PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PRRIP -or- Program)

TO: Independent Scientific Advisory Committee (ISAC) & Technical Advisory Committee (TAC)
FROM: Quinn Lewis, Ph.D., River Scientist - Executive Director's Office (EDO)
SUBJECT: No Sediment Augmentation Monitoring Plan, 2024
DATE: June 20, 2024

PURPOSE:
To better understand the impact of five years of active, mechanical sediment augmentation in the J2 return channel upstream of Overton Bridge, sediment augmentation has stopped. This "no augmentation" experiment is set to continue for five years or until J2 incision threatens to extend downstream of the Overton Bridge. This document briefly defines the problem, summarizes past data and conclusions from the active augmentation period, introduces driving questions that guide the no augmentation period, details continuing and new data analysis, and finally provides details on annual reporting during this critical phase of monitoring the J2 channel.

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1. No Sediment Augmentation Purpose and Definitions

A water control structure has been releasing clearwater return flows from a hydroelectric plant into the Platte River near Lexington Nebraska since the early 1940s. During that time, the channel that returns the water to the main stem of the Platte River (J2 Return Channel, or simply J2) just upstream of Overton Bridge has incised, reduced in longitudinal slope, and in some locations is potentially transitioning from braided to meandering channel planform. To prevent downstream progression of these changes and a resultant reduction of the suitability of whooping crane habitat, the Platte River Recovery Implementation Program (PRRIP, or Program) performed a full-scale sediment augmentation experiment approximately one mile downstream of the clearwater return in 2017. The experiment's goal was to offset channel incision and to evaluate overall J2 response to direct, mechanical sediment augmentation. In 2022, the Program determined that suspending augmentation was needed to better understand and separate the benefits of mechanical sediment augmentation from natural channel adjustment. Data collected during this new, "no augmentation" period will inform negotiations regarding the necessity, quantity, and locations of future sediment augmentation. The no augmentation period is expected to last five years (until 2027), with the caveat that annual review of channel morphology will be used to determine if the experiment must end early.

The currently proposed monitoring plan is designed to place the past sediment augmentation period into context, briefly summarize previously collected data and analyses, and explain key findings. Study questions are then introduced, followed by details on the plans for continued data collection, new data collection, and continued and new data analyses. Finally, we present the processes and expectations involved in annual reporting and a brief discussion of expected findings and possible future directions pending answers to the study questions. The focus of this document is on the broad questions that will drive the monitoring plan and the newly acquired data that will be used to answer those questions. For more details on past and continued data, we direct readers to the linked PRRIP Sediment Augmentation Data Synthesis Compilation (PRRIP 2023) and Sediment Augmentation Report 2022 Addendum (PRRIP 2023).

2. Quick Reference and Timeline Summary

Table 2.1. Quick reference and timeline of J2 sediment augmentation work

Year(s)	Augment-ation?[1]	Major Data Collected by Program	Purpose	Deliverable(s)
Pre-2017	N	Analysis of historical aerial photography, morphology, sediment, and flow metrics	J2 morphological context, historical change	
2017-2022	Y	Contracted LiDAR aerial photography	Impact of mechanical augmentation	PRRIP Sediment Augmentation Data Synthesis Compilation (PRRIP 2023) and Sediment Augmentation Report 2022 Addendum (PRRIP 2023),
2023	N	Contracted LiDAR, aerial photography, supplemental monitoring detailed in **Table 2.2**[2]	Difference between mechanical and no augmentation	Annual Report, Year 1
2024-2027	N	Contracted LiDAR, aerial photography, supplemental monitoring detailed in **Table 2.2**, additional supplements as needed	Difference between mechanical and no augmentation	Annual Reports Years 2-5
2028	N	To Be Determined	Understanding of mechanical vs. no augmentation, future augmentation needs and J2 morphological outlook	Final Sediment Augmentation Report
2030-2032[3]	?	To Be Determined		To Be Determined

[1]Full-scale, in-channel mechanical intervention

[2]See also Sections 5 and 6 of this monitoring plan for more details

[3]End of First Increment Extension

66 **Table 2.2.** Proposed annual task breakdown of the no augmentation monitoring plan.

Month	Task(s)	Deliverable(s)
January	USGS – Overton, specific gage check (Section 5.2.c)	
February	USGS – Overton, specific gage check	
March (field work)	USGS – Overton, specific gage check Breakthrough gage, XS surveys, drone flights (Section 6)	
April	USGS – Overton, specific gage check Receive LiDAR, perform analysis (Section 5.2)	
May	USGS – Overton, specific gage check	Initial monitoring report to TAC – determine any changes to plan (Section 7)
June	USGS – Overton, specific gage check	
July (field work)	USGS – Overton, specific gage check Breakthrough gage, XS surveys, drone flights Sediment sampling (Section 6.d, 6.e)	Full monitoring report to TAC (Section 7)
August	USGS – Overton, specific gage check	
September	USGS – Overton, specific gage check Receive sediment sieve data	
October	USGS – Overton, specific gage check	
November (field work)	USGS – Overton, specific gage check Breakthrough gage, XS surveys, drone flights	
December	USGS – Overton, specific gage check	

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3. Analysis of Sediment Augmentation Period (2017-2022)

Following six years of annual active sediment augmentation, the Executive Directors Office began a data analysis effort to determine if the management action was helping stabilize channel incision and preventing it from progressing downstream. A combination of LiDAR, aerial imagery, stream gage records, and hydraulic models provided insight on the channel's response to an increased sediment supply. These efforts are summarized below to provide context to this monitoring plan, and full details on the analysis can be found in the PRRIP Sediment Augmentation Data Synthesis Compilation (PRRIP 2023) and Sediment Augmentation Report 2022 Addendum (PRRIP 2023).

3.1. Data Collected

a) Annual LiDAR to resolve topography and bathymetry (2016 to 2023)
b) Annual PRRIP aerial imagery (since 2007)
c) Stream gage records (USGS and NE DNR)
d) Historical channel transects (USBR, Tetra Tech)
e) 2009 and 2012 PRRIP 1D HEC-RAS hydraulic models
f) 2016 – 2022 2D HEC-RAS hydraulic models
g) Historical aerial imagery

3.2. Analyses Performed

a. Analysis of incisional trends vs. prior predictions
b. Relative Elevation Model (REM)
c. Volume change analysis
d. Longitudinal profile – changepoint analysis
e. Specific gage analysis
f. Sinuosity
g. Wetted width
h. Slope

3.3 Key findings (reproduced from Data Synthesis Report)

Augmentation operations reduced annual bed erosion in the J2 Return Channel by approximately 20,000 – 40,000 cubic yards (CY) (45%–60%) which is consistent with the 35,000 CY increase in sediment transported out of the augmentation area following mechanical augmentation operations. Nonetheless, we observed continued incision and planform change midway down J2 (Station 70,000). **In the absence of augmentation, we would expect bed erosion in J2 to return to pre-augmentation levels and for incision and planform change to accelerate near Station 70,000**.

We have been unable to predict short term changes in the rate of incision because:

1) The absence of detailed thalweg elevation data during the pre-augmentation period (lack of LiDAR to resolve topography and bathymetry) prevents a detailed analysis of thalweg incision rates immediately prior to augmentation.

2) The confounding effect of a breakthrough channel across Jeffrey Island that contributed flow and sediment to J2 prior to 2020. That channel is now blocked from non-flood flows to protect utility infrastructure.

Long-term channel evolution with and without augmentation is also uncertain. Pre-augmentation analyses indicate that since 2002 incision has decreased and lateral erosion has increased. Will bends in the meandering portion of J2 continue to migrate and supply sufficient lateral erosion to forestall downstream incision, or will the reach stabilize and downstream incision increase? Will the elimination of flood flows (and associated sediment) through the breakthrough channel reduce the potential for episodic incision events or will the elimination of the external sediment supply accelerate baseline incision?

Regardless of these uncertainties, we can say with confidence that there is a substantial sediment deficit in J2 that impacts channel form. At present the impacts (in terms of narrowing and planform change) have not progressed downstream of Overton Bridge but might do so at some unknown point in the future. As such, mechanical augmentation at the upper end of J2 theoretically reduces future risk to downstream habitat yet near- and long-term benefits are difficult to quantify and weigh against the annual cost of augmenting sediment. Alternatives that allow for sediment replenishment without annual mechanical augmentation may offer a more effective solution but understanding the impacts of both intensive augmentation and no augmentation is paramount to making these future decisions.

4. No Sediment Augmentation Study Questions

In this section we introduce broad questions that will drive monitoring and research during the no sediment augmentation period. These questions are meant to both directly align with the overall goals of the First Increment Extension Science Plan and to improve understanding of fluvial forms and processes in and downstream of J2 – the latter is expected to assist in management decisions elsewhere along the Platte in critical habitat reaches.

Driving Questions

1. What are the differences in J2 incisional patterns and rates between the augmentation and no augmentation periods, and how can we determine the effectiveness of previously used augmentation strategies?

    1.a. Can we properly attribute incisional patterns and rates and volumetric sediment change in J2 to specific flow processes, vegetation establishment, channel planform changes, and direct augmentation?

    1.b. Can we describe or quantify the expected morphological impact of active, passive, and no sediment augmentation future scenarios while estimating the monetary and habitat costs and benefits of each?

2. How will planform change progress without sediment augmentation?

    2.a. Can we determine the specific processes that have caused the channel planform transition at Station 70,000 to better understand and predict channel planform changes?

    2.b. How might continued changes towards a meandering planform dominated by lateral erosion impact the morphology and sediment dynamics at station 70,000 and overall within the J2 channel?

    2.c. Can we predict how planform change might progress downstream of the Overton Bridge and how it might impact wetted width?

5. Continued Data

5.1. Continued Data Collection

In this section we list the major continued data acquisition and monitoring techniques to be implemented during the no augmentation period.

a) Annual LiDAR to resolve topography and bathymetry. Data acquisition will take place in the fall of each year during low flow to produce elevation rasters with a resolution of 3 ft by 3 ft. Because LiDAR requires post-processing, Digital Elevation Models (DEMs) will not be available until the following spring.
b) Annual PRRIP aerial imagery. Collected concurrently with topo-bathymetric LiDAR, with a specified resolution of 0.5 ft.
c) Stream gage records. Relevant existing gages and records include NE DNR Darr gage on the north channel, J2 Return release records for the south channel, and the USGS Overton gage downstream of the confluence of the north and J2 channel. Stage, discharge, and any available field-based measurement data to develop stage-discharge relationships or to verify these relationships such as width, depth, and velocity will be acquired.
d) Annual 2D hydraulic model. Flows ranging from 500 to 5,000 cfs run on each topo-bathymetric surface. Results will be available as 3ft by 3ft rasters. Note that this component of data collection requires processing and analysis of DEMs (Section 5.1.a, above).

5.2. Continued Data Analysis

In this section we list and discuss continued analysis efforts of the data detailed above in Section 5.1. Because continuation of the no augmentation experiment is conditional on monitoring results, we subsequently state the findings that we deem most important for annual review of the currently proposed no augmentation experiment in Section 5.3.

a) Sediment volumetric change – analysis of incisional trends

- Volumetric change estimates will be developed via LiDAR raster differencing (creation of REMs) & hydraulic modeling. Water surface elevation rasters will be used to identify areas of erosion on a year-to-year basis. This will allow quantification of total, lateral, and bed erosion volumes.

- Volumetric flux will be calculated by dividing the mass of volume change by time and wetted area at modeled stages. Similar to the distinction of discharge and specific discharge, normalizing our volume change by wetted area in each sub-reach will give us the specific transport in each sub-reach. This may further highlight sub-reaches that are in disequilibrium.

- For all volumetric change analyses, accuracy results will be created. Accuracy will be determined by differencing the elevation of locations within the DEM that do not change between surveys, for example along paved roads and bridge abutments. These results will be directly compared with accuracy and precision estimates provided by the LiDAR contractor to produce a DEM accuracy surface and provide a quantitative measure of robust volumetric change signal that exceeds noise produced by error. We will also use current state-of-the-art DEM differencing methods and tools available in the scientific literature (Glassic *et al.*, 2024).

b) Longitudinal profile elevations and change point analysis

- Longitudinal profiles of the deepest point of the channel (thalweg) provide a specific measure of spatial and temporal patterns of aggradation or degradation. Performing an annual change-point analysis will provide insight into whether the reach is continuing the degradational trend that it exhibited pre-augmentation and identify locations where degradation may be problematic.

c) Overton bridge gage analysis

- The USGS makes frequent field visits to directly measure water stage and discharge at their gage locations throughout the year. When field measurements fail to match the current stage-discharge rating curve, a temporary shift may be applied. If the change persists, then a new rating curve will be created to represent the current stage-discharge relationship. Monitoring changes in the stage-discharge relationship at the Overton Bridge gage will allow us to leverage decades of historical measurements to evaluate changes in channel depth with flow over time at the Overton Bridge (J2 and the Cottonwood Ranch Complex).

d) Sinuosity

- We will calculate sinuosity over the full reach and over smaller sub-reaches to monitor planform change. To do this we will delineate a “low flow” thalweg along the deepest part of the channel based on LiDAR data and a “high flow” thalweg based on the modeled highest velocity path at the peak of the normal hydro-cycle (1,650 cfs). This will allow us to evaluate the effect of flow on sinuosity, as well as monitor planform change over time. Changes in sinuosity can indicate threshold changes to channel morphology and planform, and thus a rigorous determination of both morphological and hydraulic sinuosity is critical.

e) Wetted width analysis

- Wetted width will be measured at 500-ft intervals from J2 to the Kearney Canal Diversion based on yearly hydraulic modeling results at low (~200 CFS) and high (~2,000 CFS) flows to help determine the sensitivity of this metric to stage. Widths during augmentation will be compared to widths during the no-augmentation period. Previous analysis of wetted widths measured at 1000-ft intervals prior to 2017 demonstrated no consistent change over time. By monitoring width at a finer scale, we seek to determine if widths remain stable or reduce in the absence of augmentation if the channel consolidates from braided to meandering planform.

f) Slope

- We will continue to calculate longitudinal slope along the reach and evaluate it as an indicator or driver of planform change. Slope decrease indicates transition towards meandering planform.

g) Normalization of volume change based on flow

- Using continuing gage data, as well as newly available gage data for the breakthrough channel (which during high flows connects the north channel to the J2 channel) and the J2 channel at Dyer (see Section 6, below), we will normalize volume change by the flow that occurred over the time when that change occurred. This will help to identify erosion occurring due to instability (sediment imbalance) from erosion due to high flow. Understanding this relationship will also enable us to estimate the sediment deficit based on different possible flow regimes.

5.3. Results from Continued Data

Continuation of the no augmentation experiment is conditional upon results from monitoring efforts. Channel incision and changes in planform will be evaluated and presented to the TAC each year. The annual analysis will be based on a Relative Elevation Model (REM) within two areas of interest (AOI). AOI-1 will be from River Station 70,000 to Overton Bridge (Figure 1). Station 70,000 is a transitional area where the river has appeared to transition from a braided to a meandering planform (Figure 2). The second area (AOI-2) will extend from Overton bridge three miles downstream into Cottonwood Ranch (Figure 1).

We will develop annual REMs of channel topography relative to the datum represented by the geomorphic grade line (GGL), or linear regression of valley slope. The annual LiDAR will be differenced from the GGL to form a REM raster that represents depth below the GGL. In GIS, we will split the REM raster into distinct classes of depth-below-GGL (DBG).

A sensitivity analysis was performed to determine which DBG class would best represent change in the channel through AOI-1 (Figure 3). A DBG class of 14 feet proved to be too restrictive, only showing growth at the upper reach near the J-2 return. Conversely, a 5-foot class was too broad, showing growth across the entire channel, the result of erosion expanding the depth class in bank areas rather than incision progressing along the thalweg. In AOI-1, a DBG class of 9 feet showed incision at the upstream end of the AOI that has progressed along the thalweg since 2016. We can clearly visualize channel incision with a close-up view of the downstream terminus of the 9-foot class (Figure 4).

Within a specified depth class, we can quantify the area of the incision at that depth or greater annually to measure an incision progression rate. Between 2016 and 2022, during active sediment augmentation, the 9-foot class increased from 4.62 to 15.94 acres in AOI-1, with most of the increase occurring along a continuous, incisional thalweg. Figure 5 shows the incision progression in AOI-1 from 2016 to 2022 while Figure 6 quantifies the annual progression rate during that period.

In the 2012 Sediment Augmentation Pilot Study, changes in water surface elevations at the Overton gage for a given flow were used as an action trigger. Figure 7 shows 1997-2023 rating curves and resulting changes in gage height at the 10th percentile low flow of 244 cfs. Bed aggradation and erosion, as well as channel widening and narrowing, can cause changes to stage-discharge relationships. If sediment transported through J2 to the Overton Bridge is reduced under the no augmentation condition, this could cause erosion and ultimately lead the USGS to implement a positive shift (to compensate for lower gage height). If a positive shift occurs, we will investigate the cause through contact with the USGS as well as analysis of bathymetric and hydrologic data. These data will include tri-annual cross-sectional bathymetric field surveys at the Overton gage location (concurrent with new sediment and drone surveying described in Section 6) to determine if channel widening or bed erosion is contributing to the change. Review of recent hydrologic data from the Darr, Dyer, and Overton gages will help inform whether a flood in the north channel may have contributed to erosion at the bridge.

6. New Data Collection and Analysis

In this section we list new data acquisition efforts and monitoring techniques to be implemented during the no augmentation period. We provide background information where necessary to connect these efforts and techniques to the study questions presented in Section 4.

a) USGS-operated stream gage at Dyer along J2 channel

The installation of a new USGS-operated stream gage at the Dyer property (Figure 8) will provide critical data on total flow through the J2 and breakthrough channel, greatly improving our ability to understand the relationship between flow, sediment flux, and channel morphology of the J2 reach. We will be able to verify the flow volume released by the J2 Reservoir, determine baseflow and the contribution of the breakthrough channel on J2 channel flow, better constrain flow and sediment modeling results, and more accurately determine the flow split between the north and south channels as they combine just upstream of the Overton Bridge. In-situ measurements of width, depth, stage, and discharge by USGS can also be used for additional specific-gage analysis at this location moving forward, although these data should be viewed as supplemental and as such are not the express goal of placing the gage in this location.

b) Stage logger in breakthrough channel

In concert with the newly installed Dyer property gage, we have installed and will continue to monitor a stage logger within the breakthrough channel to allow for estimation of flow when this channel is active (Figure 8). The breakthrough channel is not likely to be morphologically stable in response to high flows that convey considerable water, preventing the installation of permanent gaging infrastructure. However, the stage gage in the breakthrough channel will still provide valuable data that can be compared to modeled data. In addition, during flows that are expected to activate the breakthrough channel, we will estimate flow velocity and thus breakthrough channel discharge remotely using debris and particle tracking methods calculated with drone-based imagery (Eltner et al., 2020 – see Section 6.f below for more information on drone surveys). We will target the first flow of the year that activates the breakthrough channel and attempt to measure subsequent flows that are substantially higher than the initial flow.

c) Tri-annual cross section surveys at anchor points 33-36 and Station 70,000

Cross sectional surveys acquired with RTK-GPS will provide sub-annual (March, July, November) elevation data at sub-inch accuracy throughout the reach at anchor points (APs) with historical data and at actively transitioning locations (Station 70,000) (Figure 9). The AP locations are chosen because they are the location of past similar surveys and can be used to better understand sub-annual channel changes. The surveys at station 70,000 will provide simple evidence of channel changes in this braided-to-meandering transitional reach that has been identified as a key focus of planform channel changes. Sub-annual channel form measurements will provide insight into the balance between incision and lateral migration more frequently than our annual LiDAR data allows. These surveys will also be used to check the accuracy of LiDAR data collected each November. See Figure 9 for cross section locations.

d) In-channel sediment sieve analysis sampling

Sediment sampling provides valuable information on the connection between flow and changes in channel form. These data are useful for estimating sediment movement in purely hydraulic models and verifying results of mobile-bed models, interpreting rates and patterns of channel change visible in DEMs, REMs, and longitudinal surveys, and understanding sedimentology of bars and banks. However, a full-scale, dedicated sediment sampling scheme consumes much time and resources and does not in itself provide direct evidence for channel changes. Thus, the plan for sediment sampling is focused on obtaining simple, easily-accessible data that can be used to provide insight into the value of a potentially enhanced sampling scheme implemented in the future and provide comparisons and ground-truth for drone-based sediment characterization efforts (see Section 6.e, below).

Three bed sediment samples and one bar-surface sample will be collected from each anchor point every year following the method used by previous studies. In brief, bed samples will be taken from the center of the channel within the thalweg and one each on the left and right sides of the thalweg. Bar-surface samples will be collected from the top two inches of sediment on bars. Sieve analysis will be conducted to determine sediment size gradations. The sediment data will provide insight into channel bed material size that will assist in development of any future sediment models and will be compared with bar-surface sediment samples to assist in the calculation of sediment armoring ratio (see Section 6.e below for more information on sediment armoring).

e) Aerial longitudinal bed armoring sampling

Bed armoring is the process by which fine sediment is preferentially removed from the surface of the channel bed and bars compared to larger sediments, leaving a surface layer of coarse grains. Armoring generally reduces bed erosion because the larger, less mobile sediment fraction protects the more mobile sub-surface. Anecdotally, armoring appears to be present within the upstream portion of the J2 channel likely because the clearwater discharge from the J2 Return contains no incoming sediment.

Sediment sizes on exposed bars will be determined directly from imagery obtained aerially from drones (Buscombe et al., 2010). The results of image-based grain size measurements compare favorably to traditional pebble-counting methods, can cover much larger areas more rapidly in the field, and can be done automatically with limited computing resources (Takechi et al., 2021). Digital images acquired from the drone are tagged with GPS locations and will also be georeferenced with traditional aerial imagery and LiDAR data collected as part of the ongoing monitoring plan. Bar-surface sediments collected as detailed in Section

6.d, above, will be collected at the same time as the drone imagery and will be used as validation data.

Sediment size distributions and armoring ratio, the ratio of large (bar surface) to small (bed, bar subsurface) sediment, will be calculated and related to downstream distance along J2 and sections of bars themselves (such as upstream, mid-bar, and downstream). It is expected that the drone imagery surveys will not require substantial increases in workload of the field crew while capturing spatial variability of armoring. The efficacy of imagery-based sediment size classification and the importance of these data for understanding channel form and sediment transport in J2 will be assessed and altered, stopped, or expanded according to results.

f) High-resolution aerial imagery

Drone surveys represent a simple, repeatable, and flexible complement to ongoing and traditional in-channel survey techniques and have been shown to be an important tool in geomorphological analyses (Lewis et al., 2022). Drone surveys will be pre-planned and can be launched by as few as one person. As such, a particular focus of the no augmentation monitoring plan is to perform drone surveys concurrent with other field work and assess the efficacy of using imagery and video to complement continued and new data acquisition. For hydraulic and hydrologic analyses, drone surveys will be used to estimate high-flow marks during floods to confirm modeling results and will be used to estimate flow velocity and discharge in difficult-to-reach locations like the breakthrough channel. In terms of channel morphology, drone surveys will directly measure bar-surface sediment sizes and sediment armoring ratio, will be used to aid in interpretation of sub-annual vegetation characteristics, and will be used to obtain sub-annual channel morphology using three-dimensional photogrammetry (Westoby et al., 2012).

7. Annual Reporting

Annual monitoring reports are a fundamental component to the currently proposed no augmentation experiment as they will be used determine if the experiment can continue or if augmentation activities need to resume to slow/prevent incision. The goal of the annual report is thus simply to provide quantitative information on channel changes that allow the TAC to determine if the progression or total amount of incision is acceptable or worrisome, and if the current experiment should be allowed to continue (**"what we learned"**). A complementary component of annual reports will be a brief account of the monitoring efforts accomplished in the past year (**"what we did"**) and a brief discussion of any promising new monitoring strategies (**"what else could we do?"**).

The most important dataset that is used to determine channel change is the annual LiDAR-derived DEM and subsequent REM. REM analysis will be completed in April of each year, pending LiDAR delivery. The elevation differencing results from both AOIs will then be provided to the TAC annually in May to allow for time-sensitive decisions to be made regarding continuation, cessation, or alteration of the experiment. The full annual report will follow for the July TAC meeting. These results will be presented in relation to the range of variability we have seen in each AOI. This approach allows for variability within the channel, where aggradation and degradation of the same magnitude can occur from year to year.

The annual report will provide clear measures of channel change, together with calculated data accuracy, using the techniques detailed in Sections 5 and 6 above. We envision the format of the annual report to be structured as below:

a) Summary of magnitude, rates, patterns, and locations of channel change with a focus on quantitative results of the data markers and thresholds identified in Section 5.3. (**"what we learned"**)
    a. Relevant details on results of continued and new data collection and analysis that are important for assessment of experiment continuation
b) Brief account of new data collection and analysis (**"what we did"**)
c) Brief discussion of suggestions and list of options for expanding, stopping, or otherwise altering monitoring strategies (**"what else could we do?"**)

We emphasize that although the EDO cannot make the decision to continue, stop, or alter the currently proposed no augmentation experiment, we will provide and justify our recommendation. It is critical to note the annual report does not and cannot represent a detailed, systematic *analysis* of the efficacy of the no augmentation experiment.

8. References

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Eltner, A., Sardemann, H., & Grundmann, J. (2020). Flow velocity and discharge measurement in rivers using terrestrial and unmanned-aerial-vehicle imagery. *Hydrology and Earth System Sciences*, 24(3), 1429-1445. LINK

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Westoby, M. J., Brasington, J., Glasser, N. F., Hambrey, M. J., & Reynolds, J. M. (2012). 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*, 179, 300-314. LINK

9. Figures

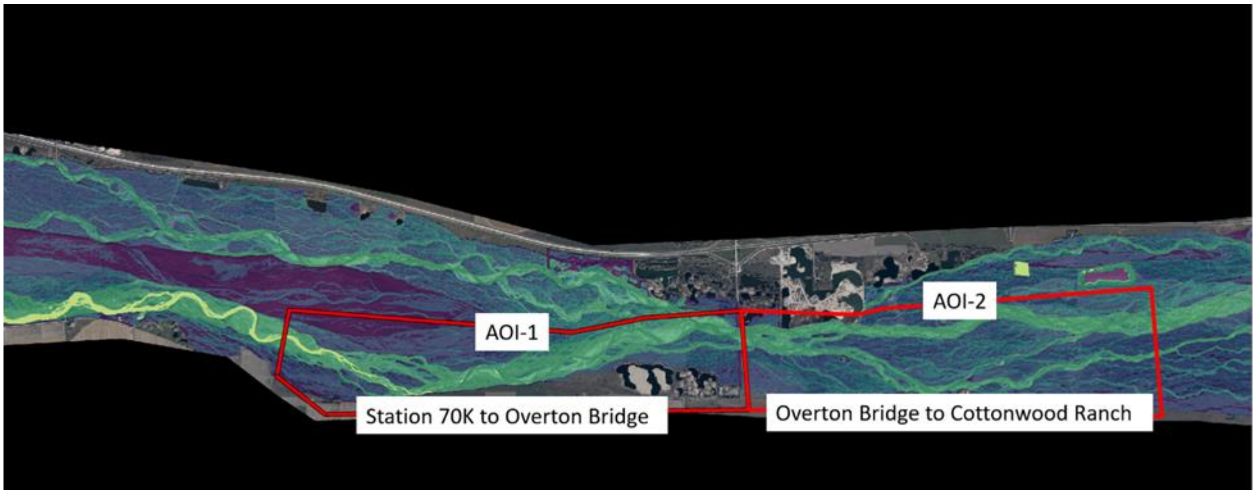


Figure 1. Areas of Interest (AOI) for Relative Elevation Model (REM) analysis.

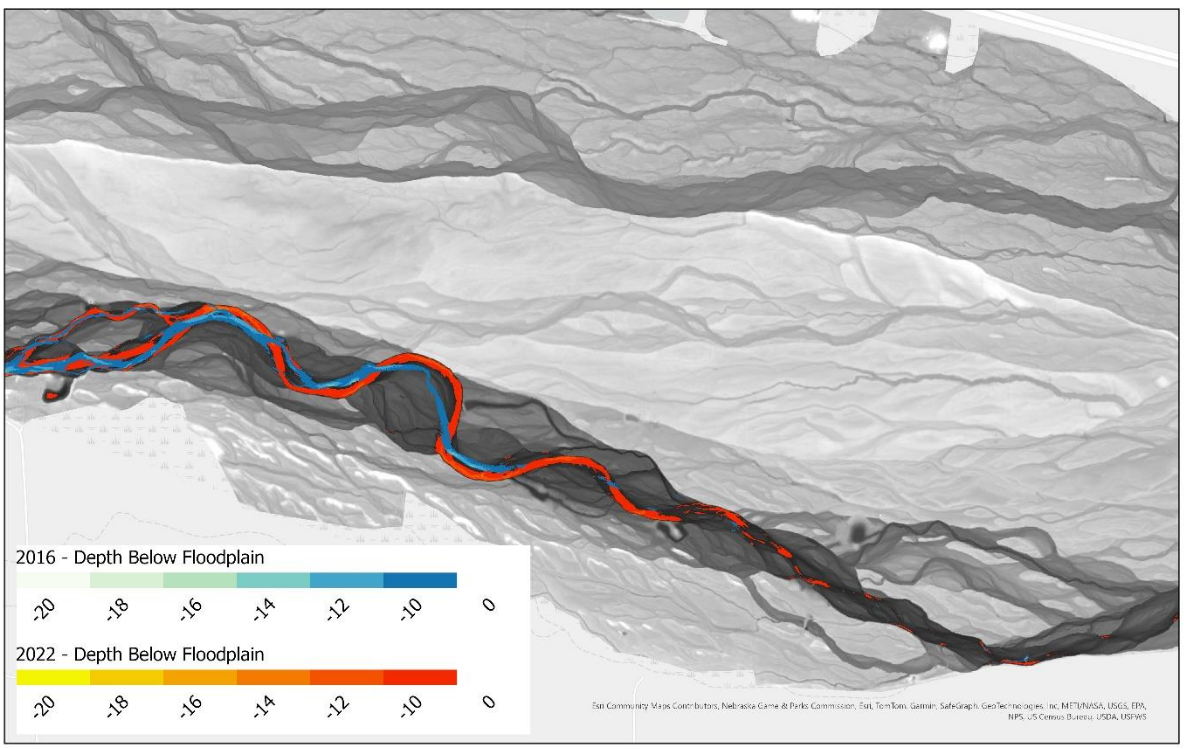


Figure 2. Station 70,000, a reach where planform meanders as seen by increase in sinuosity and lateral extension of bends between 2016 (blue) and 2022 (red). Depth below floodplain is listed in feet.

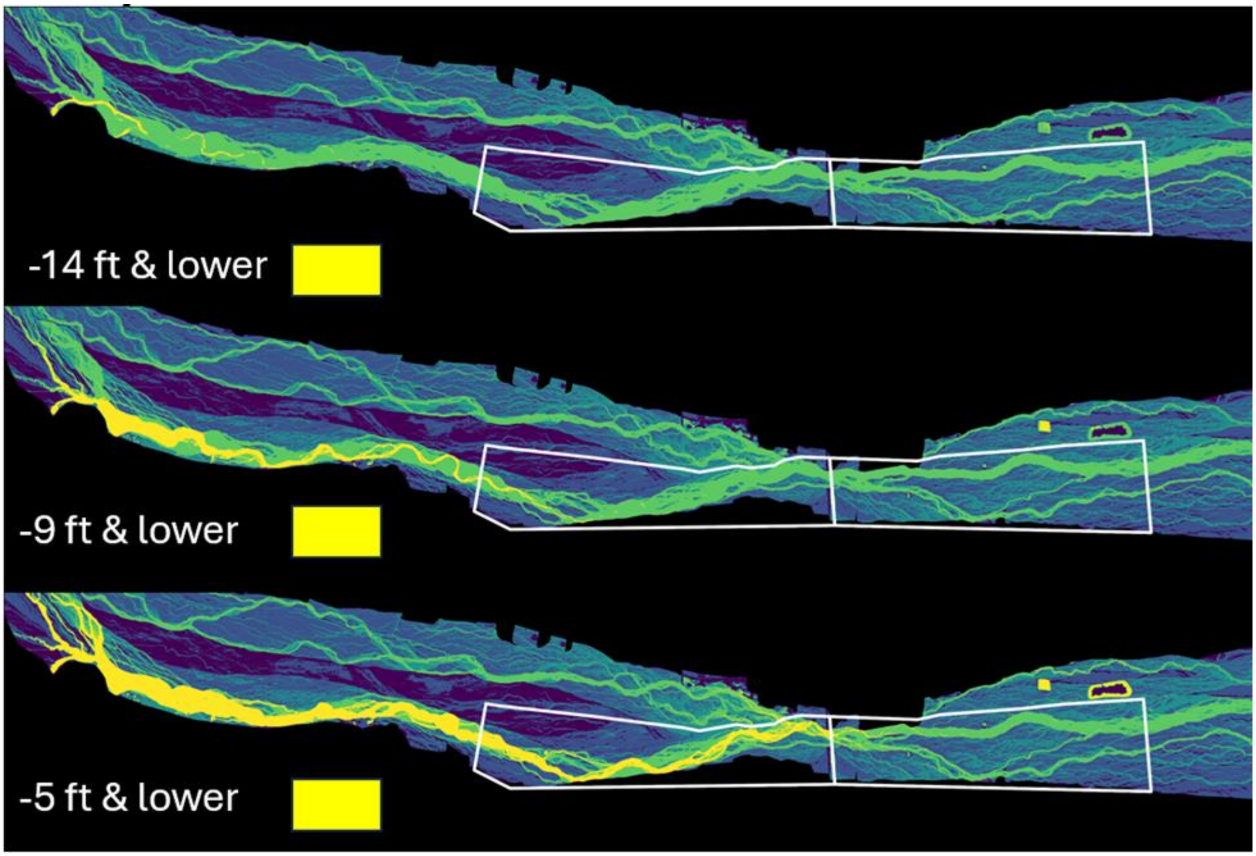
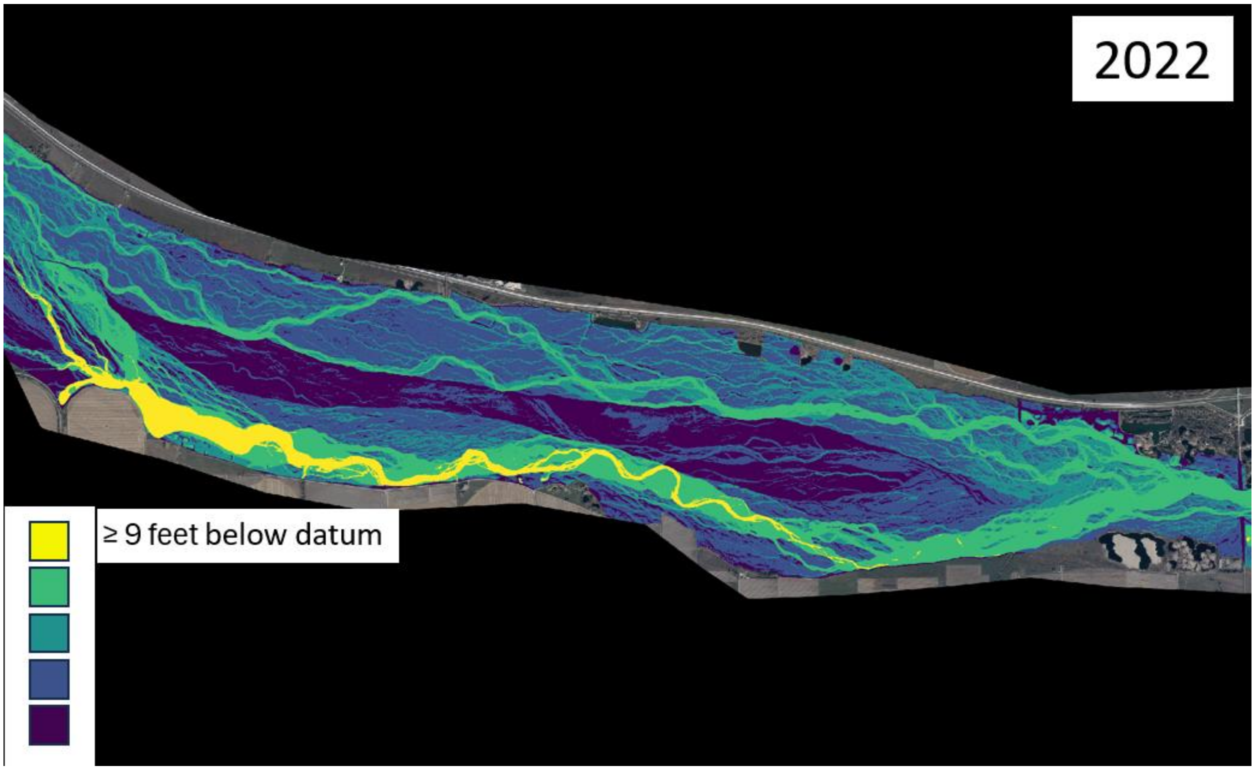


Figure 3. Sensitivity analysis for three depth classes using the 2022 REM.



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443 **Figure 4.** Zoomed-in location of the REM showing 9-foot below datum class to monitor downstream
444 progression of incision.

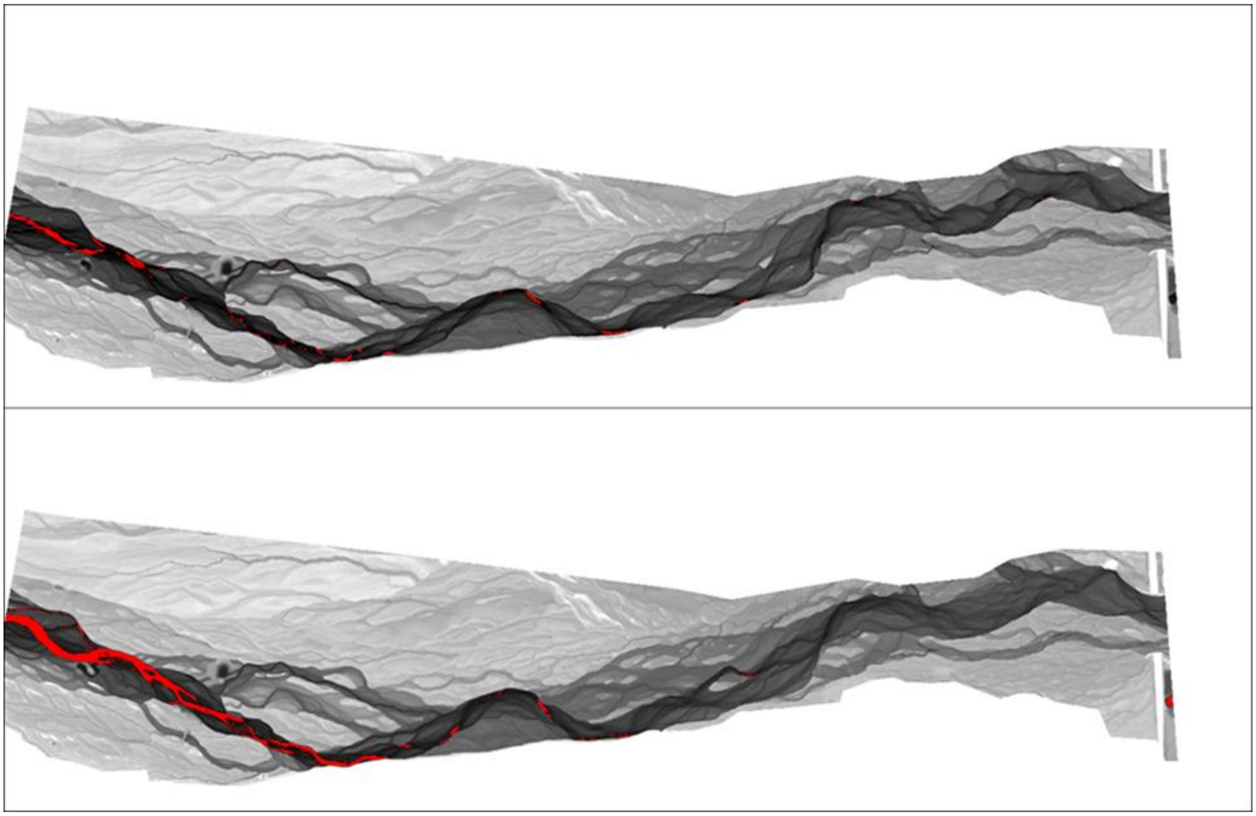

Figure 5. Depth-below geomorphic grade line ≥ 9 feet (red) in AOI-1 in 2016 (top) and 2022 (bottom).

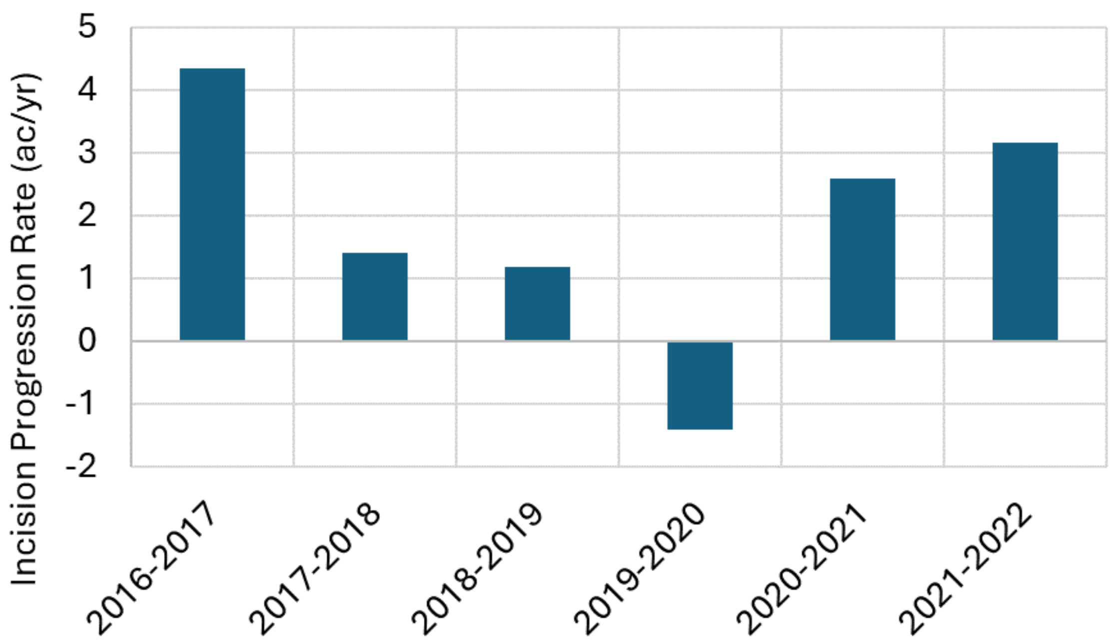

Figure 6. Annual incision progression rate in AOI-1.

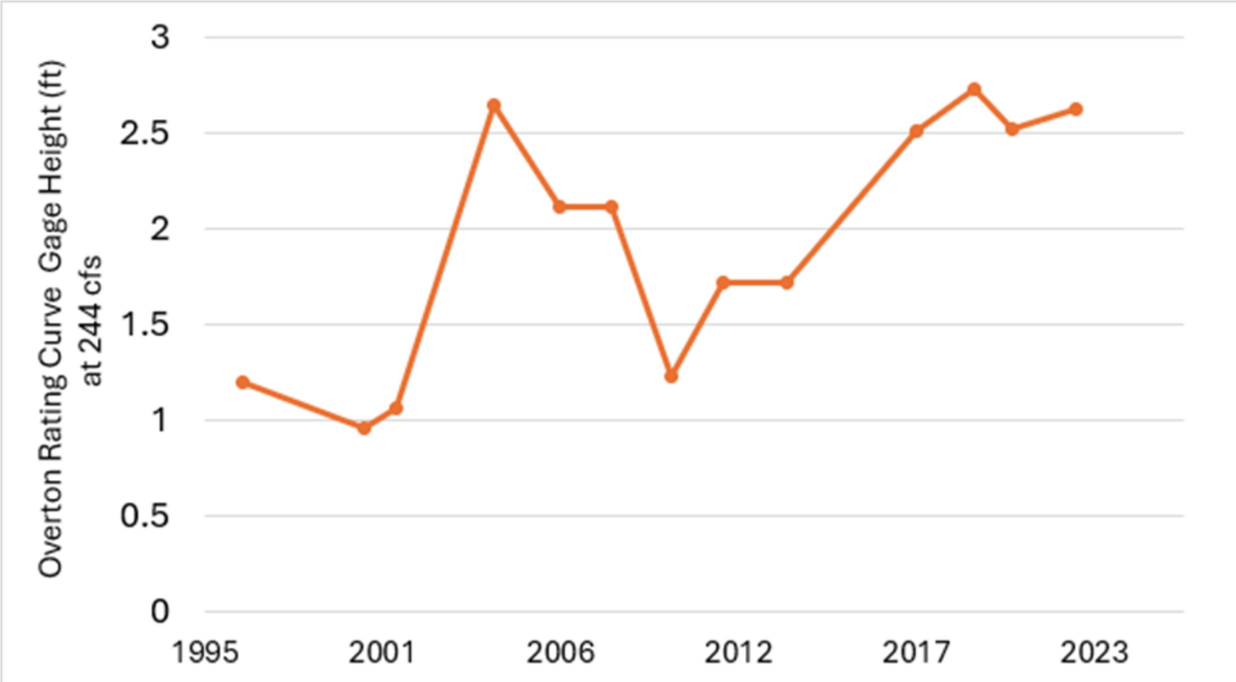

Figure 7. Gage height of the 10th percentile flow based on rating curves published by the USGS from 1997 to present. Decreases indicate potential bed erosion or widening at Overton Bridge.

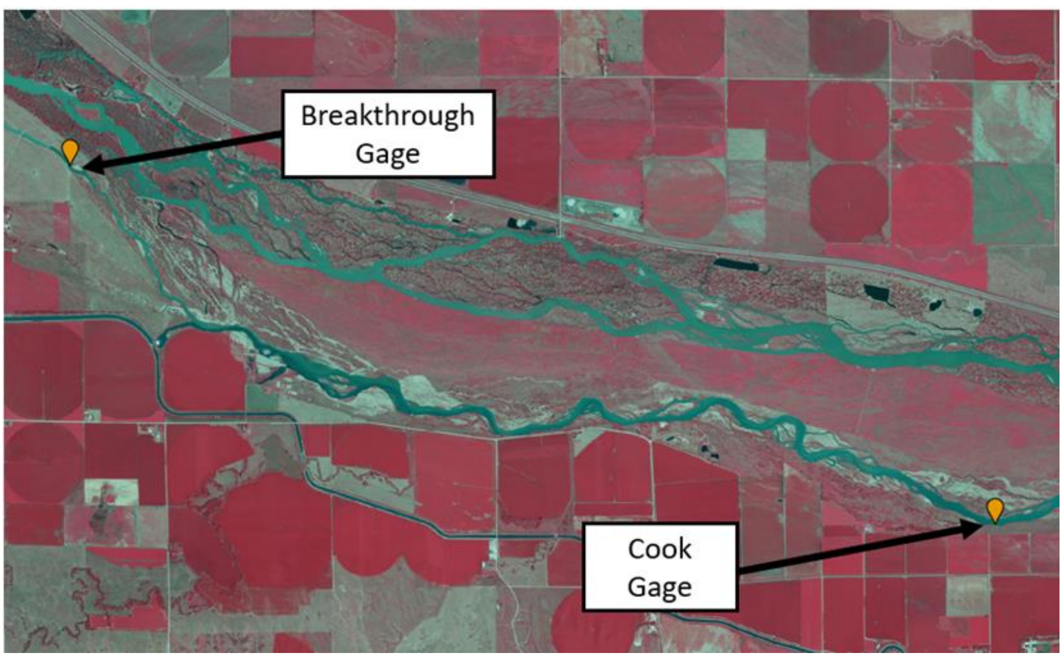

Figure 8. New gage locations. Note that the actual location of the J2 Return Gage was installed downstream of the indicated proposed location and is now on the Dyer Property.

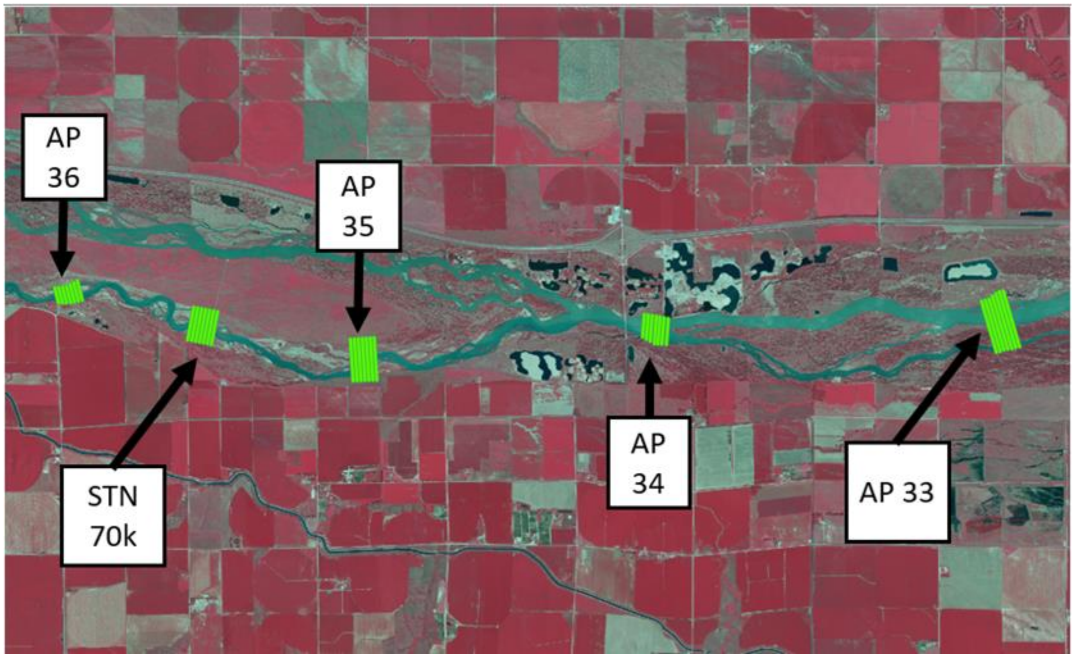

Figure 9. Proposed survey cross section locations.