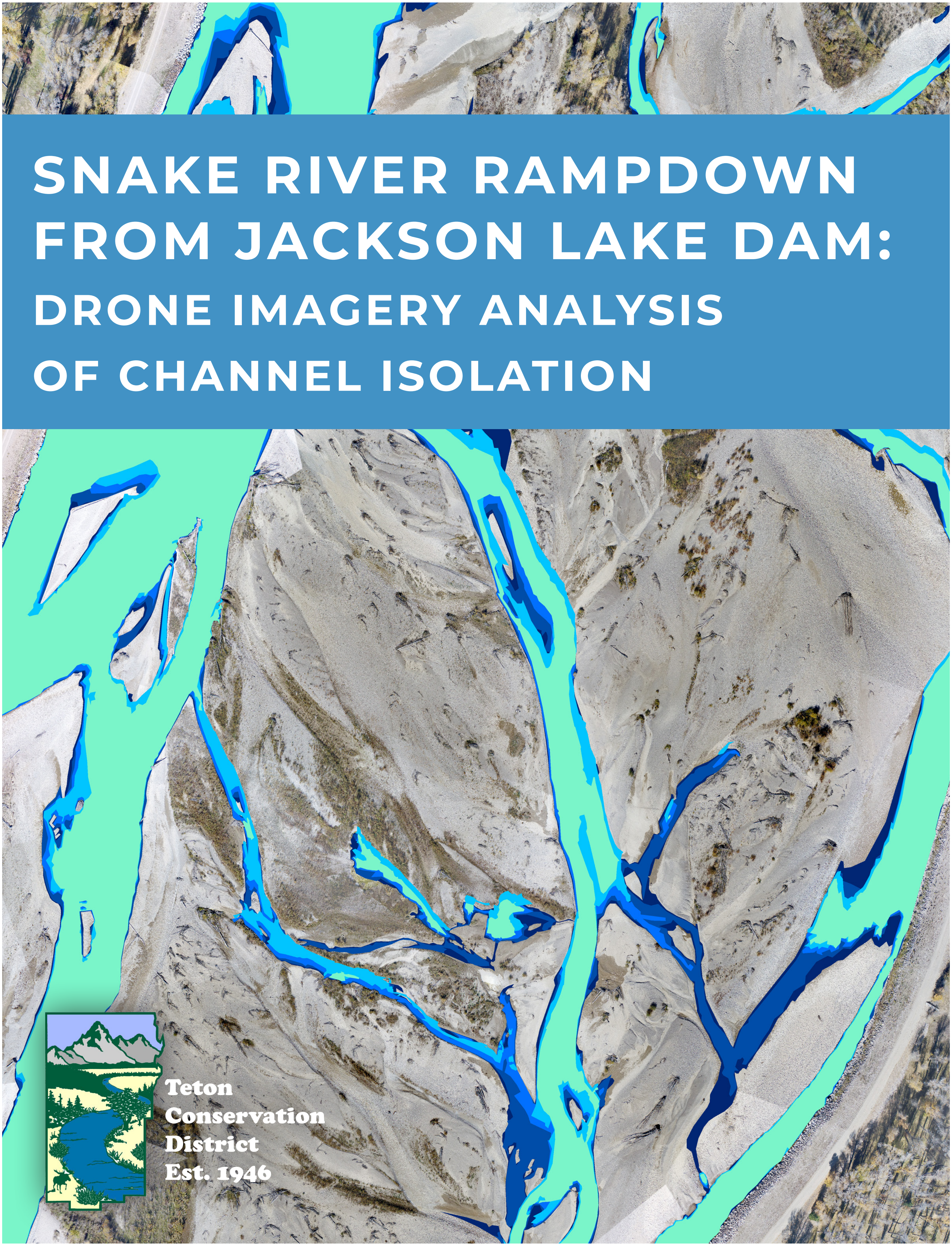
SNAKE RIVER RAMPDOWN FROM JACKSON LAKE DAM:
DRONE IMAGERY ANALYSIS OF CHANNEL ISOLATION



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Snake River Rampdown from Jackson Lake Dam: Drone Imagery Analysis of Channel Isolation

Technical Report

2023

David Lee, Emily Smith, Morgan Graham, Carlin Girard, Daniel Dauwalter*, and Matt Barney*

*** Trout Unlimited Staff**

Teton Conservation District
420 W Pearl Ave
Jackson, Wyoming 83001

For more information regarding this report or the Teton Conservation District—a political subdivision of the State of Wyoming—please contact 307-733-2110 or visit www.tetonconservation.org.

Cover Image: Snake River surface area during 2021 Snake River rampdown from Jackson Lake Dam.

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EXECUTIVE SUMMARY

This study investigated the effects of a six-day rampdown of releases from Jackson Lake Dam (JLD) in early October 2021 on the Snake River surface area and channel connection, as a proxy for available aquatic habitat on the Snake River. Daily drone flights between October 1 and October 5, 2021, were conducted to collect aerial images along a 4.8 km section of the Snake River approximately 58 km downstream of JLD. Images were mosaiced and orthorectified to produce a contiguous image of the study area for each day of the study period. This orthomosaic image was used to digitize the wetted surface area of the Snake River within the study area, classify the dynamics of side channel isolation, and quantify channel dimensions through time.

Results show that the Snake River within the study area lost 23% of its connected surface area during the study period. The largest single-day decrease in wetted surface area occurred between October 1 and October 2, where releases from the dam decreased from 1,840 cfs to 1,270 cfs and 8% of surface area was lost. Discharge at three streamgages along the Snake River near the study area were linearly correlated with measured wetted surface area. The strongest correlation (R^2=1.0) existed between the discharge at the most downstream streamgage (Snake River below Flat Creek, USGS 13018750), and the least strong correlation existed between the discharge at the JLD streamgage (Snake River near Moran, WY, USGS 13011000). The largest deviation (i.e., residual) from a linear regression with the JLD streamgage occurred between October 2 and 3, where releases from the dam decreased from 1,270 cfs to 1,060 cfs. A similar deviation from the regression with the nearest upstream streamgage to the study area (Snake River at Moose, WY USGS 13013650) occurred between October 3 and October 4, where discharges decreased from 1,580 cfs to 1,550 cfs.

A total of three major side channels (diverging from the main stem) and five minor side channels (diverging from a major side channel) lost surficial connectivity from the Snake River's main stem. The largest single-day decrease of connected channels occurred between October 1 and October 2, with two major and three minor side channels isolated. In all but one case, upstream connectivity was lost before downstream connectivity during the study period.

The average width of connected channels within the study area decreased 9.9% during the study period. Snake River main stem average width decreased by 12.2%. Major side channel average width decreased by 19.6%, while minor side channel average width was variable and ultimately decreased by 2.4%. The largest change in average channel width occurred between October 2 and October 3, where average channel width decreased by 9.3%. There was not a strong correlation between flowing channel width and streamgage discharge, nor was there a strong correlation between flowing channel length and discharge.

The change in surface area of connected channels and the surface area loss of channels that became isolated were compared to observe the effect of channel isolation on habitat. Between October 1 and October 2, the percentage of area loss attributed to channel isolation was 12.4% of the total area lost. During the study period, channels that became isolated from the connected available habitat accounted for 7.2% of total area loss within the study area. The remainder of the area lost is due to channel constriction and similar factors.

Previous investigations of braided river discharge dynamics using orthorectified images reveal a similar linear or curvilinear relationship between discharge and effective width of the river system. The deviation from the linear regression between 1,270 cfs and 1,060 cfs at JLD suggests that an inflection point may exist at this discharge range where surface area decreases more rapidly with changing flows. This has implications for aquatic species that need time to move out of present habitat into deeper water before the habitat is isolated or completely dewatered. A longer rampdown period that mimics more natural recession may minimize isolation by providing fish populations time to transition to deeper channels. This study area, with its relatively consistent historical aerial imagery and high-resolution infrared imagery available, is a strong candidate for additional investigations of short- and long-term channel change by these and other methods.

CONTENTS

1 - INTRODUCTION

A number of studies have been conducted to assess the effect of natural and anthropogenic reductions in water level on fisheries. Fish stranding is a thoroughly studied biological impact in regulated rivers. The majority of fish stranding research has been attributed to anthropogenic sources of discharge changes from hydropower operations (Nagrodski et al. 2012). Fisheries habitat located downstream of a dam can experience rapid fluctuations in discharge and water surface elevation due to changes in operations at the dam. These fluctuations can lead to stranding or entrapment of fish in isolated pools that no longer connect to a river's main channel (Bradford et al. 1995; Richmond and Perkins 2009). Rapid reductions in discharge can cause more stranding of fish in side channels than incremental reductions, as fish are not provided time to adjust to the changing water level (Hunter 1992; Bradford et al. 1995; Irvine et al. 2009). Within regulated river systems, characteristics that result in larger numbers of stranding observations within regulated river systems include gravel substrates, multiple long side channels with intermittent flow, and low-gradient bars (Hunter 1992).

Furthermore, trout overwinter survival in reservoir tailwaters can be negatively affected by many factors, including frazil ice events and temperature gradients which disrupt activity level (Annear et al. 2002). These effects often occur when dam releases provide conditions in tailwaters that are warmer than natural overwinter conditions, reducing the chance of stationary ice cover across the channel and contributing to anchor ice and frazil ice formation (Brown et al. 2011).

Every year in autumn, the Bureau of Reclamation performs a rampdown of releases from Jackson Lake Dam (JLD) from summer flows of approximately 2,500 cubic feet per second (cfs) to winter flows of 280 cfs (Figure 1). Recently, there has been increased attention to the rampdown, and questions have been raised about the impact of the fisheries habitat within the Snake River from a rapid rampdown. In 2021, the rampdown was greater interest due to its large magnitude and relatively short duration.

Including fisheries health in the planned delivery of water to downstream water right holders complicates the recommendation of winter flows in the Snake River. Instream flow studies have been performed on the Snake River below JLD to determine the recommended winter release that maintains hydraulic criteria in the main channel and adjacent side channels. These studies suggest a recommended flow of 1,286 cfs, measured at JLD, to provide appropriate hydraulic criteria in the braided river segment between Pacific Creek and Moose for side channel habitat, including riffle depth, velocity, and wetted perimeter. This is in contrast to the minimum flow recommendations of 280 cfs for the river segment between JLD and Pacific Creek (Annear 1989). However, previous research on the Snake River lacks detail regarding the dynamics of channel isolation and its potential to impact fisheries as a result of stranding.

This study investigated the effect of a six-day rampdown of releases from JLD in 2021 on river channel geomorphology, specifically channel isolation as it pertains to fisheries habitat loss, in the Snake River below JLD. This study used orthorectified aerial imagery to assess change in habitat extent and channel connectivity during the rampdown of releases from JLD from October 1 to October 5, 2021, and adds to the body of research on this topic by focusing on the less-studied leveed portion of the Snake River.

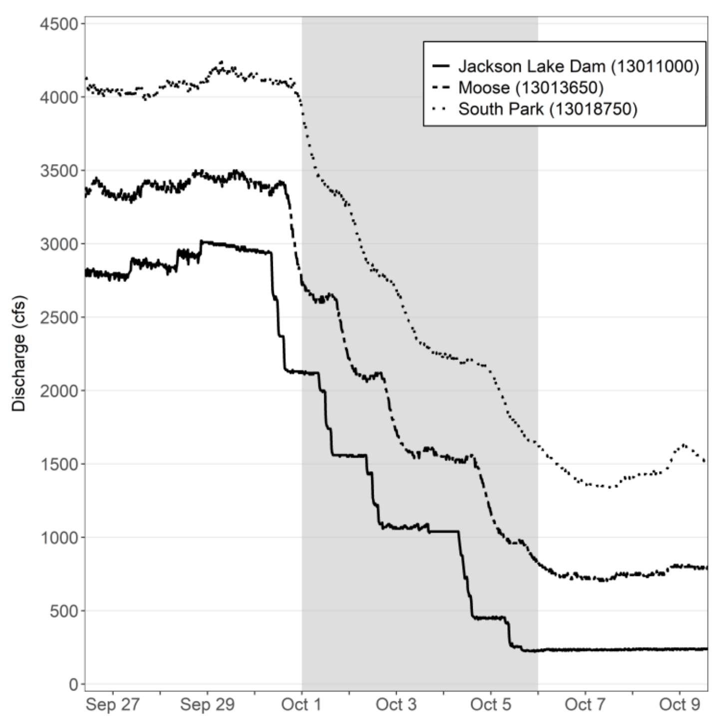

Figure 1. *Snake River 2021 rampdown discharge at USGS streamgages. Study period highlighted in grey.*

2 - METHODS

Study Area

The study area encompasses a 4.8 km section of the Snake River, approximately 1.6 km upstream of the Wilson Bridge (WY Hwy-22), and 3.2 km downstream of the bridge. This section of the Snake River was chosen because it is easily accessible and allows drone imagery collection, unlike sections closer to JLD within Grand Teton National Park where drone use is prohibited. The study area is located approximately 58 km downstream from JLD. The study period was October 1-5, 2021.

Hydorology was characterized using two streamgages above and one below the study area. USGS 13011000, Snake River near Moran, WY, is approximately 58 km upstream of the study area and only includes releases from JLD. USGS 13013650, Snake River at Moose, WY, is approximately 21 km upstream of the study area and captures additional inflows from Pacific Creek, Buffalo Fork, Spread Creek, Cottonwood Creek, and Ditch Creek. USGS 13018750, Snake River below Flat Creek, is approximately 21 km downstream of the study area and captures inflows to the Snake River from the Gros Ventre River, Fish Creek, Spring Creek, Flat Creek, and outflows from multiple irrigation diversions off of the Snake River. The study area is located downstream of the confluence between the Snake River and the Gros Ventre River and also downstream of multiple irrigation diversions. Average flow for the Gros Ventre River at Zenith during October 1-5 is 74 cfs for the period of record (1917-2021). During the study period, the average Gros Ventre River discharge at Zenith was 45 cfs.

The Snake River within the study area is bounded on both sides by artificial levees constructed by the US Army Corps of Engineers. These levees were built between 1957 and 1964 and were designed for flood protection and channel stability. There are 31 linear miles of federal levees on the Snake River, either on one bank or both banks (USACE 2000). Levees exist on both banks within the entire length of the study area.

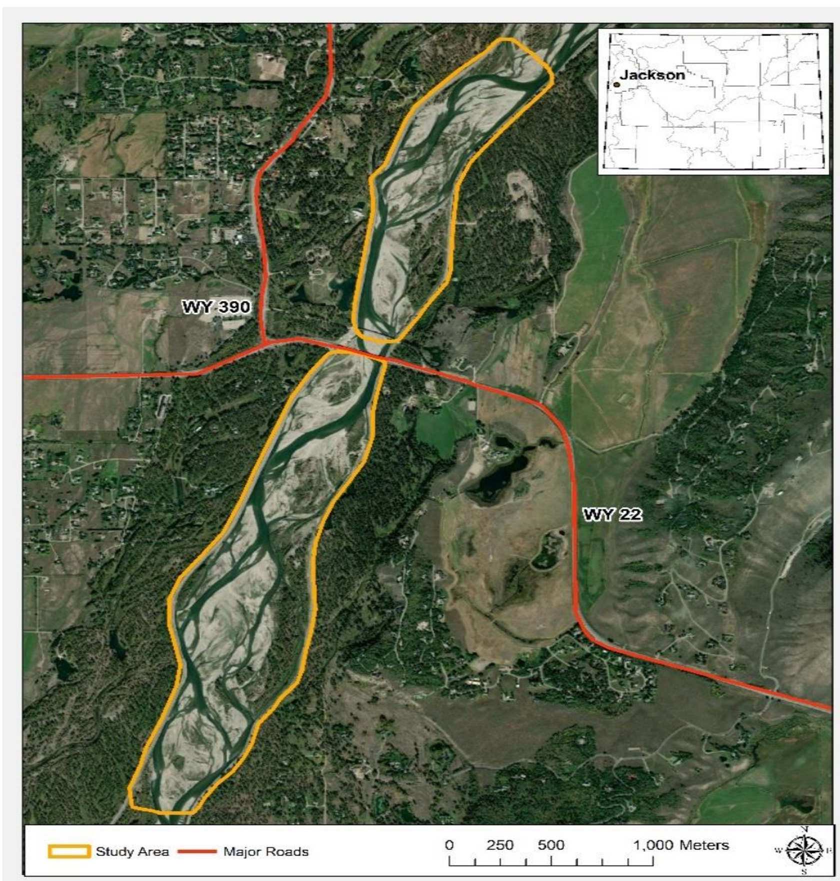

Figure 2. *Study area for the Snake River Drone Imagery study. Flow direction is from north to south.*

Imagery Data Sources

Aerial photographs were collected during the study period (October 1-5, 2021) using a DJI Phantom 4 Pro drone operated by Trout Unlimited staff. Teton Conservation District (TCD) staff performed data storage and field logistic support during imagery capture activities. Daily flights were performed at an altitude of 400 ft to capture imagery within the study area, using pre-determined flight plans designed with 75% front and 70% side overlaps between adjacent images (Figure 3).

Figure 3. *A flight plan from drone imagery collection.*

A total of five flights were completed each day, with two flights performed in the upstream section (above the bridge) and three flights performed in the downstream section of the study area (below the bridge). The five daily flights lasted approximately three to four hours and collected over 1,000 photos per day.

On October 2, a drone GPS failure occurred. A replacement drone of the same make and model was used to complete the imagery collection for October 3-5. To ensure five days of imagery were used in analysis, a portion of the study area was removed from analysis (Figure 4). This resulted in 7.9% of the original study area excluded from the analysis (173,177 m^2 of the original 2,191,660 m^2). A uniform study area was designated with boundaries at the smallest extent of the overlapped imagery for the five days, excluding where the drone failed on October 2. A series of constructed ponds within the study area were also excluded from the study area as they had no surficial connectivity to the Snake River.

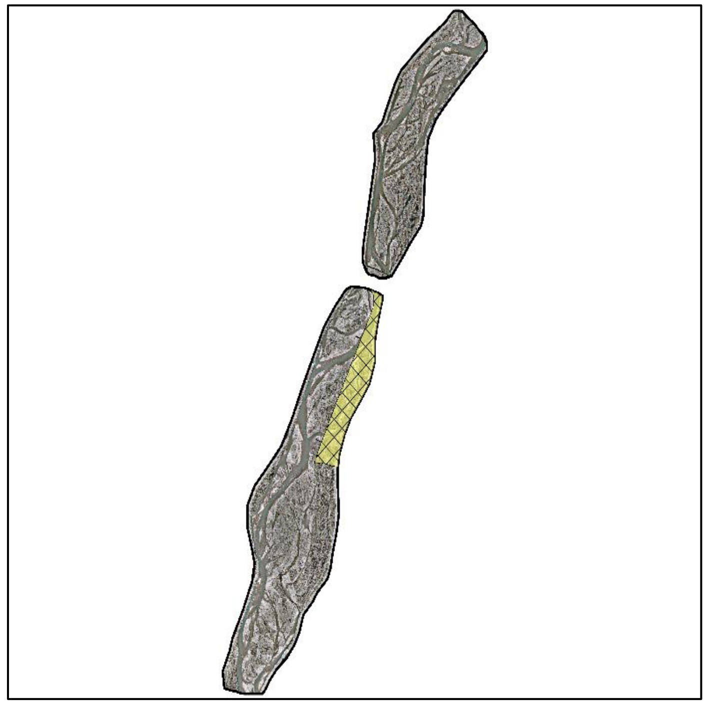

Figure 4. *The location of the drone failure on October 2nd, indicated in yellow, with the study area outlined in black.*

Orthorectification of Imagery

Each daily image collection was mosaiced and orthorectified using ArcGIS Pro 2.7.2. Raw images from each day were imported into separate Ortho Mapping workspaces. Spatial reference and camera model were populated with the raw image EXIF metadata. Tie points were subsequently calculated via the Ortho Mapping Adjust tool. Final photogrammetric correction (color balance, seamlines, orthomosaic format) was executed by accepting default settings of the Orthomosaic tool. Output drone images were 1.19-in (0.029 m) resolution. Evenly distributed ground control points were used to georeference the drone imagery datasets to 2020 3-in (0.0762 m) resolution Wyoming Department of Revenue imagery.

Because this study was comparing area changes through time using internally rectified imagery, steps were taken to measure the degree of spatial accuracy between imagery sets. Root-mean-square error (RMSE) was calculated to determine the error of the georeferencing process. The RMSE using ground control points between Wyoming

Department of Revenue imagery and the orthorectified imagery was 0.38 m. In addition, ground control points were used as vertices of a created test polygon. The area of the test polygons was within 0.02% between October 1 and October 2 imagery.

Digitization of Wetted Surface Area

The orthorectified imagery was used to digitize the total wetted surface area of the study area using ArcMap 10.3.1 (Figure 5). The extent of visible surface water of all depths was digitized as a polygon shapefile overlaying the imagery datasets, using the edge of the wetted surface area to delineate the vertices of the polygon. Variable light and weather conditions precluded the utilization of traditional supervised and unsupervised classification techniques. A scale of 1:300 was used for digitization. All surface water within the study area visible in the imagery was digitized and included in this dataset. Water not visible from above, including habitat in undercuts and debris such as log jams and boulders was not included in the dataset. Five separate polygons were created, one for each day of the study period.

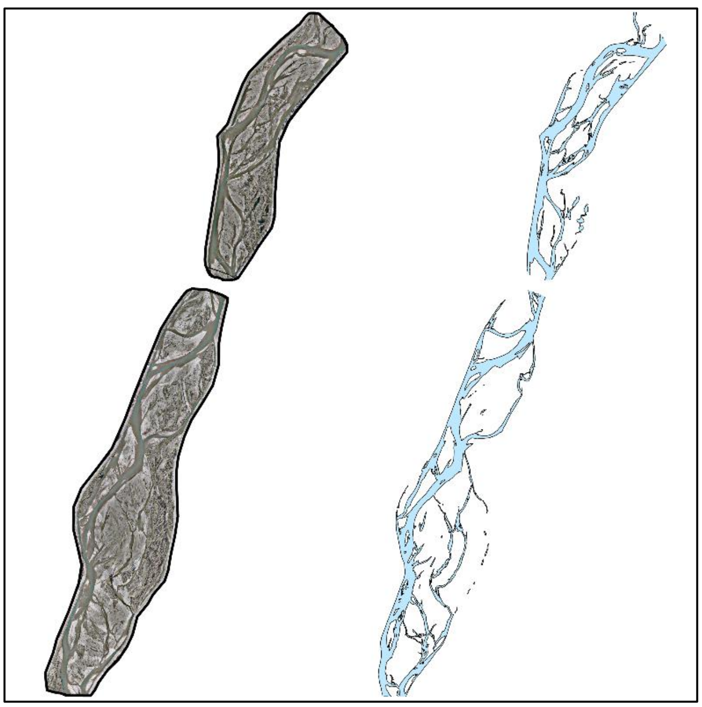

Figure 5. *Example of orthorectified drone imagery of the study area (left); and, digitized wetted area of the Snake River on the same day (right).*

Classification of Wetted Surface Area

The digitized wetted surface area polygons were classified and attributed based on their connectivity to the main stem of the Snake River. Side channels were cut along their connection to their parent channel using the ArcGIS Advanced Editing Cut tool. Side channels that diverged directly from the main stem were classified as major side channels while channels that diverged from a major side channel were classified as minor side channels. Channels were not divided further than minor side channels. Channel diversions were classified as new channels, instead of single channels split by bars or islands, if they were longer than 100 m, or if the opening of the channel was at least fifty percent of the width of its parent channel. The boundaries between differentiated channels were based on the direction of flow and geographic features.

Channels were assigned attributes for several metrics, including the day the channels were formed and/or isolated from flow, and the direction of its isolation. For example, a side channel may have existed during the first day of the study period and lost its connectivity upstream to its parent channel on the third day of the study period. Existing Google Earth imagery from October 3, 2021, was used to confirm the connectivity of three channels flowing into and out of the study area. The wetted surface area was calculated as the total habitat surficially connected to the main stem of the Snake River (Figure 6).

Channel dimensions were calculated using the existing delineated dataset. A centerline was digitized for each channel that had an area greater than 10 m^2. Total length for each channel was determined using a summation of each channel's centerlines. In instances where the centerline encountered an island or bar, the centerline would follow the apparent majority flow of water around the island or bar. An average width was calculated for each channel by dividing its total area by its total length. Side channel connectivity loss was determined for each channel in both upstream and downstream directions. Side channels were identified as disconnected when surficial connectivity was lost from their parent channel.

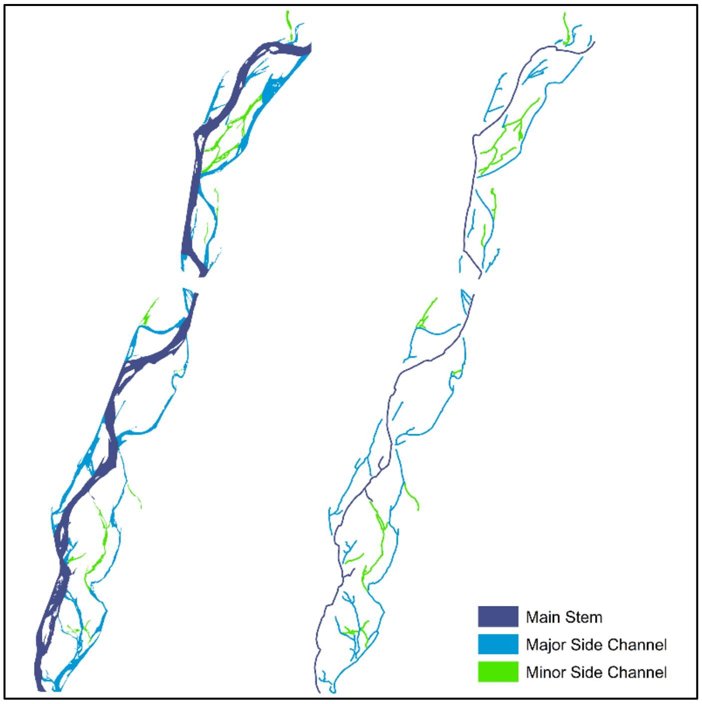

Figure 6. *Channel classification for connected channels (left). Visual centerline for the connected channels of the Snake River (right).*

Data Analysis

The total wetted surface area, side channel connectivity, and channel dimensions were computed and stored in attribute tables associated with the ArcGIS shapefiles. Discharge records for the streamgages of interest were queried from the USGS public data repository, retrieved, and stored for the study period (US Geological Survey 2022). Coefficients of determination (R^2) were developed for the wetted surface area and streamgage discharges.

Instantaneous streamgage discharges were queried for 12:00 pm MT on each day of the study period, as the drone flight for each day was approximately centered around 12:00 pm MT.

Attribute tables from the digitized dataset were exported from ArcMap 10.3.1 and imported into R. Data analysis was conducted using R, RStudio, and the ggplot2, lubridate, and dplyr packages in R (Grolemund and Wickham 2011; Wickham 2016; R Core Team 2021; Wickham et al. 2021).

3 - RESULTS

Surface Area

Results of the drone imagery analysis show that from October 1 to October 5, the Snake River within the study area lost 23% of its connected surface area (Table 1). The largest decrease in surface area observed during the study area occurred between October 1 and 2, where the Snake River lost 8.2% of its surface area. The largest decrease in discharge, from 12:00 pm to 12:00 pm MT, also occurred between October 1 and 2, where JLD releases decreased from 1,840 cfs to 1,270 cfs.

The relationship between discharge at the three streamgages and measured surface area is provided in Figure 7. To calculate a coefficient of determination from a linear regression, each discharge value at 12:00 pm MT was extracted. This time was the estimated midpoint of the duration of each drone flight and an appropriate value to provide equal time intervals between sample days. The linear regression coefficients (R^2) between discharge at three streamgages nearest the study area and the corresponding surface area for the date of measure are provided. The strongest correlation was observed with the farthest downstream streamgage, USGS 13018750 Snake River below Flat Creek, and the least strong correlation was observed with the streamgage at JLD, streamgage 13011000 Snake River near Moran, WY.

The largest deviation (i.e., residual) from a linear regression with the JLD streamgage occurred between October 2 and 3, where releases from the dam decreased from 1,270 cfs to 1,060 cfs. A similar deviation from the regression with the Snake River at Moose streamgage occurred between October 3 and October 4, where discharges at Moose decreased from 1,580 cfs to 1,550 cfs. No deviation from the linear regression occurred with the streamgage USGS 13018750 Snake River below Flat Creek (R^2 = 1).

Table 1: *Snake River discharge at two streamgages and measured surface area. All discharges occur at 12:00 pm MT.*

Date	Discharge at JLD (cfs)	Discharge at Moose (cfs)	Snake River Surface Area (m^2)	Surface Area Change (%)
October 1	1840	2620	519,777	-
October 2	1270	2100	447,041	−8.2
October 3	1060	1580	437,935	−15.7
October 4	714	1550	427,478	−17.8
October 5	248	961	398,391	−23.4

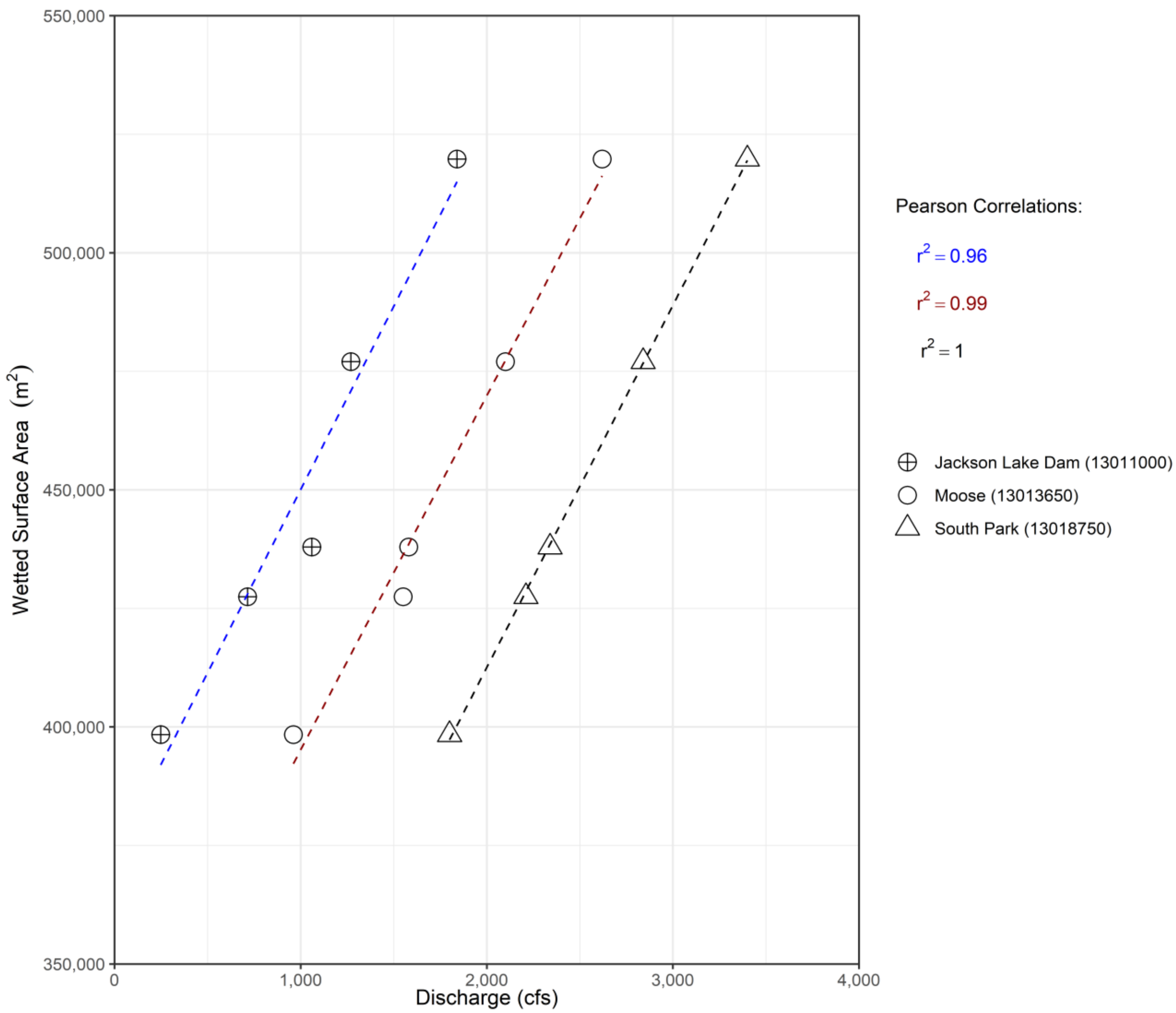

Figure 7. *Instantaneous discharge at 12:00 pm at three USGS streamgages and measured Snake River wetted surface area.*

Side Channel Connectivity

During the study period and within the study area, a total of three major side channels lost surficial connectivity from the Snake River's main stem. In addition, five minor side channels lost surficial connectivity, totaling eight channels disconnected from the main stem during the study period (Table 2; Figure 8). Between October 1 and October 2, two major and three minor side channels lost connectivity, making it the day with the largest loss of connected side channels. This loss in connectivity to the rest of the available habitat was experienced in both the upstream and downstream directions, isolating the channel from the main stem of the Snake River (Figure 8). A total of 11 side channels lost upstream surficial connectivity to the Snake River, of which six retained downstream connectivity. Seven side channels lost downstream surficial connectivity to the Snake River during the study period. In all but one case, upstream connectivity was lost before downstream connectivity during the study period. No side channels lost downstream connectivity while retaining upstream connectivity through October 5. The channels that lost upstream connectivity are displayed in Figure 9, and the channels that lost downstream connectivity are displayed in Figure 10.

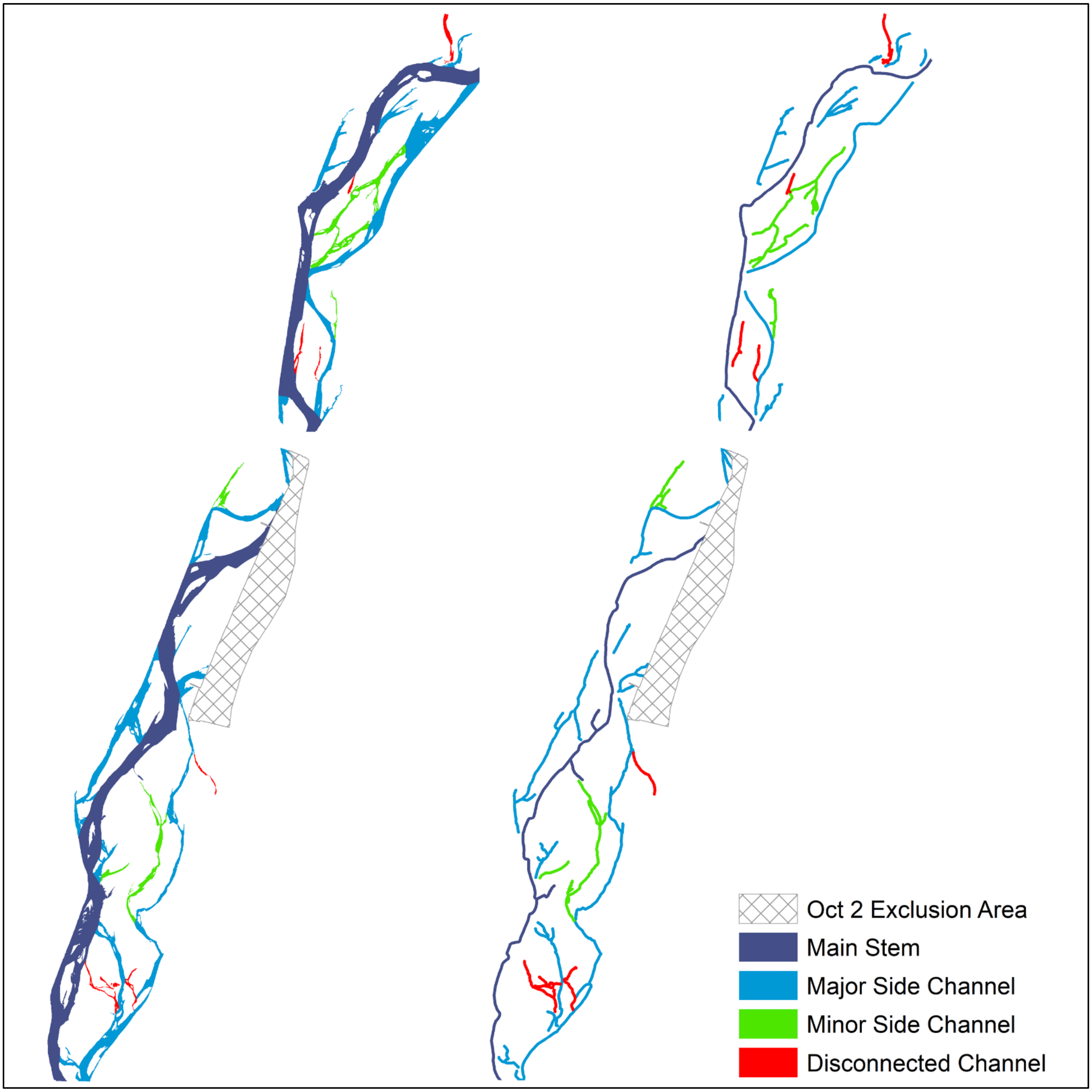

Figure 8. *Flowing channel polygons (left) and centerlines (right) on October 1, 2021. Channels highlighted in red were disconnected from the rest of the available habitat in both an upstream and downstream direction during the study period (Oct 1-5, 2021).*

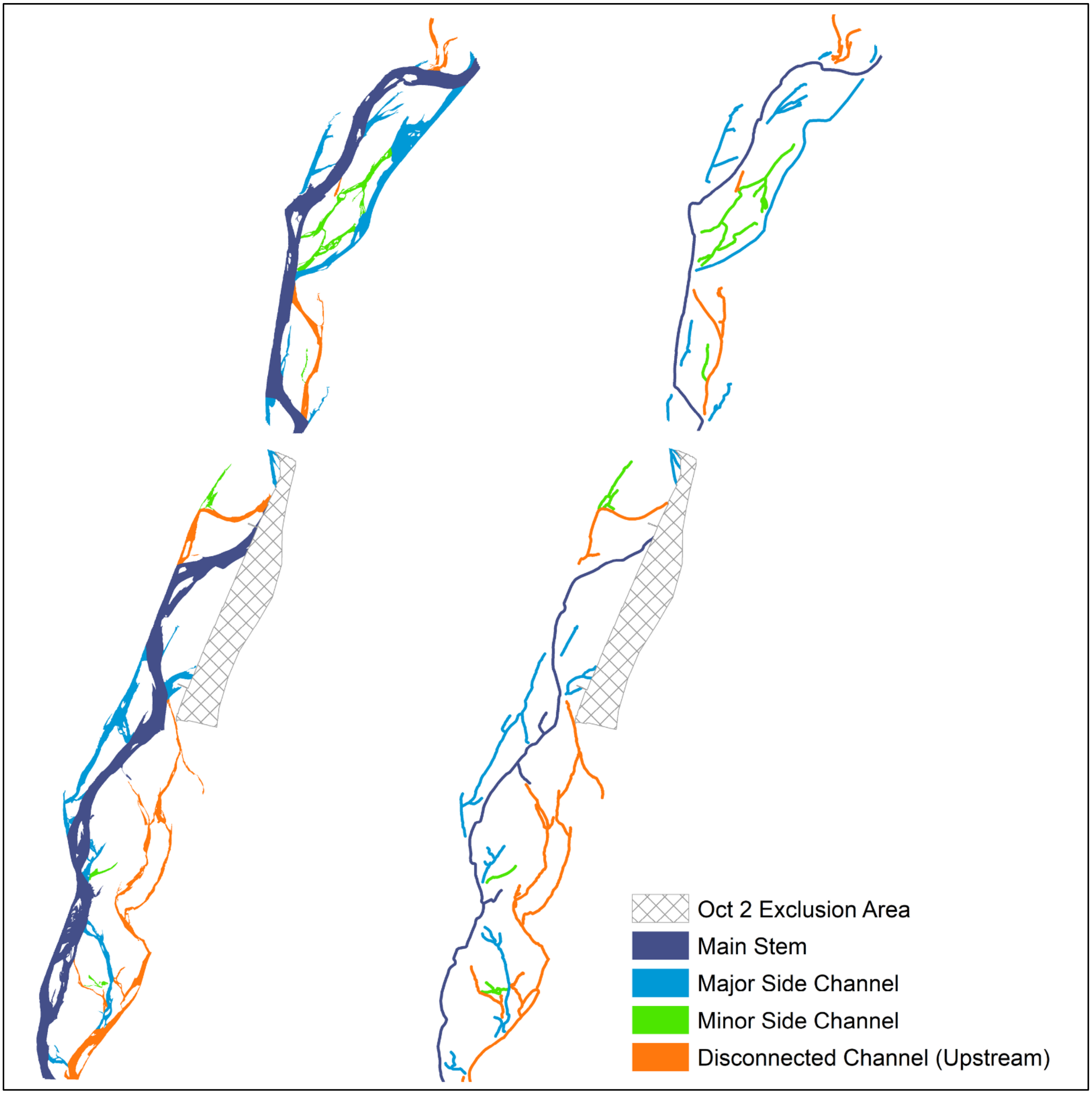

Figure 9. *Flowing channel polygons (left) and centerlines (right) on October 1, 2021. Channels highlighted in orange were disconnected from the rest of the available habitat in an upstream direction during the study period (Oct 1-5, 2021).*

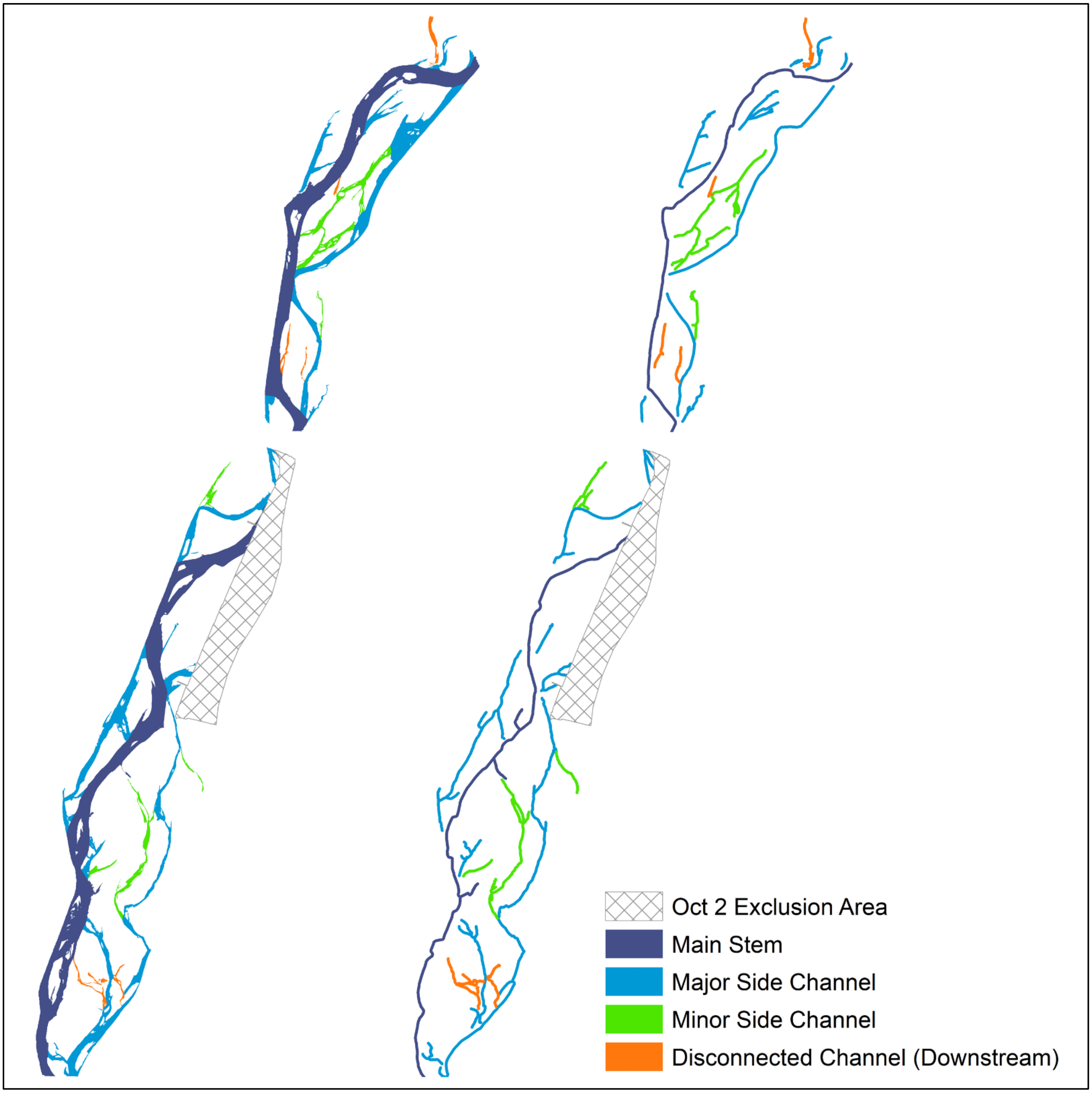

Figure 10. *Flowing channel polygons (left) and centerlines (right) on October 1, 2021. Channels highlighted in orange were disconnected from the rest of the available habitat in a downstream direction during the study period (Oct 1-5, 2021).*

Table 2: *Side channel connectivity in the Snake River study area.*

Date	Side channels connected to the Snake River	Major side channels connected to Snake River	Minor side channels connected to Snake River	Side channels disconnected in upstream direction	Side channels disconnected in downstream direction
October 1	31	20	11	-	-
October 2	26	18	8	4	5
October 3	25	18	7	4	1
October 4	24	18	6	2	1
October 5	23	17	6	1	0

Channel Dimensions

The average width of connected channels within the study area decreased 9.9% during the study period (Table 3). Snake River main stem average width decreased by 12.2%. Major side channel average width decreased 19.6%, while minor side channel average width was variable and ultimately decreased by 2.4%. The largest change in average channel width occurred between October 2 and October 3, where average channel width decreased by 9.3%.

Major side channel length decreased by 4.5%, while minor side channel length increased by 25.5% during the study period. The largest decrease in major side channel length occurred between October 3 and 4. The largest increase in minor side channel length occurred between October 3 and 4.

There was not a strong correlation between flowing channel width and streamgage discharge, nor was there a strong correlation between flowing channel length and discharge. Histograms of average channel width are provided (Figure 11).

The percentage of total area loss attributed with channel isolation was calculated by dividing the area of lost channels by the total surface area loss on each day of the study period. On October 2, the day where the largest number of flowing channels were isolated from the study area during the study period, the percentage of area loss attributed to channel isolation was 12.4%. On October 3, the percentage of area loss attributed to channel isolation was 7.1%. On October 4 and 5, the percentage of area loss attributed to channel isolation was 1.7% and 1.5%, respectively. As a percentage of total area loss during the entire study period, channel isolation accounted for 7.2% of total area loss in the study area.

Table 3: *Side channel dimensions in the Snake River study area. Standard deviations are reported in parentheses.*

Date	Avg. width of connected channels (m)	Calculated main stem width (m)	Avg. major side channel width (m)	Avg. minor side channel width (m)	Avg. major side channel length (m)	Avg. minor side channel length (m)
October 1	13.1 (10.0)	53.1	13.8 (7.5)	8.2 (4.2)	524.0 (534)	410.2 (367)
October 2	13.5 (10.2)	52.4	13.3 (7.4)	9.1 (4.0)	541.2 (556)	458.2 (383)
October 3	12.3 (9.9)	50.1	11.7 (6.8)	8.2 (4.3)	525.6 (546)	452.6 (431)
October 4	12.4 (9.8)	49.4	11.5 (6.7)	8.7 (3.7)	499.7 (556)	516.0 (428)
October 5	11.8 (9.4)	46.6	11.1 (6.4)	8.0 (3.0)	500.6 (557)	512.6 (428)

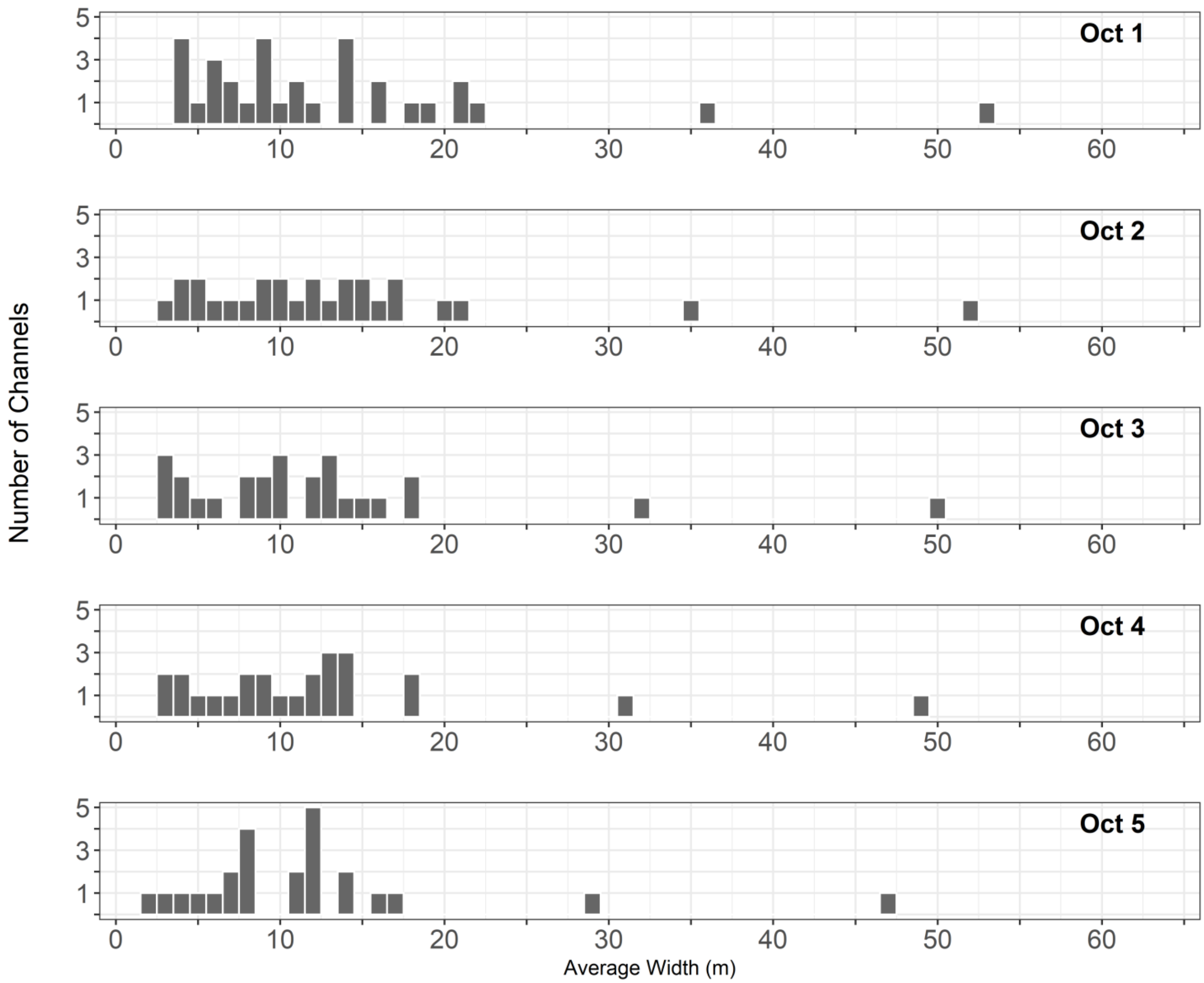

Figure 11. *Histograms of number of channels classified by average channel width.*

4 - DISCUSSION

Overview

Remote sensing is seeing increased application in fisheries and river management (Dauwalter et al. 2017), and we leveraged drone-based aerial imagery to understand how rapid rampdown of Snake River flows from JLD influenced main channel and side channel habitat. The most significant effects from the rampdown occurred between October 1 and October 3, in terms of surface area decreases and side channel connectivity losses. This study demonstrated that the largest deviation from a linear regression between discharge measured at a streamgage and surface area measured within the study area occurred between October 2 and 3, when releases at JLD decreased from 1,270 to 1,060 cfs. This deviation from the linear regression suggests that an inflection point may exist at this discharge where surface area decreases more rapidly with changing flows. This has implications for aquatic species that need time to move out of present habitat into deeper water before habitat is isolated or completely dewatered.

A linear relationship between discharge and surface area ($R^2 = 1$) was observed at the streamgage furthest downstream from JLD, USGS 13018750 Snake River below Flat Creek. This may be the result of tributary inputs and irrigation withdrawal and return decoupling changes in discharge at JLD from the study area. Previous investigations of braided river discharge dynamics using orthorectified images reveal a similar linear or curvilinear relationship between discharge and effective width of the river system (Smith 1997; Ashmore and Sauks 2006). This study used five sample points of surface area and side channel dimensions, which is a small amount of sample points to rely on for a linear regression. It should be noted that a larger sample size, including more points before and after rampdown, would strengthen the ability to define discharge and channel dimensions as a linear relationship.

A decreasing trend in the histogram of side channel width of measured channels indicates channels are constricting during the study period. There were instances where minor side channel length increases were documented. This appears to be due to bifurcation of these minor side channels as they lost discharge. Because these channels were not separated further as they lost discharge, their total length increased.

The side channels that lost connectivity to the main stem of the Snake River were identified during this study period. A significant opportunity exists to use data from this study to predict channels that will lose connectivity in future rampdown years, although channel geomorphology changes through time will impact this subset of side channels.

Recommendations

The most recent instream flow study on the Snake River, completed in 1989, recommended a JLD release of 1,286 cfs during the winter season to provide fisheries maintenance flows and maximize side channel habitat retention in the river segment between Pacific Creek and Moose (Annear 1989). However, this study area is 58 km below the dam and lag time is a significant factor in affecting these flows. A lag time of 10.5 hours from JLD to the study area, using approximate float times of recreational trips, is estimated. When adjusted for lag time, a similar deviation from a linear regression is observed near 1,040 cfs, measured at JLD.

Prior agreements recommend a minimum winter release from JLD of 280 cfs. In addition, the Bureau of Reclamation makes releases at JLD based on best available information and the needs of allocated water rights downstream of JLD. Ideally, this study provides additional data regarding the dynamics that result from JLD release rampdowns, which can be built upon with further studies.

Rampdown rate is one of the strongest predictors of fish stranding found in previous research (Hunter 1992; Bradford et al. 1995; Irvine et al. 2009; Dauwalter et al. 2013). As it is expected that side channels will lose connectivity with the main stem of the Snake River during baseflow recession and transition to winter flows, a longer rampdown period that mimics more natural recession should minimize stranding and provide fish populations time to transition to deeper channels.

Challenges and Constraints

The study area was located completely within a section of levee that results in a net loss of streambed material and elevation, unlike the depositional regime characterized above the levee section (Leonard et al. 2017). Erosive forces within the levee system may result in a channel isolation regime during rampdown that differs from previous studies of instream flow within the un-leveed section of the Snake River, closer to JLD.

This study was performed in two lateral dimensions. Many datasets exist for three-dimensional assessments of channel change, and a study performed at this temporal scale at three dimensions would provide information of channel depth and slope that offer additional insight into dewatering dynamics. LiDAR (Light Detection and Ranging) data exists for the entirety of the Snake River below Jackson Lake Dam, and metrics like Normalized Difference Water Index (NDWI) using near-surface infrared (NIR) data provide for opportunities to analyze change in surface water features over time. However, the collection frequency of these datasets is often much coarser than daily recurring drone flights, as used in this study.

A drone flight on October 6th, 2021, was not possible due to weather conditions. However, a sixth flight would have provided an opportunity to assess further dewatering within the study area after releases from JLD were at a minimum. In addition, a drone flight on September 30th, 2021, would have identified pre-rampdown conditions in the study area, and additional information on isolated channels at flows above 1,800 cfs, measured at JLD.

Fisheries surveys were conducted by Wyoming Game and Fish Department (WGFD) staff in the Snake River during the rampdown, but no fisheries data were incorporated into this study. WGFD has begun to perform annual surveys during and after the rampdown period to assess population trends. Annually recurring fisheries surveys provide an opportunity to determine the change in native fishery population estimates year over year, but do not necessarily encapsulate all direct effects from JLD on the fishery.

Study Applications and Further Information Needs

A similar approach to what was taken in this study could be applied to data acquired on a more regular basis without significant effort. 10, 20, and 60 m resolution Sentinel-2 imagery collected at mid-latitude locations every two to three days has the opportunity to address the vast range in habitat surface area and channel dimensions experienced by the Snake River during the entire water year. If the resolution difference is acceptable between hand-delineated river extent from orthorectified drone imagery and a similar analysis from Sentinel-2 imagery, this study could be repeated over a vast majority of flow regimes.

Aerial imagery can also be used to produce digital elevation models using modern digital photogrammetric techniques. Using a combination of historical imagery and orthorectified imagery, it has been shown that from these depth-based products it was possible to assess bank erosion, channel bar movement, and channel infilling over time in braided river systems (Lane et al. 2010). Additional methods provided by recent studies use aerial imagery datasets to calculate bar migration rate and bedload sediment fluxes (Strick et al. 2019).

This study area, with its relatively consistent historical aerial imagery and high-resolution infrared imagery available, is a strong candidate for additional investigations of short- and long-term channel change by these and other methods.

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6 - DISCLAIMER

The Snake River Rampdown Drone Imagery technical report and data used for this study are available for public use. Please cite Teton Conservation District (TCD) as the data author. End user assumes all responsibility for interpretation or misinterpretation of these products.

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