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To: Sarah U'Ren, The Watershed Center

From: Marty Boote, Environmental Consulting & Technology, Inc. (ECT)
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Re: Kids Creek Restoration Project Conceptual Design
NOAA Award ID No.: NA18NMF4630291
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INTRODUCTION

Environmental Consulting & Technology, Inc. (ECT) has conducted baseline and post-construction monitoring to evaluate Tier 1 project performance for fish passage. Fish passage criteria were developed based on target fish species swimming capabilities and National Oceanic and Atmospheric Administration (NOAA) guidance. The performance measures and how they were developed are listed in Table 1.

Table 1. Development and rationale for Tier 1 Fish Passage Performance Measures

Tier 1 Passage Performance Measure	Rationale
Downstream Scour Pool	Target: Less than 2 times bankfull depth, depth greater than normal pool depth indicates accelerated discharge velocity and can lead to culvert perching Baseline: greater than 2 times bankfull depth, based on survey Performance: post-construction survey
Water Surface Slope	Target: 0.16 to 0.20 percent, steep slopes create scour and high culvert flow velocity and exit velocity, low slopes and cause sedimentation due to inefficient sediment transport Baseline: 0.18 percent reach-average slope, determined from pre-construction survey Performance: post-construction survey
Adult Brown Trout Abundance	Target: Reach 1 post construction, Reach 2 should be the same as Reach 1 if culverts are not disrupting fish movement Baseline: fish survey, abundance higher downstream in Reach 1 than upstream in Reach 2 Performance: fish survey, abundance similar
Juvenile Brown Trout Abundance	Target: Reach 1 post-construction, Reach 2 should be the same as Reach 1 if culverts are not disrupting fish movement Baseline: fish survey, abundance higher downstream in Reach 1 than upstream in Reach 2 Performance: fish survey, abundance similar
Sediment Bars	Target: presence/absence, bars disrupt flow and increase velocity Baseline: longitudinal bars present between culverts, visual inspection Performance: visual inspection

Tier 1 Passage Performance Measure	Rationale
Flow Velocity	Target: less than 3 ft/s at approximately 60 cfs (bankfull) based on target fish swimming speeds in published literature, high velocity prevents or reduces fish movement Baseline: hydraulic modeling of existing conditions Performance: measured velocity post-construction
Flow Depth	Target: greater than12 inches at approximately 20 cfs, based on target fish species adult body depth and swimming capabilities, shallow water depths can discourage fish movement at low flows, water depths may vary and can only be measured at flows present during monitoring so a conservative value was chosen Baseline: pre-construction survey Performance: measured post-construction

FISH SURVEY

Baseline monitoring of the fish community was conducted in August of 2019 prior to construction. Post construction fish monitoring was conducted in August 2022. Reach 2C was longer in 2019 and Reach 3 was surveyed due to plans for a fourth crossing replacement. The fourth crossing was not replaced due to feasibility. Therefore, Reach 2c was shortened and Reach 3 was not surveyed in 2022. Reach 1 is from Front Street upstream to Cedar Street, downstream of all three crossings. Reach 2 is the combination of three sub-reaches: 2A - from Cedar Street #1 (north) to Cedar Street #2 (South); 2B – from Cedar Street #2 to Sixth Street; and 2C – from Sixth Street to the first upstream tributary (approximately 640 feet upstream of Sixth Street).

Fish abundance was used to evaluate fish passage effectiveness. Specifically, Brown Trout was used as the target fish species due to its abundance and diverse size/age range in Kids Creek; Brown Trout is the dominant game fish species in Kids Creek within the project reach. Catch-per-unit effort (CPUE) was used as a measure of fish abundance. Abundance was evaluated for adult and juvenile Brown Trout because road crossings can affect juveniles more than adults due to their smaller size and lower swimming capabilities. Adult Brown Trout were determined to be greater than 10 inches (age 3+) based on Michigan growth data in Schneider et al., 2000[1]. Pre- and post-construction Brown Trout catch data are presented in Table 2.

[1] Schneider, James C., G. R. Alexander and J. W. Merna. 2000. Age and Growth Methods and State Averages. Chapter 9 in Schneider, James C. (ed.) 2000. Manual of fisheries survey
methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries
Special Report 25, Ann Arbor.

Table 2. Brown Trout Catch Data from Reach 1 and Reach 2 of Kids Creek, Grand Traverse County, Michigan Before (Pre) and After (Post) replacement of Three Stream Crossings on Cedar Street (two) and Sixth Street (one)

Life Stage	Reach 1		Reach 2		Reach 2A		Reach 2B		Reach 2C		Total	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Number												
All	18	11	28	21	17	16	3	2	8	3	46	32
Juvenile	16	7	25	15	16	12	3	1	6	2	41	22
Adult	2	4	3	6	1	4	0	1	2	1	5	10
Percent												
Juvenile	0.89	0.64	0.89	0.71	0.94	0.75	1.00	0.50	0.75	0.67	0.89	0.69
Adult	0.11	0.36	0.11	0.29	0.06	0.25	0.00	0.50	0.25	0.33	0.11	0.31
Catch Per Unit Effort (CPUE, fish/minute)												
Juvenile	1.4	0.6	0.7	0.6	0.8	1.1	0.5	0.5	0.5	0.2	0.5	0.4
Adult	0.2	0.3	0.1	0.2	0.1	0.4	0.0	0.5	0.2	0.1	0.1	0.2

The crossings at the two Cedar Street crossings (#1, north and #2, south) and the Sixth Street crossing were likely disrupting fish movement due to longitudinal sediment bars, water surface drops at low flow, scour pools, high culvert velocities, and high culvert exit velocities. Due to disruptions in fish movement, differences in adult and juvenile fish abundance would be expected. During pre-construction surveys, the adult Brown Trout CPUE was 0.2 fish/minute in Reach 1 (downstream of the crossings) and 0.2 between and upstream of the crossings, indicating adult brown trout were more abundant downstream of the crossings prior to crossing replacement. The Brown Trout juvenile CPUE was 1.4 fish per minute in Reach 1 and 0.7 fish/minute in Reach 2, indicating juvenile Brown Trout abundance were affected even more between and upstream of the crossings. Given the crossing likely provided some passage but disrupted fish movement, it is not surprising that they affected smaller juvenile fish more than larger adult fish.

Post-construction, the adult Brown Trout CPUE in Reach 1 was 0.3 fish/minute. The Reach 2 CPUE was also 0.2 fish/minute, similar to thought slightly lower than Reach 1. The juvenile Brown Trout CPUE was 0.6 fish/minute in Reach 1 and Reach 2, indicating juvenile Brown Trout abundance was the same between and upstream of the crossings as it was downstream. This is a significant change from the baseline pre-construction condition when juvenile Brown Trout were two times more abundant in Reach 1 than Reach 2. Slight difference in adult abundance between Reach 1 and Reach 2 are expected based on habitat conditions observed. Reach 1 contains more overhanging vegetation and deeper and more abundant pools, habitat that is preferred by adult Brown Trout. The fish monitoring data suggest the crossing replacements have reduced disruptions in fish movements, especially for juvenile Brown Trout.

CULVERT FLOW VELOCITY AND DEPTH

Fish passage was evaluated on the basis of flow velocity and flow depth. Velocity and depth can affect fish passage if velocity is too high for certain fish species or fish size classes (e.g., juvenile fish).

Too shallow flow can also impede fish passage if the water depth is not high enough for adult fish based on body size. Generally, the scientific literature suggests water depths of at least 1.5 times body depth is best for fish passage. Flows in excess of 3 ft/s over an extended distance can reduce fish movement, especially for smaller fish. While adults of some fish species such as Brown Trout can swim for short distances at greater than 3 ft/s, juveniles cannot and fish of all sizes are affected when the velocity field is long. Conservative values were chosen – 12 inches for the minimum flow depth and 3 ft/s for maximum flow velocity – to cover a variety of fish species and fish sizes. Flow depth was evaluated at low flow, while flow velocity was evaluated at high flow.

Baseline conditions were evaluated using the hydraulic model developed by the City of Traverse City for crossing design. Flow velocity exceeded 3 ft/s in one or more of the culverts at all three crossings, while flow depth was less than 12 inches in one or more culverts at all three crossings. After construction, direct measurements were used to evaluate both variables. Given flow velocity could not be physically measured inside the culverts for safety, flow velocity measurements were made at the upstream and downstream faces of each box culvert at seven locations spanning the flow section. Flow depth was measured during a relatively low flow event. Flow velocity was measured during an approximate bankfull event when the culverts were nearly flowing full. Flow depth was measured on September 8, 2022; flow discharge was estimated at 9 cfs based on flow velocity and water depth across six cross-sections (2 at each crossing). Flow velocity was measured on September 26, 2022; flow discharge was estimated at 29 cfs based on flow velocity and water depth measurements across six cross-sections.

On September 9, 2022, the average depth of all three crossings at the upstream and downstream faces was one foot or greater with the exception of the downstream face of the northern Cedar Street crossing. The average flow depth on the downstream face of that crossing was 0.79 feet. The depth range across the section ranged from 0.6 to 1.05 feet. ECT observed sand and silt deposition near the downstream face of the northern Cedar Street crossing that was deposited during subsequent construction of the two upstream crossings. The northern Cedar Street crossing was the first crossing constructed. Given at least one flow measurement exceeded the one-foot flow depth target, measurements were taken at low flow, and a conservative target was selected, fish passage should not be negatively affected by the shallower depths measured on the downstream face. Furthermore, the City of Traverse City will continue to monitor the crossing to ensure the material will eventually be transported as expected.

On September 26, 2022, the maximum flow velocity measured at any given point at all three crossings and both upstream and downstream faces was 1.73 ft/s on the upstream face of the Sixth Street crossing. The mean velocity of all six flow sections measured ranged from 0.43 to 1.03 ft/s.

Based on flow depth and velocity measurements, the crossing replacements meet the performance measures and will not negatively affect fish movement.

WATER SURFACE SLOPE

Water surface slope can be affected by improper sizing or placement of culverts, specifically the invert elevations of the culverts. Developing the correct culvert invert elevations is important to maintaining sediment transport and preventing back water conditions during high flows. The City of Traverse City had some constraints to work with due to public utilities and road approaches. However, the design sought to maintain the reach average slope of Kids Creek with a target range of 0.16 to 0.20 percent. The City of Traverse City surveyed six cross-sections of the channel at each crossing – a total of eighteen cross-sections. At each crossing, the channel section was surveyed at the upstream and downstream face and one and two crossing widths upstream and downstream. The water surface slope along each of those sets of cross-sections was estimated from the surveyed water surface elevations and along the entire reach surveyed including all three crossings. Internally, the water surface slope varied from 0.1 to 0.2 percent. The slope through Sixth Street and the southern Cedar Street crossing was 0.2%. The slope through the northern Cedar Street crossing was 0.1%. The reach average slope through all three crossings (877 feet of stream from the upstream most to the downstream most cross-section) was 0.11%. Measured flow velocity follows this trend in slopes. While the post-construction water surface slope falls slightly lower than the target range, the maximum slope is within the target range and the flow depth and velocity meet the performance measurers.

DOWNSTREAM SCOUR POOL DEPTH

Road crossing culverts that are set with a slope that is too steep or are under sized for the stream flows can cause excessive exit velocity and large scour pools downstream of the culverts. Downstream scour pools cause lateral bank migration and disconnected water surface that results in a water surface drop during low flow. Water surface drops at the downstream end of road crossing culverts can cause a jump and fish passage barrier. All three crossings had large scour pools on the downstream side.

The target was set at two times bankfull depth, a value that is typical for normal pool depth formation in streams. Bankfull depth was determined from examination of the cross-section furthest upstream of Sixth Street and furthest upstream of the northern Cedar Street Crossing. The bankfull depth was determined to be 2.3 feet, which is the average depth. Cross-sections surveyed downstream of each crossing were examined to determine the maximum depth at bankfull. The maximum bankfull depth at the three crossings from upstream to downstream were 3.4, 5.4, and 3.0 feet. Those depths were 1.3, 2.3, and 1.5 times the bankfull depth respectively. The pool downstream of the southern Cedar Street crossing exceeds the target value slightly. However, this is due to the position of the crossing on a bend in Kids Creek where a large pool already existed and is maintained by the curvature of the creek. Based upon inspection and measured flow velocity at an approximate bankfull event, it does not appear the crossing is causing additional scour at that location.