TO: WAC, TAC, AND GC
FROM: EXECUTIVE DIRECTOR'S OFFICE
SUBJECT: NORTH PLATTE CHOKE POINT
DATE: SEPTEMBER, 2012

EXECUTIVE SUMMARY

Several facets of the Platte River Recovery Implementation Program (PRRIP or Program) are dependent on the release of water from the Lake McConaughy Environmental Account (EA), with the objective of routing the water to the central Platte River between Lexington and Chapman. These facets include target flows that vary throughout the year to address Program target species needs, and also short-duration high flows (SDHF) that are part of one of the Program's management strategies for creating and maintaining target species habitat within the central Platte River. A Program goal of routing up to 3,000 cfs flows from the EA through the North Platte River is based on target flows and/or SDHF for the central Platte River. However, the Program also has a policy that EA releases will not contribute to water surface elevations exceeding flood stage as set by the National Weather Service (NWS). The current NWS minor flood stage is 6.0 feet at the North Platte River (NPR) at North Platte gage. This flood stage was equivalent to a flow of approximately 3,100 cfs in 1997 when the Cooperative Agreement was initiated, but has decreased to approximately 1,600 cfs currently (**Figure ES-1**). The current hydraulic capacity at flood stage limits the Program's ability to fully utilize water stored in the EA for target flow and SDHF purposes.

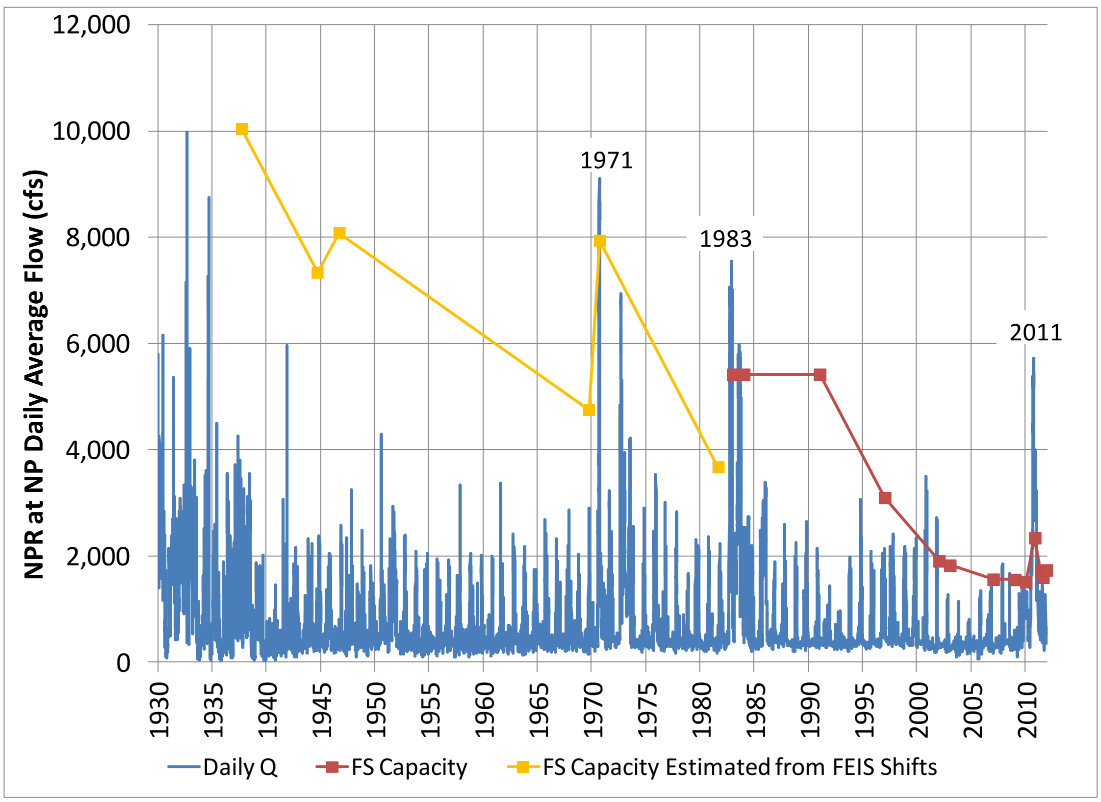

Figure ES-1. NWS Flood Stage Flow Capacity for the North Platte River at North Platte Gage

The restriction in NPR hydraulic capacity is referred to as the North Platte Choke Point by the Program. The Choke Point generally applies to the North Platte River at North Platte gage located downstream of the Highway 83 bridge crossing in North Platte, primarily because of stage measurements and compliance with NWS flood stage at this location. However, limited hydraulic capacity at the Choke Point applies to a broader area of the NPR from approximately 2 miles upstream of the Highway 83 Bridge to CNPPID's Tri-County Diversion structure, a total distance of approximately 7.5 miles (**Figure ES-2**).

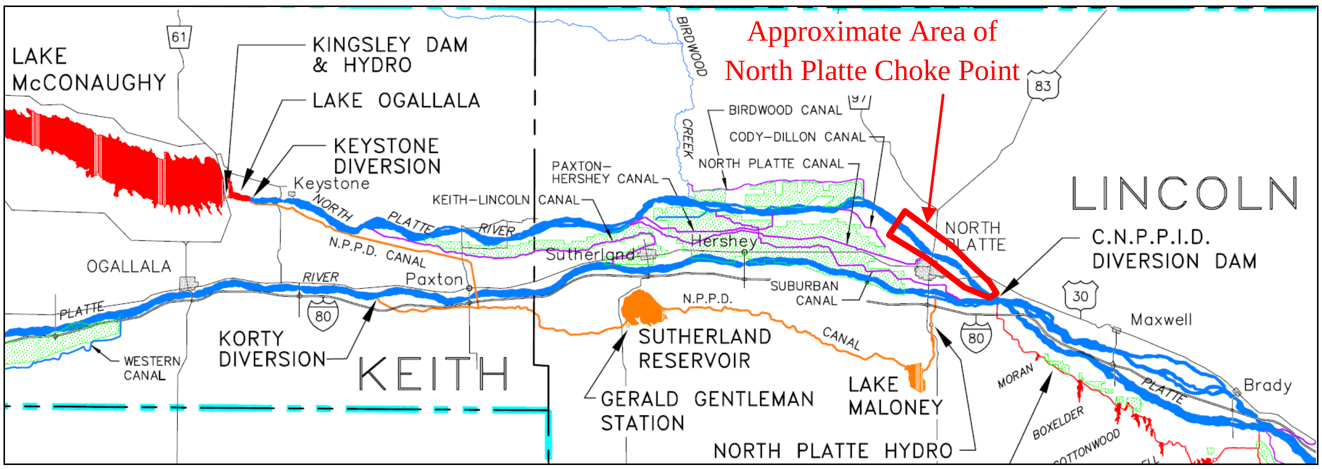

Figure ES-2. Approximate Location of North Platte Choke Point (from CNPPID 1996)

Systematic changes in NPR hydrology, hydraulics, and sediment transport have occurred over time as a result of the regulation of the system primarily as a result of construction of reservoirs and canal diversions. The magnitude and variability of NPR streamflow has decreased as a result of hydrologic regulation. For example, the 100-year recurrence interval peak flow for the NPR was 14,000 cfs for the pre-Lake McConaughy period of record (1930-1940), and is 8,300 cfs for the post-Lake McConaughy period of record (1941-2012). Additionally, the magnitude and variability of median monthly streamflow has decreased substantially in most months since completion of Lake McConaughy (**Figure ES-3**).

The NPR has shifted geomorphically from a wide (up to one-half mile width) braided stream in 1938 to a narrow (approximately 300 feet average width) slightly meandering stream with anabranches in 2010 (**Figure ES-4**). This geomorphic shift is indicative of a systematic change that likely occurred as a result of the decrease in NPR flow magnitude and variability. Vegetation encroachment in the floodplain and the main channel has also affected channel morphology and flow conveyance.

The combination of the hydrologic change, geomorphic shift to a narrower channel, and encroachment of vegetation has led to an overabundance of NPR sediment supply relative to sediment transport capacity. Approximately 10,000 cubic yards per year of sediment is deposited between the Highway 83 Bridge and the UPRR Bridge (i.e., a key reach influencing river stage at the NPR at North Platte gage). The deposition of sediment has increased the elevation of the channel thalweg, which in turn has increased water surface elevations over time (**Figure ES-5**). Although periodic high flows (e.g., 1971, 1983, and

2011) flush sediment through the NPR, lower water surface elevations (**Figure ES-5**), and increase hydraulic capacity at flood stage (**Figure ES-1**), continued sediment deposition over time has decreased hydraulic capacity at flood stage.

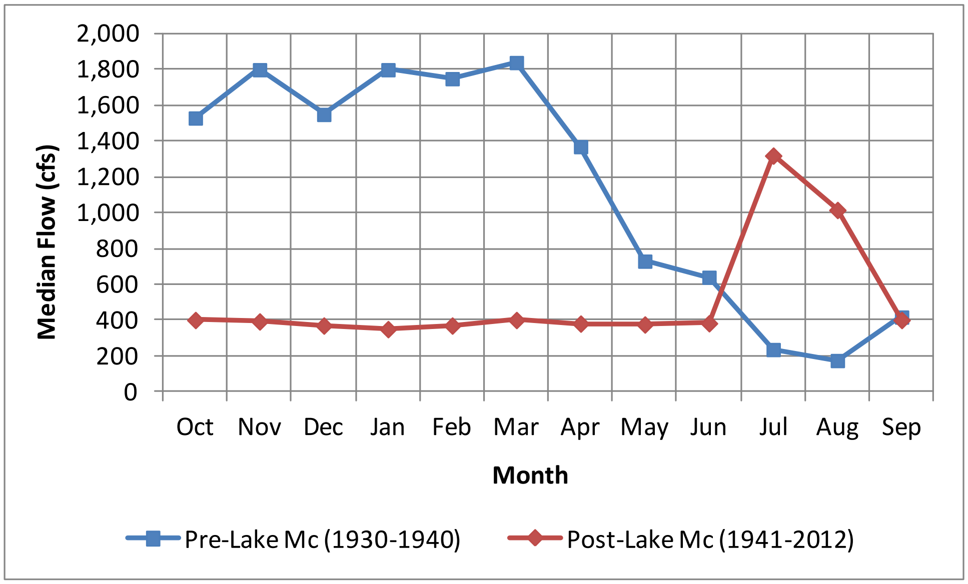

Figure ES-3. Median Monthly Streamflow for NPR at North Platte (Gage #6693000)

Figure ES-4. Historical Aerial Photographs for NPR at North Platte

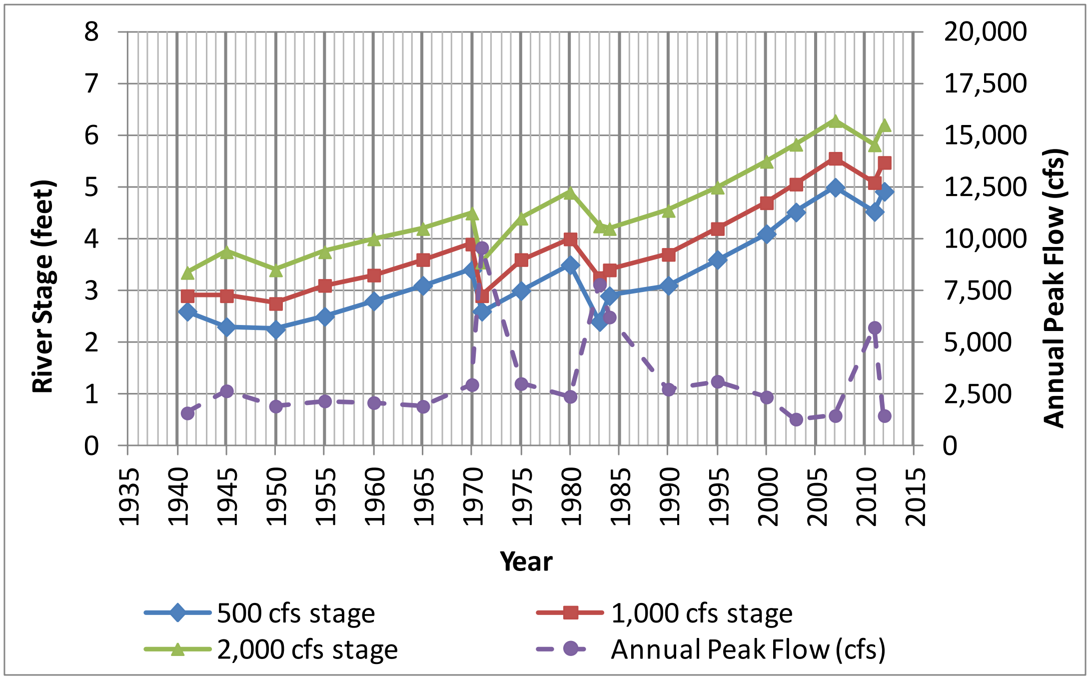

Figure ES-5. NPR at North Platte Gage River Stage and Annual Peak Flow (data from 1941 to 2000 from PRRIP FEIS 2006; data from 2003 to 2012 from NDNR rating curves and shifts)

Program efforts to date to increase NPR hydraulic capacity have included funding towards eradication of invasive phragmites within the Choke Point area, construction of a one-dimensional hydraulic and sediment transport model to simulate alternatives for increasing capacity, initiation of a ground and surface monitoring program to quantify factors that affect flooding, and collaboration with local entities to develop flood-proofing projects with the objective of minimizing flood impacts to developed areas near the NPR.

Program funding of almost $250k has been provided to the West Central Weed Management Area for vegetation treatment work focused on spraying, disking, and shredding of above ground biomass. Vegetation treatment has been completed throughout the main channel, side channels, and within the floodplain (**Figure ES-6**). Vegetation treatment has prevented further reduction in hydraulic capacity, but there has not been an increase in hydraulic capacity. The steady hydraulic capacity is likely because the below ground root mass has remained in place. Future work will not only focus on preventing above ground biomass from re-sprouting, but will also include deep disking to break up the below ground root balls with the objective of facilitating flushing of sediment during high flow events.

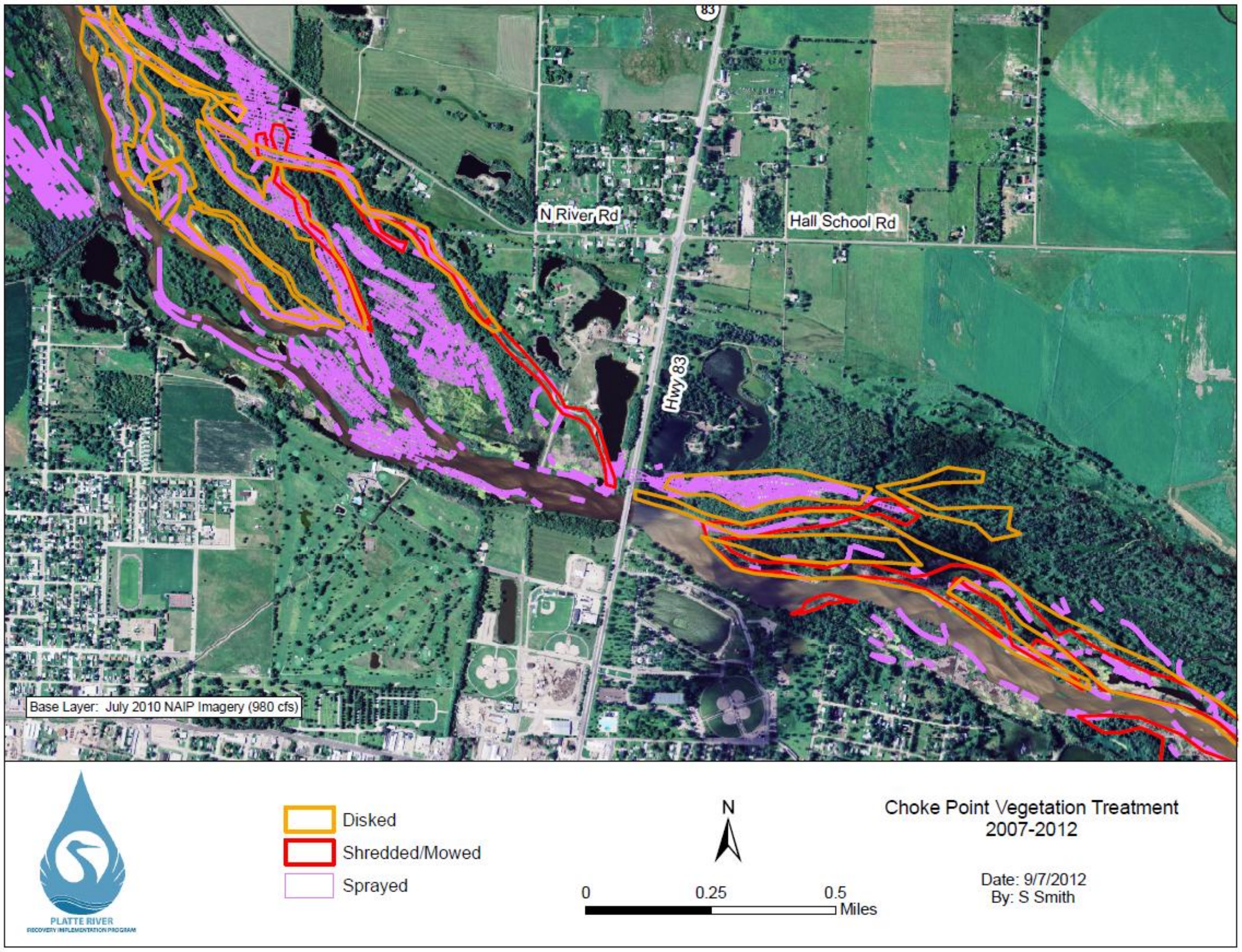

Figure ES-6. Choke Point Vegetation Treatment near Highway 83 from 2007 to 2012

Flood-proofing projects have been initiated by the Program with the objective of reducing flood impacts to properties typically impacted when NPR stage exceeds NWS minor flood stage of 6.0 feet. Many of the properties affected by flooding are located in the floodplain (**Figure ES-7**), and flood-proofing projects are intended to reduce flooding where floodplain development has occurred. If flood impacts are demonstrably reduced by flood-proofing projects as intended, the NWS may be justified in increasing minor flood stage from the current 6.0-foot level (1,600 cfs) to 6.5 feet (2,400 cfs). In addition to initiating the flood-proofing projects, the Program is also implementing a ground and surface water monitoring program to quantify the relative effects of ground and surface water on flooding near the Choke Point. The three flood-proofing projects are:

1. Re-activation of a previously active floodplain channel that historically diverted water towards the main NPR channel and away from properties that are typically flooded. The "State Channel" was constructed by the Nebraska Department of Roads around 1970, but lost functionality around the early 1990s. A flow control structure would be placed at the head of the State Channel to divert high flow to the State Channel and away from primary flooding areas, while maintaining minor flow in the existing floodplain channel for recreational/aesthetic purposes.

2. Install culverts along North River Road to improve drainage in an area that is typically flooded. The drainage improvements would be designed to convey high ground and surface water away from impacted areas, preventing flood waters from pooling behind driveways that effectively cut off road ditches.
3. Install an outlet on a key gravel pond at the downstream end of an important drainage ditch, which currently has no outlet. Under current conditions, the lack of an outlet prevents the gravel pond from draining back to the NPR.

Figure ES-7. Aerial Photo Comparison from 1958 and 2010, Showing Floodplain Development

In addition to the flood-proofing projects already being designed for the Program, potential approaches for increasing hydraulic capacity generally fall into the following three categories:

1. Remove properties that are damaged at high flow:
2. Modify the North Platte River channel to reduce flood impacts
3. Route water around the North Platte Choke Point area to minimize flooding

Removal of properties from typically flooded areas may facilitate an increase in NWS minor flood stage. Development within the floodplain since the 1960s has decreased the floodplain storage and conveyance capacity. Although removal of structures would minimize the potential for flood damage, the majority of landowners in the area are not interested in selling their property or participating in flood easements. A small number of landowners with substantial damage during 2011 flooding want to sell their property but do not believe they could get a reasonable price for their homes. It is highly doubtful that the Program could use buyouts or easements to remove properties from a large enough area to justify an increase in NWS minor flood stage, at least not within the confines of the Program's willing seller concept.

Modifications to the NPR river channel could be implemented to increase hydraulic capacity and reduce flood impacts. Program modeling tools were developed to simulate the outcome of an array of channel modification scenarios. Several options to modify channel hydraulics were evaluated, with the objective of optimizing sediment transport capacity and potentially inducing removal of previously deposited material. Options were evaluated to widen flow area at channel constrictions such as bridges and narrow channel locations. Increased channel width and flow through side channels resulted in increased flow area and decreased flow velocity and sediment transport, which is counter-productive for the goal of increasing hydraulic capacity. Alternatively, narrowing the channel at over-widened locations using hydraulic structures could increase flow velocities and sediment transport. However, the Program model predicted an increase in flow resistance through channel roughness associated with the hydraulic structures. Increases in roughness would lead to an increase in water surface elevation and an overall decrease on hydraulic capacity.

Modeling results indicate that there is an overabundance of sediment supply relative to sediment transport capacity, with approximately 10,000 cubic yards per year of sediment being deposited between the Highway 83 and UPRR bridges. Dredging the river to reduce channel thalweg elevation would decrease the water surface elevation and increase hydraulic capacity. Several dredging alternatives were compared to determine optimal dredging location, amount, and dimensions. The alternative with the longest resulting hydraulic capacity above the Program goal of 3,000 cfs would cost about $1.6M, and would include removal of approximately 230,000 cubic yards of material from the river bed. This dredging amount would be approximately three times the volume of material that CNPPID dredges upstream of their Tri-County Diversion dam on an annual basis. Program modeling tools predict that dredging maintenance would be required approximately five years after the initial dredging to maintain hydraulic capacity. Although dredging would be expensive, require permits, and would likely require occasional maintenance dredging, it may be the only standalone channel modification option for fully achieving the Program's goal of 3,000 cfs at NWS minor flood stage.

Routing water around the North Platte Choke Point could provide an alternative to attempting to overcome the systemic hydrologic, hydraulic, and sediment transport issues that have led to the gradual decrease in hydraulic capacity through the Choke Point. There may be cross-benefits between the Program, NPPD, and TPNRD for scenarios for routing water around the Choke Point, and as a result the Program will collaboratively study these options. The Program will work with TPNRD to investigate the potential to use existing canals to divert from the NPR and return to the South Platte River. Use of the existing canals is "low hanging fruit," but the additional capacity would only provide 10 to 20 percent of the 1,400 cfs additional capacity that is needed to bridge the gap between current minor flood stage capacity and the Program goal of 3,000 cfs.

Alternatives to route the full 1,400 cfs of additional capacity around the Choke Point are focused on use of the existing or expanded NPPD system. Generally NPPD currently operates their Keystone, Sutherland, and North Platte Hydro system at full capacity of 1,800 cfs. Additional capacity within the current NPPD system is limited by seepage and stability issues. There are potential opportunities to modify or expand NPPD's system, some of which could provide advantages to TPNRD, NPPD, and the Program. One example is construction of a new reservoir east of the existing Sutherland Reservoir, which could be used by the Program to route water around the Choke Point, used by TPNRD as storage of water for offsetting post-1997 depletions, and used by NPPD for system redundancy. A new return to the South

Platte River from the reservoir would also be needed to fully utilize the additional storage. Although a new reservoir and return could be designed to provide all of the 1,400 cfs of additional capacity needed by the Program, as well as benefits to NPPD and TPNRD, the cost and time to complete such a project may limit the feasibility of this scenario to solve the Choke Point capacity issue during the First Increment of the Program.

The ED Office has worked with the Choke Point workgroup and Program contractors to assess the feasibility of several approaches for reaching the Program goal of 3,000 cfs hydraulic capacity through the Choke Point. Based on NPR vegetation, hydrology, hydraulics, and sediment transport, the following path forward is recommended by the workgroup:

1. Monitor ground and surface water levels to identify and quantify flooding factors.
2. Complete the three flood-proofing projects developed in collaboration with the City of North Platte and Lincoln County. The objective of the projects is to minimize flooding of properties and structures in the area typically affected by high surface and ground water levels. The NWS may be justified in increasing minor flood stage to 6.5 feet (2,400 cfs) if flood impacts are demonstrably lower when flood-proofing projects are completed.
3. Collaboratively work with TPNRD to use existing NPR canals to divert water to the South Platte River and around the Choke Point. At a minimum, the canals should be used at their current capacity according to timing agreed to by the respective canal companies (i.e., primarily outside of the May to August irrigation season). The potential to increase capacity through canal upgrades should also be discussed with the respective canal companies.
4. Discuss this path forward at all levels of the Program, including the Technical Advisory Committee, and the Governance Committee. Implement the path once Program support is determined.
5. Initiate the best case dredging option, with the objective of achieving the full Program goal of 3,000 cfs hydraulic capacity. Prepare a dredging plan and complete the necessary permits for dredging.

INTRODUCTION

The Program's goal of achieving 3,000 cfs hydraulic capacity through the NPR is critical in the ability to fully utilize the Lake McConaughy EA, and to route water from the account to the Program's associated habitat from Lexington to Chapman. However, capacity is currently limited by various issues at the North Platte Choke Point, a section of the North Platte River that extends approximately two miles upstream of the Highway 83 Bridge to CNPPID's Tri-County Diversion Dam (a total distance of approximately 7.5 miles) (**Figure 1**). For Program purposes, hydraulic capacity through the North Platte Choke Point is defined as the flow corresponding to NWS minor flood stage at the NPR at North Platte gage (Nebraska Department of Natural Resources (NDNR) gage 6693000). The Program definition of hydraulic capacity at minor flood stage flow is based on Attachment 5 of the Program's Water Plan, which provides guidance for the use of the EA, and is based on CNPPID's 1998 FERC license stipulations restricting the EA manager from making releases that would cause the NPR or Platte River to rise above NWS flood stage.

Although the NPR hydraulic capacity was 3,100 cfs when the Program's Cooperative Agreement was signed in 1997, hydraulic capacity has decreased to approximately 1,600 cfs as of August 2012 (**Figure 2**). The reduced hydraulic capacity limits the Program's ability to fully utilize the EA for releases for target flows and short-duration high flows (SDHF). Based on the current NDNR rating curve for the NPR at North Platte gage, the Program goal of 3,000 cfs is equivalent to a stage of 6.8 feet at the NPR at North Platte gage, or 0.8 feet above NWS minor flood stage (**Figure 3**).

To successfully utilize Program water stored in the EA, alternative solutions for increasing NPR hydraulic capacity need to be identified. Critical to identifying feasible alternatives for increasing hydraulic capacity is an understanding of the causes of decreased NPR hydraulic capacity and flooding in the area of the Choke Point. In general, flooding occurs as a result of increased NPR river stage over time (**Figure 4**). Increased NPR water levels have caused surface water flooding as flows rise out of the active channel, and also have caused higher ground water levels as a result of alluvial aquifer water levels responding to higher river levels.

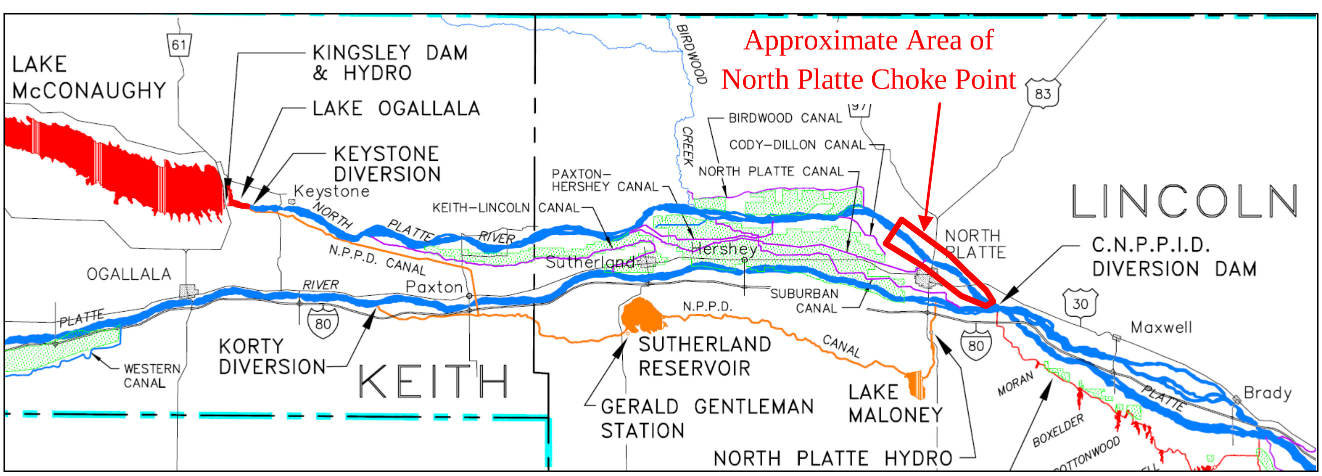

Figure 1. Approximate Area of North Platte Choke Point for Previous Program Work (from CNPPID 1996)

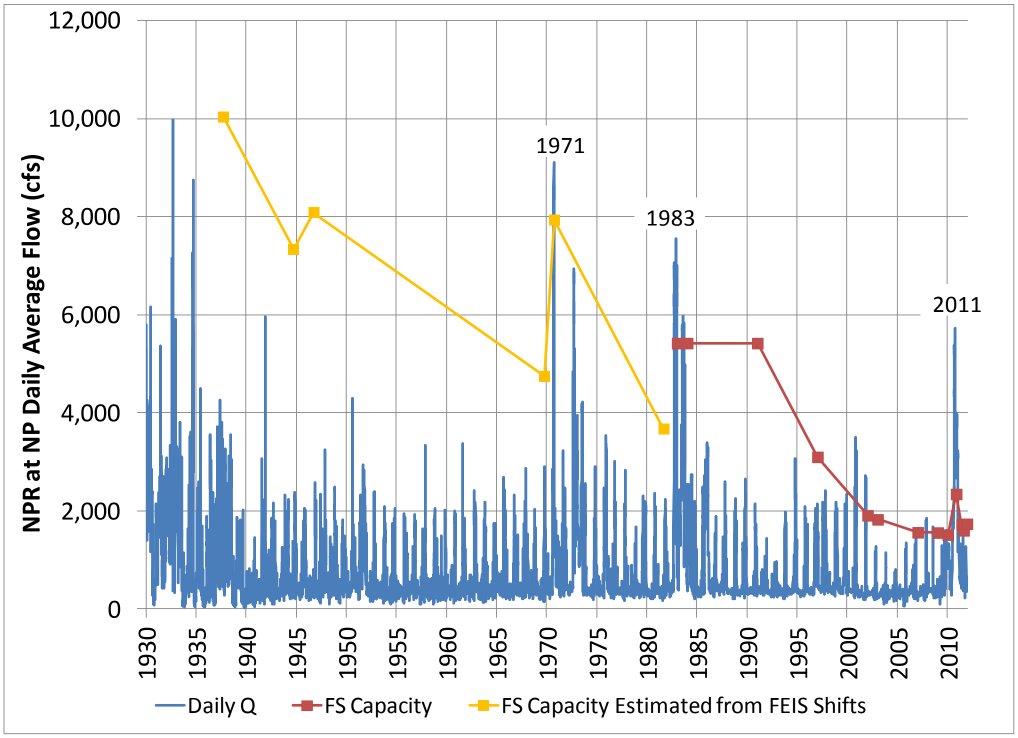

Figure 2. NWS Flood Stage Flow Capacity for the North Platte River at North Platte Gage DNR #6693000 Note flood stage of 6.0' prior to 2002; 5.7' 2002-2008; and 6.0' 2008-present.

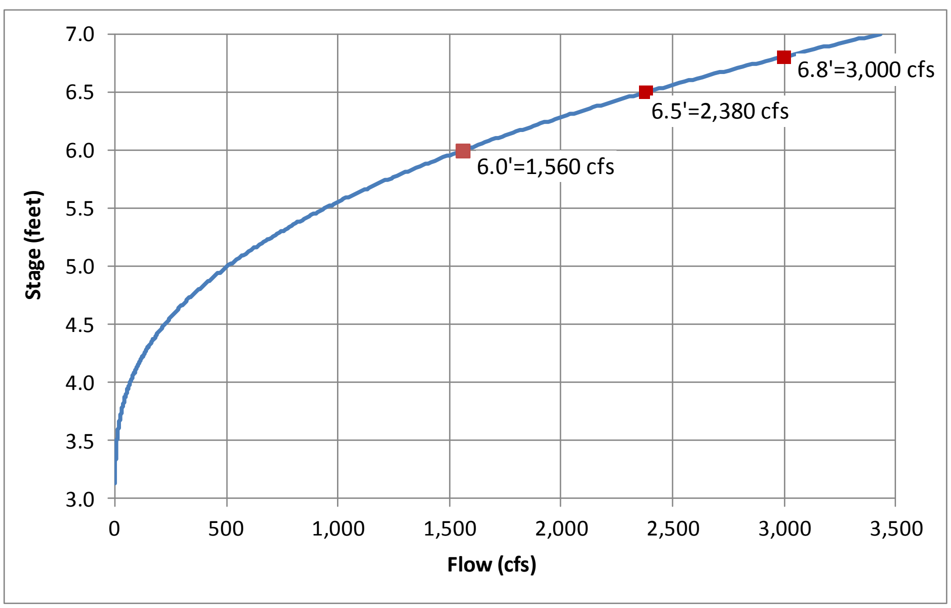

Figure 3. Rating Curve for North Platte River at North Platte Gage

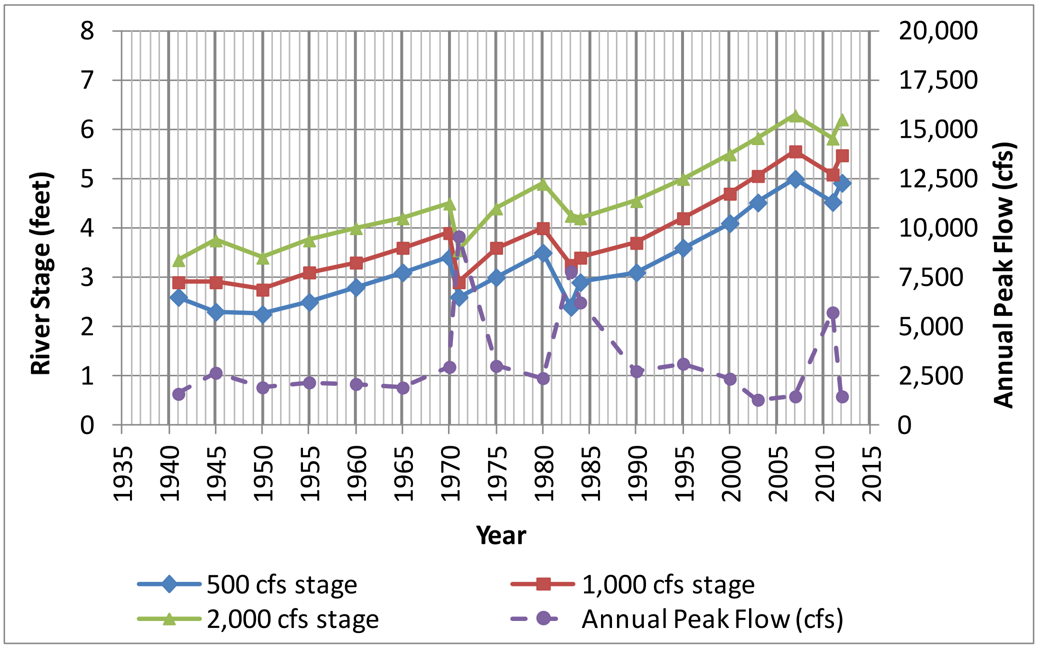

Figure 4. NPR at North Platte Gage River Stage and Annual Peak Flow (data from 1941 to 2000 from PRRIP FEIS 2006; data from 2003 to 2012 from NDNR rating curves and shifts)

There are several potential causes of increased NPR river stage and decreased hydraulic capacity, all of which are likely related to an overabundance of sediment supply compared to sediment transport capacity. The overabundance of sediment supply results from some combination of high sediment supply and low sediment transport capacity. Potential causes of the sediment imbalance and increased water levels include:

- Narrowing of the river channel at bridge crossings (e.g., in the early 1970s the Highway 83 Bridge opening was reportedly reduced from a few thousand feet to the current width of about 350 feet) has led to slow velocity backwater areas upstream of bridge crossings that have reduced sediment transport capacity.
- The magnitude of spring flushing flows has decreased as a result of upstream flow regulation, reducing the NPR's ability to maintain hydraulic capacity by flushing accumulated sediment through the reach.
- Growth of invasive phragmites in the early 2000s has closed several side channels, increased flow resistance, and increased resistance to bed scour. The growth of phragmites has locked sediment in place, and dampened the previous effect of flushing flows scouring out the main channel and "resetting" hydraulic capacity immediately after high flows. Sharp increases in hydraulic capacity were observed following high flows in 1971 and 1983, but a smaller magnitude increase in capacity was observed following 2011 high flows (**Figure 2**).
- Sand bars have moved into the reach and increased in size as a result of sedimentation. The growth of phragmites has locked the bars in place, and limited the ability for bars to move through the reach. Water levels have increased over time as a result of larger bars reducing channel capacity.

Development in the floodplain has occurred since the late 1960s, concurrent with increased NPR river stage described above. Flooding has occurred in the floodplain as a result of surface flow overtopping channel banks, and also because of ground water levels that have increased in response to higher NPR river stage. Both natural drainages and constructed road ditches have been cut off by development within the floodplain, effectively reducing storage within and conveyance through the floodplain. Flooding of developed areas within the floodplain has driven the NWS's decision to maintain minor flood stage at a relatively low stage of 6.0 feet.

The Program's ability to use water stored in the Lake McConaughy EA is limited by the hydraulic capacity of the NPR at NWS minor flood stage, which has decreased over time as a result of increased river stage related to sediment surplus relative to sediment transport capacity. The Program's Executive Director's Office (ED Office) and Program contractors have considered multiple causes of reduced hydraulic capacity and related alternatives for increasing hydraulic capacity. In addition to alternatives to increase hydraulic capacity of the NPR, other approaches were considered for routing water around the North Platte Choke Point area. The results of these analyses have been synthesized and distilled into a recommendation for increasing the Program's ability to fully utilize its EA water.

METHODS

Studies of NPR hydraulic capacity and flooding issues have been completed by the ED Office and Program contractors in an effort to understand causes for reduced hydraulic capacity and to identify related alternatives for increasing hydraulic capacity. Additionally, some work has been completed with the objective of restoring floodplain conveyance and storage capacity. For the purpose of this Program document, the studies and channel work are lumped into similar types of solutions rather than by individual study. This solution-based approach was done in order to compile similar work and results with similar content, and to facilitate analysis of each unique approach for increasing NPR hydraulic capacity and decrease flooding.

The primary data used to assess Choke Point hydraulic capacity are:

- Historical USGS streamflow data from 1941 to 1993 for the NPR at North Platte gage (USGS gage 6693000)
- Historical NDNR streamflow data from 1994 to 2012 for the NPR at North Platte gage (NDNR gage 6693000)
- Program LiDAR data (collected in 2009 and 2011)
- Historical aerial photography (1938 to 2011)
- Topographic surveys (2010)
- Bed material sediment samples (2010)

The following methods were used to complete hydrologic analyses of NPR streamflow data:

- Daily flow exceedance analysis to construct a flow-duration curve, which is a typical hydrologic plot showing flow magnitude vs. percent of time the magnitude is equaled or exceeded.

- Annual peak flow exceedance analysis using Bulletin No. 17b, Guidelines for Determining Flood Flow Frequency (USGS 1982).

One-dimensional hydraulic and sediment transport models were developed to assess NPR hydraulic capacity and to simulate alternatives for increasing capacity. One-dimensional hydraulic models were developed by Short Elliot Hendrickson, Inc. (SEH 2008), and also by HDR et al. (2011) for an area extending from CNPPID's Tri-County Diversion Dam upstream approximately ten miles. The hydraulic models were developed using the Corps of Engineers' HEC-RAS software. The HDR et al. (2011) hydraulic model was more detailed than the SEH (2009) model, and was based on the 2009 topography (Program LiDAR) in combination with three surveyed cross-sections to delineate the sub-aqueous portion of the channel not detectable in the LiDAR data. HDR et al. also constructed a one-dimensional sediment transport model using HEC-6T, which is proprietary mobile bed model software marketed by Mobile Boundary Hydraulics (MBH 2010). The ED Office used the HDR (2011) one-dimensional hydraulic and sediment transport models to evaluate several alternatives for increasing hydraulic capacity of the NPR.

The extent and magnitude of NPR flooding were determined through anecdotal information obtained from the NWS (2012) and also from individual property owners located in typically affected areas (PRRIP 2012d). Anecdotal flooding information included results during the record high river stage of 7.69 feet that occurred in June 2011. The likelihood of removal of affected landowners via property buyouts or easements was assessed by interviewing landowners in the flooding area (PRRIP 2012d). The cost of buyouts was estimated as 120 percent of the 2011 assessed value according to the Lincoln County Assessor's website (Lincoln County 2012). The cost of flood easements were estimated as $2,000 per acre, based on typical cost of a flood easement for accretion ground in the Central Platte Valley. A best alternative of a combination of property buyouts and easements was identified that would have the highest potential for cooperation with existing landowners and also include enough potentially affected properties removed from the floodplain to justify an increase in flood stage by the NWS.

The following approaches for analyzing the cause of decreased hydraulic capacity, and solutions for increasing hydraulic capacity and decreasing flooding are described based on existing literature and Program modeling and analyses:

- NPR hydrology
- NPR main channel hydraulics and geomorphic characterization
- Main channel sediment imbalance and approaches for achieving sediment balance
- Addressing higher river stage and flooding with the use of flood-control structures
- Vegetation-related causes/solutions (i.e., phragmites infestation and treatment)
- Decreased capacity issues, and increasing flow area to increase capacity
- Floodplain development effects and addressing perched floodplain water
- Removal of potentially affected properties in the floodplain
- Routing water around the North Platte Choke Point

RESULTS

Results from various sources are compiled by hydraulic capacity and solution categories listed in the Methods Section above. Some of the results have been fleshed out in more detail than others. A variable level of detail was used to analyze the reduction in hydraulic capacity because some alternatives were screened out more quickly than others by the ED Office and Choke Point workgroup.

NPR Hydrology

The NPR is a snowmelt-dominated river that originates at an elevation of 12,180 feet on the Continental Divide in Colorado, and flows through Colorado, Wyoming, and Nebraska to an elevation of approximately 2,800 feet at its mouth in North Platte, Nebraska (FEMA 2009). NPR hydrology has changed over time because of flow regulation that has occurred in both Wyoming and Nebraska. Construction of Lake McConaughy, approximately 60 miles upstream of North Platte, has the largest impact on flows through the Choke Point because of its proximity to the Choke Point.

Annual peak flows have decreased for the 1941 to 2012 post-Lake McConaughy period of record when compared to the short pre-Lake McConaughy period of record (**Table 1**). Reduction in NPR streamflow magnitude has resulted in less flushing flows to transport sediment through the Choke Point area, and has also reduced the ability to erode existing material from the Choke Point area. Lower streamflow magnitude has also resulted in the river decreasing in channel width, as described below in the section on NPR hydraulics and geomorphology.

The median NPR streamflow was approximately 1,000 cfs for the short pre-Lake McConaughy period of record from 1930 to 1940, and is approximately 400 cfs for the 1941 to 2012 post-Lake McConaughy period of record (**Figure 5**). Flows were greater than 1,000 cfs approximately 55 percent of days during the 1930 to 1940 period of record, but only 18 percent of days during the 1941 to 2012 period of record. Monthly median pre-Lake McConaughy flows were higher than those for post-Lake McConaughy except for the months of July and August (**Figure 6**), which are higher for the post-Lake McConaughy period because of summer irrigation releases from Lake McConaughy.

Alternatives for addressing hydrologic factors influencing the decrease in NPR hydraulic capacity are provided in **Table 2**. Due to the substantially higher pre-Lake McConaughy flows, it would be cost prohibitive to release water from Lake McConaughy in an attempt to match pre-Lake McConaughy hydrology. A total cost of approximately $107 million per year would be needed to increase flows from the existing median monthly flows to pre-Lake McConaughy median monthly flows, assuming a cost of water of $186 per acre-foot (PRRIP 2010).

Table 1. Annual Peak Flows

Recurrence Interval (Years)	Annual Probability (%)	Annual Peak Flow (cfs)	
		1930-1940	1941-2012
10	10%	8,500	4,600
50	2%	12,000	7,100
100	1%	14,000	8,300
500	0.2%	18,000	12,000

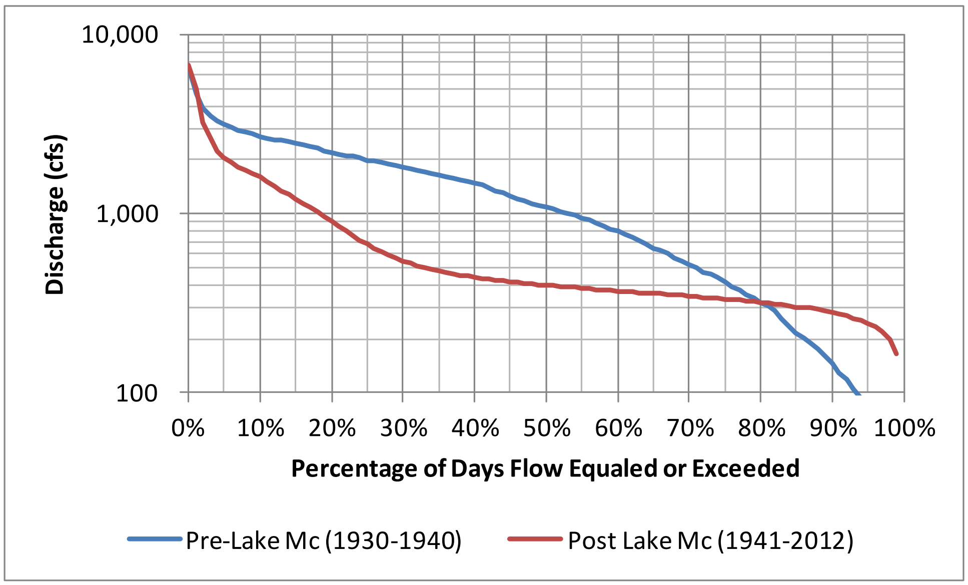

Figure 5. Flow Duration Curves for North Platte River at North Platte Gage (#6693000)

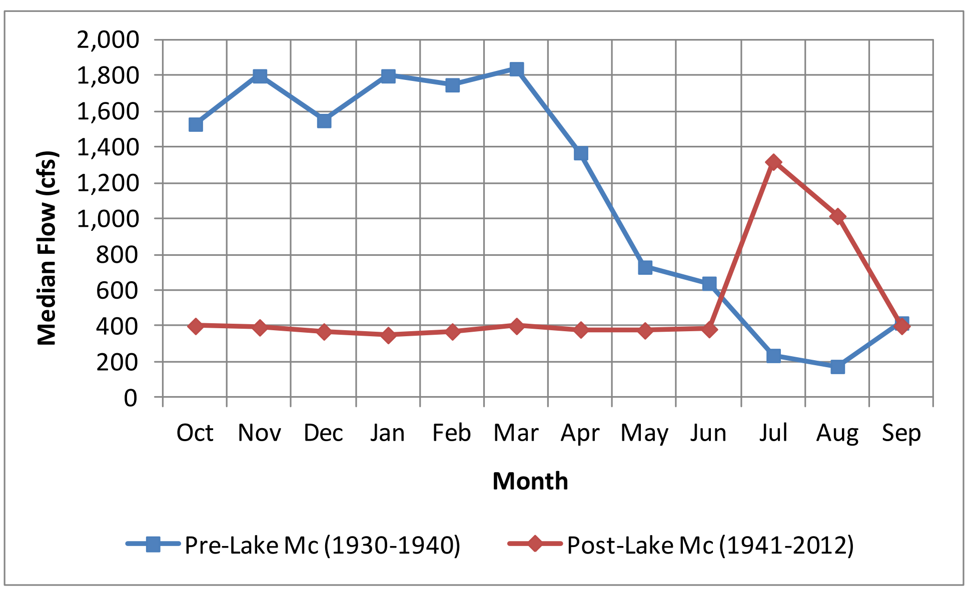

Figure 6. Median Monthly Streamflow for NPR at North Platte (Gage #6693000)

Table 2. Alternatives for Addressing Hydrologic Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Flow releases to match pre-regulation streamflow	Increase sediment transport capacity and scour existing sediment	• Potential to cause flooding • Cost prohibitive

NPR Main Channel Hydraulics and Geomorphic Characterization

The NPR is a low slope (i.e., average thalweg slope of 0.1%, **Table 3** and **Figure 7**) sandbed stream that was historically braided (see 1938 aerial photograph in **Figure 8**), and has shifted to a slightly meandering stream with anabranches (see 2010 aerial photograph in **Figure 8**). Channel width has decreased from a total braided stream width of approximately one-half mile in 1938, to a currently slightly meandering stream with a width of less than 500 feet. This reduction in channel width and shift away from braided river to a slightly meandering stream is likely related to the change in hydrology (discussed in the previous section) due to upstream flow regulation in the NPR basin in both Wyoming and Nebraska. Bed material is primarily medium to coarse sand, with a median particle diameter of 0.5 to 0.7 mm (**Figure 9**).

Table 3. Summary of NPR Main Channel Hydraulic Properties near North Platte at Current NWS Minor Flood Stage (6.0 feet, or 1,600 cfs)

Hydraulic Parameter	Minimum	Maximum	Average
Wetted Width of Active Flow Area (feet)	140	470	270
Channel Slope	-0.1%	0.4%	0.1%
Velocity (feet per second)	0.84	2.9	5.8
Hydraulic depth (feet)	1.0	3.8	2.1
Floodplain Width (miles)	0.3	0.6	0.5

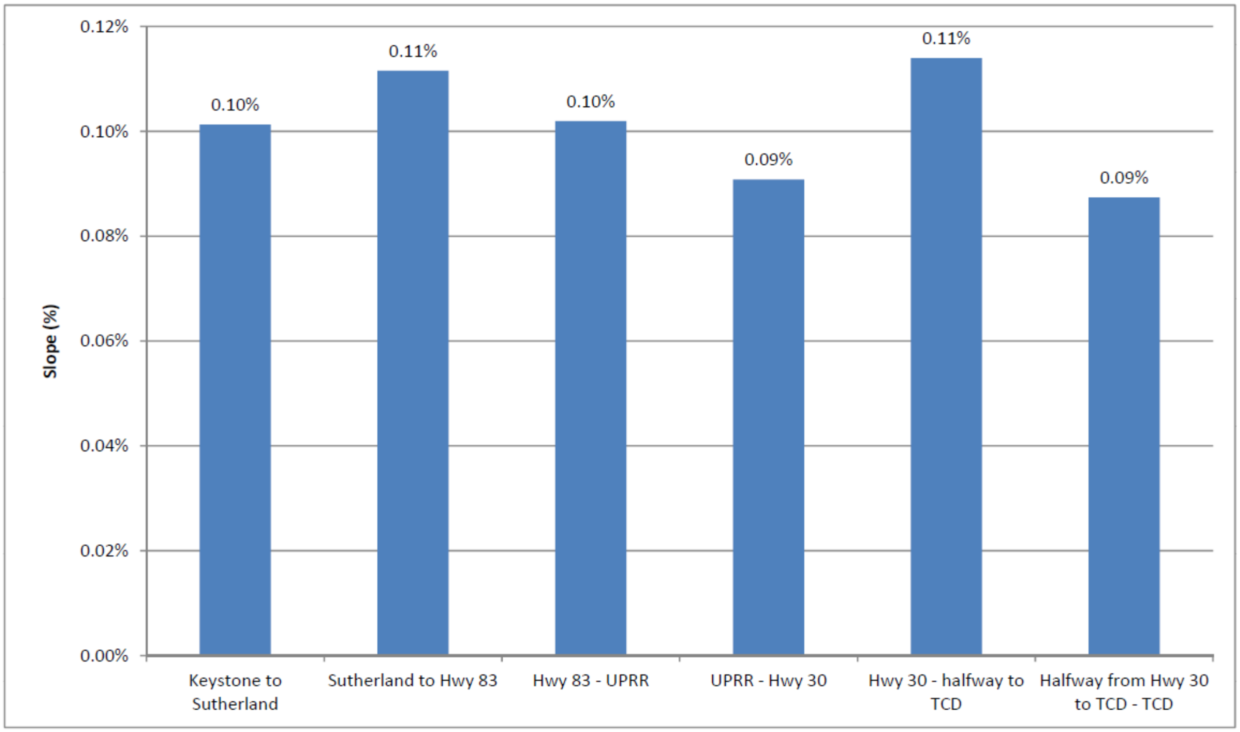

Figure 7. NPR Channel Slope from Keystone Diversion to Tri-County Diversion (based on Program 2009 LiDAR data)

Figure 8. Aerial Photograph Comparison for North Platte River near Highway 83

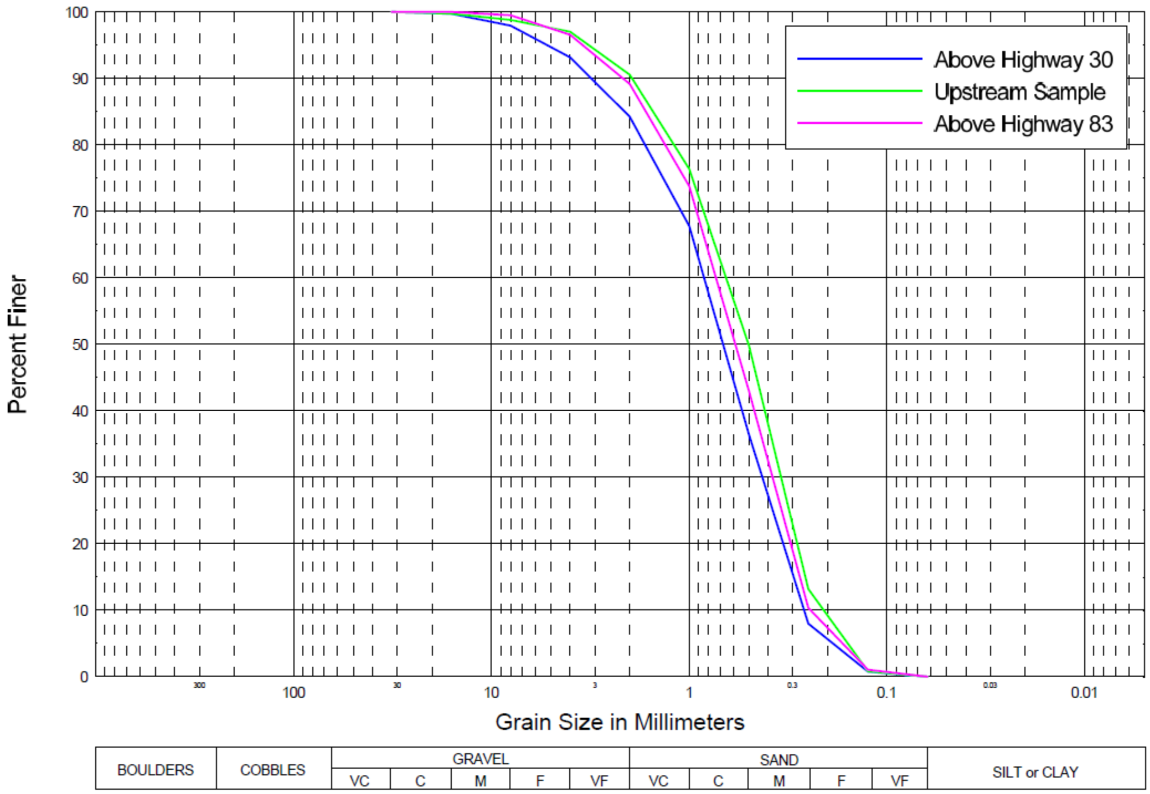

Figure 9. Gradation Curves for Composite Bed Material Samples ("Above Highway 30" sample collected approximately 500 feet upstream of Highway 30, Upstream Sample collected approximately 4.5 miles upstream of Highway 83, and Above Highway 83 sample collected approximately 800 feet upstream of Highway 83)

A plot showing sediment discharge and effective discharge for the NPR at North Platte demonstrates the relationship between NPR flow frequency and sediment discharge (**Figure 10**). This type of plot is used to combine flow frequency and sediment rating curves to determine which flows transport the most sediment over time. Flows with both relatively high frequency and relatively high sediment transport will transport the most sediment over time, and thus have the greatest influence on channel morphology. The flow with the highest product of sediment load and flow frequency is generally referred to as the effective discharge, and represents the flow that moves the most sediment over time. Flow frequency in the figure was based on daily NPR at North Platte flows from 1941 to 2012 (i.e., post Lake-McConaughy conditions). The sediment load rating curve was based on sediment transport model calibration completed by HDR et al. (2011). As shown in the figure below, the effective discharge for the 1941-2012 post-Lake McConaughy period of record is approximately 2,000 cfs. Flows of approximately 2,000 cfs have the greatest impact on NPR geomorphology under the current flow regime, and flows of approximately 400 cfs also have a substantial impact on NPR geomorphology.

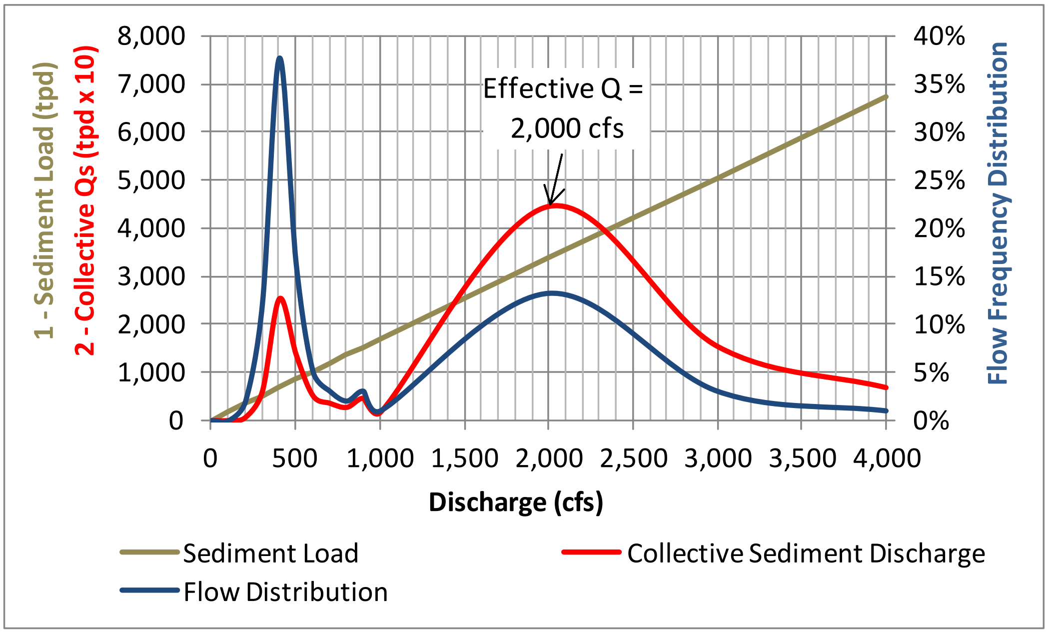

Figure 10. Sediment Discharge and Effective Discharge Plot for North Platte River at North Platte

The following notable hydraulic and geomorphic characteristics and changes over time may help to develop an understanding of why hydraulic capacity has decreased over time.

- Parsons (2003) reviewed historical measurements of flow velocity, depth, and cross-sectional area collected by NDNR and USGS as part of streamflow measurements for the North Platte River at North Platte gage. A significant decrease in channel capacity was noted in approximately 1990. This observation was based on a 20 to 25 percent decrease in flow velocity and depth, along with an increase in top width and flow area. The shift towards wider, shallower flow has likely led to decreased sediment transport capacity and subsequent sedimentation that has reduced hydraulic capacity of the NPR. Parsons suggested vegetation expansion increased resistance to flow, causing minor backwater effects upstream of vegetation. Parsons also suggested that migration of macroform sandbars into the area could have resulted in backwater areas upstream of the macroforms.
- Variations in channel width (140 to 470 feet, **Table 3**) result in variations in flow area. Flow velocity is slower in wider channel sections and higher in narrower sections. Sediment transport varies with flow velocity, and as a result sediment carried through a narrow, faster flowing reach may be depositing in downstream wider, slower flowing reaches.
- Sediment accumulation on the order of 1 foot have resulted between 2006 and 2009. Based on an ED Office review of 2009 LiDAR data to 2006 elevations in the City of North Platte's Flood Insurance Study, sedimentation has occurred at significant channel constrictions where backwater effects occur (**Figure 11**).

Alternatives for addressing hydraulic contributions to reduced hydraulic capacity are summarized in **Table 4**. Vegetation eradication has occurred since 2007, including extensive spraying of phragmites, and above ground clearing of both herbaceous and woody vegetation. Although vegetation eradication has likely slowed the rate of reduction in hydraulic capacity, it has not achieved an increase in capacity and is thus not a standalone fix. Removal of macroforms may increase sediment transport capacity, but the outcome of these actions on hydraulic capacity is not certain. Narrowing or widening channel width may create a uniform width and sediment transport capacity. However, hydraulic and sediment transport modeling using Program one-dimensional models (HDR 2011) indicates that modifications to channel width will not increase hydraulic capacity, and may actually increase flooding in the case of installing weirs or jetties to achieve a uniform narrow channel width. Alternatives focused on modifying NPR hydraulics are not likely to increase hydraulic capacity to the Program goal of 3,000 cfs.

Table 4. Alternatives for Addressing Hydraulic Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Vegetation eradication	Relatively cheap	• Annual maintenance required • Not a standalone fix
Remove macroforms (i.e., dredge)	High likelihood of increased capacity	• Repeated maintenance required • Permitting difficulty (e.g., 404 permit)
Narrowing channel width throughout, using jetties or weirs, to a uniform width equivalent to width at current restrictions	Sustainable option to achieve uniform sediment transport and minimize deposition	• Hydraulic structures increase resistance to flow, increase water levels, and thus increase potential for flooding • No increase in hydraulic capacity
Widening channel width at current restrictions to make channel width uniform	Sustainable option to achieve uniform sediment transport and minimize deposition	• Prevents further decreases in capacity, but may not increase capacity • Landowner access required to modify channel width • Permitting difficulty (e.g., 404 permit)

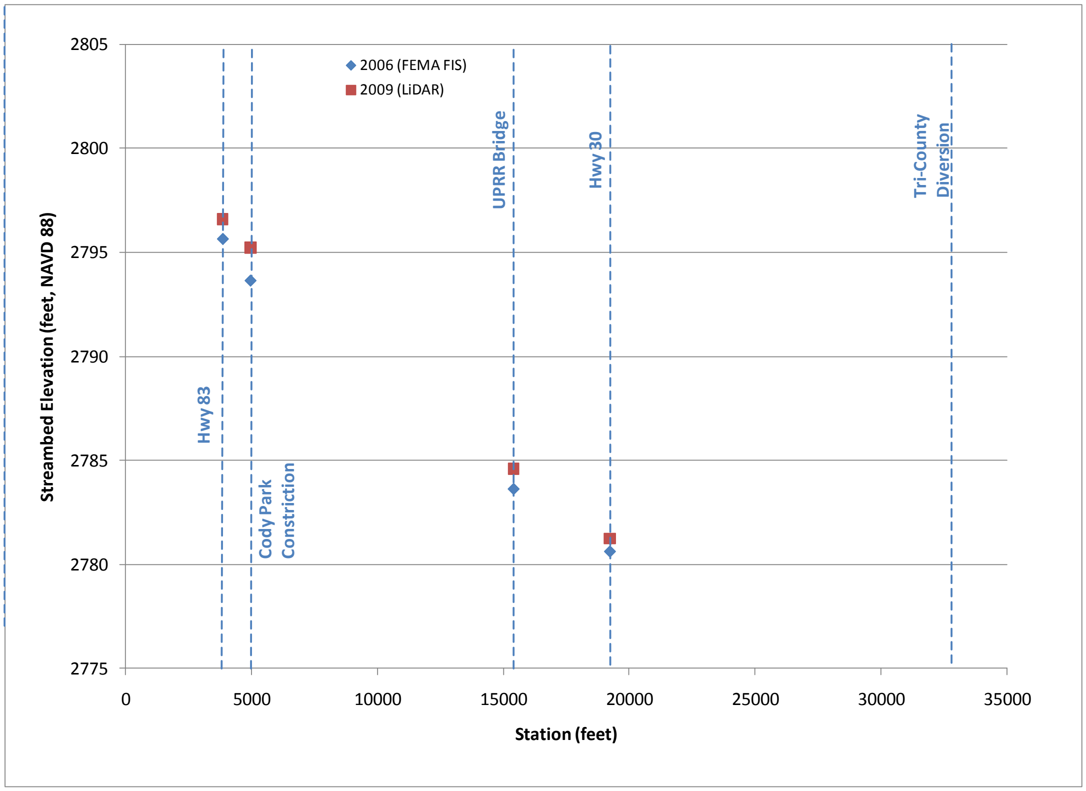

Figure 11. North Platte River Streambed Elevation Comparison (2006 vs. 2009) at Key Locations

Main Channel Sediment Imbalance and Approaches for Achieving Sediment Balance

The sediment imbalance between Highway 83 and the UPRR Bridge was simulated with the Program's one-dimensional sediment transport model (HDR et al. 2011). The model predicts slightly less than 10,000 cubic yards per year of material is deposited between Highway 83 and the UPRR Bridge, a total distance of approximately 2.2 miles (**Table 5**). This reach of the NPR was modeled because of its key influence on river stage at the NPR at North Platte gage.

Table 5. Sediment Budget for North Platte River between Highway 83 and UPRR Bridge

Modeled Sediment Parameter	Value	Unit
Sediment Input at Hwy 83	142,000	tons/yr
Sediment Out at UPRR	130,000	tons/yr
Sediment Deposition between Hwy 83 and UPRR	9,600	yd^3/yr

Notes:

[1] Material density assumed to be 1.3 tons/yd^3 based on similar density results from bed material samples collected on the Central Platte River for the Program's sediment augmentation feasibility study (The Flatwater Group et al. 2010).

Alternatives for addressing sediment imbalance contributions to reduced hydraulic capacity are summarized in **Table 6**. Dredging would result in a predictable reduction in water surface elevation (i.e., approximately equal to the depth of dredging if dredging is uniform across channel width), which would increase hydraulic capacity to the Program's goal of at least 3,000 cfs at NWS minor flood stage. Dredging alternatives were modeled with the Program's one-dimensional sediment transport model, and the best dredging alternative was identified (i.e., the alternative with the longest period of achieving the Program's goal of at least 3,000 cfs at NWS minor flood stage). The best dredging alternative included removal of 1.25 feet from the channel bottom between Highway 83 and the UPRR Bridge. While dredging would be an expensive alternative that could require repeated maintenance, it may be the only standalone option for fully achieving the Program's goal of at least 3,000 cfs at NWS minor flood stage.

Sediment removal at the upstream end of the Choke Point was also considered. The Choke Point workgroup considered the option of installing a sediment collector similar to the application installed on Fountain Creek just upstream of Pueblo, Colorado. While the theory behind sediment removal is sound, the technology is relatively new and untested. The Fountain Creek Watershed Authority conducted a one year demonstration project at a cost of approximately $800,000. Results have generally been positive thus far, but there have been some issues that have limited the effectiveness of the collector (e.g., variable streamflow). The Choke Point workgroup decided not to pursue the sediment collector option further because of unknown results and high cost.

Table 6. Alternatives for Addressing Sediment Imbalance Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Dredging	• Best alternative modeled provides about 5 years of hydraulic capacity • Known results of lowered channel bottom and water surface elevation	• High cost (best alternative ~$1.6M) • Repeated maintenance required • Permitting difficulty (e.g., 404 permit)
Sediment removal (e.g., sediment collector)	Potentially sustainable	• Unknown results for untested technology • High cost (~$800k for demonstration project) • Permitting difficulty (e.g., 404 permit)

Addressing Higher River Stage and Flooding with the Use of Flood-Control Structures

Flooding in the Choke Point area is generally known to be caused by a combination of surface flows overtopping channel banks, and also high ground water levels at least partially in response to high river stage that interact with alluvial ground water levels. Flood levees along the NPR channel banks and banks of floodplain side channels could minimize flooding related to surface flow overtopping channel banks. However, levees would generally squeeze flows into a narrower flow area and result in higher river stage that could in turn increase ground water flooding. Additionally, the current Flood Insurance Study in the most flood-prone area (west of Highway 83 and south of North River Road) indicates that levees at this location would be located in the floodway. The USACE permitting process would be onerous and time-consuming for constructing levees in the floodway. Additionally, levees would likely be required to be excessively tall (i.e., three feet of freeboard above the 100-year recurrence interval peak flow of 9,690 cfs (FEMA 2000)). Levees at that height would likely not be acceptable to residents along North River Road. The Choke Point workgroup decided not to pursue flood-control structures such as levees to prevent surface flooding, primarily because of the potential for levees to exacerbate ground water flooding, and also because of likely local opposition to high levees.

Table 7. Alternatives for Addressing Sediment Imbalance Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Levee along the south bank of the NPR to protect Cody Park, similar to that installed summer 2011 by FEMA	Would protect Cody Park at high flows (i.e., greater than 6,000 cfs)	• No flood protection at Program flow of up to 3,000 cfs
Levee along the north bank of the NPR to protect area south of N River Road that is typically flooded at flows above minor flood stage	Would minimize flooding related to surface flows overtopping channel banks	• Could increase ground water flooding as a result of increased river stage • Difficulty for permitting levees within NPR floodway

Vegetation-Related Causes/Solutions (i.e., Phragmites Infestation and Treatment)
Vegetation encroachment, including the proliferation of invasive phragmites since the early 2000s, has decreased flow velocity and sediment transport capacity by increasing resistance to flow. Vegetation encroachment has also stabilized existing sediment, limiting the ability of spring high flushing flows from moving sediment out of the Choke Point area.

The Program has spent approximately $241,000 since 2007 in an effort to eradicate phragmites in the North Platte Choke Point area, i.e., from the North Platte Airport to approximately three miles upstream of Highway 83 (personal contact with West Central Weed Management Area 2012). From 2007 to 2011, within the area between the airport and three miles upstream of Highway 83, approximately 380 acres of phragmites were sprayed, 190 acres were shredded, and 260 acres were disked and shredded. Figure 12 demonstrates the level of vegetation eradication that has occurred in the vicinity of the Highway 83 Bridge. Although the effort has prevented further reduction in hydraulic capacity, there has been no increase in hydraulic capacity. This is likely because the effort so far has focused on spraying and chopping above the ground. But phragmites root balls have remained in place, and continue to limit the ability of spring flushing flows from moving sediment out of the Choke Point area.

Alternatives for addressing vegetation-related factors influencing the reduction in hydraulic capacity are listed in **Table 8**. Continued spraying and chopping/mowing will likely prevent further reduction in hydraulic capacity, but root balls would need to be removed via deep disking to increase hydraulic capacity. Deep disking would be more costly than spraying, and some areas may not be accessible by heavy machinery required to accomplish deep disking. Deep disking may also require additional Section 404 permitting through the Corps of Engineers. Regardless of which vegetation treatment methods are employed, the effectiveness will be dependent on whether high flows are capable of flushing sediment following treatment.

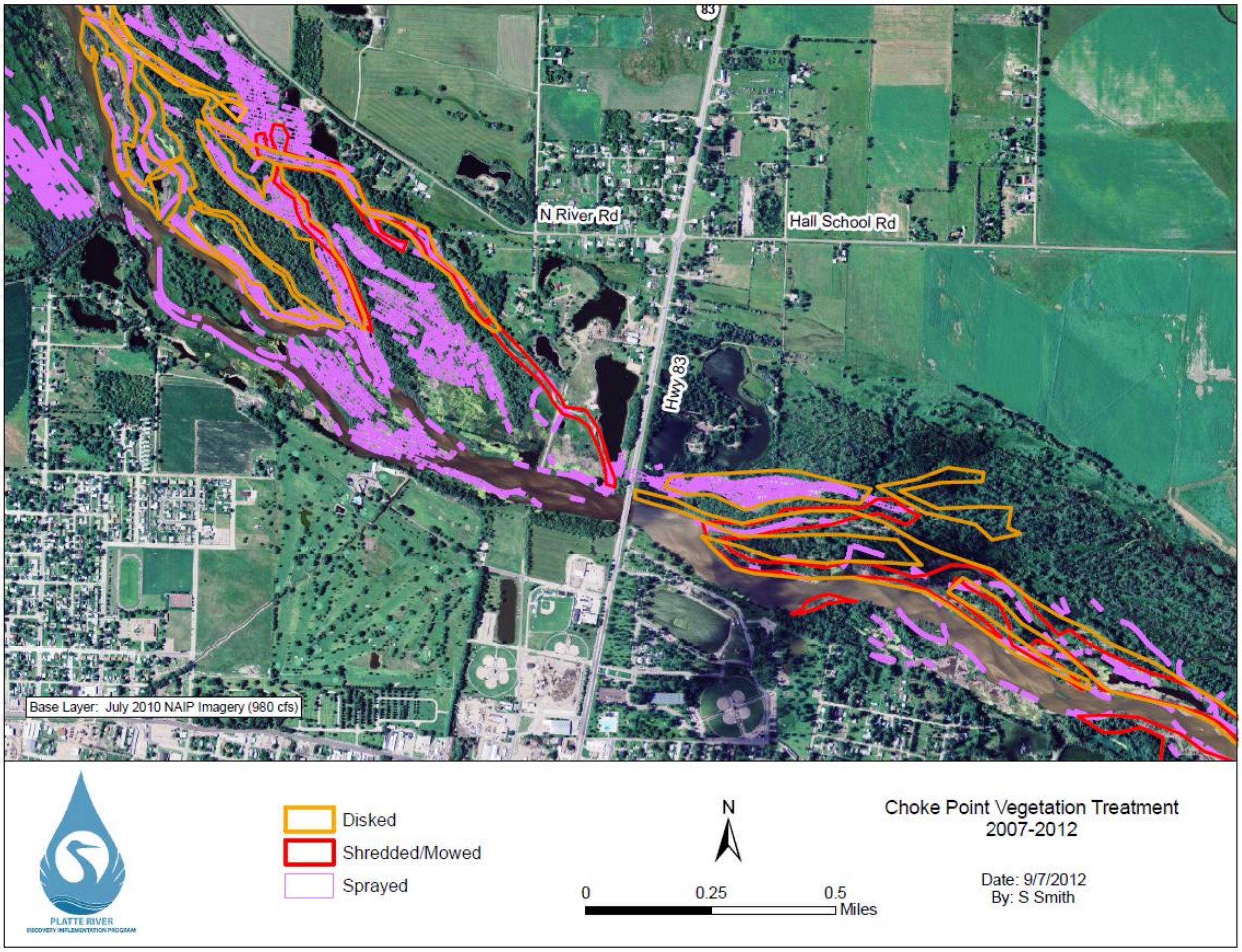

Figure 12. Choke Point Vegetation Treatment near Highway 83 from 2007 through 2012

Table 8. Alternatives for Addressing Vegetation Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Vegetation spraying	Prevents further propagation of vegetation and reduction in hydraulic capacity	• Minimal increase in hydraulic capacity, because root balls remain in place
Vegetation chopping and disking	May break up existing root balls, and facilitate sediment flushing	• Higher cost than spraying alone • Access issues for heavy machinery in the floodplain • Potential 404 permitting requirements

Decreased Capacity Issues and Increasing Flow Area to Increase Capacity

Flow velocity decreases upstream of flow constrictions where the channel width is decreased, and backwater areas upstream of the constrictions can lead to sediment deposition that reduces hydraulic capacity. As noted in **Table 3**, channel width at flood stage varies between 140 and 470 feet, and deposition of on the order of one foot has occurred near channel constrictions such as the Highway 83, UPRR, and Highway 30 bridges (**Figure 11**). Although backwater areas affect river hydraulics for a localized area upstream of channel constrictions, hydraulic modeling indicated that backwater effects are localized and relatively minor. Sediment transport modeling of several alternatives to increase channel width at constrictions indicated that sediment deposition at the widened locations would be exacerbated by channel widening as velocities are decreased (HDR et al. 2011).

Alternatives for addressing flow area factors influencing hydraulic capacity are presented in **Table 9**. Widening the channel at key constrictions would result in a net increase in sediment deposition according to hydraulic and sediment transport modeling. As a result, the Choke Point workgroup decided not to consider these alternatives further.

Table 9. Alternatives for Addressing Flow Area Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Widen constrictions (e.g., bridges at Hwy 83, UPRR, Hwy 30)	Reduce local backwater areas at constrictions	• Net overall increase in deposition because of increased flow area

Floodplain Development Effects and Addressing Perched Floodplain Water

Floodplain development along the north bank of the NPR has adversely affected floodplain drainage. The area west of the Highway 83 Bridge and between the NPR and North River Road is an area that has been developed since about the mid-1960s (**Figure 13**). This area is typically flooded during high NPR flows and ground water levels. NWS flood stage is based in large part on flooding effects in this North River Road area (NWS 2012). NWS has indicated that flooding effects in the North River Road area include:

- Limitations on private property access to accretion ground when NPR stage is between 6.0 and 6.5 feet.
- Initial impacts to structures within the floodplain when NPR stage reaches approximately 6.5 feet.

Figure 13. Aerial Photo Comparison from 1958 and 2010, Showing Floodplain Development

The NWS, PRRIP stakeholders, and general public along North River Road generally agree that flooding is caused by an uncertain combination of surface water flows and high ground water levels. However, there are minimal data available to accurately quantify the relative magnitude of flooding from ground water versus surface water. As a result, the ED Office and Choke Point workgroup developed a monitoring plan (PRRIP 2012) with the objective of collecting ground and surface water levels at key locations. Data will be used to reduce the uncertainty in the relative magnitude of ground and surface water effects on flooding. Automated water levels will be recorded on a 30-minute interval at key three key locations (SW-2, GW-1, and GW-3), and water levels will be manually recorded during 12 monitoring events per year to be coordinated with the ED Office (monitoring locations shown in **Figure 14**).

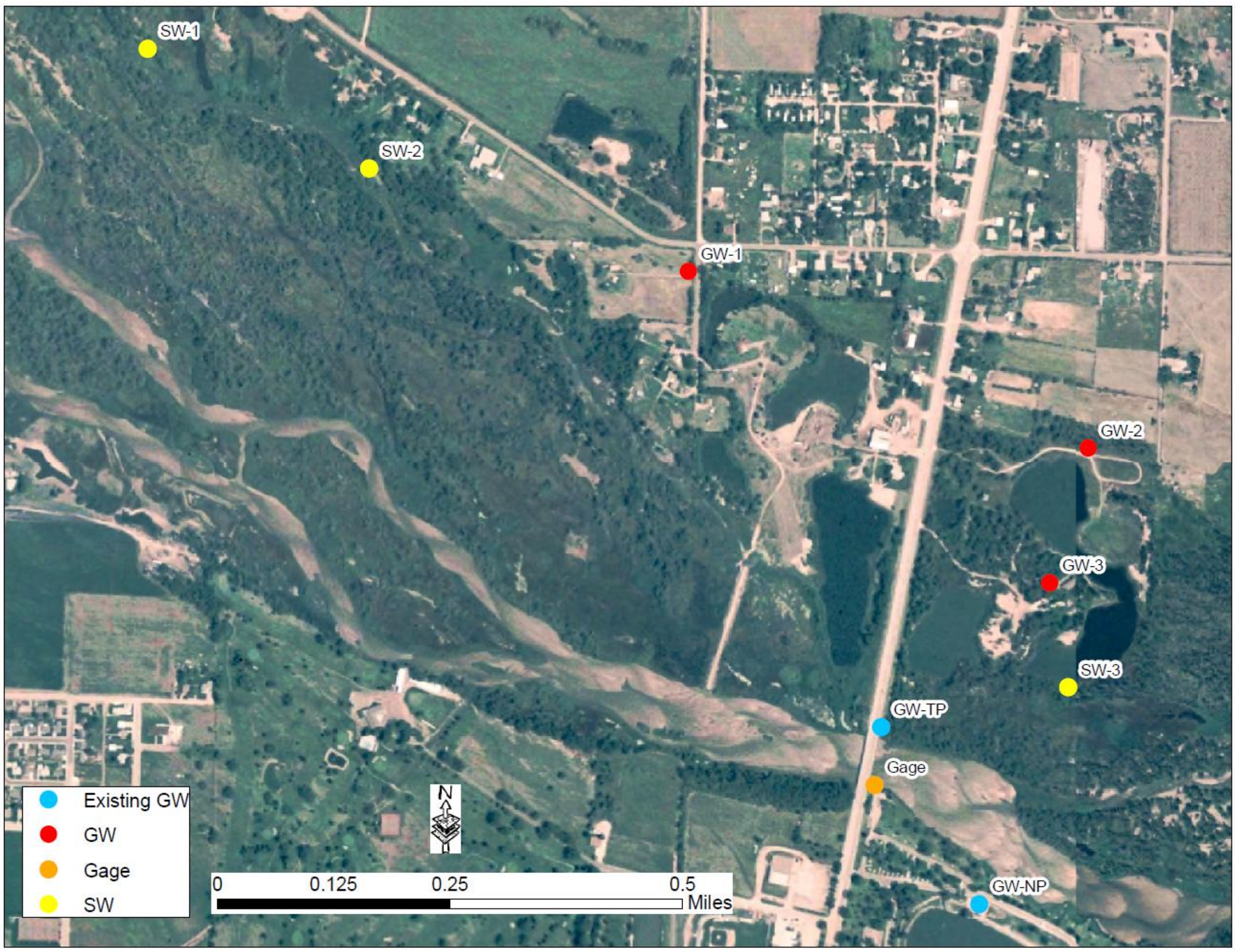

Figure 14. Choke Point Monitoring (GW=PRRIP ground water monitoring wells to be installed September 2012, SW=PRRIP surface water gages to be installed September 2012, Existing GW=existing TPNRD ground water monitoring well monitored twice per year, and Gage=existing NDNR NPR at North Platte river gage)

Alternatives for addressing floodplain drainage factors influencing hydraulic capacity are presented in **Table 10**. The three flood-proofing projects in the table were collaboratively conceived by the ED Office, the City of North Platte, and Lincoln County (PRRIP 2012b). The Choke Point workgroup and the WAC have also supported the flood-proofing projects. The objective of the flood-proofing projects is to improve drainage in the area that is typically flooded during high NPR flows, and to route surface flows away from the developed portion of the floodplain. Cost of the flood-proofing projects would be relatively low, with pre-feasibility level cost estimates of approximately $150k including engineering, design, surveying, and construction (PRRIP 2012c).

The NWS staff indicated that the flood-proofing projects may decrease flooding to a point that minor flood stage could potentially be increased from the current level of 6.0 feet (approximate flow of 1,600 cfs) to 6.5 feet (approximate flow of 2,400 cfs) (NWS 2012). Ground and surface water monitoring described above will be utilized to demonstrate the effects of the flood-proofing projects, and the ED Office will communicate results to the NWS with the objective of justifying an increase in minor flood stage following completion of flood-proofing projects.

Table 10. Alternatives for Addressing Flow Area Factors in Reduced Hydraulic Capacity

Alternative	Pros	Cons
Re-activation of the "State Channel" upstream of primary flooding area	Divert high flow away from primary flooding area, but maintain minor flow for recreational/aesthetic purposes	• Potential 404 permitting constraints
Install culverts along N River Rd to improve drainage	Improve drainage of ground and surface water in primary flood area	• None
Install outlet on gravel pond that currently limits outflow from N River Rd area to NPR	Improve drainage of ground and surface water in primary flood area	• Topography may limit ability to drain pond during NPR high flows

Removal of Potentially Affected Properties from the Floodplain

The NWS has indicated that flood stage is highly influenced by the impacts to the developed area within the floodplain between North River Road and the NPR, and within approximately two miles of the Highway 83 Bridge. This area has historically been flooded, with limits to property access at NPR river stage above 6.0 feet, and initial damage to structures at NPR river stage above 6.5 feet. Removal of potentially affected property owners from the typically affected floodplain area could potentially justify an increase in flood stage by the NWS.

Alternatives for removal of affected properties from the floodplain are presented in **Table 11**. Several scenarios were developed for removal of potentially affected properties (PRRIP 2012e). The best case scenario included a combination of property buyouts for developed areas with anecdotal flooding effects, and flood easements for less developed areas that have been flooded in the past. Approximately 270 acres of flood easements and 25 acres of property buyouts would likely be needed to remove potentially affected properties if flood-proofing projects do not reduce flooding as anticipated (**Figure 15**). Assuming maximum benefits of flood-proofing projects, property buyouts/easements will likely not be needed for the red area along North River Road in **Figure 15**. Cost estimates for removing affected properties from the floodplain range from approximately $2M to $4M, assuming maximum and minimal benefits of flood-proofing projects, respectively. The biggest factor limiting the feasibility of successful buyouts and easements is that the majority of current landowners are not interested in selling or providing easements (PRRIP 2012d). Although there are a few landowners on the fringes of the impacted area that might be interested in settling, there are several key landowners with large properties that are not interested in moving.

Table 11. Alternatives for Removal of Affected Properties from the Floodplain to Increase Hydraulic Capacity

Alternative	Pros	Cons
Buyouts and easements with minimal impact of flood-proofing projects	May justify an increase in minor flood stage to 6.5 feet (2,400 cfs)	• Not enough willing seller area to justify increased flood stage • High cost with uncertain results
Buyouts and easements with anticipated benefits of flood-proofing projects	• Smaller area needed because of flood-proofing • May justify an increase in minor flood stage to 6.5 feet (2,400 cfs)	• Not enough willing seller area to justify increased flood stage • High cost with uncertain results

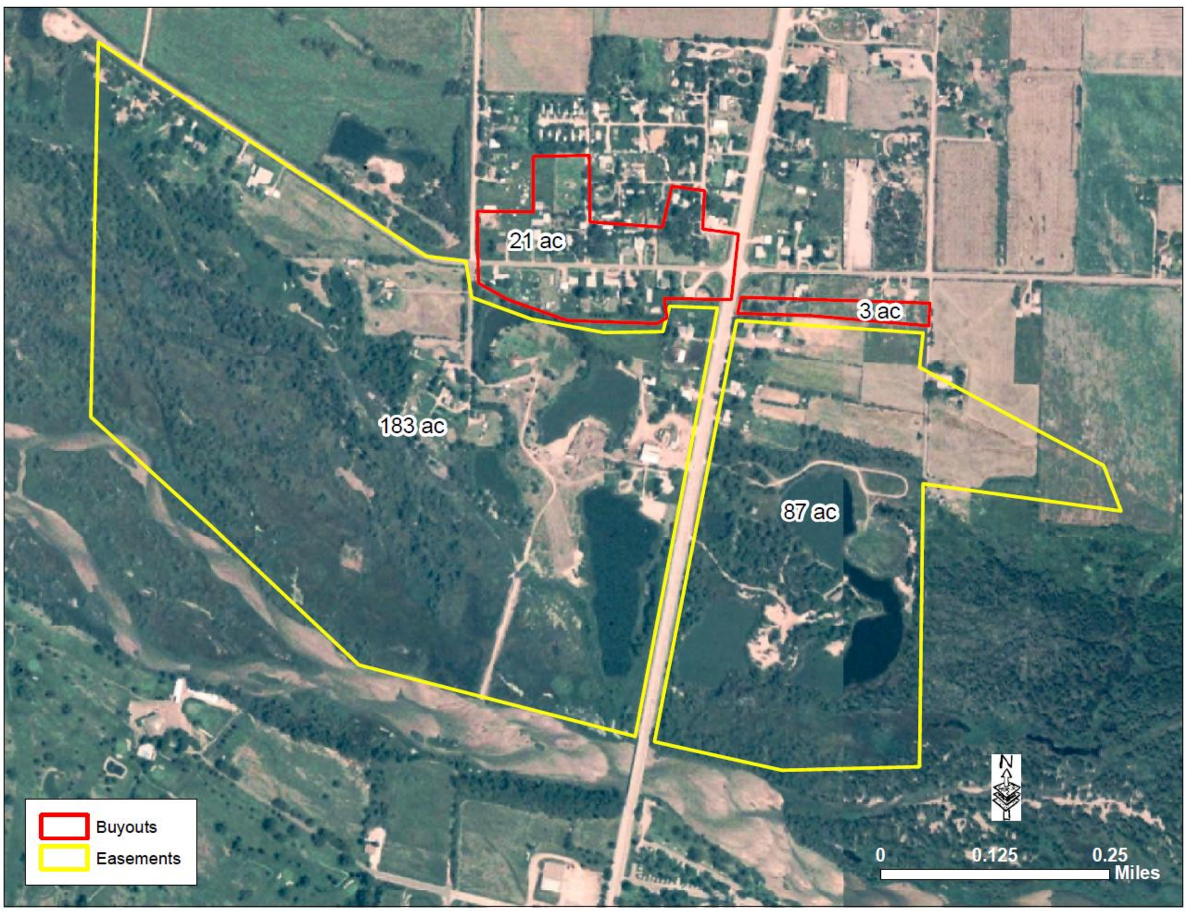

Figure 15. Property Buyouts and Easement Combination Alternative

Routing Water around the North Platte Choke Point

Routing water around the North Platte Choke Point would be an alternative to all of the alternatives described above that were focused on addressing systematic hydrologic, hydraulic, and geomorphic issues on the NPR. Alternatives for routing water around the North Platte Choke Point are summarized in **Table 12**. Options include use of existing infrastructure to gain a small amount of capacity (e.g., existing canals), or building new infrastructure (e.g., reservoirs and pipelines) to add a larger amount of capacity. When considering alternatives for routing water around the Choke Point, the objective is to find an alternative with approximately 1,400 cfs in capacity (i.e., the difference between the 1,600 cfs minor flood stage capacity in North Platte, and the Program's goal of 3,000 cfs through the Choke Point).

Existing canals that divert from the NPR and either return or waste back to the South Platte River could be used to route water around the Choke Point. Variations on the use of existing canals are to either use the canals as-is with limited capacity (i.e., less than 200 cfs at the South Platte River), or to improve the canals and associated wasteways to increase capacity to about 300-350 cfs at the South Platte River. The ED Office received initial positive reaction from the canal operators and TPNRD regarding the potential to operate the following three canals for PRRIP purposes: Keith-Lincoln Co., North Platte, and Suburban canals (PRRIP 2012f). Although there would be high seepage losses from the NPR canals, return flows from seepage could potentially be credited to PRRIP or TPNRD for purposes of offsetting depletions to target flows or post-1997 depletions, respectively. The ED Office will continue to work with TPNRD to determine an optimal approach to present to the boards of directors for each of the potential canals. Although use of existing canals only provides a portion (up to 350 cfs) of additional capacity needed to achieve the Program's goal (1,400 cfs additional capacity), the Choke Point workgroup and WAC support the use of North Platte Canals to route water around the Choke Point because of the quick and easy nature of using the existing canals with minimal improvements needed.

Water could be bypassed around the North Platte Choke Point using NPPD's Keystone Diversion, with the addition of a bypass just before or after the Paxton Siphon to the South Platte River. There is approximately 40 feet of head at this location (NPPD 2012), which could be used to gravity feed water to the South Platte River via a pipeline installed immediately above or below the Paxton Siphon. NPPD has provided initial feedback on this alternative, including a desire not to modify the existing Paxton Siphon. However, the feasibility and cost of this alternative still need to be determined. One factor to consider is the potential hydropower bypass cost that would need to be paid to NPPD. Hydropower bypass cost may be something on the order of the cost of EA bypass water at CNPPID's Tri-County Diversion Dam, or approximately $11.10 per acre-foot of bypassed water (PRRIP 2008).

Of several options to use NPPD's existing system, or potentially expanded system, the most feasible option may be a new reservoir with a new return to the South Platte River (NPPD 2012). The Program goal of 3,000 cfs for the North Platte Choke Point is already based on an assumed maximization of South Platte River return flow from NPPD's North Platte Hydro (i.e., 1,800 cfs). Additional capacity using NPPD's existing system is unlikely because of stability and seepage issues for canals that supply water to the North Platte Hydro. NPPD previously completed a Sutherland System water utilization study (NPPD 1993), which included consideration of options to increases storage capacity on the Sutherland System. A new "Sutherland East" reservoir approximately 2.5 miles east of Sutherland Reservoir was determined to be one of the more feasible options, and NPPD suggested to the ED Office that the site may provide the following benefits:

- Program benefits – additional capacity to make up for lack of NPR capacity, and ability to store excess South Platte River flows for future releases for both SDHF and target flows.
- NPPD benefits – additional hydropower revenue, and system redundancy in case of emergency shutdown of the North Platte hydropower return.
- TPNRD benefits – water stored for subsequent release to offset post-1997 depletions.

A new return to the South Platte River would also be needed to fully utilize additional storage capacity at the East Sutherland site. The alignment of the return could run directly to the South Platte River, or potentially to the Fremont Slough. The Fremont Slough discharges to NPPD's North Platte Hydro return, with an existing crossing underneath Interstate-80. Capitalizing on the Freemont Slough's existing I-80 crossing would reduce project cost. Cost to construct the Sutherland East Reservoir would be approximately $50M, based on NPPD (1993) reservoir construction costs scaled up to 2012 values according to U.S. Bureau of Reclamation construction cost indices. Cost of a new South Platte River return would be on the order of $10M, based on Choke Point workgroup input (PRRIP 2012g). Construction of an East Sutherland Reservoir and new return would achieve the Program goal of 3,000 cfs capacity through the Choke Point, and additional benefits to NPPD and TPNRD. However, the high cost and long project duration may limit the feasibility of this alternative to be completed during the Program's First Increment.

A pipeline from the North Platte River to the South Platte River was investigated, but determined to be infeasible. The infeasibility is primarily based on the large number of headgate diversion wells that would be needed to divert from the North Platte River and pump water over the divide between the North and South Platte rivers. Ten headgate wells with maximum pumping rates of approximately 1,000 gallons per minute (gpm) per well would provide a total pipeline flow rate of only 22 cfs. Pre-feasibility cost estimates of $75,000 per well, and pipeline cost of approximately $750,000, indicate a total cost of approximately $1.5M for a rate of only 22 cfs. As a result, the Choke Point workgroup decided not to pursue this alternative further.

Table 12. Alternatives for Routing Water around the North Platte Choke Point

Alternative	Pros	Cons
Existing canals and wasteways to route water from the NPR to the South Platte River	Existing infrastructure and low cost	• Low capacity (<200 cfs) • High seepage loss (~40% of NPR diversion) • Limited operation outside of irrigation season
Improve existing canals or wasteways to route water from the NPR to the South Platte River	• Relatively low cost (yet to be determined) • Higher capacity than option without canal improvements	• Low capacity (~300-350 cfs) • High seepage loss (~40% of NPR diversion) • Limited operation outside of irrigation season
NPPD siphon bypass at South Platte River	• Up to ~1,700 cfs capacity at South Platte River	• Would require hydro-bypass agreement
Sutherland East Reservoir and new Return to South Platte River	• Flexibility in reservoir and return capacities • Benefits to TPNRD, PRRIP, and NPPD	• High cost • Delayed project completion (>5 years)
Pipeline from NPR to South Platte River	No limits on operating schedule	• Limited capacity (<25 cfs) • High cost

DISCUSSION

The current NPR hydraulic capacity of approximately 1,600 cfs at NWS minor flood stage is less than the Program's goal of 3,000 cfs capacity through the NPR. The Program has spent considerable time and effort to understand the potential causes of the limited hydraulic capacity, and to identify potential alternatives for increasing the capacity and the ability to fully utilize Program water stored in Lake McConaughy for releases to the Central Platte River via the NPR.

The reduction in hydraulic capacity can be traced over time from over 3,000 cfs in 1997 when the Program's Cooperative Agreement was signed, to approximately 1,600 cfs in 2012. A related increase in river stage has been observed as far back as 1941 when Kingsley Dam was completed. Short-term decreases in river stage have occurred in years with abnormally high peak flows (e.g., 1971, 1983, and 2011), because of high sediment transport capacity during high flows that flushes the river channel.

Development in the floodplain has exacerbated the problems occurring along with the reduction in hydraulic capacity. Adverse consequences of development include reduction in floodplain conveyance and storage capacity. Surface water overtopping channel banks and high ground water levels are both commonly accepted as contributing factors to flooding that is driving NWS flood stage. However, the relative contribution from ground and surface water is unknown due to a lack of detailed monitoring data. The Program has initiated a program to monitor ground and surface water levels, with the objective of using the data collected to quantify the contribution of flooding from ground water versus surface water.

Systematic changes in NPR vegetation, hydrology, hydraulics, and sediment transport have led to reductions in hydraulic capacity over time. Annual peak flows have decreased since 1941 when Lake

McConaughy was completed. Flows after 1941 have generally decreased in magnitude, and have substantially less variability than before upstream water storage projects were completed. The reduction in magnitude and variability of NPR streamflow has reduced the river's ability to transport sediment through the North Platte area. Encroachment of vegetation such as the invasive phragmites in the floodplain and within the main NPR channel has also increased resistance to flow and decreased flow velocities. The Program will continue to collaboratively work to treat vegetation with the objective of minimizing the effects on hydraulic capacity.

An overabundance of sediment supply relative to the NPR's sediment transport capacity has resulted in sediment deposition occurring on the channel thalweg, sandbars, and even in the floodplain. Deposition has led to increased water levels and more frequent overbank flows that can cause damage to development that has occurred in the floodplain since about the 1960s. Hydraulics upstream of manmade structures such as bridge openings and diversion dams indicate localized deposition occurs as a result of backwater areas upstream of the structures. Vegetation expansion and the formation of large sandbars have also likely played a role in the reduction in flow velocity and sediment transport capacity.

Scenarios to increase the Program's ability to fully utilize its EA water generally fall into the following three categories:

1. Remove properties that are damaged at high flow
2. Modify the North Platte River channel to reduce flood impacts
3. Route water around the North Platte Choke Point area to minimize flooding

Acquisition and removal of properties that are damaged during flooding is not a feasible option under the Program's policy of willing seller land acquisition. The small number of landowners that have expressed interest in property buyouts or flood easements would not result in a large enough area to justify an increase in flood stage by the NWS.

Of several channel modification scenarios simulated with the Program's one-dimensional hydraulic and sediment transport models, dredging appears to be the only option with a high likelihood of meeting the Program goal of at least 3,000 cfs hydraulic capacity. Dredging of approximately 230,000 cubic yards of material from the NPR channel thalweg between the Highway 83 and UPRR bridges was simulated with the Program model to approximately five years of at least 3,000 cfs hydraulic capacity. The disadvantages of dredging include the potential need for periodic dredging to maintain hydraulic capacity, the approximate initial dredging cost of $1.6M, and the potential difficulty in permitting.

Routing water around the North Platte Choke Point provides an alternative to trying to solve systematic hydrologic, hydraulic, and geomorphic NPR issues. The quickest and most feasible option for routing water around the Choke Point is to use existing canals that divert from the NPR and return or waste back to the South Platte River. These canals could provide additional NPR capacity to the Program of up to 200 cfs without improvements, and up to 350 cfs with improvements. The ED Office will work collaboratively with TPNRD to determine the best approach for using the existing canals to increase hydraulic capacity. A more long-term and potentially beneficial option to TPNRD, NPPD, and the

Program would be to expand NPPD's Sutherland system to provide the ability to route water around the Choke Point. However, the cost and time to construct a new reservoir and South Platte River return may prevent this option from being feasible during the Program's First Increment.

The ED Office has worked with the Choke Point workgroup and Program contractors to assess the feasibility of several approaches for reaching the Program goal of 3,000 cfs hydraulic capacity through the Choke Point. Based on NPR vegetation, hydrology, hydraulics, and sediment transport, the following path forward is recommended by the workgroup:

1. Monitor ground and surface water levels to identify and quantify flooding factors.
2. Complete the three flood-proofing projects developed in collaboration with the City of North Platte and Lincoln County. The objective of the projects is to minimize flooding of properties and structures in the area typically affected by high surface and ground water levels. The NWS may be justified in increasing minor flood stage to 6.5 feet (2,400 cfs) if flood impacts are demonstrably lower when flood-proofing projects are completed.
3. Collaboratively work with TPNRD to use existing NPR canals to divert water to the South Platte River and around the Choke Point. At a minimum, the canals should be used at their current capacity according to timing agreed to by the respective canal companies (i.e., primarily outside of the May to August irrigation season). The potential to increase capacity through canal upgrades should also be discussed with the respective canal companies.
4. Discuss this path forward at all levels of the Program, including the Technical Advisory Committee, and the Governance Committee. Implement the path once Program support is determined.
5. Initiate the best case dredging option, with the objective of achieving the full Program goal of 3,000 cfs hydraulic capacity. Prepare a dredging plan and complete the necessary permits for dredging.

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