Logan River Conservation Action Plan (CAP) Monitoring Protocol

1. INTRODUCTION

1.1. Logan River Watershed

The Logan River, an integral part of the greater Bear River ecosystem, originates within the Bear River Mountains in the headwaters of Logan Canyon and terminates at its confluence with the Little Bear River in Cutler Reservoir. The river is an asset to residents of Logan City and Cache County and has historically supported many beneficial uses. The Logan River was an important resource for Native Americans and pioneers and remains valuable today. Cache Valley citizens are attracted to the river and enjoy the aesthetics, recreational values, and wildlife resources associated with this high-quality river, which supports fish, wildlife, and many plant species unique to riparian and wetland habitats. The Logan River also provides water for irrigation, municipal water supply, and hydroelectricity.

1.2. Logan River Conservation Action Plan

To protect the Logan River from degradation and the growing threats of floodplain development, a Conservation Action Plan (CAP) was developed in 2016 for the portions of the Logan River from First Dam (at the mouth of Logan Canyon) through Cache Valley to the confluence with the Little Bear River at Cutler Reservoir (Figure 1). The development of a short- and long-range vision for the river was needed to coordinate and prioritize conservation efforts and ensure a sustainable river system for future generations. Stakeholder groups representing residential, commercial, recreational, and agricultural interests participated in the development of this CAP. The CAP is a dynamic set of objectives that can be revised as needed when new threats or conservation solutions are identified. More CAP information, planning process, methods, and individual reach description can be found in Appendix A.

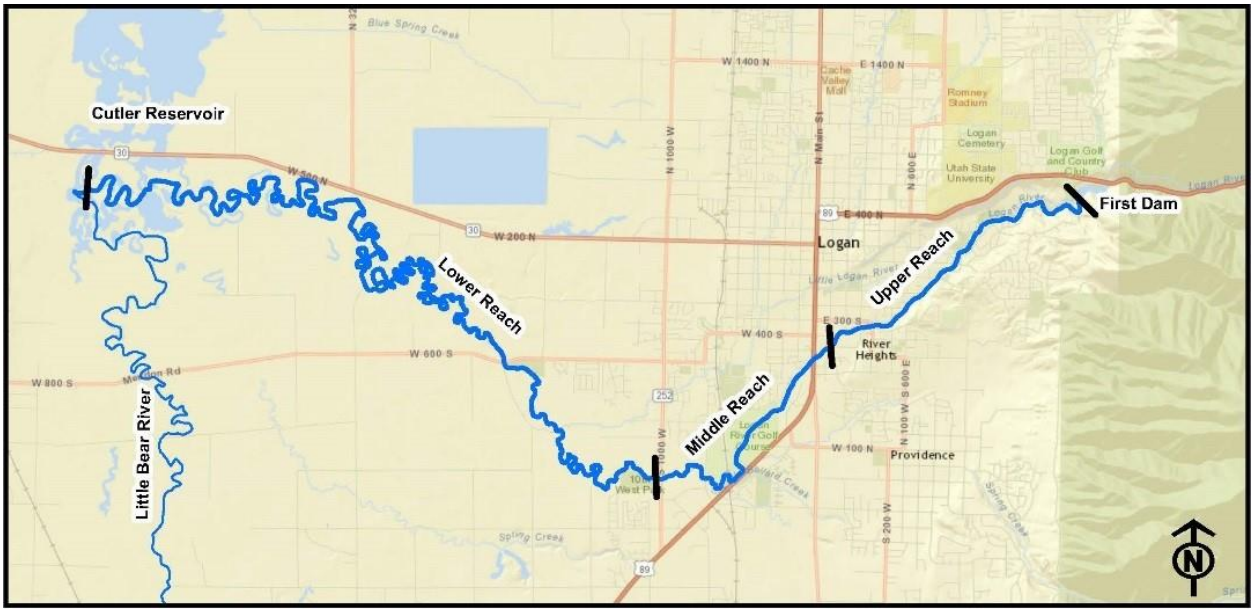

FIGURE 1. LOGAN RIVER RESTORATION CONSERVATION ACTION PLAN (CAP) STUDY AREA DIVIDED BY REACHES.

1.3. Logan River Task Force

In 2014, the Logan River Task Force (Task Force) was formed and was composed of a group of Utah State University professors, state and local government officials, and interest group representatives including but not limited to Logan City, Utah Division of Water Quality (DWQ), Utah Division of Wildlife Resources (DWR), Utah Division of Water Rights (Stream Alterations), Natural Resources Conservation Services (NRCS), Utah Association of Conservation Districts, Trout Unlimited, Bridgerland Audubon Society, USU Extension, USU College of Natural Resources, USU College of Engineering (Water Lab). The main goal of the Task Force is to develop a method for improving areas along the Logan River. The Task Force and Logan City are working with BIO-WEST, Inc. (BIO-WEST), a local environmental consulting firm, to develop and implement the CAP and design restoration concepts for the river. This monitoring protocol provides the foundation for river network monitoring of the CAP indicators and seconds as part of the storm water monitoring for Logan City. More Task Force information can be found in Appendix A.

2. OBJECTIVES

The main objective of monitoring is to assess the physical, chemical, and biological characteristics of the Logan River and determine individual and cumulative successes of various restoration projects and conservation efforts being implemented within the Study Area (Figure 1). The first CAP restoration project implemented was at Denzil Stewart Nature Park fall 2016 in the residential dominated Upper Reach, followed by two larger restoration projects near Rendezvous Park implemented 2017-2019 in the recreational portion of the Middle Reach, followed by the Main Street to 100 East restoration project 2018-2019 in the commercial portion of the Middle Reach. The CAP approach was adapted for the Logan River and includes environmental, recreational, and public values.

2.1. CAP Indicators (Existing, Desired) and Key Attributes

The Task Force selected a broad range of river health indicators and public uses in order to identify existing and desired conditions for the Logan River. A total of 22 indicators were chosen, many apply to the entire river, but the CAP separates existing and desired conditions for specific reaches where it is appropriate to do so. Existing and desired conditions for each indicator are rated on the color-coded, four-point scale: poor, fair, good, and very good (Appendix A). In addition, each indicator rationale is explained and strategic actions to achieve or maintain the desired conditions are listed. To monitor the conditions of Logan River and its riparian corridor, the following attributes are being monitored and analyzed by a wide group of partners.

3. KEY ATTRIBUTES

3.1. Flow Regime

Flow regime is a critical monitoring component of aquatic ecosystems as it shapes river channels and floodplains, dictates ecological processes and determines the biodiversity of river ecosystems. The CAP includes two indicators of flow regime:

- Spring peak flows, which are generally good conditions for all study area reaches as all upstream dams are run-of-the-river diversion structures that do not have significant storage capacity, allowing for a generally natural spring runoff conditions in the study area reaches of the river.

- Summer base flows, which are generally poor conditions for all reaches due to water diversions into Cache Valley irrigation canals.

The USGS gage 10109000 Above First Dam captures the flow regime right before it enters the CAP study area. Streamflow is also monitored at 3 locations on the Logan River (Figure 2) established through the Innovative Urban Transitions and Aridregion Hydro-sustainability (iUTAH) project, now operated by the Logan River Observatory (lro.usu.edu). The stations record gage height, water temperature and water quality attributes. Gage height is later converted to stream discharge using flow-stage rating curves developed for each site. All of the sites in the CAP Logan River study area—Logan River at the Utah Water Research Laboratory (UWRL) bridge, Logan River at Main Street, and Logan River at Mendon Road—have been operational since 2014 and collect data in fifteen-minute intervals. Continuous data is also being collected on Spring Creek and the Blacksmith Fork River just above their respective confluences with Logan River. In addition to continuous data, discharge is measured periodically at these sites. Discharge is also measured bi-monthly during the water quality data collection at following sites (UDWQ): Logan River near the Trapper Trails Council Boy Scouts of America Building, Spring Creek before Logan River confluence, Logan River at Park Avenue, Logan River Above Trapper Park Diversion, and the Little Logan River before Logan River confluence.

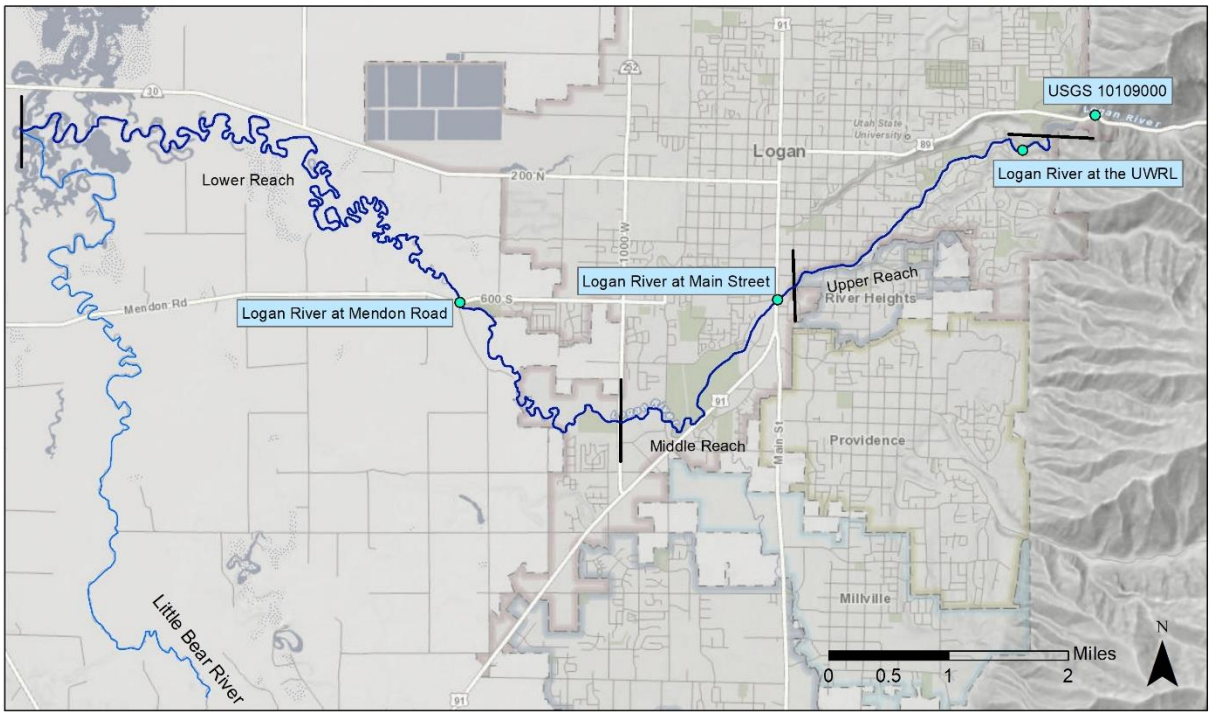

FIGURE 2. LOGAN RIVER CONTINUOUS FLOW AND WATER QUALITY MONITORING STATIONS. USGS GAGE IS LOCATED ABOVE THE STUDY AREA WITH THREE LOGAN RIVER OBSERVATORY SITES THROUGHOUT THE STUDY AREA, ONE IN EACH REACH (UPPER, MIDDLE, LOWER).

3.2. Water Quality and Temperature

Water quality and temperature data are collected at different spatial and temporal scales throughout the study area by different groups. Continuous temperature and water quality are measured at all Logan River Observatory locations. The water quality measurements include dissolved oxygen (DO), pH, specific conductance, turbidity, nitrogen as dissolved nitrate (NO3), Fluorescent Dissolved Organic Matter (FDOM), chlorophyll Fluorescence; the last three are only recorded at the most upstream (Logan River at UWRL) and downstream site (Logan River at Mendon Road). Grab samples collected by UDWQ bi-monthly include: temperature, DO, specific conductance, turbidity, pH, Filtered Nutrients-Phosphate (TDP) D-Nitrite+Nitrate (No2-+No3-), D-Total Nitrogen (inorganic), Unfiltered Nutrients-Ammonia as NH3, Nitrite + Nitrate (NO2 +NO3), and Phosphorus (T-PO4). Temperature was also measured continuously at fifteen locations throughout the study area at fifteen-minute intervals from July through November 2019. There were various projects conducted by iUTAH and USU that captured temperature and water quality throughout the study area over the recent period of time, including storm drain sampling in 2015. There are multiple monitoring locations proposed in addition to existing locations that will be installed as additional funding is acquired.

The CAP indicators for water quality are the State water quality standards for all beneficial uses, which were assessed by the Task Force as having good quality in the Upper and Middle Reaches but fair conditions in the Lower Reach. Water temperatures and dissolved oxygen concentrations in the 2014 303d listing were within State 3A Standards at the Main Street Logan River Observatory gage (above Middle Reach) but exceedances of both water temperatures >20 °C and <6mg/l of dissolved oxygen had occurred for the past two years at the Mendon Logan River Observatory gage (below Middle Reach).

3.3. Sediment Regime

BIO-WEST conducted bedload and suspended sediment sampling in the Middle Reach near Rendezvous Park during 2016 and 2017 runoff seasons. Sediment samples were collected at three locations during the 2016 season and resulted in 9 samples all together. The 2017 sampling season included two locations on Logan River (above and below Rendezvous Park), and included a new location on Blacksmith Fork, resulting in 8 samples for Logan River and 4 samples for Blacksmith Fork River. Bedload samples were dried, sieved, and weighed by BIO-WEST. Water samples were processed by USU Analytical Laboratories and analyzed for total phosphorus (TP, mg/L) and total suspended solids (TSS, mg/L).

Bedload samples were collected using the Toutle River sediment sampler (TR-2) lowered from the bridges (Figure 3). The sampler was borrowed from USU and has a 6”x12” inlet nozzle and 1.4 expansion ratio. Each sample was collected using ten verticals (stations) 6 minutes each. This resulted in one-hour samples. Collected samples were bagged and brought to the lab for further analysis. This included drying off the samples, separating sediment from any organic material and sieving the samples in to individual size classes. The size classes ranged from very fine sand (0.075 mm) to a small cobble (64 mm). Particle size distribution for each sample, bedload transport and total (bedload + suspended load) load were calculated.

FIGURE 3. LOGAN RIVER BEDLOAD SEDIMENT SAMPLING USING TOUTLE RIVER SEDIMENT SAMPLER (TR-2). A) SAMPLING FROM THE GOLF CART BRIDGE. B) GOLF COURSE ROAD BRIDGE SAMPLING.

Painted rocks were part of the initial sediment sampling campaign in 2016 (Figure 4). A pebble count was performed upstream of the Golf Cart Bridge using heel-to-toe method (Wolman, 1954) and the D50 (median of the cumulative frequency particle-size distribution) and D84 was determined. The rocks in the D50 (66 – 73 mm) and D84 (95 – 105 mm) range were then collected and painted with two different colors. Rocks in D84 range were placed on one line while the rocks in the range of D50 were placed on the second line about 50 ft apart both covering the active channel width. After a moderate spring runoff receded, the distance of moved rocks from the original line was recorded for each particle that moved. The D84 line contained 100 particles and had 100% success of recovering the moved rocks. The D50 line contained 200 particles and recovery success rate was 70%. This is due to some of the rocks being carried longer distance or being buried by other particles and not visible during the recovery time.

FIGURE 4. PAINTED ROCKS PLACED ACROSS THE CHANNEL BEFORE THE HIGH FLOWS (A) AND AFTER THEY MOVED AFTER THE HIGH FLOWS RECEDED IN 2016.

3.4. Hydrology, Channel Change and Floodplain Function

CAP indicators include flood conveyance and floodplain function. The baseline flood conveyance condition as assessed by the Task Force was fair. The Task Force's assessment was that flood conveyance for the infrequent runoff event (>25-yr flood event) through all reaches was being partially impacted by sand/gravel deposition and woody debris accumulation. Floodplain function was assessed as poor condition for all three reaches. Poor condition is described in the CAP as being a condition in which floodplain functions are severely limited with widespread portions of the floodplain non-existent on one or both sides of channel. The floodplain is highly manipulated and/or disconnected from the channel due to anthropogenic factors such as channelization, bank manipulation, filling and/or levee development. The banks that have been restored were literally lined with concrete slabs and trash, and was used as a near town disposal site by previous land owners in their attempt to stabilize the banks.

The CAP also includes an indicator for instream habitat, assessed as fair condition for all three reaches (34-66% departure from natural). This indicator includes consideration of hydraulic complexity and habitat diversity, including a natural sequence of pools and riffles, a variety of pool sizes and depths, and stable woody materials in the bed and banks.

Multiple USU groups are involved in monitoring of channel change and instream habitat. TheEcogeomorphology and Topographic Analysis Lab (Dr. Joseph Wheaton) provided a pre-construction survey of the channel and used LiDAR data to explore geomorphic units for approximately two miles of Logan River (Figure 5). The study reach included Logan River through Rendezvous Park and the study shows conditions prior to restoration project (2017). The study was funded by Logan City and used the Geomorphic Unit Tool (GUT) which delineates instream geomorphic units from topography using a 3-tiered hierarchical classification adapted from Wheaton et al., 2015. A post-construction survey and geomorphic unit mapping is recommended to compare types and quantity of habitats accomplished with the Rendezvous Park restoration projects to-date.

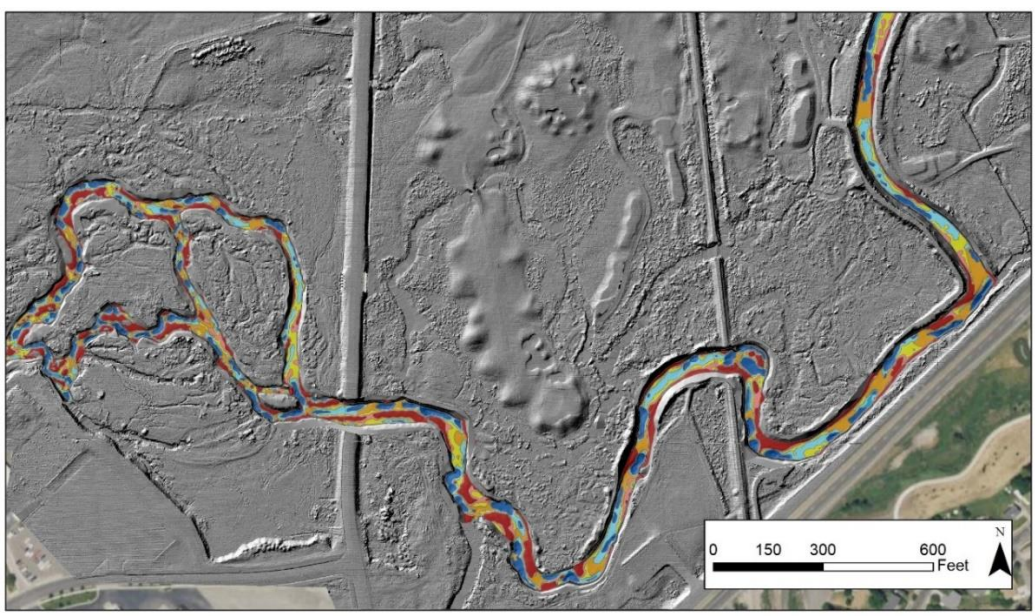

FIGURE 5. SECTION OF LOGAN RIVER THROUGH RENDEZVOUS PARK WHERE GEOMORPHIC UNIT TOOL (GUT) WAS USED TO DELINEATE PRE-CONSTRUCTION INSTREAM GEOMORPHIC UNITS FROM TOPOGRAPHY.

The Hydrology and Fine Sediment Lab under Dr. Patrick Belmont uses Logan River as part of the field classes. Additional cross-sections were surveyed to study the channel change in the Rendezvous Park area in 2018.

Logan City surveys the Logan River and its floodplain for flood conveyance, floodplain mapping, and hydraulic modeling. The latest dataset collected captures post-restoration conditions in 2019.

3.5. Riparian Ecology (including weeds)

CAP indicators of riparian ecology are riparian vegetation condition and extent of noxious weed invasion. Riparian vegetation was assessed by the Task Force as having poor condition for all three reaches, representing a 66% or greater departure from natural condition. Noxious weed conditions were assessed as good for the Upper Reach (minimally present), but poor condition for the Middle and Lower Reaches (noxious weeds common in the riparian corridor).

BIO-WEST has been conducting yearly riparian vegetation monitoring needed for the CWA Section 404 permit as required for the Rendezvous Park restoration projects. To ensure success of the restoration project, BIO-WEST is monitoring riparian and wetland vegetation conditions at Rendezvous Park for 3-5 years of anticipated required post-construction monitoring, or until the performance standards are met (BIO-WEST, 2018, Table 4). The pre-construction (2017), year one post-construction (2018), and year two post-construction (2019) conditions were mapped and photo documented up to this date along the Logan River at Rendezvous Park as part of the Rendezvous Park Channel and Floodplain Restoration Project (BIO-WEST, 2018, 2019). The project is subject to U.S. Army Corps of Engineers wetland monitoring and will be monitored through 2020.

Thirty-four vegetation-monitoring points were established throughout the restoration area in 2017 and three more were added in 2018 for the Confluence to Park Avenue section restored in 2019. These monitoring plots were located on existing upland levees and trails, wetland areas, and locations modified by the new design. The plots were established to show the existing conditions of the site and record changes through future growing seasons (Figure 6). The plot locations were recorded using a sub-meter accurate GPS unit. Plots 1-34 were monitored and photographed in July 2017 and one year later monitored and photographed again in August 2018. Plots 35-37 were monitored and photographed in December 2018. All plots were monitored again in 2019 and monitoring report was prepared which is nearly ready to be submitted to the U.S. Army Corps of Engineers. The monitoring includes an estimate of aerial percent cover of each vegetation strata (tree, shrub, herbaceous) by dominant species within a 30-foot radius of each point. At the same time, photographs are being taken from each point center in the four cardinal directions. Other relevant information such as soil moisture, hydrology indicator observations and any visible channel instability indicators in riverine channel and wetland restoration and enhancement areas are recorded as well. The photographs and monitoring data forms provide a simple and rapid assessment of changes within the project area from one year to the next.

Weed treatment, as part of the riparian ecology, is project based as well and it has been in place for the Denzil Stewart Nature Park and Rendezvous Park Channel and Floodplain Restoration Projects. BIO-WEST monitors for noxious and/or invasive weeds in the restoration areas and applies mechanical and/or chemical treatment as necessary to control spread of undesirable vegetation during the 3-5 year

anticipated required monitoring. The success criteria include 80% or more of native vegetation cover with less than 1% noxious weed cover after 3 years of monitoring.

The monitoring plan does not currently include a protocol for monitoring weeds throughout the CAP reaches. Potentially a monitoring protocol could be developed in coordination with Logan City and the Cache County Weed Control Program. A volunteer-effort riparian area weed control effort could be organized or combined with other volunteer weed control efforts that are done in the area. Another possibility would be to conduct weed control through the College of Natural Resources intern program.

At publicly accessible restoration areas (Denzil Stewart Nature Park and Rendezvous Park), existing sign boards could have information posted about weeds that the public can help pull and dispose of. Information can be posted at key times (spring) when this would be most effective.

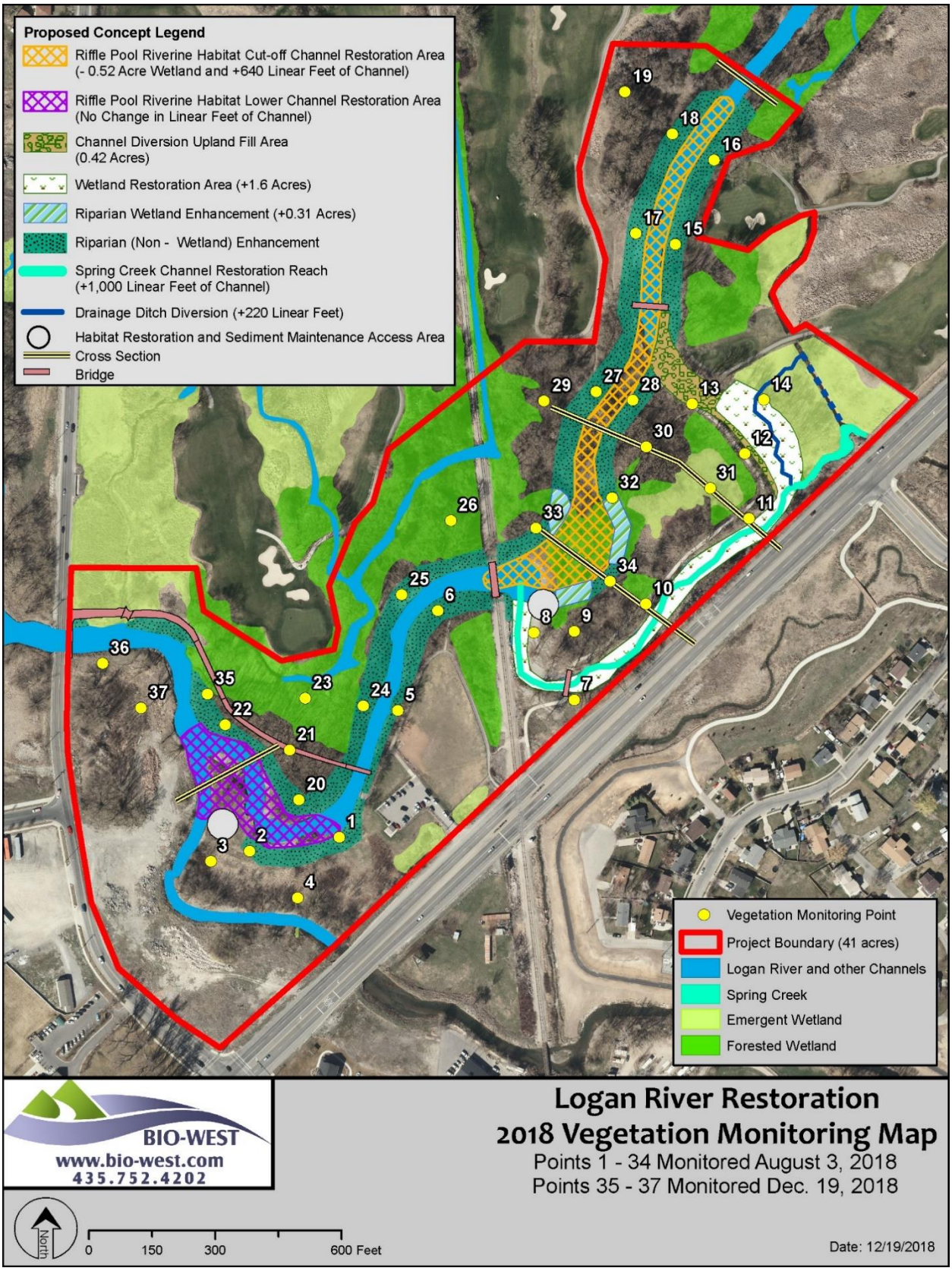

FIGURE 6. LOGAN RIVER RESTORATION AT RENDEZVOUS PARK VEGETATION MONITORING MAP.

3.6. Aquatic Biology

CAP indicators of aquatic biology are trout density and size and benthic invertebrate expected taxa presence. The Task Force's baseline assessment of the trout indicator was poor condition in all three reaches. Improvements to instream habitat and summer base flows are likely necessary to achieve higher trout density and size. Baseline conditions for benthic invertebrate taxa were assessed as being very good in the upper reach (greater than 85% of expected taxa present) and declining to poor condition in the lower reach (less than 70% of expected taxa present).

3.6.1. Fish

Multiple monitoring efforts took place or still continue on different parts of Logan River. Some of the previous monitoring studies could be used for baseline data if more surveys and monitoring is planned in the future.

i) Previous monitoring

<u>2001 to 2008 Logan River Monitoring:</u> The USU Fish Ecology Lab (Dr. Phaedra Budy) monitored the fish community of the Logan River annually at eight long-term sites from 2001 to 2008. Sites spanned from the upper headwaters (Franklin Basin) to the lower Logan River (Rendezvous Park area, 1000W Bridge). The overall objectives of this study were to monitor and evaluate the population dynamics, abundance, and distribution of trout in the Logan River, and to determine the present and potential impacts of disease, habitat, interspecific interactions and recruitment in determining the abundance and distribution of trout species (Budy, P. et al., 2009, 2010).

Fish were collected during base flow conditions using a three-pass depletion technique. Block nets were placed at the lower and upper end of each stream section (100 m sections in the headwaters and tributaries, 200 m in the mainstem). Electrofishing voltage varied depending on the stream conditions (216 - 387 µS/cm, 8 - 15 oC, ~40-Hz pulsed DC, ~160 - 500 V, 0.2 - 4 amps). The backpack-mounted electrofishing unit for smaller streams, and a canoe-mounted electrofishing unit for the larger mainstem surveys were used. Captured fish were anesthetized with a light dose of MS-222 (aka Finquel). Lengths (mm total length, TL) and weights (g) were recorded for all fish, and in addition, fish were checked for external signs of whirling disease (e.g., black tail, deformities of the cranium, mandible, or vertebrae). When possible, 10 subadults and 10 adults from each species were kept. The subadult cutthroat trout was classified as fish < 150 mm TL and subadult brown trout as fish < 180 mm TL based on prior size-at-age information (Budy et al. 2001, 2002, 2003, 2004, 2005). These fish were euthanized using a lethal dose of MS-222 and placed on ice in labeled bags after lengths and weights were measured. These fish were used for diet analysis, PCR testing for *Myxobolus cerebralis*, tissue collection, and scales and otoliths
were taken for ageing analysis. In 2008, as in 2007 and 2006, due to concerns that the surveys may be causing impacts to these trout which exhibit high site-fidelity rates (on average 92%; Budy et al. 2007b), new random sample site locations were selected. Random site selection options included the original site (2001 – 2005 sample seasons) or upstream or downstream of the top or bottom of the original site; however, some modifications were made for logistical and safety concerns.

<u>Condition analysis</u>

All captured fish was weighed (nearest 0.01 g) and measured (nearest mm total length, TL). The length-weight relationship was calculated, and the condition of all fish using Fulton's K (Fulton's KTL = W / L3 × 100,000) were computed. These calculations were then compared seasonally and temporally when sample sizes were adequate.

Population estimates

The population abundance was estimated using a closed model, generalized maximum likelihood removal estimator calculated in Program MARK (White and Burnham 1999). Based on previous analyses (Budy et al. 2005), the population abundance and recapture probabilities for fish (> age-0, > 100 mm) at each site were calculated. The abundance was then scaled up to determine the total number of fish per linear km and/or fish per m^2, and express these estimates as fish per km with 95% confidence intervals.

Trout population trends

The population trend for cutthroat trout and brown trout was estimated using population estimates from seven years of depletion sampling, 2001 – 2008 (only to 2007 for brown trout), using linear regression of log-transformed annual changes in population growth rate as a function of time step (Morris and Doak 2002). The trend was expressed as lambda (λ), the annual population growth rate with 95% confidence intervals. An overall λ for the entire Logan River population was also calculated and based on pooled abundance estimates across sites. A $\lambda > 1$ indicated positive population trend, $\lambda = 1$ indicated no change in population growth rate, and a $\lambda < 1$ indicated the population is declining; however, given the short, time series available, when 95% confidence intervals overlap 1.0, the population increase or decrease could not be ruled out completely. In the analyses, the research team accounted for losses of fish due to take of sample fish (for parasite and diet analyses) and mortalities incurred during sampling events due to electroshocking or other stressors, such that final λ values represent the observed trend at each site, in the absence of these minor fish losses.

Whirling disease analyses

For a subsample of cutthroat trout and brown trout, fish heads from each specimen were removed, frozen, and tested for prevalence of *M. cerebralis* following the polymerase chain reaction method (Hsp-70 gene segment PCR; Andree et al. 1998). PCR samples were processed by Pisces-Molecular LLC (Boulder, Colorado).

Abiotic and biotic variables

Sampling for physical, chemical, and biological characteristics of stream habitat was generally conducted prior to fish sampling.

- *Temperature* — Temperature at each site was recorded at 90-minute intervals using temperature loggers set in stream, generally year-round; however, not all data loggers were recovered due to high, spring run-off flows or mechanical failures in some years.
- *Discharge* — Discharge was measured using the mid-section method (Harrelson et al., 1994). Thus, we measured depth and mean water column velocity at 20-30 locations along a cross-sectional transect at each site using an electromagnetic flow meter. Although collected, those measurements are not reported here. We also tracked stream flows online using USGS real-time water data (Gage: USGS site 10109000; Website: *http://waterdata.usgs.gov/nwis/rt*) to obtain daily mean flows for the Logan River above First Dam (Cache County, Utah, Hydrologic Unit Code 16010203, Latitude 41°44'36", Longitude 111°46'55" NAD27, Drainage area 214 square miles, Gage datum 1,426 m above sea level NGVD29).
- *Other abiotic variables* — In addition to temperature information from data loggers set in selected index sites, we collected a suite of abiotic variables including water conductivity, pH, turbidity, salinity, and dissolved oxygen.

2016 fish survey:
The 180-meter-long stretch of river in the Rendezvous Dog Park section was surveyed using 3-pass depletion technique with both, upstream and downstream end blocked by nets. The abundance estimates for brown trout, carp, whitefish, sculpin, Utah sucker, and rainbow trout were calculated. The estimates are shown in the table below (Table 1, Budy, P., unpublished data, 2016).

Table 1. Population estimate of fish species present in the Rendezvous Dog Park section of the Logan River, Utah in September 2016, prior to habitat restoration work. Abundance estimate (with lower and upper 95% confidence intervals) for a 180-m section is shown, along with an expanded fish per km estimate.

Species	Estimate	Lower CI	Upper CI	Number per km
Brown trout	87.8	81.2	108.4	488
Mountain whitefish	65.2	17.9	1260	362
Mottled sculpin	867.3	452.0	2279	4818
Rainbow trout	1	–	–	6
Utah sucker	1	–	–	6
Common carp	1	–	–	6

ii) Current monitoring

Logan River monitoring from Blacksmith Fork River confluence to Rendezvous Park pedestrian bridge:
A full fish survey monitoring conducted in 2016 and 2018. The survey is planned to be repeated every two years.

Logan River monitoring by fish habitat unit:
Fish survey monitoring by habitat unit (riffle/run and pool) is a yearly monitoring by USU fish class and provides information on relative number of fish and species per habitat unit in the stretch of the Logan River between the confluence with Blacksmith Fork River and railroad bridge. The monitoring started in 2015 and usually takes place in September.

3.6.2. Macroinvertebrate

Benthic macroinvertebrates inhabit the sediment or live on the bottom substrates of rivers. The macroinvertebrate assemblages in rivers reflect overall biological integrity of the benthic community and monitoring these assemblages is useful in assessing the status of the water body and discerning trends. Benthic communities respond differently to a wide array of stressors. As a result of this, it is often possible to determine the type of stress that has affected a benthic macroinvertebrate community (Plafkin et al., 1989; Klemm et al., 1990). Because many macroinvertebrates have relatively long-life cycles of a year or more and are relatively immobile, macroinvertebrate community structure is a function of past conditions.

The macroinvertebrate monitoring for Logan River is part of multiple research efforts and groups.

i) Project based sampling for Rendezvous Park Channel and Floodplain Restoration Project was conducted by BLM/USU National Aquatic Monitoring Center (Bug Lab) in August 2017 (pre-project). Samples were taken from five different locations along the Rendezvous Park reach:

Logan River downstream from confluence with Blacksmith Fork River, Logan River at dog park below the bridge, Logan River, above railroad crossing, Logan River above the golf cart bridge, and Logan River above the restoration project work zone. The multimetric approach was used, where different structural and functional attributes of the assemblage are characterized as "metrics". Individual metrics that respond to different types of stressors are scored against expectations under conditions of minimal human disturbance. The individual metric scores are then summed into an overall index value that is used to judge the overall level of impairment of an individual river reach. Common metrics used to asses the freshwater biological integrity for Logan River were used, as well as basic field and lab processing methods. The values of richness-based metrics were standardized to operational taxonomic units (OTUs; Cuffney at al., 2007) and a fixed count of 300. The density metrics were based on the raw taxa list. The Utah Department of Environmental Quality (UTDEQ) 2015 all seasons model observed/expected (O/E) index was used to asses the biological conditions of sampled sites. O/E models compare the macroinvertebrate taxa observed at sites of unknown biological condition (i.e., 'test sites') to the assemblages expected to be found in the absence of anthropogenic stressors (see Hawkins et al. 2000 for details). Biological condition was subsequently assessed based on the precision of the reference site data set used to develop the UTDEQ O/E model (mean =1.002744, standard deviation (SD) = 0.2139), with test sites scoring less than one SD below the mean of reference sites in "Good" biological condition (i.e. comparable to reference conditions); sites scoring between one SD and two SD in "Fair" biological condition; and sites scoring more than two SD below the mean of reference sites in "Poor" biological condition. Detailed information on methods could be found in the metadata provided by the Bug Lab and also available at http://www.usu.edu/buglab/SampleProcessing/ResultsAndReports/#item=85.

ii) Middle/ Lower Logan River Reach monitoring includes sampling conducted by Utah State University researchers and groups, Department of Water Quality as well as data associated with EPA projects (Environmental Monitoring and Assessment Program, EMAP). The data are available through the Western Center for Monitoring and Assessment of Freshwater Ecosystems (WMC) and the National Aquatic Monitoring Center (NAMC) database of biological and environmental data (http://www.qcnr.usu.edu/wmc/data).

3.7. Terrestrial Biology

CAP indicators for terrestrial biology include:

- Bird species richness and diversity, calculated using Shannon-Wiener Index. Baseline conditions were assessed by the Task Force as Fair for all three reaches
- Native vs. nonnative amphibian and reptile species composition. Baseline conditions were assessed as fair in the Upper and Middle Reaches and poor in the Lower Reach.

3.7.1 Birds

The Logan River Bird Monitoring Protocol (LRBMP) is based on a hybrid of the Utah Riparian Bird Monitoring Program and the USGS Breeding Bird Survey (Howe, 2016). The protocol requires extensive

expertise in identification of Utah birds by sight and sound. It is designed to yield an annual diversity index value (Shannon-Wiener) and a species richness estimate. The LRBMP is also intended to lead to a "citizen science" bird monitoring protocol that will require less expertise in identification of all Utah birds and focus on several select species; this protocol will be developed after 3-5 years of LRBMP data is collected.

The planned protocol includes specification regarding the timing, sampling points, data collection methods, and data analysis.

Surveys are completed once between 1 June and 15 July to capture breeding birds and avoid migrants. Surveys should be conducted from sunrise to no later than 10:00. The 2-3 sampling points randomly located for each 0.5 river miles (RM) provide relatively uniform coverage of the river from 1st dam (RM 0.0) to the Mendon Bridge (RM 8.7) (Figure 7-9). Points have been established below Mendon Bridge to Cutler Reservoir but have not been surveyed because of access and logistical issues. Points are named based on the RM in which they occur, for example, sampling point 0.5a is the first point below 1st dam between RM 0.0 and RM 0.5. and sampling point 3.0c is the last point between RM 2.5 and RM 3.0. Points were randomly selected within each 400 m stretch of the river and adjusted slightly where trespass on private property was an issue (permission to trespass was granted at most locations). Point locations were established using Google Earth (*.kml file) and uploaded to a GPS unit after conversion to *.gpx file. At each sampling point, the sampling point's number, starting time, and all birds seen or heard in a 5-minute time period are recorded. The fly-overs are recorded separately (this is to separate birds that are "using" the site from those that are simply passing by/flying over it, e.g., birds that are foraging above the site would not be counted as fly-overs. To avoid double counting (i.e., counting the same bird at 2 different points), birds are recorded from the sampling point to a distance ½ the way to any adjacent sampling points. Any obvious pairs, juveniles with or without parent(s), and nests are noted as well. Any excessive noise that continuously impacts the ability to hear birds singing at a point is noted.

For the entire survey, survey date, as well as starting and ending time, temperature (°F), wind (Beaufort Scale) and sky (0=clear or few clouds, 1=partly cloudy, 2=mostly cloudy or broken clouds, 4=fog, 5=drizzle, 7=snow, 8=rain showers. If the temperature is above 80°, wind is greater than 5, or Sky is 7 or 8 or 4 with <250 m visibility) the surveys are not conducted.

Data analysis follows the Utah Riparian Bird Monitoring Program. Species richness is calculated as the number of different species within each Logan River Task Force Reach (Upper = RM 0.0– 3.0, Middle = RM 3.0-5.5, Lower = RM>5.5). Similarly, a Shannon-Wiener Index of species diversity is calculated for each river reach.

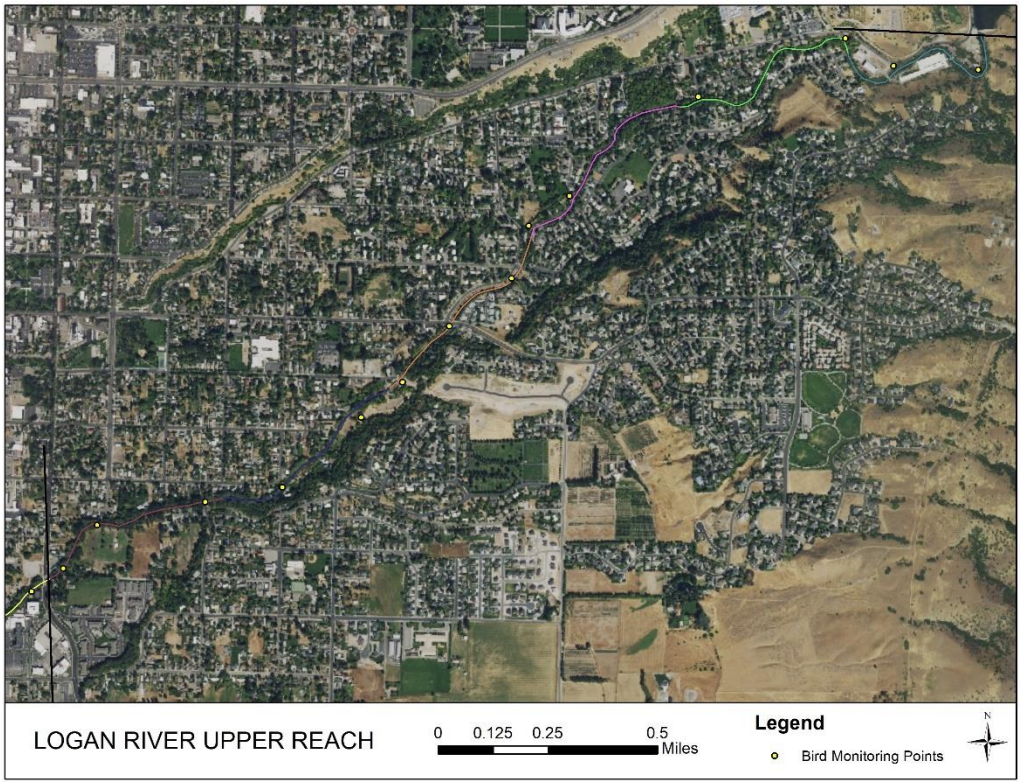

FIGURE 7. BIRD MONITORING SAMPLING POINTS AND INDIVIDUAL RIVER SEGMENTS FOR THE UPPER REACH.

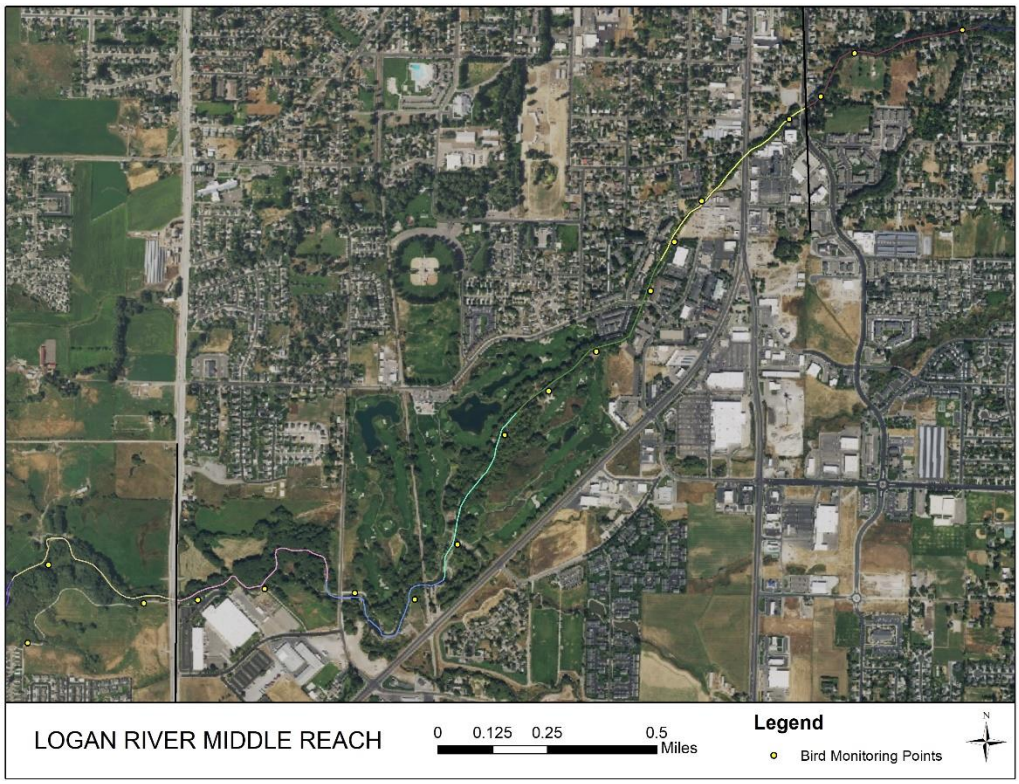

FIGURE 8. BIRD MONITORING SAMPLING POINTS AND INDIVIDUAL RIVER SEGMENTS FOR THE MIDDLE REACH.

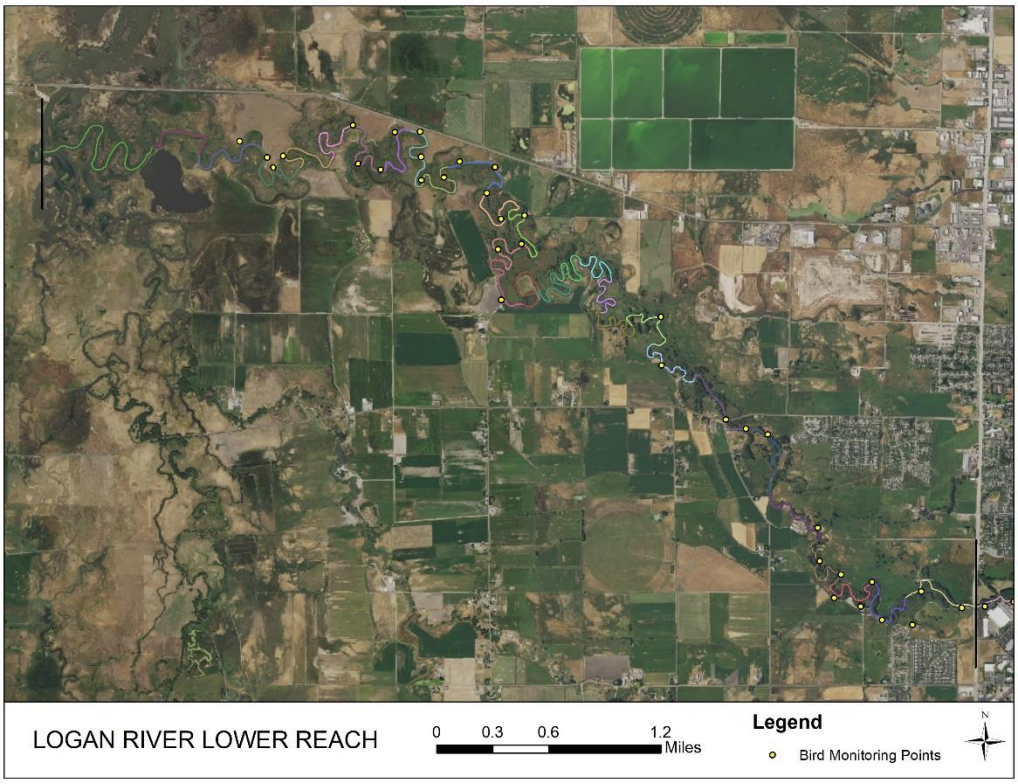

FIGURE 9. BIRD MONITORING SAMPLING POINTS AND INDIVIDUAL RIVER SEGMENTS FOR THE LOWER REACH.

3.7.2. Amphibians and Reptiles

Native species for the Logan River CAP study area include two snakes: wandering garter snake (*Thamnophis elegans vagrans)* and common garter snake *(Thamnophis sirtalis);* three frogs:northern leopard frog (*Lithobates pipiens*), boreal chorus frog (*Pseudacris maculate*), and woodhouse's toad), and tiger salamander (Ambystoma tigrinum). All of these species except for the toad and the salamander occur in all three reaches; the toad and the salamander likely occur only in the Lower Reach.

A baseline assessment of condition by reach, based on professional judgement, was: Upper Reach: fair, Middle Reach: fair, Lower Reach: poor. Potential threats to improved condition may include: destruction of hibernation sites, erosion and sedimentation, loss of riparian habitat to development and river channelization, poor water quality, and possible predation by bullfrogs.

In general, river and riparian restoration projects that increase floodplain habitat will be more beneficial for amphibians, by creating side channels and ponds, for example, and may be detrimental to some existing habitat for reptiles that are not riparian-dependent (e.g, garter snakes that have established hibernacula along the Logan River). Hibernacula can be inadvertently destroyed by earthmoving and grubbing activity during construction of a restoration project. Mapping hibernacula prior to construction could be used to potentially avoid removal if this can be accomplished with the project design.

For monitoring, some individual observations have been made for Rendezvous Park (Rendezvous Park Herp Monitoring, 2019) but f a protocol for monitoring by reach still needs to be planned and implemented. The USU Student Chapter of the Wildlife Society survey (Rendezvous Park Herp Monitoring, 2019) conducted in spring of 2019 could be used as a template for a monitoring protocol.

The monitoring consists of two sets of surveys, conducted in the spring. Each survey set includes both visual encounter and auditory surveys. The first survey set is conducted within 1 week of first observing garter snakes at known hibernacula locations (late March/early April), and the second survey set is conducted about a month later (late April/early May). The first visual encounter survey aims to identify areas where garter snakes are likely to have hibernacula under the assumption that the snakes have not moved far from their hibernacula yet. The second visual encounter survey aims to identify areas where garter snakes are most abundant after they have had time to move away from their hibernacula locations. Observations of herpetofauna other than garter snakes are also of interest and searched for during the visual encounter surveys. Visual encounter surveys consist of club members searching the full extent of the survey area and recording the species and GPS coordinates of all herpetofauna encountered.

Visual encounter surveys are conducted in the evening, and auditory surveys are conducted at least 30 minutes after sunset on the same day. Auditory surveys consist of a 2-minute acclimation period at each survey location prior to 3 minutes of listening for calling frogs. In addition to yearly reports, the results of the auditory surveys are also uploaded to FrogWatch USA.

Data collected during these visual encounter and auditory surveys are summarized as follows:

- Wandering garter snake kernel density quantiles
- Observations of non-wandering garter snake species
- Auditory survey results
- Wandering garter snake habitat use through time
- Wandering garter snake habitat use versus availability

The visual encounter surveys covered a total area of 5.62 ha, 1.67 ha of which has been “Treated” and 3.95 ha of which has been left “Untreated” during the river restoration project. For the purpose of this protocol, “Treated” areas are those which have had their vegetation removed, and “Untreated” areas are those that still retain their pre-restoration vegetation as determined via time-lapse Google Earth imagery (Figure 10). For results and detail information refer to Rendezvous Park Herp Monitoring (2019) or contact the USU Student Chapter of Wildlife Society at usuwildlife@gmail.com.

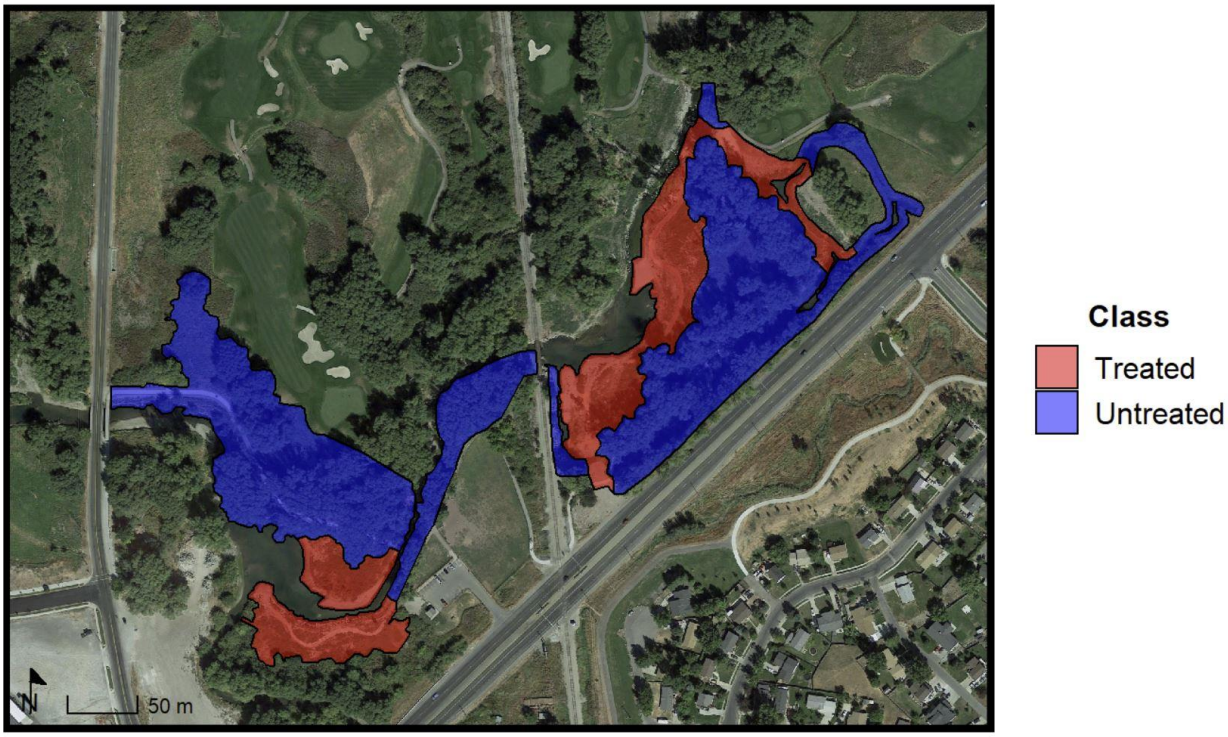

FIGURE 10. LOGAN RIVER RENDEZVOUS PARK HERP SURVEY AREA; GOOGLE EARTH IMAGE FROM SEPT. 14, 2018 (RENDEZVOUS PARK HERP MONITORING, 2019).

Another possibility for monitoring, or additional technology that could be deployed, would be to utilize frog loggers at key locations to monitor frogs over time, such as restoration areas at Rendezvous Park were frog ponds were created in the restoration design. Depending on the location loggers can also be used to detect bats.

3.8. Recreation

CAP indicators of recreation quality and baseline conditions as assessed by the Task Force are:

- Trail miles per river mile—the ratio of trail miles per river miles provides an indicator of the quantity of riparian or river trail experience available for the public to experience the river
- Trail continuity—baseline condition of poor in all reaches with no continuous trails through any reach
- Blue Trail—assessed based on the presence of river hazards/navigability of the river, assessed as having good baseline condition for the Middle Reach but poor in the Upper and Lower Reaches
- Legal access to the river bed (wading) —assessed as very good in all reaches (greater than 75% of reach accessible by wading)
- Legal access to the river bank (walking) —assessed as poor condition in all reaches (less than 25% of river bank publicly accessible)

- Access facilities (pedestrian/ADA access points, parking, boat launches, desirable river features for kayaking, tubing, canoeing) —assessed as poor in the Upper and Lower Reaches (no facilities) and fair in the Middle Reach (some facilities)
- Fishing success—assessed by catch rates of brown trout and whitefish, with baseline condition of fair in the upper and middle reaches and poor in the lower reach.
- Blue Ribbon Fishery status—the degree to which a river reach would be able to satisfy criteria for designation as a Blue Ribbon Fishery; baseline condition of the Upper Reach was fair, the Middle Reach, good, and the Lower Reach, poor.

3.8.1. Trails

A river trail for the purposes of the CAP is identified as a trail segment located in the riparian zone of Logan River and/or a trail segment providing the river experience (for example, an upland trail segment overlooking the river). Currently, no protocol for monitoring and assessing the quality of the trail system has been established or implemented throughout the study area reaches. In the CAP, the Logan River Task Force proposed that the general quality of river trails condition by evaluating the length of the trails, trail continuity, legal access to river bank and river bed, and presence of access facilities.

The ratio of trail miles per river mile (Trail Miles/ River Miles) by individual reaches will be used to account for new trails added as new projects are completed. The internal trails coming into or close to the river from the upland trail will be a part of the river trail. The following bracketing of conditions is proposed:

i) Poor Condition: < 50 %

ii) Fair Condition: 50 – 100 %

iii) Good Condition: 100 – 150 %

iv) Very Good Condition: > 150 %

Trail continuity is designed to capture any breaks, for example at-grade road crossings without the pedestrian crossings, and/or signals. The CAP project is not promoting trail development through property of unwilling landowners. Therefore, trail continuity would be achieved by routes that connect existing and future parks, trails, and access points without necessarily paralleling the river throughout the entire river corridor. Possibly property could be acquired for river access or park development/expansion. The following bracketing of conditions is proposed:

i) Poor Condition: more than two breaks within the reach

ii) Fair Condition: two breaks

iii) Good Condition: one break

iv) Very Good Condition: no breaks

Legal access reflects legal access to river bank and/or river bed using public property, not private property. In case of river bed (wading) river is assumed to be a public water (Public Trust Doctrine). For both, river bank and bed the evaluation goes as follow:

i) Poor: < 25 % of reach length

ii) Fair: 25 – 50 % of reach length

iii) Good: 50 – 75 % of reach length

iv) Very Good: > 75 % of reach length

Ensuring the legal access also addresses the impact on private property from public recreation. Littering, vegetation trampling, damage to fences, parking problems, trespassing or other negative impacts were noted by riverside landowners in stakeholder interviews completed by the Task Force leading up to development of the CAP. Access facilities, including pedestrian/ADA access points, parking, boat launches indicate river access or support river use. The determination of adequacy is based for each reach separately:

i) Poor: adequate on no facility types

ii) Fair: adequate on 1-2 facility types

iii) Good: adequate on 2-3 facility types

iv) Adequate on all 4 facility types

3.8.2. Blue Recreation/Trail

A Blue Trail is a river adopted by communities that are dedicated to improving family friendly recreation such as fishing, boating, hiking, and wildlife watching, and conserving the river and surrounding lands (American Rivers.org, Logan River Blue Trail Master Plan, January 2020).

The Logan City Council officially adopted the Logan River Blue Trail Master Plan in January 2020. The plan envisions the Logan River as a world-class recreational asset adding to existing community amenities and tourist attractions. The Plan has four main goals:

- Improve and develop river access points and improve recreational access to the Logan River (including carry-in watercraft access)
- Create and maintain safe river passage
- Promote the Logan River Blue Trail as a community amenity
- Foster community involvement, volunteerism, and stewardship of the Logan River.

The plan describes existing conditions of the Logan River relative to creating a Blue Trail. Current hazards to navigation are described along with appropriate treatments to provide safe passage. The plan identifies a network of access points to provide a variety of river experiences, ranging from leisurely family floats to day-long river excursions (Figure 11).

Many of the access points utilize City-owned property and are within Logan River Restoration project areas. General concepts for ecologically sound, ADA accessible landings are provided. Existing access resources, such as public parking and restrooms, are identified, along with conceptual designs for future facilities. The plan lays out a phased development strategy starting with the core area from Rendezvous Park to Trapper Park (Phase 1), expanding upstream to Stewart Park and downstream to 600 South Bridge near 2000 West (Phase 2), and culminating with future additional linkages. However,

development of the Logan River Blue Trail should be driven by opportunities as it develops, regardless of its phase. In addition to access facilities, this plan outlines the location and concept for a proposed kayak play park on a short, section of the river from 100 North to Center Street in Logan.
For more details on the Logan River Blue Trail please see Logan River Blue Trail Master Plan (January 2020).

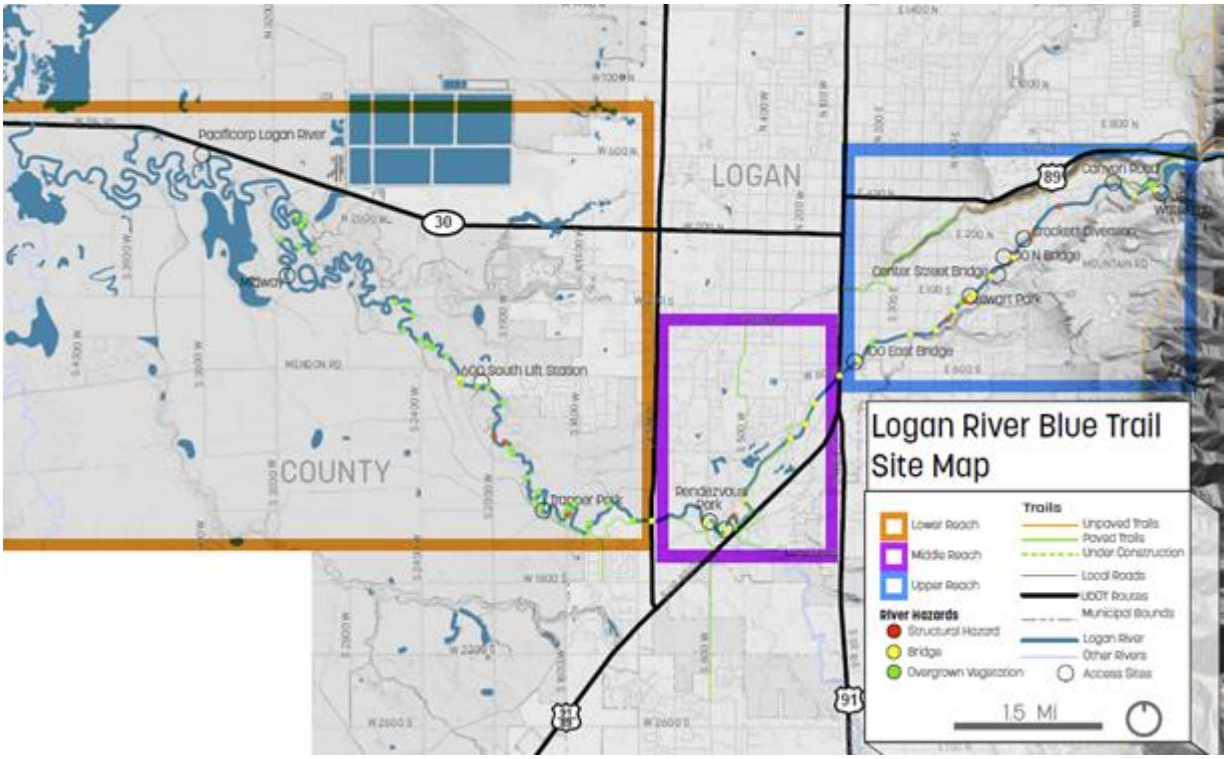

FIGURE 11. EXISTING CONDITIONS OF THREE REACHES OF LOGAN RIVER WITH CURRENT KNOWN OBSTACLES, LAND USES, ROAD AND TRAIL NETWORKS, AND PROPERTY OWNERSHIP ALONG THE RIVER (LOGAN RIVER BLUE TRAIL MASTER PLAN, 2020).

3.8.3. Fishing

The Logan River supports a popular fishery for native Bonneville cutthroat trout (*Oncorhynchus clarkii utah*), naturalized brown trout (*Salmo trutta*), stocked rainbow trout (*O. mykiss* including albino strains), and naturalized brook trout (*Salvelinus fontinalis*). A creel census conducted in the Upper Reach and upstream in 2002 revealed that the fishery gets consistent, moderate pressure, is fished by a wide variety of anglers, and most angling is catch and release (Budy et al. 2003). The great majority of the anglers ranked their fishing trip on the Logan River as “very satisfactory”, the highest possible category, demonstrating the popularity of this fishery for recreation enthusiasts; in addition, most (94%) caught trout on the Logan River are released, further indicating a community commitment to the future sustainability of the resource (Budy et al. 2003). This was consistent with 2017 creel survey where 95% of the fish were released (Budy et al., 2017).

The Trout Unlimited with cooperation of Utah State University, Utah Division of Wildlife Resources and USGS performed a creel survey on approximately 6.4 km (4 miles) of the Lower Reach of Logan River from April 1st to October 31st, 2019. The angler effort and catch data to calculate mean monthly catch

rates were collected. In addition, continuous stream temperature and flow from a river gage was collected and monthly means were calculated. The goal of the study was to determine if river flows and higher water temperatures influence angler catch rates of Brown Trout in the Lower Reach of Logan River (Coleman, DeRito, Penne, Thiede, Budy, 2020).

3.9. Property Impacts

The CAP includes two indicators of property impacts. One is potential adverse impacts associated with recreation use of the river on private property, such as litter or vandalism. Baseline condition was assessed as fair for all reaches, based on interviews and conversations with property owners at the time the CAP was being developed. The other indicator is the potential impacts of river restoration projects on private property owners. The Task Force also assessed this indicator as fair condition for all reaches as the baseline condition, and a key reason why the CAP was developed, to improve public input/knowledge of changes being made to the Logan River and to reduce the experience of adverse effects from these changes.

In general, stream proximity and quality have positive effects on property values and sales (Nicholls and Crompton, 2017). The effects of restoration projects on residential property value are inconclusive as some studies report increases – California properties studies which saw 3 - 13 % increase in property value (Streiner and Loomis, 1996) and some report decreases in values – Western Oregon stream frontage study showed 3 – 11 % price reduction for an average house (Mooney and Eisgruber, 2001). The benefits of river restoration along Logan River are being anecdotally identified but have not been systematically measured to date and there is not currently an identified monitoring protocol for these indicators. The river trail is one of the most popular places to walk, run and ride in Logan and is used extensively by the nearby residents.

Periodic surveys/interviews of riverside landowners (residential, commercial, and agricultural) could be included in the trails monitoring protocol previously described. Even a periodic/annual check-in phone call to a limited number of riverfront property owners by a Task Force representative prior to Task Force meetings could help maintain interest in the CAP; this is being done informally as projects and activities associated with the CAP and other river-focused projects are occurring, but could be better documented in Task Force meeting notes, for example.

3.10. Repeat Photography

Repeat photography is being used to qualitatively capture the success of individual restoration projects. Photography series can help illustrate changes in multiple CAP indicators: riparian vegetation, floodplain function, and recreation opportunity. Repeat photography is also being used in public outreach materials: brochures, website, signage. BIO-WEST is collaborating with Utah Department of Agriculture and Utah Water Watch to collect a restoration-project-based repeat photography database. BIO-WEST and the volunteer through Utah Water Watch takes photographs several times per year to show conditions prior to construction/restoration, during, and after restoration is complete (Figure 12). In addition to ground repeat photography, some aerial drone images are repeated over time as well (Figure 13).

FIGURE 12. REPEAT PHOTOGRAPHY AT LOGAN RIVER RESTORATION AT STEWART NATURE PARK.

FIGURE 13. AERIAL REPEAT PHOTOGRAPHY OF LOGAN RIVER RESTORATION AT RENDEZVOUS PARK.

4. LOGAN RIVER RESTORATION PROJECTS

4.1. Projects Completed

- Denzil Stewart Nature Park
- Rendezvous Park and Lower Golf Course
- Main Street to 100 East

Revegetation and weed control are still in progress for these projects.

1.2. Current projects and maintenance

- Logan City removed accumulated gravels in the upper end of the upper pool at Rendezvous Park which was used for riprap work on the eroding banks upstream of the golf cart bridge and upstream of the upper pool. This work was completed and the site reseeded April 2020. Additional wetland plantings will be planned when the Covid19 social distancing protocols are not needed.

1.3. Planned Projects

Stream restorations of wetland mitigation projects for:

- Kunzler Property East – part of SR30 Wetland Mitigation, Park Ave to 10th West (UDOT)
- Kunzler Property West – 73-acre conservation easement below 10th West (Logan City)

1.4. Potential Projects

- UWRL hillslope stabilization (Logan City, US Army Corps of Engineers)
- Crockett Diversion to Denzil Stewart Nature Park – diversion structure remodel, two bridge replacements, trail connections
- Providence Canal Diversion to River Heights Bridge – fish barrier removal, diversion and canal replacement, bank stabilization, floodplain restoration
- Main Street West (?)
- Restoration of upstream portion of the Golf Course Reach (Logan City)
- Projects included in the Logan River Blue Trail Master Plan

REFERENCES

Andree KB, MacConnell E, Hedrick RP. A nested polymerase chain reaction for the detection of genomic DNA of Myxobolus cerebralis in rainbow trout Oncorhynchus mykiss. Diseases of Aquatic Organisms. 1998 Oct 8;34(2):145-54.

Budy, P., E.A. de la Hoz, and G.P. Thiede. 2002. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. Annual Report to Utah Division of Wildlife Resources. Utah Cooperative Fish and Wildlife Research Unit. Logan, Utah. 67 pages.

Budy, P., E.A. de la Hoz, and G.P. Thiede. 2001. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. Annual Report to Utah Division of Wildlife Resources. Utah Cooperative Fish and Wildlife Research Unit. Logan, Utah. 64 pages.

Budy, P., G.P. Thiede, E.A. de la Hoz, and S. Vatland. 2003. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. 2002 Annual Report to Utah Division of Wildlife Resources. USGS Utah Cooperative Fish and Wildlife Research Unit. Logan, Utah. 50 pages.

Budy, P., P. McHugh, and G.P. Thiede. 2004. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. 2002 Annual Report to Utah Division of Wildlife Resources. USGS Utah Cooperative Fish and Wildlife Research Unit. Logan, Utah. 61 pages.

Budy, P., P.M. McHugh, G.P. Thiede, and E. VanDyke. 2005. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. 2004 Annual Report to Utah Division of Wildlife Resources. UTCFWRU 2005(2):1-129.

Budy, P., G.P. Thiede, E.S. Hansen, and J. Wood. 2007a. Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah. 2006 Annual Report to Utah Division of Wildlife Resources. Sport Fish Restoration. Grant number XIII. Project F-47-R. 52 pages.

Budy, P., G.P. Thiede, P. McHugh. 2007b. A quantification of the vital rates, abundance, and status of a critical population of endemic cutthroat trout. North American Journal of Fisheries Management 27:593-604.

Budy, P., Thiede, G., Meredith, C., Seidel, S., Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah, Annual Report, USGS Utah Cooperative Fish and Wildlife Research Unit, 2009.

Budy, P., Thiede, G., Meredith, C., Chaston, R., Logan River whirling disease study: factors affecting trout population dynamics, abundance, and distribution in the Logan River, Utah, Annual Report, USGS Utah Cooperative Fish and Wildlife Research Unit, 2010.

Budy et al., unpublished Logan River data, 2016.

Coleman, T., J. DeRito, C. Penne, G.P. Thiede, and P. Budy. 2020. Fishing success goes with the flow: correlation between stream flow and temperature and angler catch rates. Oral presentation. Annual Meeting of the Utah Chapter of the American Fisheries Society, St. George, Utah, 26-27 February 2020.

Cuffney TF, Bilger MD, Haigler AM. Ambiguous taxa: effects on the characterization and interpretation of invertebrate assemblages. Journal of the North American Benthological Society. 2007 Jun;26(2):286-307.

Hawkins CP, Norris RH, Gerritsen J, Hughes RM, Jackson SK, Johnson RK, Stevenson RJ. Evaluation of the use of landscape classifications for the prediction of freshwater biota: synthesis and recommendations. Journal of the North American Benthological Society. 2000 Sep;19(3):541-56.

Howe, F., Logan River Bird Monitoring Protocol, 2016.

Klemm, D. J., Lewis, P. A., Fulk, F. and Lazorchak, J. M.: 1990, *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*, EPA.600/4-90/030, Environmental Monitoring Systems Laboratory, Office of Modeling, Monitoring Systems, and Quality Assurance, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.

Lazorchak JM, Klemm DJ, Peck DV, editors. Environmental Monitoring and Assessment Program Surface Waters: Field operations and methods for measuring the ecological condition of wadeable streams.

Logan River Restoration Conservation Action Plan (CAP), Logan River Task Force, Logan City, BIO-WEST, May 2016.

Logan River Restoration at Rendezvous Park, 2017 Pre-construction Riparian Vegetation Conditions Monitoring Report, BIO-WEST, Inc., 2018.

Logan River Restoration at Rendezvous Park, 2018 Year 1 (Post-construction) Riparian Vegetation Conditions Monitoring Report, BIO-WEST, Inc., 2019.

Logan River Restoration at Rendezvous Park, 2018 Year 2 (Post-construction) Riparian Vegetation Conditions Monitoring Report, BIO-WEST, Inc., 2020.

Logan River Blue Trail Master Plan, January 2020.
Mooney, S., & Eisgruber, L. M. (2001). The influence of riparian protection measures on residential property values: The case of the Oregon plan for salmon and watersheds. Journal of Real Estate Finance and Economics, 22, 273–286. https://doi.org/10.1023/A:1007899716050

Morris WF, Doak DF. Quantitative conservation biology. Sinauer, Sunderland, Massachusetts, USA. 2002.

Nicholls S, Crompton JL. The effect of rivers, streams, and canals on property values. River Research and Applications. 2017 Nov;33(9):1377-86.

Plafkin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K. and Hughes, R. M. 1989. *Rapid bioassessment protocols for use in streams and rivers*, Benthic macroinvertebrates and fish. EPA/444/4–89/001 160Washington: Office of Water Regulations and Standards, U.S. Environmental Protection Agency.

Rendezvous Park Herp Monitoring, The USU Student Chapter of The Wildlife Society's Rendezvous Park herp monitoring project, 2019.

Streiner, L., & Loomis, J. B. (1996). Estimating the benefits of urban stream restoration using the hedonic price method. Rivers, 5, 267–278.

Wheaton JM, Fryirs KA, Brierley G, Bangen SG, Bouwes N, O'Brien G. Geomorphic mapping and taxonomy of fluvial landforms. Geomorphology. 2015 Nov 1;248:273-95.

White GC, Burnham KP. Program MARK: survival estimation from populations of marked animals. Bird study. 1999 Jan 1;46(sup1): S120-39.

http://www.usu.edu/buglab/SampleProcessing/ResultsAndReports/#item=85.

http://www.qcnr.usu.edu/wmc/data