2D HYDRODYNAMIC MODELING SUMMARY

OVERVIEW

In 2017, PRRIP discontinued field-based monitoring initiated remote sensing-based geomorphology and vegetation monitoring in the Associated Habitat Reach (AHR). In 2019, as part of the reach-wide monitoring effort, the EDO developed a series of six 2D hydrodynamic models spanning the entire AHR to evaluate channel conditions and subsequent target species habitat over time. The main purpose of the models is to predict depth, velocity and corresponding inundation area across a range of in-channel (non-flood) flows to finer level than previous efforts could reliably produce. The six models span all active channels of the AHR and begin and end at bridge crossings where the river is largely consolidated to a single channel and all boundaries except Chapman have permanent stage gages. This model was designed to serve as reporting tool but provides seamless data with relatively good accuracy to make informed decisions and provide boundary conditions for finer scale studies.

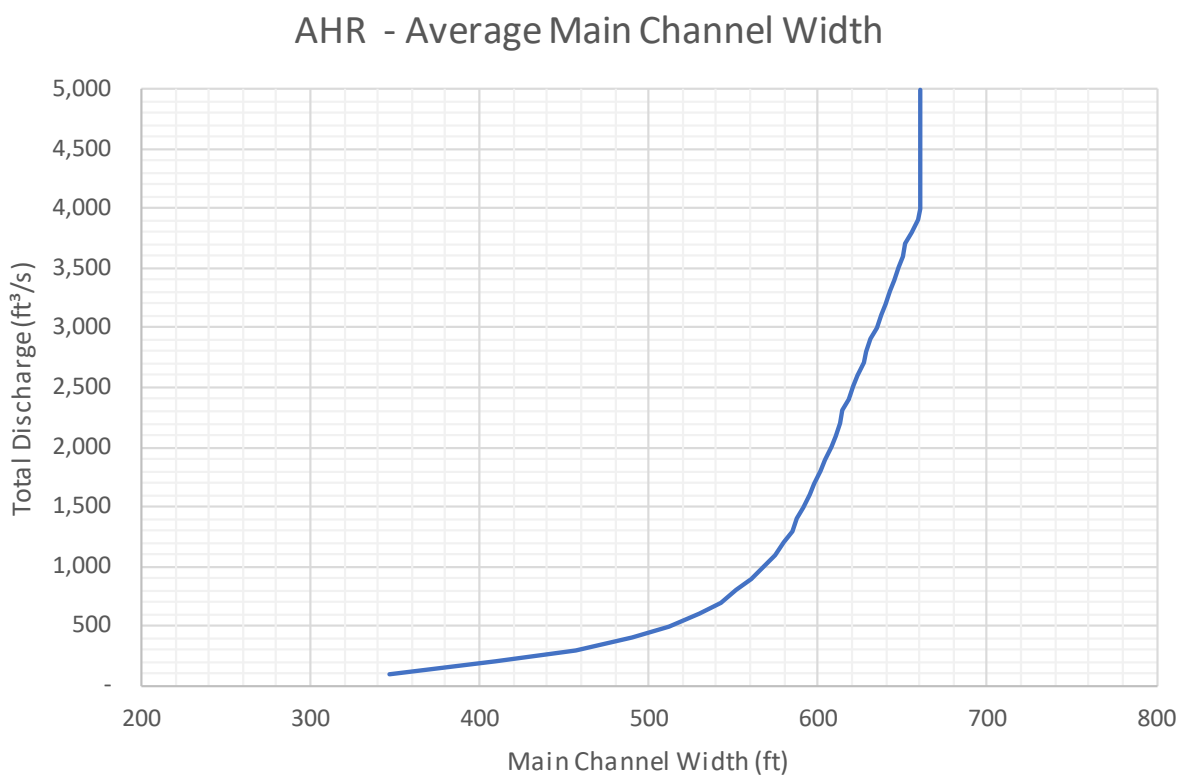
MODELING ASSUMPTIONS AND PERFORMANCE

Each computational mesh is comprised of triangular elements with a node spacing of approximately 20 feet. The topography source is from PRRIP fall 2018 bathymetric LiDAR which will be updated every year. Model boundary conditions are used directly from stream gage measurements and rating curves and will be updated as necessary. Each model was calibrated using a single in-channel Manning's N-value to a measured stage and discharge during fall migration season and validated against a differing stages and discharges during the spring migration season. Preliminary results are now complete for 100 cfs to 4,000 cfs in 100 cfs increments and 5,000 cfs. Predicted stage elevations for the main channel are within ±0.1 feet and side channels are within ±0.17 ft of measured stage between the Lexington and Chapman bridges.

PRELIMINARY RESULTS

Main channel results have been extracted for the AHR and Cottonwood Ranch (CWR) to illustrate the utility of 2D modeling in flow scenario planning to translate flow to quantifiable habitat, scour potential, flow splits, etc. Results shown below are limited to a 4,000 cfs maximum inundation area due to processing methodology which explains the sharp uptick in the graphs at 5,000 cfs. Widths were limited to the main channel from Overton to Chapman and side channels were not included as they generally provide little habitat value for whooping cranes.

As a reference, 650 feet has been found to be a highly suitable maximum unvegetated width (MUCW) for whooping cranes. Two potential flow-related management strategies the Program could undertake to maintain existing unvegetated channel widths for whooping cranes would be to inundate the channel during the germination season to prevent vegetation establishment and another would be to remove the ≤1-year old vegetation by scouring it in the fall. A total unvegetated channel (TUCW) width of 650 feet would be inundated by 3,500 cfs of flow throughout the AHR and by 2,000 cfs of flow within the main channel at Cottonwood Ranch which has been managed for wide unvegetated widths for whooping cranes (Figure 1). Similarly, 80% of the main channel area would be inundated by a flow of 600 cfs throughout the AHR and 750 cfs at Cottonwood Ranch (Figure 2). We also looked at flows necessary to scour ≤1-year old cottonwood seedlings in the fall by a 5,000 cfs short duration high flow release. We found a fall SDHF would have the potential of scouring vegetation from approximately 21% of the main channel throughout the AHR and only 9% of the main channel at Cottonwood Ranch.



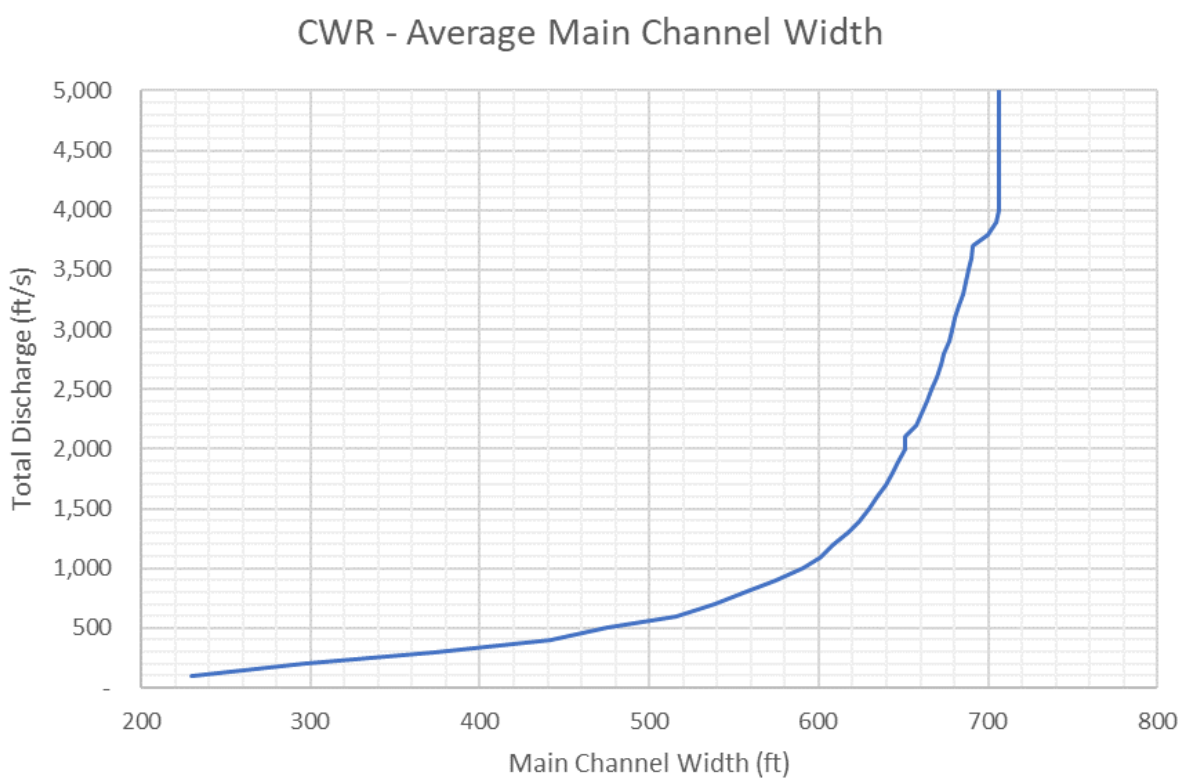


Figure 1. Total unvegetated width of the main channel inundated by various levels of discharge for the Associated Habitat Reach (top) and a managed river channel at Cottonwood Ranch (bottom).

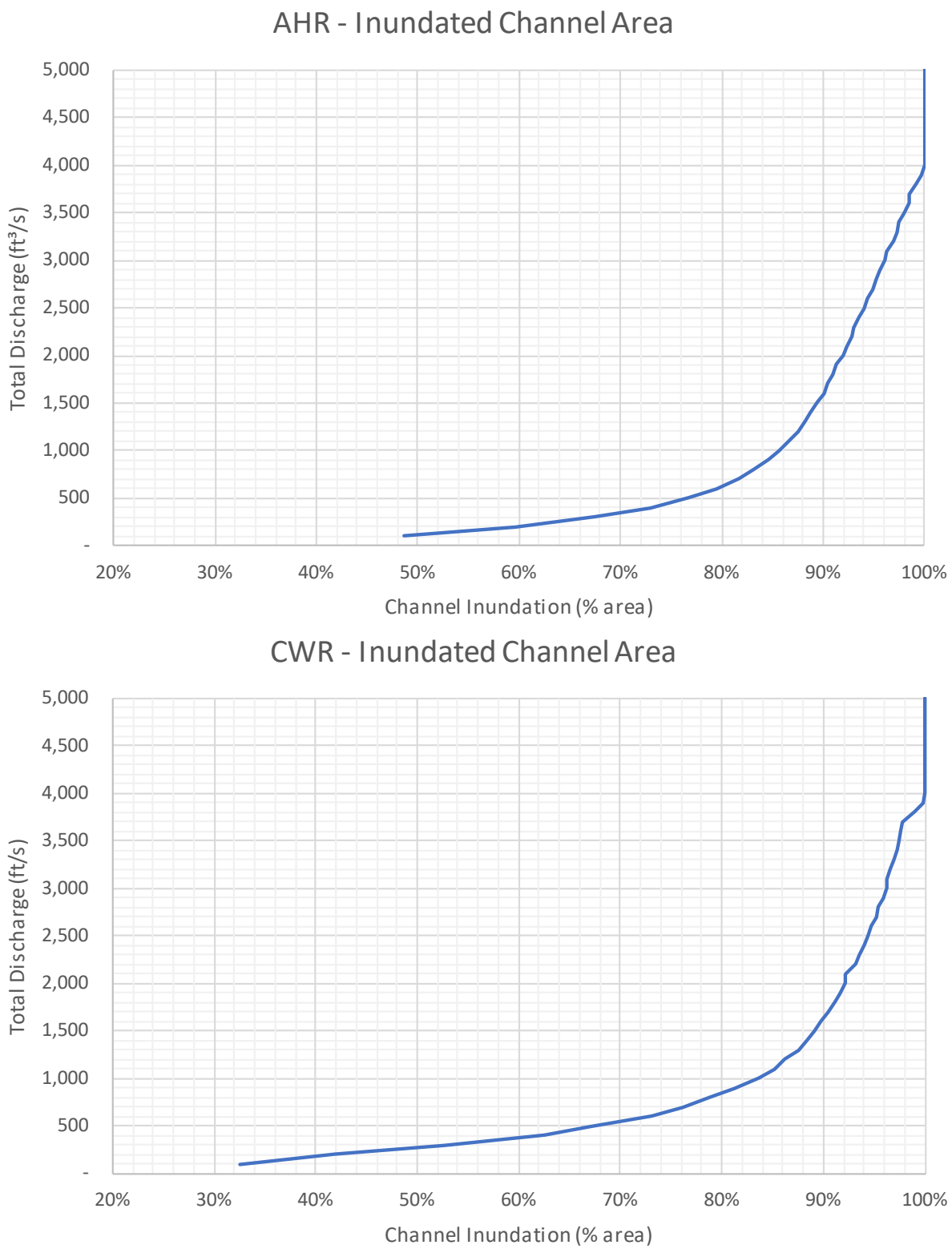
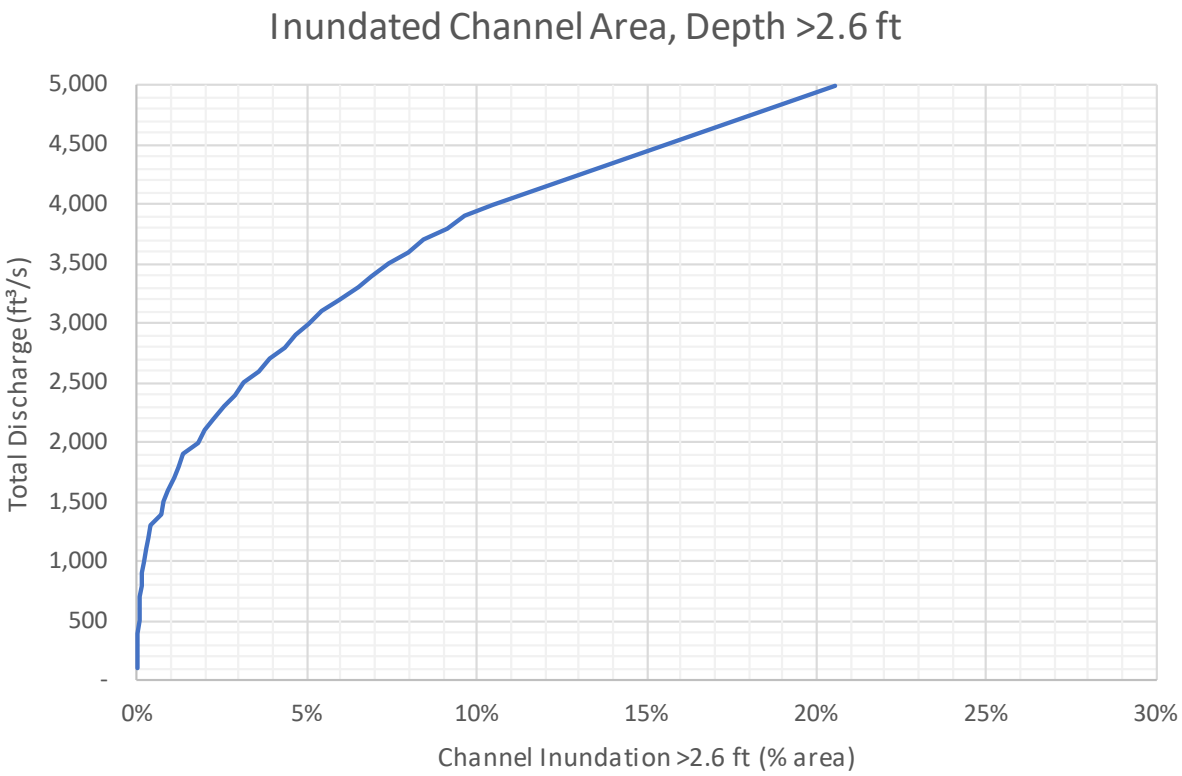


Figure 2. Cumulative inundated channel area of the main channel inundated by various levels of discharge for the Associated Habitat Reach (top) and a managed river channel at Cottonwood Ranch (bottom).



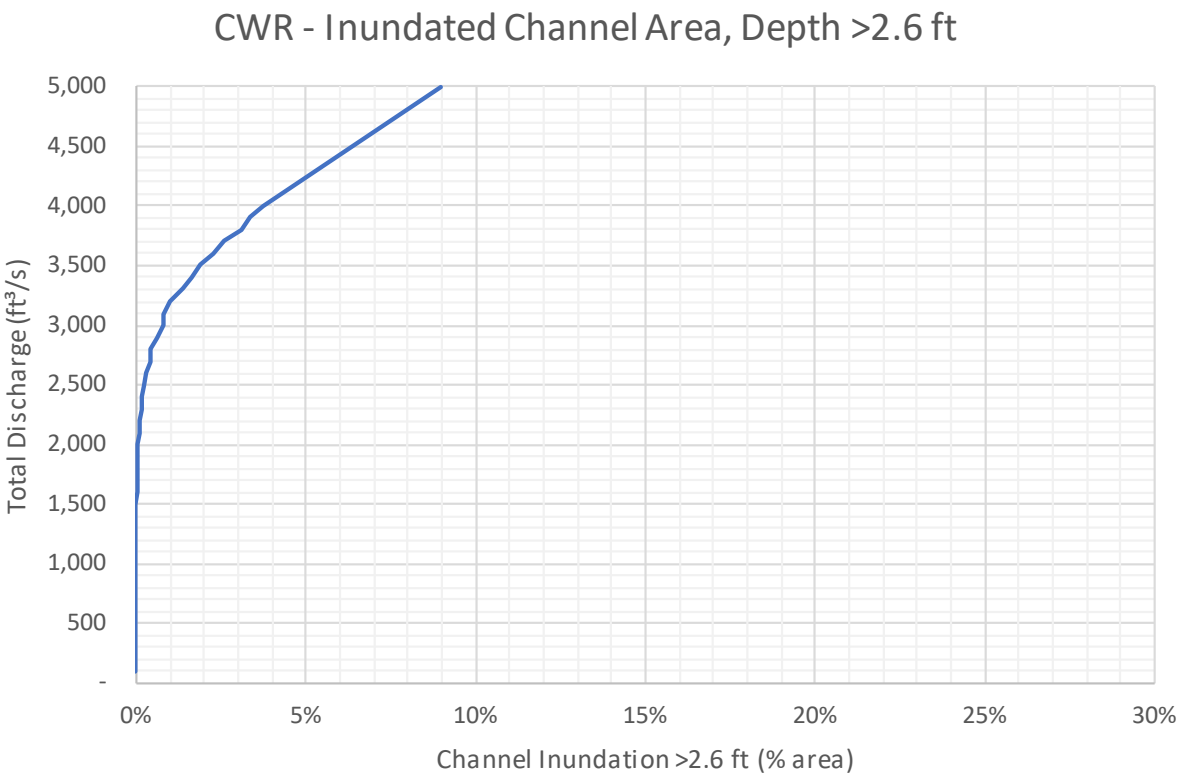


Figure 2. Cumulative channel area of the main channel inundated by ≥2.6 feet at various levels of discharge for the Associated Habitat Reach (top) and a managed river channel at Cottonwood Ranch (bottom).

FLOW EXPERIMENT SCENARIO TOOL

SCENARIO OVERVIEW

The flow experiment scenario tool seeks to evaluate how much water would be available to test four potential Program flow management actions including a spring whooping crane release, a germination season flow release, a fall short duration flow release (SDHF), and a fall whooping crane season release and were based on past hydrology. Two time periods were selected for the scenario runs: 1998 – 2007 and 2008 – 2018. The first time period represents a shift from wetter conditions in the late 1990s to dry/drought conditions in the early and mid-2000s. The second period represents a shift from dry initial conditions in 2008 to wetter/variable conditions, 2010 – 2018. The scenario tool uses average daily flows in the Platte River at Grand Island along with historic natural inflows into Lake McConaughy to simulate environmental account (EA) accruals and releases.

All of the water for the releases originates in the Lake McConaughy EA. We set the EA to begin with a volume of 100,000 AF in 1998 and 2008. Losses were subtracted from the releases based on the historic real time hydrologic condition. During wet periods, losses were assumed to be 15%, during normal periods losses were assumed to be 25%, and during dry periods losses were assumed to be 35%.

A key assumption made in the scenario tool is that there was sufficient capacity in the North Platte River and NPPD Keystone/Sutherland canal system to convey the needed water from the EA to Grand Island. This may not hold true for the fall SDHF release until the North Platte choke point capacity is increased. This also may not hold true for the summer germination season release when Grand Island flow is very low and the North Platte River and NPPD system are running water for irrigation needs.

The scenario tool does not account for evaporative losses from EA water in Lake McConaughy. These losses are typically on the order of 1% of the EA volume per month and can be incorporated in future versions of the tool.

RELEASE PERIODS

Four flow release periods were considered:

- A spring whooping crane release from March 6 to April 20 with a flow target of 1,500 cfs,
- A 30-day summer vegetation germination season release from 15 June through 14 July with a flow target of 2,000 cfs
- A 5-day fall short duration high flow (SDHF) release from 15 September through 19 September
- A fall whooping crane release from 15 October to 20 November.

The scenario tool can be modified to evaluate other flow releases or combination of flow releases moving forward.

RELEASE LOGIC

The scenario tool uses the following logic to determine when a release should be made:

- The summer germination season release was the first priority. If there was enough water in the EA for a full release, a summer release would be made.

- One fall SDHF release was made during each time period. The SDHF release was made as soon as enough water was available in the EA and was not made during a year that a summer germination season release was made.
- Fall and spring whooping crane releases were made only if there was extra water available in addition to what was needed for the upcoming summer germination release. If there wasn't enough water for a summer germination release, no whooping crane release would be made.
- To determine if fall and spring whooping crane releases could be made, the volume of water needed for the upcoming summer germination season release was estimated based on the real time hydrologic condition and median flow volumes during wet, normal, or dry conditions.

SCENARIO RESULTS

Time period one: Wet to dry conditions, 1998 to 2007

This period began with wet conditions (see **Figure 1** for daily flows in the Platte River at Grand Island and **Table 1** for specific release volumes) for the first three years. Several releases could have been made from 1998-2000 and most flow targets would have been met. A fall SDHF release could have been made in 1998. In 2001, conditions became slightly drier and there wasn't enough EA water to meet the fall 2001 whooping crane release target and still have water left for the 2002 summer germination release. In 2002, dry conditions set in with very low summer flows and there was not enough water in the EA for a full summer germination release. A partial release could have been made during the fall 2002 and spring 2003 whooping crane migration seasons, leaving enough water in the EA for a full summer germination season release in the summer of 2003. River flows remained very low in 2003 and 2004 causing the EA to hold all of its water until the spring of 2005, when a partial fall whooping crane release could have been made, followed by a full summer germination season release during the summer of 2005. There wasn't enough water for a summer germination season release in the summer of 2006. A partial fall whooping crane release could have been made in 2006, followed by a full spring 2007 whooping crane release, a full summer 2007 germination release, and a nearly full fall 2007 whooping crane release as river conditions became wetter.

Summary:

- During wet years, practically all the specified flow targets could have been met.
- During dry years, the summer germination season release would have consumed most if not all of the available EA water and could only be implemented every other year.
- Little to no water would have been available for dry-year spring and fall whooping crane season releases to accrue enough water for summer releases.
- During normal years a full summer germination season release typically would have been possible in addition to a full or partial spring and/or fall whooping crane release.

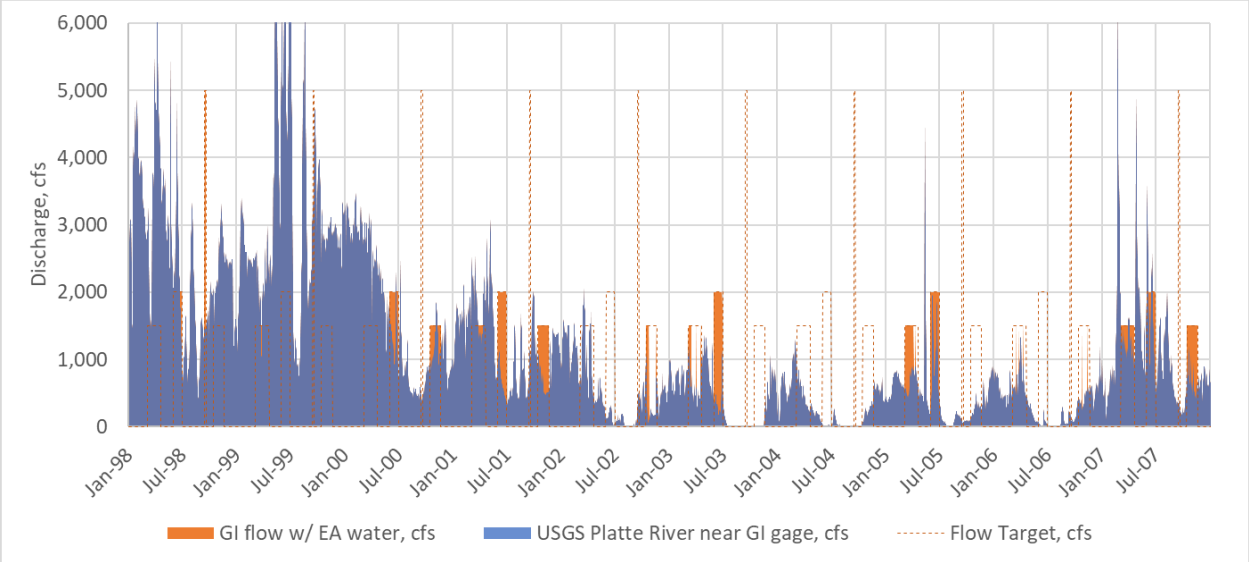


Figure 1. Grand Island daily flow and potential flow releases for the 1998-2007 time period.

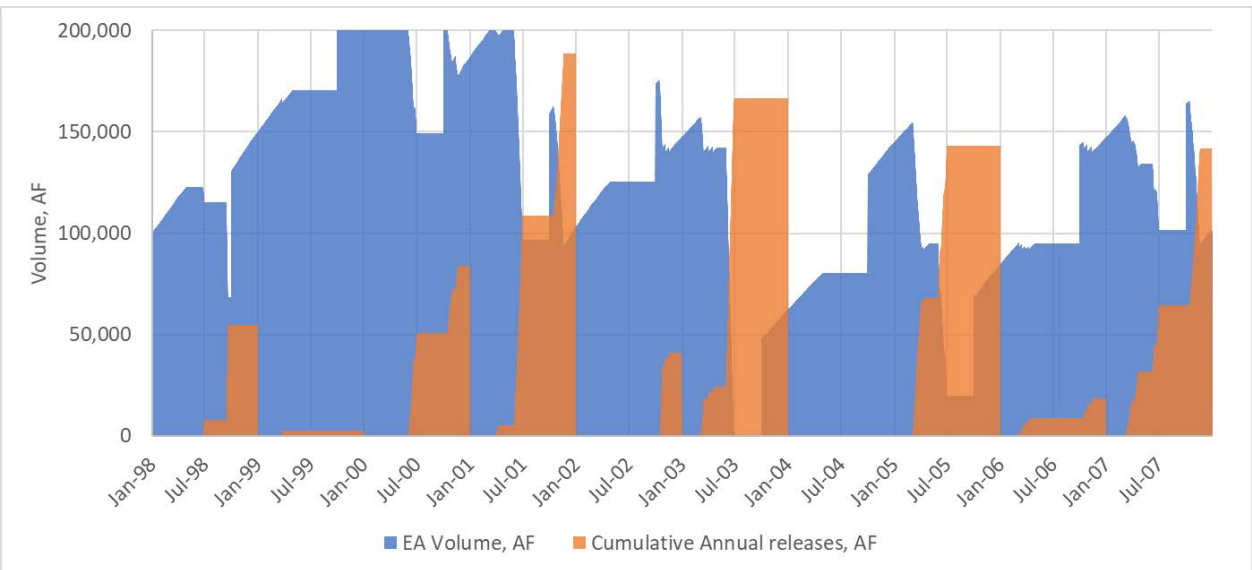


Figure 2. Lake McConaughy EA volume and potential cumulative release volumes for the 1998-2007 time period.

Table 1. Potential EA volume and potential releases 1998-2007

Year	Release Period		EA Volume, AF	EA water needed, AF	EA release, AF	Unmet release volume, AF
1998	1	Spring whooping crane	112,490	99	132	-
1998	2	Summer germination	122,898	6,639	7,810	-
1998	3	Fall SDHF	115,088	35,107	46,810	-
1998	4	Fall whooping crane	133,740	-	-	-
1999	1	Spring whooping crane	162,488	1,924	2,565	-
1999	2	Summer germination	170,462	-	-	-
1999	3	Fall SDHF	170,462	14,936	-	-
1999	4	Fall whooping crane	200,000	-	-	-
2000	1	Spring whooping crane	200,000	-	-	-
2000	2	Summer germination	200,000	38,186	50,914	-
2000	3	Fall SDHF	149,086	45,419	-	-
2000	4	Fall whooping crane	200,000	24,764	33,018	-
2001	1	Spring whooping crane	199,773	3,967	5,289	-
2001	2	Summer germination	200,000	77,552	103,402	0
2001	3	Fall SDHF	96,598	39,308	-	-
2001	4	Fall whooping crane	163,388	61,706	79,767	1,880
2002	1	Spring whooping crane	116,076	38,269	-	38,269
2002	2	Summer germination	125,402	109,630	-	109,630
2002	3	Fall SDHF	125,402	45,608	-	-
2002	4	Fall whooping crane	175,594	88,963	41,097	62,249
2003	1	Spring whooping crane	157,560	81,667	24,320	65,859
2003	2	Summer germination	142,157	95,363	142,157	2,961
2003	3	Fall SDHF	-	49,587	-	-
2003	4	Fall whooping crane	50,212	108,061	-	108,061
2004	1	Spring whooping crane	72,529	91,029	-	91,029
2004	2	Summer germination	80,517	118,187	-	118,187
2004	3	Fall SDHF	80,517	49,587	-	-
2004	4	Fall whooping crane	131,312	91,615	-	91,615
2005	1	Spring whooping crane	154,958	72,591	68,197	21,443
2005	2	Summer germination	94,857	56,102	74,803	0
2005	3	Fall SDHF	20,053	48,916	-	-
2005	4	Fall whooping crane	70,813	89,462	-	89,462
2006	1	Spring whooping crane	95,390	70,445	8,677	63,937
2006	2	Summer germination	95,098	115,110	-	115,110
2006	3	Fall SDHF	95,098	48,100	-	-
2006	4	Fall whooping crane	145,354	77,929	10,085	71,373
2007	1	Spring whooping crane	158,180	23,911	31,881	-
2007	2	Summer germination	134,250	24,389	32,518	0
2007	3	Fall SDHF	101,731	46,064	-	-
2007	4	Fall whooping crane	165,365	59,861	77,281	1,900

<u>Time period two:</u> Normal and wet conditions, 2008-2018

This period began with average/normal conditions in 2008 and 2009 (see **Figure 3** for daily flows in the Platte River at Grand Island and **Table 2** for specific release volumes). The initial volume of 100,000 AF in the EA and additional gains throughout the year in 2008 would have allowed for a spring whooping crane release, a summer germination release, and a fall SDHF release. High summer flows in 2008 coincided with the summer germination season release resulting in only 16,600 AF of EA water that would have been needed to meet the specified flow target. Enough water remained in the EA that a partial spring 2009 whooping crane release and a full summer germination and fall whooping crane release could have been made. 2010 saw a shift to wetter conditions resulting in much less EA water needed to meet specified flow targets. Full spring and fall whooping crane releases could have been made as well as a fall SDHF. Flows at Grand Island remained above the summer germination season target and no additional releases were needed in 2010. 2011 was a very wet year, with flows above the specified spring, summer, and fall targets and no releases were needed. The EA reached maximum capacity by the end of 2011. 2012 saw significantly less flow than 2011, but the 200,000 AF in the EA would have allowed for a full spring whooping crane release and a full summer germination season release. There wouldn't have been enough water left in the EA to make a fall 2012 release and there would only have been enough for a partial spring 2013 whooping crane release. The entire EA would have been emptied to make a full summer 2013 germination season release. A shift to average and wet conditions starting in 2014 which would have allowed for all the specified flow targets to be met from summer 2014 through 2018. High summer flows in both 2015 and 2016 resulted in no need for a summer germination season release and the EA volume maxed out by the end of 2016. The EA volume remained above 100,000 AF from the fall of 2014 through the remainder of the scenario period, ending just shy of 200,000 AF in 2018.

Summary: This period of wet and normal years would have allowed for:

- A summer germination season release every year (even in the dry conditions of 2012).
- A full spring and/or fall whooping crane release in most wet years.
- A full to partial spring and fall whooping crane release in normal years.

The EA volume would have remained above 100,000 AF for much of the time period and would have maxed out at 200,000 AF twice (2011 & 2016) during the wettest years.

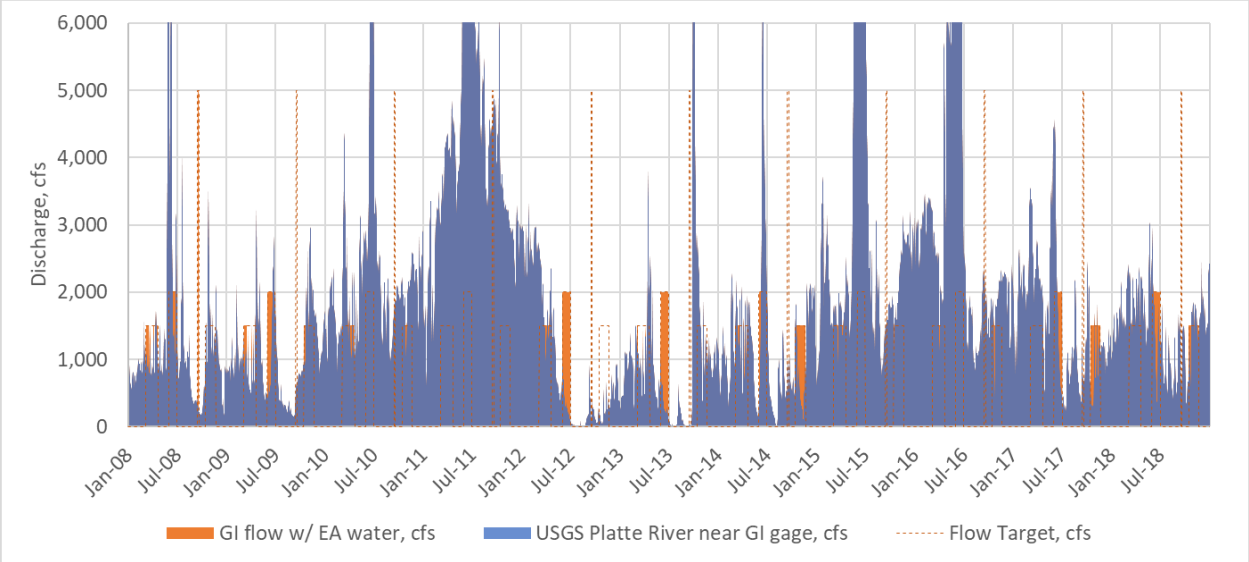


Figure 3. Grand Island daily flow and potential flow releases for the 2008-2018 time period.

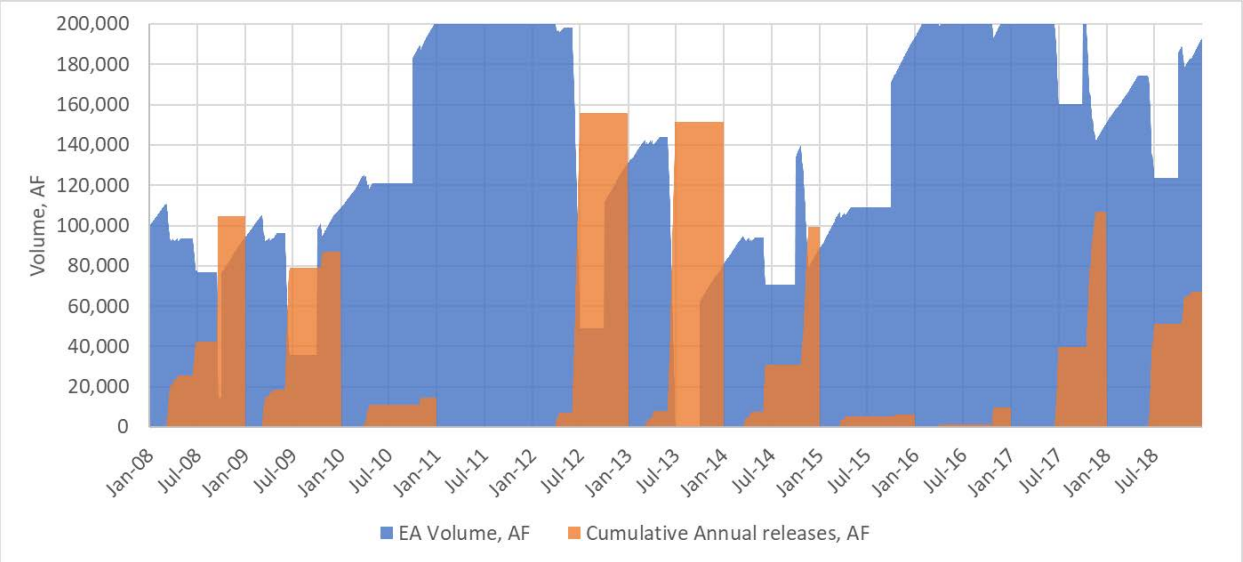


Figure 4. Lake McConaughy EA volume and potential cumulative release volumes for the 2008-2018 time period.

Table 2. Potential EA volume and potential releases 1998-2007

Year	Release Period		EA Volume, AF	EA water needed, AF	EA release, AF	Unmet release volume, AF
2008	1	Spring whooping crane	111,233	44,003	25,812	24,645
2008	2	Summer germination	93,645	14,102	16,591	-
2008	3	Fall SDHF	77,054	46,812	62,416	0
2008	4	Fall whooping crane	79,089	11,599	-	11,599
2009	1	Spring whooping crane	105,402	57,402	18,385	43,613
2009	2	Summer germination	96,068	46,151	60,477	793
2009	3	Fall SDHF	35,591	43,551	-	-
2009	4	Fall whooping crane	101,066	6,996	8,230	-
2010	1	Spring whooping crane	120,345	8,212	10,949	-
2010	2	Summer germination	120,828	-	-	-
2010	3	Fall SDHF	120,828	31,636	-	-
2010	4	Fall whooping crane	186,512	3,235	3,806	-
2011	1	Spring whooping crane	200,000	-	-	-
2011	2	Summer germination	200,000	-	-	-
2011	3	Fall SDHF	200,000	3,412	-	-
2011	4	Fall whooping crane	200,000	-	-	-
2012	1	Spring whooping crane	200,000	5,211	6,947	-
2012	2	Summer germination	198,218	96,886	149,056	0
2012	3	Fall SDHF	49,163	47,377	-	-
2012	4	Fall whooping crane	114,638	92,520	-	92,520
2013	1	Spring whooping crane	142,489	44,180	7,803	39,108
2013	2	Summer germination	143,841	97,216	143,841	3,719
2013	3	Fall SDHF	-	49,295	-	-
2013	4	Fall whooping crane	65,244	23,486	-	23,486
2014	1	Spring whooping crane	93,245	20,844	7,542	15,187
2014	2	Summer germination	94,109	17,599	23,466	0
2014	3	Fall SDHF	70,643	41,534	-	-
2014	4	Fall whooping crane	138,260	58,134	68,392	0
2015	1	Spring whooping crane	104,387	4,126	5,501	-
2015	2	Summer germination	109,219	-	-	-
2015	3	Fall SDHF	109,219	33,937	-	-
2015	4	Fall whooping crane	175,497	774	910	-
2016	1	Spring whooping crane	200,000	1,111	1,481	-
2016	2	Summer germination	200,000	-	-	-
2016	3	Fall SDHF	200,000	28,879	-	-
2016	4	Fall whooping crane	200,000	6,897	8,114	-
2017	1	Spring whooping crane	200,000	-	-	-
2017	2	Summer germination	200,000	33,665	39,606	0
2017	3	Fall SDHF	160,394	41,790	-	-
2017	4	Fall whooping crane	200,000	50,543	67,390	0

PERCENT EXCEEDANCE RESULTS (FOR REFERENCE):

The following figures show the volumetric flow requirements for the four releases over a range of conditions at Grand Island. The figures indicate how much water would be needed in addition to the flow at Grand Island for each of the exceedances shown. The flow was increased by the assumed routing losses with losses low in wet years and higher in dry years (see the spreadsheet for the breakdown of the losses). The 50% exceedance indicates the median volume required for a given release.

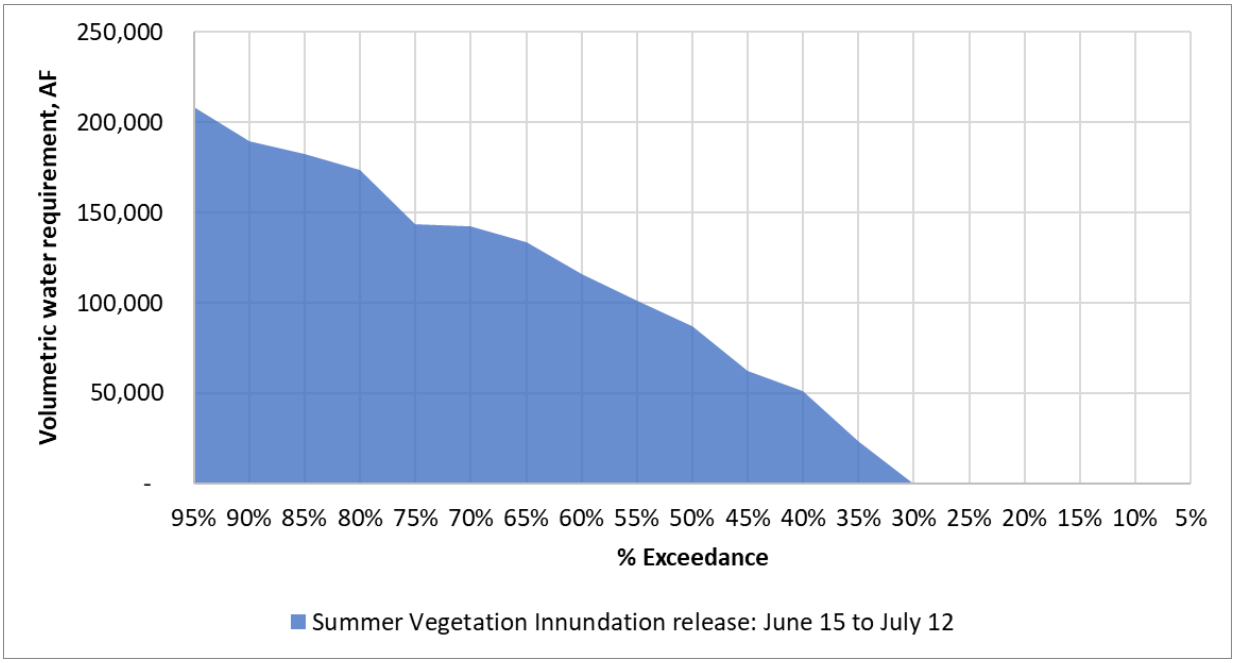


Figure 5. Volumetric requirements for the specified 2,000-cfs summer vegetation germination release

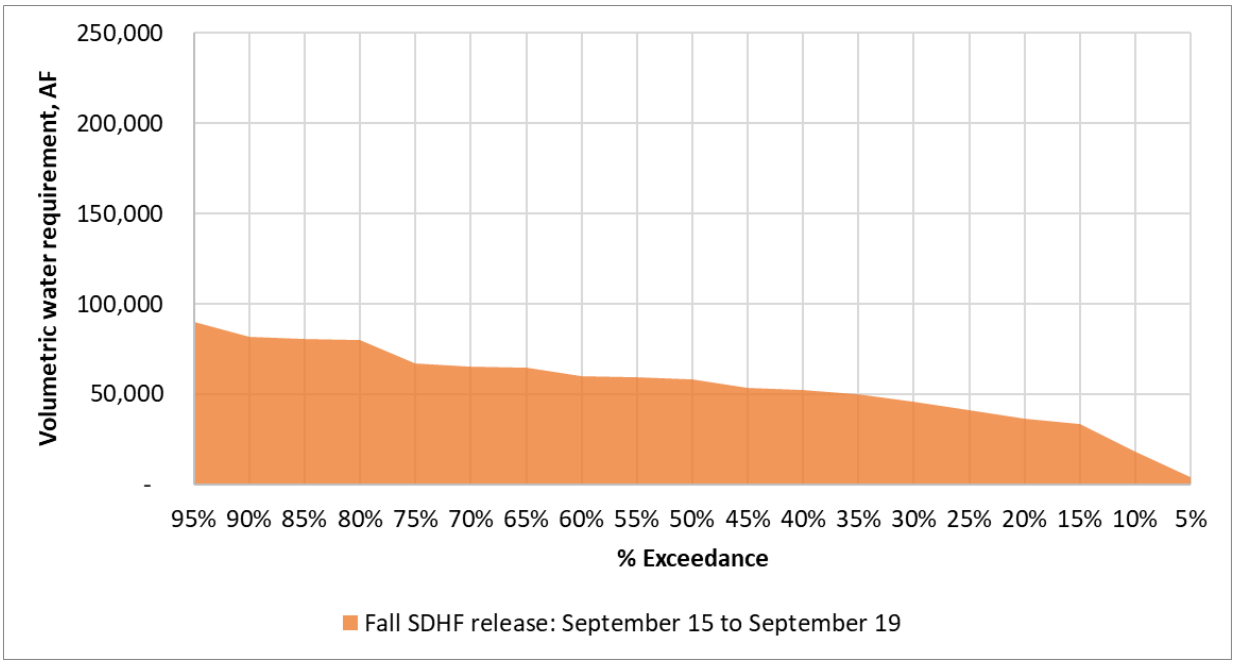


Figure 6. Volumetric requirements for a 5-day, 5,000-cfs fall short duration high flow release

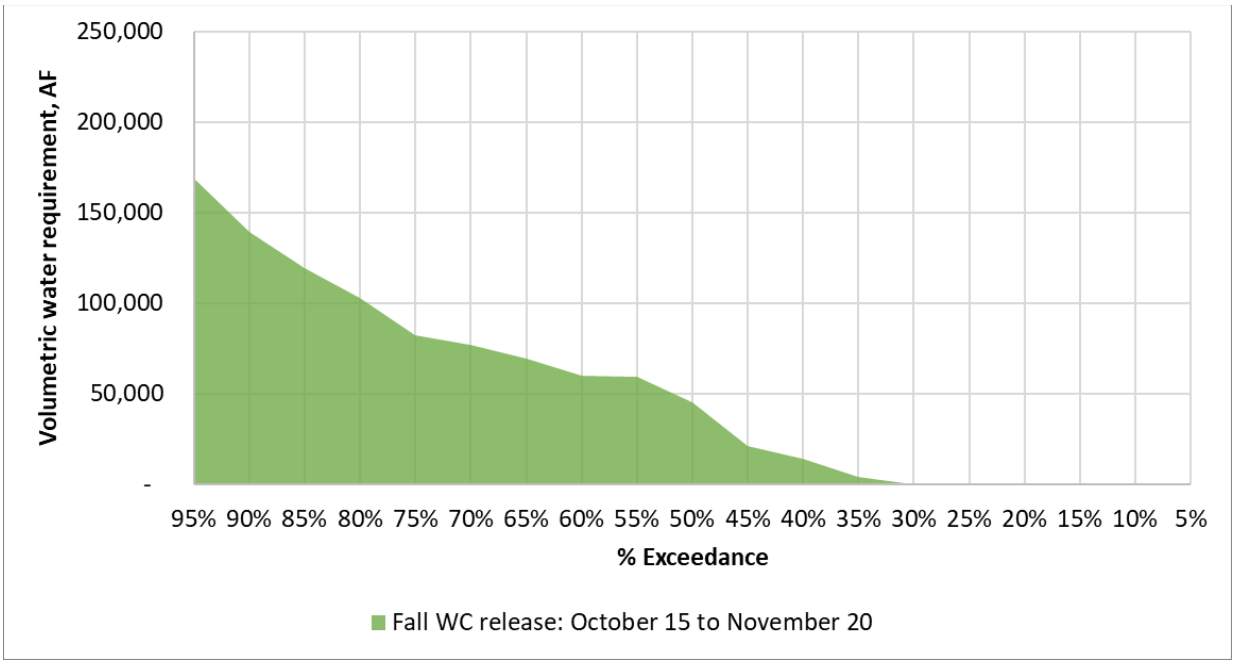


Figure 7. Volumetric requirements for the specified fall whooping crane release of 1,500 cfs, 15 October – 20 November.

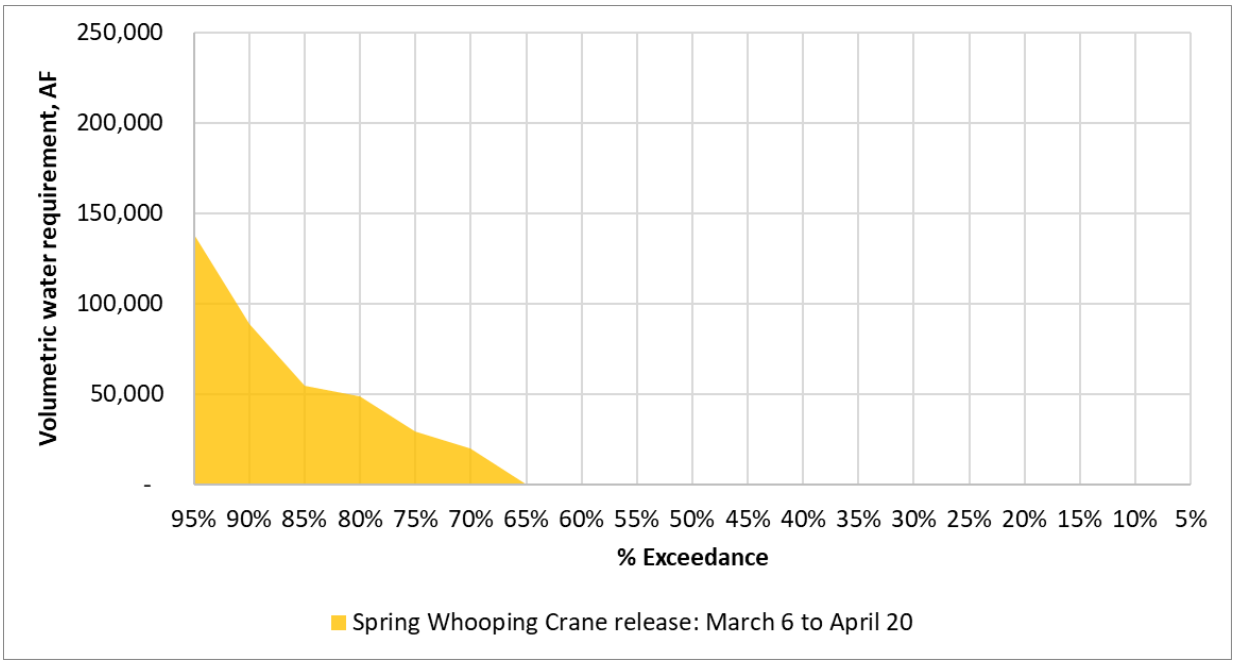


Figure 8. Volumetric requirements for the specified spring whooping crane release of 1,500 cfs, 6 March – 20 April.

Tool Description: Unvegetated Channel Width Decision Tree Model

The Program has developed past models of unvegetated channel width to predict channel width suitability for whooping crane roosting. Farnsworth et al. (2018) was primarily used predict channel widening/narrowing and to predict total unvegetated channel width (TUCW) and maximum obstructed channel width (MUCW). These models were adequate for describing flow/channel width relationships in the Associated Habitat Reach (AHR) prior to 2016. After the 2015 high flow event, however, channel widths in 2016-2018 were remarkably similar to 2015 in the absence of the high flows experienced in 2015. Predictions from the Farnsworth et al. (2018) underestimated channel widths in 2016-2018, suggesting flow/channel width relationships may have been altered following the 2015 widening event and that different flow mechanism may be important for channel width maintenance.

Due to system-wide channel conditions becoming and remaining suitable for whooping cranes from 2015-2018, an important uncertainty to consider during the First Increment Extension is how to maintain these wide unvegetated channel widths with flow. To support investigations into channel maintenance flows, an unvegetated channel width decision tree model was developed to identify how flows relate to the creation and maintenance of unvegetated channel widths. This model directly utilizes annual flow data and change in unvegetated channel width relationships, along with physical channel maintenance activities, to predict unvegetated channel widths over multiple years from a specified starting year.

The decision tree model assumes germination season flows and fall flows are the most important seasonal flows to sustain suitable unobstructed channel widths for whooping cranes. We incorporated simple linear regression relationships of annual change in main channel total unvegetated channel width (ΔTUCW-Main) and average 1 June – 15 July flows, as well as 14-day, 1 September – 15 October mean peak flows, to predict ΔTUCW-Main resulting from each seasonal flow using data from 1998-2018. Flow components, along with disking and reach-wide herbicide application, were inputted into the decision tree model as variables to adjust TUCW-Main within years. Disking was transect specific, but herbicide was considered at a reach-wide level that began in 2008 and has continued to present. Channel width constraints were also inputted to set physical channel extremes at any given transect. Maximum TUCW-Main was constrained to the main channel total channel width (TCW-Main), while the minimum TUCW-Main was constrained to 300 ft unless TCW-Main was less than 300ft, in which case the TCW-Main was considered minimum. Each transect was evaluated within a year to produce an end-of-year TUCW-Main width to be utilized in the subsequent year. For example, observed channel widths in 2012 were used as a starting point to predict changes in TUCW-Main from 2013-2018 (Figure 1). Following the high flow event of 2015, the decision tree model more accurately predicts the maintenance of wide unvegetated channel widths observed throughout the AHR than the Farnsworth et al. (2018) model.

In addition to the aforementioned components, the inherent modeling flexibility of the decision tree model provides the capability to modify and explore other flow scenarios, flow-channel width relationships, to introduce other components important to ΔTUCW-M, and to modify assumptions.

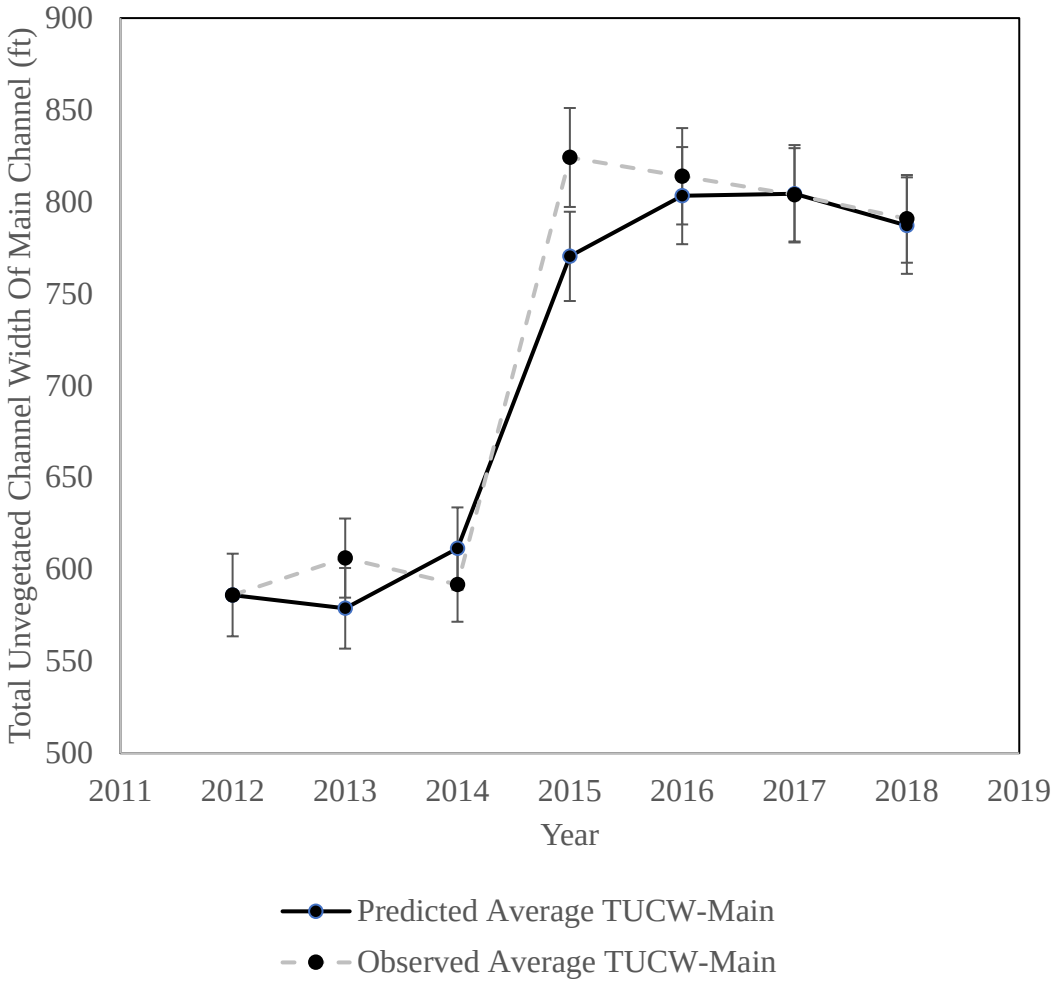
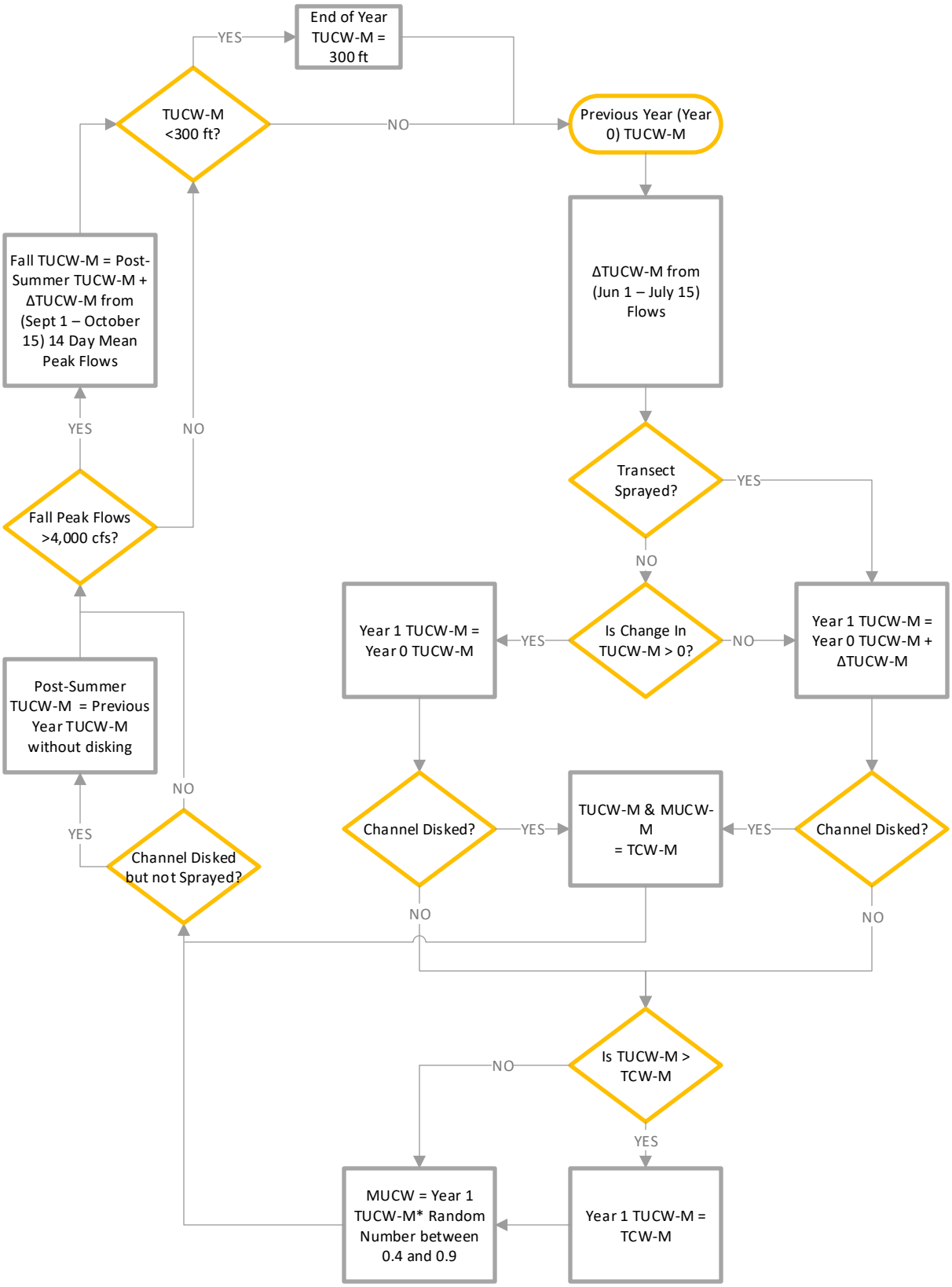


Figure 1. Predicted average main channel total unvegetated channel width (TUCW-Main) compared to observed average annual measurements of TUCW-Main at Associated Habitat Reach river transects (n= 435) using the unvegetated channel width decision tree model. Predictions start in 2013 and extend through 2018; error bars represent 95% confidence intervals.

Unvegetated Channel Width Decision Tree Model