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Warner Sucker Passage Success at Deep Creek and Honey Creek Diversion Dams

Contract Numbers: F20AC10347, L21AC10267, 222-8215-19379

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Obermeyer weir and fishway channel at Plush-Town Diversion on Honey Creek. Photo credit: Troy Brandt, River Design Group

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ABSTRACT

Warner Suckers *Catostomus warnerensis* are endemic to the lakes and tributaries of the Warner Basin in southeastern Oregon. The species was listed as threatened in 1985 due to habitat fragmentation from numerous irrigation diversion dams on the tributaries and threats from introduced nonnative fish in the lakes (U.S. Fish and Wildlife Service 1985). Recent recovery efforts have focused on providing passage at three irrigation diversion dams on lower Deep Creek (Relic, Starveout, and Adel-Town diversions) and at the Plush-Town Diversion on lower Honey Creek. Extreme low water conditions in 2021 hampered our evaluation of passage effectiveness at the Deep Creek diversions. Our objectives in 2022 were to: 1) re-assess upstream passage effectiveness of the rock ramps at Starveout and Adel-Town diversions on Deep Creek; 2) assess upstream passage effectiveness at the newly constructed rock ramp at the Plush-Town Diversion on lower Honey Creek; and 3) assess fish entrainment into the Adel-Town and Plush-Town irrigation ditches for fish successfully passing the respective diversions.

Deep Creek stream flow was higher in 2022 than the previous year, and we documented improvement in successful upstream passage at the ramps. In 2021 only 2 of 23 suckers released directly downstream of the Starveout ramp passed upstream, but in 2022 an additional seven suckers from the 2021 release group passed upstream. At the Adel-Town Diversion in 2021, only 3 of 15 suckers released directly downstream of the ramp passed upstream, but in 2022 an additional eight suckers successfully passed. A conservative passage efficiency estimate for the combined years were 39% and 73% for Starveout and Adel-Town, respectively.

A total of eight suckers released at various locations downstream of the Adel-Town Diversion in 2020-2021 were detected in the Town irrigation ditch in 2022. Of the 10 suckers known to have passed the Adel-Town ramp in spring 2022, six (60%) subsequently entered the Town irrigation ditch. Almost all were last detected on the downstream end of the irrigation ditch control structure, indicating they remained in the ditch system through the study period.

At the Plush-Town Diversion on lower Honey Creek, 10 of 13 suckers released downstream of the diversion were detected passing upstream from April through June for a passage efficiency of 77%. All passage events where the route could be verified occurred through the fishway channel. Several suckers made repeated upstream/downstream movements in the fishway channel. It's unclear if this behavior was due to most downstream flow directed over the Obermeyer weir instead of the fishway channel. It's expected that flows into the fishway channel will increase in future years once vegetation becomes established and more flow is directed into it. Minor modifications to the fishway channel headgate could foster this expected result. No fish were detected exiting the bypass pipe of the irrigation ditch fish screen, suggesting fish either did not enter the irrigation ditch or were able to swim back into the creek if they did enter the ditch.

INTRODUCTION

Warner Suckers *Catostomus warnerensis* are endemic to the Warner Basin, a semi-arid endorheic subbasin of the Great Basin in southeastern Oregon, northwestern Nevada, and extreme northeastern California. The presumed historical range of the Warner Sucker consists of the low- to moderate-gradient reaches of Twentymile, Honey, and Deep creeks, the three relatively permanent lakes (Hart, Crump, and Pelican lakes), and several ephemeral lakes during periods of abundant precipitation (U.S. Fish and Wildlife Service 1985; Williams et al. 1990; Figure 1). Stream-dwelling suckers exhibit a fluvial life-history and spawn in the tributary drainages. Lake-dwelling suckers typically exhibit an adfluvial life history. However, when upstream spawning migration may be blocked by low stream flows during low water years or by irrigation diversion dams, spawning can occur in nearshore areas of the lakes (White et al. 1990) with unknown success. Furthermore, it is believed that stream-dwelling populations recolonize the lakes following drought-induced desiccation events that periodically decimate lake-dwelling sucker abundance.

Warner Sucker abundance and distribution has declined over the past century and the species was federally listed as threatened in 1985 due to habitat fragmentation from numerous irrigation diversion dams and threats posed by the proliferation of piscivorous nonnative game fishes in the lakes (U.S. Fish and Wildlife Service 1985). Recovery criteria for Warner Sucker includes, in part, providing passage and screening improvements at the diversion dams in the basin (U.S. Fish and Wildlife Service 1998).

The Warner Basin Aquatic Habitat Partnership (WBAHP), a collaboration of local, state, and federal partners, is committed to the recovery of the Warner Sucker through the completion of passage, screening, and habitat enhancement projects with participating landowners. Passage projects have been completed most recently at diversion dams on Deep and Honey creeks– all diversion dams have been modified with rock ramps (roughened channels) to allow upstream passage. The Adel-Town and Starveout diversions on Deep Creek were complete barriers to upstream movement, while the Relic diversion was a partial barrier (Monzyk 2019). Construction of the Adel-Town rock ramp was completed in late 2019 and the Relic and Starveout ramps were completed in early 2021. Combined, these fishways provided Warner Sucker access to 12 of the 15 km of occupiable habitat in Deep Creek below Deep Creek Falls (Figure 1). Passage evaluations in 2021 showed that Warner Suckers were able to pass upstream at all three ramps, but low stream flows resulted in low numbers of PIT-tagged fish from the release groups successfully passing upstream. In addition, 2 of 3 fish that passed the Adel-Town Diversion entered the Town ditch and did not return to the creek (Monzyk et al. 2021), likely due to high water velocities at the ditch headgates. We re-installed PIT antennas at the Starveout and Adel-Town diversions to continue passage evaluations in the spring of 2022.

On Honey Creek, a passage project was completed at the Plush-Town Diversion in early 2022. At this diversion, an Obermeyer weir replaced a concrete dam, and a fish bypass channel was added (Figure 2). Prior to passage improvements, the dam was a

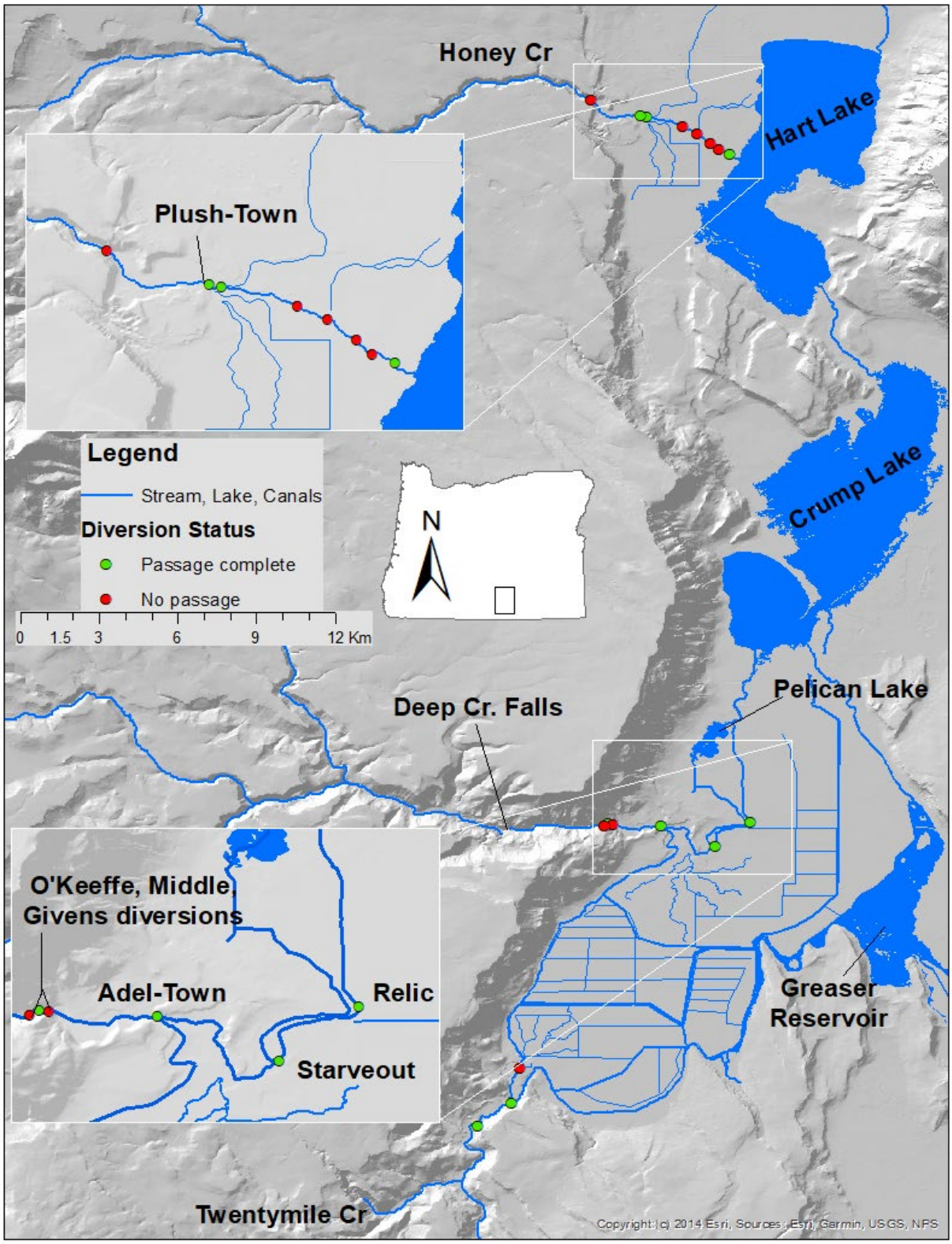

Figure 1. Map of the Warner Basin showing lakes, canals, streams, and irrigation diversion dams with their fish passage status. Inset shows the location of diversion dams on lower Deep and Honey creeks.

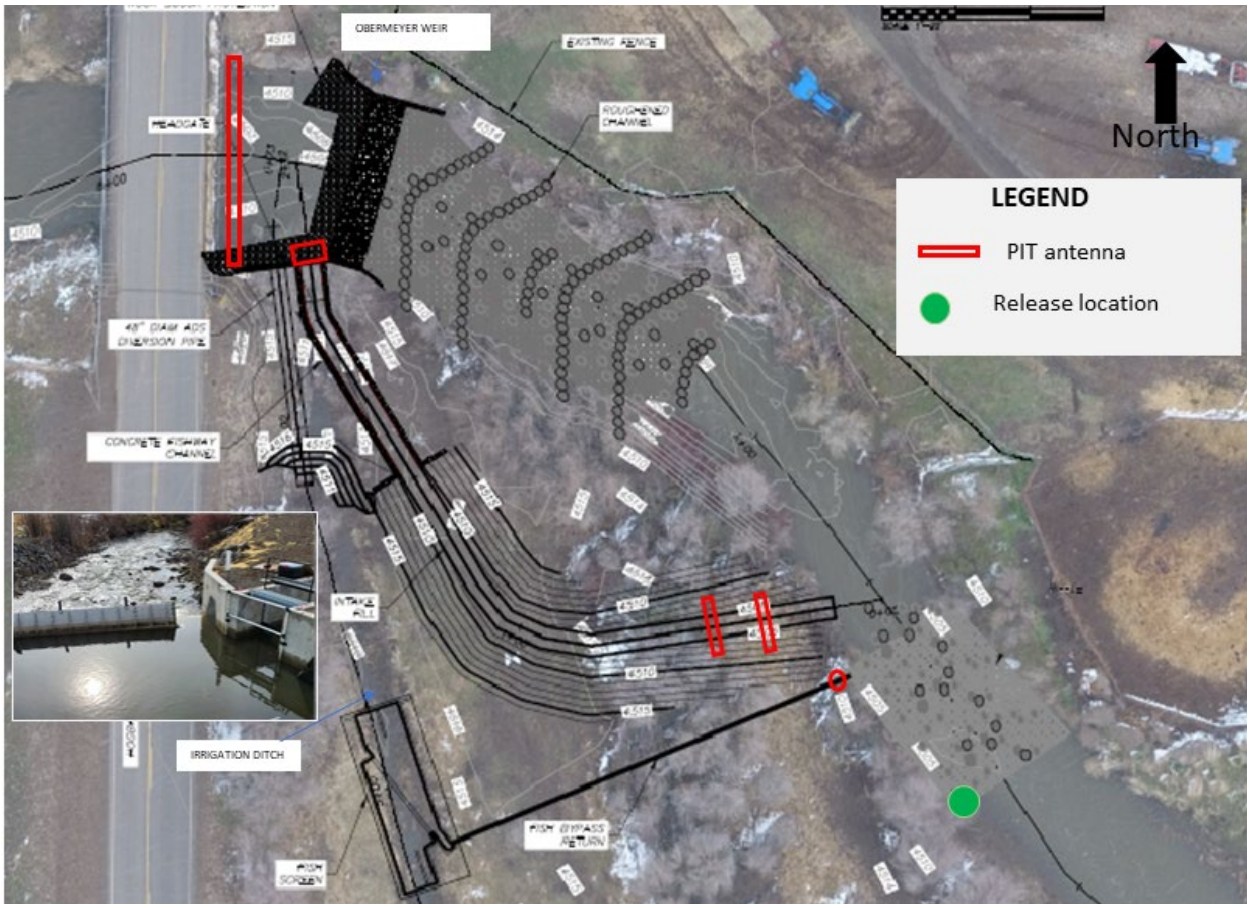

Figure 2. Aerial photo of Plush-Town Diversion showing location Obermeyer weir, fishway channel, PIT antennas and Warner Sucker release location in 2022. Inset photo shows partially open weir and pass-through antenna housed in PVC pipe located at upstream outlet of fishway channel.

complete barrier to upstream movement of Warner Suckers (Coombs et al. 1979). Our main objectives for this study were to: 1) re-assess upstream passage effectiveness of the rock ramps at Starveout and Adel-Town diversions on Deep Creek; 2) assess upstream passage effectiveness at the newly constructed fishway bypass channel at the Plush-Town Diversion on lower Honey Creek; and 3) assess fish entrainment into the Adel-Town and Plush-Town irrigation ditches for fish known to have passed over the respective diversions.

SITE DESCRIPTION

Deep Creek.- Lower Deep Creek has been extensively altered by irrigation development from its historic condition. Prior to irrigation development, Deep Creek fanned out in a large alluvial plain to the southeast of the town of Adel, inundating low-lying marshland. Remnants of the distributary channels are still evident on the valley floor (Appendix

Figure 1). Many of the remnant distributary channels are now part of the Town irrigation ditch network. During spring high-flow periods, Deep Creek water would merge with water from Twentymile Creek and follow the gradual slope of the valley floor north through marshland to the lakes with no well-defined channels (Whistler and Lewis 1916; Stricklin and Perry 1923; Hunt 1964). The construction of the Reclamation Ditch at the turn of the twentieth century carried water ~2.9 km from the main distributary channel SE of Adel, across a low ridge, to the marshland NE of Adel (Appendix Figure 1). Erosive forces soon enlarged the ditch so that it resembled a natural stream and carried most of the flow during high flow periods (Stricklin and Perry 1923). Subsequent dredging of another canal connected the ditch directly to Crump Lake. Six irrigation diversion dams were constructed in lower Deep Creek (Figure 1) to improve the land for cattle production.

Recently, Warner Sucker upstream passage was provided at the Relic, Starveout, and Town diversions by replacing the vertical concrete dams with rock ramps (roughened channels) with a slope <4%. The Starveout Diversion consisted of two dams and a split channel, with the west channel set higher in elevation and only flowing during high water periods. Both the Starveout and Adel-Town rock ramps can become dry during low-flow periods when all stream flow is diverted into irrigation ditches. During these periods, the water in the creek channel downstream of the diversions is maintained by subsurface flow. Generally, all Deep Creek flow up to ~120 cfs is diverted into the Town Ditch throughout the year, so creek flows greater than ~120 cfs are needed before the ramps become watered and available for fish passage.

Honey Creek.- Before major irrigation development occurred, Honey Creek spread out into numerous channels to form an alluvial fan once it emerged from the canyon (Stricklin and Perry 1923). The water was well distributed over a wild grass meadowland of approximately 2,000 acres by both natural channels and artificial spur ditches before eventually flowing into Hart Lake and the low-lying marshland to the south. Irrigation development has since confined Honey Creek to a single channel that drains to Hart Lake. Eight low-head dams and headworks have been constructed along the length of the channel to divert water into irrigation canals (Figure 1).

The largest diversion dam is the Plush-Town Diversion (7th diversion upstream). In 2021, the dam was replaced with an Obermeyer weir that can be lowered during high flow events to prevent flooding and debris build-up. A roughened channel was constructed downstream of the weir to provide a possible passage route when weir gates are completely lowered. A 60-m fishway bypass channel was constructed around the weir that consists of an approximately 25-m long concrete channel with rock substrate at the upstream end that transitions to a 35-m long roughened channel (rock ramp) at the downstream end (Figure 2). Near the upstream end of the fishway channel, a metal ‘stoplog’ with a ~15x30” opening regulates stream flow into the fishway (Appendix Figure 2). Lastly, a fish screen was constructed in the irrigation ditch that directs fish downstream of the diversion via a return pipe.

METHODS

Deep Creek.- On 05 April 2022, we re-installed passive integrated transponder (PIT) antennas at the upstream end of the rock ramps at Starveout and Adel-Town diversions (Figure 3). Only the east channel at Starveout was refitted with an antenna. Antennas were initially installed in 2021 to evaluate passage success of PIT-tagged suckers released directly downstream of the diversions in 2021 (23 suckers downstream of Starveout and 15 downstream of Adel-Town). The ramp antennas were single antennas laid on the stream substrate (pass-over antennas) that did not provide information on directional fish movement. We assumed any first-time detections in 2022 from fish released in 2021 were successful upstream passage events. In addition to the 2021 release groups used for passage effectiveness evaluations, there were 74 PIT-tagged suckers released between the Adel-Town and Relic diversions in 2020 as part of earlier study assessing abundance (Monzyk et al. 2021).

An antenna array was also re-installed in the Adel-Town irrigation ditch in 2022 to assess fish movement into the irrigation system (Figure 3). Pass-over antennas were located immediately upstream and downstream of a water control structure in the ditch, approximately 190 m downstream of the diversion headgates. The two antennas provided information on fish movement near the control structure. Beacons were installed on all antennas to monitor the functional continuity of the antenna systems throughout the 2022 study period. Fish detection data from the antennas was uploaded approximately once a month from April through June to assess passage timing and success. Details on fish PIT-tagging and release methods can be found in Monzyk et al. (2021).

River Design Group (RDG) installed water level loggers (Onset HOHBO® U20L) in the forebay pools of each diversion to monitor water elevation above mean sea level (MSL) every 15 minutes. We used the water level data and the elevation of the ramp crests to determine periods when water was flowing over the ramps. The timestamp recorded with tag detections at the ramps were compared to water elevation data to evaluate water depth on the ramps during successful upstream passage events.

Honey Creek.- We installed antenna arrays at the Plush-Town Diversion on 06 April 2022 to assess passage effectiveness. Two pass-over antennas were located at the downstream end of the rock ramp fishway channel, approximately 5 m apart to determine directional movement of fish in the channel (Figure 5). A single pass-through antenna was located at the upstream outlet of the fishway channel to verify successful passage and calculate travel time through the channel. Travel time through the fishway channel was calculated as the difference between the last detection on the lower fishway antenna and the first detection on the upper fishway antenna. A single pass-through antenna was also placed on the end of the fish screen return pipe to detect fish that entered the irrigation ditch and were screened back into the creek. Lastly, a single pass-over antenna was installed in the forebay pool upstream of the bypass channel and weir (Figure 2).

Following antenna installation, we captured fish using hoop nets set 0.1-1.5 km upstream of the diversion. All Warner Suckers were measured for fork length (FL) and interrogated for previously implanted PIT tags. If not previously tagged, we implanted into the body cavity a 23-mm half-duplex PIT tag. In addition to suckers, a Redband Trout *Oncorhynchus mykiss* was PIT-tagged. All tagged fish were released approximately 15 m downstream of the fishway channel confluence (Figure 2).

On 20 April 2022, we installed water level loggers in the fishway channel, the Obermeyer weir tailrace, and in the forebay pool to record water depths every 15 minutes to monitor flow routes at the diversion during the spring.

Figure 3. Aerial photos of Starveout (A), and Adel-Town (B) diversions showing location of rock ramps, PIT antennas re-installed in 2022, and Warner Sucker release locations in 2021. Inset photo shows water control structure located between the two PIT antennas in the Town irrigation ditch.

RESULTS AND DISCUSSION

Deep Creek Diversion Passage.- Deep Creek stream flows in the spring of 2022 were greater than 2021 (Figure 4), resulting in more frequent flows over the rock ramps and improved fish passage success. At the Starveout Diversion ramp in 2022, there were seven detections of successful upstream passage from the 23 suckers released immediately downstream of the ramp in 2021 (Figure 5), an improvement from just two detections in 2021 from this release group. Combined 2021-22 passage success for the release group at Starveout was 39%. In addition, a sucker that passed over the Relic Diversion in 2021 was detected passing the Starveout Diversion in 2022. Passage events occurred between 21 April and 03 June 2022 (Figure 5), with all occurring at night.

At the Adel-Town Diversion, we detected 8 of the 15 suckers released downstream in 2021 passing the ramp in 2022, an improvement from 3 detections in 2021. Overall passage success (combined 2021-22 detections) was 73% for suckers released directly downstream of the ramp. Two additional suckers tagged and released at locations farther downstream of the ramp also passed in the spring of 2022, including the fish released below Relic Diversion in 2021 that passed Starveout in 2022 (6 d between Starveout and Adel-Town detections). The 10 total passage events at the Adel-Town Diversion occurred between 22 April and 16 June 2022 (Figure 5), with 60% occurring at night.

The combined 2021-22 passage success at both diversions improved considerably from last year. It should be noted that passage success rates reported here are likely conservative because we were not able to account for mortality among the release groups since their release in the spring of 2021. In addition, it is unknown how many fish from the original release groups passed the ramps prior to PIT-antenna reinstallation and were never detected.

The difference in passage success rate between the Starveout and Adel-Town diversions may be related to the smaller size of tagged fish released downstream of Starveout Diversion (mean 128mm FL; range 91-171mm) compared Adel-Town Diversion (mean 135 mm; range 116-179). Smaller suckers are weaker swimmers than larger fish (Scheerer and Clements 2013) so may not have been able to pass upstream or may have experienced a greater mortality rate since release.

We assumed that all 2022 first-time detections of fish from downstream release groups were upstream passage events. However, it’s possible that some fish passed upstream prior to antenna re-installation and were detected making downstream or localized movements near the antennas. This potential bias would affect passage timing but not passage effectiveness. Several fish (n=9) tagged and released in the Starveout forebay pool in 2020 were detected on several occasions at the Starveout ramp antenna in the spring of 2022. Many of these fish were detected on several occasions in 2021 as well, suggesting fish regularly make localized movements near the antenna.

Adel-Town Irrigation Ditch.- Eight Warner Suckers were detected on the PIT array in the Adel-Town irrigation ditch in 2022, all originating from release locations in Deep Creek downstream of the Adel-Town ramp. Six were detected at the Adel-Town ramp antenna prior to detection in the ditch indicating that approximately 60% of suckers that pass upstream at the Adel-Town ramp eventually enter the Adel-Town irrigation ditch. The time duration between the first detection at the Adel-Town ramp antenna and the first detection on the ditch array ranged from <1 d to 20 d (mean=6.5 d). All fish entered the irrigation ditch even though there was flow over the rock ramp at the time.

Seven of the suckers were last detected on the downstream antenna in the Adel-Town irrigation ditch suggesting that they were residing in the irrigation ditch system at the end of the study period. One sucker was detected in the ditch on 28 May and subsequently detected on the Adel-Town ramp antenna on 29 May, suggesting it successfully made it upstream through the ditch headgates. However, the detection at the ramp antenna was suspect given that flows in Deep Creek at the time ranged from ~200-240 cfs with at least 120 cfs entering the ditch headgates. Under these conditions there would be about 1.5 m (5 ft) of head at the headgate opening and water velocity through the headgate opening is believed to be too high for a sucker to pass upstream.

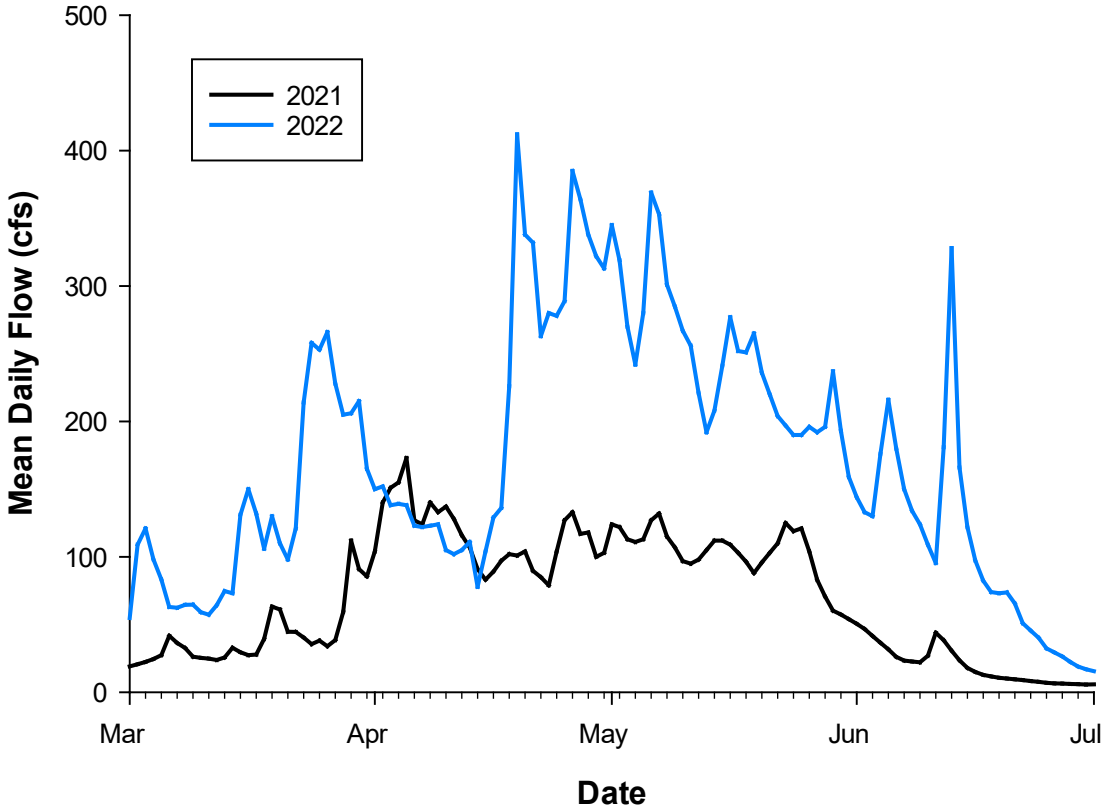

Figure 4. Comparison of spring 2021 and 2022 Deep Creek mean daily discharge. Flows greater than 120 CFS are typically required to permit fish passage at the Adel-Town rock ramps.

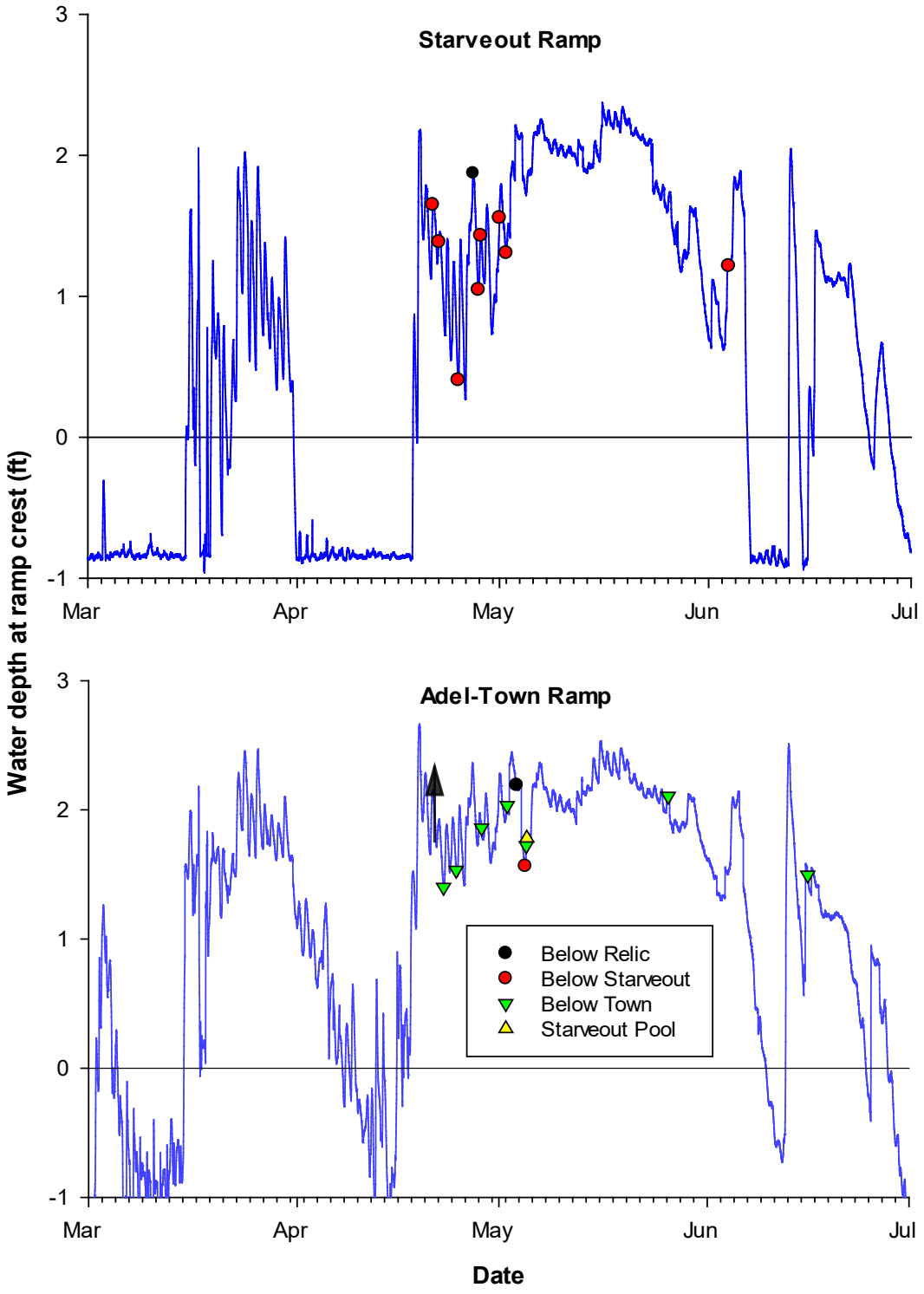

Figure 5. Water elevation of the Starveout and Adel-Town ramps and Warner Sucker passage events in 2022 for fish released in 2020-21 at various locations downstream. .Horizontal line marks the lowest point of the ramp crest, so negative depths indicate the ramp was dry. Arrow on date axis marks beginning of PIT antenna operation.

Also, the detection data at the ramp antenna was atypical since the fish was detected for only a fraction of a second. Generally, fish are detected at an antenna for several seconds if not longer. The ramp antenna was ~2 m from the ditch headgate at its closest point. It's possible that under the right conditions, the fish got close enough to the ramp antenna to be briefly detected within the read range of the ramp antenna, but still on the downstream side of the headgate. Modelling the hydraulics through the headgates under conditions that this event occurred would help inform if this fish truly made it back into the creek through the headgate.

Plush-Town Diversion Passage.- We PIT-tagged and released 13 Warner Suckers downstream of the Plush-Town Diversion between 06-20 April 2022. Suckers range in size from 144-217 mm FL. One Redband Trout (245 mm FL) was also released on 20 April. A total of 10 suckers were detected upstream of the diversion from April through June for a passage efficiency of 77% (Table 1). The Redband Trout passed via the fishway on the night of 22 April.

The PIT antennas in the fishway channel malfunctioned on 16 May so we could not verify passage route after this date but could verify successful passage based on detections at the forebay pool antenna (Figure 2). For fish that were detected passing through the fishway channel prior to this date (n=6), travel times through the fishway range from 0.7-11.8h and all fish entered the fishway at night or near the end of civil twilight (Table 1).

Several suckers (n=6) made upstream/downstream movements in the fishway based on detection timestamps at the two lower fishway antennas. The suckers included some that eventually moved back upstream and successfully passed through the fishway channel. Fish were detected moving upstream past the antenna array and remained somewhere in the fishway channel for a duration that ranged from 2 minutes to 10 hours before moving back downstream past the array. The length of time individual fish remained downstream of the array (likely in the mainstem Honey Creek) before moving back upstream into the fishway channel ranged from 19 minutes to 9 days. It's unclear if the movement pattern was an indication of unsuccessful upstream passage attempts due to flow conditions in the fishway channel or whether it was an indication of normal movement/feeding behavior.

Several factors with water diversion operations in 2022 may have impeded upstream passage. Generally, irrigators followed a schedule whereby most water was sent down the irrigation ditch for a period of 7-10 days followed by 7-10 days when all water was sent to downstream users via the fishway and/or the Obermeyer weir (Figure 6). During this relatively low water year, irrigators used plywood to block flow into the fishway opening to maximize ditch flow when it was in use. When water was directed downstream, the plywood was often left in place to reduce flow in the fishway channel over concerns about bank erosion prior to vegetation establishment along the banks of the fishway channel. Instead, most water was sent downstream over the partially lowered Obermeyer weir (Appendix Figure 2). These conditions resulted in less frequent periods of water flowing in the fishway channel. In addition, there were times when

Table 1. Passage details of Warner Suckers released downstream of the Plush-Town Diversion in 2022. Passage dates in italics were detected on the forebay antenna so passage route is unknown. Numbers in parenthesis are travel times in the fishway channel for fish known to pass that route.

Release Date	Fork Length (mm)	Sex	PIT Code	Passage Data	Passage Route (travel time)
04/07/22	201	M	982.000361656948	n/a	
04/07/22	217	M	982.000361656949	4/16/22 14:48	Fishway (11.8h)
04/08/22	207	M	982.000361656914	4/16/22 02:08	Fishway (4.8h)
04/08/22	176	M	982.000361656975	4/17/22 23:06	Fishway (1.1h)
04/08/22	175	F	982.000361679104	n/a	
04/08/22	198	M	982.000361679103	4/23/22 02:55	Fishway (1.4h)
04/08/22	181	F	982.000361678999	*5/25/22 22:08*	unknown
04/19/22	144	F	982.000361679004	*5/25/22 14:12*	unknown
04/19/22	212	M	982.000361678994	4/22/22 20:38	Fishway (0.7h)
04/21/22	165	F	982.000361656916	*5/25/22 17:14*	unknown
04/21/22	193	F	982.000361679051	4/23/22 00:24	Fishway (0.9h)
04/21/22	201	F	982.000361679042	*6/12/22 06:48*	unknown
04/21/22	212	M	982.000361679014	n/a	

[a] Passage date and times were fist detection at the upper fishway antenna

water would spill over the metal stoplog and leak around the edges to provide some flow in the fishway channel, but the opening was blocked with plywood. Despite these passage limitations, the modified diversion was effective at passing suckers upstream when a route was available. The 77% passage rate for the adult-sized suckers in this study is greater than rates typically seen at other passage studies in the basin that range from 50-68% (Scheerer et al. 2017; Monzyk and Meeuwig 2018). It's expected that passage conditions will improve in future years when the fishway is prioritized over the Obermeyer weir for directing downstream flows once vegetation in the channel becomes established.

No fish were detected on the fish screen bypass pipe antenna, suggesting that fish either did not enter the irrigation ditch after successfully passing the diversion or were able to easily reenter the creek if they entered the ditch. This is in stark contrast to the observation at Deep Creek where ~60% of the suckers that passed the diversion eventually entered the irrigation ditch and remained there. There are several possible reasons for the observed difference. First, it should be noted that Honey Creek fish used in this study originated from upstream of the diversion whereas Deep Creek fish originated downstream of the diversion. So, Honey Creek fish may have been more inclined to return to their upstream place of capture. Second, a sucker population is present upstream of the Plush-Town Diversion and during the spawning season, they may have acted as an attractant to the fish passing the diversion. In Deep Creek, it is not clear if suckers are currently residing upstream of the diversion. Prior to Adel-Town passage project completion, no suckers were found upstream of the diversion (Monzyk

and Harrison 2019). If present now, they would be recent colonizers in the last few years and likely still low in abundance. And lastly, the headgate hydraulics at each irrigation ditch are different, allowing conditions for fish to reenter Honey Creek but not at Deep Creek.

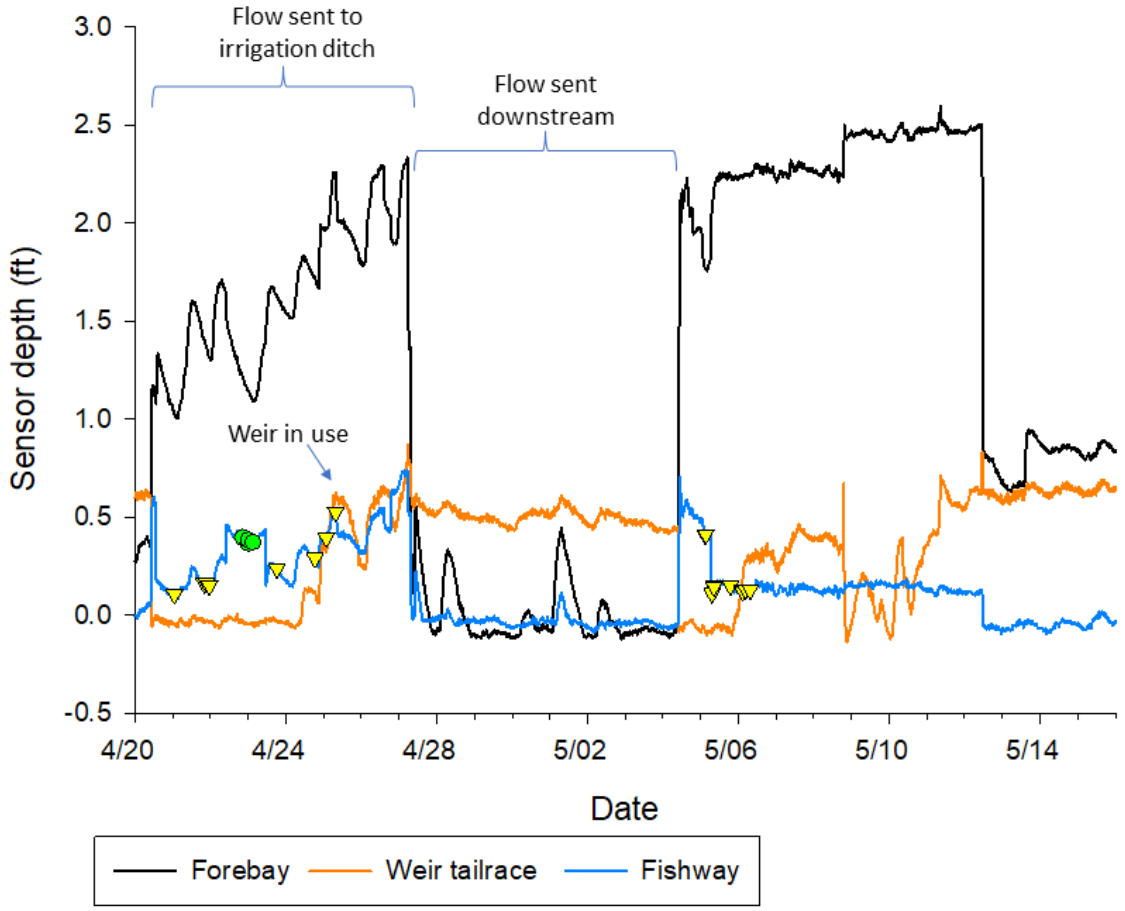

Figure 6. Water depths over pressure sensors located at the Plush-Town Diversion from 20 April – 16 May 2022. Successful passage (green circles) and fish fallback events (triangles) are depicted on the fishway channel depth line. High weir tailrace depths indicate Obermeyer weir use.

MANAGEMENT IMPLICATIONS

Restoration of upstream passage in Deep Creek provides an opportunity for the Deep Creek population– the bulk of which is currently resides in a relatively short (0.5 km) reach upstream of the Starveout diversion– to access more habitat and increase its resilience and abundance. Our PIT-tag detection data showed that most suckers passing the Adel-Town Diversion eventually enter the irrigation ditch and did not reenter the creek, likely due to headgate hydraulics preventing upstream movement. Upstream passage conditions at the headgates are better during summer low-flow periods but, based on mark-recapture studies in other tributaries, suckers do not travel long

distances in the summer months (Scheerer et al. 2011). In addition, dam boards at ditch control structures may make upstream movement prohibitive, especially during low flow periods. Thus, under current passage conditions it's likely suckers that enter the irrigation ditch will remain in the irrigation network and will be unable to spawn with suckers residing in the mainstem creek. Currently, WBAHP is assessing the hydraulics at the headgates and possible modifications to improve upstream passage during high flows. Additionally, the habitat in the ditch network and possible fish screening locations are also being evaluated. The quality of the habitat in the ditch network appears to be good in many places. Portions of the irrigation network are composed of the remnant distributary channels (appendix Figure 1) that were likely historic habitat for suckers prior to irrigation development. These channels currently have abundant submergent vegetation (appendix Figure 3) and remain watered year-round given the current irrigation practice of sending all summer stream flows into the irrigation ditch for stock watering purposes. Improving passage conditions at the headgates and the ditch control structures would allow Warner Suckers to utilize all the available habitat in the subbasin, ensure subpopulations do not become genetically isolated, and increase overall population resilience.

In Honey Creek, completion of the Plush-Town Diversion passage project removes the only known compete barrier to upstream movement for Warner Suckers in the subbasin. Passage projects has been completed at the Rookery and Flood Ditch diversions and the remaining five diversions are only partial barriers, depending on when dam boards are installed during the irrigation season. Lake-dwelling sucker can now theoretically access all the habitat in Honey Creek under the right conditions but providing permanent upstream passage at the remaining five diversions will improve overall passage conditions in lower Honey Creek.

The passage efficiency observed this year at the Plush-Town Diversion was high despite limited flow in the fishway channel this year. During this study, the Obermeyer weir was used often to send water downstream instead of the fishway channel. Working with the irrigators to prioritize flows in the fishway channel in the future should only increase passage efficiency. It can be reasonably assumed that irrigators will want to send the maximum allowable flow into the irrigation ditch during future drought years by blocking the fishway opening, as was done this year. To improve fish passage and ease of operation during these times, it's suggested that the fishway opening be modified with a slide gate (instead of plywood) to allows irrigators to easily reduce flow in the fishway channel when needed. The slide gate could be constructed with a small orifice that would allow a small amount of flow and a fish passage route in the fishway channel when closed, but easily lifted out of the way when water is directed downstream.

In total, nine irrigation diversion passage projects have been completed in the Warner Basin, significantly decreasing habitat fragmentation of the Warner Sucker populations. It is expected that the completion of all passage projects by WBAHP will restore passage within and among the three major streams of the Warner Basin, achieving one of the major delisting criteria for the species.

ACKNOWLEDGEMENTS

We would like to thank Justin Miles for many hours of assistance with installing PIT antennas and tagging fish. We would also like to thank Sandy Taylor, Joe Cahill, and John Flynn for graciously allowing us access on their property to conduct this study. Thanks to River Design Group, Inc. for providing information on water elevation and diversion designs. Funding for this work was provided by the Lake County Umbrella Watershed Council, the Bureau of Land Management, and the U.S. Fish and Wildlife Service.

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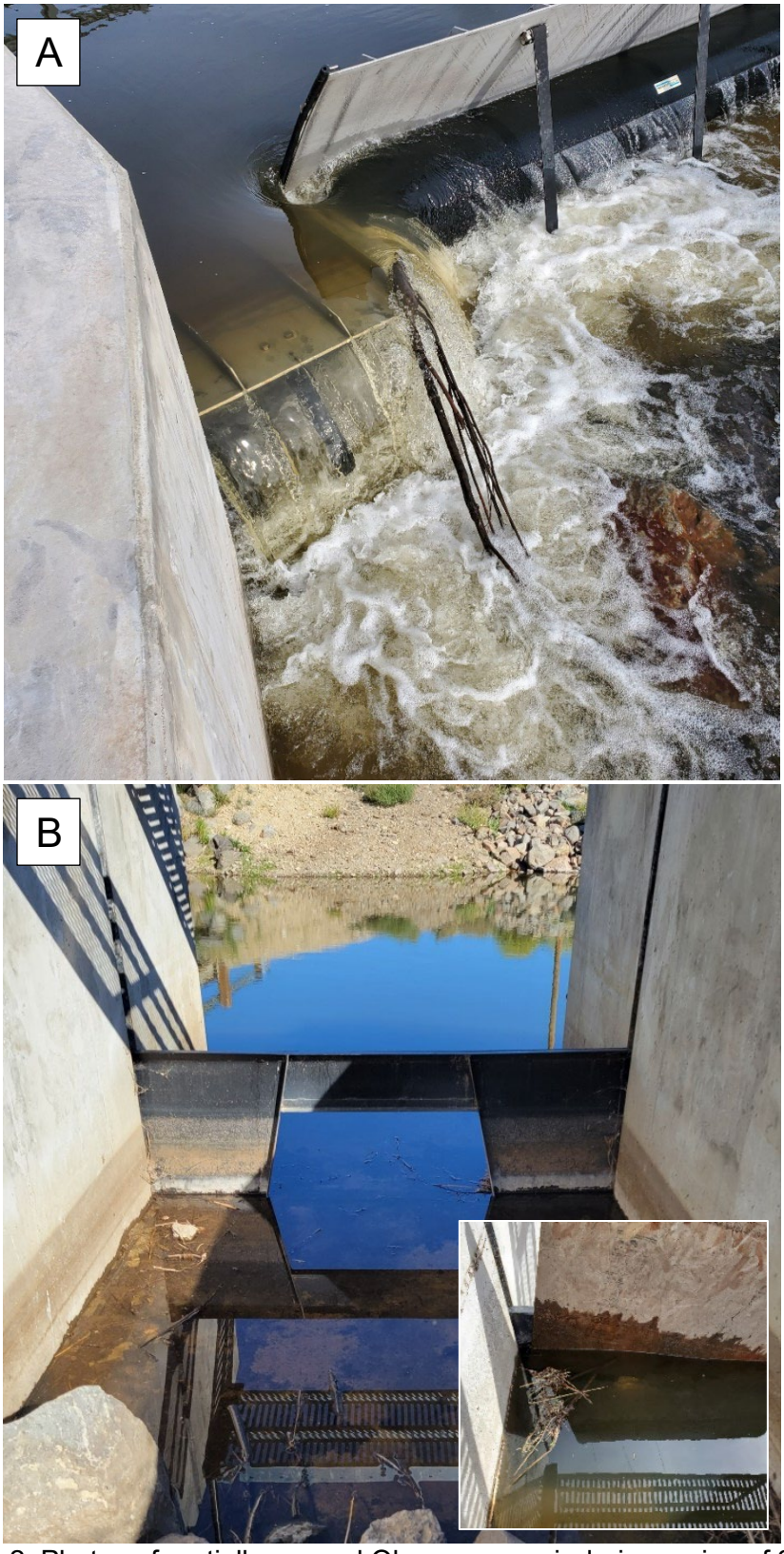
APPENDIX

Appendix Figure 1. Satellite imagery showing the remnant distributary channels and Reclamation Ditch (highlighted) terminating in the marshland on the valley floor of Deep Creek. Imagery from Google Earth.



Appendix Figure 2. Photos of partially opened Obermeyer weir during spring of 2022 (A) and metal stoplog with orifice at upstream end of the fishway channel (B) at Plush-Town Diversion. Inset photo in photo B show orifice blocked with plywood.

Appendix Figure 3. Photos showing portions of the Adel-Town irrigation network comprised of remnant distributary channels of Deep Creek.

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