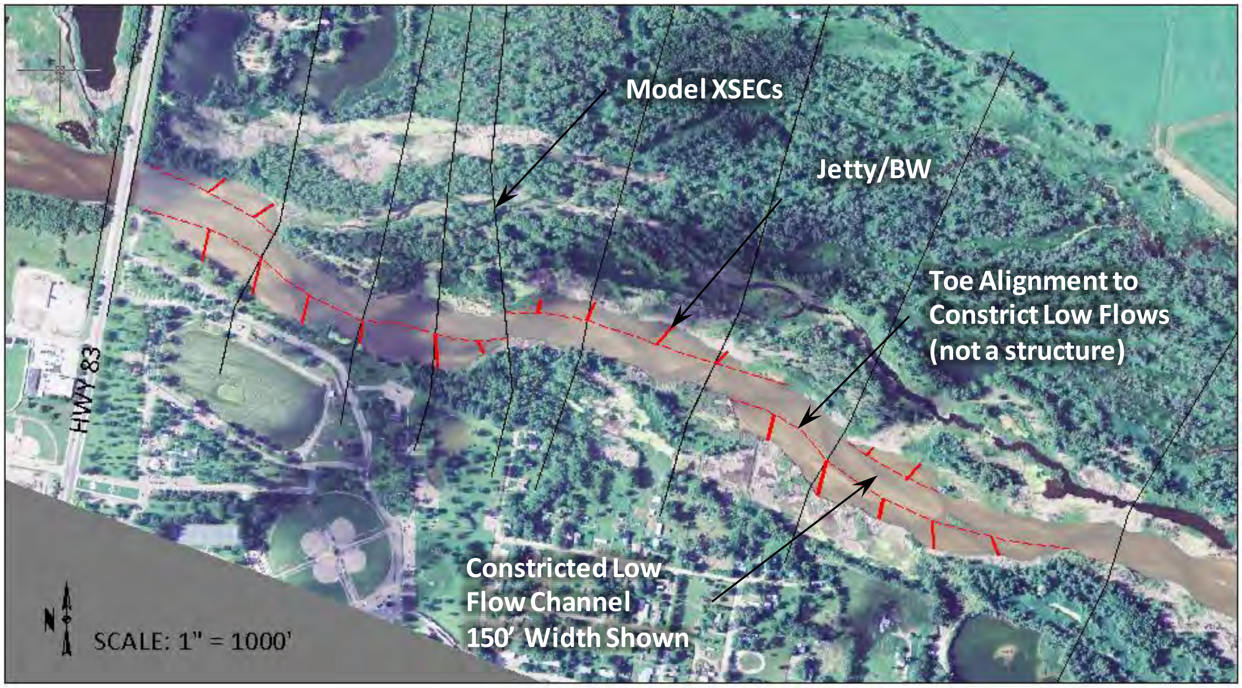



**Figure 16. Conceptual Jetty/Bendway Weir Layout**

Reach-average sediment transport capacity for the channel modifications associated with Alternative E was computed using SIAM and compared with existing conditions, see Figure 17. Proposed channel modifications upstream of Highway 83 reflect a reduction in transport potential in Reach 2 of approximately 75%. Transport capacity has been significantly increased in Reach 3. A decrease in capacity is noted in Reaches 4 and 5. Note that the combination of improvements associated with Alternative E have resulted in a homogenization or evening out of sediment transport capacity throughout the length of the study reach. Consistency in the rate of sediment transport potential from reach to reach should result in a more balanced system.

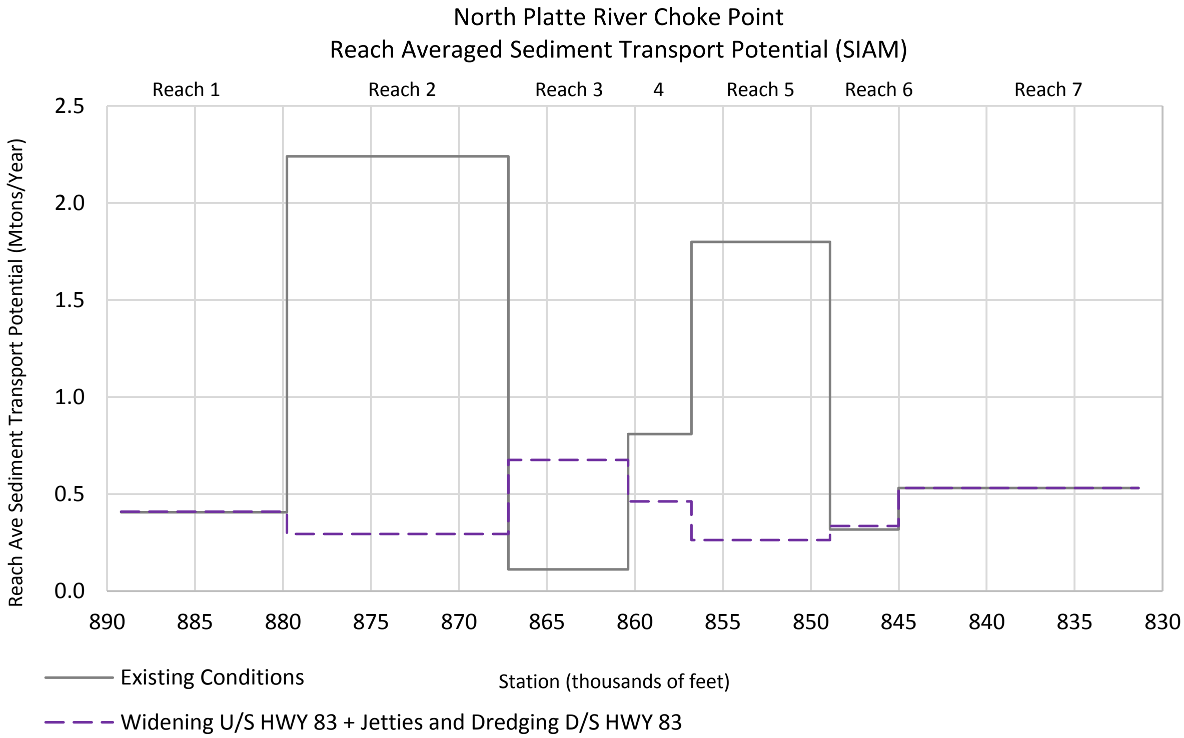
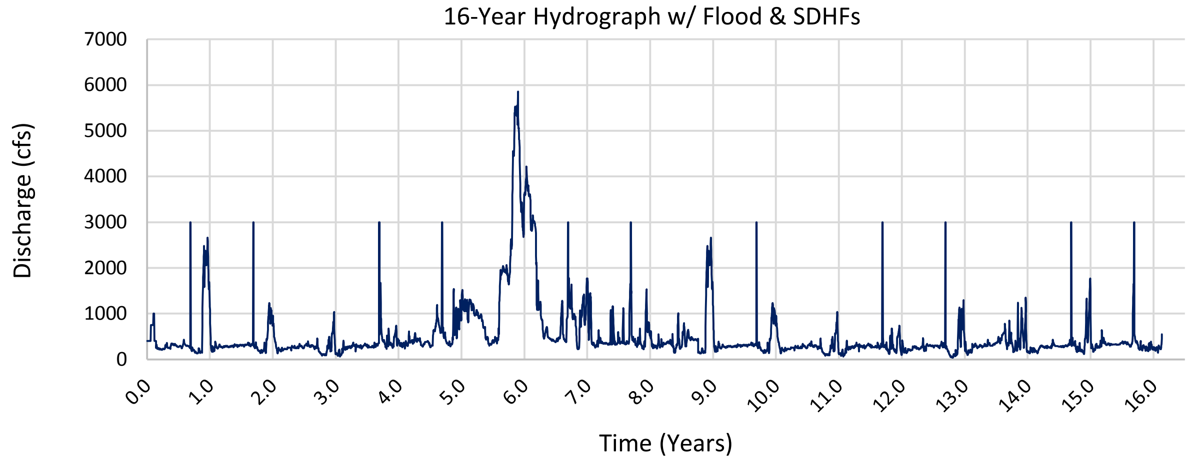



**Figure 17. North Platte River Choke Point Reach-Averaged Sediment Transport Potential, Existing vs Alternative D (Widening U/S HWY 83 + Dredging D/S HWY 83).**

**Run 6 – Alternative E, Channel Widening Upstream of Highway 83 + Jetties/Bendway Weirs and Dredging Downstream of Highway 83 for 16-Year Hydrograph with 2009 - 2013 Historic Hydrograph (2011 Flood) and SDHFs**

This simulation was conducted to determine the long-term performance of Alternative E combined improvements under hydrologic conditions that consider both SDHFs and historic flooding. Figure 18 shows the 16-year hydrograph with the 2011 flood and SDHFs along with the computed hydraulic capacity at minor flood stage for Alternative E. More detailed model results are provided in Figures A-17 – A-20 provided in Attachment A. Initial hydraulic capacity is 3,200 cfs, which is due to the placement of jetties/bendway weirs, dredging and channel widening downstream of Highway 83. Hydraulic capacity is increased to 5,000 cfs between year five and six just prior to the flood. At the peak of the flood, occurring around year six, hydraulic capacity is reduced to approximately 3,200 cfs. Within 2 years after the flood hydraulic capacity steadily increases up to 4,700 cfs and remains above 4,000 cfs for the remainder of the 16-year period. The Alternative E improvements are able to meet and maintain the hydraulic capacity target over the long-term simulation. This is attributed to the combination of reduced hydraulic capacity upstream of the Highway 83 and increased capacity by use of jetties/bendway weirs downstream of Highway 83, see Figure 17.



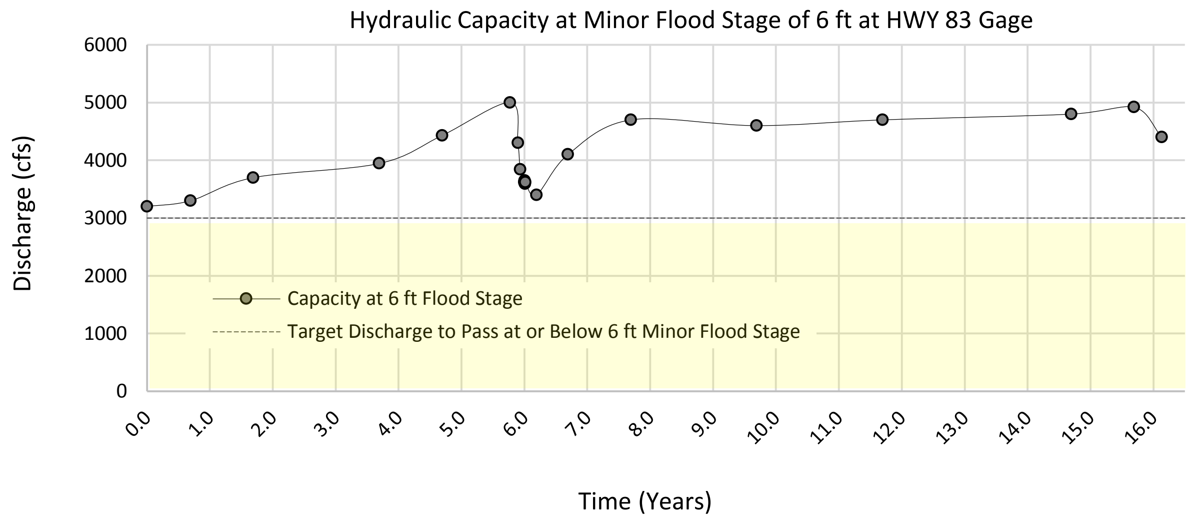




**Figure 18. Run 6 - Alternative E, Channel Widening Upstream of Highway 83 + Jetties/Bendway Weirs and Dredging D/S Highway 83 - 16-Year Hydrograph with Flood and SDHFs (top) and Hydraulic Capacity at Minor Flood Stage (bottom).**

Figure 19 shows the cumulative mass bed change over the simulation period for Alternative E compared with Alternative D. Figure 19 indicates that Reaches 2, 3, and 4 are at equilibrium or degradational (indicated on the figure by a negative number). This is attributed to the consistency in transport capacity upstream and downstream of Highway 83 resulting in a more balanced system.

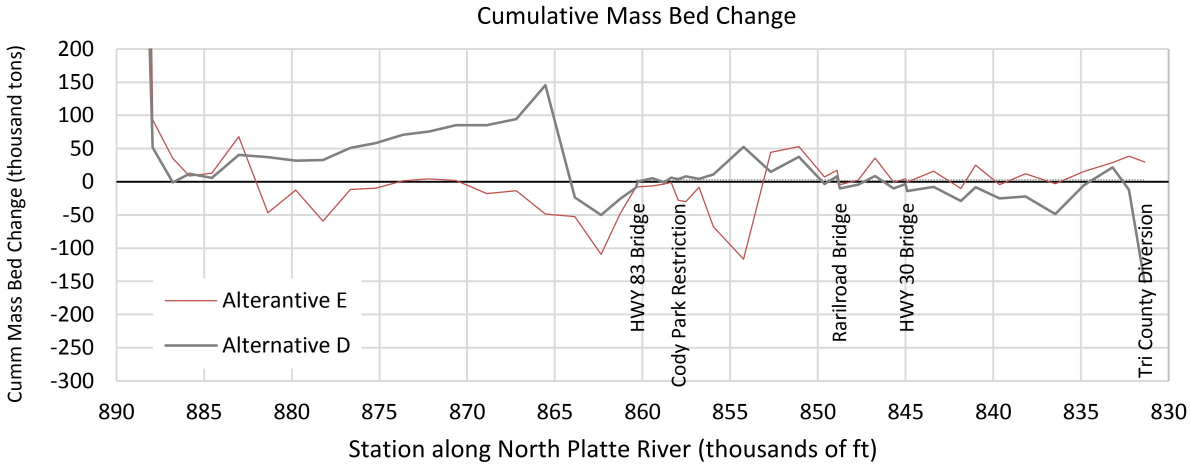



**Figure 19 Cumulative Mass Bed Change – Comparison of Alternative D and Alternative E 16-Year Hydrograph w/ SDHFs**

In summary, the results of the sediment transport modeling for the Alternative E (16-year hydrograph) compared to the existing conditions indicate the following:

- The modifications associated with this alternative meet the long-term target hydraulic capacity.
- Transport capacity from reach to reach is consistent with Alternative E improvements resulting in balance or degradation occurring in Reaches 2, 3, and 4.
- Reach 5 continues to exhibit slight degradation within the channel with localized areas of aggradation.
- Reach 6 and 7 reflect slight aggradational trends throughout the channel.
- The impact of the improvements on the water surface elevation associated with the 100-year flood event (9,690 cfs) was also evaluated. The proposed improvements created a minimal rise in water surface elevation (0.2 ft) which can be reduced through minor changes in the configuration of the jetties/bendway weirs.

## Considerations/Conclusions

- The 1D sediment transport model is capable of recreating observed trends in hydraulic capacity before and after the 2011 flood event. However, the temporal rate at which the model predicts changes in hydraulic capacity is slower than what has been observed in the field. Channel response likely occurs quicker than the sediment transport model is predicting. This could be attributed to use of a standard sediment transport equation, coarsening of the bed material, changes in upstream sediment sources, or changes in channel geometry that may have occurred after the 2009 LiDAR was collected. This would likely be true for all sediment transport runs.
- Review of existing conditions indicates that Reach 2, a 3-mile section of river located upstream of Highway 83, has an extremely high capacity for sediment transport relative to other reaches along the

Choke Point. This reach is likely supplying sediment to the depositional reaches around the Highway 83 Bridge and Cody Park Restriction area, resulting in diminished hydraulic capacity at Highway 83 gage. Reach 2 is characterized by differing channel characteristics when compared with other reaches, with a notable reduction in channel width.

- Widening of the channel along Reach 2, along with some modification to channel slope, will decrease the transport capacity of the reach. Reduction in transport capacity along Reach 2 was found to improve hydraulic capacity conditions at the Highway 83 gage.
- Results of modeling indicate that upstream channel improvements coupled with dredging downstream of Highway 83 do not maintain long-term target hydraulic capacity without some channel maintenance following flood events in excess of 4,000 cfs.
- Modeling results indicate that upstream channel improvements coupled with installation of jetties/bendway weirs and dredging downstream of Highway 83 appear to be able satisfy the long-term hydraulic capacity target.
- Consideration should be given to extending the jetties/bendway weirs and dredging improvements immediately upstream of Highway 83.
- More detailed analyses is recommended to confirm the feasibility and practical implementation of the upstream and downstream improvements to meet program objectives. The initial construction costs coupled with annual maintenance requirements associated with these improvements should be determined and compared with the cost of property acquisition.

## A. Attachment A – Detailed Results of Choke Point 1D Sediment Transport Modeling

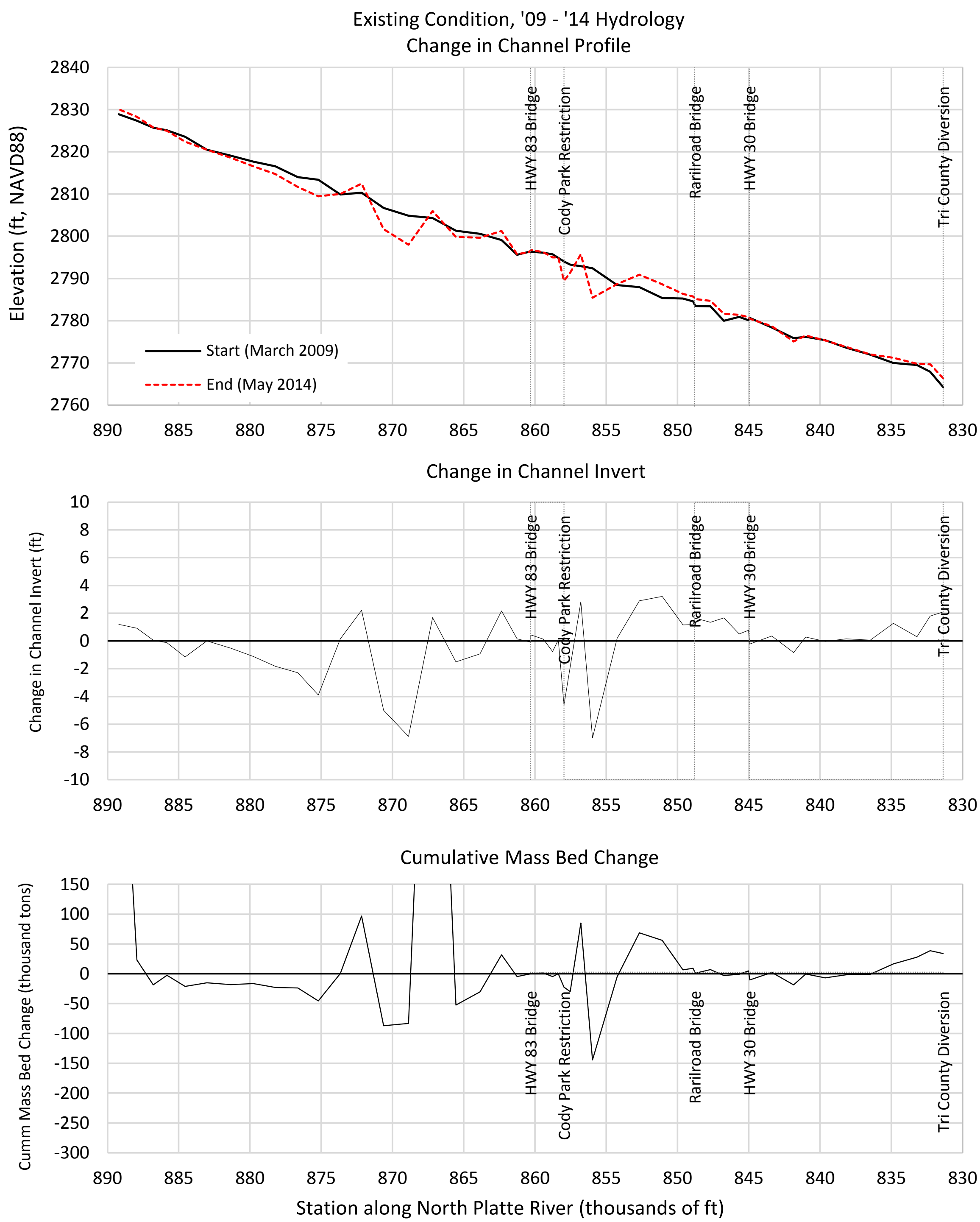



**Figure A-1 Spatial Results, Run 1 Alt A Existing Condition 2009 – 2014 Hydrology – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**

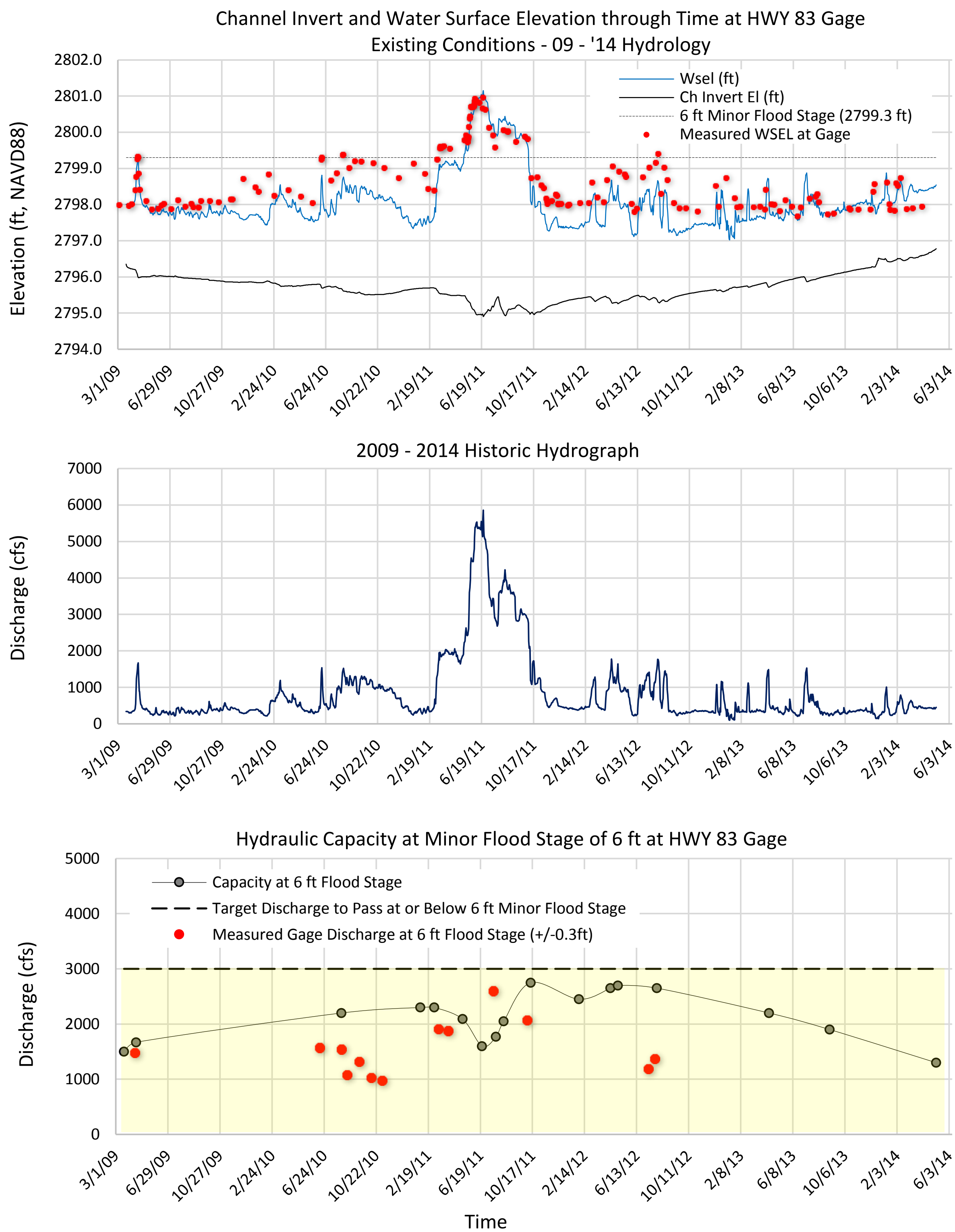



**Figure A-2 Results through Time, Run 1 Alt A Existing Condition 2009 – 2014 Hydrology – Channel Invert and Water Surface Elevation at HWY 83 Gage (top), 2009 – 2014 Daily Discharge Hydrograph (middle), and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

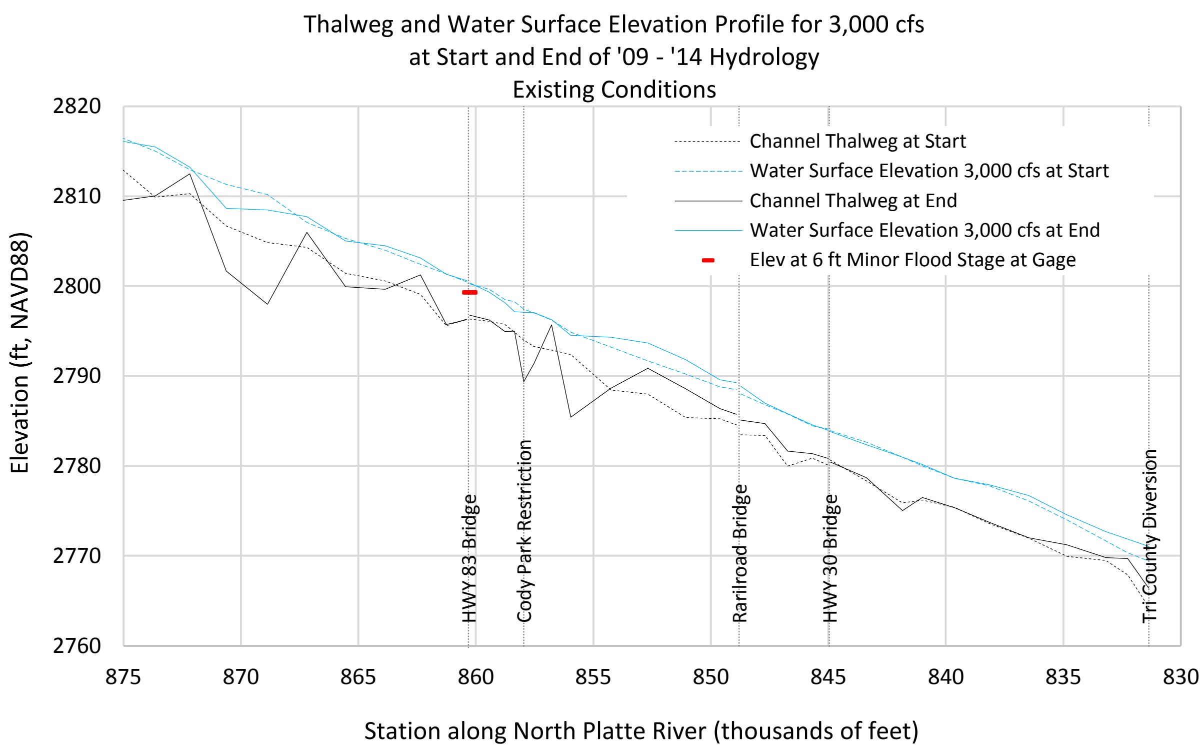



**Figure A-3 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 2009 – 2014 Hydrology for Run 1 Alt A Existing Conditions.**

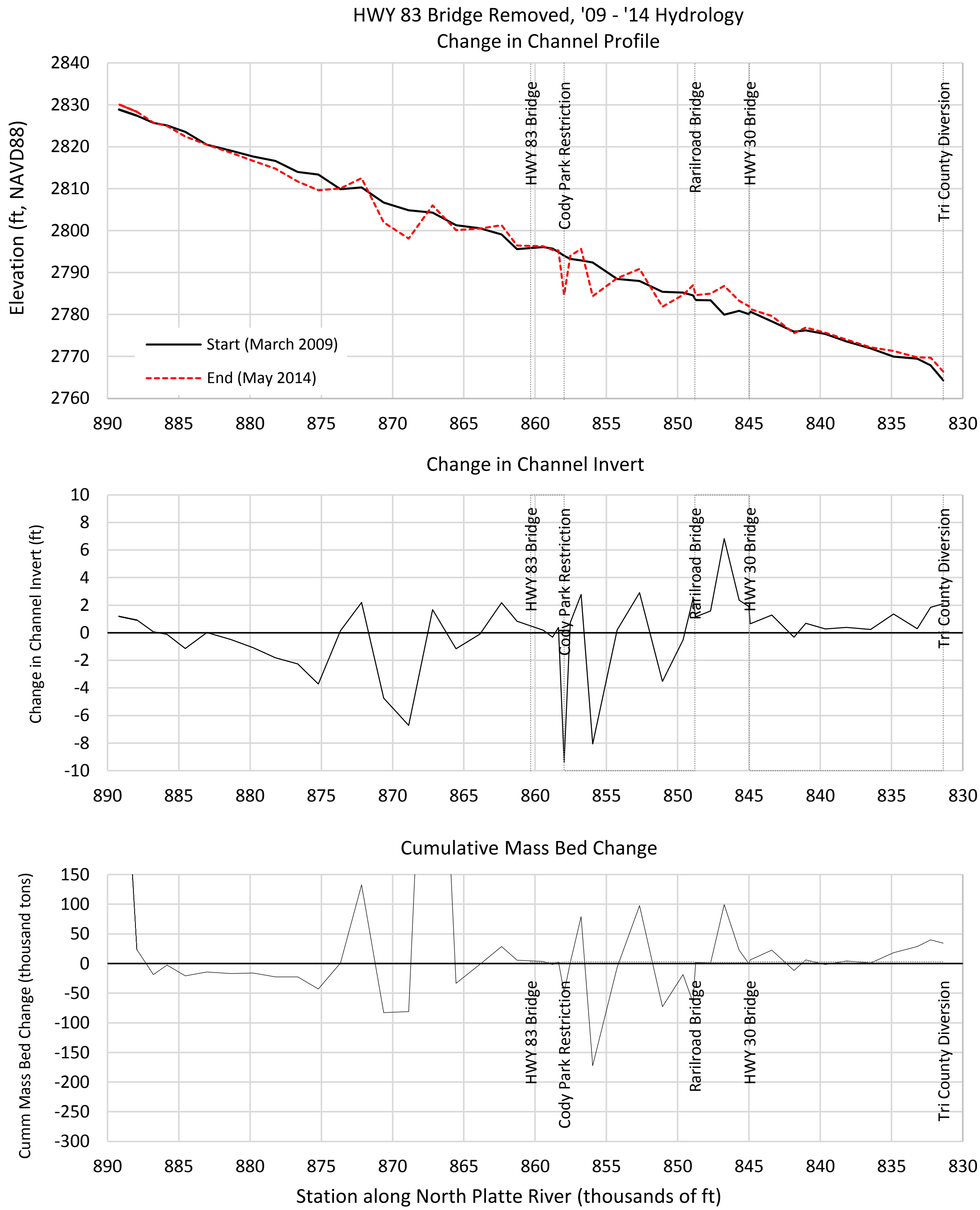



**Figure A-4 Spatial Results, Run 2 Alt B HWY 83 Bridge Removed 2009 – 2014 Hydrology – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**

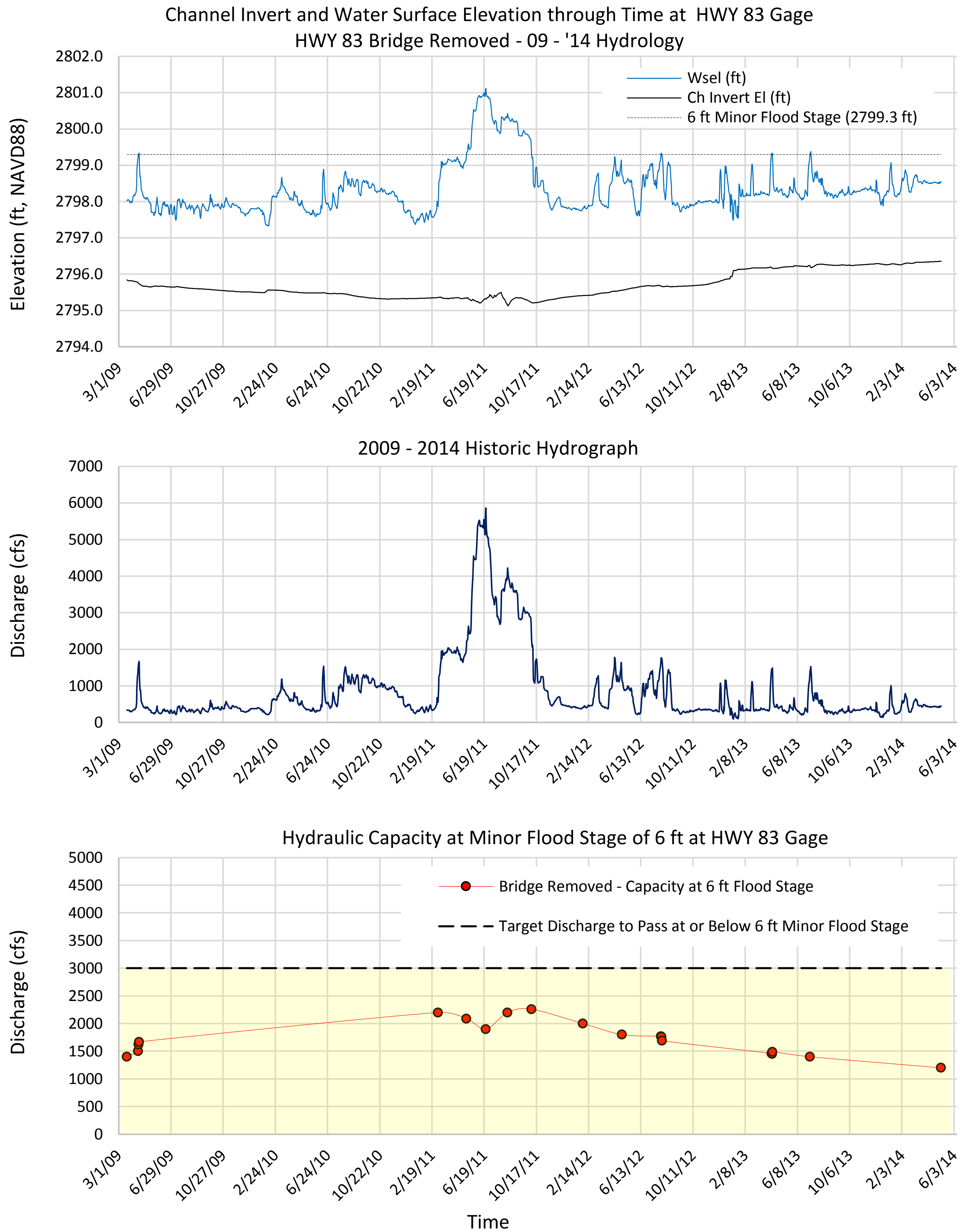



**Figure A-5 Results through Time, Run 2 Alt B HWY 83 Bridge Removed 2009 – 2014 Hydrology – Channel Invert and Water Surface Elevation at HWY 83 Gage (top), 2009 – 2014 Daily Discharge Hydrograph (middle), and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

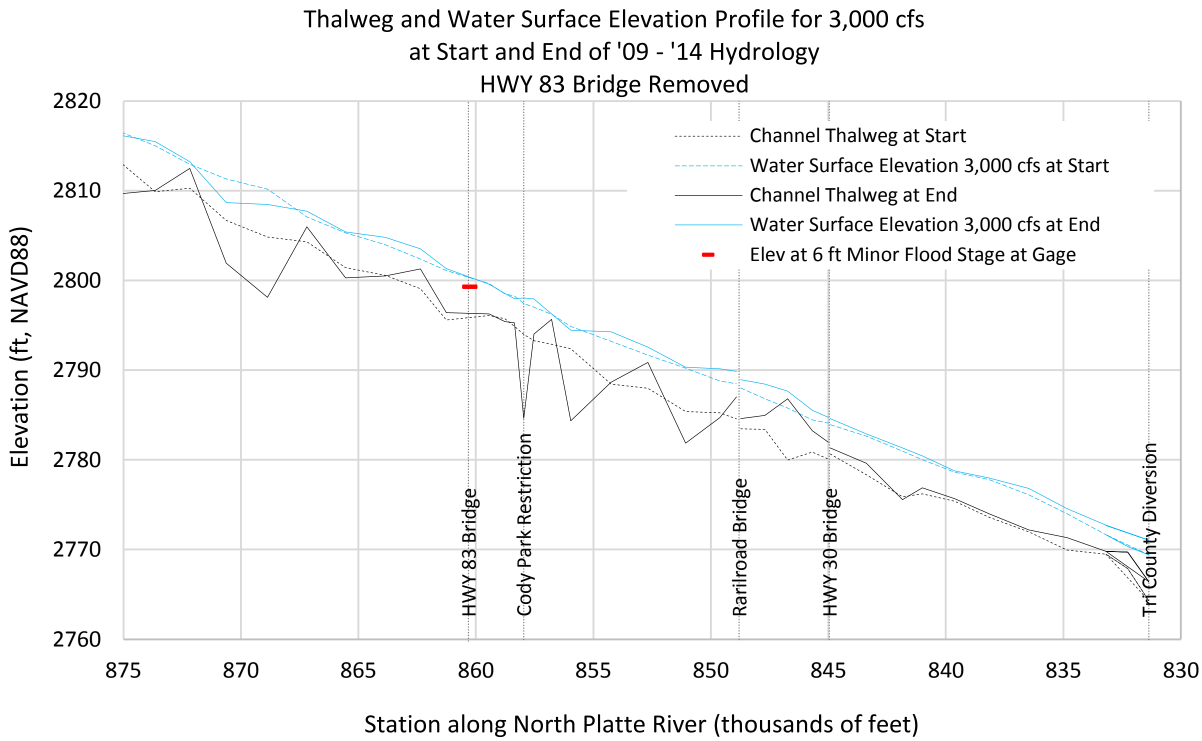



**Figure A-6 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 2009 – 2014 Hydrology for Run 2 Alt B HWY 83 Bridge Removed.**

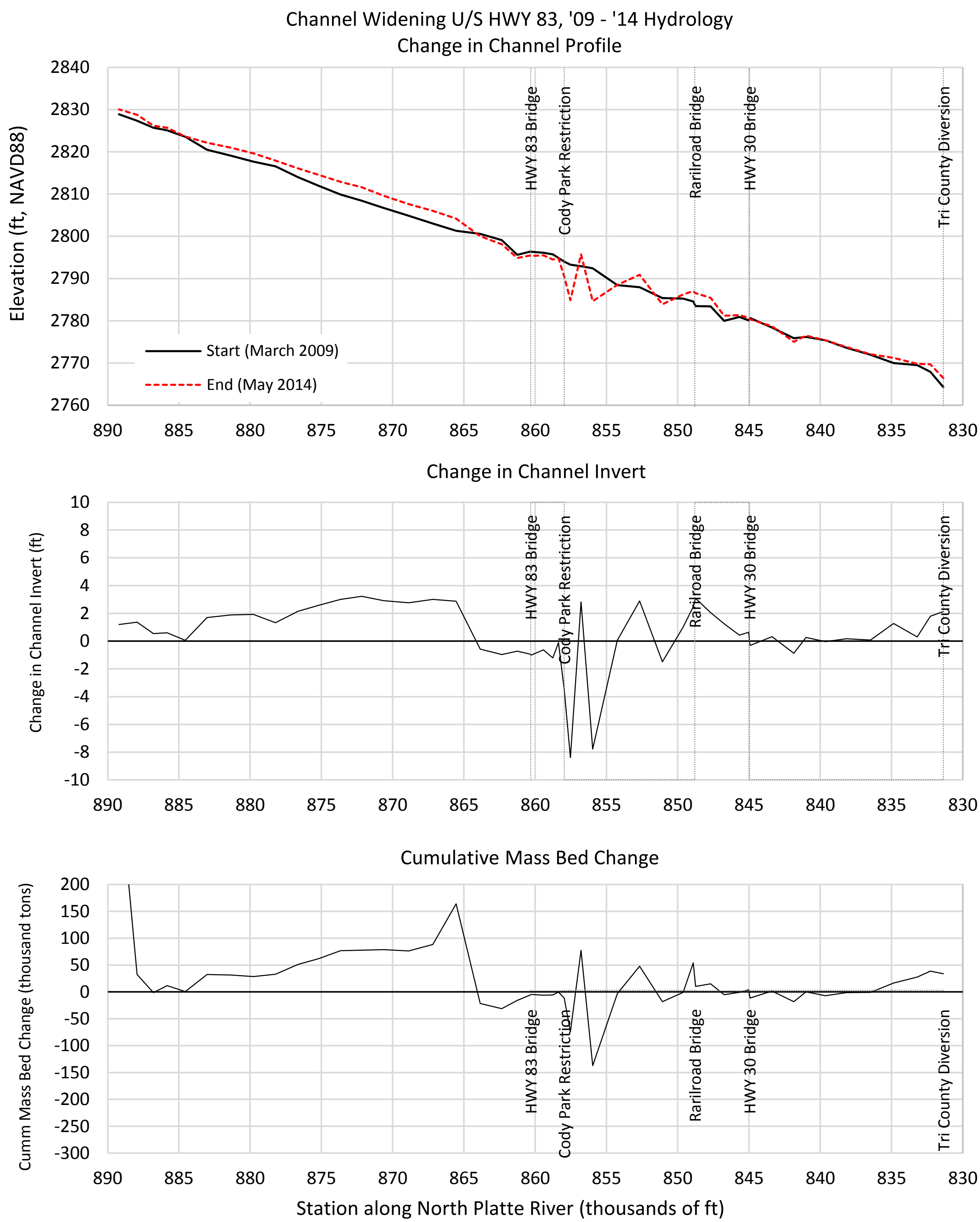
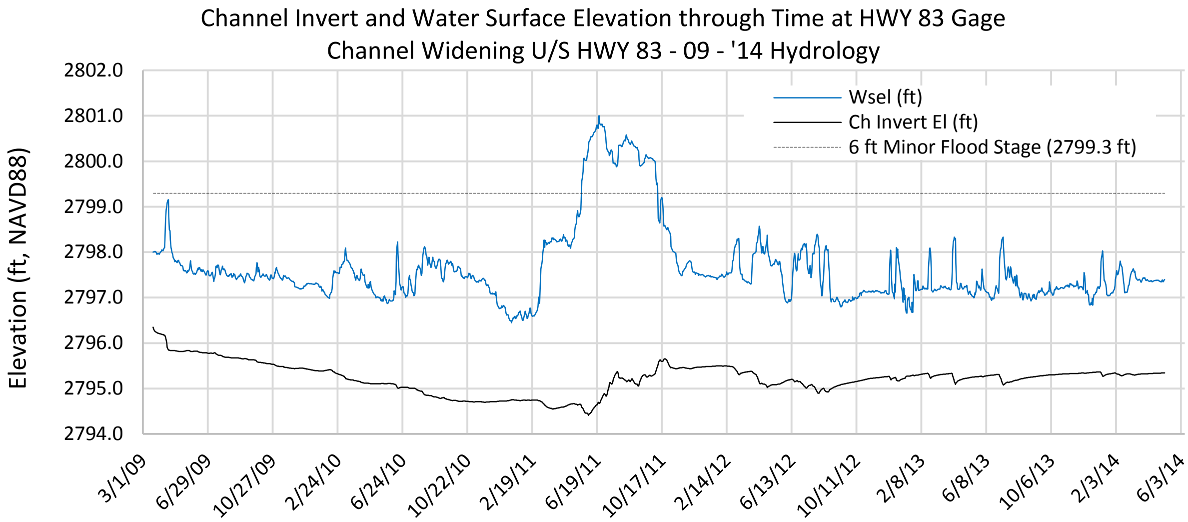
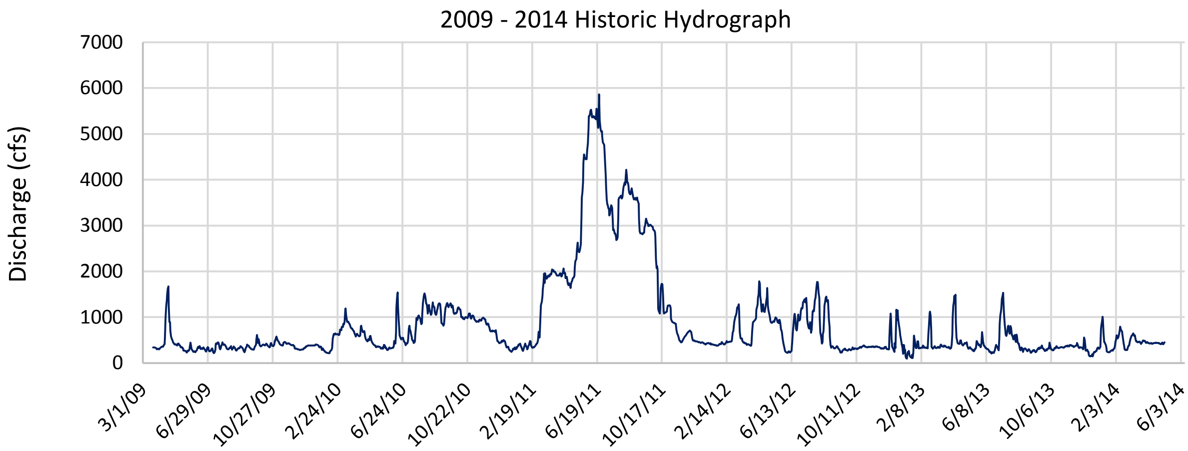



**Figure A-7 Spatial Results, Run 3 Alt C Channel Widening U/S HWY 83 2009 – 2014 Hydrology – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**



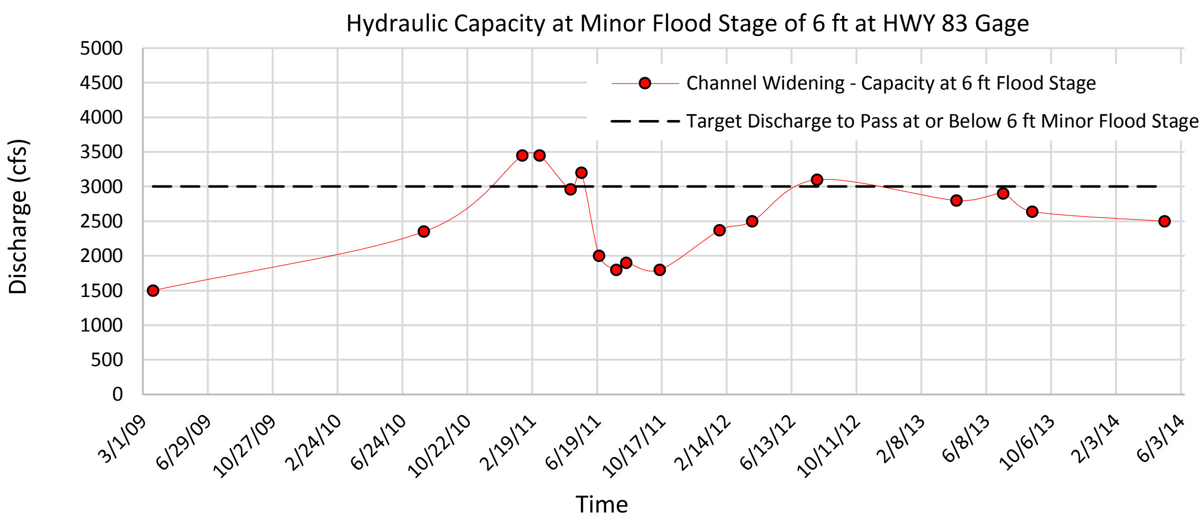




**Figure A-8 Results through Time, Run 3 Alt C Channel Widening U/S HWY 83 2009 – 2014 Hydrology – Channel Invert and Water Surface Elevation at HWY 83 Gage (top), 2009 – 2014 Daily Discharge Hydrograph (middle), and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

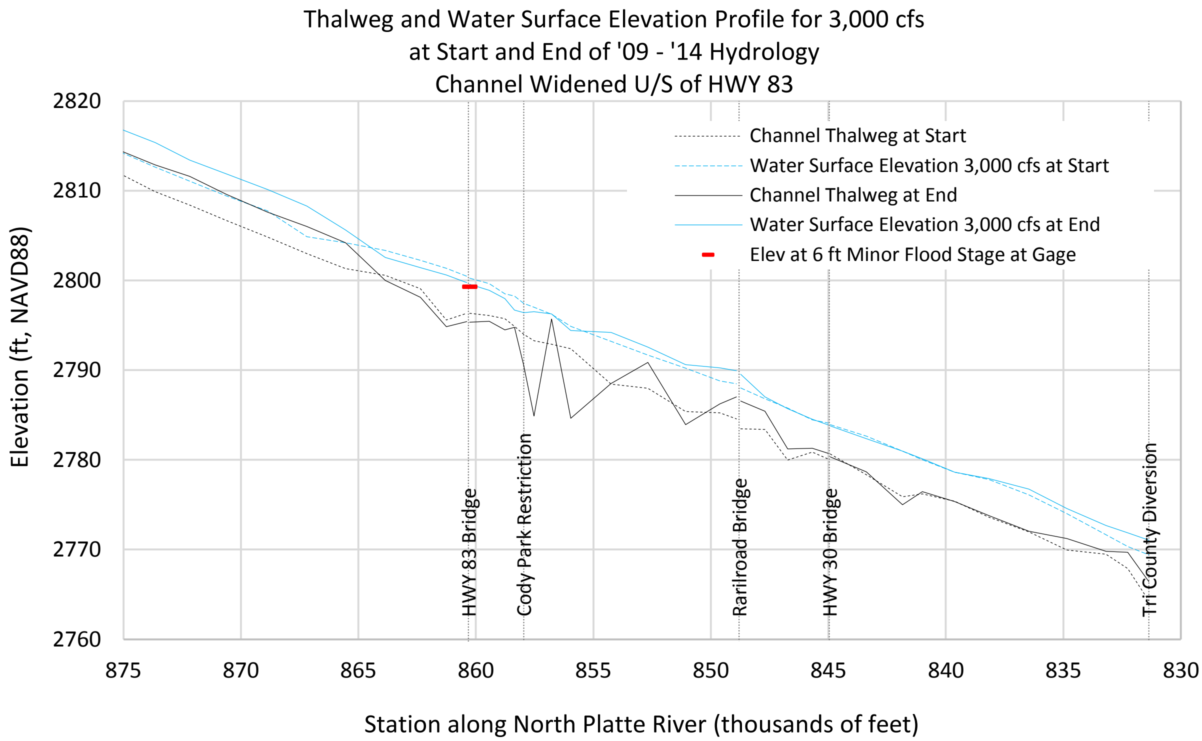



**Figure A-9 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 2009 – 2014 Hydrology for Run 3 Alt C Channel Widening U/S HWY 83.**

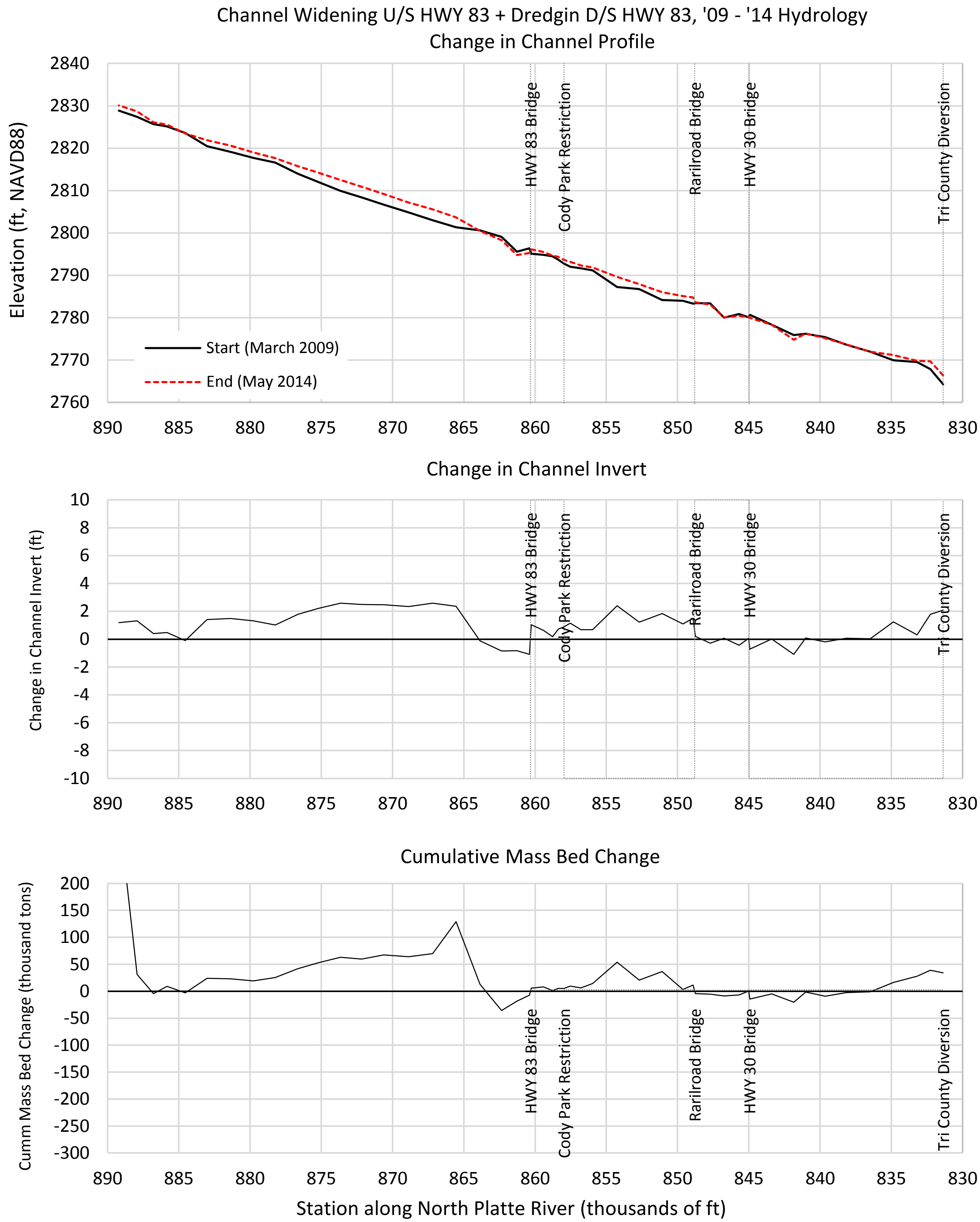



**Figure A-10 Spatial Results, Run 4 (Alt D) Channel Widening U/S HWY 83 + Dreding D/S HWY 83 2009 – 2014 Hydrology – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**

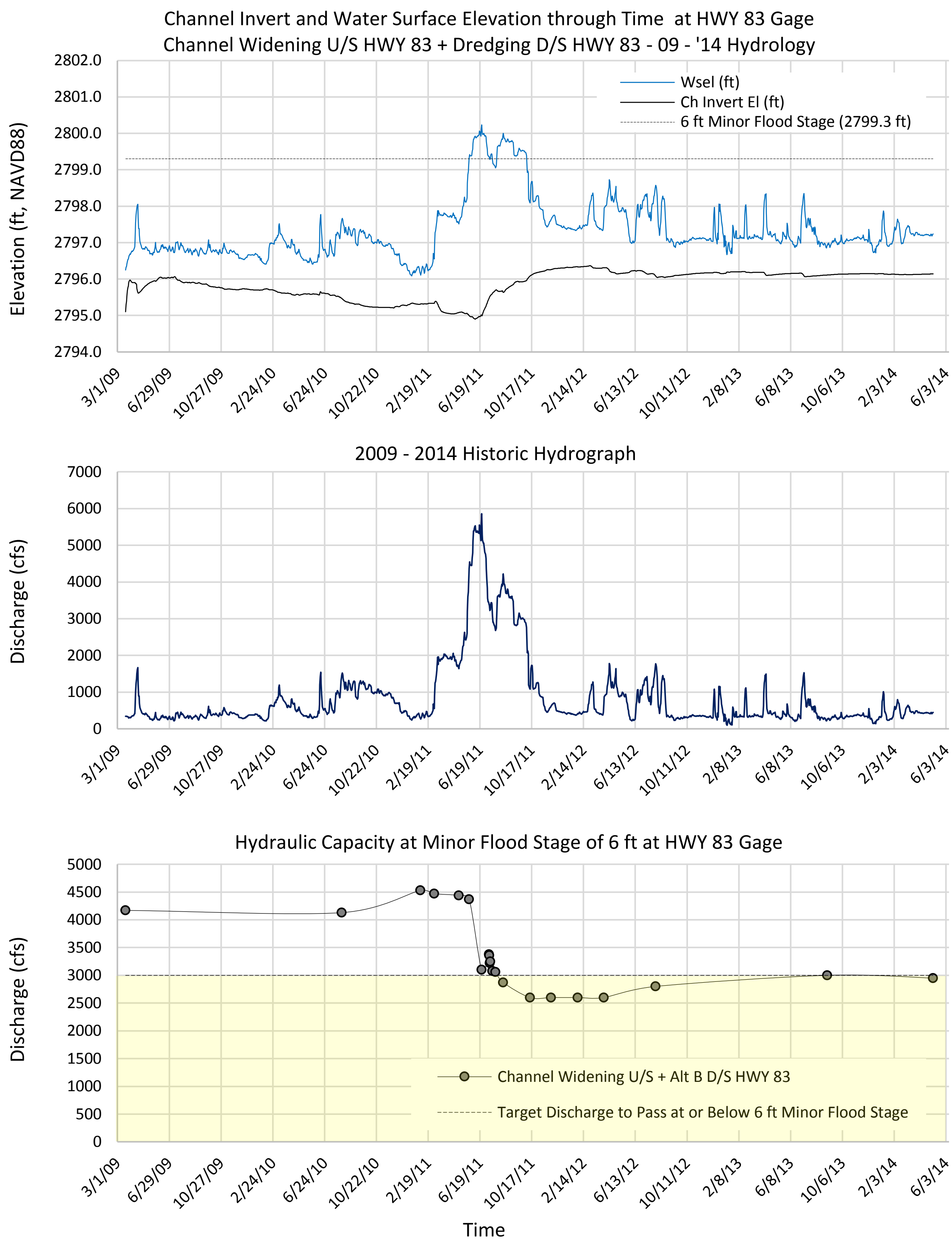



**Figure A-11 Results through Time, Run 4 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83 2009 – 2014 Hydrology – Channel Invert and Water Surface Elevation at HWY 83 Gage (top), 2009 –2014 Daily Discharge Hydrograph (middle), and Hydraulic Capacity at Minor Flood Stage at HWY 83 Gage (bottom).**

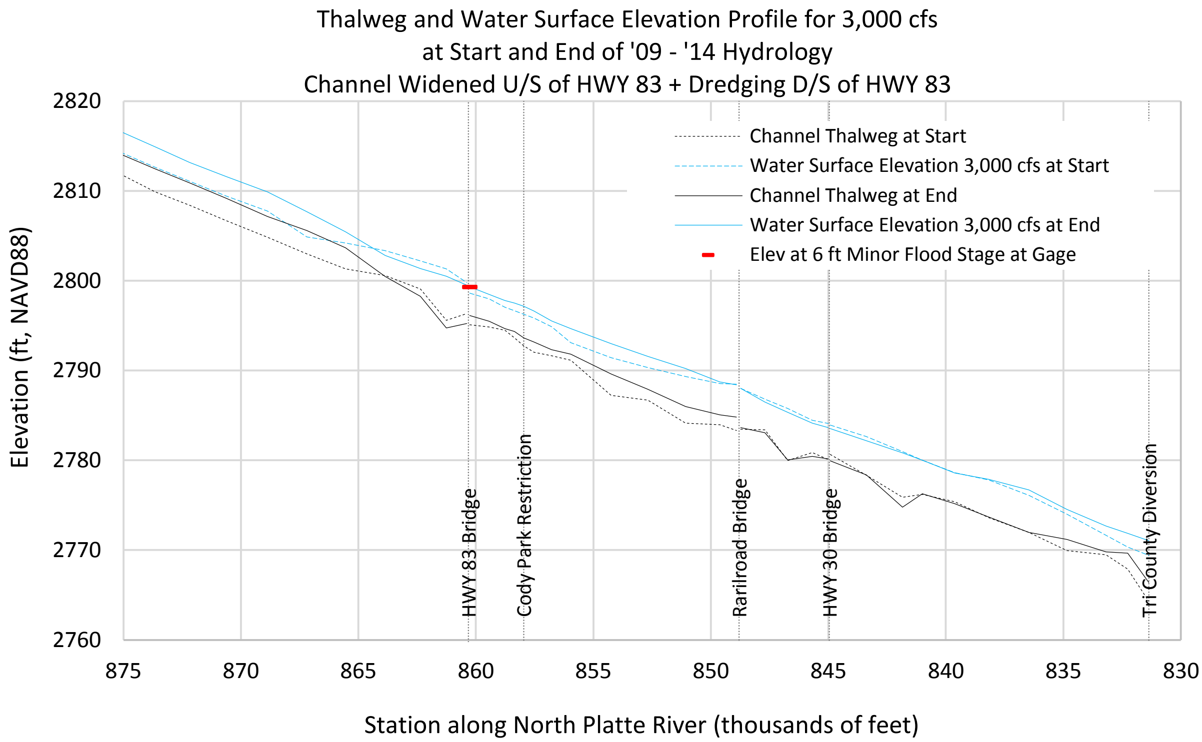



**Figure A-12 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 2009 – 2014 Hydrology for Run 4 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83.**

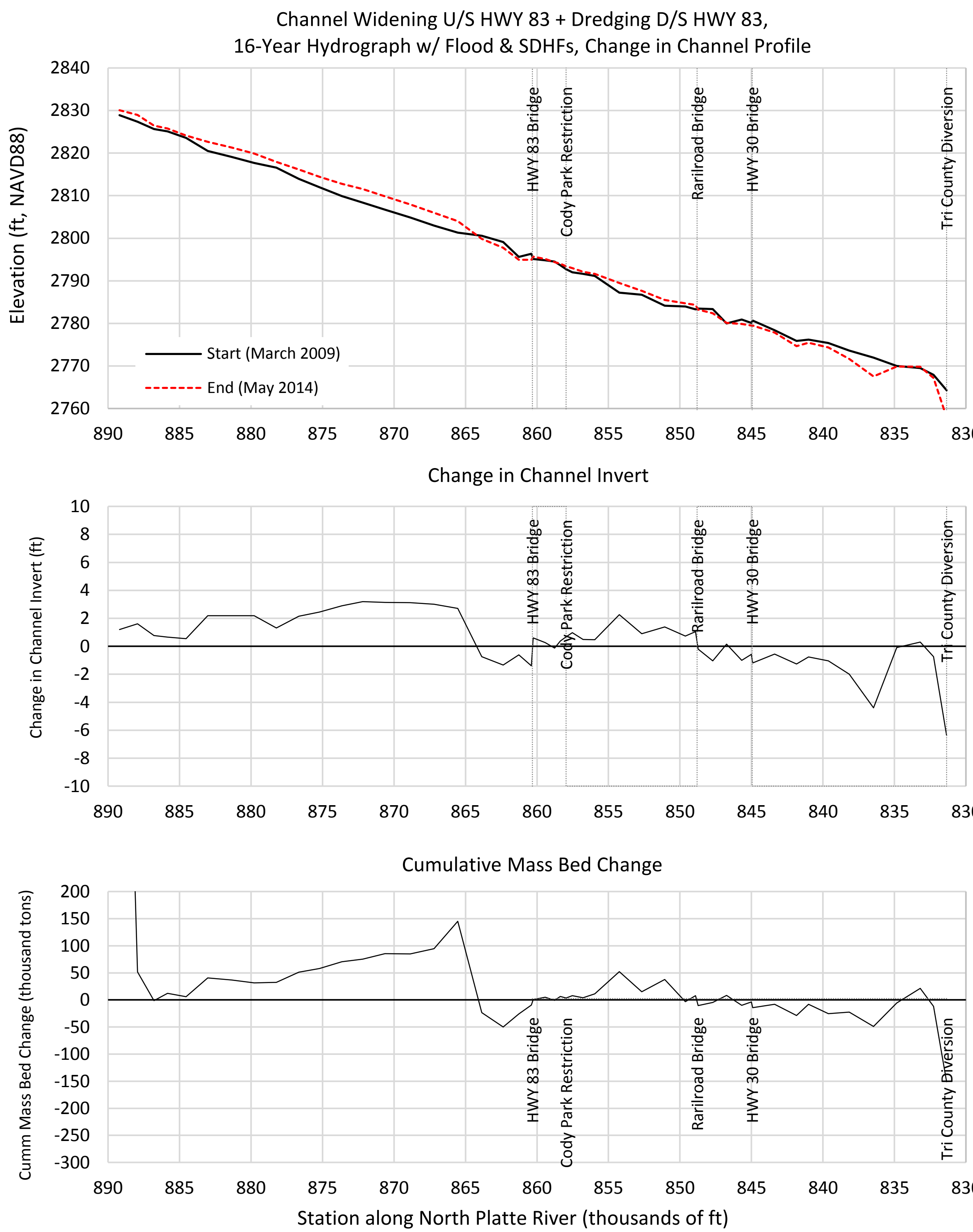



**Figure A-13  Spatial Results, Run 5 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**

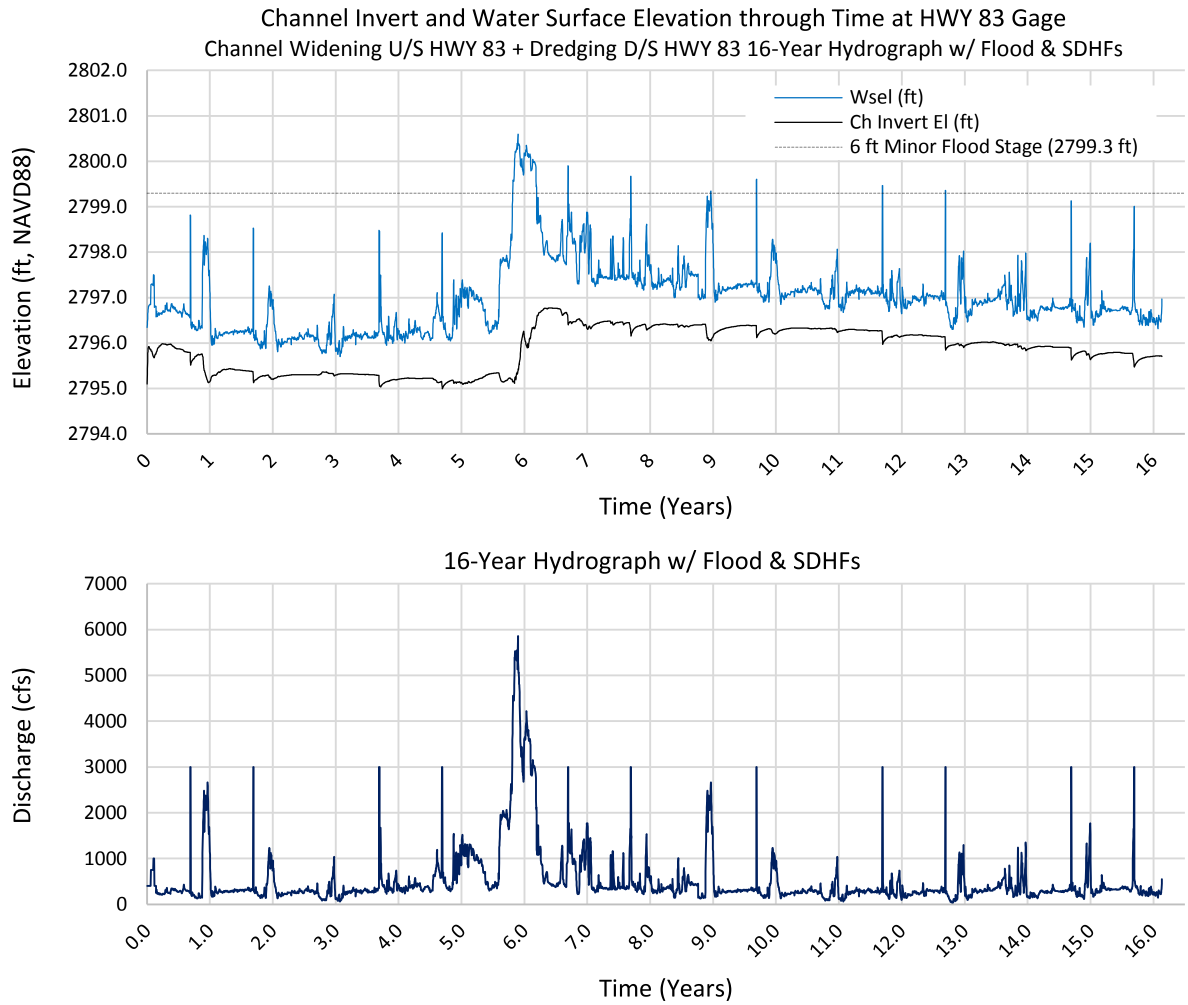



**Figure A-14 Results through Time, Run 5 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs - Channel Invert and Water Surface Elevation at the HWY 83 Gage (top), 16-year Daily Discharge Hydrograph w/ Flood and SDHFs (bottom).**

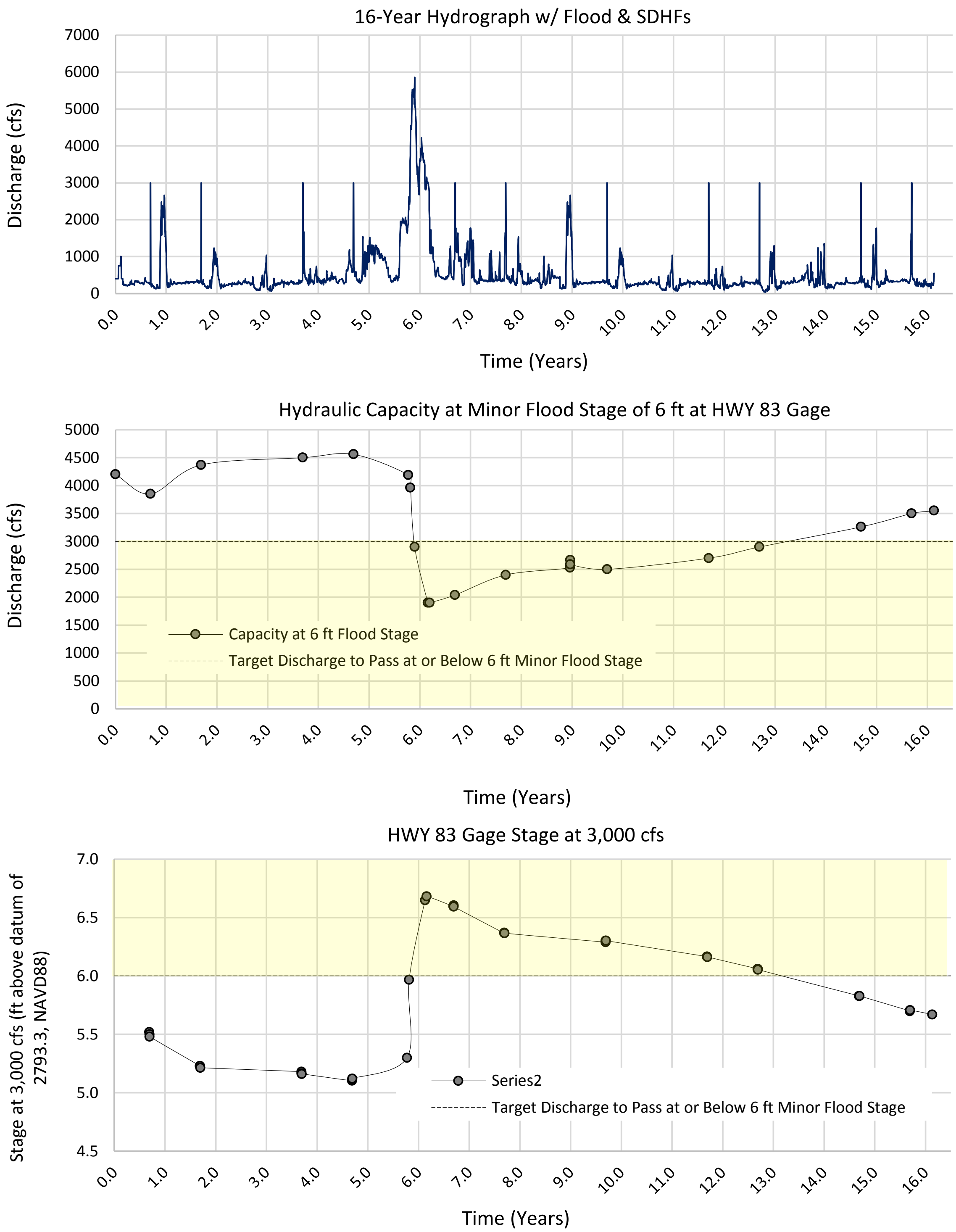



**Figure A-15 Capacity at HWY 83 Gage through Time, Run 5 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs – 16-year Daily Discharge Hydrograph w/ Flood and SDHFs (top), Hydraulic Capacity at Minor Flood Stage (middle), and Stage at 3,000 cfs (bottom).**

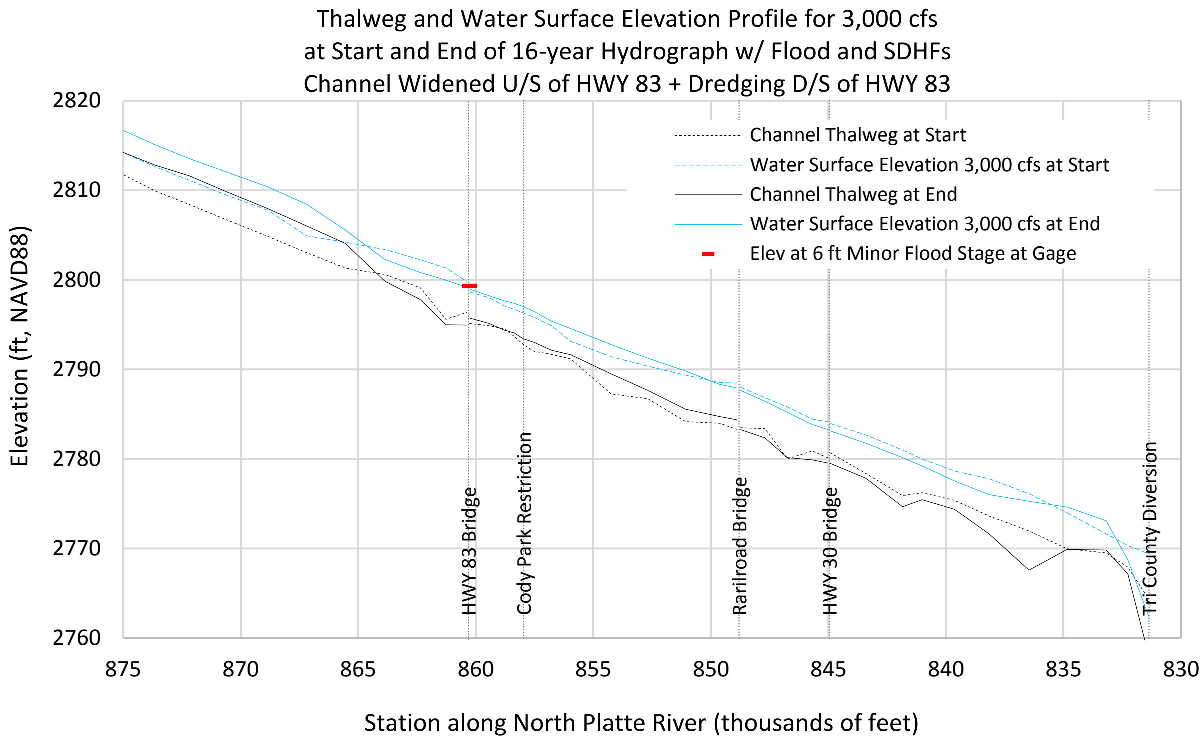



**Figure A-16 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 16-year Hydrograph w/ Flood and SDHFs for Run 5 (Alt D) Channel Widening U/S HWY 83 + Dredging D/S HWY 83.**

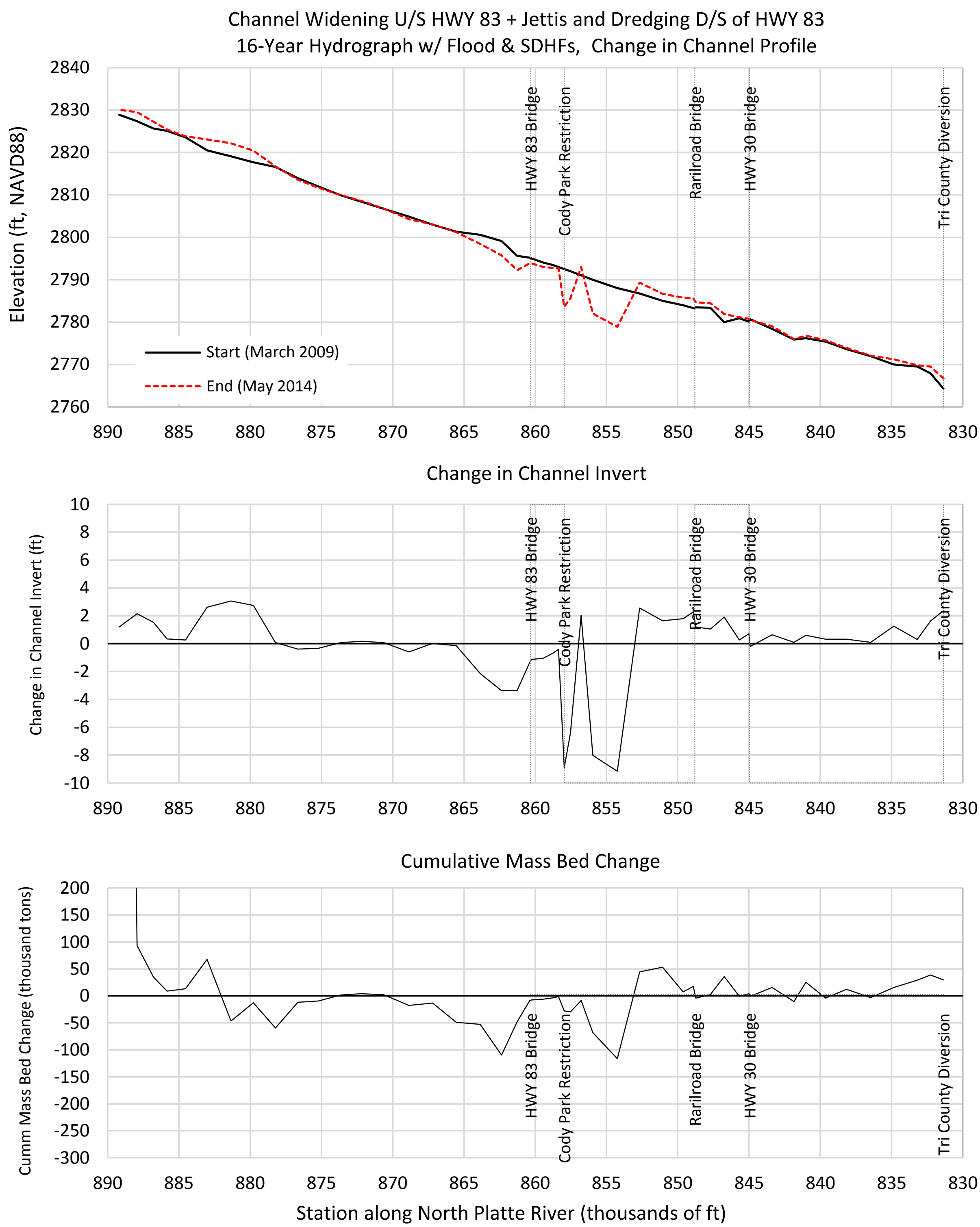



**Figure A-17 Spatial Results, Run 6 (Alt E) Channel Widening U/S HWY 83 + Jetties and Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs – Channel Profile at Start and End (top), Change in Channel Invert Elevation (middle), and Cumulative Mass Bed Change (bottom).**

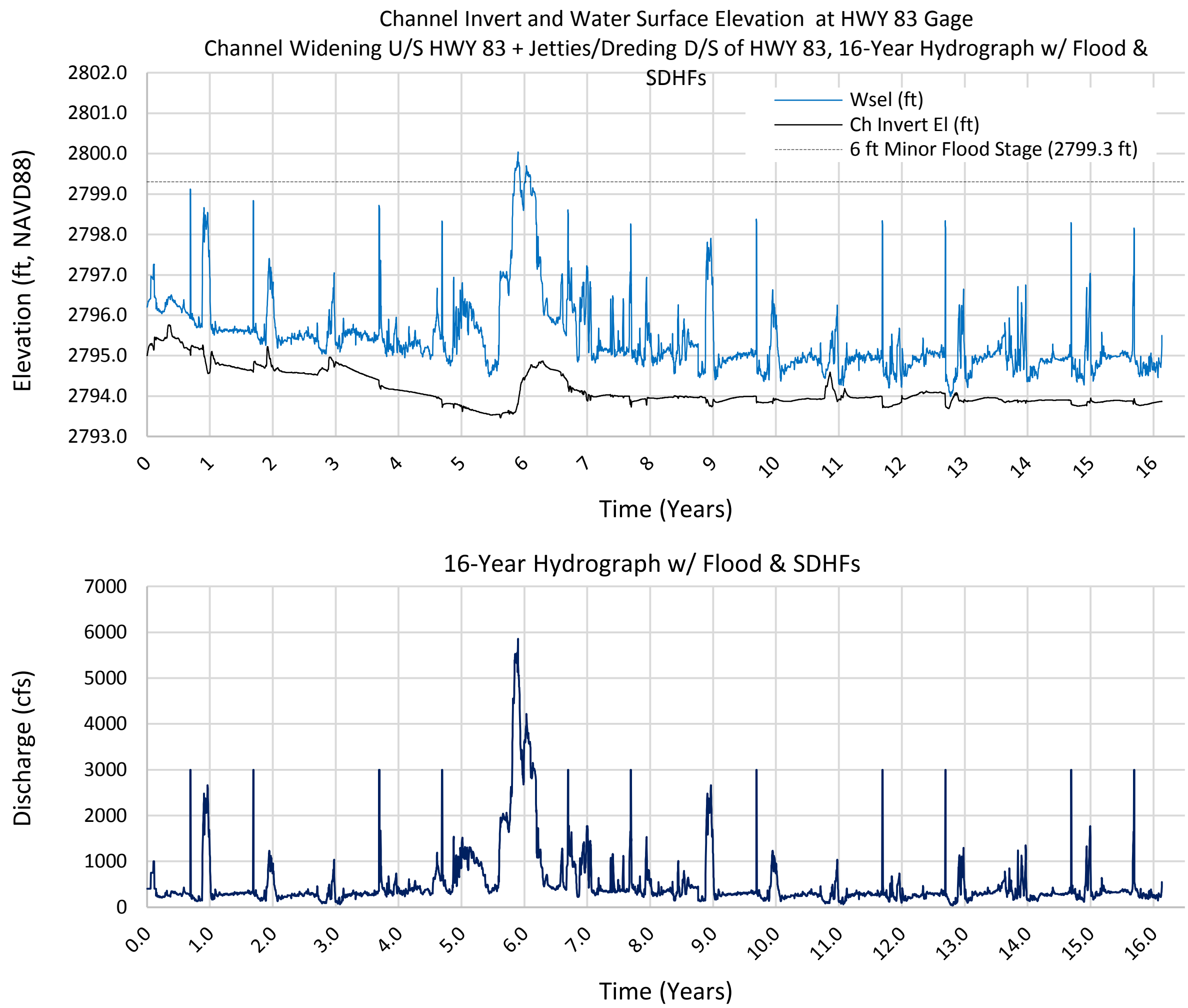



**Figure A-18 Results through Time, Run 6 (Alt E) Channel Widening U/S HWY 83 + Jetties and Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs - Channel Invert and Water Surface Elevation at the HWY 83 Gage (top), 16-year Daily Discharge Hydrograph w/ Flood and SDHFs (bottom).**

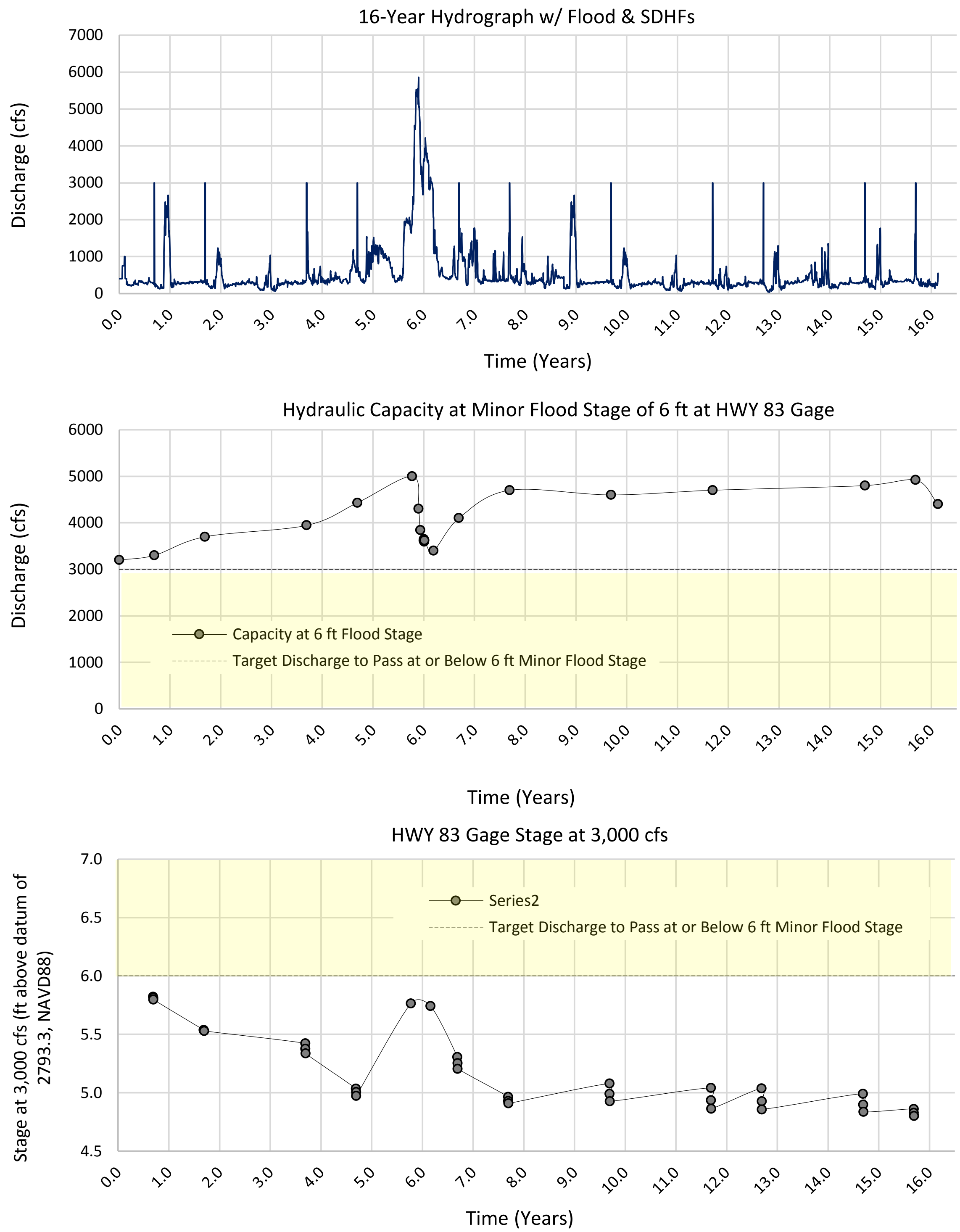



**Figure A-19 Capacity at HWY 83 Gage through Time, Run 6 (Alt E) Channel Widening U/S HWY 83 + Jetties and Dredging D/S HWY 83 16-year Hydrograph w/ Flood and SDHFs – 16-year Daily Discharge Hydrograph w/ Flood and SDHFs (top), Hydraulic Capacity at Minor Flood Stage (middle), and Stage at 3,000 cfs (bottom).**

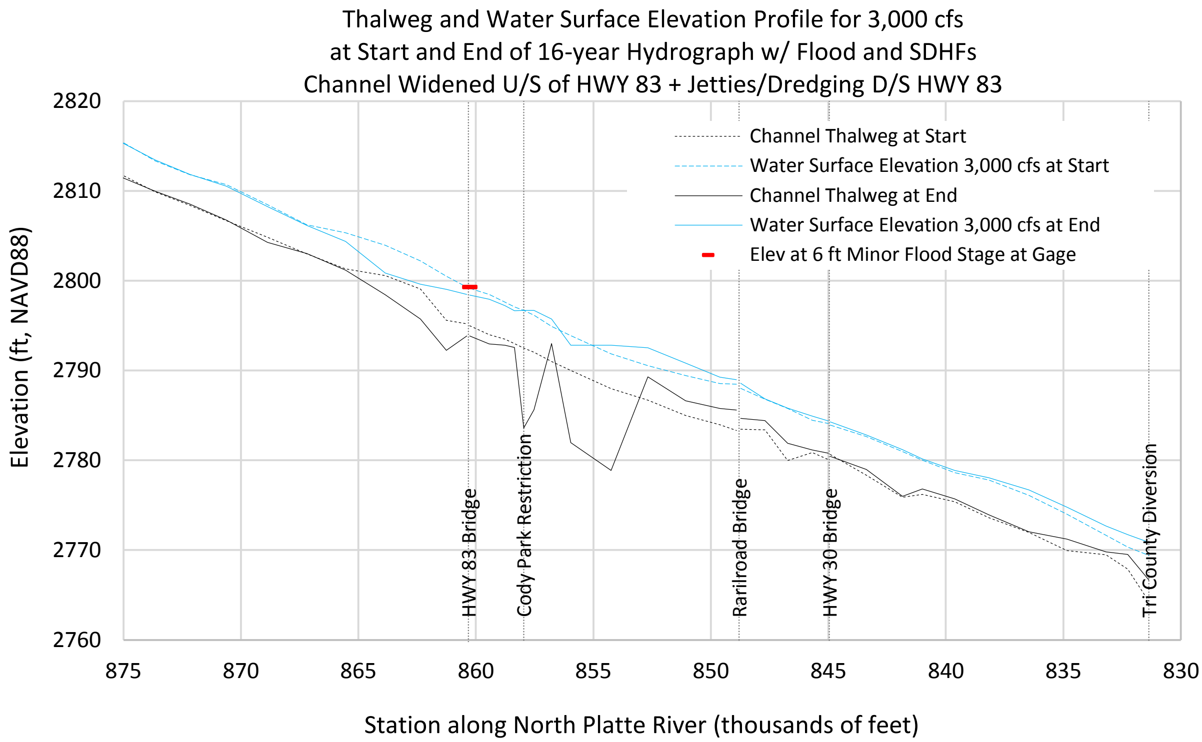



**Figure A-20 Profile of Channel Thalweg and Water Surface Elevation at 3,000 cfs at Start and End of 16-year Hydrograph w/ Flood and SDHFs for Run 6 (Alt E) Channel Widening U/S HWY 83 + Jetties and Dredging D/S HWY 83.**

### B. Attachment A – Choke Point SIAM Reaches

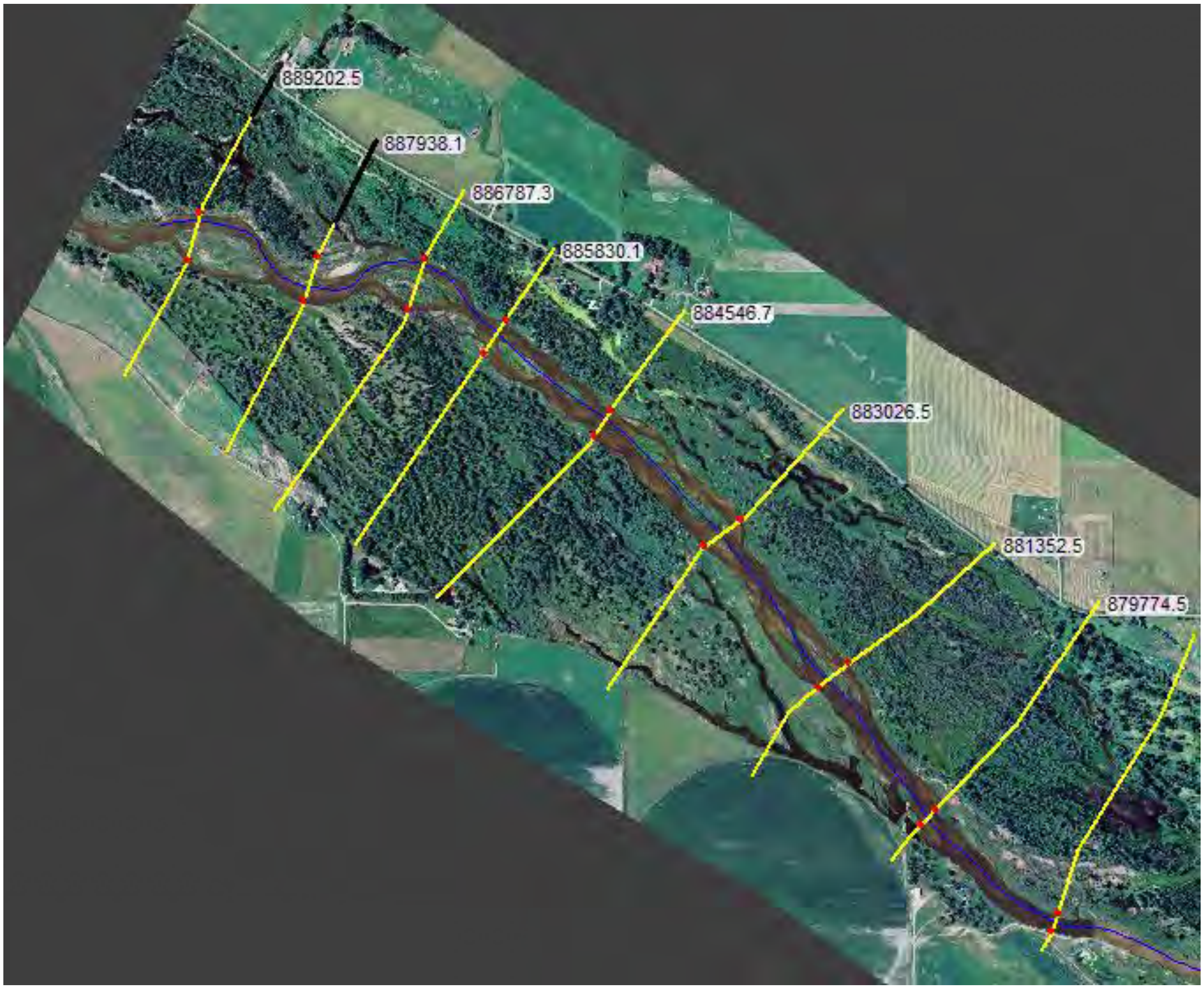



**Figure B-1 Choke Point SIAM Reach 1 - Station 889202 – 879774**

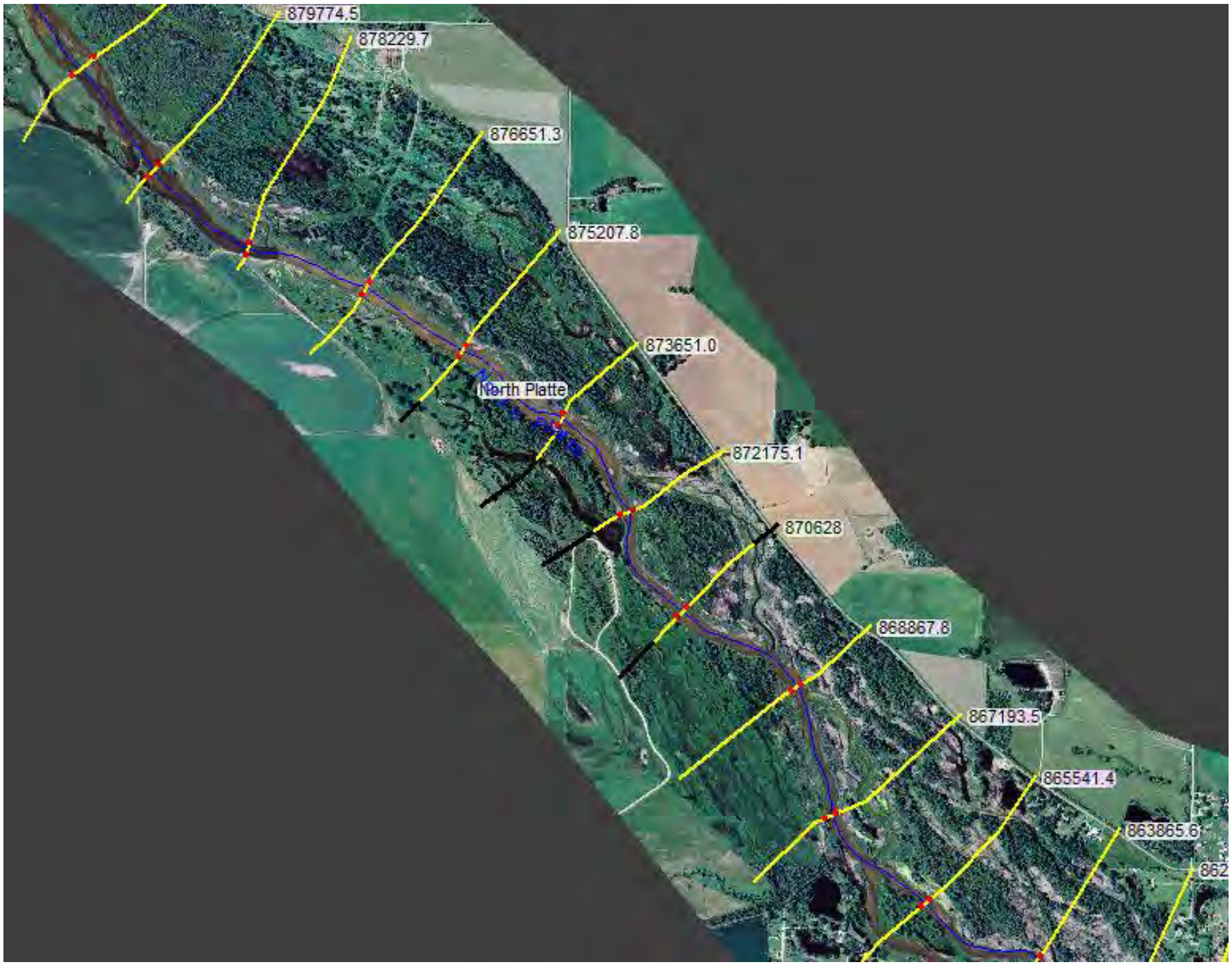



**Figure B-2  Choke Point SIAM Reach 2 – Station 878229 – 867193**

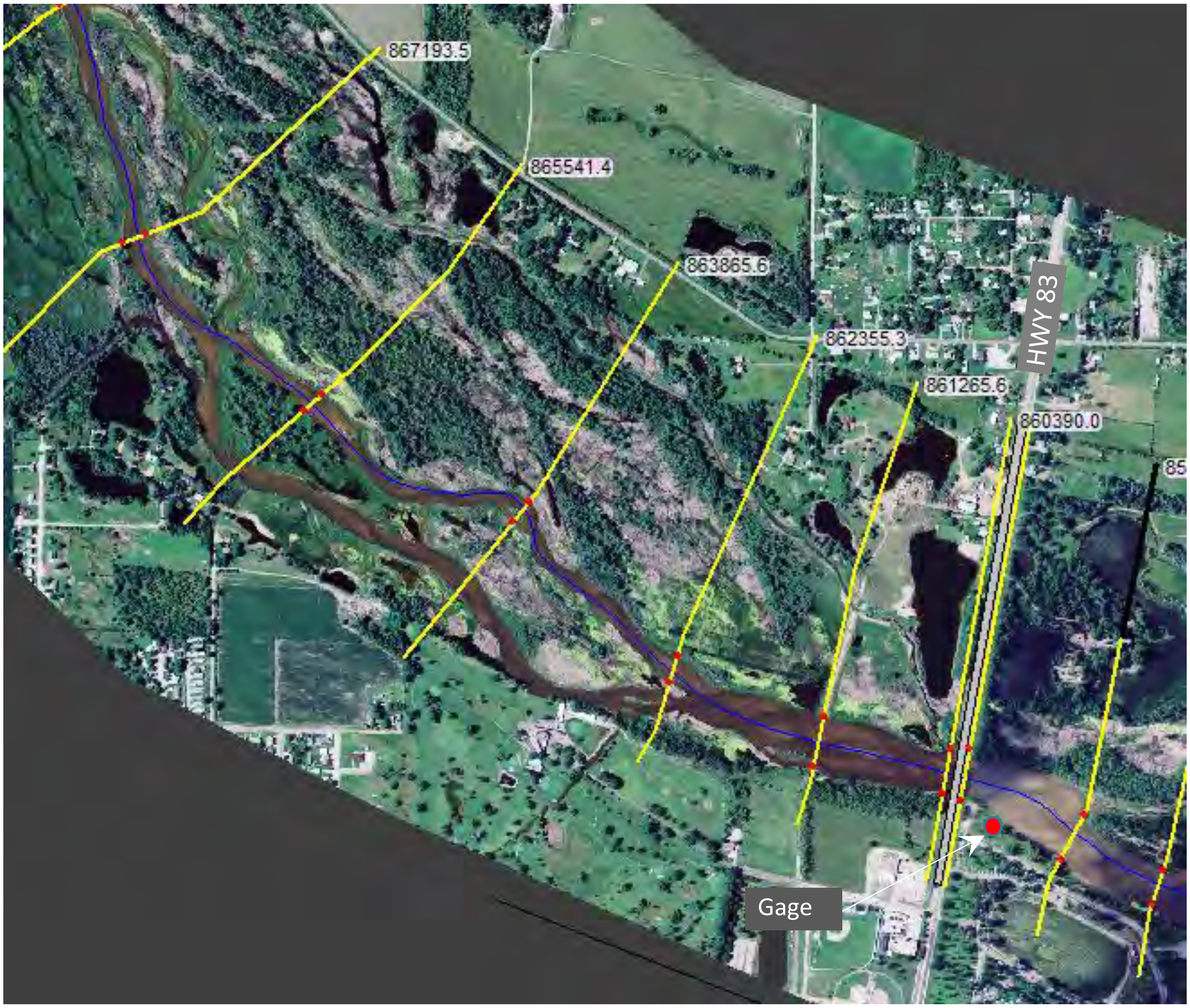



**Figure B-3 Choke Point SIAM Reach 3 – Above HWY 83, Station 865541 – 860390**


**Figure B-4  Choke Point SIAM Reach 4 – HWY 83 to Cody Park Restriction, Station 860268 – 856779**


**Figure B-5  Choke Point SIAM Reach 5 – Cody Park Restriction to RR Bridge, Station 855960 – 848912**

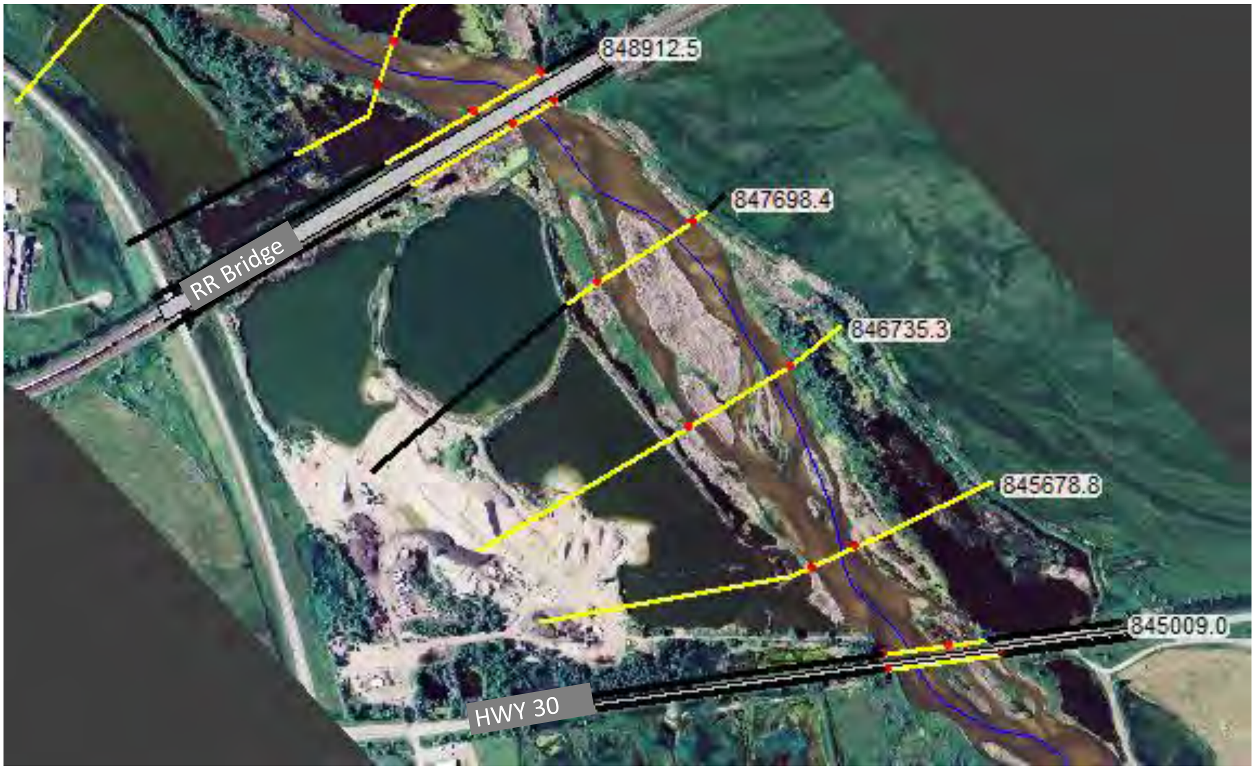



**Figure B-6 Choke Point SIAM Reach 6 – RR Bridge to HWY 30, Station 848735 – 845009**

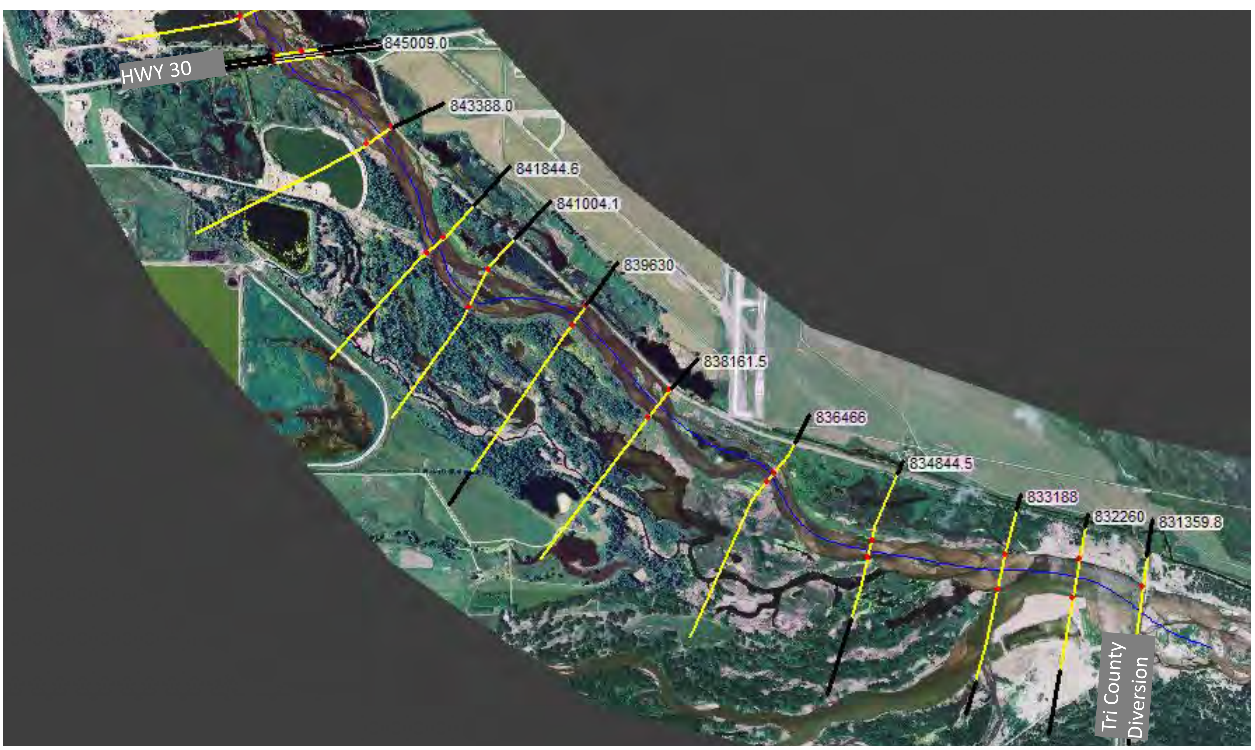



**Figure B-7 Choke Point SIAM Reach 7 – HWY 30 to Tri County Diversion, Station 844919 – 831359**