Flow and Channel Width Modeling Tool

Introduction & Background

- Maximum width of channel unobstructed by dense vegetation, referred to as maximum unobstructed channel width (MUCW) is the best in-channel predictor of whooping crane (WC) roost location (Baasch et al. 2019).
- 2017 WC Synthesis Chapters included a multiple- quantile regression analysis of the relationship between hydrologic, morphologic and management metrics and two width response variables; MUCW and total unvegetated channel width (TUCW). TUCW was the total width of the channel unobstructed by dense vegetation and included as a morphologic response variable that eliminates the randomness of MUCW due to bar/island locations within the channel.

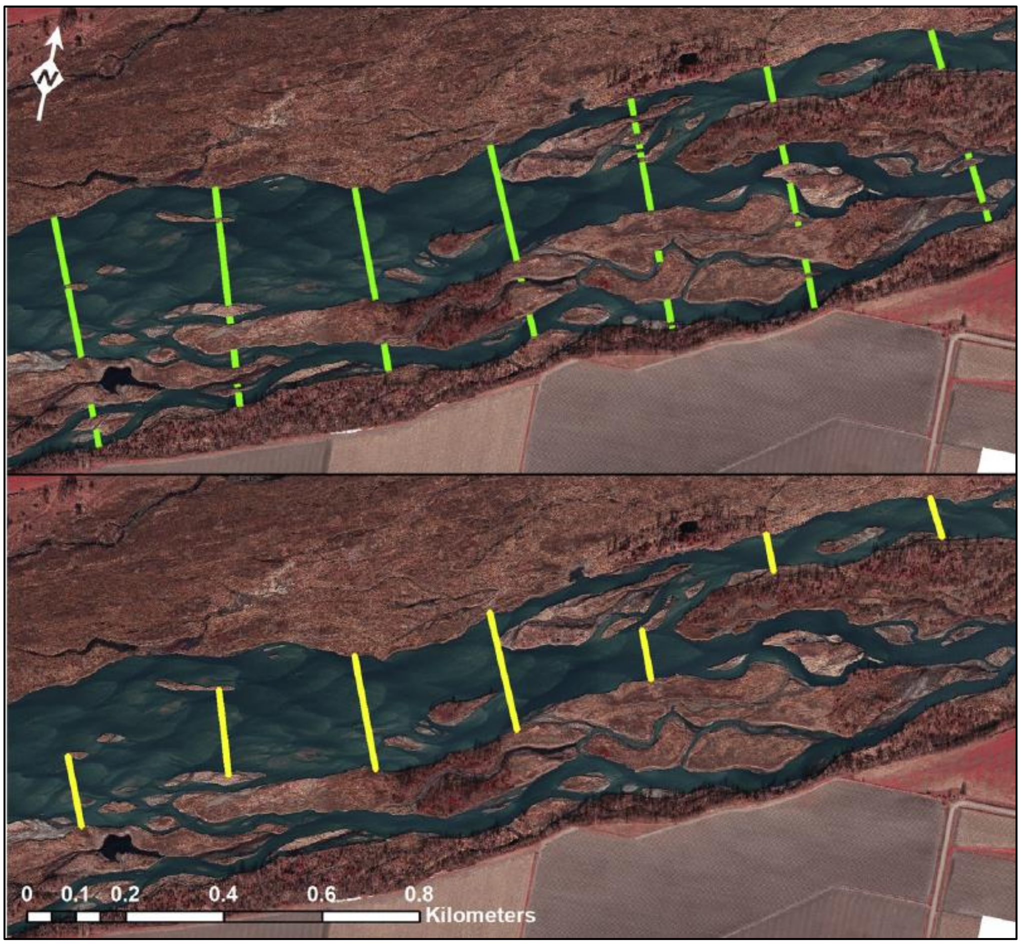


Figure 1. Examples of total unvegetated channel width (top) and maximum unobstructed channel width (bottom) at Associated Habitat Reach monitoring transects.

- Important TUCW explanatory variables included 40-day mean peak discharge, disking, herbicide and wetted width of the channel at bankfull discharge. Performance was generally good during the model period (2007-2015) but poor during the period of 2016-2020 when the model predicted a substantial decrease in TUCW but observed TUCW remained high (Figure 2).

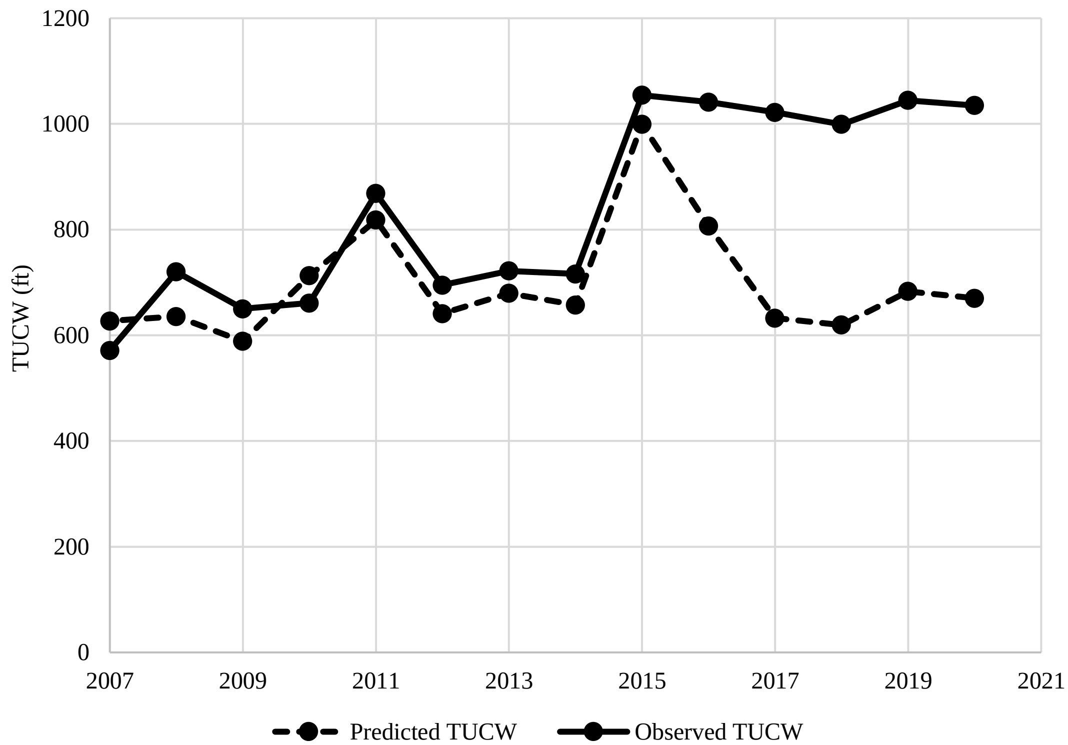


Figure 2. Average observed and predicted annual total unvegetated channel width (TUCW) along the central Platte River from 2007-2020.

- This led to the hypothesis that other physical processes were maintaining TUCW in absence of peak flows – specifically that channel inundation during the germination season is preventing establishment of vegetation that would otherwise reduce TUCW.
- This is likely the primary flow-related priority question for the Extension – Can flow releases to maintain an average flow of approximately 2,000 cfs in June maintain TUCW and (by extension) suitable MUCW? Concept was first proposed by Carter Johnson[1] but not included in the original AMP.
- During 2019 AMP Reporting Session, ISAC recommended scrapping the prior modeling approach and instead investigate machine learning methods.
  - We have been working on an updated machine learning model and will discuss methods, preliminary results, and questions for ISAC feedback.

[1] Johnson, W. C. (1994). Woodland expansions in the Platte River, Nebraska: patterns and causes. Ecological monographs, 64(1), 45-84.

Machine Learning Model

- Random Forest machine learning models were utilized to account for highly complex relationships between variables and non-linear relationships, while staying resistant to overfitting. These models incorporate aggregations of tree-based analysis method, where a dataset is split by rules identified by a search algorithm that divide it into increasingly homogenous groups (Breiman 2001).[2] Random Forest models often produce increased predictive abilities over traditional statistical techniques.
- *Dependent variable* – **Shifted focus from predicting TUCW in two ways: (1)** focused on the main channel unobstructed width by removing side channels that do not support suitable whooping crane roosting habitat and included short, sparse vegetation in width. **(2)** Modeling annual change in main channel total unobstructed channel width ($\Delta TUCW_M$). Instead of modeling channel width directly, change in channel width provides the ability to understand channel narrowing, channel widening, and channel maintenance through various conditions experienced along the central Platte River.
- *Independent variables* – 7 variables were included in a global Random Forest model to predict patterns of $\Delta TUCW_M$.
    - **Main Channel Total Channel Width (ft):** Total channel width of the main channel at bankfull discharge. Metric included to represent practical upper limit on width adjustment potential. Widths were delineated from June 2011 aerial imagery, which was flown at near bankfull discharge. Areas of shallow overbank flow were omitted.
    - **Previous Year's Unobstructed Channel Width (ft):** Previous year's measurement of main channel total unobstructed width at a specific transect. Widths were delineated by observers based on annual fall imagery.
    - **Germination Suppression (ft^3/s):** Mean daily discharge during the early growing season (1-June through 30-June) assessed from the Overton, Kearney, Grand Island, and Duncan USGS rivers gages.
    - **Annual Disking (linear ft):** If any portion of an unobstructed channel width along a transect was intersected by the same year disking polygon, the length of disking along the transect was measured and utilized as annual disking effort.
    - **Annual Herbicide (Linear feet):** If any portion of an unobstructed channel width along a transect was intersected by the previous year's herbicide polygon, the length of herbicide application along the transect was measured and utilized as annual herbicide application from the previous year.
    - **40-Day Mean Max w/ Legacy Effect (ft^3/s):** A summation of 40 day mean peak discharge from current year (100%) and decaying legacy effects from previous 4 years (80%, 60%, 40%, 20%) assessed from the Overton, Kearney, Grand Island, and Duncan USGS rivers gages.
    - **Geomorphic Reach (Categorical):** Unique, contiguous sections of Associated Habitat Reach active channels characterized by geomorphic qualities as described by Fotherby (2009).[3]

[2] Breiman, L. 2001. Random Forests. Machine Learning 45:5–32.
[3] Fotherby, L. M. 2009. Valley confinement as a factor of braided river pattern for the Platte River. Geomorphology 103:562–576.

Results

Model Performance

- $\Delta TUCW_M$ Random Forest models explain 76.5% model variation.
- Test dataset model MSE was 104.5 ft, which was 16.8% of the average $TUCW_M$ in the full dataset (Figure 4A).
- Compared to the Farnsworth et al. TUCW quantile regression model MSE of 677.3 ft, which was 83% of average TUCW in the full dataset (Figure 4B).
- Using observed ($TUCW_M$) from 2003 as a starting year, annual $TUCW_M$ derived from $\Delta TUCW_M$ prediction starting in 2004 were very similar to observed values through 2020 (Figure 5).
- Previous Year Unobstructed Channel Width, Germination Suppression and Main Channel Total Channel Width were the most important variables to explain $\Delta TUCW_M$ due to greatest percent increase in mean squared error (Figure 6).

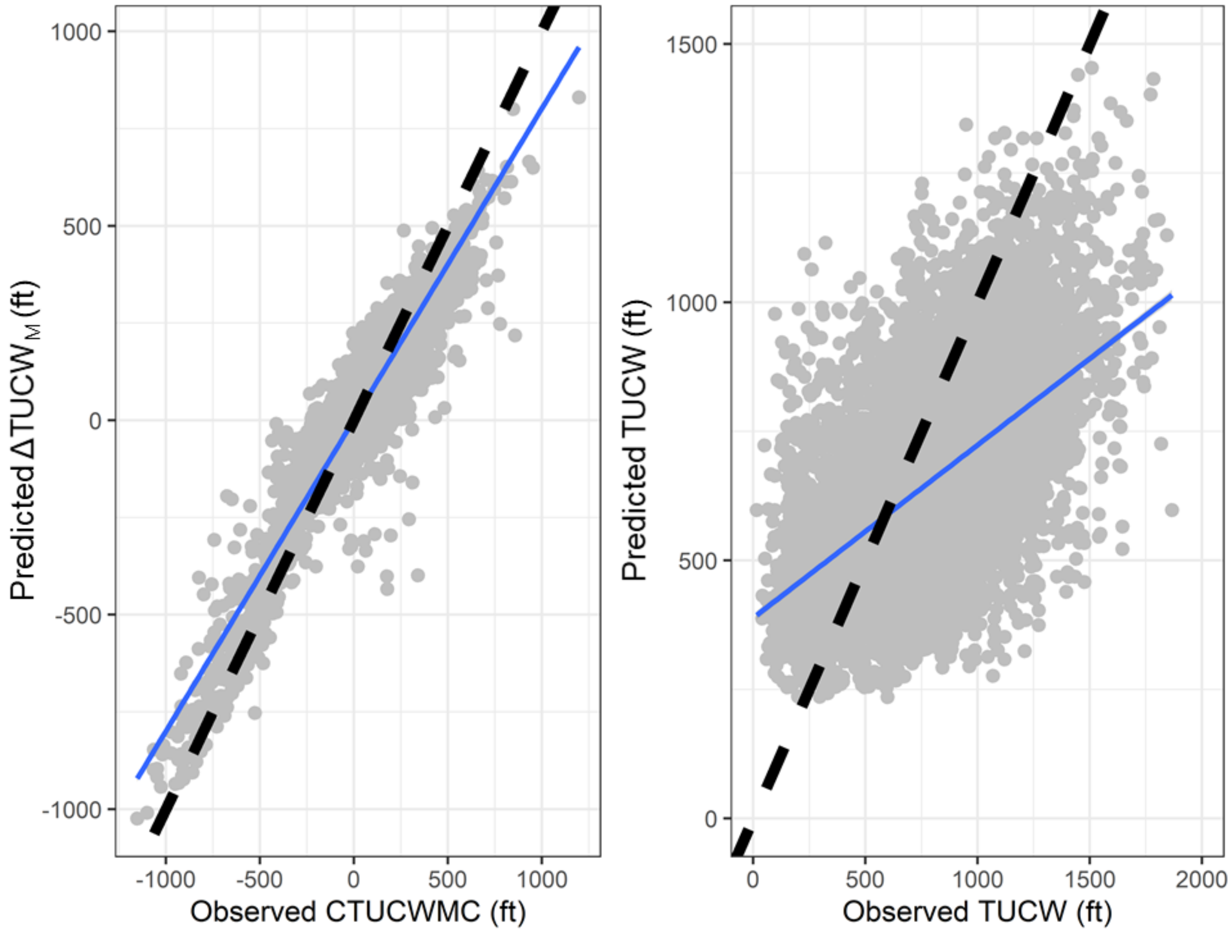


Figure 4. Observed vs. predicted (A) annual change in main channel total unobstructed width ($\Delta TUCW_M$) of the test dataset based on Random Forest model results and (B) Observed vs. predicted total unvegetated channel width (TUCW) from all transects using the Whooping Crane Synthesis Chapters' quantile regression model. The dashed line indicates a perfect model fit (1:1) and the blue line represents the linear relationship between observed and predicted values from the test dataset.

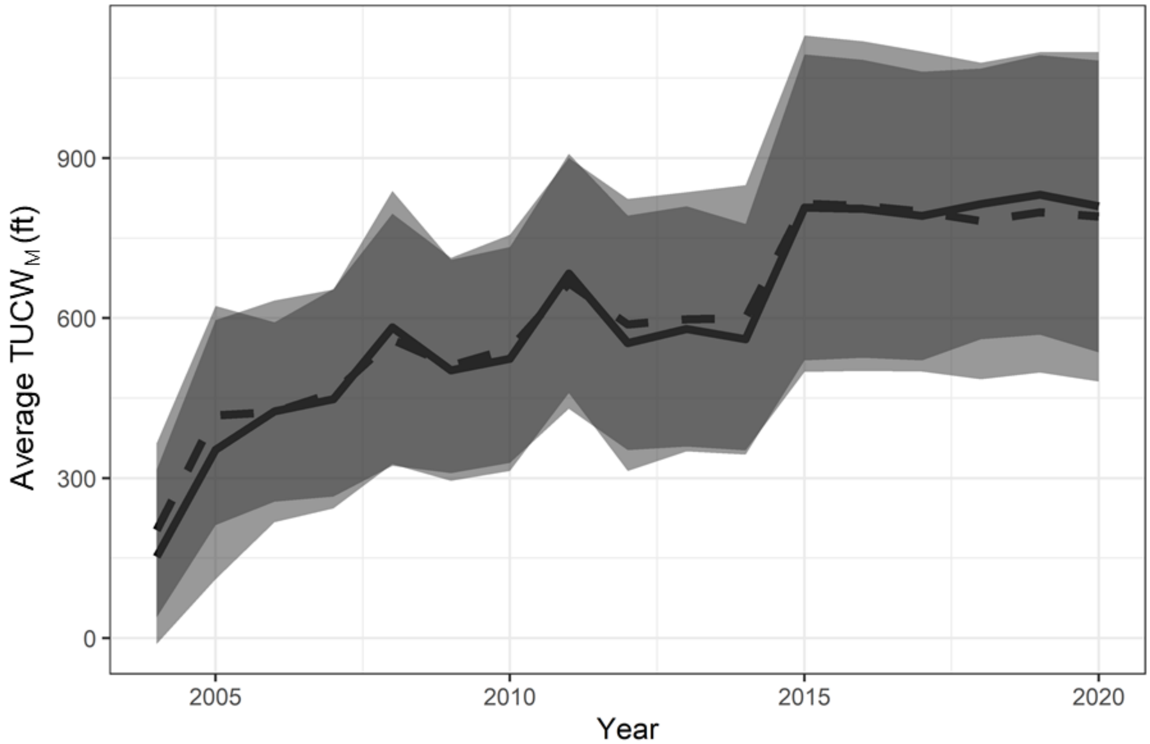
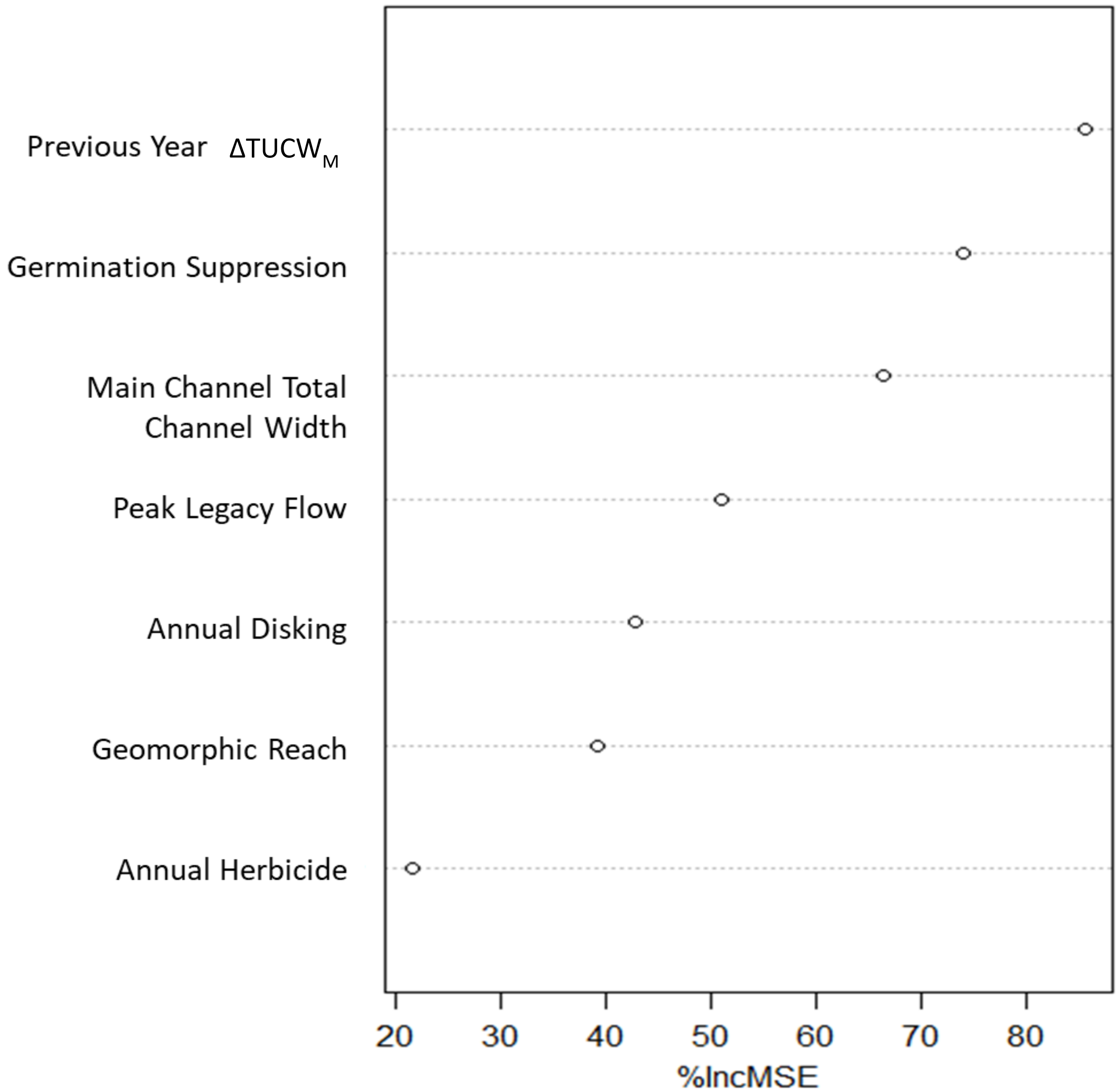


Figure 5. Observed (solid line) vs. predicted (dashed line) annual average $TUCW_M$ of the test dataset based on ΔTUCWM Random Forest model results added annually from a $TUCW_M$ starting point in 2003 for 2004 to 2020. Shaded regions represent ± 1 standard deviation from average annual value where darker shaded region is overlap between both distributions.



92 **Figure 6.** Change in main channel total unobstructed channel width ($\Delta TUCW_M$) Random Forest variable importance measurements of independent variables. Greater percent increase in mean squared error (%IncMSE) indicates a variable of greater importance.

Extension Drought Simulation with Germination Suppression Releases

- Using the Random Forest Model, developed a preliminary $TUCW_M$ simulation for the period of 2021-2032 (First Increment Extension).
- Drought Scenario
    - Used observed drought conditions during the period of 2002 – 2013. Specifically – hydrology observed during that period would repeat beginning in 2021. (Any combination of years can be used for future scenarios)
        - Germination suppression releases simulated using existing EA water supply projects.
            - Use all available water supplies to attempt to implement annual germination suppression release to achieve 2,000 cfs at GI for month of June.
            - Release magnitude limited by choke point capacity.
            - Release ends when EA volume exhausted.
        - Flow Routing Tool used to route Environmental Account water releases from Lake McConaughy through AHR.
    - Two Future Scenarios (Figures 7 and 8):
        1. Drought scenario **without** germination suppression flow releases
        2. Drought scenario **with** germination suppression flow releases

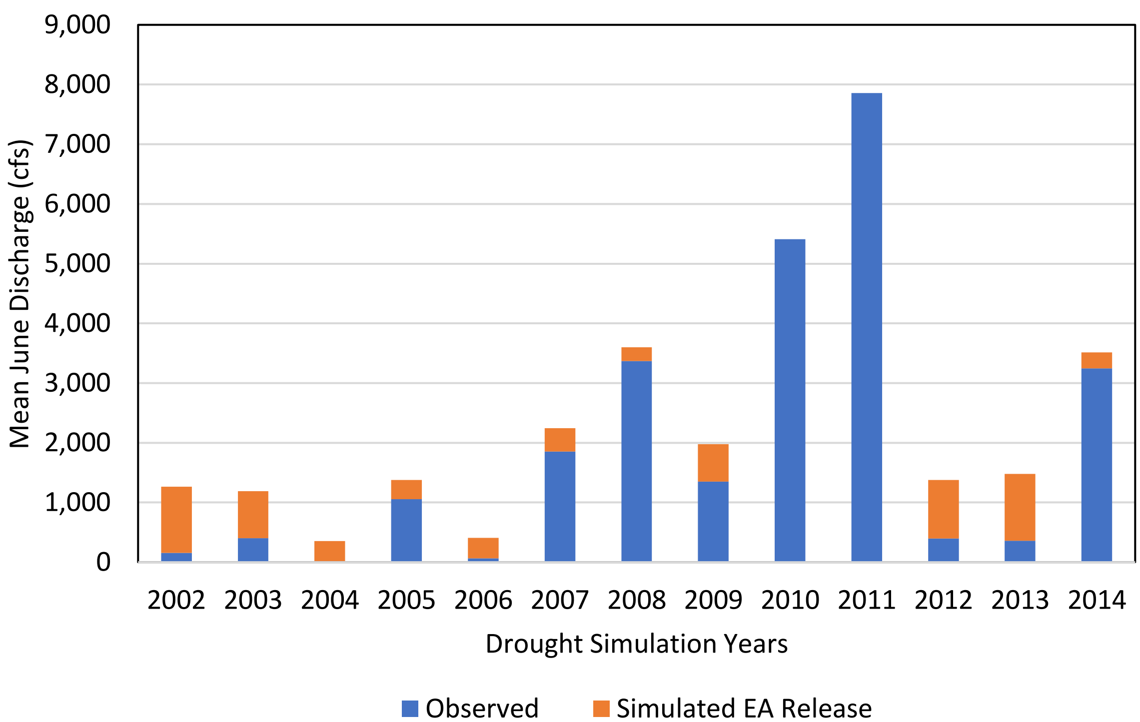


Figure 7. Drought scenario mean June discharge with and without germination suppression releases.

- Disking occurred at spatial effort (acres) observed in 2020 but only focused on PRRIP properties.

- Herbicide application also occurred at spatial effort (acres) observed in 2020 throughout the AHR.

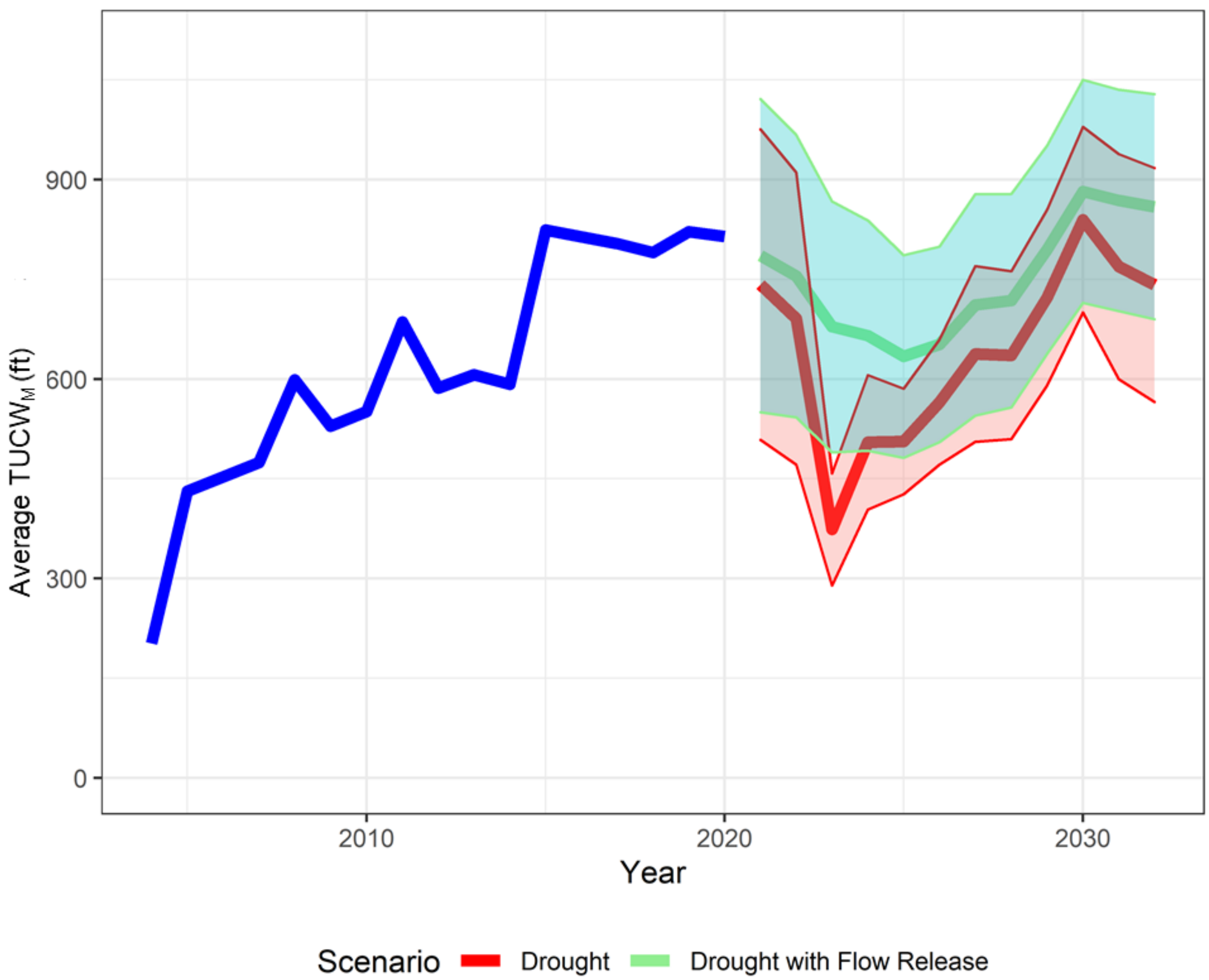
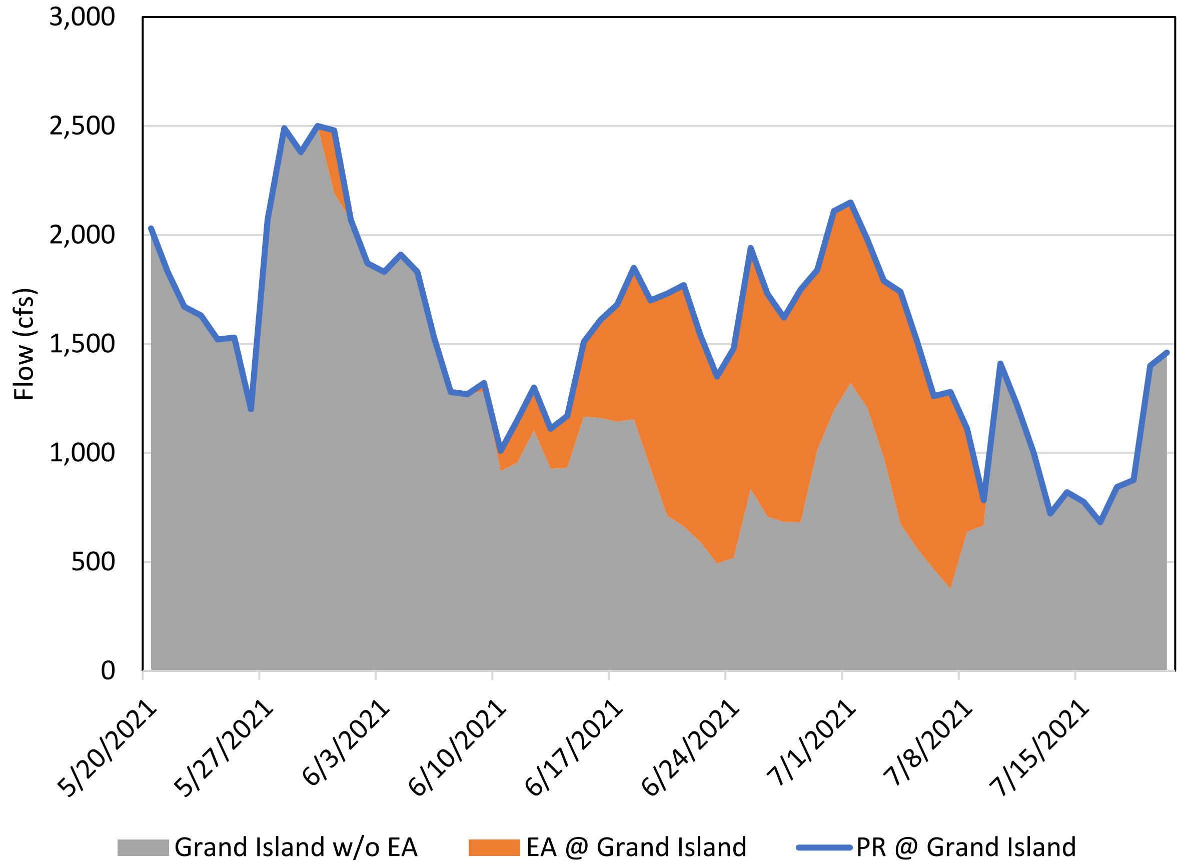


Figure 8. Mean $TUCW_M$ measurements in the central Platte River from 2004 to 2020 (blue line) and predicted mean channel widths based on future drought scenario (2003-2014 hydrology) with (green line) and without (red line) germination suppression flow releases. 2020 channel widths were used as a known starting point and predicted 2021 $TUCW_M$ were derived from 2020 channel widths plus predicted 2021 $\Delta TUCW_M$. After 2021, predicted previous year's $TUCW_M$ plus annual $\Delta TUCW_M$ calculated annual $TUCW_M$. Shaded regions represent ± 1 standard deviation of predictions.



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128 **Figure 9.** 2021 germination suppression flow release natural flow and EA water at the Grand Island gage.