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Feasibility of Estimating Salmon Abundance in the Koyukuk River Using Sonar, 2025

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Cover: Sonar tent near the Koyukuk River.

Feasibility of Estimating Salmon Abundance in the Koyukuk River Using Sonar, 2025

Shane R. Ransbury

Abstract

The Koyukuk River is a major tributary to the Yukon River and supports several fisheries for Chum Salmon (*Oncorhynchus keta*), Chinook Salmon (*O. tshawytscha*), and whitefish (*Stenodus, Coregonus,* and *Prosopium* spp.). In 2025, feasibility work began regarding a mainstem Koyukuk River sonar project to enumerate annual fish passage. After initial review using remote sensing, boat-based bathymetric surveys were conducted between the junction of the two primary Koyukuk River mouths and the confluence of the Gisasa River. These surveys unveiled five candidate sites for a future large-scale sonar project, of which the most promising two were trialed with DIDSON imaging and HTI split beam sonars to determine fish passage orientation (i.e., distance from shore and depth). The trials took place at two sites near the Alaska Department of Fish and Game (ADFG) Check Station from June 30 to July 9 during high water. Water temperatures exceeded the 18°C threshold for fish heat stress in 84 out of 194 hours (43.3%). The site closest to the Check Station appeared reasonable as a site for future sonar work with more than 95% of the upriver-swimming fish observed in the area ensonified by the DIDSON passing within 17 m of shore on north bank and 29 m on south bank. In the split beam, more than 95% of the upriver-bound targets were within 15 m of north bank and 53 m of south bank, although the range on north bank was severely restricted. Future feasibility work must investigate (1) the estimated proportion and count of each fish species transiting the site, (2) the optimal split-beam sonar settings and configuration required by the site, (3) the optimal timing for sonar operation at the site, and (4) whether Nikolai Slough is allowing fish passage that would cause a sonar project at the site to under- or overestimate fish passage into the Koyukuk River.

Introduction

Summer Chum Salmon (*Oncorhynchus keta*) are the main food fish used in subsistence fisheries in the Yukon River drainage (Ransbury et al. 2022; Padilla and Scurr 2025). Annual returns of summer Chum Salmon adults are assessed using the Pilot Station sonar and the Andreafsky River aerial survey (both forks) to estimate the drainagewide escapement for the stock. In addition to the drainagewide goal of 500,000–1,200,000 fish, there are two localized escapement goals, one on the Anvik River (with a goal of 350,000–700,000 fish) and another on the East Fork of the Andreafsky River (>40,000 fish; Ransbury et al. 2022). Using single nucleotide polymorphisms (SNPs), the summer Chum Salmon stock can be broken into three distinct groupings: Lower Yukon, Upper Koyukuk and Mainstem, and Tanana (Flannery et al. 2010, McKinney et al. 2022, JTC 2025). Two of these groups spawn in the Koyukuk River (Flannery et al. 2010; Larson et al. 2017). The Lower Yukon genetic grouping includes fish spawning between the Yukon River mouth and approximately the village of Hughes in Koyukuk River drainage, and the Koyukuk and Mainstem reporting group includes the upper Koyukuk River drainage and the Tozitna River, a tributary to the mainstem Yukon River (Flannery et al. 2010). Since the fish returning to the Koyukuk River are split between two genetics reporting groups, it is not currently possible to estimate escapement into the Koyukuk River using genetics. Aerial surveys are conducted annually for many of the tributaries, and there are fish counting weirs at the Gisasa River and Henshaw Creek (Ransbury et al. 2022). Subsistence harvest of summer Chum Salmon in the Koyukuk River ranged from 3,509 to 12,152 fish in 2010 through 2020 (Padilla and Hamazaki 2024), but low returns led to severe fishing restrictions in 2020–2024 (JTC 2025), limiting recent harvest (Padilla and Scurr 2025).

Management of summer Chum Salmon subsistence fisheries in the Koyukuk River drainage is based largely on the Koyukuk and Mainstem genetics grouping proportion relative to the Pilot Station sonar passage counts, plus additional information garnered from the Gisasa River weir counts. The Henshaw Creek weir project is a good escapement assessment tool, but it is too far upriver to be used for inseason fisheries management. In addition, both weir projects frequently miss counts or are unable to operate due to high water conditions (Farnham 2018; Carlson 2024; JTC 2025). Creation of a sonar assessment project in the lower Koyukuk River would: (1) provide the first estimates of escapement into the full Koyukuk River drainage, (2) allow managers to regulate inseason subsistence fisheries in the Koyukuk River drainage separately from the Yukon River, and (3) allow for an estimate of how many summer Chum Salmon return to mainstem Yukon River tributaries that are in the Lower Yukon genetic reporting group but do not ascend the Koyukuk River.

Chinook Salmon (*Onchorhynchus tshawytscha*) also enter the Koyukuk River to spawn and are caught in subsistence fisheries (Eiler et al. 2014; Padilla and Harding Scurr 2025). Chinook Salmon have three major and 14 minor spawning areas in the drainage (Brown et al. 2017). Koyukuk-bound Chinook Salmon are assessed similar to Chum Salmon, using Pilot Station genetics-based estimates that include fish from other Yukon River tributaries (JTC 2025). There are no direct estimates for Chinook Salmon escapement in the Koyukuk River drainage because the Lower Yukon genetics reporting group includes areas in the Lower Koyukuk River. However, unlike Chum Salmon, Chinook Salmon have a Koyukuk genetics reporting group that includes the upper Koyukuk River drainage with no populations from the middle Yukon River. The Gisasa weir in the lower Koyukuk River saw an average of 37 fish during the two years that it operated during the same period (2022 and 2023; Farnham et al. 2024; Carlson 2024). Subsistence harvest of Chinook Salmon in the Koyukuk River ranged from 60 to 1,005 fish from 2010–2020 (Padilla and Hamazaki 2024).

Whitefish species in the Koyukuk River include Sheefish (*Stenodus leucichthys*), Broad Whitefish (*Coregonus nasus*), Humpback Whitefish (*C. clupeaformis*), Least Cisco (*C. sardinella*), and Round Whitefish (*Prosopium cylindraceum*). Of these, Sheefish, Broad Whitefish, and Humpback Whitefish are commonly targeted in the subsistence fisheries, and these three species plus Least Cisco migrate to the ocean (Brown et al. 2012). Sheefish enter the Koyukuk River in July and August for their spawning migration to the Alatna River, though some appear to enter the Koyukuk River purely for foraging purposes (Brown and Burr 2012; Brown et al. 2025). An early pulse of Sheefish past the village of Koyukuk, which is located near the confluence of the Yukon and Koyukuk rivers, has also been noted as early as March, but the purpose of that migration is unclear and the fish may remain primarily in the Yukon River. Broad and Humpback Whitefish move up the Koyukuk River during break-up and into June, shortly before the Chinook Salmon arrive, although the pulses of these fish appear to be less distinct (Brown et al. 2012). Whitefish species in the Koyukuk River drainage are not managed to escapement goals or abundance indexes, and it is unknown what their abundance is in most years. A comprehensive traditional ecological knowledge subsistence survey estimated the 2002 subsistence harvest of whitefish in the Koyukuk River at 43,100 kg (95,000 pounds), comprised of approximately 3,000 Sheefish, 7,300 Broad Whitefish, 8,300 Humpback Whitefish, and 7,800 Least Cisco (Andersen et al. 2004). Estimates from the annual subsistence survey for that year are lower (Brase and Hamner

2002), likely due to the difference in methods, and it is possible that the annual harvest estimates for the years since the comprehensive survey skew low as well.

A Koyukuk River mainstem sonar project could improve assessment of salmon and whitefish in the drainage. In recent years, it has become increasingly difficult to maintain salmon assessment projects at the Gisasa and Henshaw rivers due to issues with high river discharge, staffing, and funding (Farnham 2018; JTC 2025). Even if these projects operate, they only report escapement into two key tributaries. Sonar projects are much less likely to be disrupted by high water events, and a project in the lower Koyukuk River may be easier to staff and supply due to its proximity to the communities of Galena and Koyukuk, mainstem Yukon River barge routes, and the U.S. Fish and Wildlife Service (USFWS) Koyukuk, Nowitna, and Innoko National Wildlife Refuge (NWR) complex office. Similar size projects operate annually near the communities of Pilot Station and Eagle on the Yukon River mainstem (JTC 2025), and many of the methods can be adapted for a potential Koyukuk River mainstem sonar project. Sonar projects are expensive, but a mainstem Koyukuk sonar may not be more expensive than the tributary weir projects. The last reported funding levels for the Gisasa (last operated in 2023) and Henshaw (2021) river weir projects combined totaled $355,140 annually (personal communication, Cory Graham, February 5, 2025). In addition, several entities have already expressed interest in future collaboration on the proposed sonar project, which may lead to assistance with long-term funding, including the Native Village of Koyukuk, Tanana Chiefs Conference (TCC), and Alaska Department of Fish and Game (ADFG). For these reasons, the U.S. Fish and Wildlife Service conducted a sonar feasibility study beginning in 2025, with the potential for additional years of feasibility depending on external funding and public feedback.

The overall objective of the Koyukuk Sonar Feasibility Project is to determine whether a sonar project can effectively count summer Chum and Chinook salmon passage into the Koyukuk River while correctly apportioning out passage of whitefish and other nontarget species. For the first year of feasibility conducted in 2025, the following sub-objectives were pursued: (1) conduct bathymetric transects of the Koyukuk River and determine 2-3 candidate sites for a sonar project that meet desired criteria, and (2) operate sonars in the candidate sites to determine fish bank orientation and depth. Due to the turbidity of the Koyukuk River, future years of feasibility will require fishing as part of creation of the species apportionment protocol for the sonar. Additionally, variation in fish passage at different flow regimes will need to be assessed and the timing of the Chinook and summer Chum Salmon runs past the sonar site will need to be established to ensure accurate abundance estimates if a full-sized sonar project is established.

Methods

Study Area

The study area, approximately 97 river kilometers (rkm) in length, extended from a point at the confluence of the Koyukuk River and a slough of the Yukon River approximately 10 rkm upstream of the village of Koyukuk (64.921918° N, -157.552667° W) to a point at the confluence of the Gisasa and Koyukuk rivers (65.263020° N, -157.672092° W; Figure 1). Satellite imagery, topographic maps, and records of spawning locations for Chum and Chinook salmon were used to determine its extent, which ranged from the most downstream major Chum Salmon spawning population in the Koyukuk River drainage to the most downstream point where the Koyukuk River is a single channel. Notably, this study area includes Nicolai Slough, a long meandering slough of the Yukon River, and Woodyard Creek, the furthest downstream tributary of the Koyukuk River that summer Chum Salmon have been observed in (https://experience.arcgis.com/experience/1a4eb07b42ff4ebb8c71ba45adaedf0c/, accessed August 19, 2025). Land ownership in the study area is mixed (Figure 2), and the fish passage spatial orientation portion of the study was confined to lands owned by the Koyukuk National Wildlife Refuge and the Gana-A'yoo Corporation, where explicit permission was obtained for the study to take place.

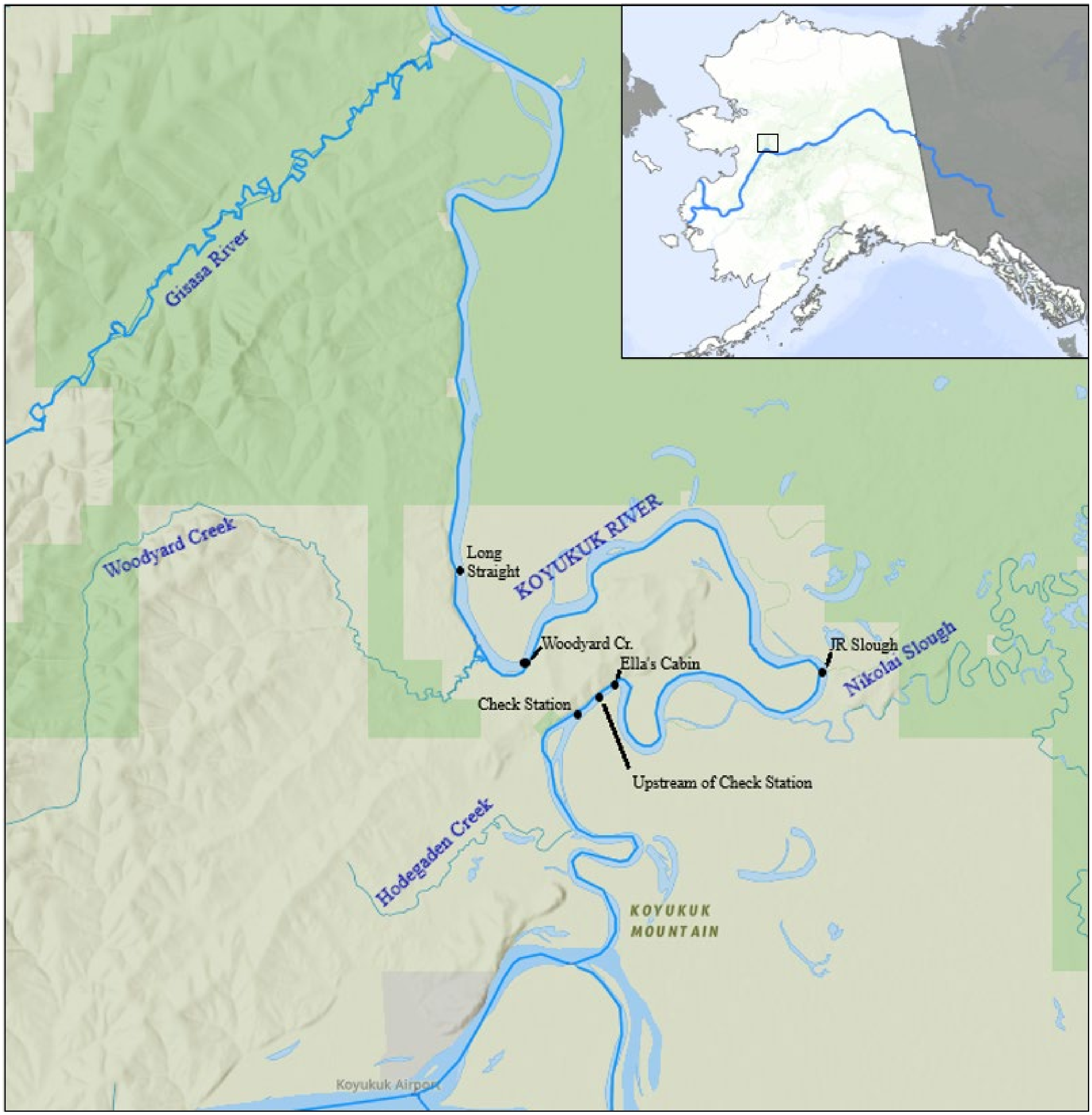


Figure 1. Study area in the Koyukuk River between the confluence of the Gisasa River and the unnamed Yukon River slough near Koyukuk Mountain. Sites discussed in this report are shown as black dots. Basemap is modified from the Anadromous Waters Catalog map (https://www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=main.interactive, accessed October 7, 2024) and a thumbnail by the UAF Geophysical Institute (https://www.uaf.edu/news/wading-into-the-icy-yukon-river-for-science.php, accessed October 7, 2024).

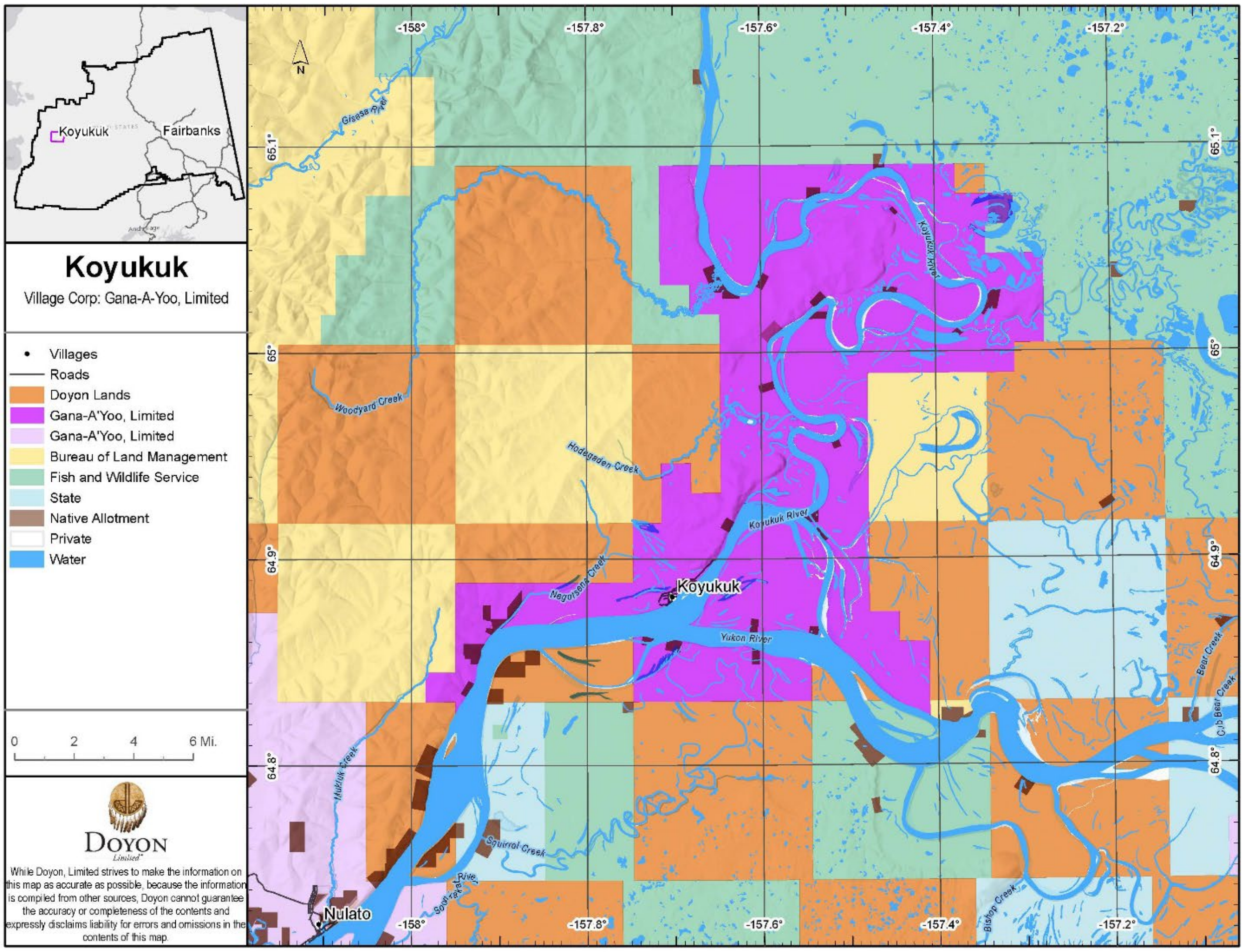


Figure 2. Land status of the study area (https://www.doyon.com/wp-content/uploads/2023/05/Koyukuk-Color.pdf, accessed October 7, 2024).

Site selection

Prior to field work, 9 areas of interest (AOIs) in the study area were identified, through communication with local residents and examination of satellite imagery and topographic maps, as having a single channel with a raised area on one side to mitigate flooding. The study area was transited by boat on June 24, 2025, to search for viable future camp areas near these locations with:

- Room for multiple wall tent platforms;
- Nearby water from a tributary stream with little to no silt content;
- Relatively clear bank area on both sides of the river, so that sonar pods can be easily moved up or down the bank to accommodate for water level;
- Enough topography on each bank to avoid or mitigate flooding events;
- An area where an outhouse could be dug;
- A reasonable view of the southern sky on at least 1 bank to make solar power viable;
- No obvious riverbed substrate issues such as jutting bedrock that disrupt sonar imaging; and
- No braids in the river immediately in front of the camp area.

On June 25, a boat-mounted Hummingbird Helix 7 MSI GPS G3 depth finder and Hummingbird 408920-1 AS GRP external GPS receiver were used to scan the river bottom in slow transects perpendicular to the flow of water and traveling completely across the river in the 9 AOIs. If site conditions were poor, only a few transects were taken, but better sites or areas of higher interest had at least 10 transects taken to produce bathymetric maps. A recreational fish finder was chosen due to its low cost and availability on smaller vessels, allowing for shallower transects (Ridgeway et al. 2024). In addition, boat pitch, roll, and yaw have been shown to have a negligible effect on depth readings from recreational fish finders (Bio et al. 2022). Transect data were saved on a microSD card and transferred to a computer at the end of each day. The data were processed in Reefmaster2 (ReefMaster Software Ltd.) to create bathymetric maps of each area that show depth, relative roughness, and relative hardness.

The bathymetry maps, corresponding camp conditions, and nearby land status were assessed to identify 2–3 candidate sites for deployment of two DIDSON (Sound Metrics Corp) imaging sonars and a Hydroacoustic Technology Inc. (HTI) Model 243 split-beam sonar. A site with ideal bathymetry would have: (1) smooth, sloped transition from the bank to the thalweg, with no areas that will obstruct a transiting fish from the sonar's view; (2) uniform, non-turbulent flow; (3) a single thalweg near the middle of the river; and (4) a bottom substrate somewhere between cobble and gravel, with no "soft" spots that suggest a sandbar may form over time. These sonars were operated from shore, so sites were limited to Koyukuk National Wildlife Refuge and Gana-A'yoo lands where permission was granted for camping.

Determination of spatial orientation of transiting fish

From June 30 through July 9, 2025, small sonar camps were operated at the candidate sites. The DIDSONs and split-beam sonar were mounted on pods side by side as close as possible to each other without creating interference on the echograms, which was generally at least 10 m apart, and the sonars were operated on each bank with a target of at least 24 useable hours for each bank covering a full diel cycle. This portion of the project occurred during the expected operational period of a potential future full-scale project. Based on run timing estimates created using the daily Pilot Station passage estimates and an approximation of swim speed, an average of roughly 40% of the summer Chum Salmon (2008–2024) and 58% of the Chinook Salmon (2019–2024) entering the Koyukuk River do so between July 1 and July 14.

Equipment for this phase of the project included the following:

1. Two DIDSON units (12° x 29° nominal beam dimension), configured to transmit and receive at 700 kHz and controlled via software installed on a laptop PC.
2. Two 250 ft (76.2 m) DIDSON underwater cable to connect the DIDSON to the "topside box" and laptop PC.
3. A Hydroacoustic Technology Inc. (HTI) Model 243 echosounder configured to transmit and receive at 120 kHz, controlled via Digital Echo Processing software installed on a laptop PC.
4. An HTI 120 kHz split-beam transducer with a 4° x 10° or 6° x 10° nominal beam width.
5. A 250 ft (76.2m) HTI split-beam transducer cable connecting the sounder to the transducer.
6. A Remote Ocean Systems (ROS) PTC1-DM Pan & Tilt Controller.
7. An ROS Model PT-25 pan and tilt rotator.

DIDSON settings followed the standards established by USFWS for the operation of the Teedriinjik (Chandalar) sonar project (Melegari 2023). The DIDSONs operated in low frequency mode (700 kHz). One DIDSON (hereafter referred to as the "passage DIDSON") was mounted to view fish moving horizontally to establish a passage estimate of upstream fish from 0–30 m. The other DIDSON (hereafter the "depth DIDSON") was mounted sideways to view the depth of targets passing the sonar in an upstream or downstream direction, of which an unknown number would be fish.

Split-beam sonar settings followed the standards established by the Alaska Department of Fish and Game for the operation of the Pilot Station sonar project (Morrill and Lozori 2023). The split-beam sonar transmitted and received at 120 kHz, used a 40 log*R* time-varied gain (TVG), and used a 0.4 millisecond (ms) transmit pulse duration during operation. The receiver bandwidth was automatically determined by the equipment based on the transmit pulse duration. The angle of transducer used on each bank was selected based on the bank profile observed during bathymetric transects, with a smaller angle used on shallower slopes.

Split-beam sonar ranges were set so that the combined range of the right and left bank split-beam sonars would cover roughly half of the river's width at the site as determined by the bathymetry transects. The ping rate was set as an integer below the maximum ping rate calculated by the formula:

$$Ping_{max} = \frac{1450\ m/s}{2(R)} \tag{1}$$

Where *R* is the range in meters. The effective ranges of the split-beam sonars were shortened from *R* due to the aim and unique bathymetry at each location.

Transducers of both sonars were placed as close to shore as possible, depending on the water level. The DIDSON sonars were mounted on brackets that allow for manual aim adjustments to be made. The split-beam transducer was on a rotator to make it easier to make fine aim adjustments. Transducers faced perpendicularly away from the bank to maximize fish detection, with an allowable range of 15° off perpendicular in the upstream and downstream directions to ensure optimal aim in each location. Care was taken to ensure that the sonars were aimed slightly above the riverbed through as much of the range as possible. Once an optimal aim was obtained, the rotator settings were documented for each site and each subsequent aim correction. The downward tilt angle of the depth DIDSON was not measured, so the sonar was angled downward until the riverbed was in view. Bathymetric transects taken by boat were then compared to the location of targets traveling along the riverbed to create an approximation of target depth. All target depths reported by the depth DIDSON are therefore estimates.

Sonar Data Collection and Analysis

Hourly fish passage rates for each bank were plotted for the season and examined for diel patterns. Range distributions of fish targets were evaluated to consider the likelihood of fish passing beyond the detection range of the DIDSON and split-beam sonars, though this will not be able to be confirmed until further research is conducted.

Water Monitoring

A calibrated Tidbit v2 HOBO temperature logger (Onset Computer Corp.) was deployed at the ADFG Check Station during July 2–9 to monitor water temperature during the study. Chinook Salmon are susceptible to heat stress in warm water >18 °C and in 2019, Chum Salmon experienced a mass mortality event, likely due to heat stress, in the Koyukuk River drainage (von Biela et al. 2020, 2022). Water temperatures were therefore important to record, as a largescale Koyukuk River mainstem sonar project would be an important monitoring tool for heat stress.

Results

Candidate Site Selection

Field examination of the bathymetric, bank, and nearby camp characteristics of the nine AOIs identified five candidate sites where conditions were adequate to warrant creation of bathymetric maps (Table 1; Figure 1; Appendices A1–A2, A4–A6). In addition, a bathymetric map of the area in front of Ella's Cabin (65.024853 °N, -157.530441 °W) was created due to the high amount of public input we received regarding that site, though the poor bathymetry at this location excluded it from further investigation (Appendix A3).

Table 1. List of candidate sites ordered from downstream to upstream.

Candidate Site	*Coordinates*
Check Station	65.01497 °N, -157.55725 °W
Upstream of Check Station	65.01977 °N, -157.54296 °W
JR Slough	65.02760 °N, -157.34533 °W
Woodyard Creek	65.03310 °N, -157.60866 °W
Long Straight	65.06553 °N, -157.66668 °W

Only 2 of the 5 candidate sites were further examined with the DIDSON and split-beam sonars, largely due to issues with land status. All 5 candidate sites had at least 1 bank owned by Gana-A'yoo, and none were on the Koyukuk NWR. The Upstream of Check Station, JR Slough, and Woodyard Creek sites all had Native allotments on at least one bank, where approval from the owners was not obtained prior to the 2025 field season. Meanwhile, the Long Straight site had issues with a slight underwater "hump" near the shore of both banks where fish could pass undetected. Although it is possible that there are a few areas of the site with a good sonar image, it was also the furthest site from the village of Koyukuk and upstream of Woodyard Creek, where 106 spawning condition Chum Salmon were observed in 2014 (https://www.adfg.alaska.gov/FDDDOCS/NOM_PDFs/INT/15-111.PDF, accessed August 19, 2025).

Further investigation was centered around the Check Station site due to its reasonable bathymetry, good potential south facing camp location, a slightly turbid water source, and proximity to the village of Koyukuk. Both sides of the Check Station site were owned by Gana-A'yoo, and permission was obtained in-season to use the ADFG camp located at this site on north bank. The nearby Upstream of Check Station site was also further examined on north bank (owned by Gana-A'yoo) due to its excellent bathymetry, excellent potential south-facing camp location, a clear water source, proximity to the village of Koyukuk, and potential for a reasonable south bank sonar spot downstream of a nearby Native allotment.

Sonar Data Collection and Analysis

In 2025, data collection operations began on north bank of the Upstream of Check Station site at 7:00 P.M. on June 30, rotated to south bank of the Check Station site, and finished on Right Bank of the Check Station site at 10:34 A.M. on July 9, for a total of 152.6 hours of passage DIDSON, 103.2 hours of the depth DIDSON, and 105.3 hours of HTI split beam (Table 2). The goal of 24 hours of counts for each sonar at each site was met, and each site had at least 24 hours of the passage DIDSON and split beam operating at the same time so that target passage through the overlap in their ranges, generally around 5–30 m, could be compared.

Due to turbidity and other factors, the DIDSON sonars generally had an effective range of around 30 m, but were able to clearly ensonify 40 m in some instances. The transects suggested that the river was roughly 254–289 m in width at the Upstream of Check Station site and 311–392 m at the Check Station site. At both sites, north bank was steeper than south bank and there was a long, relatively shallow slope to the thalweg at ~10 m depth (Figures 3 and 4). The spacing between the sonars led to slight variability in the transects ensonified, and sonar placement was shared between the DIDSON sonars (with no temporal overlap) on the north bank of the Check Station site because of difficulty finding good installation spots there. The HTI split-beam sonar was initially planned to detect from 0 to 150 m depending on the site and bank (Table 3), but due to a desire to have overlap in the split-beam and passage DIDSON images, the split-beam was angled further down than normal and was only effective out to 40–125 m depending on the site.

The differences in sonar placement, timing, and output clarity introduced errors into any comparisons sought between the sonars, but a reasonable sample size was acquired for each location (Table 4). The passage DIDSON gave the best image and could identify both the presence of fish and their direction of travel. The depth DIDSON could not identify the targets as fish nor determine the direction of travel but could determine depth. The split-beam sonar could observe the direction of movement, but it was not possible to confirm that the upstream moving targets were fish, though the upstream movement of other animals is likely insignificant compared to fish passage. Downriver-swimming fish were counted in the passage DIDSON due to the clarity of its image. Downriver targets were not counted in the split-beam images due to the significant amount of floating and submerged driftwood, which were difficult to differentiate from fish. In the depth DIDSON, direction of travel was unknown, so both upriver and downriver oriented fish were counted together. Due to the large amount of driftwood, the targets recorded by the depth DIDSON are inflated and do not represent the true number of fish that passed by, though it is likely that most driftwood was at the surface and had a depth near zero. An uninterrupted 24-hour diel period was obtained for each sonar and site except for slightly over 2 hours in the depth DIDSON at the Upstream of Check Station site, and 12 hours in the North Bank Check Station site.

Table 2. Start and stop times of the sonars at each site.

	Start	Stop	Hours
Upstream of Check Station (North Bank)			
Passage DIDSON	6/30/25 7:59 PM	7/5/25 12:59 AM	101.0
Depth DIDSON	6/30/25 7:00 PM	7/2/25 8:37 AM	37.6
HTI Split Beam	7/4/25 11:38 AM	7/5/25 1:14 PM	25.6
Check Station (North Bank)	Start	Stop	Hours
Regular DIDSON	7/8/25 9:34 AM	7/9/25 10:34 AM	25.0
Depth DIDSON	7/6/25 8:55 PM	7/7/25 9:07 PM	24.2
HTI Split Beam	7/7/25 9:49 PM	7/9/25 10:01 AM	36.2
Check Station (South Bank)	Start	Stop	Hours
Regular DIDSON	7/5/25 6:08 PM	7/6/25 8:45 PM	26.6
Depth DIDSON	7/2/25 3:01 PM	7/4/25 8:23 AM	41.4
HTI Split Beam	7/5/25 6:50 PM	7/7/25 3:15 PM	44.4
Totals			Hours
Passage DIDSON			152.6
Depth DIDSON			103.2
HTI Split Beam			105.3

Figure 3. Depths (m) recorded in the transects in front of each sonar at the Upstream of Check Station site, looking downstream.

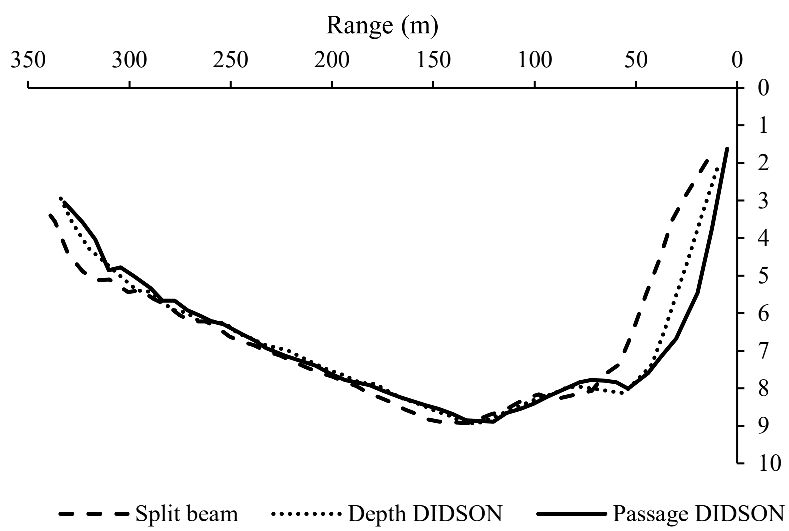


Figure 4. Depths (m) recorded in the transects in front of each sonar at the Check Station site at (A) south bank and (B) north bank, looking downstream.

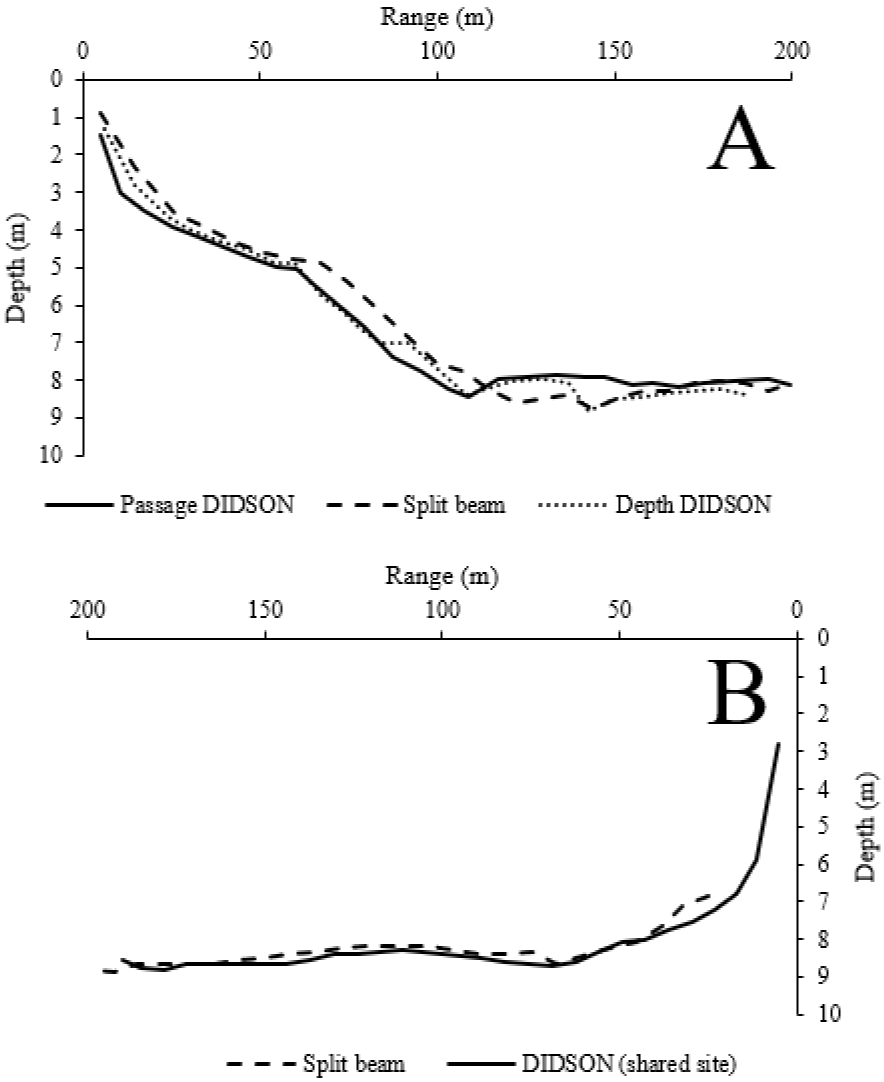


Table 3. Initial split-beam sonar settings at the Koyukuk River Sonar Feasibility Project, 2025.

Site	*Component*	*Setting*	*Left Bank*	*Right Bank*
Upstream of Check Station	Transducer	Beam size (h x w)		6°x10°
	Echosounder	Transmit power (dBW)		20
		Time varied gain (dB)		-4
		Receiver gain (dB)		-6
		Source level (dBµPa @ 1m)		211.16
		Through-system gain (dB)		-171.93
		Pulse width (ms)		0.4
		Blanking range (m)		0
		Ping rate (pps)		5
		Range (m)		0 to 100
Check Station	Transducer	Beam size (h x w)	4°x10°	6°x10°
	Echosounder	Transmit power (dB)	21	21
		Receiver gain (dB)	-4	-4
		Source level (dBµPa @ 1m)	-6	-6
		Through-system gain (dB)	-169.83	-171.93
		Pulse width (ms)	0.4	0.4
		Blanking range (m)	0	0
		Ping rate (pps)	4	4
		Range (m)	0 to 150	0 to 120

Table 4. Number of fish traveling in both directions in the passage DIDSON, targets traveling both directions in the depth DIDSON, and targets traveling upstream in the split-beam sonar observed during the Koyukuk River Sonar Feasibility Project, 2025.

	Upstream of Check Station			Check Station		
	DIDSON			DIDSON		
	Passage	Depth	Split-beam	Passage	Depth	Split-beam
Right (north) bank	2,970	2,846	648	790	484	411
Left (south) bank				2,111	2,367	3,732

Upstream of Check Station Site

At the Upstream of Check Station site, range distribution data indicated that upriver swimming fish (passage DIDSON) and targets (split beam) were shore-oriented and that most were within the sonar range (Figures 5 and 6). However, at this site, only north (right) bank was ensonified, and the split-beam sonar was unable to pick up fish at distances over 32 m. This shortened range in the split-beam sonar was due to the desire to have overlap in the DIDSON and split-beam sonar ensonified area, which introduced issues after 50 m when the bottom leveled out, coupled with a potential blind-spot at 30–50 m produced by a slight rise in the bathymetry of the split beam’s transect around 30 m (Figure 3). Using the DIDSON, more than 95% of upriver swimming fish were within 25 m of the bank (max range ~30 m; Figure 5). In the split beam, more than 95% were within 26 m of the bank (Figure 6). No clear diel trends in fish passage were observed in the DIDSON (Figure 7), but the split-beam sonar did observe more fish between 6 P.M. and 6 A.M. than during midday (Figure 8). Targets passing the site were generally either at the surface (likely indicative of driftwood) or near the bottom, and no clear diel patterns in depth were observed (Figure 9).

Figure 5. Upstream (A) and downstream (B) fish passage observed within the DIDSON range at the right (north) bank of the Upstream of Check Station site over 101.0 hours. Although the sonar was set to 40 m, image quality deteriorated after 30 m.

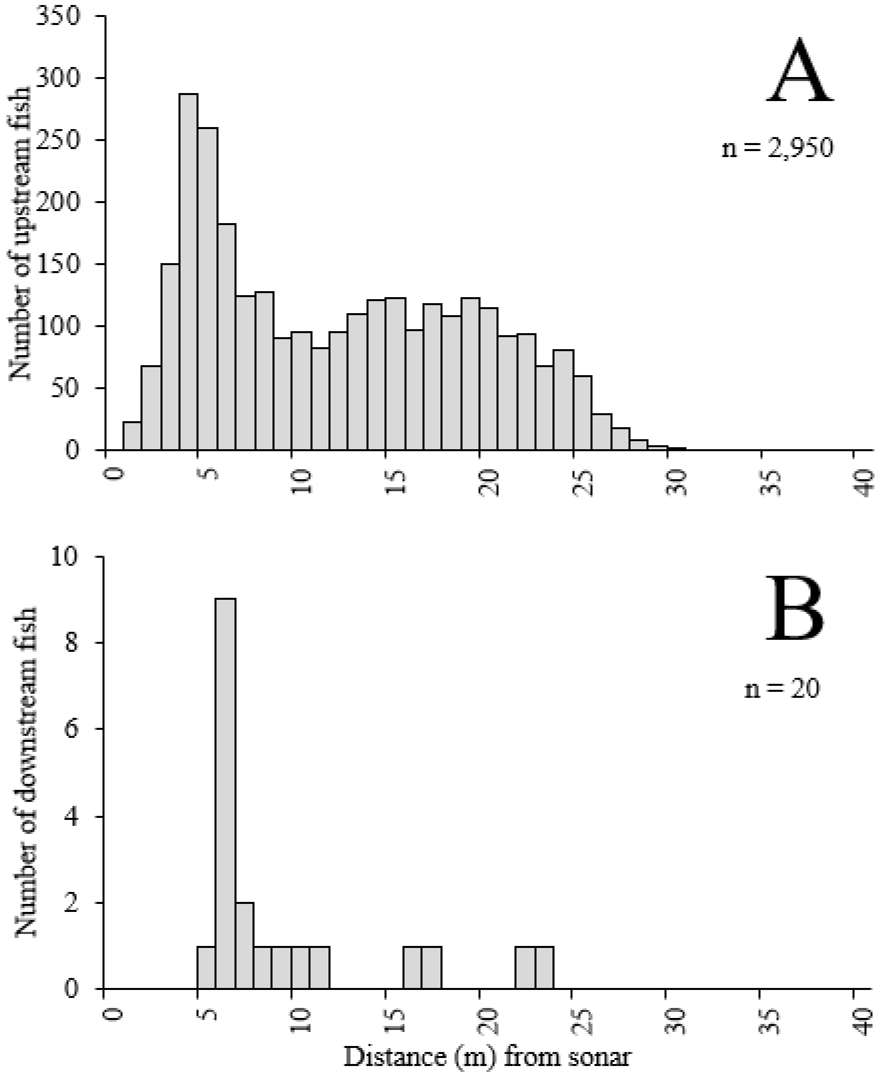


Figure 6. Upstream-bound passage (n) observed within the HTI split-beam sonar range at the right (north) bank of the Upstream of Check Station site over 25.9 hours.

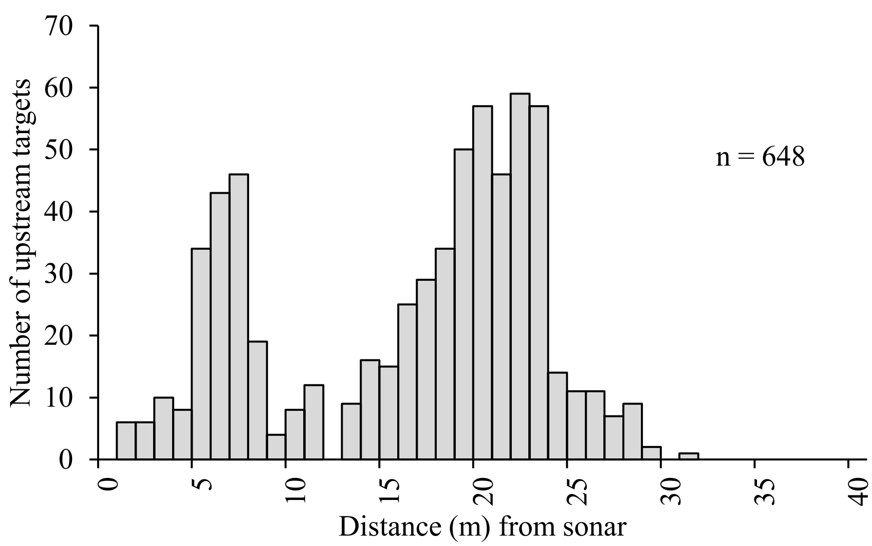


Figure 7. Diel fish passage (upstream and downstream) observed within the DIDSON range at the right (north) bank of the Upstream of Check Station site for one 24-hour period.

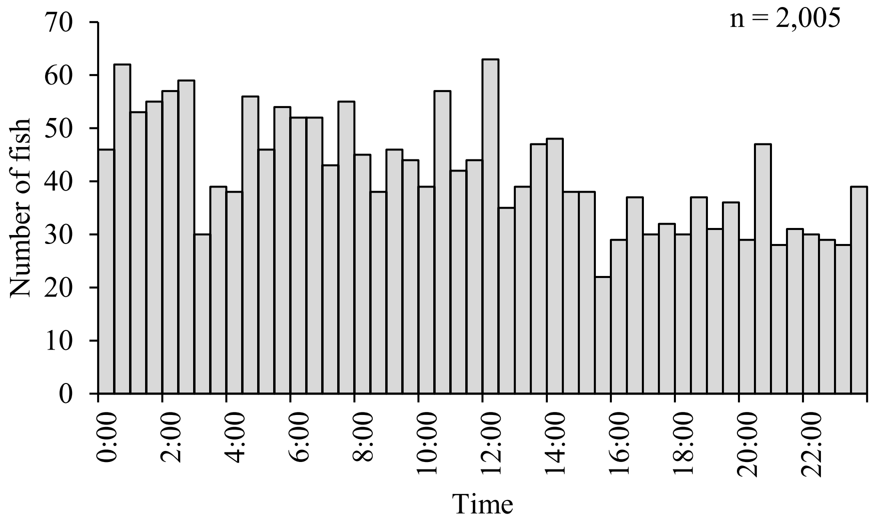


Figure 8. Diel upstream-bound fish passage observed within the HTI split-beam sonar range at the right (north) bank of the Upstream of Check Station site for one 24-hour period.

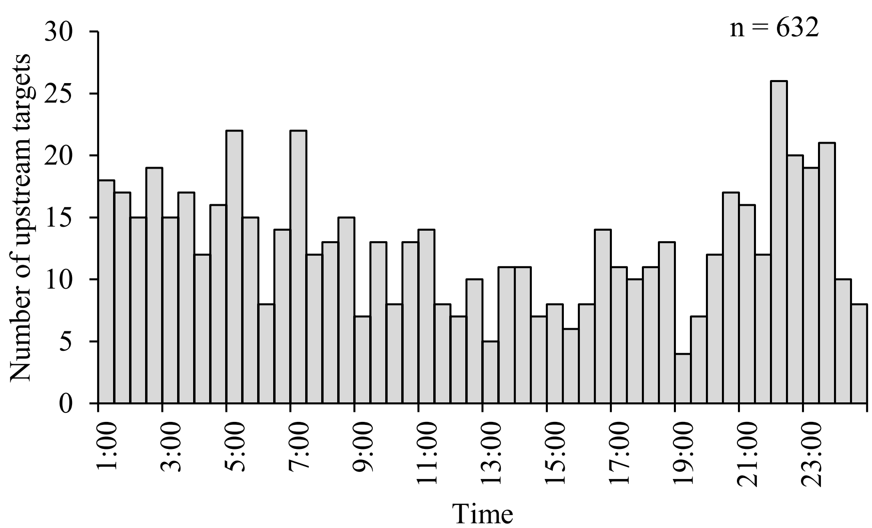
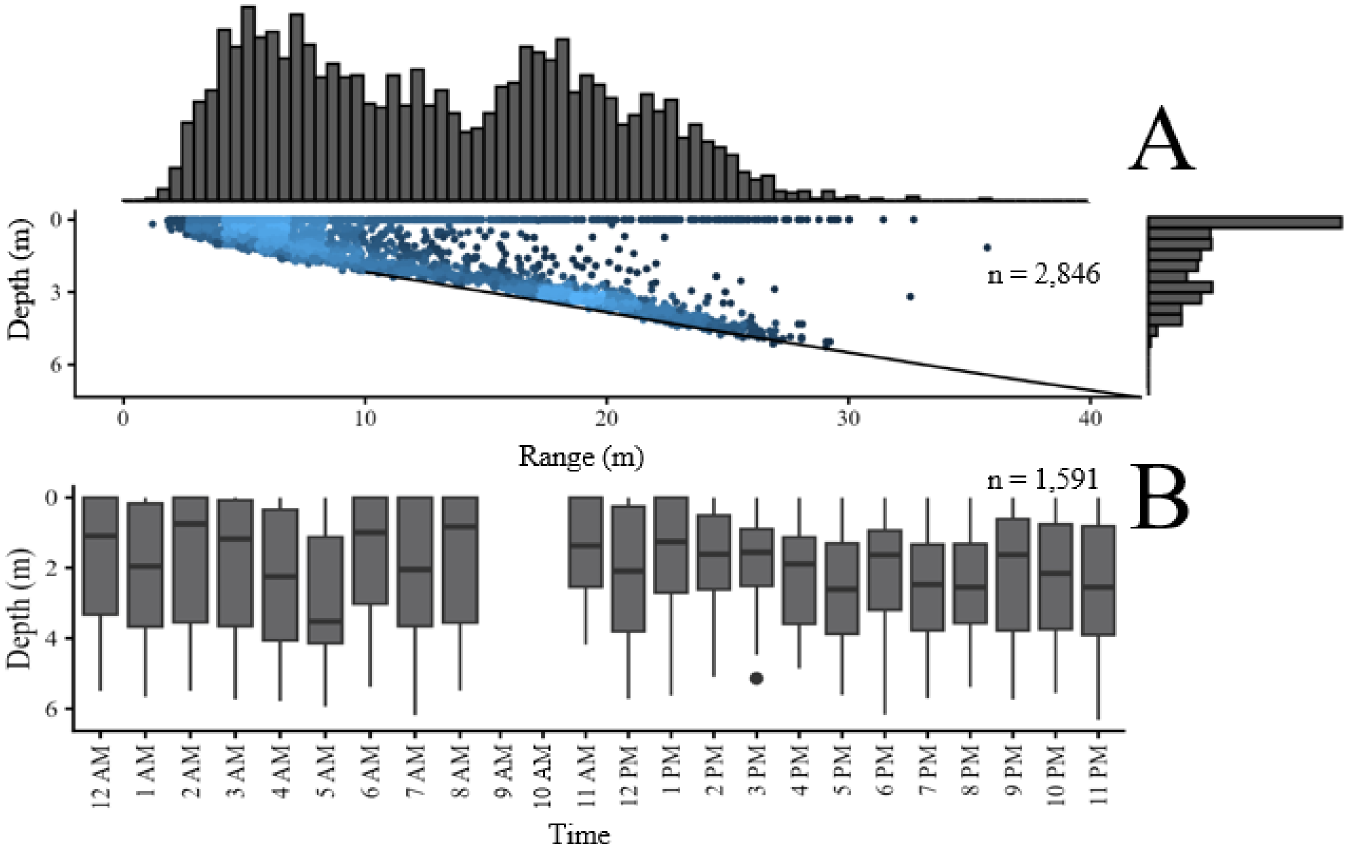


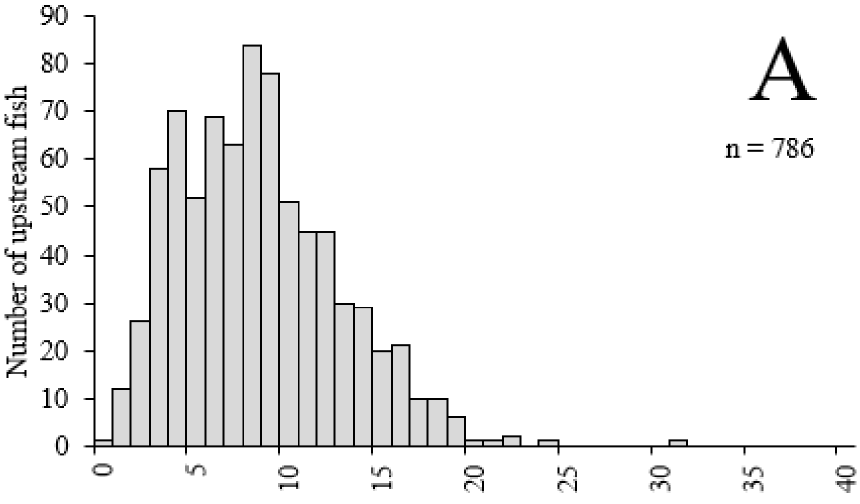
Figure 9. Depth of targets passing (upstream and downstream) the DIDSON at the north (right) bank of the Upstream of Check Station site for the entire dataset (37.6 hours; A) and for one 24-hour period (B). Target depths are an approximation based on the boat-mounted sonar transects taken in front of the DIDSON sonar. Target density scales from black (low density) to light blue (high density).



Check Station Site

On the north bank at the Check Station site, range distribution data indicated that upriver swimming fish (passage DIDSON) and targets (split beam) were shore-oriented and that most were within the sonar range (Figures 10 and 11). In the DIDSON positioned on north bank, more than 95% of the observed upriver-swimming fish were within 17 m of the bank (max range ~30 m; Figure 10). In the split beam, more than 95% were within 15 m of the bank (max range ~80 m; Figure 11). There was a slight increase in fish passage observed in the DIDSON during the night, but the split-beam sonar, using data from a separate day, had higher passage during the day (Figures 12 and 13). More days of data will be needed to adequately assess any diel passage trends that may be present at north bank. The DIDSON used to detect target depth was unable to ensonify the surface and the bottom simultaneously at this site, but of the observed targets, most passed the sonar view near the riverbed (Figure 14). Due to an equipment failure shortly after midnight on the last day of operation, only a 12-hour sample of target depths was recorded at this site, and depths were variable during that time.

Figure 10. Upstream (A) and downstream (B) fish passage observed within the DIDSON range at the right (north) bank of the Check Station site over 25.0 hours. Although the sonar was set to 40 m, image quality deteriorated after 30 m.



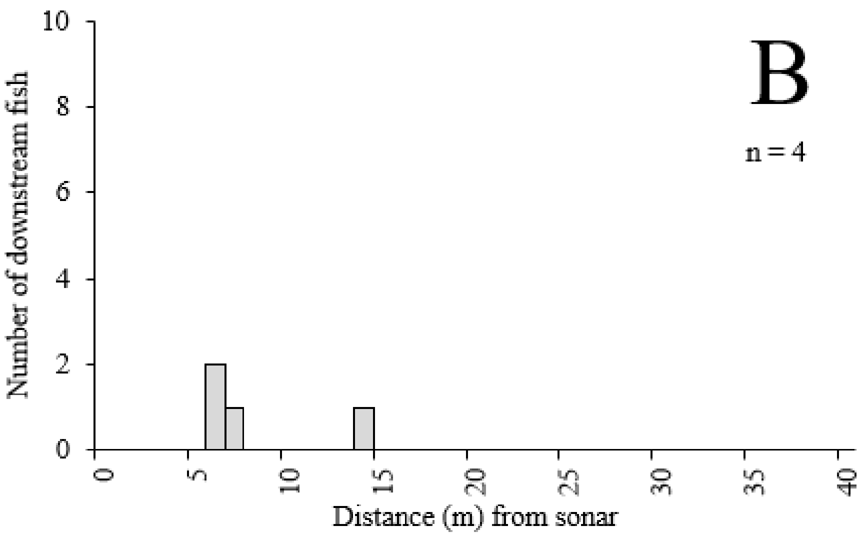


Figure 11. Upstream-bound passage observed within the HTI split-beam sonar range at the right (north) bank of the Check Station site over 36.2 hours.

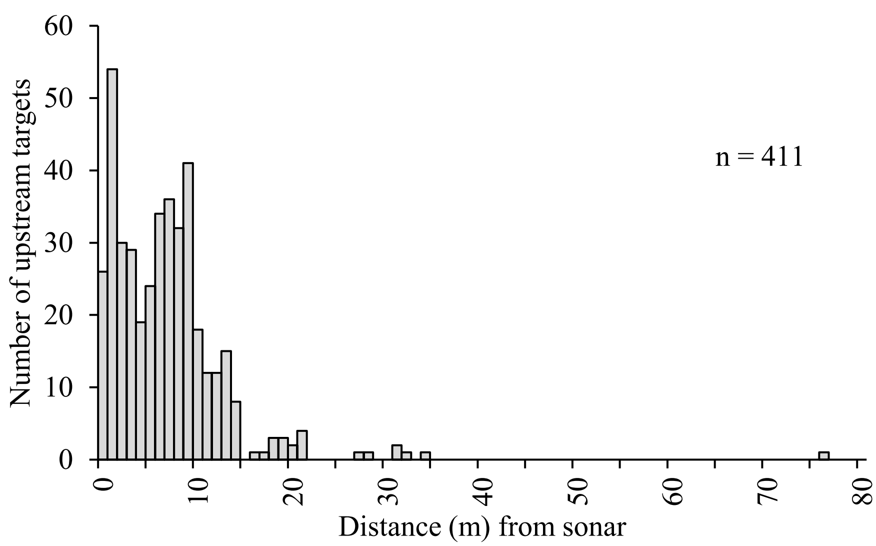


Figure 12. Diel fish passage (upstream and downstream) observed within the DIDSON range at the right (north) bank of the Check Station site for one 24-hour period.

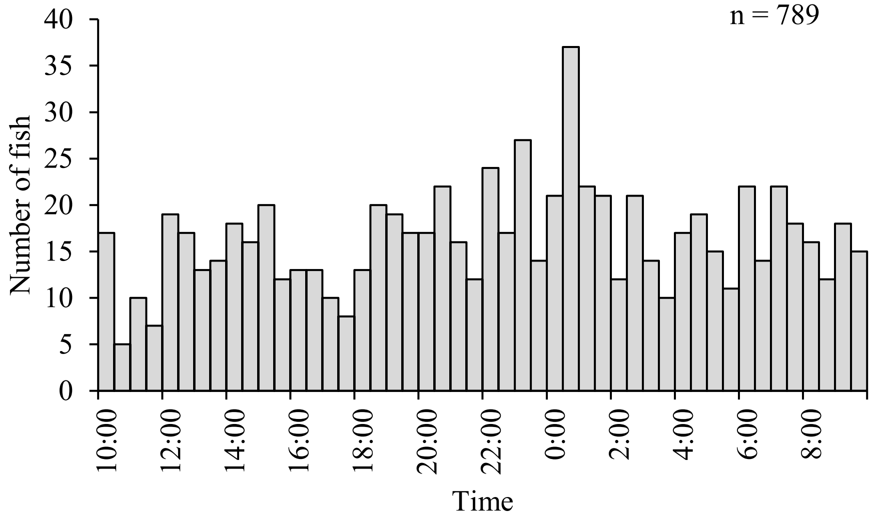


Figure 13. Diel upstream-bound fish passage observed within the HTI split-beam sonar range at the right (north) bank of the Check Station site for one 24-hour period.

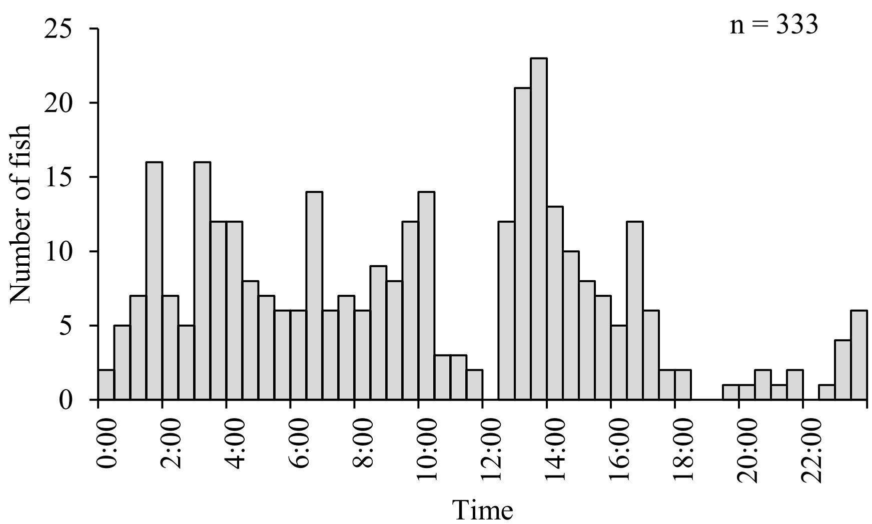
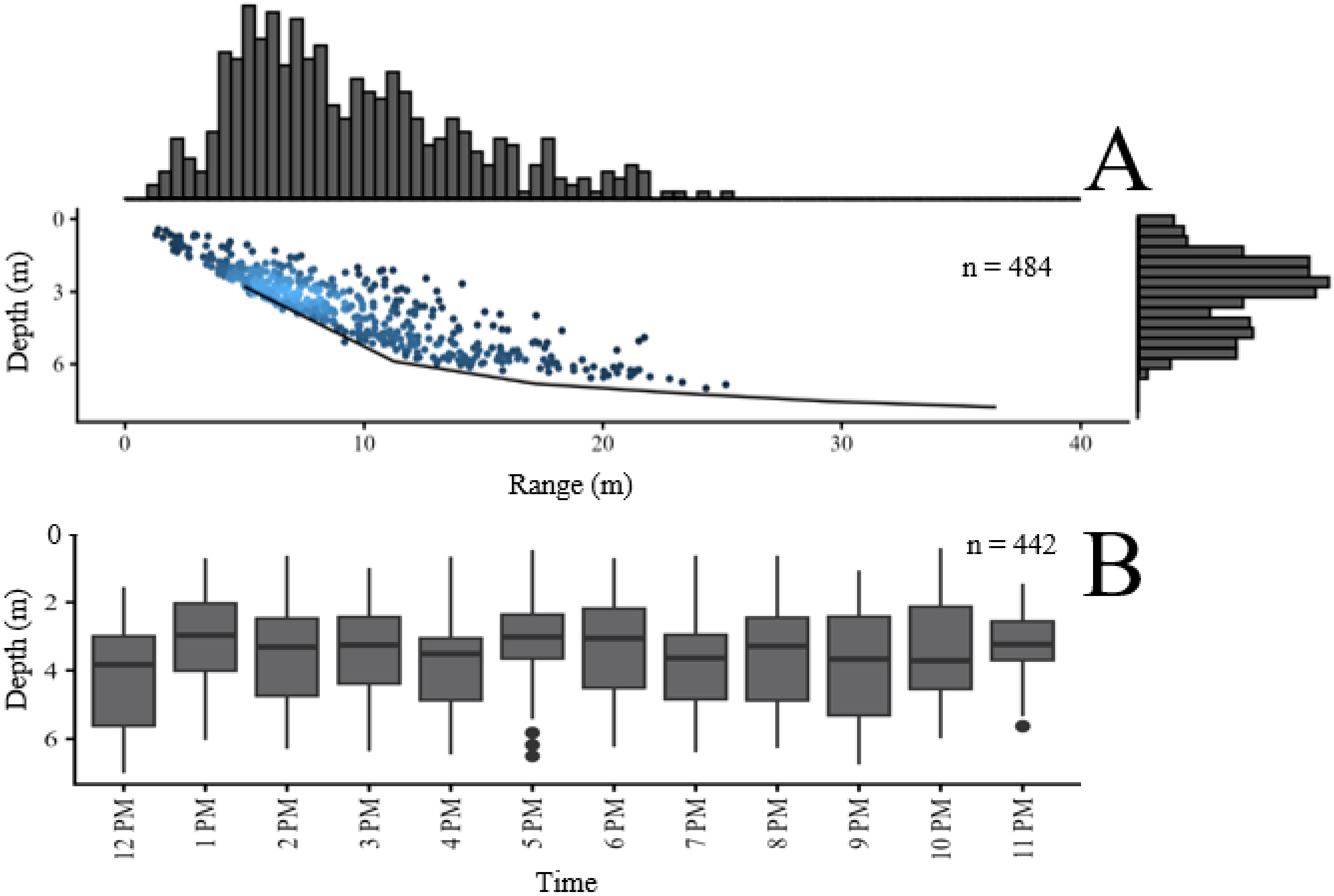


Figure 14. Depth of targets passing (upstream and downstream) the DIDSON at the north (right) bank of the Check Station site for the entire dataset (24.2 hours; A) and for one 12-hour period (B). Target depths are an approximation based on the boat-mounted sonar transects taken in front of the DIDSON sonar. Target density scales from black (low density) to light blue (high density).



On south bank at the Check Station site, range distribution data indicated that upriver swimming fish (passage DIDSON) and targets (split beam) were shore-oriented and that most were within the sonar range (Figure 15 and 16). In the DIDSON positioned on south bank, more than 95% of the observed upriver-swimming fish were within 29 m of the bank (max range ~40 m; Figure 15). In the split beam, more than 95% were within 53 m of the bank (max range ~125 m; Figure 16). Fish passage observed in the DIDSON and split-beam sonars showed no clear diel pattern, though the split-beam sonar (operating during a different time period from the DIDSON) appeared to have one or more pulses come through (Figures 17 and 18). More days of data will be needed to adequately assess any diel passage trends that may be present at north bank. Targets passing the site were generally either at the surface (likely indicative of driftwood) or near the bottom, with a slight trend toward targets in deeper water through the evening (Figure 19). The bathymetric transect from the boat did not correspond very well with the sonar image between 10 and 30 m, introducing more error to the estimates of target depth.

Figure 15. Upstream (A) and downstream (B) fish passage observed within the DIDSON range at the left (south) bank of the Check Station site over 26.6 hours. The image quality was higher at this site, and fish were easily observable within 40 m of the sonar.

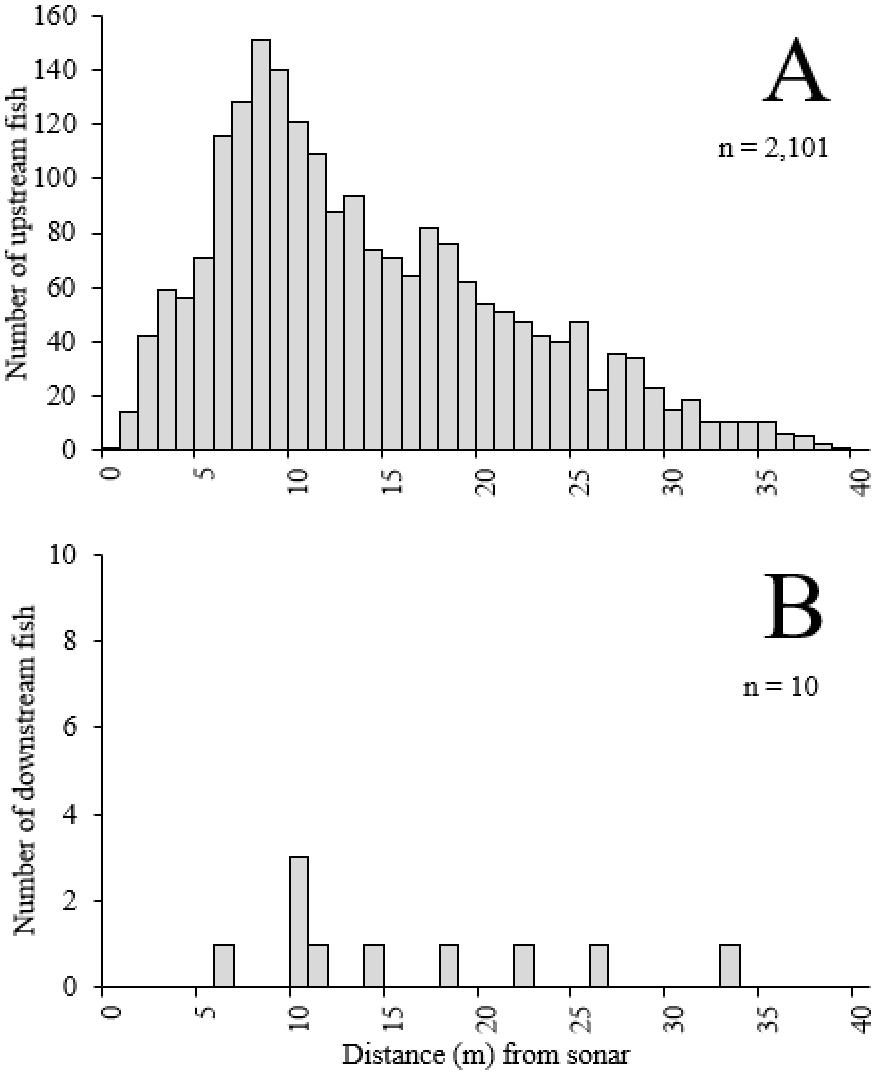


Figure 16. Upstream-bound passage observed within the HTI split-beam sonar range at the left (south) bank of the Check Station site over 44.4 hours.

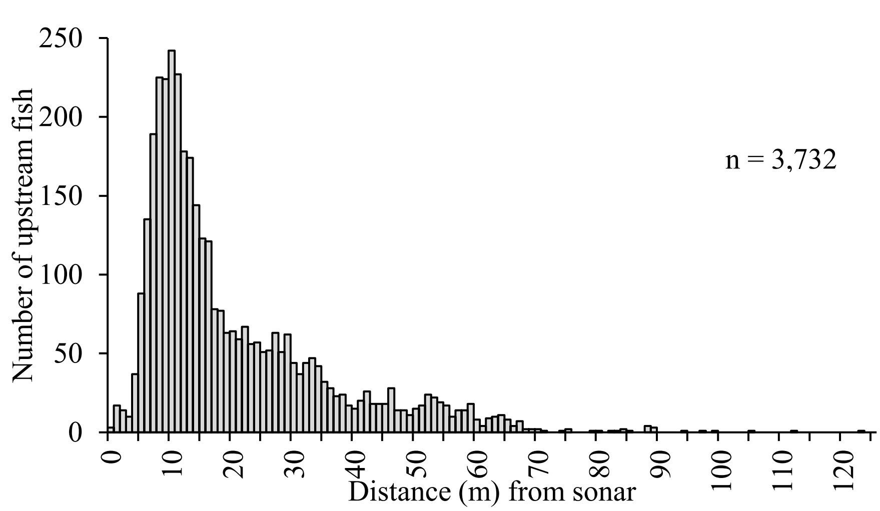


Figure 17. Diel fish passage (upstream and downstream) observed within the DIDSON range at the left (south) bank of the Check Station site for one 24-hour period.

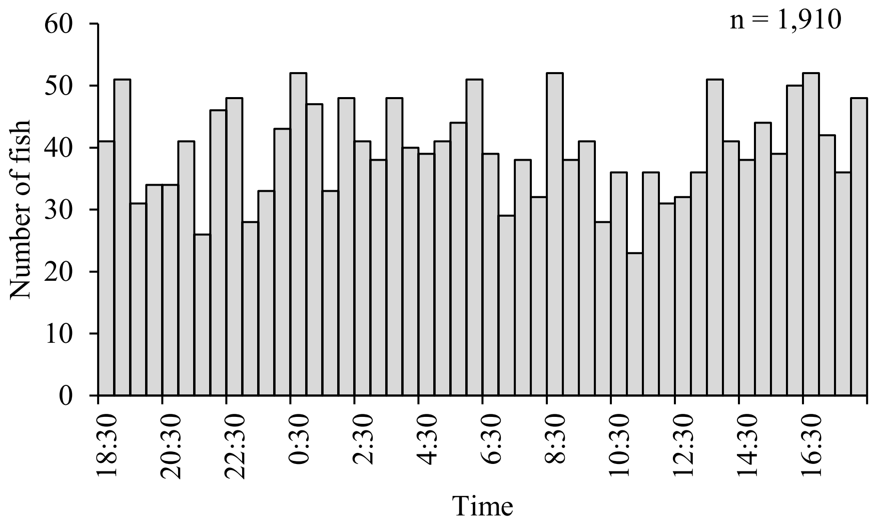


Figure 18. Diel upstream-bound fish passage observed within the HTI split-beam sonar range at the left (south) bank of the Check Station site for one 24-hour period.

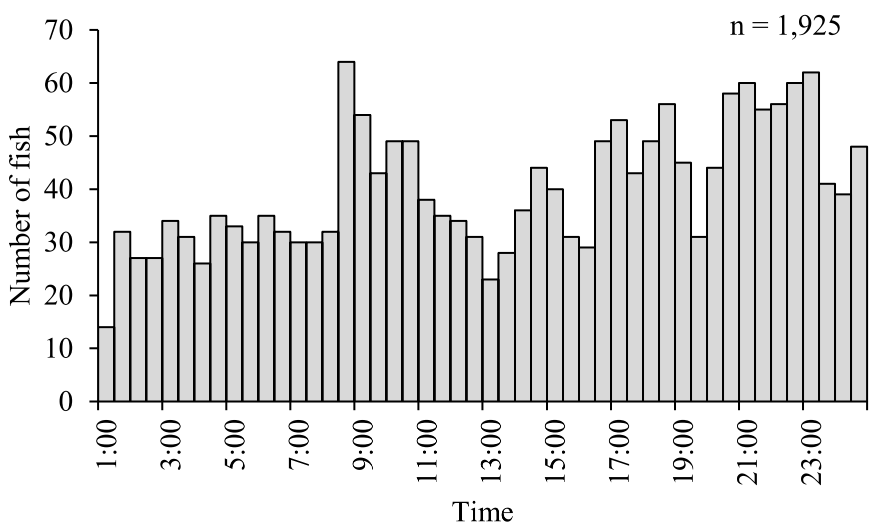
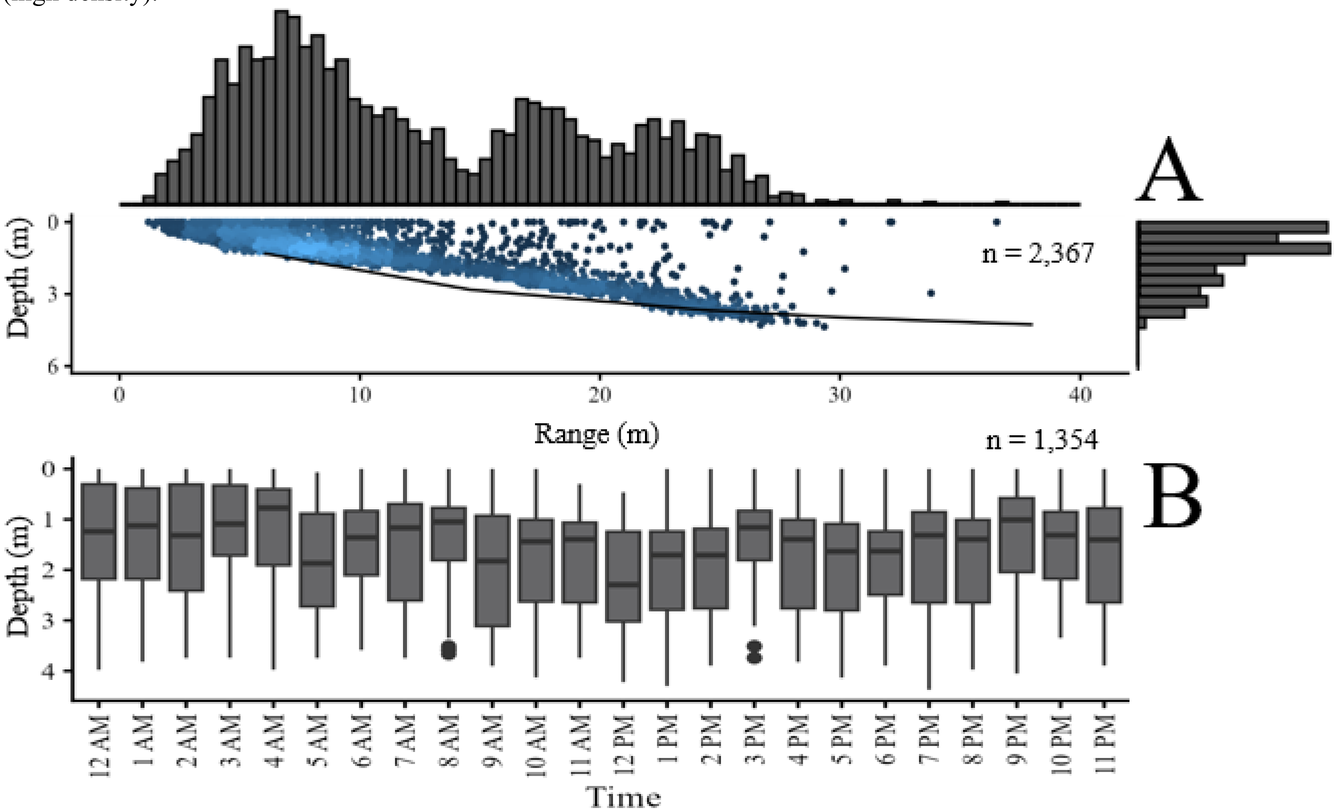


Figure 19. Depth of targets passing (upstream and downstream) the DIDSON at the south (left) bank of the Check Station site for the entire dataset (41.4 hours; A) and for one 24-hour period (B). Target depths are an approximation based on the boat-mounted sonar transects taken in front of the DIDSON sonar. Target density scales from black (low density) to light blue (high density).



Water Temperature

The HOBO Logger was deployed in shallow water (~1 m) on north bank at the ADFG Check Station, near the tent platforms, from 10 P.M. on July 1 until 11 P.M. on July 9. The maximum observed water temperature was 20.0 °C on July 7 at 1400 hours. The temperature exceeded the 18 °C temperature stress threshold for 84 out of 194 hours (43.3%; Figure 9). Water levels were high (in the tree line) during the beginning of the study but receded approximately 2 m by the end.

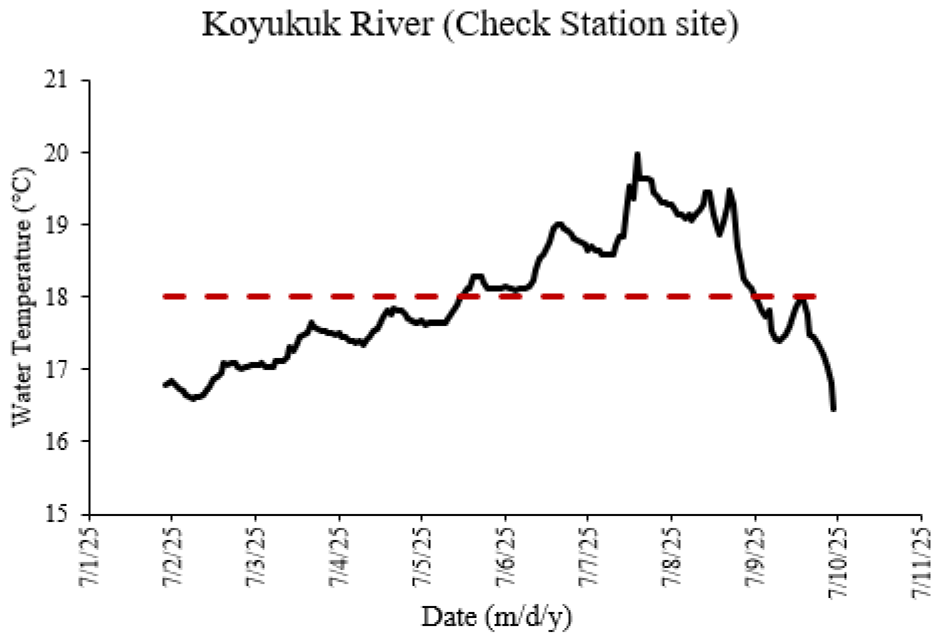


Figure 20. Water temperatures in the Koyukuk River during the study. Heat stress threshold of 18°C is shown as a dashed red line.

Discussion

Bathymetric study

Before fieldwork began, review of remote imagery suggested that the most promising location for a future sonar site was in the portion of the Koyukuk River between Nikolai Slough and Woodyard Creek (Figure 1) This area was downstream of Woodyard Creek, but far enough upstream of the Yukon River confluence to avoid flow reversals through the project site due to high water on the Yukon River. However, field investigations revealed that sites in this area with adequate bathymetric properties (the JR Slough and Woodyard Creek sites; Appendices A4 and A5) were limited by land ownership permissions, eddies, and lack of clear water source for the camp. The bathymetric complexity of these sites also suggested that the options for sonar placement would be limited.

Woodyard Creek is the furthest downstream known spawning area of Chum Salmon in the Koyukuk River, so any sonar sites above the creek would produce underestimates of passage. Transects were taken of this area in narrow single-channel portions of the river as far upstream as the Gisasa River confluence, but only the Long Straight site was reasonable. Unfortunately, in addition to missing Chum Salmon returning to Woodyard Creek, the Long Straight site was far from the village of Koyukuk, which would make future operations more difficult, and it had marginal bathymetry due to a slight hump that could allow fish to pass undetected. Further investigation at this site may reveal that the overwhelming majority of fish would not be obscured by bathymetry.

After the bathymetric review was completed, focus was therefore directed toward sites downstream of Nikolai Slough, particularly in an area near the ADFG Check Station for hunters, which provided two sites called “Upstream of Check Station” and “Check Station” (Appendices A1 and A2). Ella’s Cabin was assessed due to local recommendation, but the rocky bottom led to a complex bathymetry (Appendix A3). The two closely related Check Station sites had a steep slope on north bank that transitioned into a relatively flat riverbed for most of the width of the river and rose gradually to south bank. The sites are located in a straight stretch of the Koyukuk River, so there was initial concern that fish may swim closer toward the middle of the channel than at sites like JR Slough, which was on a bend in the river. Sonars were only operated on one bank at a time in 2025, so direct comparisons in the proportion of fish passage along each bank could not be made. However, operations in 2025 suggested that fish overwhelmingly pass on south bank at Check Station, which, although in a straight stretch, is on the inside edge of the river bends upstream and downstream from the sites.

It is possible for fish to travel around a sonar in either of these sites via Nikolai Slough, so further investigation of the slough is needed before final placement of the mainstem Koyukuk Sonar Project. However, Nikolai Slough has relatively low discharge compared to the Koyukuk River. Nikolai Slough enters the Yukon River upstream of the two mouths of the Koyukuk River, so it is unlikely for many salmon to enter the Koyukuk River through Nikolai Slough. Fish would also have to swim roughly an additional 104 km to reach the Koyukuk River and Nikolai Slough confluence using Nikolai Slough, instead of taking the Koyukuk River mainstem. The slough is fed by tributary creeks, and during field work in 2025, the clear water of Nikolai Slough flowed into the murky Koyukuk River, instead of being dominated by Koyukuk River flows, which were observed at high water into the tree line. However, local knowledge indicated that the Koyukuk River regularly flows into Nikolai Slough, making it more likely for salmon to attempt to enter the Koyukuk River through the slough. In addition, whitefish movements through the area may be more complex than expected. Sheefish were easily caught in the turbidity transition between Nikolai Slough and the Koyukuk River during 2025.

DIDSON and split-beam operation

The Upstream of Check Station site provided better drinking water and potential for a large-scale sonar camp to be constructed. However, permission from the owner of the land on the south bank was not received before the field visit, so no sonars were placed there in 2025. On the north bank, fish passage was also roughly bimodal, with peaks around 5 m and 17 m, though this tapered off sharply near 30 m (Figure 5). The slope on north bank was also steep and transitioned abruptly to a flatter surface around 30 m out, which led to issues in our split beam image because we tried to overlap its range with that of the DIDSON sonars. Although the passage numbers declined toward the maximum effective range at that site in 2025 (30 m), it is unclear if fish are traveling further away from shore. In future years at this site, the split-beam sonar should not overlap the DIDSON sonar image at all to provide better clarity at range. It is unclear how the abrupt change in bottom profile will affect reflections off the bottom in the split-beam output. This output can be difficult to troubleshoot, so more study at this site is needed. Test net fishing further out could also help determine how many fish are passing in this area.

In contrast, the Check Station site allowed clear access to be granted to both banks and tent platforms owned by ADFG on north ban, which we received permission to use in 2025. However, while a small creek does run through the camp on north bank, it was nearly as sediment laden as the Koyukuk River, so more complicated freshwater filtering would be required.

Fish distribution in the area flowing through the Check Station site was much more favorable. On north bank, passage through the DIDSON sonar's range revealed a peak at 9 m distance that tapered off to very few fish by 25 m. In the split-beam sonar, the image again had issues with the transition to the flat riverbed, but overall very few fish were seen beyond 22 m. On south bank, passage through the DIDSON sonar's range revealed a peak at 9 m distance that taped off to relatively few fish by the time the DIDSON sonar's maximum range of 40 m was reached. The split-beam sonar observed a peak at 11 m that slowly tapered to around 72 m, though the furthest upstream-bound target was observed at 124 m, near the effective range at that site. The high passage well within the maximum ranges of the sonars on both banks suggests that relatively few fish transit the site in the middle, which was not ensonified in 2025. Similar to the Upstream of Check Station site, the sonar ranges at this site should not overlap in future years to allow for acquisition of targets through the split-beam sonar at a greater range.

Environmental conditions

In recent years, there has been concern over the high-water temperatures being recorded on the Koyukuk River. High water temperatures had been correlated with a large summer Chum Salmon die-off in 2019 and general heat stress in salmon (von Biela et al. 2020, 2022). The water temperature series recorded at the Check Station site from 10 P.M. on July 1 until 11 P.M. on July 9 exceeded the 18 °C temperature stress threshold for 84 out of 194 hours (43.3%; Figure 9), suggesting that a mainstem Koyukuk River sonar project could be an important platform for heat-stress studies and long-term temperature monitoring. However, these periods of high temps could also affect the success of running an apportionment program that involves test fisheries that will capture fish. In Alaska, the U.S. Fish and Wildlife Service has a policy to avoid handling fish during periods of heat stress as it can lead to mortality or unmeasured effects (Shink 2020). In years with large returns, all test fishing during high temperatures at a mainstem Koyukuk River sonar could be assumed to be lethal sampling, with fish distributed to local communities. In years with low returns, test fishing would likely need to cease during high temperatures, with apportionment for missed days estimated based on catch preceding and following the high temperature events.

The impetus for this project was to replace weir projects in the Koyukuk River drainage that have been hampered by high water, and 2025 was no exception, with high water into the tree line and a fair amount of driftwood passing through the sonar, especially during the first week. Although the high water allowed bathymetric transects nearly to the tree line, it later slowed feasibility operations by necessitating more thought into data tent and sonar placement. Despite this, the sonars operated well, and the topography of the north bank makes future issues with high water unlikely. On south bank, the topography is flatter, and may experience extensive flooding if the highest water seen in 2025 (already in the tree line) is exceeded by another 1–2 m. This could be problematic as more fish were seen passing south bank in 2025, though direct comparisons between banks could not be made due to only one bank being ensonified for passage at a time. With a short weir to block fish passage behind the sonar, as is used at the Teedriinjik Sonar project (Maschmann 2026), sonar operations during higher water on south bank should be able to continue in most instances.

Future test fishing considerations

Both sites examined by the depth DIDSON were relatively shallow, with thalwegs of around 9 m or less. Future iterations of mainstem sonar feasibility on the Koyukuk River will need to include a species apportionment protocol, which could draw heavily on the apportionment protocol used by Pilot Station sonar due to the similarities in species present. The gillnets currently used at Pilot Station sonar are 8 m deep (Morrill et al. 2025), which would nearly touch the bottom of the Koyukuk River throughout the sites examined. Bank orientation appears to be strong at the sites, and the riverbed did not reach 8 m in depth until roughly 50–80 m from shore. Nets that deep are therefore likely unnecessary at a Koyukuk River sonar project placed in either of these locations. The depth DIDSON observed a high concentration of targets near the riverbed, so it stands to reason that a future apportionment protocol might seek to fish the area 0–50 m from shore and touch bottom most of the time, which would require a net of roughly 6 m in depth.

The existing sonar projects near Pilot Station and Eagle both use nets that are 25 fathoms (45.7 m) in length, and the Check Station site examined during this study is a similar width to that of the Eagle sonar site. In the Koyukuk River, test nets that are 25 fathoms in length are therefore possible, though catch is expected to be higher than at the Eagle sonar, so the future years of the Koyukuk River sonar may opt for shorter nets to reduce catches. The sonars near Pilot Station and Eagle both use 5.25” (133 mm), 6.5” (165 mm), 7.5” (191 mm), and 8.5” (216 mm) stretched mesh gillnets, with the sonar near Pilot Station also fishing 2.75” (70 mm) and 4.0” (102 mm) stretched mesh to cover the smaller whitefish species found there (Davis and Jackson 2025; Morrill et al. 2025). Due to large variety of whitefish species expected at the Koyukuk River sonar, the mesh sizes used should reflect those of Pilot Station sonar.

Other apportionment methods are unlikely at these locations. The Koyukuk River was very turbid, similar to the Yukon River, so visual identification of species was not possible. The current appeared reasonable for traps, such as fish wheels or fykes, but the high temperatures encountered suggest that holding fish for long periods would not be viable. Additionally, although north bank was deep enough for a fish wheel, using one for apportionment is not recommended due to how many targets were observed close to the riverbed.

Conclusions

Annual estimates of Chum Salmon, Chinook Salmon, and nonsalmon passage in the Koyukuk River are vital for sustainably and effectively managing the complex mixed-stock subsistence and commercial fisheries in the Yukon River. The Koyukuk River stocks are crucial to the total Yukon River runs and are important to users throughout the drainage. Daily in-season counts and post-season passage estimates from a mainstem Koyukuk River sonar project could provide important escapement information to managers and users of these resources, allowing for better-informed management decisions and evaluation of previous management actions. These data will become more important as stressors such as climate change and disease continue to increase.

Based on the 2025 field investigations, the Check Station site was the best location for a future mainstem Koyukuk River sonar project. However, further years of investigation are required to determine (1) the estimated proportion and count of each fish species transiting the site, (2) the optimal split-beam sonar settings and configuration required by the site, (3) the optimal timing for sonar operation at the site, (4) whether Nikolai Slough is allowing fish passage that would cause a sonar project at the site to under- or overestimate fish passage into the Koyukuk River, and (5) whether low water is problematic to sonar operations at the site.

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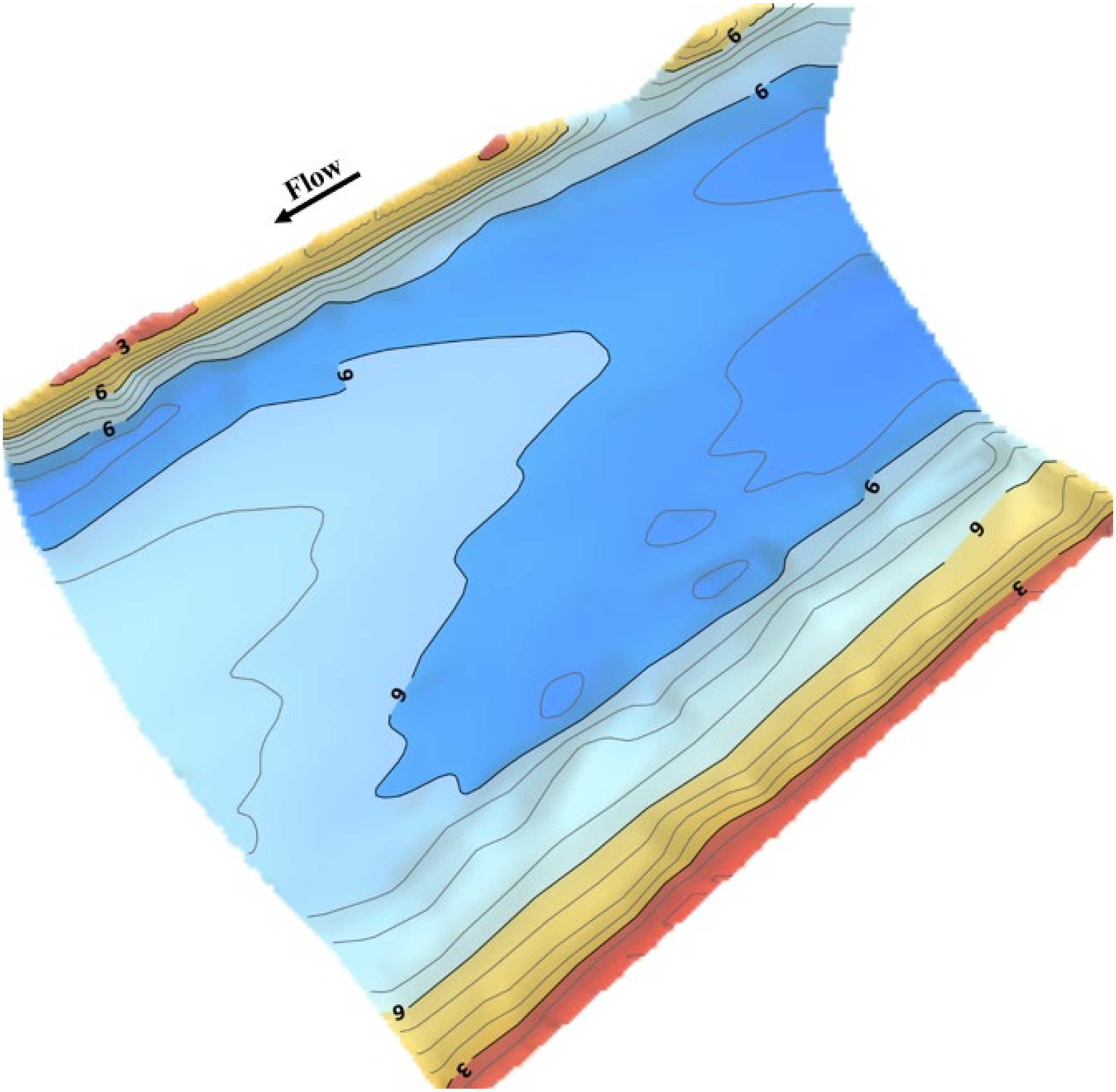
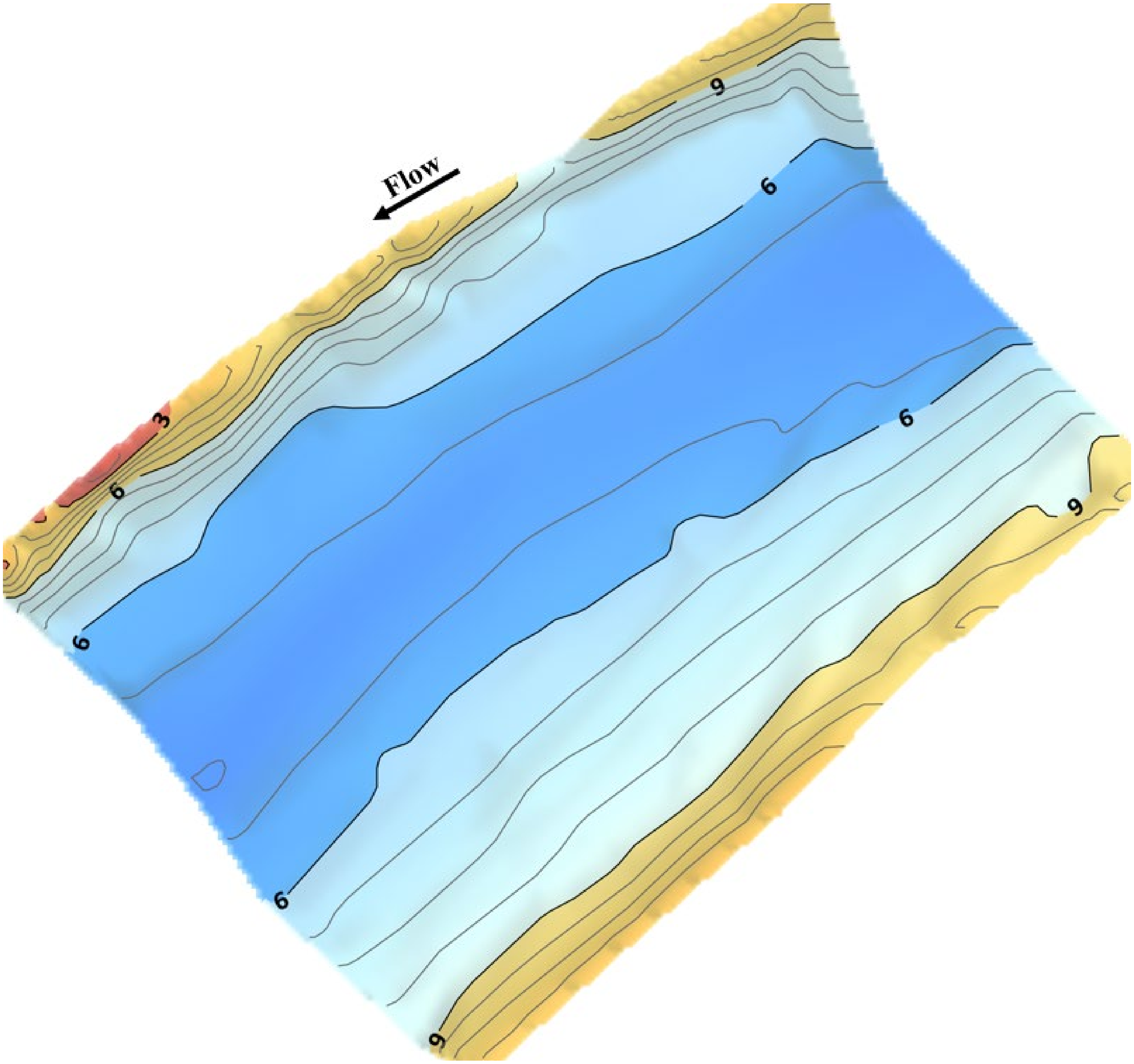
Appendix A. Bathymetric Maps

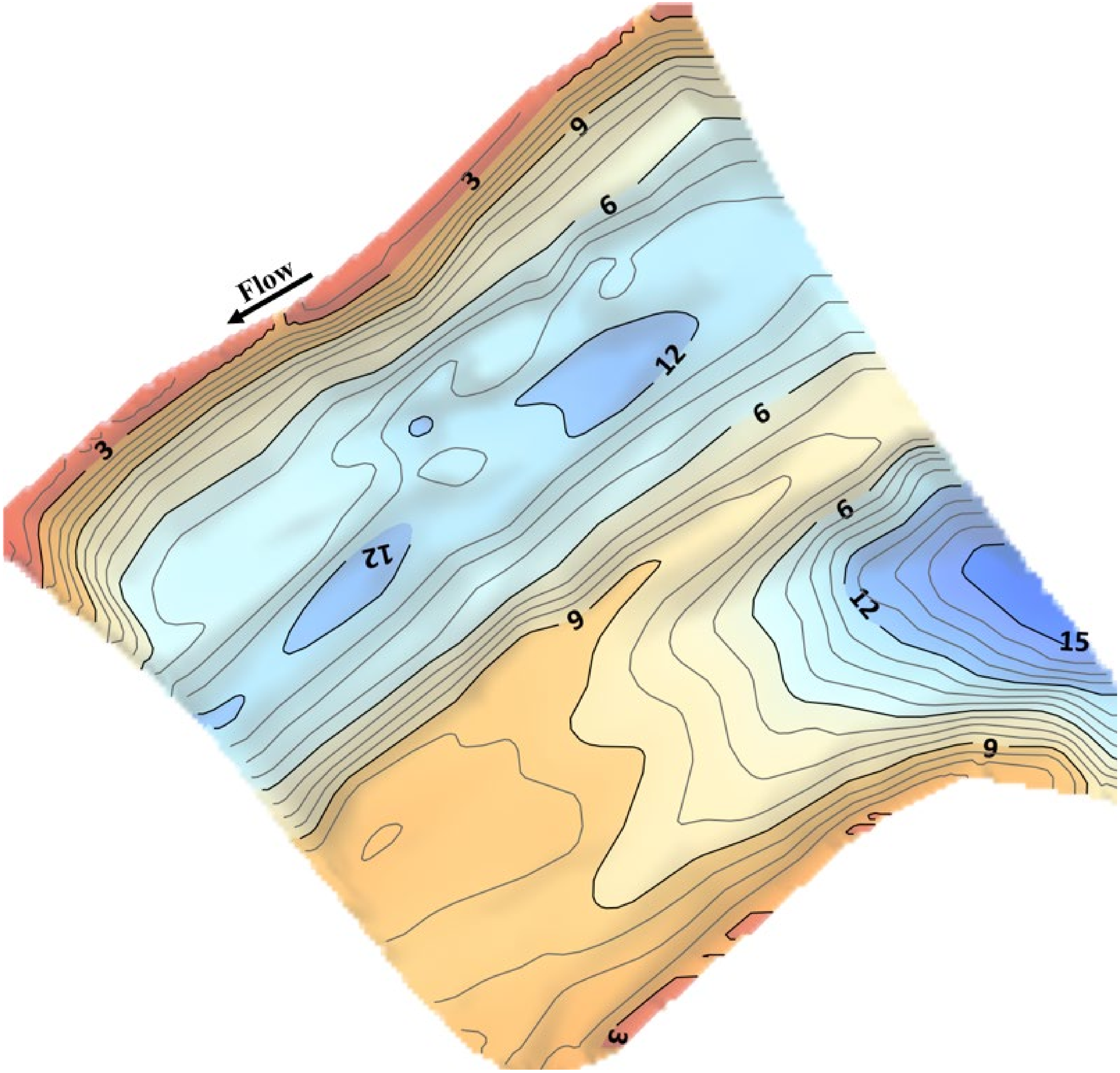
(Presented in order from downriver to upriver.)



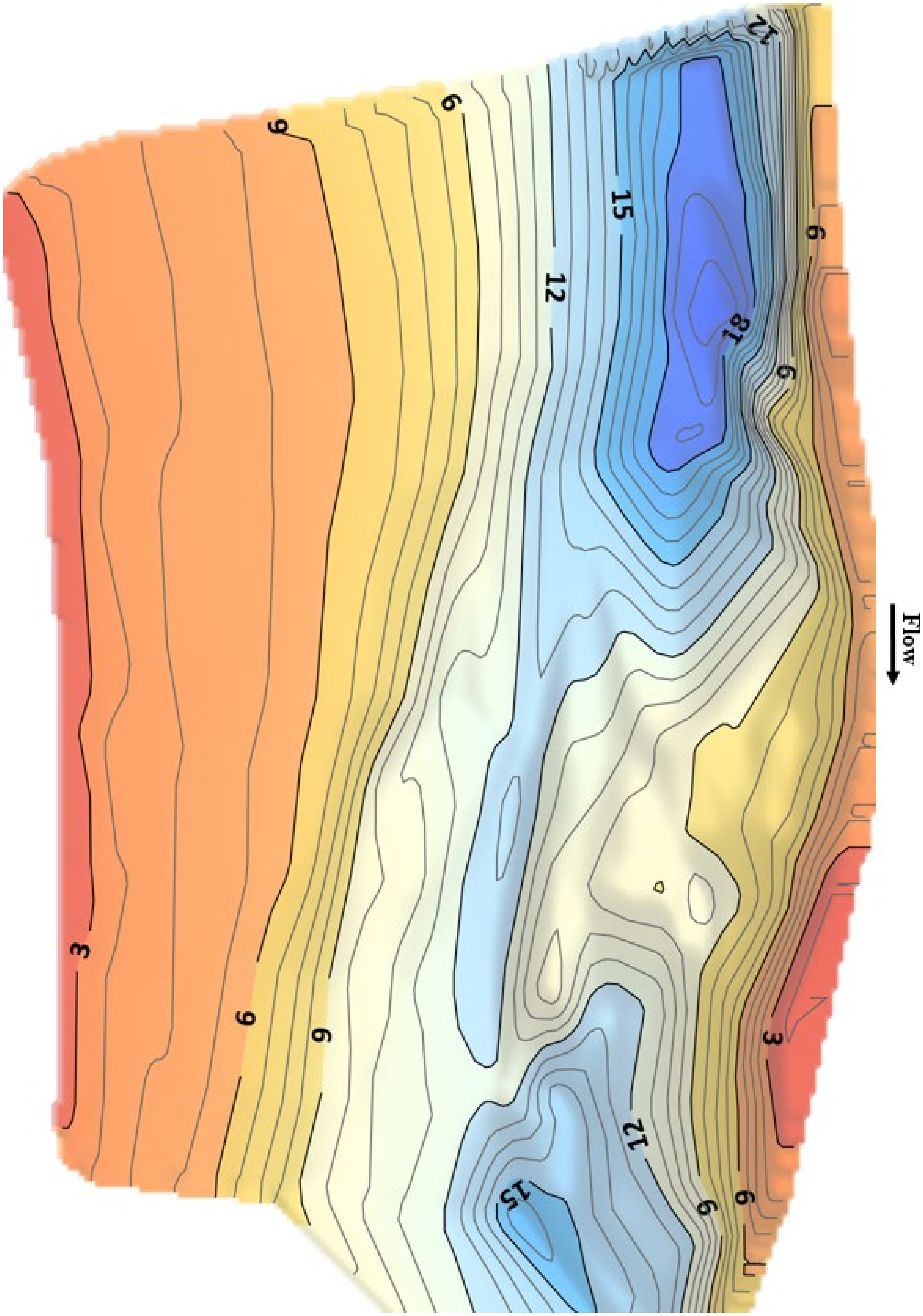
Appendix A1. Bathymetric map of the Check Station site. Depth is shown in meters.



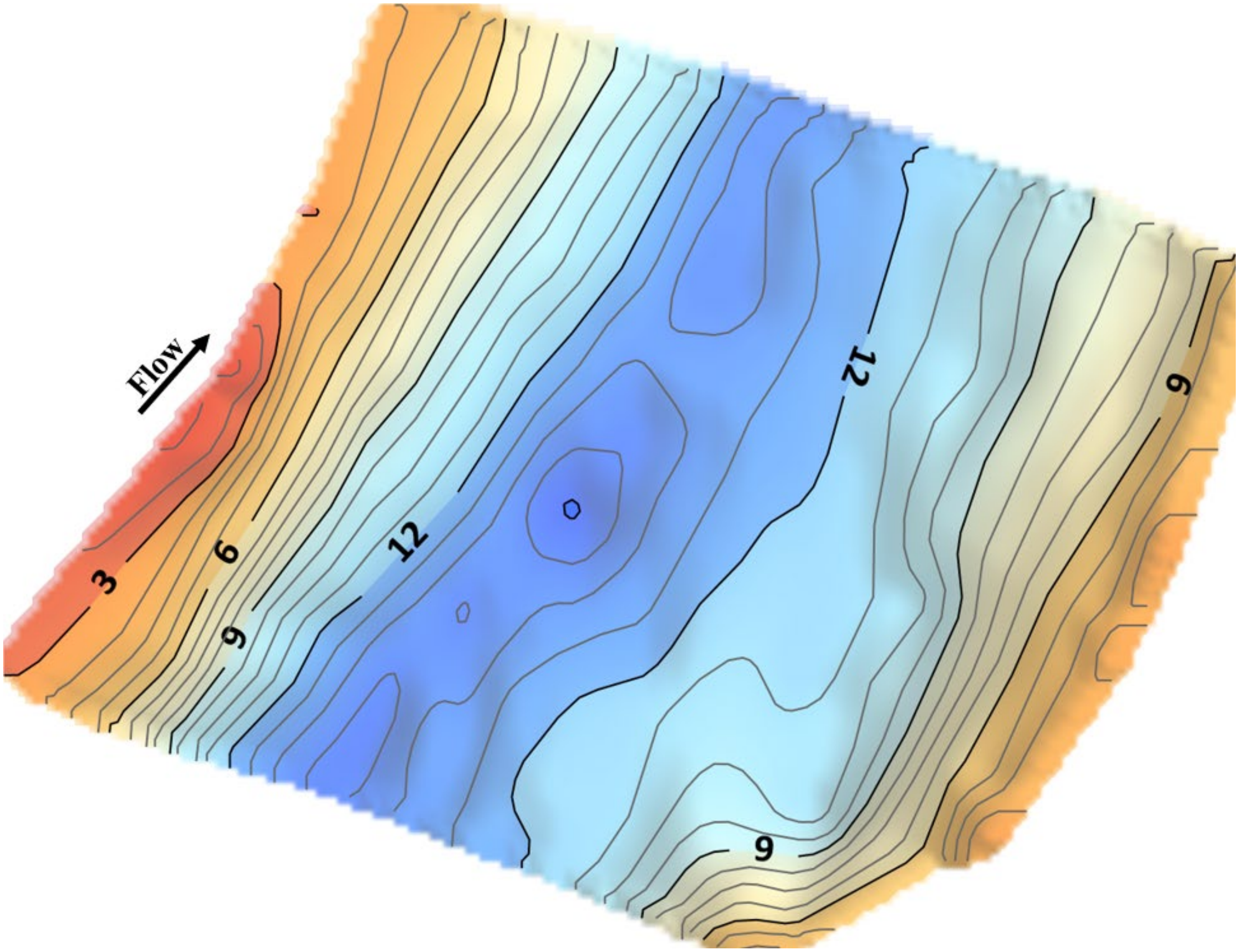
Appendix A2. Bathymetric map of the Upstream of Check Station site. Depth is shown in meters.



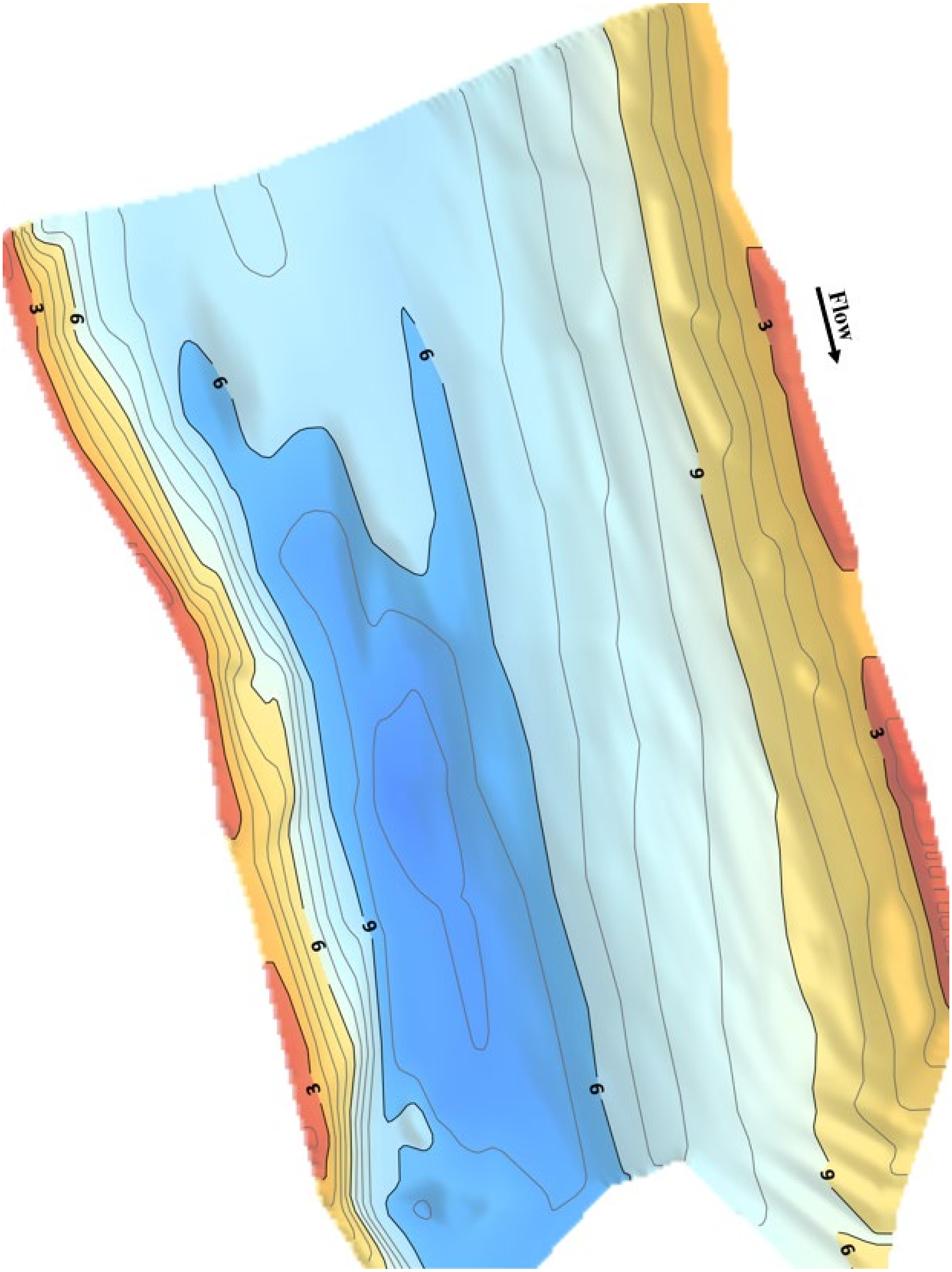
Appendix A3. Bathymetric map of the Ella's Cabin site. Depth is shown in meters.



Appendix A4. Bathymetric map of the JR Slough site. Depth is shown in meters.



Appendix A5. Bathymetric map of the Woodyard Creek site. Depth is shown in meters.



Appendix A6. Bathymetric map of the Long Straight site. Depth is shown in meters.