Imaging sonar deployment in the lower Copper River to enhance early season management - 2017.

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Executive Summary/Abstract

In order to enumerate up-migrating Copper River Salmon, two Tritech Gemini 720is sonars were deployed May 9 to June 9 2017 in the lower Copper River, at a site by the confluence of the Clear Martin and Copper rivers, approximately 10 river miles north of the open ocean. Hourly and daily counts of upriver passage were determined, and the results posted multiple times per day via internet for use by ADF&G managers and the general and fishing public.

A post-deployment analysis of the difference between the Clear Martin sonar and the ADF&G sonar site at Miles Lake showed that the Clear Martin site counted considerably fewer fish than were counted at Miles Lake. Given generally good conditions for counting fish in the lower delta in 2017, it is suggested that fish in the lower delta do not tend to travel along the banks like they tend to do at Miles Lake. However, if fish are approximately evenly distributed across the river, counts may be corrected based on the proportion of the river that is sampled by the sonars. Lagged correlations suggest that the salmon took 1 to 4 days to transit between the Clear Martin and Miles Lake, which is within the range of swimming speeds by Sockeye salmon observed elsewhere.

Background/Rationale

The Copper River salmon fishery is managed in part with an acoustic weir operated by the Alaska Department of Fish and Game (ADF&G) at the Million Dollar Bridge/Miles Lake at mile 50 of the Copper River Highway. ADF&G operates two sonar systems at the site (one on each bank), and fish are counted by technicians from 10 minute subsets done at two frequencies. The sonar systems used by ADF&G are highly specialized imaging multibeam sonars that produce a video-like image by scanning at high frequencies. This allows individual fish to be counted as the pass the sonar, which results in very good estimates of escapement.

The ADF&G sonar site is located at the first point above the Copper River delta where the river is confined to a single channel, and is approximately 35 miles from the nearest ocean entry point to the Copper River Delta at Kokenhenik Bar. Direct measurement of the swimming velocity of up-migrating salmon has not been done in the Copper River, but estimates from matching up abundance peaks between the fishery, a site at Flag Point (~15 miles from the ocean) or the clear Martin River (~10 miles from the ocean) and the Miles Lake site suggest that it takes 2 to 5 days for salmon to transit through the delta (Degan et al., 2005). The lag between the time when the fish enter the river (and are no longer available to the fishery) and when they pass the counters at Miles Lake complicates timely management of effort by the fishery, and can lead to escapements in excess of expectations.

The main channel of the Copper River has been transitioning from having the bulk of the flow through the western side of the delta at Flag Point (mile 27 of the Copper River Highway), towards the east (Brabets and Conaway, 2009). Those changes in flow regime lead to significant damage to a number of the bridges of the Copper River Highway in the early 2000's. After being almost completely undermined by the new main channel, bridge 339 at mile 37 was closed in 2011 and became the new terminus of the Copper River Highway. In the years since the channel has continued to migrate eastward.

Presently, during periods of low discharge, essentially all the water in the river passes through the main channel at bridge 339; as discharge increases and water levels rise, other channels begin to come on-line (Jeff Conaway, USGS Hydrologist, personal communication). Landsat imagery also suggests that during low water, the river is confined to a relatively small number of channels until a point near where the Clear Martin River enters the delta (~10 miles from Kokenhenik Bar), and is heavily braided below that (figure. 1). A pilot study done in 2015 for the CR/PWSMA indicated that the channel near the Clear Martin River was the lowest possible point in the Copper River delta where fish might be counted with acoustic methods: a 720 kHz imaging sonar deployed at the site in late June observed fish passage in the main channel.In 2016, the CR/PWSMA board funded a proposal submitted by the Prince William Sound Science Center (PWSSC) to deploy an imaging sonar at the Clear Martin site for the early portion of the Copper River salmon run (approximately for the month of May). PWSSC technicians deployed a

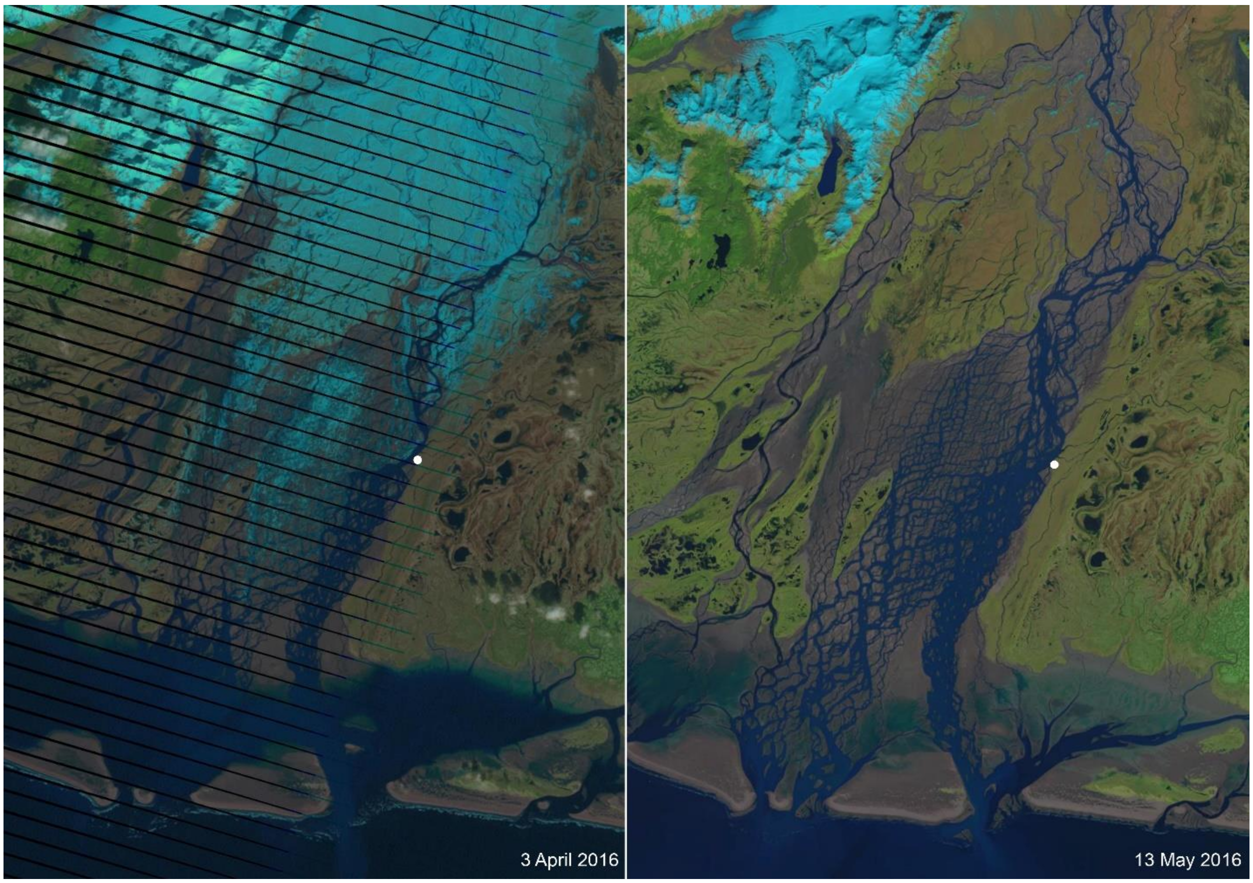

Figure 1: LANDSAT images of the Copper River delta taken on April 3 (left) and 13 May 2016 (right). The black bands in the April 3 image are from a failure in the LANDSAT 7 imager. The position of the sonar camp is denoted by a white dot.

DIDSON sonar at the site from May 4th to June 1st. Although a large initial pulse of fish was observed, the sonar undercounted salmon passage relative to counts made at Miles Lake; it was suggested that higher than average water levels may have played a role, and that the sonar was only counting fish on one bank. In 2017 the CR/PWSMA board again funded an imaging sonar deployment at the Clear Martin site. For the 2017 deployment two sonars (Gemini 720is) were used, one on each bank; this report outlines the results of that deployment.

Narrative of the deployment

Two sonar systems were rented from Tritech, Inc., they were identical Gemini 720is units (http://www.tritech.co.uk/product/gemini-720is-1000m-or-4000m). The 720is sonars operate at 720 kHz, which is similar to the lower frequency employed by DIDSON sonars. The sonars arrived in late April, to allow time to fabricate mounts and write software to automate their operation.

The winter of 2016/2017 was average in terms of snow accumulation, but the spring breakup was relatively late. The Copper River highway was cleared to mile 36 on May 5th, but launching boats there was not possible because the main channel had migrated further to the east, and several large snow drifts lay between the road and the river. On May 7-8th, a route was pioneered through one of the dry summer channels that intersects the highway at ~35 mile; trucks and boats were floated across snow banks on 2x12 lumber. On May 8th jet skiffs were launched and an attempt made to transit to the Miles Lake site. River conditions were not initially conducive or safe to travel, occasional heavy ice choked the jets and made maneuvering difficult. Late on May 8th the team found that the river was completely blocked by a large ice dam at Heart Island (where the main channel crosses from the west side to the east side at the Clear Martin), and the skiffs returned to 36 mile for the night. The skiffs returned to Heart Island on the morning of May 9th, waited for the ice jam to clear, and made way to the Clear Martin site. The camp was struck the same day, and the sonars were deployed and recording on the east bank of the river (adjacent to the camp) later that evening. The west bank of the river was initially covered with land-fast ice and snow, the west bank sonar was deployed on May 15th when the bank cleared.

The east bank sonar was placed at a site immediately below a cutbank, and slightly set back from the main channel (so that the sonar would not be in danger of being hit by floating debris). A 40' long x 20' deep net weir made from seine web (donated by Mike Maxwell at LFS) was set up just downstream of the sonar frame to move up-migrating fish away from the bank so that they might be better ensonified. The west bank sonar was initially set up immediately across the river from the camp, at a site where the bottom sloped off fairly gently and with a good site on the bank to place the batteries that power the sonars. By May 23rd, a newly opened channel upstream of the west bank sonar began discharging material down on the west bank sonar, partially burying the frame and weir. Neither could be recovered by digging, and both were recovered on May 24th with a high volume gas pump. The west bank sonar was re-sited slightly downstream later the same day, where it remained for the rest of the deployment. The sonars and camp were removed on July 9th.

A small number of salmon-sized targets were enumerated in the first week of deployment, followed by several days with no counts (figure 2, top panel), a large Eulachon run was also observed early on, but those fish were excluded from counts by virtue of their size. Fish counts increased in mid-May and were fairly steady, with several pulses of fish observed.

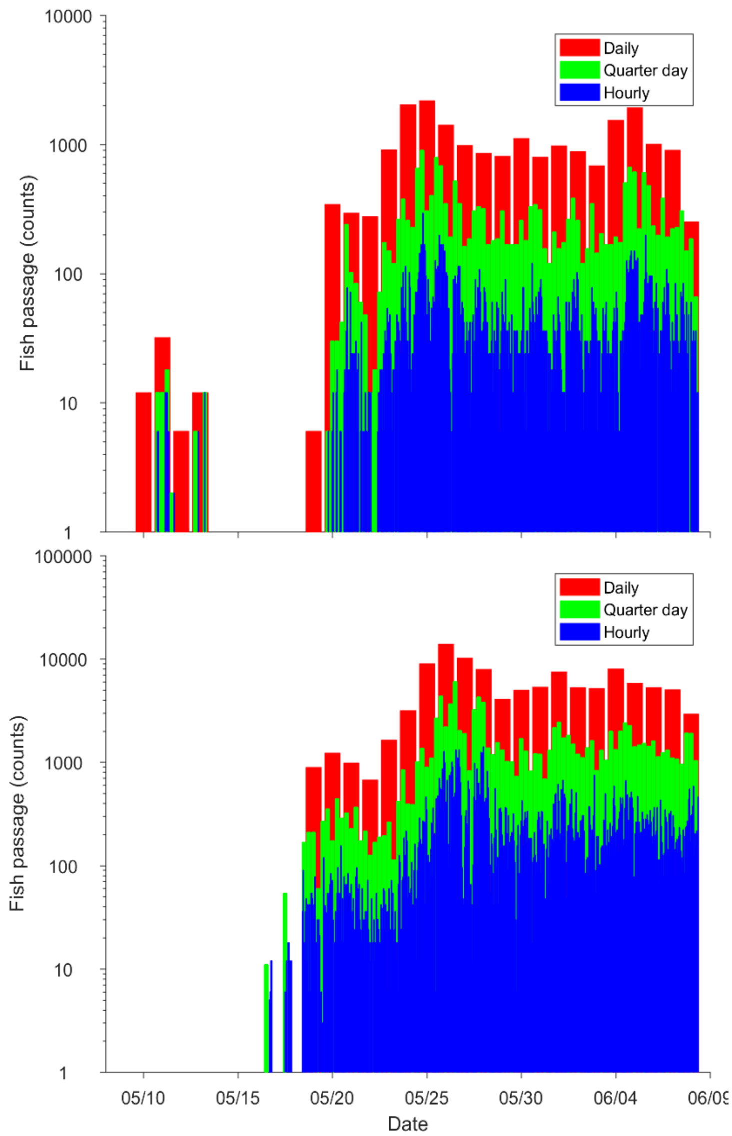

Figure 2: Counts of fish passage made at the Clear Martin sonar site (this project, top panel) and the ADF&G sonar site at Miles Lake (bottom panel). Hourly counts (blue bars) were binned into 6 hour (quarter-day) and 24 hour (daily) bins for further analysis.

Methods

Both of the sonars transmit data via an Ethernet connection, and data logging was done through a small standalone network set up in the main tent of the camp. Data from the west bank sonar was streamed to the camp via a wireless data link. Data logging and processing was done by two dedicated laptops (one per sonar), and fish counting was done with a third laptop also connected to the network. Network address translation and data transmission was done through a Sierra Wireless RV50 cellular modem connected to the Copper Valley Wireless cellular network. An active diversity directional antenna was pointed at the cellular repeater on Wolverine ridge. Connection quality was generally very good, in the -60 to -70 dB range (-50 dB is an excellent “5 bar” connection, and a very poor connection is in the -100 to -110 dB range), and data transmission speeds were acceptable.

The Gemini software does not have a provision for automated recording, so routines were developed in the AutoIT scripting language to start and stop recording by the sonars and the processing of the data collected. The Gemini software does not appear to be a native windows program, and could not always be run by keystrokes or interacting with dialog boxes. The routine for automated recording thus used a combination of recorded mouse gestures and clicks plus keystrokes to start and stop recording. The system worked reliably, but meant that the laptops could not be used while the routines were being run, necessitating the third laptop for counting. The east bank sonar was set to record the first 10 minutes out of every hour and the west bank sonar was set to record for 10 minutes starting at 15 minutes after the hour.

Following recording, the videos were automatically processed with a number of routines also scripted in the AutoIT programming language. The routines did the following:

1. Transfer raw Gemini files from the recording directory to a processing directory.
2. Run the Gemini software on the raw files to produce an uncompressed video file (.avi).
3. Convert the .avi video file to a compressed .mp4 file using FFMPEG (ffmpeg.org). FFMPEG is a free, open source media compression library. Files were compressed with an H.264 encoder (libx264) with a Constant Rate Factor of 36, which was chosen as a compromise between final file size and video quality. The compressed .mp4 files were generally 80-90 MB in size, though occasionally larger when the sonograms were more complex.
4. Transfer the compressed .mp4 files to the PWSSC server (sonar.pwssc.org) via File Transfer Protocol (FTP) with WinSCP.

The processing routines were run immediately after each recording run, and generally took about 45 minutes to complete. The Gemini software does not produce modal dialog boxes that can be interacted with by AutoIT programs, which made programming the routines challenging. Ultimately timers were used to suspend operations to allow the Gemini software to do its processing. This for the most part worked, but sometimes lead to breakdowns in the processing (when the Gemini software took longer than expected to finish its processing). When that occurred the processing was done manually by the technicians.

Fish passage counts were done on the third laptop using the high resolution videos and a video viewer (Videolan: www.videolan.org), and also sometimes with the Gemini software to play the raw files. The Gemini software broke up each 10 minute recording into several files, which made using the Gemini software more cumbersome than the video files. Occasionally, the Gemini software produced very large numbers of very small files (up to 100 in a 10 minute interval), which were very difficult to deal with. We consulted with the manufacturer, but were not able to discover the cause. It was suggested that ethernet dropouts might have been the cause.

Counts from each 10 minute period were converted to hourly counts by multiplying the number of counts in the subset by the fraction of each hour that was recorded (i.e. 6). Hourly counts were posted several times per day, and each day's hourly counts summed up to produce a daily count. Spreadsheets with the hourly and daily counts were posted to the PWSSC lower Copper Sonar website (http://pwssc.org/lower-copper-sonar/) directly by the technicians several times per day as the counts were finished.

2017 Copper River stage height

The state of the river during the deployment may be inferred by examining the hydrograph of discharge during the Clear Martin deployment (figure 3). Discharge data from the USGS station at the Million Dollar Bridge were furnished by the USGS office in Anchorage and from the NWIS water data website (discharge is derived from stage height observations, and are thus a proxy for water height). The data record at that site is patchy, but includes several years of observations from 1988 to present.

To put the 2016 river height (the red line in figure 3) in context, an "average" discharge was calculated with two methods – by averaging all observations for each individual day (the black line in figure 3), or by fitting a fifth order sinusoidal curve through all of the data (the blue line in figure 3). The latter method produces a smooth curve, while the former does not.

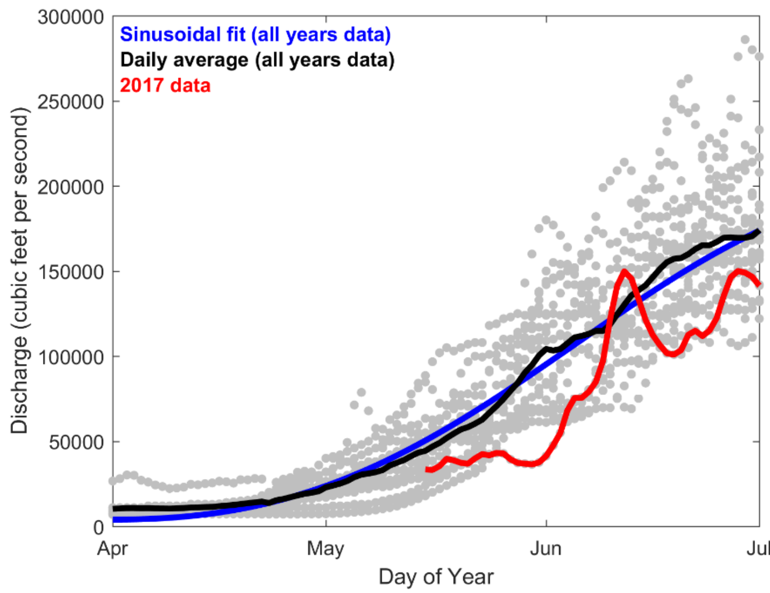

Figure 3: Discharge hydrograph at USGS station 15214000 (Million Dollar Bridge) during May. Grey dots are all observations (i.e. made between 1988 and present), and the red line indicates observations made in 2017. "Average" discharge is indicted as a daily average (black line), or from a sinusoid (blue line, see text) fit through the entire dataset.

The 2017 hydrograph starts relatively late, because ice-out at the Million Dollar Bridge was also late. All indications are that water levels in 2017 were for the most part below average. This fits with observations at the Clear Martin site that water levels were much lower than in 2016.

Comparison between the Clear Martin site and the ADF&G Miles Lake site

Hourly counts of fish passage at the Miles Lake site were made available by Shane Shepherd at the ADF&G Miles Lake weir (figure 2, bottom panel). Hourly counts from the North and South bank sonars were summed, and then binned into both quarter-day (i.e. 6 hour) counts, and daily (24 hour) counts. The choice of bin size is somewhat arbitrary, the quarter-day counts appear to preserve most of the “pulses” of fish moving through, while removing some of the high frequency variability of the hourly counts.

The Miles Lake site showed a steady ramping up of fish passage until late May, with counts more or less steady after that. The Miles Lake sonars counted approximately an order of magnitude more fish than the Clear Martin sonars.

There is a lag time between when fish were counted at the Clear Martin site and when they passed the sonars at Miles Lake. If one assumes that the fish travel at a roughly constant rate, then there may be some coherence between the two sites that will be indicated by the correlational lags between the two sites. The counts made at the Clear Martin site may be correlated against counts made at Miles Lake at some point in the future – this is termed a lag (e.g. counts made at the Clear Martin site at time X can be correlated against counts made at Miles Lake 1, 2 or 3 days later, and so forth). For each correlation, a Pearson’s correlation coefficient was determined, and the statistical significance of each correlation tested using a Student’s t distribution for a transformation of the correlation. The probability value of the test indicates the probability that a correlation was detected when none exists. Correlations with probabilities < 5% are presented as statistically significant (i.e. there was a 1 in 20 probability that the correlation occurred by chance alone)

The lagged correlations showed the best correspondence between the Clear Martin and Miles Lake sonars between 1 and 4 days, with the best correlations in the range of 1 to 2 days. If one assumes that up-migrating salmon use the main channel of the river, the distance between the Clear Martin site and Miles lake is approximately 25 miles. A transit time of two days between the Clear Martin site and Miles like implies an average velocity of 0.23 m/s (slightly more than a half mile per hour), which is toward the lower end of swimming speeds observed in sockeye salmon migrating up the Fraser River, where speeds have been observed to vary between 0.14 and 3 m/s (Hinch and Rand 1998; Hanson et al 2008).

Lessons learned and recommendations

The 2016 and 2017 Clear Martin sonar deployments both counted significantly fewer fish overall than the Miles Lake sonar site. Stage heights in 2016 were above average (perhaps giving up-migrating fish more channel options), and only a single sonar was deployed on the eastern bank, which it was thought might have resulted in the relative undercounting. The 2017 deployment featured a second sonar on the west bank for more complete coverage, and fish were indeed counted by both sonars, but were still considerably less than the Miles Lake counts again. Conditions in 2017 were very good for counting fish at the Clear Martin site. Water levels were below average, which tends to lead to essentially all of the flow going past the Clear Martin site. The main western branch of the delta (which passes Flag Point at mile 27 of the Copper River Highway) has continued to shoal, and was not connected to the main stem until relatively late in the season: water in that branch was clear into June, indicating that no Copper River water (which is extremely turbid) was entering.

The results from the sonars in 2017 suggest that up-migrating salmon may not be aggregating along the banks in the lower delta like they tend to do at Miles Lake, and a large proportion of fish migrated in mid-channel, out of the range of the sonars. The bed gradient at Miles Lake is much steeper (it is immediately above a rapid) than it is at the Clear Martin site, so fish in the lower delta (which is almost flat) may not need to travel along the banks as much to conserve energy. This is consistent with observations of seals hunting near the sonar camp: there were generally on order of 100 seals in the vicinity of the sonar camp during the deployment, and they were observed all across the river, not just at the banks.

When deployed from a riverbank looking out, the area sampled by the sonars is not well defined; the furthest distance is "fuzzy", and depends on the number of particulates in the water (which scatter sound), the shape and type of the bed surface (e.g. rock is acoustically "bright", sand and silt less so), and the orientation of the sonar beam. Viewing the videos from the 2017 deployment suggests that the practical range of the Gemini sonars was approximately 25 to 35 feet. The width of the river bank at the Clear Martin site is approximately 700 feet, which means that the sonars were only sampling 7 to 10% of the entire river. The counts made at the Clear Martin site were also on the order of 10% of the Miles Lake counts. If true, this presents a problem for the project, because not all of the fish passing can be counted. However, if the up-migrating salmon have no preference for any portion of the river (i.e. they are more or less evenly distributed bank-to-bank), then the counts can be corrected for the proportion of the river that is sampled, in much the same way that subsamples made in time (i.e. measuring 10 minutes out of the hour) are corrected.

It is also possible to make better use of the geometry of the sonar beams to cover a larger proportion of the river. The Gemini sonars have an extremely wide field of view, covering 120 degrees. In comparison, the DIDSON sonars used at Miles Lake have a 14 degree field of view (which can be doubled to 28 degrees with a plano lens). In a side-looking configuration (from a riverbank looking out), much of the wide field of view of the Gemini sonar is therefore wasted. A downward-looking configuration would allow making fuller use of the wide beam to cover more water. These differences are shown diagrammatically in figure 4. The approximate beam extent of the bank mounted sonars is shown in green, and that of a downward looking sonar in red. The downward looking sonar samples much more of the water column and bottom, particularly where the water is deeper. Mounting sonars at the surface does present some deployment and engineering challenges: any platform would need to be engineered to withstand the considerable floating ice and woody debris that is a feature of the Copper River; it would require a stout anchoring system as well.

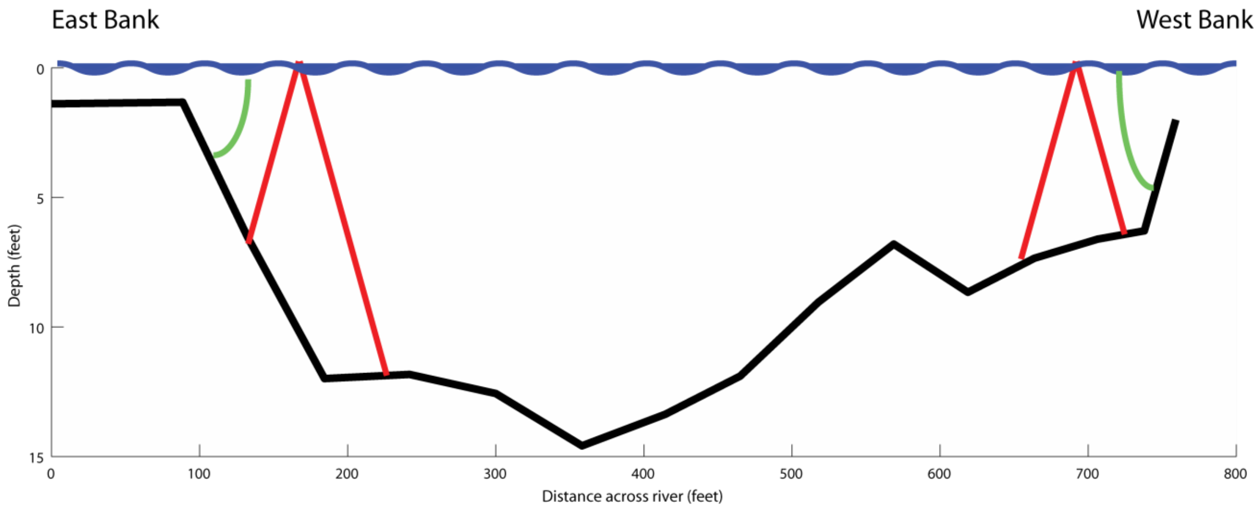

Figure 4: Schematic of estimated coverage from bank mounted (green) and down-looking (red) sonars. The extent of the area sampled from the beam was estimated from the specifications of the Gemini sonar (120° field of view) and the practical range of the sonars determined from the 2017 deployment. Note that the vertical scale is exaggerated to show depth, this narrows the apparent angle of the sonars.

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