Salt Lake City Riparian Corridor Study

Final Red Butte Creek Management Plan

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Submitted to:

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EXECUTIVE SUMMARY

Salt Lake City's urban creeks and their associated riparian corridors are unique and important natural resources. To recognize the importance of these resources, Salt Lake City passed a Riparian Corridor Overlay Zone ordinance in 2008. In conjunction with passage of the ordinance, the City Council authorized the Salt Lake City Department of Public Utilities (DPU) to conduct stream corridor studies to assess baseline conditions on the above-ground portions of City, Emigration, Parleys, and Red Butte Creeks within Salt Lake City's municipal boundaries.

This Red Butte Creek Riparian Corridor Study Management Plan document introduces the study and describes the importance of riparian functions (Chapter 1), presents the methods (Chapter 2 and Appendix A) and results (Chapter 3) of baseline assessment of stream and vegetation conditions, describes various recommended techniques to improve riparian conditions (Chapter 4 and Appendix B), presents the vision for the desired future condition of the corridor as determined from public and stakeholder input (Chapter 5), provides maps and recommendations for specific stream reaches within the Red Butte Creek riparian corridor (Appendix C), and includes approximate cost estimates for recommended projects (Appendix D).

Study findings indicate that tree cover and shading are generally good throughout the corridor, and that community members value and appreciate the corridor for its aesthetic and ecological values. Common issues affecting riparian function include litter, streambank erosion, streambed lowering, invasive plants, lack of shrub and understory cover, storm drain outfall erosion, failing bank revetment, and problems associated with small-diameter stream crossing culverts. Recommendations include invasive plant removal/control, storm drain outlet protection, culvert replacement, revegetation of streambanks, installation of grade control and toe protection features, reach-scale streambank stabilization, stream cleanup and adoption, and measures to reduce impervious cover and improve watershed condition.

This document is intended to be used as a tool to help guide and inform future efforts to enhance riparian conditions within the Red Butte Creek stream corridor and achieve the vision statement for the corridor. Chapter 4 provides information on permitting requirements (Table 4.5), costs and benefits (Tables 4.6 and 4.7), maintenance and monitoring considerations (Table 4.8), and grant resources (Table 4.9) for different types of improvement projects. This information can be used in combination with reach-specific recommendations and objectives (Table 5.1, Table 5.2, Table 5.3, Appendices C and D) to plan for funding and implementation of improvement projects. The tools in this document are intended to be flexible and useful for a variety of implementation approaches, including corridor-scale approaches that target a specific issue (e.g., planning for phased upgrades to storm drain outfalls throughout the riparian corridor) and reach-specific approaches that apply a variety of improvement measures to a specific section of stream (e.g., bank stabilization, invasive plant removal, and trash cleanup within a 1,000-foot-long stream reach between road crossings). Owners of individual stream-side properties can also use resource references in the document (sidebars in Chapter 4) to help select appropriate improvement techniques, obtain necessary materials, and contact appropriate agencies/organizations for guidance and support.

Various action items are recommended for implementation (Chapter 5), including a recommendation to establish a riparian corridor working group. This entity may help identify more detailed funding approaches, leadership, and schedules for individual projects. Dependent on available funding and to the extent possible, DPU's implementation efforts will be balanced among the City's four creeks (City, Red Butte, Emigration, and Parleys) and the Jordan River.

Cost estimates for the improvement measures identified for each fully-assessed study reach are summarized in Table ES1. These cost values are highly approximate. Site-level design work and engineering are required for many projects, and cost estimates may vary substantially once detailed designs are prepared for a given study reach. In addition, the proposed improvement measures are not intended to be exhaustive, and as site-specific designs are completed additional improvement measures may be included. Appendices C and D provide additional details about the recommended projects and cost estimates.

Table ES1. Summary of estimated approximate costs for improvement measures by reach.

REACH NUMBER	REACH DESCRIPTION	REACH LENGTH (feet)	APPROXIMATE COST ESTIMATE FOR INITIAL IMPLEMENTATION OF IMPROVEMENT MEASURES [a]	
			With Culvert Replacement and/or Daylighting	Without Culvert Replacement and/or Daylighting [b]
URB_R09	Upper Red Butte Garden	2,297	N/A	$14,720
URB_R10	Middle Red Butte Garden	827	reach not fully assessed	reach not fully assessed
LRB_R01	Lower Red Butte Garden	281	N/A	$160
LRB_R02	University - Below Red Butte Garden	451	$171,280	$80,280
LRB_R03	University - Above Chipeta Way	1,041	N/A	$92,650
LRB_R04A	University - Below Chipeta Way	961	$729,640	$97,840
LRB_R04B	University - Near Tennis Courts	595	$584,190	$57,690
LRB_R04C	University - Above Foothill Drive	1,294	$553,150	$131,950
LRB_R05A	VA Medical Center - Below Foothill Drive	433	$1,217,430	$125,430
LRB_R05B	VA Medical Center - Above Sunnyside Park	1,081	$857,010	$134,210
LRB_R05C	Sunnyside Park	887	$1,174,080	$121,080
LRB_R06	Sunnyside Avenue to 900 South	492	reach not fully assessed	reach not fully assessed
LRB_R07	Miller Park/ Bonneville Glen	2,084	$4,024,650	$487,350
LRB_R08	Below 1500 East	1,059	reach not assessed	reach not assessed
LRB_R09	Above 1300 E ast	633	reach not fully assessed	reach not fully assessed
LRB_R10	1300 East to 1100 East	1,449	reach not fully assessed	reach not fully assessed
LRB_R11	Below 1100 East	301	reach not fully assessed	reach not fully assessed
TOTAL FOR RED BUTTE CREEK CORRIDOR			$9,311,440	$1,343,370

[a] Estimated cost values include materials and installation and 30% contingency for design, permitting, right of way, legal administrative etc. expenses. Values do not include annual monitoring or maintenance costs.

[b] If culvert outlets are protected but culverts are not removed or replaced with wider-span/open-bottom structures, stream stability is expected to improve but the additional benefits associated with replacement (improved connectivity, habitat, conveyance, reduced risk of clogging, etc.) will not be gained.

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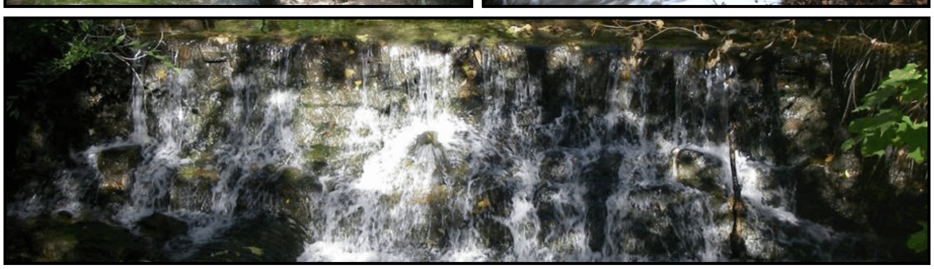
1.0 INTRODUCTION

Salt Lake City's urban creeks and their associated riparian corridors are unique and important natural resources. To recognize the importance of these resources, Salt Lake City (the City) passed a Riparian Corridor Overlay Zone (RCO) ordinance on July 22, 2008. The RCO ordinance establishes restrictions and provisions for land uses occurring within 25, 50, and 100 feet of any above-ground city stream channel. In conjunction with passage of the ordinance, the City Council authorized the Salt Lake City Department of Public Utilities (DPU) to conduct stream corridor studies to assess baseline conditions on the above-ground portions of City, Emigration, Parleys, and Red Butte Creeks within City boundaries. This Riparian Corridor Study (RCS) Management Plan document presents the results of the baseline assessment of the Red Butte Creek riparian corridor, describes the desired future condition of the corridor as determined from public and stakeholder input, and identifies opportunities for improvement projects within the corridor.



Riparian Corridor Study and Management Plan Goals

The City has identified four primary objectives of the Red Butte Creek RCS as follows:

- to assess existing stream and riparian vegetation conditions;
- to determine desired future conditions;
- to identify opportunities for restoration and remediation of the Red Butte Creek corridor; and
- to use the information, data, and maps developed during the study to inform planning, permitting, and administrative processes of the RCO ordinance.

In addition to these objectives, specific purposes of the RCS public outreach process include the following:

- to elicit community and stakeholder participation,
- to identify public values and concerns, and
- to communicate results of the study for public awareness, education, and support.

The Red Butte Creek RCS and public outreach process is separate from but related to the previously completed RCO ordinance public outreach process. The RCS is intended to provide critical information that will guide the implementation and permitting aspects of the ordinance but is not intended to result in changes or revisions to the ordinance.

Study Area

In addition to the Red Butte Creek riparian corridor described in detail in this document, the complete DPU study also includes assessment of the above-ground portions of the Emigration Creek, Parleys Creek, and City Creek riparian corridors within City boundaries (Figure 1.1). The overall study is being completed in two phases. The studies on Emigration and Red Butte Creeks are being completed as the first phase of the project, from fall 2008 through fall 2009; studies on Parleys and City Creeks are being completed as the second phase of the project, from spring 2009 through spring 2010. More detailed information on all four of the riparian corridor studies can be found by accessing the DPU website at www.slch2o.com.

Importance and Functions of Riparian Corridors

Streams and riparian areas are unique, rare, sensitive, and highly important elements of the landscape. Riparian corridors, which encompass in-stream, riparian, and adjacent terrestrial habitats, function as complex interdependent ecosystems (Figure 1.2). The size, shape, flow regime, and bed material

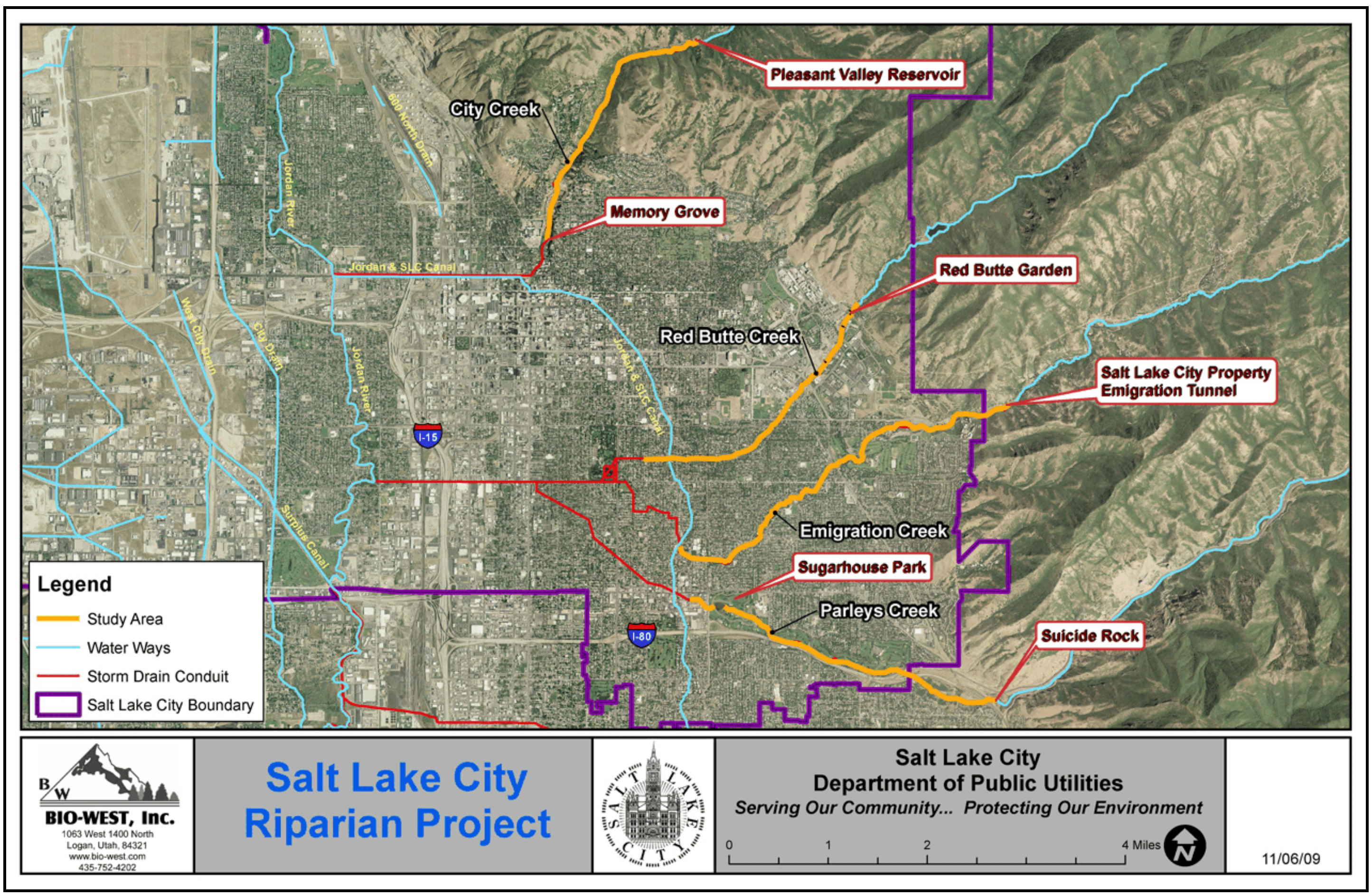


Figure 1.1. Emigration, Red Butte, Parleys, and City Creeks study areas.

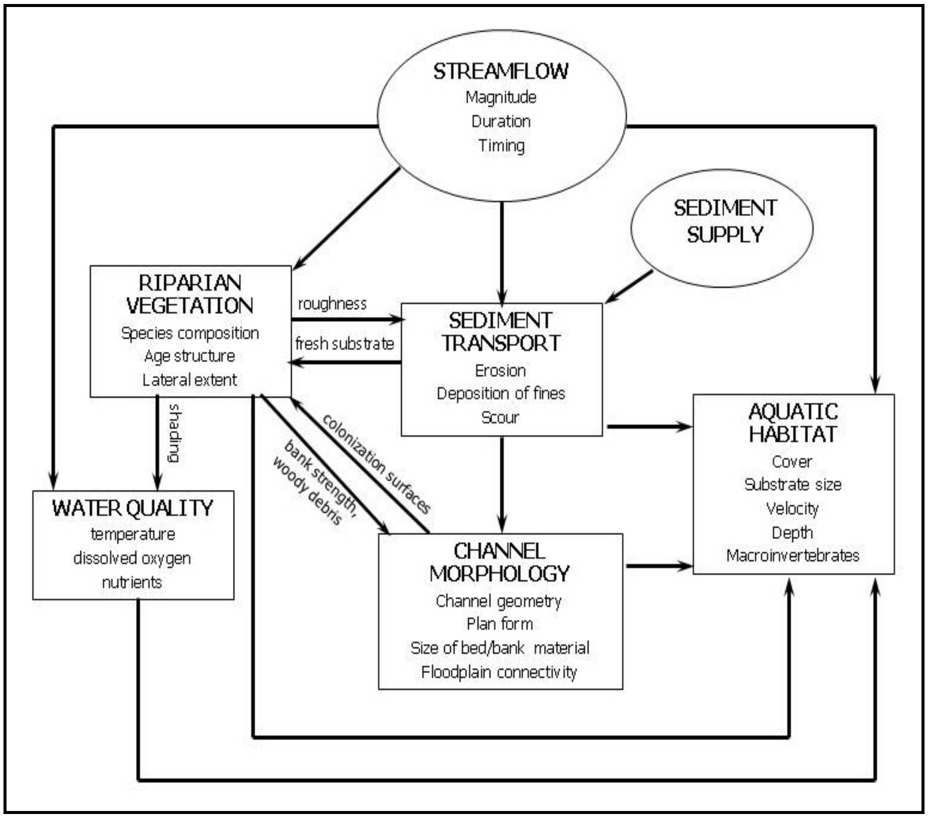


Figure 1.2. Schematic illustration of major interactions among riparian corridor resources and processes.

characteristics of the stream channel influence the amount, type, and distribution of vegetation on the streambanks. In turn, the condition, density, and composition of streambank vegetation communities influence the size, shape, and stability of the stream channel (Simon et al. 2004). These reciprocal influences operate through a variety of mechanisms including streambank shear strength, soil moisture content, flow resistance, bank steepness, flooding dynamics, erosion, and deposition.

Because of the complexity of riparian systems, alterations to any single component of the system can have positive or negative effects on multiple other components of the system. In healthy riparian corridors, stream channel processes such as flooding, meandering, erosion, and deposition provide colonization surfaces and moisture to support diverse, healthy riparian vegetation communities. In turn, healthy riparian vegetation communities provide streambank stability, shading, and woody debris inputs to support diverse, healthy aquatic communities.

Riparian areas occupy only a small proportion (less than 3%)

Riparian Corridor Definition

There is no universally agreed upon scientific definition of the term "riparian;" however, the term is typically used in modern scientific literature to describe the transitional area located between aquatic (in-stream) and upland habitats. Riparian plants that occupy this transitional area are typically adapted to conditions that are periodically wet and periodically disturbed by flood events.

Within the legal framework of the City's RCO ordinance, the term "riparian corridor" is defined as the area within 100 feet horizontally on either side of the annual high water level (AHWL) of above-ground streams (Figure 1.3). Depending on the stream channel and streambank conditions at a specific location, the legally defined riparian corridor often includes upland fringe and developed stream-side areas in addition to those areas that would be considered "riparian" based on the scientific definition. Within the City's RCO ordinance, the term "stream corridor" is defined as including the active stream channel as well as the 100-foot riparian corridor on each side of the channel. Therefore, the total stream corridor width equals 200 feet plus the width of the stream at high water, which varies depending on the specific location along the stream channel. The Red Butte Creek RCS addresses conditions within the Red Butte Creek stream corridor according to this definition.

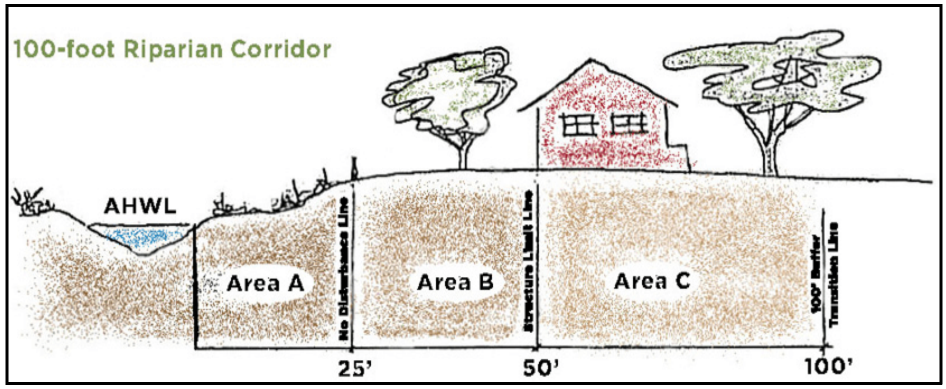


Figure 1.3. One hundred-foot Riparian Corridor Overlay Zone ordinance riparian corridor.

of the land area of Utah (USU 2003) and comprise about 1.2% of the land area of Salt Lake City. Despite their small size, riparian corridors serve a variety of important functions within the landscape, as discussed below.

Habitat for Mammals, Birds, and Fish

The ecological role of riparian zones is disproportionate to their small size. In Utah approximately 75% of the state's bird species rely on riparian habitat (USU 2003), and in the western United States up to 80% of all mammal and bird species rely on riparian zones for some part of their life cycle (Krueper 1993). The habitat importance of Red Butte Creek and the other above-ground stream corridors in Salt Lake City is enhanced because these streams lie close to the Great Salt Lake, an ecosystem of hemispheric significance in terms of providing resting, staging, and nesting habitat for migratory bird populations. Much of the value of riparian zones can be attributed to the fact that moisture and nutrients accumulate in these low-lying areas, leading to a greater diversity and density of plant communities. Healthy riparian corridors also support multiple structural layers of vegetation, including understory, shrub, and canopy layers that further contribute to habitat complexity (USU 2003).

Shading and Water-Temperature Control

Healthy stream-side vegetation provides a canopy that insulates the stream from the potentially harmful effects of excessive solar radiation. When water gets too warm, its oxygen-carrying capacity is reduced, which can harm fish and aquatic insect populations. Therefore, intact tree and shrub cover along streams, such as Red Butte Creek, is important for water quality. Shaded riparian areas also provide a cool, pleasant environment for City residents seeking refuge from summertime heat. Depending on how steep the streambanks are in a particular location, the shading function may be provided by moisture-dependent plants alone or by a combination of these plants plus the plants growing in adjacent, drier locations higher up on the banks. Therefore, even in areas where streambanks are steep and active floodplain surfaces are limited, the condition of the broader "stream corridor" (as defined in the RCO ordinance) is relevant to the shading and water-temperature control function.

Aesthetics

In arid Salt Lake City, the relatively lush, green, tall vegetation within riparian corridors is visually distinct from the remainder of the landscape

and has a unique aesthetic value. The sound of flowing water is also pleasing and calming. Because riparian corridors have these aesthetic qualities, people gravitate to these areas to have picnics, go for walks, and find quiet respite from the urban landscape. The aesthetic function is commonly highlighted as a valued amenity of properties located along stream corridors in the City.

Recreation and Open Space

Many of Salt Lake City's parks and open-space areas are located along riparian corridors. These areas function as important pockets of green space within an otherwise urbanized city environment. They provide opportunities for residents to experience and learn about the unique, natural processes and ecology of riparian corridors, as well as opportunities for both active and passive recreation.

Floodplain Storage and Flood Damage Reduction

Well-vegetated, pervious streambanks and low-lying floodplain surfaces act as sponges that absorb snowmelt and flood water and can reduce downstream flooding. Intact riparian vegetation also slows flood-water velocities and dissipates erosive energy. Floodplain and pervious streambed areas enable recharge of springtime runoff water into the ground, providing a source of streamflow later in the year during the dry summer months (Montgomery 1996). Because much of Red Butte Creek within Salt Lake City has a naturally steep and entrenched shape, the extent of flat, hydrologically connected floodplain surfaces is limited relative to flatter-gradient alluvial rivers. Nevertheless, some floodplain surfaces are present, particularly in areas where the channel width has not been confined by fill, bank stabilization, or channel-straightening activities. These areas of the riparian corridor provide some level of flood storage and groundwater recharge, while these functions are missing in areas where the creek has been piped or lined with impervious concrete.

Travel Corridors and Connectivity

The linear nature of riparian corridors makes them natural travel routes for fish, birds, mammals, and other aquatic and terrestrial species. In Salt Lake City, the corridors provide a longitudinal connection between habitats in the mountains and habitats in the valley.

Organic Matter Inputs

Well-vegetated riparian corridors provide a supply of leaf litter and woody debris to the stream channel and aquatic environment. In small streams where photosynthesis is typically less significant, these organic matter inputs supply the primary source of energy and nutrients for aquatic insects and fish (USU 2003). Snags, branches, and leaf litter provide important cavity habitat and cover for birds and other terrestrial animals that use streambank areas, while woody debris jams within the stream channel add to aquatic habitat complexity and provide cover for fish.

Filtration of Sediment and Pollutants

Where a buffer of vegetation, especially tall grass or dense shrubs, is present along streambanks, the vegetation is able to physically trap sediment and associated pollutants conveyed in runoff from upland areas (Montgomery 1996). Vegetation communities with high stem and root densities are especially effective in this function. Well-vegetated floodplain surfaces serve a similar filtration and trapping function when they are inundated during flood events and can reduce the amount of sediment and pollutants entering downstream receiving waters. Vegetation can also reduce pollutant loads via biological uptake of nutrients and other chemicals attached to runoff.

In portions of the City's riparian corridors, this filtration function is "bypassed" to some extent because much of the storm runoff enters the creeks in a concentrated fashion through storm drain pipes. However, a significant amount of runoff still enters via the streambanks, and water that exits storm drain outfalls often flows along streambank areas for some distance before reaching the main stream channel. Therefore, healthy streambank vegetation positively influences water quality even in an urban storm water runoff setting.

Streambank Stability

Healthy vegetation communities add significantly to the strength and stability of streambanks. Vegetation protects the underlying soil from erosion due to raindrop impact or concentrated runoff. Roots add tensile strength to the soil and can anchor the soil to more resistant underlying soil or rock layers. Woody stems and trunks impart resistive strength that protects against lateral bank scour during high-flow events. Streambank vegetation also increases surface roughness, which helps dissipate energy and reduce flow velocities (Gray and Sotir 1996). Woody plants and plants with dense, deep root networks are especially valuable in terms of streambank stability.

Storm Water and Irrigation Water Conveyance

Within the developed portions of Salt Lake City, most of the runoff generated from rooftops, roads, and other impervious surfaces during storm events is conveyed first into curbside gutters, then into storm drains and underground pipes, then into the City's streams, including Red Butte Creek. The City relies on these natural steam channels to convey storm water to downstream conduit and detention facilities in a safe manner that minimizes the risk of damage to infrastructure from flooding. The Red Butte Creek channel is further used to deliver water to points of diversion for irrigation purposes per established water rights.

Public Outreach and Involvement

The preparation of the Red Butte Creek RCS Management Plan has required extensive public and agency involvement activities throughout the 15-month planning process. The planning process included a broad outreach element that emphasized public and agency involvement in identifying desired future conditions for the creek. The overall goal of the public outreach element was to elicit community and stakeholder participation and identify public values and concerns associated with the riparian corridor, including environmental issues, aesthetic values, private property interests, public lands access, water quality, wildlife habitat, and flood control. In addition, it is the intent to effectively convey in this plan the results of the study for public awareness, education, and support.

Several methods of public and agency involvement were used to gain insight into the concerns of those potentially affected by this plan. These methods included facilitation of public workshops, formation of a stakeholder committee, and development of an interactive web page to disseminate information. Each method is described in more detail below.

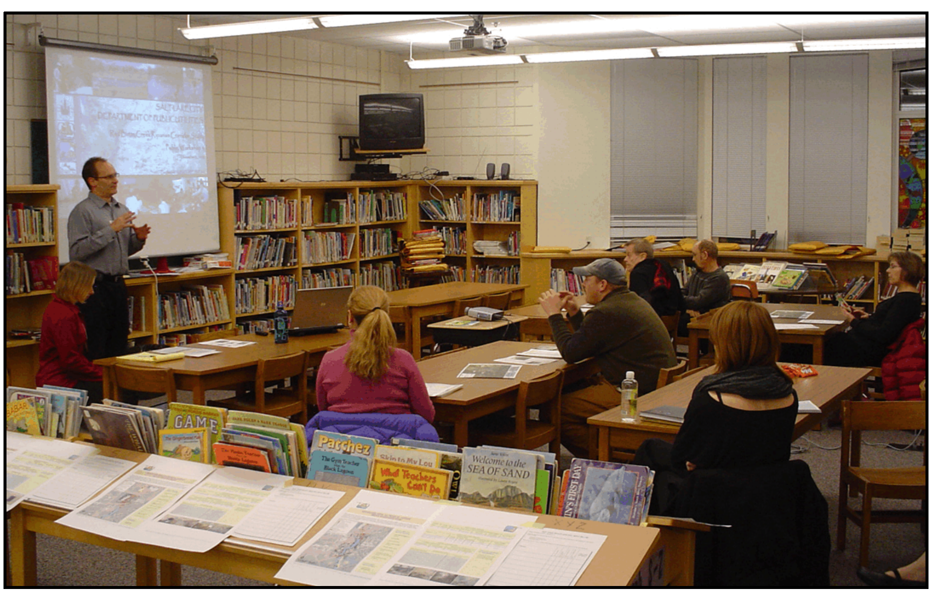
Public Workshops

A series of four public workshops were conducted during the planning process to solicit and obtain public input and to share the results of project activities. These public workshops consisted of both a “formal” presentation and question-answer period and an “informal, open-house” period whereby individuals could freely participate. Each workshop was held at a convenient location near the study area, and both City and consultant staff were on-hand to answer questions and record input. Each workshop was advertised on the City’s web page for the RCS projects and at local media outlets. Workshop flyers were posted around the City at public locations and postcard notices were distributed to those individuals on the project mailing list.

The first public workshop was held on October 28, 2008, at East High School. The first workshop allowed public and agency participants the opportunity to identify the issues, concerns, and opportunities that exist relative to the project study area. Maps and photographs of the study area were available to orient participants and elicit their site-specific input. An overview of the planning process was presented, including specific public outreach and baseline condition assessment activities, and participants were educated about important riparian corridor functions. Participants were encouraged to fill out a workshop response form, as well as a private property access permission form for data gathering. Approximately 16 individuals attended the first workshop.

The second public workshop was held on February 19, 2009, at Uintah Elementary School. The second workshop focused on reviewing baseline stream and vegetation assessment results and initiating development of a vision statement for the plan. Maps, graphs, and photographs of the study area that identified resource locations and conditions were presented, along with detailed handouts, to help inform interested participants. An update of the planning process timeline was also presented. Comments from participants on the project vision statement were solicited on the workshop response forms that were provided. Approximately 24 individuals attended the second workshop.

The third public workshop was held on May 14, 2009, at Uintah Elementary School. The third workshop was a forum for presenting and discussing the range of variable riparian corridor improvement projects and presenting and discussing the draft vision statement for the management plan. Maps, photos, and schematic drawings



“Our goal is that this study will use a collaborative approach to information exchange, joint information gathering, consultation, and consensus in a way that will promote legitimacy and transparency, encourage creative problem-solving, and support a timely implementation.”

–Mayor Ralph Becker’s goal for community involvement in the Riparian Corridor Study Management Plan projects were used to present the proposed types of projects and provide guidance regarding the appropriate scale and locations for the projects. Summaries of the proposed projects were provided in workshop handouts. An update of the planning process timeline was presented and opportunities for participants to comment on the proposed projects were provided. Participants were asked to help prioritize projects and specifically asked to comment on the draft vision statement provided on the workshop response form. Approximately 21 individuals attended the third workshop.

The fourth and final public workshop was held on December 9, 2009, at Uintah Elementary School. The fourth workshop provided an opportunity for participants to comment on the Draft RCS Management Plan document. An overview of the plan document was presented and opportunities for providing comments were discussed. Comments from participants were encouraged. Approximately 10 individuals attended the fourth workshop.

Riparian Corridor Study Subcommittee Meetings

The RCS Subcommittee was formed to provide guidance to DPU throughout the studies and broadly represent the various stakeholders who have an interest in the planning process. The Subcommittee helped identify issues, evaluate data and data collection methods, develop the vision statement, recommend and critique restoration projects, and review chapters of the plan document. Subcommittee members were solicited by the City to participate in the project.

Members of the RCS Subcommittee included the following:

- Red Butte Creek Residents
- Emigration Creek Residents
- Hogle Zoo
- Red Butte Garden and Arboretum
- Salt Lake City Public Utilities Advisory Committee
- Salt Lake City Parks
- Salt Lake County
- Salt Lake Valley Health Department
- Trout Unlimited
- University of Utah
- Utah Open Lands
- Utah Rivers Council
- Utah Department of Environmental Quality
- United States Veterans Administration Medical Center

The RCS Subcommittee convened a total of five times during the 15-month planning process.

Interactive Web Page

Salt Lake City DPU dedicated a page on their web site specifically for the RCS projects (www.slcgov.com/utilities/ud_riparian_corridor_stream_study.htm). A history of the RCS project was provided on the web page, along with information related to the RCO ordinance. A map of study area streams could be downloaded by web site visitors, as could all information disseminated at each of the public workshops including presentations, handouts, comment forms, and meeting announcements. Web-based public comment forms and property-access permission forms were also made available on this web page.

Management Plan Approach

The planning process for the Red Butte Creek RCS Management Plan involved the coordination and cooperation of members of the public, state and local government agency staff, and consultant team planners and resource scientists working together over a 15-month period to complete this document.

Those involved helped perform key activities during the planning process including public and agency involvement, baseline resource inventories and analyses, vision statement formulation, and improvement project identification. Figures 1.4 and 1.5 provide an overview of the Red Butte Creek RCS planning process organization and timeline.

Initial steps during the planning process focused on compiling relevant and available resource data, topography, mapping layers, and aerial photography. A reconnaissance-level field assessment was performed early in the planning process to help determine appropriate data collection efforts and divide the creek into specific study reaches. Once preliminary reaches were defined and data collection protocols established, field work was conducted to characterize stream channel, streambank, and riparian vegetation conditions throughout each reach. Relevant data for both the stream condition and vegetation condition assessments were collected and assembled in a Geographic Information System (GIS) format.

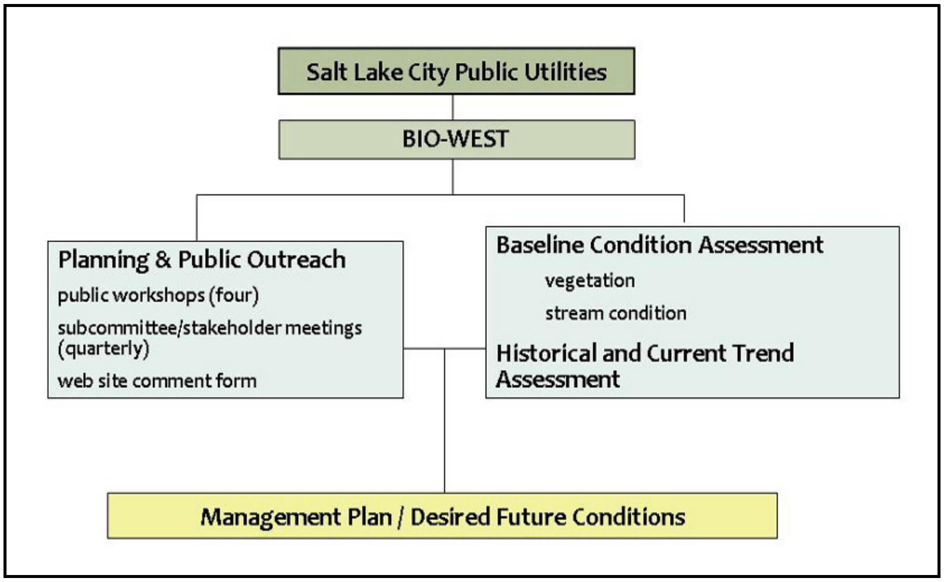


Figure 1.4. Organizational Chart for the Salt Lake City Riparian Corridor Management Plans.

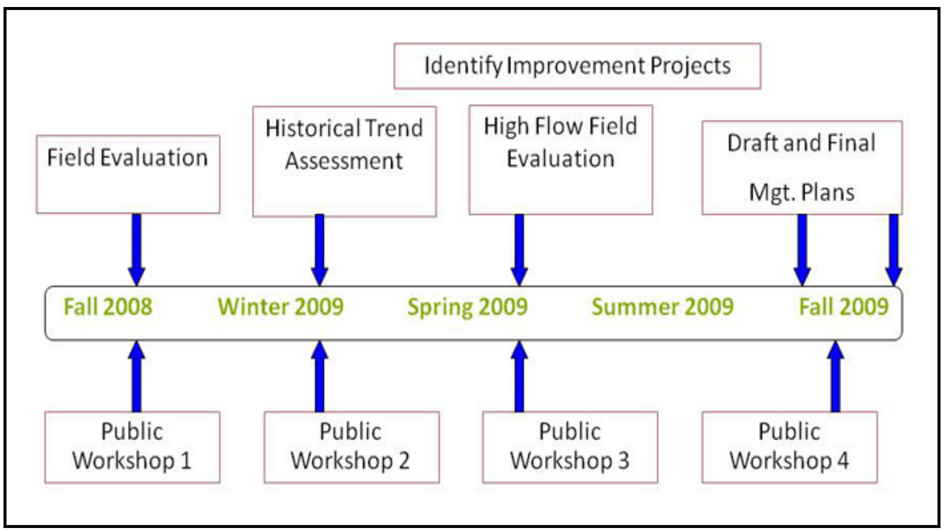


Figure 1.5. Timeline of Salt Lake City Riparian Corridor Studies and Management Plans.

Desired future conditions for each study stream were determined primarily through public outreach and stakeholder participation efforts. Historical data and trend assessment results were used to help define realistic, reach-appropriate riparian vegetation and stream condition targets. Targets are focused toward achieving the specific riparian corridor functions identified as priorities during the outreach process. Desired future conditions were compared with existing conditions determined through the baseline assessment process to assess how well riparian functions are being achieved in the different reaches. Appropriate types of improvement projects were identified for each reach, and costs for the different types of projects were estimated. Specific projects were then prioritized and ranked based on costs, benefits, and public input.

2.0 BASELINE ASSESSMENT METHODS

Study Reaches

Conditions within the Red Butte Creek corridor were assessed between the upstream boundary of Red Butte Garden and approximately 1050 East (Figure 2.1). Total above-ground channel length within the study area is approximately 3.1 miles. For assessment purposes, the stream was divided into individual reaches, with each reach generally between 300 to 1,400 feet in length. Reach breaks were initially identified based on reaches previously established by Salt Lake County (the County); several of these County reaches were further subdivided at road crossings or where significant changes in stream condition occurred. Seventeen study reaches were established within the overall Red Butte Creek study area.

Reach names and numbers were assigned based on established County watershed abbreviation and stream numbering conventions (SLCO 2009). Red Butte Creek includes the upper Red Butte (URB) and lower Red Butte (LRB) subwatersheds, with the break occurring at the canyon mouth. Within each subwatershed, reach numbers are assigned consecutively in an upstream to downstream

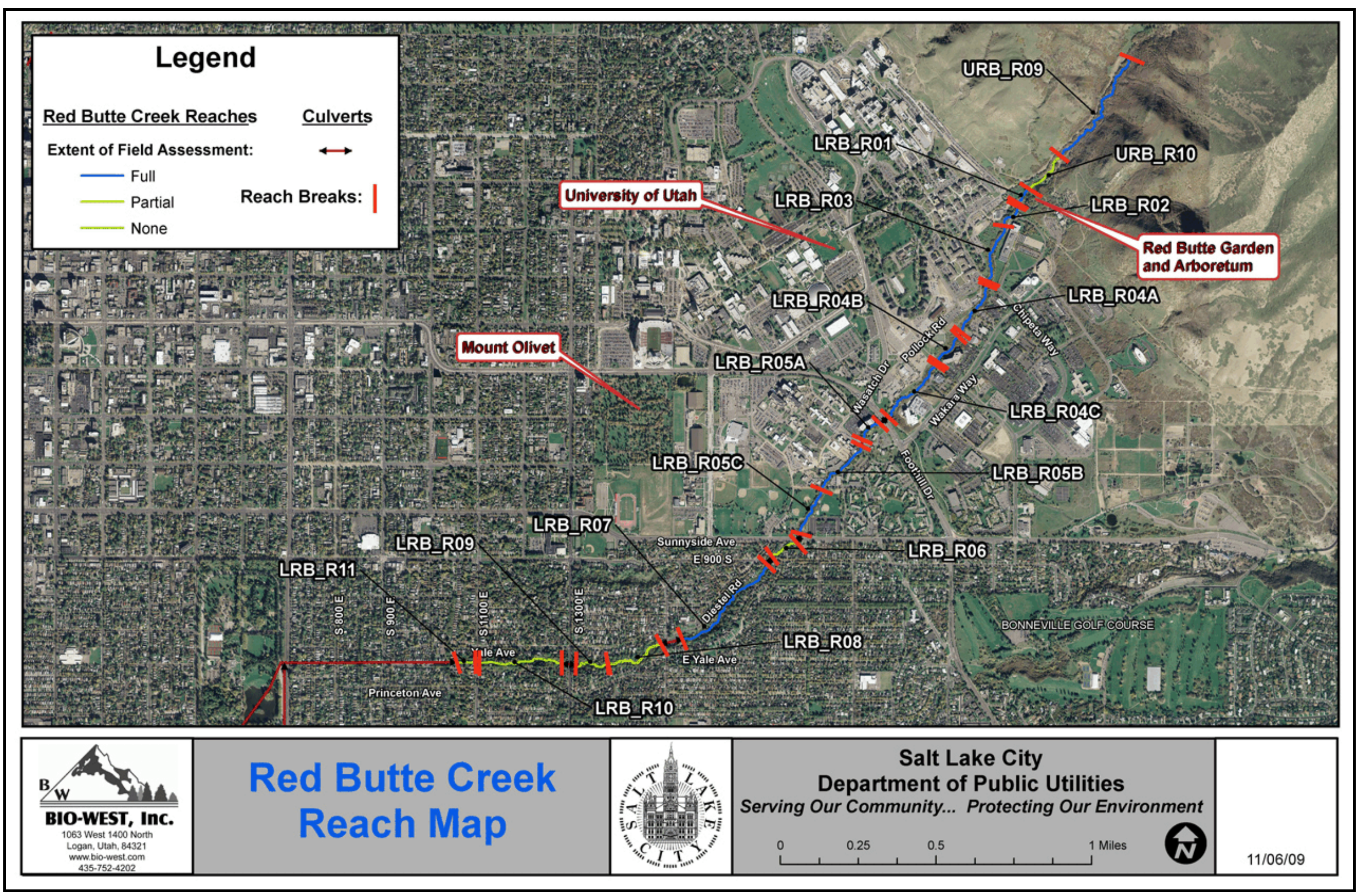


Figure 2.1. **Red Butte Creek reach map.**

direction, resulting in reach numbers such as LRB_R01 (lower Red Butte Creek Reach 1), LRB_R02, etc. For the reaches that were subdivided, an alpha character was appended to the end of the number, resulting in numbers such as LRB_R02A, LRB_R02B, etc. Table 2.1 provides a complete list of the Red Butte Creek study reaches.

Stream Condition Assessment

For each study reach, stream condition was assessed using both qualitative and quantitative measures. Base maps (1 inch = 100 feet scale) for field use were prepared using 2006 aerial imagery (1-foot resolution color orthophotography) and light detection and ranging (LIDAR)-based elevation data (3 foot contour interval). Field data collection methods for this study were designed to compliment available stream condition information collected by Salt Lake County in 2007 and 2008.

The County assessed 13 reaches within the Red Butte Creek study area, and for each reach completed components of a Level III Stream Inventory (Rosgen 1996). Information gathered included Rosgen (1996) stream type, estimates of riparian vegetation width and density, extent of artificial bank stabilization in the reach, visual estimates of streambed material size, and a qualitative channel stability evaluation (Pfankuch 1975). Detailed cross-section surveys were not completed as part of this County effort; rather, at one representative location within each reach, the bankfull

Table 2.1. Reach names.

REACH NUMBER	REACH DESCRIPTION	EXTENT OF FIELD ASSESSMENT	FIELD ASSESSMENT DATE
URB_R09	Upper Red Butte Garden	full	10/14/2008
URB_R10	Middle Red Butte Garden	partial	10/14/2008
LRB_R01	Lower Red Butte Garden	full	10/14/2008
LRB_R02	University - Below Red Butte Garden	full	10/14/2008
LRB_R03	University - Above Chipeta Way	full	10/15/2008
LRB_R04A	University - Below Chipeta Way	full	10/15/2008
LRB_R04B	University - Near Tennis Courts	full	10/15/2008
LRB_R04C	University - Above Foothill Drive	full	10/15/2008
LRB_R05A	VA Medical Center - Below Foothill Drive	full	10/16/2008
LRB_R05B	VA Medical Center - Above Sunnyside Park	full	10/16/2008
LRB_R05C	Sunnyside Park	full	10/16/2008
LRB_R06	Sunnyside Avenue to 900 South	partial	5/14/2009
LRB_R07	Miller Park/ Bonneville Glen	full	10/16/2008
LRB_R08	Below 1500 East	none	N/A
LRB_R09	Above 1300 East	partial	5/1/2009
LRB_R10	1300 East to 1100 East	partial	11/22/2008
LRB_R11	Below 1100 East	partial	4/15/2009

channel was visually identified and estimates of bankfull width, depth, and entrenchment ratio were measured with a rod. Additional information on the County stream assessment methods can be found in the Salt Lake Countywide Water Quality Stewardship Plan (SLCO 2009).

The techniques used for the Salt Lake City RCS field evaluations provide an additional level of quantitative and site-specific data to supplement the available County information. Overall, the objective of the baseline stream condition assessment is to gather information on how well the riparian functions of aesthetics, floodplain storage, connectivity, organic matter inputs, stability, and conveyance are being met within the Red Butte Creek riparian corridor.

Field Data Collection

Field assessments were completed during low-flow conditions during fall 2008 in publicly accessible study reaches and in privately owned reaches where stream access permission was obtained. Access to privately owned reaches was solicited via postcard mailings to stream-side residents as well as at the fall 2008 public workshop and on the project website, where property owners could fill out a web-based permission form. Privately owned reaches where access permission was not obtained were not fully evaluated in the field. In some cases it was only possible to evaluate a small section or single property within a study reach; in these cases the field evaluation was considered "partial" (Table 2.1), and only qualitative field data and photographs were collected. In some cases access permission was not obtained until after the second or third public workshop, and partial evaluations of those properties were completed during spring 2009. Study reach URB_R10 was also not evaluated fully because it consists of a sequence of landscaped ponds within the formal garden portion of Red Butte Garden, where standard types of stream measurements (cross section survey, pebble count, etc.) are not applicable.

A standard Stream Assessment Data Form (Appendix A) was created to document observations and record data. In reaches that received full field evaluations, this form was completed after walking the entire study reach. Additional site-specific field observations were collected by recording a point feature using a GPS device and data logger, and photographs of the GPS points were taken for reference. Notes were also created and stored with each GPS point. Spatial accuracy of the GPS data was somewhat limited due to tree canopy and steep bank conditions; it was typically approximately 10 meters.

Within each fully evaluated study reach, one representative riffle was selected as a cross-section

Types of Field Data Collected

Qualitative information on:

- streambed material
- streambank material
- water appearance/clarity
- extent of sediment deposits/bars
- frequency of undercut banks
- accessible flat floodplain surfaces
- amount of in-channel woody debris
- evidence of reach-scale streambed lowering

Presence and condition of:

- bed hardening or grade structures
- exposed pipe crossings (sewer, water, etc.)
- stream-crossing structures (culverts, bridges, etc.)
- in-channel structures (diversions, weirs, etc.)
- artificial bank treatments (rock, concrete, gabions, etc.)
- storm drain outfalls
- access trails
- significant trash areas
- vertical/severely eroding banks
- tributaries/springs/seeps

location for quantitative data collection, and its position was recorded as a GPS point feature. At each selected riffle, the cross-sectional shape of the active channel was surveyed using an engineer's level, survey rod, and measuring tape. A pebble count (Wolman 1954) was also completed to characterize the size of the streambed material. During the pebble count, the number of rocks that were embedded (i.e., surrounded by fine sediment and difficult to pick up) was noted. Local streambed slope was determined by surveying the bed elevation at the nearest riffle upstream and downstream of the cross section and measuring the channel length between the points. Survey and pebble count data were entered into a spreadsheet and plotted to determine wetted width at low flow, local slope, median streambed-material particle size, and percent embeddedness.

During spring 2009 the cross sections were revisited and water surface elevations were surveyed during high-flow conditions. General observations were noted on a field data sheet (Appendix A), and photos were taken to document conditions during spring runoff. High-flow data were overlaid onto the cross-section plots and used to develop a calibrated estimate of wetted width at the AHWL. To determine the streamflow magnitude representative of average annual high water conditions, mean daily flow data collected at Salt Lake County's gage at 1600 East and at the U.S. Geological Survey (USGS) gage in Red Butte Canyon (Figure 2.1) were analyzed. The maximum 1-day flow was determined for each water year, and the average for the analysis period (1981–2005) was calculated to determine the average annual high-flow value for Red Butte Creek.

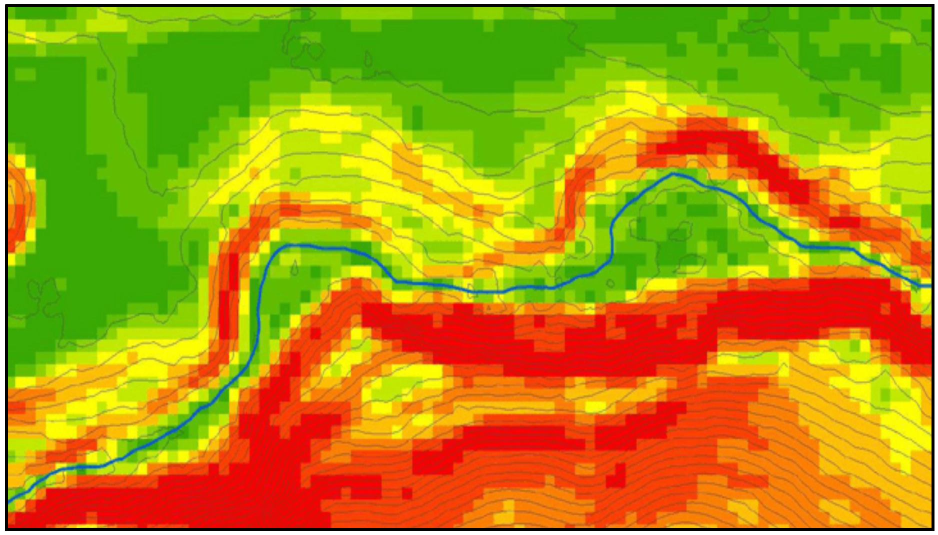


Figure 2.2. Using digital elevation data to draw the channel centerline.

Analyses Using Digital Data

To compliment the data collected in the field, several additional analyses were completed using 2006 LIDAR-based digital-elevation grid data (2-meter resolution) obtained from the City. Using slope and contour maps generated with ArcMap software to identify the low point of the channel, a new channel centerline alignment was digitized for the study area (Figure 2.2). Relative to previously available GIS stream-channel shapefiles, this new centerline file more closely follows the bends of the stream and provides more accurate information on total channel length. The digital contour maps were also used to identify more precise inlet and outlet locations of road-crossing culverts and update an existing "culverts" shapefile obtained from the County. Using the profile tool in ArcMap, a longitudinal profile of the channel centerline was extracted and plotted for each reach to determine total reach length and reach-averaged streambed slope. Culvert lengths were also determined, and a comprehensive longitudinal profile plot of the full study area was generated by combining the reach profile and culvert length data. The updated culvert shapefile was also attributed with data measured in the field (pipe diameter, outlet scour depth).

The channel cross sections surveyed in the field included the active channel and bank areas within and immediately beyond the AHWL; however, in most reaches, the stream is deeply entrenched below the surrounding terrain and it was not practical to field survey the entire upper portions of the slopes. Therefore, these upper-slope sections were extrapolated using the digital-elevation grid data. At each cross-section location in ArcMap, the profile tool was used to draw a line section (typically about 100 feet long) perpendicular to the channel and spanning its entire inset width. Because the accuracy of the GPS-based cross-section position data is only about 10 meters, the expanded portions of the cross-section plots may represent conditions slightly upstream or downstream of the actual field-surveyed cross section and, therefore, should be used only as a general indication of the overall shape and degree of entrenchment within a given steam reach.

Information Recorded on the Vegetation Data Form:

- species composition of canopy, shrub, and understory layers
- relative amount of woody debris on banks/ floodplain
- invasive species presence/dominance
- evidence of active recruitment of riparian willows/cottonwoods
- notes/issues affecting vegetation quality

To assess the degree to which developed infrastructure is currently present within the riparian corridor, buffer coverages were generated in ArcMap extending 50 feet and 100 feet to each side of the approximate AHWL location. The buffer lines were overlaid onto the aerial imagery, and the extent of infrastructure in each study reach was visually classified for both the right and left (facing downstream) sides of the channel. The infrastructure categories used were none, low (less than one third of the area developed), moderate (one to two-thirds developed), and high (more than two thirds developed). Infrastructure was considered to include buildings, parking lots, and roads; sidewalks and unpaved trails were not considered developed infrastructure for this analysis. The approximate AHWL location was determined by calculating the study area average of the estimated "wetted width at AHWL" values determined for each cross section and adding the average width value to the digitized channel centerline prior to generating the buffer. This approach is intended simply to provide a consistent way to assess the relative degree of development throughout the study area, not to create an accurate comprehensive map of the AHWL. The wetted width and location of the AHWL varies substantially within each reach, can change with time, and needs to be determined on a locally site-specific basis to be accurate. Such an effort is beyond the scope of this current study.

Vegetation Assessment

The objective of the vegetation assessment work on Red Butte Creek is to evaluate the lateral extent, species composition, structure, and general health of associated riparian vegetation communities found along the creek. As part of their channel-stability monitoring work, the County characterizes the overall riparian vegetation density and extent for each stream reach; however, no species-specific data are collected. Therefore, a focus of the RCS was to collect more detailed information on dominant vegetation species within the riparian corridor, including invasive species. The data collected through the vegetation assessment provide information on how well the riparian functions of shading, habitat, organic matter inputs, filtration, and stability are being met within the Red Butte Creek corridor.

Field Mapping

Riparian vegetation communities were delineated in the field on base maps (1 inch = 100 feet scale) prepared with available aerial imagery (1-foot resolution 2006 color orthophotography). Boundaries delineating individual vegetation polygons were placed where obvious demarcations between communities were found. Polygon boundaries did not necessarily match established stream reach boundaries. In some cases a single vegetation polygon spanned multiple stream reaches; in other cases a single stream reach contained multiple vegetation polygons. Vegetation mapping was completed in October 2008 with the exception of reach URB_R09, which was mapped in May 2009.

Information about each mapped polygon was recorded on a Riparian Vegetation Mapping Data Form developed for this study (Appendix A). To evaluate overall structural quality of the vegetation, overall percent cover was classified for canopy (plants >15 feet tall), shrub (plants 3–15 feet tall) and understory (plants < 3 feet tall) layers. This classification used the following coverage ranges: 0, 1–5%, 6–25%, 26–50%, 51–75%, and 76–100%+.

Vegetation Community Classifications

For each field-mapped vegetation polygon, species composition was recorded for all species that comprised 20% or more of the vegetation community. Species composition was recorded separately for each of the structural layers (canopy, shrub, understory). Each polygon was then classified as a specific vegetation community type based on the National Vegetation Classification for Utah, which is based on the National Vegetation Classification Standard and the Standardized National Vegetation Classification System (SNVCS) (USDI 1994). Communities were characterized to the association level. Associations are often named for the dominant canopy or tallest species and the dominant species in the ground layer or shrub layer. In many single-layer communities either a single species is used in the name or co-dominant species may be used in the name.

Environmental features are sometimes used in the name of associations where the feature provides information that the dominant species alone would not. The physiognomic type is also often used in the name of associations.

Detailed descriptions of associations are found in the NatureServe Database (NatureServe 2008), which is the depository of vegetation community information for most

Examples of Vegetation Community Associations:

- Box Elder Forest
- Gambel Oak Forest
- Box Elder - Eastern Cottonwood / Redosier Dogwood Forest

state and national agencies and organizations, and follows the SNVCS. These attributions to an association were based on the collected species composition data and environmental characteristics of each mapped polygon.

Data Analysis

Field-mapped polygons were digitized into a GIS shapefile using ArcMap and attributed with dominant species cover and other data recorded on the Riparian Vegetation Mapping Data Form, as well as assigned a vegetation community association. Polygons were also assigned an invasive species classification based on the combined mapped percent cover of species identified as weeds on the Utah Department of Agriculture's noxious weed list (UDAF 2008) and the Salt Lake City Watershed Division (V. Welsh 2009, pers. comm.) weed list. Introduced or ornamental species that have naturalized within the study area and are exhibiting invasive characteristics (e.g., self perpetuation, overtaking/dominating native vegetation communities) were also included when determining the invasive species classification. Invasive classification categories (Dewey and Andersen 2004) included none, low (1–5% cover), moderate (6–25% cover), high (26–50% cover), and majority (51–100% cover).

Watershed and Historical Information

The data collection effort for this study focused on gathering information on physical stream-channel conditions and riparian-vegetation characteristics. Detailed collection or analysis of data on water quality, hydrology, water rights, macroinvertebrates, or use of the corridor by wildlife was not the primary purpose of this study, although these items are all important aspects of riparian corridor condition. General information on these resources was summarized from available existing reports. Summaries of overall watershed condition were also prepared from information included in the recently completed Salt Lake Countywide Water Quality Stewardship Plan (SLCO 2009; available at www.waterresources.slco.org/html/wtrQualSteward/WaQSP_Final.html). Supplemental information was obtained through discussions with City, County, and state agency staff as well as RCS

Subcommittee members and public workshop attendees. Geologic information (Bryant 1990) was also reviewed to develop an understanding of the geologic setting affecting the different study reaches.

To obtain a better understanding of the Red Butte Creek corridor historic conditions, land use patterns, and channel changes through time, various sources of historical information were researched. The University of Utah Marriot Library, Utah State Historical Society, Daughters of Utah Pioneers, Sons of Utah Pioneers, and U.S. Geologic Survey offices were visited to review available historic photos, maps, aerial imagery, and journal accounts describing riparian corridor conditions. Historic newspaper articles mentioning the creek were also researched. More recent information regarding alterations to the creek was obtained through discussions with City, County, and state agency staff, and corridor residents, and by reviewing permit documents available at the County Flood Control office and through the Utah State Stream Alteration permit database (UDWRT 2009).

3.0 BASELINE ASSESSMENT RESULTS

Watershed Conditions

Size and Land Use

Red Butte Creek is located between City Creek to the north and Emigration Creek to the south (Figure 3.1). The upper subwatershed, located above the University of Utah, drains 5,403 acres of mountainous land primarily owned and managed by the U.S. Forest Service (USFS). Nearly 80% of the stream through the upper subwatershed is adjacent to public land. Public access is limited, though, as much of the area is managed as a Research Natural Area with a focus on study and research of the relatively pristine natural forest and riparian habitats (SLCO 2009). The estimated impervious cover of the upper subwatershed is 9.1%.

From its headwaters at an elevation of about 8,200 feet, the stream flows through a relatively wide canyon for just over 4 miles before it enters Red Butte Reservoir. This approximately

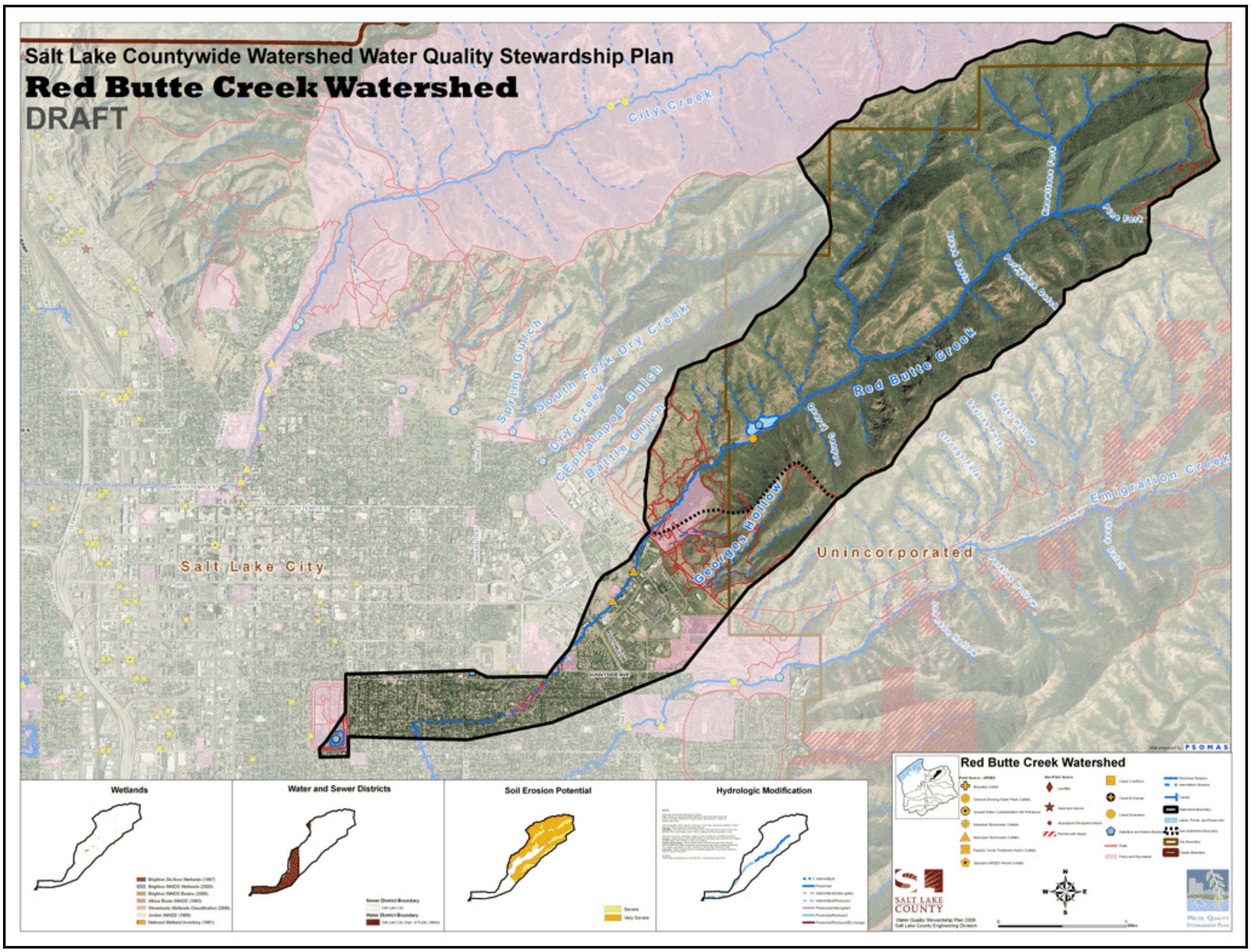


Figure 3.1. Red Butte Creek watershed. (Map from SLCO 2009).

400-acre-foot reservoir was originally constructed in 1930 by the U.S. Army, and in 2003–2004 ownership and management of the dam and reservoir transferred to the Central Utah Water Conservancy District (Billman et al. 2006). The reservoir is currently managed to maintain a generally constant reservoir elevation; during the early springtime, however, the reservoir is typically lowered to provide some flood storage capacity during the snowmelt runoff period (J. Crofts 2009, pers. comm.). During the nonrunoff portion of the year, reservoir inflows and outflows are typically similar. Reservoir management focuses on maintaining habitat quality for the refuge population of endangered June sucker (*Chasmistes liorus*) that currently inhabit the reservoir (Billman et al. 2006).

The lower Red Butte Creek subwatershed is much smaller, draining 1,652 acres from the mouth of Red Butte Canyon downstream 2.7 miles to a point just west of 1100 East (SLCO 2009). The creek flows through the University of Utah campus and research park, the Veteran's Affairs (VA) Medical Center complex, Sunnyside Park, and then though primarily residential neighborhoods. The open-channel portion of Red Butte Creek terminates in the 1300 South conduit, which conveys the creek to the Jordan River via a 3.4-mile-long pipe. Red Butte Creek has the most highly urbanized lower subwatershed of the four streams included in the RCS, with impervious cover estimated at 31.9%.

Hydrology

Because of natural alluvial deposition patterns, Wasatch mountain streams—including Red Butte Creek—naturally lose some surfaceflow to groundwater where the canyons transition to the valley. Within most of the RCS study area, Red Butte Creek flows through areas mapped as primary and secondary groundwater recharge zones, and studies have estimated losses to groundwater to be around 0.2 cubic feet per second (cfs) in summer and fall and up to 2.3 cfs during spring (SLCO 2009). In its lower reaches below 1600 East, Red Butte Creek gains flow from various springs that discharge along the streambanks.

Urbanization and development throughout the watershed have altered surface water-groundwater patterns. As more of the watershed has been converted to impervious surfaces, a greater proportion of storm water runs off as surfaceflow rather than infiltrating into the ground, leaving less groundwater available to supply baseflow to the creek during the summer dry period (Figure 3.2). Red Butte Creek is classified as having

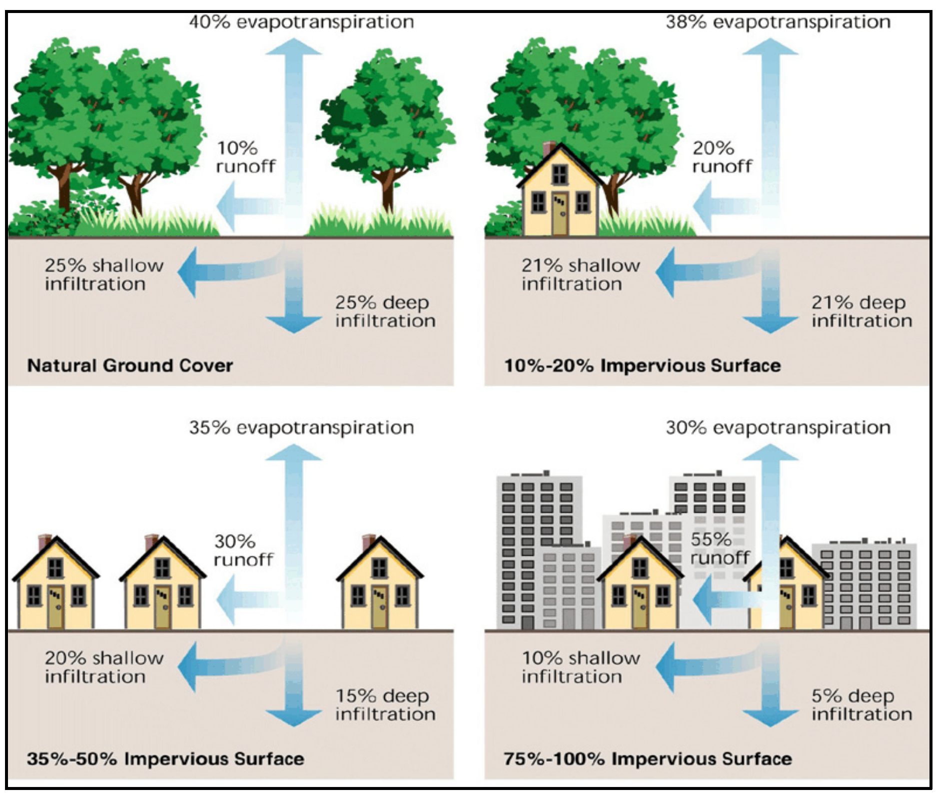


Figure 3.2. Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. (Diagram and caption text from FISRWG 1998).

perennial flow upstream of Red Butte Reservoir and is considered to have “perennial-reduced” flow below that point, indicating that flows are artificially reduced by stream diversions (SLCO 2009). At the RCS public workshops, residents of the lower portions of the creek indicated concerns over summertime reduced flows apparently associated with diversion operations.

Within the study area, recorded points of diversion include a structure near the middle of reach LRB_R05C (a 3.8-cfs water right) and several small springs on residential properties between 1100 East and 1500 East (UDWRT 2010). During baseline assessment field work, diversion headgates were also observed at the downstream end of reach LRB_R05B.

Red Butte Creek’s hydrology is characterized by a distinct springtime peak typical of snowmelt-driven systems. Based on analysis of flow data recorded at the County gage near 1600 East from 1984–2005, average monthly flow is highest in May (Figure 3.3), and peak daily flow occurs on April 30 on average (SLCO 2009). Average annual high flow is 22 cfs while typical base flows are approximately 2 cfs. Field observations during storm events suggest that flows in the lower reaches of the creek are quite “flashy” with rapid, brief rises in flow during storms. This is a common hydrologic pattern in urbanized systems (Figure 3.4). An example of this storm flow response can be seen in Figure 3.5, which plots the flows recorded at the USGS gage above Red Butte Reservoir and at the County gage near 1600 East during a rain event in April 2009. Analysis of flow records at the two gages provides further evidence of the flashy hydrology at the urbanized lower gage site,

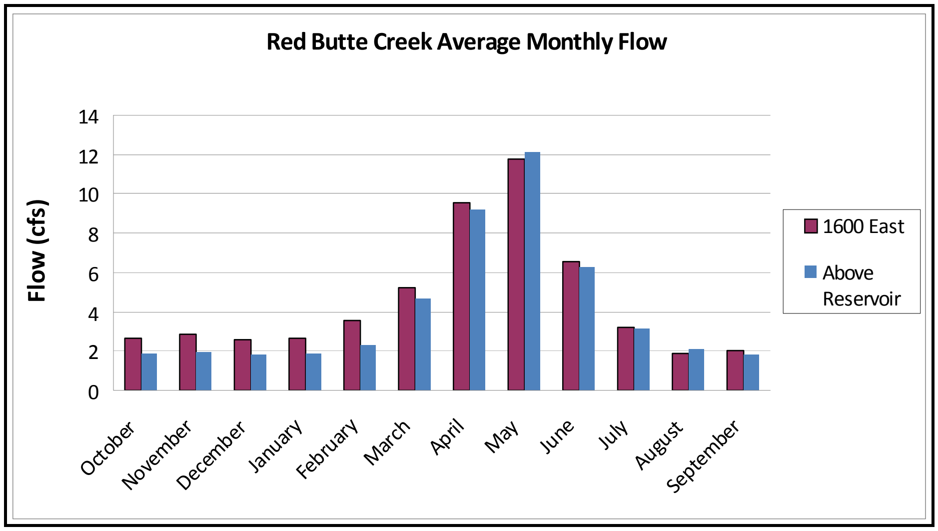


Figure 3.3. Monthly flows at Salt Lake County’s gage at 1600 East and the U.S. Geological Survey gage above Red Butte Reservoir.

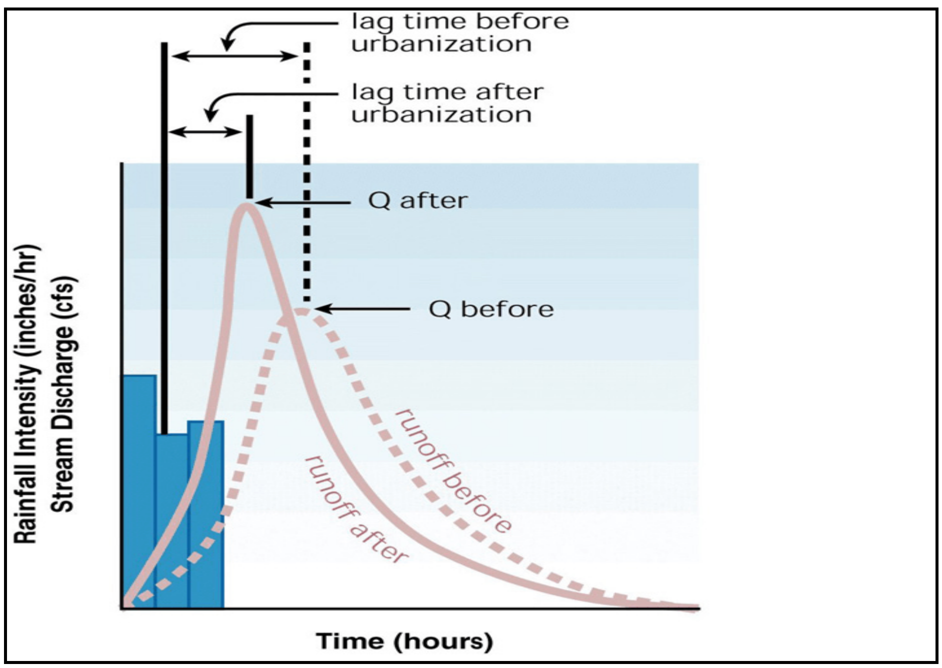


Figure 3.4. A comparison of hydrographs before and after urbanization. The discharge curve is higher and steeper for urban streams than for natural streams. (Diagram and caption text from FISRWG 1998).

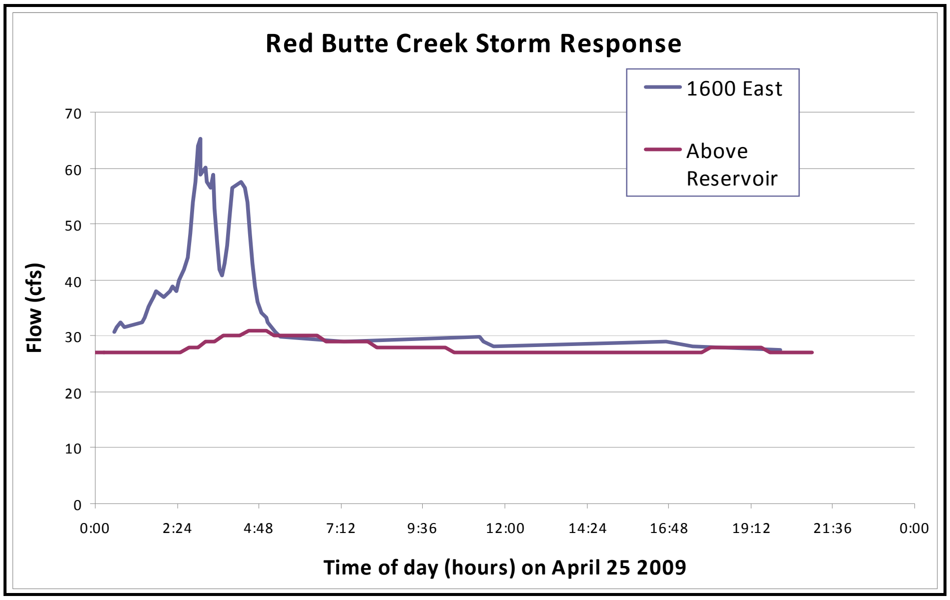


Figure 3.5. Streamflow response to April 25 storm event (0.5 inch of rain between midnight and 3:30 AM) at the gages above the reservoir and 1600 East. At the 1600 East gage, which drains the urbanized lower subwatershed (31.9% impervious cover), flows increased by 30 cubic feet per second (cfs) in response to the rain event while flows in the upper subwatershed (9.1% impervious cover) only increased by 4 cfs.

which has rise and fall rates about five times greater than the undeveloped upper gage site.

As discussed above, Red Butte Reservoir is managed to provide some degree of flood storage (J. Crofts 2009, pers. comm.). However, analysis of flow data indicates that the magnitude and timing of annual peak flows is similar above and below the reservoir and the dam influence on flood hydrology is relatively minor. The potentially more significant dam effect is on downstream sediment supply, as all bedload is trapped in the reservoir and only a portion of the suspended load is conveyed downstream.

Water Quality

Designated beneficial uses of upper Red Butte Creek above the reservoir are 1C (high-quality drinking water), 2B (secondary contact recreation, and 3A (cold-water fishery). Below the reservoir the creek is designated with the default classifications of 2B and 3D (waterfowl/shorebird protection). Red Butte Creek is currently assessed as meeting its designated beneficial use classifications (DWQ 2006). As part of its standard water quality monitoring program, the Utah Division of Water Quality (DWQ) collects water quality data at three monitoring stations in upper Red Butte Creek above the reservoir (STORET numbers 4992100, 4992110, and 4992120) and at one station below the reservoir at the USFS boundary (STORET number 4992090; EPA 2009). During spring and summer 2009, additional E. coli sampling was also conducted by the DWQ at the station at the USFS boundary as part of an on-going bacteriological sampling effort. The County also collects macroinvertebrate (aquatic insect) data on Red Butte Creek as part of its Stream Function Index data collection program (SLCO 2009).

No established DWQ water quality monitoring stations are present on lower Red Butte Creek within the RCS study area. However, data have been collected for several years at a station on the 1300 South conduit (STORET 4992070). Water in the conduit originates from Emigration, Parleys, and Red Butte Creeks, so the data collected at this monitoring station provide an indication of water quality conditions and storm water effects within the lower, urbanized portions of these creeks. Potential nonpoint source pollution contributors within lower Red Butte Creek include urban runoff, active construction sites, and managed parks and campus areas.

Geology and Soils

The surficial geology of the upper Red Butte Creek subwatershed is composed of various members of the Triassic Ankareh formation, as well as Jurassic/Triassic Nugget Sandstone (Bryant 1990). Approximately 50–86.2% of the soils in the upper subwatershed have severe to very severe erosion potential. Once it exits the canyon, Red Butte Creek flows through alluvial and debris fan deposits and a series of Pleistocene Lake Bonneville deposits. These deposits range in size from finer-grained silt and clay deposits to coarser sand and gravel deposits. In the lower subwatershed, 20–35% of the soils have severe to very severe erosion potential (SLCO 2009).

After Lake Bonneville receded approximately 16,000 years ago, it left a series of old shoreline deposits that now form prominent "benches" along the edges of Salt Lake Valley. To reach its modern base level at the Jordan River, Red Butte Creek had to carve through these deposits. In part because of this natural geologic history, stream gradient is relatively steep and the creek is entrenched between tall slopes that extend up to the Bonneville bench levels. Various human-caused alterations to the creek—including channel straightening, installation of road crossing culverts, fill placement, and bank hardening—have further contributed to the steep grade and entrenched shape of the channel.

Fish, Birds, and Wildlife

Quantitative data on fish and wildlife populations within the urban portion of Red Butte Creek are limited. A managed population of native Bonneville cutthroat trout (*Oncorhynchus clarki utah*) exists in the creek above the Red Butte Reservoir (Billman et al. 2006). Lower Red Butte Creek is not reported in agency publications as supporting a fishery (SLCO 2009) but RCS workshop attendees indicated that they have seen fish in the creek within the RCS study area, perhaps from private landowners stocking small numbers of trout for fishing.

Deer were observed in the Sunnyside Park area during RCS field assessment work. During the Audubon Society's 2005 Christmas bird count, a total of 30 different bird species were observed within the University of Utah survey area, which includes portions of the Red Butte Creek riparian corridor (Carr 2009). At the RCS public workshops, residents reported regularly seeing nuisance wildlife species including racoons and skunks. Reach LRB_R07, which includes the Miller Bird Refuge and Bonneville Glen park areas, is a recommended site for recreational birding within the County.

Historical Conditions and Current Trends

Red Butte Creek History

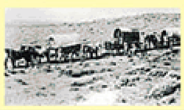
Red Butte Creek played an important role in the initial settlement and development of Salt Lake City by the Mormon pioneers who entered the valley in 1847. The creek was tapped for water supply for homes and orchards built in the early 1850s. The pioneers also quarried sandstone and some limestone from the canyon, building a quarry access road in 1848 (Ehleringer et al. 1992). Some minor logging and grazing activity also took place during the initial settlement period.

When Fort Douglas was established by the U.S. Army in 1862, conflicts arose with Salt Lake City over the use and quality of the Red Butte Creek water supply (Figure 3.6). The upper Red Butte Creek watershed has been under Federal ownership and protection since about 1900, and today functions as a USFS Research Natural Area (Red Butte Canyon RNA 2009). Because of this history of protection, the upper watershed remains in a relatively pristine condition.

Early descriptions of the stream and its riparian corridor are limited. One account describes abundant green grass growing along the creek (LDS CHO 1990). Publications suggest the stream historically supported a Bonneville cutthroat trout fishery that provided a food supply to the pioneers (Billman et al. 2006). One pioneer account describes a broad, grassy marsh area at the confluence of Parleys, Emigration, and Red Butte creeks

1847

Portions of Red Butte Canyon were logged and sandstone was mined by pioneers that had just arrived in Salt Lake Valley. Bonneville cutthroat trout likely inhabited Red Butte Creek when the Salt Lake Valley was settled and settlers used the fish for food.[1]



1853

"Red Butte Creek was an early water supply for the Mormon Pioneers. On July 9, 1853, the City Council passed an ordinance creating the office of Water Master. The duties consisted of overseeing the construction and repair of gates, locks and sluices as necessary to admit into the City the water from City Creek, Red Butte and Emigration Canyons and to divide the water throughout the City to best serve the public interest for irrigation, domestic and other purposes."

-Red Butte Canyon Research Natural Area Website[2]

1862-90

On-going court battles between Salt Lake City and the U.S. Army over water use and water quality of Red Butte Creek. Ultimately, the majority of water rights went to the U.S. Army and Fort Douglas.[2]

1863

"On October 26, 1862, Fort Douglas was established by a garrison of volunteer troops under the command of Colonel Conner. These troops used the waters of Red Butte Creek for domestic and irrigation purposes. The Army constructed ditches and a reservoir to supply its domestic needs and irrigation of gardens and grounds. The diversions of water by the garrison affected 3,000 Salt Lake City residents located in the First and Fourth Municipal Wards who used Red Butte Creek as their water supply.

1930-85

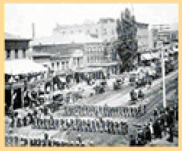
Member of the University of Utah botany department and co-founder of The Nature Conservancy, Dr. Walter P. Cottam, began conducting botanical research on campus land. The state legislature recognized Cottam's work and designated the campus landscape as a Utah State arboretum. The university later dedicated 100 acres at the mouth of Red Butte Canyon as a regional botanical garden, and the community raised funds to change the name from State Arboretum to Red Butte Garden and Arboretum.

1983-87

Red Butte Creek and Reservoir were treated with a fish toxicant prior to stocking Bonneville cutthroat trout. Major flooding also occurred during this time, destroying beaver dams in Red Butte Canyon and affecting creek-side city residents.[1]

Figure 3.6. Red Butte Creek historical timeline.

The following spring a Grand Jury presented to the United States District Court for the Third Judicial District of Utah Territory a statement of fact that the watercourse or stream called Red Butte was conducted into the City for the use of its inhabitants and 3,000 citizens depend entirely upon this water for irrigation, culinary, and drinking purposes.

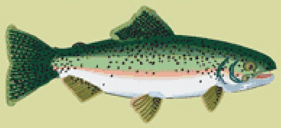


That on or about October 20, 1862 the California Volunteers established a military encampment and built stables, yards, corrals and diverted the water from its channel through the yards built for their animals and have built privies on or near the stream and thus polluted the water so badly that the 3,000 citizens downstream could not use it for any purpose including irrigation since it was filthy. (The first and fourth municipal wards included the area between Third and Thirteenth East, and South Temple to Ninth South Street)"
- Red Butte Canyon Research Natural Area Website

2

1930

Red Butte Dam is erected through a joint effort by the Army and Salt Lake City.[1]

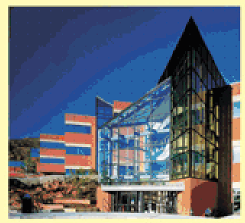


1947

The military created a recreational fishery for its personnel on Red Butte Reservoir and the U.S. Fish and Wildlife Service began stocking the reservoir and stream.[1]

1968-70

The several thousand-acre Red Butte watershed was transferred to the Forest Service, and the University of Utah was granted the area now occupied by Research Park.[3]



FOOTNOTES

1 Billman et al. 2006
2 http://redbuttecanyon.net/protectedwatershed.html 2009
3 http://web.utah.edu/facilities/fd/history/history.html 2009
4 http://www.redbuttegarden.org/about-us/mission%2526history 2009
5 CUWCD et al. 2005

EEK HISTORY

1991-93

Fort Douglas closes and lands are transferred to the Utah National Guard, U.S. Army reserve units, and the University of Utah.[4]

1992

June sucker, an endangered fish native to Utah Lake, stocked into Red Butte Reservoir.[5]

1998

U.S. Army abandons active management of Red Butte Dam.[2]

2004

Ownership and management of the reservoir transferred to the Central Utah Water Conservancy District.[5]

2005

Reservoir drained for dam improvement work and to control illegally introduced exotic crayfish.[2]

Historical activities that have altered riparian corridor conditions:

- mining and quarrying for sandstone
- beaver trapping and removal
- channel clearing and debris removal
- flow diversion for irrigation and drinking water
- development and piping of springs
- road and stream crossing construction
- residential and commercial development
- introduction of invasive, nonnative plants
- piping of the creek in underground conduits
- channel relocation/ straightening
- bank armoring
- placement of fill within floodplain areas
- construction and management of Red Butte Dam and Reservoir
- development and operation of Fort Douglas

that made wagon travel challenging (Dixon 1997). Modern descriptions of the protected upper reaches of Red Butte Creek, above the RCS study area, suggest that the presence or absence of beaver dams plays a highly significant role in the condition of the channel and its riparian area. Prior to the 1983 spring flood, numerous beaver dams were present in the upper portions of Red Butte Creek. The frequent "checks" on flow velocity provided by the beaver dams created pool and run habitats surrounded by diverse, marshy riparian vegetation. These habitats were greatly reduced when the beaver dams were washed out by the 1983 flood (Ehleringer et al. 1992). Considerable slope slumping, streambed erosion, and gully formation also occurred during the flood.

Alterations to the Riparian Corridor

Over the last 160 years, the various activities associated with development and population growth in Salt Lake Valley have resulted in significant alterations to the stream channel and riparian conditions of lower Red Butte Creek. Among other factors, systematic programs to remove beaver populations have likely contributed to the currently reduced vegetation density relative to historical conditions. When beaver were more common, their dams increased inundated streamside habitat area, elevated the water table, reduced flood velocities and erosion, and trapped sediment and nutrients (Gardner et al. 1999).

As beaver populations were reduced, the "checks" on sediment and water created by beaver dams also decreased, resulting in greater flow velocities and streambed down-cutting (Wohl 2000). Beaver populations flourished in Red Butte Canyon (above the RCS study area) from 1928 until 1982, when they were removed by the U.S. Army over concerns about bacteriological contamination of the water supply to Fort Douglas. The absence of live beaver populations prior to, during, and immediately following the 1983 flood contributed to erosion damage caused by the flood. Beaver populations appear to be currently absent within the RCS study area.

Many of the direct alterations to lower Red Butte Creek have occurred in order to address flooding concerns and accommodate urban development and population growth. One of the most significant direct changes to the creek was the construction of the 1300 South conduit, which converted the western open-channel portions of Emigration, Red Butte, and Parleys Creeks to an underground pipe system. The exact date of conduit construction is not known but housing stock located over the conduit system dates to the late 1920s, suggesting that construction was complete prior to that time. No creek channel can be seen west of 1100 East in 1938 air photos of Salt Lake City (Bowman and Beisner 2008).

In general, the channel alignment of Red Butte Creek does not appear to have changed dramatically since 1938. Some relatively minor bend straightening is evident in portions of the channel within the areas that are now Bonneville Glen and Sunnyside Park (Figures 3.7 and 3.8). Another significant change since 1938 has been an increase in length and number of culvert pipes. Near 1500 East, approximately 300 feet of what used to be open stream channel (Bowman and Beisner 2008) is now piped under a parking lot (Figure 3.7). Similarly, just downstream from Foothill Drive, approximately 130 feet of what was once forested stream channel is now piped under a road crossing (Figure 3.8). The construction of culvert crossings and the piping of portions of Red Butte Creek facilitated urban growth but also reduced total channel length, resulting in greater channel slope and higher stream velocities. The culverts have also disrupted the connectivity of the riparian corridor by creating barriers to fish and wildlife migration.

In some residential areas along the creek, it appears that tree canopy density has increased

Figure 3.7. 1938 aerial photograph of Red Butte Creek from 900 South to 1500 East. Photograph is overlaid with 2006 channel alignment in red; gaps in line indicate underground culverts.

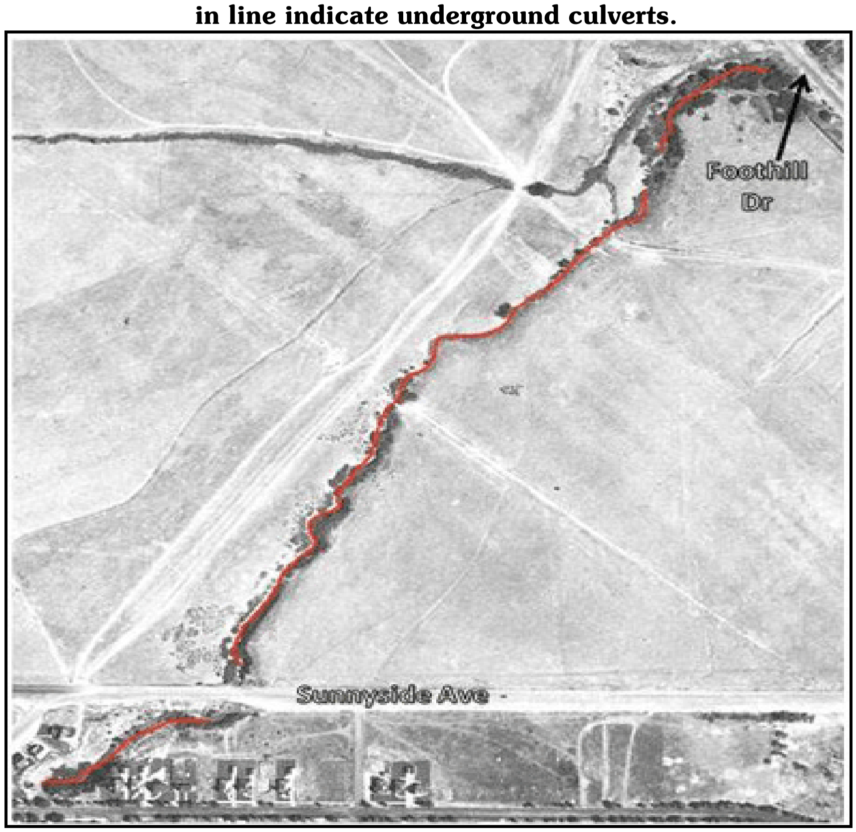


Figure 3.8. 1938 aerial photograph of Red Butte Creek from Foothill Drive to Sunnyside Avenue. Photograph is overlaid with 2006 channel alignment in red; gaps in line indicate underground culverts.

since 1938. This is most likely the result of landscaping and tree planting as dense residential neighborhoods were built along the creek. Much of the residential development within the RCS study area is estimated to have occurred between 1915 and 1940. This development primarily affected areas downstream from Sunnyside Avenue (Figure 2.1). A second phase of urbanization within the areas upstream of Sunnyside Avenue began around 1970.

This second phase involved development of the VA Medical Center complex and University of Utah research park facilities. Building expansion work and new construction projects continue in these areas today.

Urban Channel Adjustments

Urbanized streams have been found to undergo a sequence of typical channel adjustments in response to changes in hydrology and sediment supply (Wolman 1967, Riley 1998, and Colosimo and Wilcock 2007). Studies of urban channel adjustment generally identify two main stages of adjustment: an early depositional phase and a later, fully urbanized phase. The early phase occurs during initial development when active construction leads to increased fine sediment supply, increased bar deposits, and reduced channel size. The late/fully urbanized phase occurs after construction activities are essentially complete and the watershed has become stable with a high percentage of impervious surface area and runoff magnitudes and volumes have correspondingly increased. Channels in the "late urbanized" phase are typically enlarged relative to their original form due to an oversupply of water relative to sediment supply. These channels have few bar deposits and are commonly down-cut (incised) with reduced floodplain access (Figure 3.9). Many of the reaches of Red Butte Creek that we assessed exhibit characteristics of the "late urbanized" phase, such as evidence of down-cutting and low bank erosion/root scour.

Other influences such as localized sediment inputs from eroding storm drain outfalls or sediment deposition near culvert inlets modify conditions from this generalized "late urbanized" channel condition. Existing channel conditions within the Red Butte Creek corridor reflect a complex response to a variety of historical and on-going alterations throughout the makes it difficult to distinguish whether channel lowering and

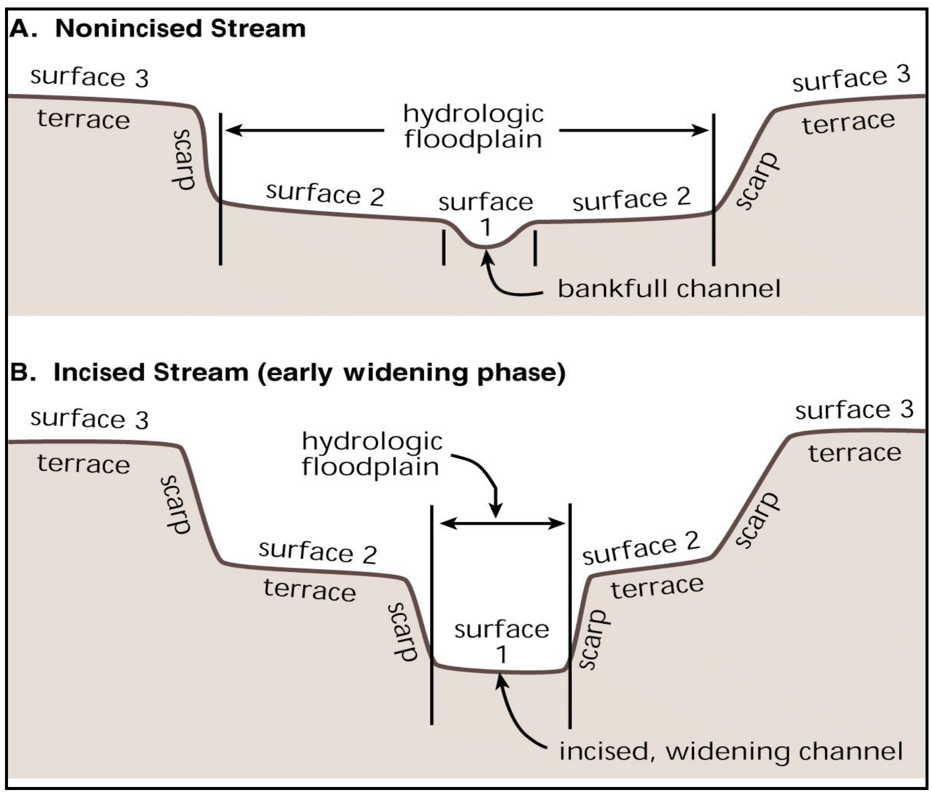


Figure 3.9. Illustration of streambed lowering (incision) process common on urbanized streams. Following initial incision (B), the channel may continue to incise and widen until a new equilibrium channel/floodplain geometry is reached, posing a potential risk to urban development on terrace surfaces adjacent to the channel (Diagram from FISRWG 1998).

watershed. This complexity bank erosion observed in a specific location are due to a corridor-scale streambed lowering trend, a localized culvert or bank treatment effect, or combination of several factors.

Recent and Anticipated Future Trends

Anticipated future land use changes are minimal within the upper Red Butte Creek subwatershed. Within the lower subwatershed, additional development is primarily anticipated to occur within the areas occupied by the University of Utah's research park and the VA complex. The impervious cover of the lower subwatershed is expected to increase significantly by 2030, to a total impervious cover value of 43.8% (SLCO 2009).

Climate change is another factor that can be anticipated to affect the Red Butte Creek riparian corridor. Climate projections for the southwestern region of the United States show increased temperatures, reduced mountain snowpack, a 10–20% decrease in annual runoff volume, reduced springtime precipitation amounts, and anticipated water supply shortages (Karl et al. 2009). The risk of drought, as well as the risk of flooding, is also expected to increase. The changes in temperature will likely result in a shift in vegetation communities, and altered precipitation patterns will influence stream hydrology and channel conditions. The timing of snowmelt runoff is expected to occur earlier in the spring, with a reduction in summertime base flows anticipated (Karl et al. 2009).

Stream and Vegetation Conditions

Stream Channel Characteristics

Salt Lake County has classified the stream reaches within the lower Red Butte Creek subwatershed as entrenched to moderately entrenched, meaning the channel is vertically confined. Over 60% of the channel in the lower subwatershed received a fair to poor stream stability rating during County stream studies; upper subwatershed reaches URB_R09 and URB_R10 both received fair stability ratings (K. Collins 2009, pers. comm.). During field assessments in 2008, the County classified lower Red Butte Creek as Rosgen (1996) stream types A3 and B3 between lower Red Butte Garden and 1500 East (reaches LRB_R01 through LRB_R07), and types A4 and B4 below 1500 East. Stream reaches in the upper subwatershed were assessed in 2007 and the assigned stream type for reaches URB_R09 and URB_R10 was B3 (K. Collins 2009, pers. comm.). County bankfull width estimates for the stream reaches in lower Red Butte Creek ranged from 8 to 20 feet, with an average of 13 feet. Estimates for reaches URB_R09 and URB_R10 were 14 and 15 feet, respectively (K. Collins 2009, pers. comm.).

Results of RCS field surveys and GIS analyses further illustrate the fact that the Red Butte Creek channel is commonly entrenched and typically inset between tall, steep slopes (Figure 3.10). Because of this characteristic, residents along the creek corridor who attended the RCS public workshops often refer to the channel as a "gully" or "ravine." The steep side slopes also make access to the creek challenging in many areas. However, the extent of vertical confinement varies, and in some locations the channel shape is wider (Figure 3.10). These wider areas are important because they allow water to spread out horizontally during flood events, dissipating velocity and reducing erosion potential.

Surveyed channel width values are quite variable, ranging from about 4–11 feet at low flow, with an average value of 8 feet (Table 3.1). High flow surveys were conducted at a streamflow of 19 cfs, which is close to the average annual high flow value of 22 cfs. Width at this high flow value varies from about 6 to 16 feet, with an average of 10 feet. In some reaches, particularly the downstream reaches in older residential neighborhoods, channel width is directly affected by installed bank hardening measures such as grouted rock walls. Channel slope, as determined for each stream reach from digital elevation data,

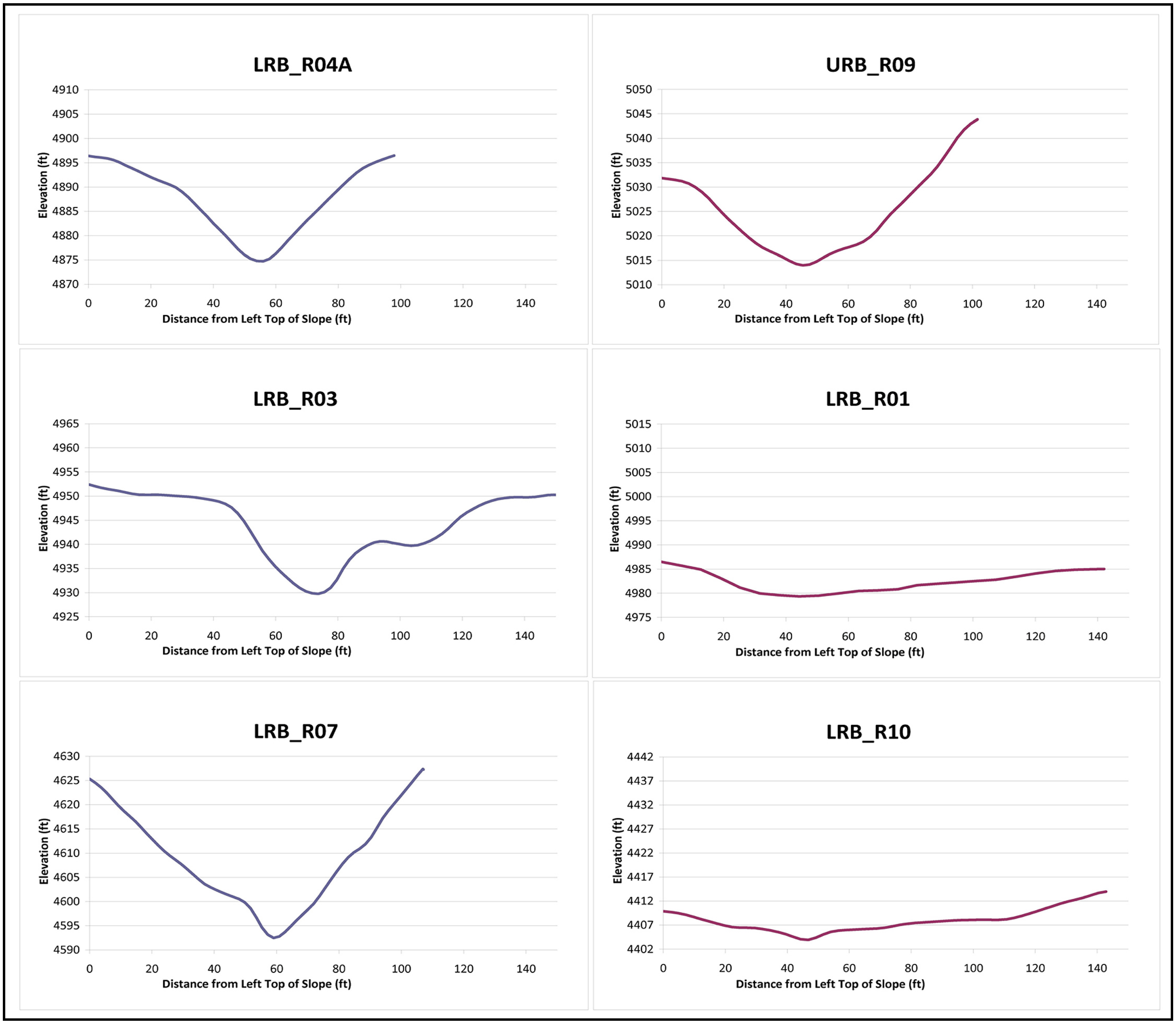


Figure 3.10. **Cross-section plots extrapolated from digital elevation data. Plots on left (in blue) exhibit a high degree of vertical confinement between tall, steep side slopes. Plots on right (in red) exhibit less vertical confinement.**

varies from 3.1–6.7% within the RCS study area with an average value of 4.6% (Figure 3.11, Table 3.1).

Red Butte Creek does not show any consistent spatial trends in gradient through the study area because the valley slope remains steep throughout the study area, which traverses Lake Bonneville bench deposits. The valley becomes significantly flatter west of 1100 East and, historically, Red Butte Creek would have shifted to a flatter, less confined, more sinuous channel type in this area. However, this portion of the creek is now piped underground in the 1300 South conduit.

Median (D50) streambed particle sizes at the measured cross

Table 3.1 Summary of streambed material, channel geometry, and slope data.

REACH NUMBER	MEASURED VALUES AT RIFFLE CROSS SECTION							REACH DATA	
	STREAMBED MATERIAL SIZE DATA				CHANNEL GEOMETRY				
	D16 (mm) [a]	D50 (mm) [a]	D84 (mm) [a]	Percent Embedded	Low Flow Wetted Width (ft) [b]	Wetted Width (ft) [b] at 16 cfs [c]	Local Slope (ft/ft) [d]	Reach Slope (ft/ft) [d]	Reach Length (ft) [b]
URB_R09	12	75	164	25	10.0	10.5	0.036	0.051	2297
URB_R10	-	-	-	-	-	-	-	0.067	827
LRB_R01	6	51	111	9	6.7	16.2	0.023	0.043	281
LRB_R02	<2	12	27	5	7.0	11.3	0.009	0.053	451
LRB_R03	5	30	181	32	10.8	11.1	0.094	0.062	1041
LRB_R04A	<2	23	86	15	4.3	6.0	0.032	0.053	961
LRB_R04B	9	45	95	11	6.3	8.9	0.018	0.040	595
LRB_R04C	3	27	79	16	7.9	8.6	0.048	0.032	1294
LRB_R05A	9	42	104	6	9.9	10.4	0.054	0.055	433
LRB_R05B	12	41	104	4	8.4	10.2	0.042	0.031	1081
LRB_R05C	9	42	134	16	5.8	7.6	0.028	0.037	887
LRB_R06	-	-	-	-	-	-	-	0.046	492
LRB_R07	12	37	111	10	9.4	10.0	0.021	0.036	2084
LRB_R08	-	-	-	-	-	-	-	0.044	1059
LRB_R09	-	-	-	-	-	-	-	0.053	633
LRB_R10	10	32	77	3	5.8	7.4 [e]	0.057	0.041	1449
LRB_R11	-	-	-	-	-	-	-	0.043	301

[a] The 16th, 50th, and 84th percentile values of the particle size distribution, in millimeters.
[b] Feet.
[c] Cubic feet per second.
[d] Feet per feet.
[e] Wetted width at 10.5 cubic feet per second.

sections range from 12–75 millimeters, indicating that medium- and large-sized gravel are the dominant substrate sizes in riffle areas of Red Butte Creek (Table 3.1). At most of the cross-section riffles, fine gravel comprises the D16 particle size and cobble-sized material comprises the D84 particle size (Table 3.1). Embeddedness values are highly variable. In flatter-gradient portions of the channel, such as run and pool areas, particle sizes are smaller with sand and silt often dominant. No consistent upstream-to-downstream trends are evident in the pebble count results; rather, bed material size and embeddedness appear to be largely a function of local factors such as sediment inputs from erosion areas and composition of bank material.

Vegetation Characteristics

Table 3.2 lists all dominant plant species noted on the data forms during the mapping effort for the study area. Species are identified with their common and scientific names, wetland indicator status (USFWS 1988), and whether the species is native to Utah or introduced (NRCS 2009). A total of 41 different species were noted during Red Butte Creek mapping work, with a little more than half of the species being native to Utah. As seen in Table 3.3, most of the nonnative species within the corridor occur

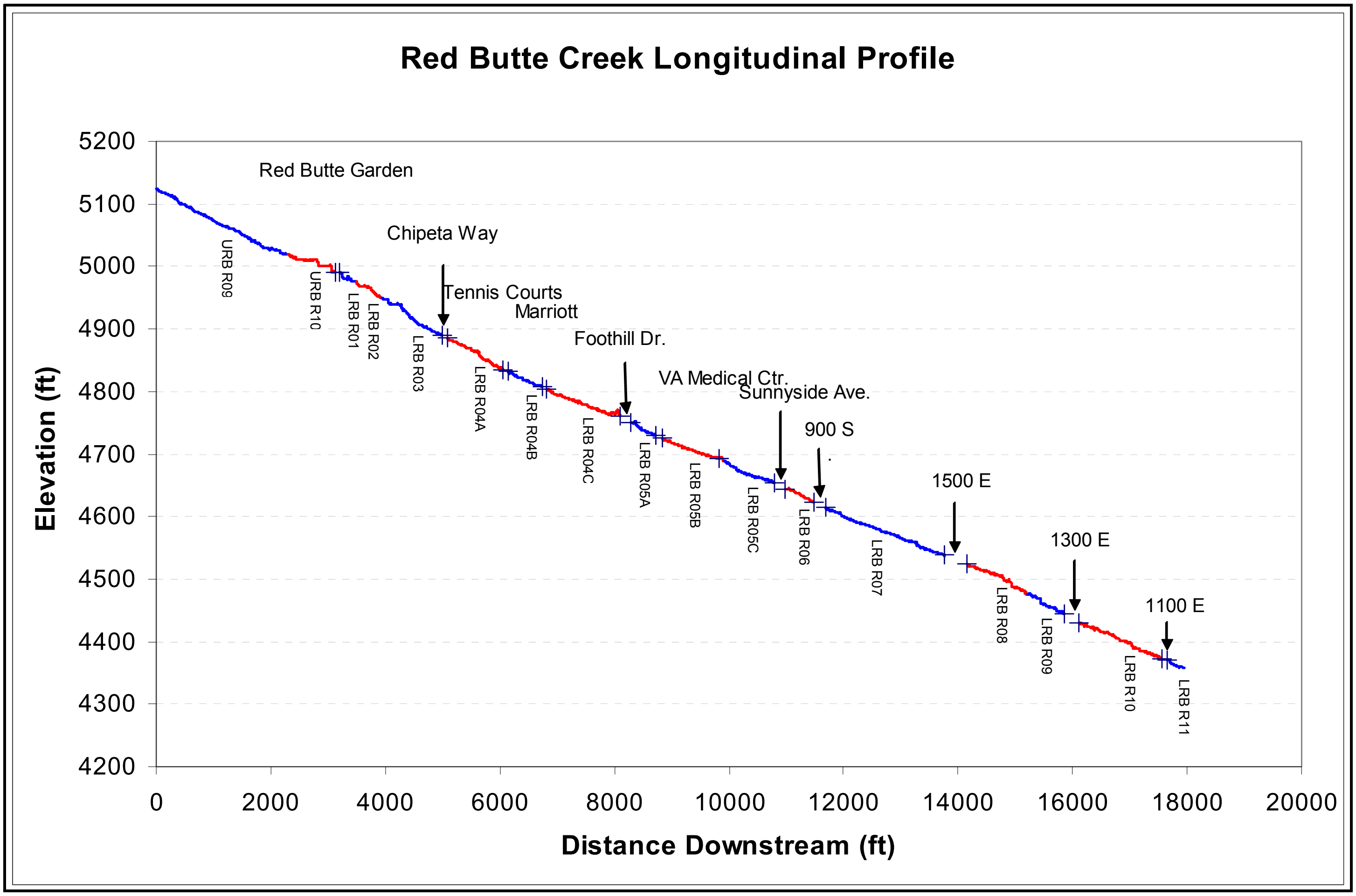


Figure 3.11. Longitudinal profile plot of Red Butte Creek streambed. Black cross marks indicate culvert inlets or outlets; red and blue lines indicate open channel stream sections.

in the canopy and understory vegetation layers while the shrub layer is dominated entirely by native species. The most common trees along the stream-side areas of Red Butte Creek are box elder (*Acer negundo*) and cottonwood (*Populus* sp.), with Gambel oak (*Quercus gambelii*) dominant in undeveloped upper slope areas. Siberian elm (*Ulmus pumila*), an introduced invasive tree species, is fairly common in the study area. Russian olive (*Elaeagnus angustifolia*), also an introduced invasive tree, is present but less prominent (Table 3.3). Common shrub species include redosier dogwood (*Cornus sericea*), twinberry honeysuckle (*Lonicera involucrata*), and narrowleaf willow (*Salix exigua*), with Woods' rose (*Rosa woodsii*) common on upper portions of slopes. The understory vegetation layer includes native species such as Western poison ivy (*Toxicodendron rydbergii*) and Virginia creeper (*Parthenocissus quinquefolia*) in some reaches, with field horsetail (*Equisetum arvense*) present in others. Introduced species such as ornamental English ivy (*Hedra helix*), common periwinkle (*Vinca minor*), climbing nightshade (*Solanum dulcamara*), smooth brome (*Bromus inermis*), and lesser burdock (*Arctium minus*) are significant components of the understory cover in several reaches. In addition, the upper slope portions of some reaches contain the invasive species whitetop (*Cardaria draba*) and houndstongue (*Cynoglossum officinale*) (Table 3.3).

Canopy (tree) cover is generally high throughout the study area,

Table 3.2. Dominant species noted during Red Butte Creek vegetation mapping work.

SCIENTIFIC NAME	COMMON NAME	WETLAND INDICATOR STATUS	NATIVE TO UTAH OR INTRODUCED
Acer grandidentatum	bigtooth maple	no indicator	native
Acer negundo	box elder	facultative wetland	native
Agoseris glauca	pale agoseris	facultative upland	native
Ambrosia artemisiifolia	annual ragweed	facultative upland	native
Arctium minus	lesser burdock	no indicator	introduced
Balsamorhiza macrophylla	cutleaf balsamroot	no indicator	native
Balsamorhiza sagittata	arrowleaf balsamroot	no indicator	native
Betula occidentalis	water birch	facultative wetland	native
Bromus inermis	smooth brome	no indicator	introduced/naturalized
Bromus tectorum	cheatgrass	no indicator	introduced
Cardaria draba	whitetop	no indicator	introduced
Cornus sericea	redosier dogwood	facultative wetland	native
Cynoglossum officinale	gypsyflower (houndstongue)	*not designated*	introduced
Elaeagnus angustifolia	Russian olive	facultative	introduced
Elymus repens	quackgrass	facultative upland	introduced
Equisetum arvense	field horsetail	facultative	native
Fraxinus pennsylvanica	green ash	facultative wetland	native
Gleditsia tricanthos	honeylocust	facultative	native
Hedera helix	English ivy	no indicator	introduced
Juglans nigra	black walnut	*not designated*	native
Lonicera involucrata	twinberry honeysuckle	facultative	native
Maianthemum racemosum	feathery false lily of the valley	no indicator	native
Mahonia repens	creeping barberry	no indicator	native
Maianthemum stellatum	starry false lily of the valley	facultative	native
Melilotus officinalis	yellow sweetclover	facultative upland	introduced
Onopordum acanthium	scotch cottonthistle	no indicator	introduced
Parthenocissus quinquefolia	Virginia creeper	*not designated*	native
Phalaris arundinacea	reed canarygrass	obligate wetland	native
Populus angustifolia	narrowleaf cottonwood	facultative	native
Populus deltoides	eastern cottonwood	facultative wetland	native
Poa pratensis	Kentucky bluegrass	facultative upland	introduced
Prunus virginiana	western chokecherry	facultative upland	native
Quercus gambelii	Gambel oak	obligate upland	native
Rhus trilobata	skunkbush sumac	no indicator	native
Rosa woodsii	Woods' rose	facultative	native
Salix exigua	narrowleaf willow	obligate wetland	native
Solanum dulcamara	climbing nightshade	facultative	introduced
Symphyotrichum ascendens	western aster	no indicator	native
Toxicodendron rydbergii	western poison ivy	facultative upland	native
Ulmus pumila	Siberian elm	no indicator	introduced
Vinca minor	common periwinkle	no indicator	introduced

Table 3.3. List of mapped canopy, shrub, and understory plant species found in each assessed stream reach.

PLANT SPECIES															
	Common Name	Scientific Name	URB_R09	URB_R10	LRB_R01	LRB_R02	LRB_R03	LRB_R04A	LRB_R04B	LRB_R04C	LRB_R05A	LRB_R05B	LRB_R05C	LRB_R06	LRB_R07
CANOPY	Bigtooth maple	*Acer grandidentatum*											X	X	X
	Box elder	*Acer negundo*	X	X	X	X	X	X	X	X	X	X	X	X	X
	Water birch	*Betula occidentalis*	X	X											
	Green ash	*Fraxinus pennsylvanica*										X	X		
	Black walnut	*Juglans nigra*										X		X	
	Narrowleaf cottonwood	*Populus angustifolia*			X		X								X
	Eastern cottonwood	*Populus deltoides*			X			X	X			X	X	X	X
	Gambel oak	*Quercus gambelii*	X			X	X	X	X	X			X		X
	Honeylocust	*Gleditsia tricanthos*											X		X
	Siberian elm [a]	*Ulmus pumila* [a]						X			X	X	X		X
	Russian olive [a]	*Elaeagnus angustifolia* [a]					X					X	X		
SHRUB	Western chokecherry	*Prunus virginiana*	X										X		
	Skunkbush sumac	*Rhus trilobata*											X		
	Redosier dogwood	*Cornus sericea*	X	X	X	X	X	X	X						
	Twinberry honeysuckle	*Lonicera involucrata*	X										X	X	X
	Woods' rose	*Rosa woodsii*	X		X			X	X	X		X		X	X
	Narrowleaf willow	*Salix exigua*			X							X	X		
	Creeping barberry	*Mahonia repens*	X			X	X								
UNDERSTORY	Arrowleaf balsamroot	*Balsamorhiza sagittata*	X												
	Cutleaf balsamroot	*Balsamorhiza macrophylla*	X												
	Field horsetail	*Equisetum arvense*	X									X			
	Feathery false lily of the valley	*Maianthemum racemosum*									X				
	Starry false lily of the valley	*Maianthemum stellatum*	X												
	Virginia creeper	*Parthenocissus quinquefolia*									X	X			
	Kentucky bluegrass	*Poa pratensis*	X										X		
	Climbing nightshade	*Solanum dulcamara*											X		
	Western aster	*Symphyotrichum ascendens*					X								
	Western poison ivy	*Toxicodendron rydbergii*					X	X	X	X					
	Smooth brome [b]	*Bromus inermis* [b]								X			X		
	Lesser burdock [a]	*Arctium minus* [a]	X	X		X	X								
	Whitetop [a]	*Cardaria draba* [a]	X							X			X	X	
	Quackgrass [a]	*Elymus repens* [a]								X					
	Scotch cottonthistle [a]	*Onopordum acanthium* [a]													X
	Gypsyflower (Houndstongue) [a]	*Cynoglossum officinale* [a]		X											
	Cheatgrass [c]	*Bromus tectorum* [c]												X	X
	Common periwinkle [c]	*Vinca minor* [c]												X	X
	English ivy [c]	*Hedera helix* [c]												X	X
	Yellow sweetclover [b]	*Melilotis officianalis* [b]											X		
	Pale agoseris	*Agoseris glauca*											X		
	Reed canarygrass	*Phalaris arundinacea*											X		
	Annual ragweed	*Ambrosia artemisiifolia*											X		

[a] State- or city-listed, nonnative, noxious weed species.
[b] Species not native to Utah.
[c] Nonnative, invasive species.

Vegetation associations present in the study area:

- Bigtooth Maple / Gambel Oak Forest
- Box Elder - Eastern Cottonwood / Redosier Dogwood Forest
- Box Elder - Eastern Cottonwood Semi-natural Woodland
- Box Elder - Narrowleaf Cottonwood / Redosier Dogwood Forest
- Box Elder / Gambel Oak Woodland
- Box Elder Forest
- Box Elder Semi-natural Woodland
- Designed Ornamental Semi-natural Perennial Mix
- Gambel Oak / Skunkbush Sumac Woodland
- Gambel Oak Forest
- Introduced Trees, Shrubs and Grasses
- Mixed Semi-natural Introduced Forbes and Grasses

with all but six of the mapped vegetation polygons having a percent canopy cover greater than 75%. Because of the high quality tree cover within the Red Butte Creek riparian corridor, the riparian functions of shading and water temperature control are being met to a high degree within the corridor. In contrast, plant cover within the lower structural layers is typically much lower, with 23 and 21 of the mapped polygons having cover of 50% or less in the shrub and understory communities, respectively (Table 3.4). Invasive species cover was variable throughout the study area, with about half of the vegetation polygons having an invasive species class of "low" or "none" (i.e., 5% cover or less), with the other half classified as moderate, high, or majority invasive cover (Table 3.4).

Issues Affecting Riparian Functions

During the baseline assessment work, several common issues were observed to be affecting and limiting riparian functions in the Red Butte Creek corridor. These issues are discussed by function below.

Aesthetics

Although many visually appealing portions of Red Butte Creek exist, the presence of trash and debris degrades corridor aesthetics in a number of locations. Common types of trash include miscellaneous small items such as bottles, cans, food wrappers, plywood, plastic containers, tarps, etc. Another common category of trash is remnant/obsolete infrastructure such as pieces of concrete and asphalt, broken fencing, old pipes and barrels, obsolete erosion-control devices such as failing silt fence, etc. In many instances the concrete pieces are associated with prior bank stabilization efforts that have failed due to the concrete being undermined by scour or streambed lowering. Twelve individual, significant litter areas were mapped in the study area during RCS baseline assessment work.

Table 3.4. Percent cover and invasive species class for mapped vegetation polygons.

REACH	POLYGON NUMBER	PERCENT CANOPY COVER	PERCENT SHRUB COVER	PERCENT UNDERSTORY COVER	INVASIVE SPECIES CLASS
LRB_R01	1	76–100+	76–100+	0	none
LRB_R02	2	76–100+	0	0	none
LRB_R02/3	3	76–100+	51–75	1–5	low
LRB_R03	4	51–75	51–75	26–50	low
LRB_R04A	5	76–100+	51–75	51–75	moderate
LRB_R04A	6	76–100+	0	26–50	none
LRB_R04B	7	76–100+	51–75	6–25	none
LRB_R04B	8	76–100+	6–25	0	none
LRB_R04B	9	76–100+	26–50	6–25	none
LRB_R04B	10	76–100+	26–50	6–25	none
LRB_R04C	11	51–75	26–50	26–50	none
LRB_R04C	13	76–100+	26–50	76–100+	high
LRB_R04C	14	76–100+	26–50	76–100+	high
LRB_R05A	15	76–100+	0	26–50	high
LRB_R05B	16	76–100+	6–25	6–25	moderate
LRB_R05B	17	76–100+	6–25	6–25	low
LRB_R05C	18	76–100+	26–50	0	moderate
LRB_R05C	19	76–100+	51–75	6–25	moderate
LRB_R07	20	76–100+	0	26–50	high
LRB_R07	21	76–100+	26–50	76–100+	majority
LRB_R06	22	76–100+	6–25	51–75	majority
URB_R10	23	0	0	76–100+	none
URB_R10	24	51–75	51–75	6–25	moderate
URB_R09	25	76–100+	6–25	51–75	low
URB_R09	26	76–100+	76–100+	51–75	moderate
LRB_R04A	60	76–100+	51–75	26–50	none
LRB_R05C	201	26–50	0	76–100+	high
LRB_R05C	202	76–100+	0	76–100+	high
LRB_R05C	203	26–50	0	76–100+	moderate
LRB_R05C	204	76–100+	26–50	6–25	moderate
LRB_R05C	205	76–100+	26–50	6–25	moderate
LRB_R05C	206	76–100+	26–50	6–25	low

Invasive plants of concern in the study area:

- Russian olive
- Siberian elm
- tree of heaven
- lesser burdock
- whitetop
- periwinkle vine
- English ivy
- cheatgrass
- quackgrass
- Scotch thistle
- houndstongue

Factors limiting shrub and understory cover:

- oversteepened slopes
- inadequate revegetation efforts following construction
- soil compaction from heavy foot traffic
- uncontrolled runoff from upland areas

Wildlife Habitat and Connectivity

A wide range of native bird and mammal species rely on native insects as a key food source (Tallamy 2009). These insects must share an evolutionary history with plants in order to recognize them and use them as a food source. Therefore, healthy native plant communities are necessary for a riparian corridor to function to its maximum potential in terms of wildlife habitat. As discussed above, invasive nonnative plant species are a concern in about half of the study reaches within the Red Butte Creek corridor, and they affect the composition of the understory and canopy vegetation layers. In some areas invasive species comprise the majority plant cover within a vegetative layer, limiting the ability of native plants to thrive and support native insects, birds, and wildlife. The lack of understory and shrub cover in many reaches also limits habitat quality in terms of structural diversity, which is particularly important for bird populations.

Another issue affecting wildlife habitat, as well as riparian connectivity, is the presence of stream crossing culverts. Twelve culvert crossings were mapped within the study area (Figure 3.11). Several of these culverts impede or block fish passage due to steep vertical drops at their outlets and high flow velocities within the smooth concrete pipes. This limits the ability of fish populations to use Red Butte Creek as a continuous travel corridor. The small diameter of the culverts also blocks passage by mammal species such as deer. Within the study area, a total length of 0.35 mile of stream is contained in culvert pipes, limiting the overall length of open channel stream available as aquatic habitat. The longest continuous segments of stream in the study area include study reach URB_R09, which is 2,300 feet long; reach LRB_R07, which is 2,080 feet long; a 1,700-foot-long segment between 1500 East and 1300 East; and a 1,500-foot-long segment between Red Butte Garden and Chipeta Way (Figure 3.11).

Nutrient Filtration and Sediment Trapping

As discussed above, many areas of the Red Butte Creek corridor lack the dense understory and shrub cover that are needed to maximize the ability of the riparian corridor to filter sediment, nutrients, and pollutants from storm runoff. In some areas, understory cover is high but the community is dominated by invasive periwinkle or ivy vines. Because these vines have shallow, low-density root and stem systems, they do not serve the filtration function as well as native grass and forb communities would.

Stream Stability

A number of different issues were noted as affecting stream stability within the Red Butte Creek riparian corridor. Specific issues are discussed in the subsections below.

Stream Crossing Culverts

Localized erosion and deposition problems were noted at several of the stream crossing culverts within the study area. Most of the culverts have diameters of 3 to 7 feet (Table 3.5), which is significantly smaller than the 13-foot average bankfull channel width. Because of this width discrepancy, a hydraulic constriction occurs at culvert inlets, slowing flow velocities and leading to deposition and accumulation of sediment and debris. At three crossings within the study area, the size of the openings at the culvert inlets and the conveyance capacities of the structures have been substantially reduced as a result of this deposition process. During RCS public workshops and stakeholder meetings, no one reported experiencing any flooding problems on Red Butte Creek since the 1983 floods; however, problems may occur in the future unless measures are taken to restore the conveyance capacities of these crossing structures.

The size and design of the stream crossing culverts also contribute to stability concerns at some of the culvert outlets. During high flows, velocities at the outlets of the longer culverts are accelerated because of width constriction and a lack of bed roughness within the smooth concrete pipe material. Scour problems and vertical drops were noted at three of the assessed crossing outlets within the study area (Table 3.5).

Storm Drain Outfalls

Erosion was commonly observed at storm drain pipe outfalls within the study area. These outfalls deliver storm water runoff to the creek from streets, gutters, and rooftops. The outfalls often lack adequate outlet protection to dissipate runoff velocities and protect against erosion. Even where outlet protection is provided, stabilized conveyance channels are typically lacking between the protected outlet and the main Red Butte Creek channel and evidence of rill erosion in these areas is common. Of the 25 mapped outfall locations, 12 were ranked as medium- or high-priority areas for stability improvements.

Top left: Debris and sediment accumulation at culvert inlet. Top right: Erosion at storm drain outfall. Bottom left: Invasive vines on streambank. Bottom right: Scour at culvert outlet.

Table 3.5. Size and condition of stream crossing culverts in the study area.

Crossing Location/ Description	Reach Number(s)	Approximate Culvert Length (ft) [a]	Vertical Drop from Inlet to Outlet [b] (ft) [a]	Culvert Type	Approximate Culvert Size/ Diameter (ft) [a]	Inlet Condition	Outlet Condition
Trail at south end of Red Butte Garden	between LRB_R01 and LRB_R02	50	2	3 round pipes	2.5 each	fair; affected by silt fence/construction at time of assessment	good; minimal scour
Chipeta Way	between LRB_R03 and LRB_R04A	108	5	concrete arch	6.5 H x 5.5 W [c]	fair; sticks placed across inlet	good; minimal scour
Crossing near tennis courts	between LRB_R04A and LRB_R04B	90	4	concrete arch	7 H x 6 W [c]	fair; boards partially block inlet	good
Crossing near Marriot	between LRB_R04B and LRB_R04C	72	4	concrete arch	6 H x 6 W [c]	fair; partially blocked by sediment/debris accumulation	good
Foothill Drive	between LRB_R04C and LRB_R05A	192	9	concrete box (inlet); eliptical metal pipe (outlet)	6.5 H x 6 W (inlet); 6 H x 7 W (outlet) [c]	fair; bare slopes around concrete headwall	poor; scour and bank erosion; 2-foot drop from pipe to water surface
Hall Street	between LRB_R05A and LRB_R05B	128	5	round concrete pipe	6	fair; some bare slopes/erosion around concreteheadwall	fair; scour pool present below concrete apron
Crossing within VA Medical Center complex	near downstream end of LRB_R05B	20	1	concrete arch	5	poor; nearly blocked by sediment and debris	poor; 2/3 of arch filled with sediment
Sunnyside Avenue	between LRB_R05C and LRB_R06	180	10	two vertically stacked concrete boxes	each 3 H x 3 W [c]	good	not assessed
900 South	between LRB_R06 and LRB_R07	210	9	round metal pipe	3	not assessed	fair; some scour/ undercutting
Trail in Miller Park	middle of LRB_R07	16	N/A [d]	open-bottom arch	9 H x 12 W [c]	excellent	excellent
1500 East	between LRB_R07 and LRB_R08	400	14	round concrete pipe	4	stable; concrete and rip-rap	not assessed
1300 East	between LRB_R09 and LRB_R10	260	14	round concrete pipe	3 or 4	not assessed	not assessed
1100 East	between LRB_R10 and LRB_R11	90	1.5	round concrete pipe	3 or 4	stable; all concrete	stable; all concrete

[a] Feet.
[b] Elevation change between inlet and outlet based on digital elevation data.
[c] H = height, W = width.
[d] Not applicable.

Streambank Erosion

Lateral erosion of streambanks is a natural process in stream channels, which are dynamic systems. Erosion and sediment transport are necessary for the creation and maintenance of important habitat features such as scour pools, undercut banks, and spawning gravels. Deposition of sediment onto floodplain areas is also important, as it provides fresh substrate for the growth of willow and cottonwood seedlings that are needed to maintain native riparian forests. However, excessive amounts of erosion or deposition can degrade habitat and water quality, and threaten municipal infrastructure and residential homes.

Top: Terrace erosion at outside of bend. Bottom: Low bank/root zone erosion.

Several types of bank erosion were observed in the study area. Low bank erosion/root zone scour are evident in nearly all study reaches and are associated with the flashy urban hydrology that produces frequent, erosive runoff events during storms. In some areas, it appears that streambed lowering is also contributing to low bank erosion by causing the toe of the slope to become undermined. In some reaches tall, vertical, bare banks are present where the creek has migrated laterally into a fine-grained Bonneville terrace deposit. This type of terrace erosion at the outside of bends is a natural process, but it is a concern where it poses a risk to infrastructure. Localized bank erosion caused by direct channel alterations is another type of erosion problem observed in the study area. In several locations, bank erosion problems were observed in unprotected areas opposite or adjacent to banks that have been hardened with rock or concrete. This type of problem can occur when bank stabilization efforts are not implemented comprehensively throughout a reach because measures taken to fix erosion in one location may alter channel shape and flow hydraulics and inadvertently create erosion in a different location.

4.0 RECOMMENDED IMPROVEMENT PROJECTS

Overview of Project Types

A variety of improvement projects are recommended to address the issues identified as limiting riparian functions in the Red Butte Creek corridor and to improve overall riparian conditions. To be effective, different types of projects must be implemented at different spatial scales. Therefore, the presentation of projects has been organized into four groups based on the appropriate implementation scale.

"General" projects include measures that are appropriate to implement at any scale within the riparian corridor. General projects are effective when implemented at a single point or property within the corridor, and they are also effective when implemented at a broader scale throughout an entire stream reach or the entire riparian corridor.

"Local-scale" projects are relevant to specific individual locations or features such as a particular storm drain, stream-crossing culvert, or in-channel diversion structure. These types of projects are appropriate to implement at a local scale, although upstream and downstream reach and watershed conditions should be considered in the design of local-scale projects.

"Reach-scale" projects are most effective when implemented throughout an entire stream reach or throughout a series of connected stream reaches. Bank-stabilization efforts that affect channel areas within the AHWL, grade-control projects to improve streambed stability, and projects involving pedestrian access are examples of reach-scale projects. The starting and ending locations for reach-scale projects should typically be established "hard" points such as stream crossings where the channel position is fixed.

"Watershed-scale" projects are applicable both within and beyond the riparian corridor, throughout the entire watershed area that drains to Red Butte Creek (Figure 4.1). Watershed-scale efforts attempt to halt or reverse some of the root causes of riparian corridor degradation, such as hydrologic alteration, sediment-supply alteration, and/or water quality pollution.

General Projects

Stream Cleanup

This improvement measure involves organizing a group of people to pick up trash within a specific riparian corridor area. Cleanups on private property should only be held after coordinating with and receiving permission from all landowners within the cleanup area. Planning a cleanup event involves selecting a date and specific location, publicizing the event and recruiting volunteer help, making arrangements for proper disposal and recycling of

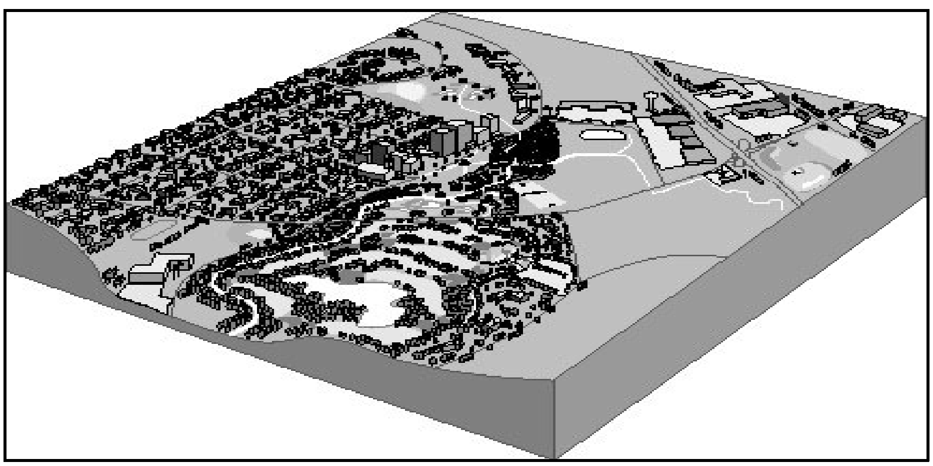


Figure 4.1. Schematic illustration of a contributing watershed area draining to an urban riparian corridor. (Illustration from FISRWG 1998).

Potential partnering organizations for stream-cleanup projects:

- Trout Unlimited
- Natural Resources Conservation Service
- Utah Division of Wildlife Resources
- Utah Federation for Youth
- Girl Scout and Boy Scout Groups
- Utah State University Water Quality Extension
- School Groups or Classrooms
- American Rivers National River Cleanup Program

the collected trash, and obtaining supplies via purchase or donations (trash bags, first aid kits, waders, water/refreshments, etc.). Stream cleanups can be organized by local individual citizens, school groups, local government entities, or other organizations.

A special consideration on Red Butte Creek is that western poison ivy is prevalent in some reaches; cleanup organizers should be sure to educate volunteers to identify and avoid the plant and provide preventative lotions as needed. A County flood-control permit may be required for certain types of cleanup projects. Stream-cleanup projects enhance the aesthetic function of riparian corridors and can also improve water quality by removing potential pollution sources from the riparian corridor.

Mechanized Trash Removal

Many of the litter areas that were noted and mapped during baseline assessment efforts consist of heavy, over-size items that would not be possible to remove by hand during a volunteer cleanup event. Therefore, trash removal in certain locations would require mechanized equipment such as backhoes or all-terrain vehicles. City or County crews would most likely be the most appropriate entities to implement this type of project, as they have the appropriate equipment and trained labor on staff. However, there may also be opportunities to use volunteer labor or equipment by involving local construction or landscaping businesses in the cleanup project.

Planning a mechanized trash cleanup project involves selecting a date and specific location for the project, making arrangements for proper disposal and recycling of the collected trash, constructing temporary equipment access routes if needed, and revegetating access routes once work is complete. As with stream cleanups, mechanized trash removal projects in privately owned areas should only be completed after coordinating with and receiving permission from all relevant landowners. In locations where the trash to be removed includes failed bank revetment or in-channel structures (concrete pieces, etc.), the mechanized cleanup project may need to be implemented in conjunction with a bank or streambed stabilization project to ensure that the removal of the old materials does not initiate any new erosion. Relevant City, County, and/or State permits will be needed if the project would cause significant disturbance or involve the use of heavy equipment in riparian areas. Mechanized trash removal projects enhance the aesthetic function of riparian corridors and can also improve habitat and filtration functions when revegetation is included as a component of the project.

Stream Adoption

The state of Utah has established an "Adopt-a-Waterbody" program through a partnering effort between the Utah Department of Environmental Quality, the Utah Department of Natural Resources, and the Utah Department of Agriculture and Food with support from Utah State University Water Quality Extension (www.adoptawaterbody.utah.gov/). Modeled after the national "Adopt-a-Highway" program, this program provides a way for community volunteer groups or local businesses to make a formal commitment to take care of specific sections or

Internet resources for improvement projects:

Stream cleanup and adoption:

- www.adoptawaterbody.utah.gov/
- www.americanrivers.org/assets/pdfs/national-river-cleanup/nrc-organizer-handbook.pdf

Invasive species control:

- www.recreation.slco.org/planning/natural.html
- www.weeds.slco.org/html/weedInfo/index.html
- extension.usu.edu/weedweb/www.utahweed.org
- www.slch2o.com

Utah State University Extension - firewise plant information:

- www.utahfireinfo.gov/prevention/firewiseplants.pdf

Center for Watershed Protection (low impact development and storm water management):

- www.cwp.org/

areas of a stream, lake, or wetland. Activities could include organizing stream cleanups, monitoring water quality, controlling invasive species, or planting native riparian vegetation. Stream adoption and improvement activities within privately owned land should only take place after coordinating with and receiving permission from all relevant landowners. The Yalecrest Community Council is currently listed as having adopted the section of Red Butte Creek between 900 South and 1500 East.

Removal of Invasive Plant Species

This improvement measure involves controlling and removing invasive plant species and replacing them with native plants. Invasive plant removal projects are important for the enhancement of riparian functions including habitat for wildlife and birds, filtration of sediment and pollutants, and stream stability. Table 4.1 provides a comprehensive list of invasive vegetation species to avoid planting within the Red Butte Creek corridor. In reaches where these species are present, removal of the invasive species and replacement with native plants are recommended.

Techniques for invasive species control and removal include physical, cultural, biological, and chemical measures. Physical controls, also known as mechanical controls, involve pulling or otherwise removing plants or portions of plants. Types of physical controls including hand pulling, disking, or mowing. Cultural controls involve establishing vigorous, desirable plant species that are able to out-compete the invasive weed species. Biological controls involve reducing invasive weed populations through the introduction of insect or pathogen bio-control agents. Chemical controls involve applying herbicides to weed infestations. Because of the sensitive nature of riparian areas, chemical controls should always

Best management practices for herbicide application in streamside areas:

- use herbicides cautiously as one element of an integrated weed control strategy
- spot spray rather than broadcast spray
- avoid spraying during windy conditions
- avoid spraying in the rain or when rain is forecast
- only use chemicals formulated and approved for use near water
- reduce chemical runoff from lawns by leaving a no-mow buffer at the edge of turf areas

Local sources of watershed safe herbicides: [a]

- Steve Regan Company, Salt Lake City, 801-268-4500
- Wilbur Ellis Company, Ogden, 801-399-3775

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

Table 4.1. List of weeds and invasive species to avoid planting within the riparian corridor. Where these species are present, they should be controlled using appropriate techniques and replaced with native species.

COMMON NAME	SCIENTIFIC NAME	UTAH STATE-LISTED NOXIOUS WEED [a]	CITY WATERSHED DIVISION-LISTED WEED	OTHER INVASIVE SPECIES TO AVOID	SPECIES NOTED AS CURRENTLY PRESENT IN THE RED BUTTE CREEK RIPARIAN CORRIDOR
Black henbane	*Hyoscyamus niger*	X	X		
Diffuse knapweed	*Centaurea diffusa*	X	X		
Leafy spurge	*Euphorbia esula*	X	X		
Medusahead	*Taeniatherum caput-medusae*	X	X		
Oxeye daisy	*Chrysanthemum leucanthemum*	X			
Perennial sorghum (Johnson grass)	*Sorghum halepense*	X	X		
Purple loosestrife	*Lythrum salicaria*	X	X		
Spotted knapweed	*Centaurea maculosa*	X	X		
Squarrose knapweed	*Centaurea squarrosa*	X	X		
Yellow starthistle	*Centaurea solstitialis*	X	X		
Yellow toadflax	*Linaria vulgaris*	X	X		
Musk thistle/Nodding plumeless thistle	*Carduus nutans*	X	X		
Bermudagrass	*Cynodon dactylon*	X	X		
Broad-leaved peppergrass	*Lepidium latifolium*	X	X		
Dalmation toadflax	*Linaria dalmatica*	X	X		
Dyer's woad	*Isatis tinctoria*	X	X		
Whitetop (Hoary cress)	*Cardaria spp.*	X	X		X
Poison Hemlock	*Conium maculatum*	X			
Russian knapweed	*Centaurea repens*	X	X		
Squarrose knapweed	*Centaurea virgata*	X	X		
Canada thistle	*Cirsium arvense*	X	X		
Gypsyflower (Houndstongue)	*Cynoglossum officinale*	X	X		X
Saltcedar	*Tamarix ramosissima*	X	X		
Quackgrass	*Elymus repens*	X	X		X
Puncture vine	*Tribulus terrestris*	X	X		
Purple starthistle	*Centaurea calcitrapa*		X		
Myrtle spurge	*Euphorbia myrsinites*		X		
Scotch thistle	*Onopordum acanthium*		X		X
Bull thistle	*Cirsium vulgare*		X		
Common burdock	*Arctium minus*		X		X
Garlic mustard	*Alliaria petiolata*		X		
Camelthorn	*Alhagi pseudalhagi*		X		
Goatsrue	*Galega officinalis*		X		
Russian olive	*Elaeagnus angustifolia*		X		X
Siberian elm	*Ulmus pumila*		X		X
Chinese elm	*Ulmus parvifolia*		X		
Tree of heaven	*Ailanthus altissima*		X		X
Jointed goatgrass	*Aegilops cylindrica*		X		
Field bindweed	*Convolvulus spp.*		X		
English ivy	*Hedera helix*			X	X
Periwinkle spp.	*Vinca minor/major*			X	X
Black locust	*Robinia pseudoacacia*			X	
Rampion bellflower	*Campanula rapunculoides*			X	
Norway maple	*Acer platanoides*			X	
Cheatgrass	*Bromus tectorum*			X	X

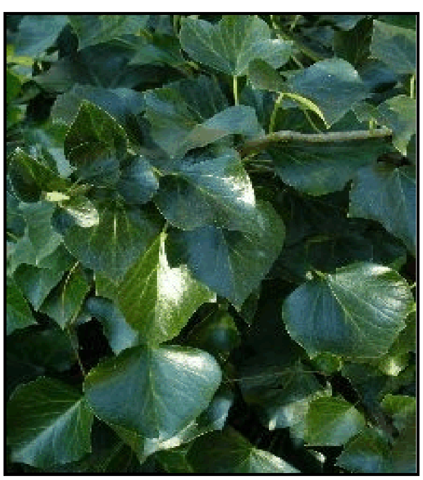
[a] Utah State-listed noxious weeds (http://ag.utah.gov/divisions/plant/noxious/documents/noxUtah.pdf) are subject to regulation by State law under Section 4-17-3, Utah Noxious Weed Act.

be implemented using best management practices (BMPs).

Species-specific control recommendations for many of the species listed in Table 4.1 are described in existing available publications, many of which are available online. Specific control recommendations are included below for several invasive species common to the study area that are not as well documented in available literature. City and County permits may be required for certain types of invasive species removal projects.

English Ivy Control

English ivy is a woody, evergreen climber that has advantageous roots along the stems. The leaves have a dark green, smooth, waxy surface and are found along the length of the stems. This species is a traditional ornamental that establishes a thick mat along the ground and also climbs up adjacent vertical elements, such as trees, fences, and buildings. This species is present as a ground cover within forested riparian areas adjacent to development and has the potential to out-compete native understory, shrub layers, and canopy vegetation components. Because it has a shallow root system and low stem density, English ivy performs poorly in terms of serving the riparian functions of bank stabilization and nutrient filtration.

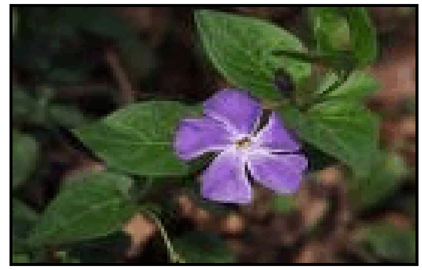


English ivy (*Hedera helix*). From Jeff McMillian, Plants.usda.gov.

Manual control has been sited as one of the best options for effective control of English ivy. Mowing, raking, pulling, and digging accessible plants are viable options. Due to the waxy leaves of English ivy, herbicide treatments have not been very successful. This species is considered tolerant to many herbicides because of the thick, waxy cuticle. If herbicide use is necessary, particular attention should be paid to actively young/growing plants. Make sure that any herbicide used within the riparian corridor is approved for use near water. There are no known biological controls available for this species. Revegetation with native understory plants should always accompany English ivy removal efforts. Revegetation areas should be monitored for successful regrowth of desirable species.

Periwinkle Vine Control

Periwinkle vine (*Vinca major/Vinca minor*) is a perennial, herbaceous species that is low growing and has a trailing or climbing habit. This



Periwinkle vine (*Vinca major/Vinca minor*). From Bermuda-online.org.

Siberian elm (*Ulmus pumila*).

species has been introduced as an ornamental that does well in shaded areas and has naturalized; thus it can be found to dominate areas within urban settings. The foliage is a deep green with a glossy or smooth leaf surface and purple blooms. Because it has a shallow root system and low stem density, periwinkle vine performs poorly in terms of serving the riparian functions of bank stabilization and nutrient filtration.

Periwinkle vine can be removed by digging, raising the runners with a rake, and mowing the plants. All of the plant must be removed. It can also be controlled by cutting the plants in the spring followed by applying a

Local sources of native plants: [a]

- Blue Sky Perennials
  801-718-7715
  www.blueskyperennials.com
- Cactus and Tropicals
  801-485-2542
  www.cactusandtropicals.com
- Dryland Horticulture
  801-597-6051
  DrylandHorticulture@yahoo.com
- Grow Wild LLC
  801-467-8660
  www.growwild.biz/
- Growing Empire Perennials and Shrubs
  801-685-7099
  www.growingempire.net
- High Mountain Nursery
  435-731-0107
  www.highmtnnursery.com
- Millcreek Gardens
  801-487-4131
  www.millcreekgardens.com
- Sun Mountain Growers
  801-941-5535
  sunmtngrowers@comcast.net

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

glyphosate herbicide to the regrowth. The uptake of applied herbicide may be limited due to the waxy leaves characteristic of periwinkle species. It is recommended that a combination of mechanical and chemical controls be implemented for increased success in control efforts. The herbicide Rodeo® has been approved to use near water. It is suggested that by specifically treating young/new growth, applied herbicide can be more effective. No biological controls have been identified for periwinkle vine. Revegetation with native understory plants should always accompany English ivy removal efforts. Revegetation areas should be monitored for successful regrowth of desirable species.

Siberian Elm Control

Siberian elm (*Ulmus pumila*) is a deciduous tree that has escaped cultivation and become an invasive component within riparian forest ecosystems, around lakes, and other natural areas. This species propagates readily from seeds, establishes in harsh environments, and grows rapidly. It is a brittle tree that often sheds its branches, even during mild winds. This species has been a popular choice as a shade tree.

Girdling the trunks has been cited as a viable option for the control of mature Siberian elm. Girdled trees die over the course of 1–2 years and have been reported not to resprout if the girdling is implemented correctly. This practice should be implemented in late spring to mid summer. When girdling, avoid cutting into the woody part of the tree and only strip a band through the bark. Often, when woody portions of trunks are impacted, resprouting from the roots can occur. Seedlings and small trees can be removed by pulling or using a weed wrench or grubbing hoe.

The use of glyphosate is recommended for use as cut-stem application for large trees and resprouts. Herbicide applications are recommended during fall or winter to prevent spring resprouts. There are no known available biological controls for Siberian elm.

Revegetation with Native Plants

As a general practice, revegetation with native plants is recommended for existing disturbed areas or areas where invasive plants have been removed. Revegetation practices can also be used to re-establish native understory or shrub communities where these vegetative layers are currently lacking. Projects to re-establish healthy, structurally diverse native riparian plant populations can enhance the riparian functions of habitat, nutrient filtration, bank stability, organic matter inputs, shading, and floodplain storage. To be successful, general revegetation efforts should only occur in areas where any underlying causes of disturbance (e.g., streambank erosion or scour, soil compaction from foot traffic) have been addressed. Otherwise, the revegetation efforts should be implemented in conjunction with other types of projects (access control, bank stabilization, etc.), as appropriate.

Steps involved in general revegetation projects include: adding or preparing and loosening topsoil; planting with native vegetation using seed, containerized plants, and/or live plant stakes; and protecting the area with mulch. To maximize wildlife habitat, shading, and filtration, use a mix of understory, shrub, and tree species selected from the recommended riparian corridor planting lists (Tables 4.2, 4.3, 4.4), as appropriate. Bark, straw, or wood fiber mulch is typically adequate to protect relatively gentle slopes of 3:1 or flatter. For slopes between 3:1 to 2:1 in steepness, use the planting techniques described above, but instead of mulch use a biodegradable erosion-control blanket (matting or netting made of jute, wood fiber, straw, or coconut) to protect the revegetated area. Use of additional preparation techniques, such as slope roughening or micro-terracing, can also improve revegetation success on slopes in this steepness range. On slopes steeper than 2:1, revegetation efforts should incorporate biotechnical slope stabilization measures to prevent slope erosion (Figure 4.2).

Containerized plants susceptible to herbivory by deer or other wildlife should be protected using wire mesh or other methods. Fall (September 15–December 1) is the recommended time period for revegetation efforts using seed and containerized plants; projects completed during the spring are often successful as well. Late winter/early spring is the recommended time period for conducting projects using live plant stakes, which should be harvested while dormant and planted prior to the growing season.

Biotechnical Slope Stabilization

This improvement measure involves combining revegetation with more traditional, "hard"

Table 4.2. Recommended native canopy (tree) species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS			SPECIES SUITABLE FOR PLANTING AS A LIVE CUTTING
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area	
Bigtooth maple	*Acer grandidentatum*	X				X		
Chokecherry	*Prunus virginiana*	X			X	X		
Douglas fir	*Pseudotsuga menziessi*	X			X			
Gray alder	*Alnus incana*	X				X		
Narrowleaf cottonwood	*Populus angustifolia*	X				X		X
Netleaf hackberry	*Celtis laevigata*	X				X		
Peachleaf willow	*Salix amygdaloides*	X				X	X	X
Twoneedle pine	*Pinus edulis*	X			X			
Utah juniper	*Juniperus osteosperma*	X			X	X		
Water birch	*Betula occidentalis*			X		X		

Table 4.3. Recommended native shrub species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS			SPECIES SUITABLE FOR PLANTING AS A LIVE CUTTING OR STAKE
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area	
Alderleaf mountain mahogany	*Cercocarpus montanus*	X			X			
Antelope bitterbrush	*Purshia tridentata*	X			X			
Big sagebrush	*Artemisia tridentata*	X			X	X		
Creeping barberry	*Mahonia repens*			X	X	X		
Golden currant	*Ribes aureum*			X	X	X		
Mallow ninebark	*Physocarpus malvaceus*			X	X	X		X
Mountain snowberry	*Symphoricarpos oreophilus*			X	X	X		
Narrowleaf willow	*Salix exigua*			X		X	X	X
Oregon boxleaf	*Paxistima myrsinites*		X			X		
Redosier dogwood	*Cornus sericea*			X		X	X	X
Skunkbush sumac	*Rhus trilobata*			X		X		
Snowbrush ceanothus	*Ceanothus velutinus*	X				X		
Twinberry honeysuckle	*Lonicera involucrata*		X			X		X
Utah mountain-lilac	*Ceanothus martinii*	X				X		
Utah serviceberry	*Amalanchier utahensis*	X			X	X		
Western snowberry	*Symphoricarpos occidentalis*		X			X		
Whitestem gooseberry	*Ribes inerme*	X				X		
Woods' rose	*Rosa woodsii*			X	X	X		X
Yellow willow	*Salix lutea*			X		X	X	X
Yellow rabbitbrush	*Chrysothamnus viscidiflorus*	X			X			

Table 4.4. Recommended native understory (ground cover) species for planting efforts within the riparian corridor.

COMMON NAME	SCIENTIFIC NAME	PREFERRED LIGHT CONDITIONS			PREFERRED MOISTURE CONDITIONS		
		Sun	Shade	Part Sun/ Shade	Relatively Dry Upper-Slope Areas	Seasonally Moist Areas	Spring or Seep Area
Arctic rush	*Juncus arcticus*						X
Arrowleaf balsamroot	*Balsamorhiza sagittata*	X			X		
Aspen fleabane	*Erigeron speciosus*	X			X		
Blue wildrye	*Elymus glaucus*			X		X	
Butterfly weed	*Asclepias tuberosa*			X	X		
Desert needlegrass	*Achnatherum speciosum*	X				X	
Feathery false lily of the valley	*Maianthemum racemosum*		X			X	
Fendler's meadow-rue	*Thalictrum fendleri*					X	
Firecracker penstemon	*Penstemon eatonii*	X			X	X	
Hairy false goldenaster	*Heterotheca villosa*	X				X	
Indian ricegrass	*Achnatherum hymenoides*	X				X	
Indianhemp	*Apocynum cannabinum*			X		X	
Littleseed ricegrass	*Poptatherum micranthum*	X				X	
Longleaf phlox	*Phlox longifolia*			X	X		
Mountain phlox	*Phlox austomontana*	X			X		
Muttongrass	*Poa fendleriana*			X	X		
Prairie flax	*Linum lewisii*	X				X	
Purple threeawn	*Aristida purpurea*	X				X	
Rocky Mountain penstemon	*Penstemon strictus*	X			X	X	
Showy lupine	*Lupinus polyphyllus*	X			X	X	
Slender cinquefoil	*Potentilla gracilis*	X			X		
Starry false lily of the valley	*Maianthemum stellatum*		X			X	
Sticky purple geranium	*Geranium viscosissimum*			X		X	
Torrey's rush	*Juncus torreyi*						X
Towering Jacob's ladder	*Polemonium foliosissimum*			X		X	
Wasatch beardtongue	*Penstemon cyananthus*	X			X	X	
Western sweetroot	*Osmorhiza occidentalis*			X		X	
Western columbine	*Aconitum columbianum*						X
Western white clematis	*Clematis ligusticifolia*			X		X	
White sagebrush	*Artemisia ludoviciana*	X			X		
Wild bergamot	*Monarda fistulosa*			X		X	

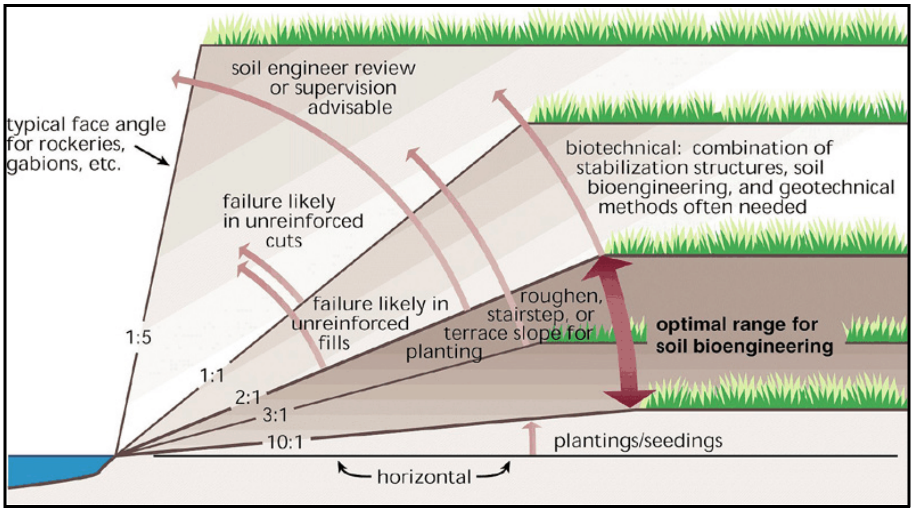


Figure 4.2. **Importance of slope steepness in selecting appropriate revegetation and stabilization measures. (Illustration from FISRWG 1998).**

Native seed sources: [a]

- Ames Utah Native Seed, Eureka
  435-433-6924
  xeriseeds@yahoo.com
- Granite Seed Co., Lehi
  801-768-4422
  www.graniteseed.com
- Maughan Seed Co., Manti
  801-835-0401

Other Planting Resources:

- Utah Native Plant Society
  www.unps.org
- Intermountain Native Plant Growers Association
  www.utahschoice.org
- Tree Utah
  www.treeutah.org

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

geotechnical slope-stabilization techniques. Biotechnical slope-stabilization methods incorporate structural elements that make it possible to achieve stability on steep slopes where plants alone would not provide adequate strength. Because they incorporate vegetation, these techniques enhance the riparian functions of habitat, filtration, aesthetics, organic matter inputs, shading, and floodplain storage as well as bank stability. Stabilization methods that lack vegetation (e.g., concrete walls, rip-rap) are not recommended for the study area because they decrease the ability of the corridor to serve these riparian functions. In general, the use of concrete and other impervious treatments should be avoided because of widespread erosion problems observed at soil-concrete interfaces during RCS field assessments. Concrete structures are also generally less aesthetically pleasing than vegetative techniques and are prone to being defaced with graffiti.

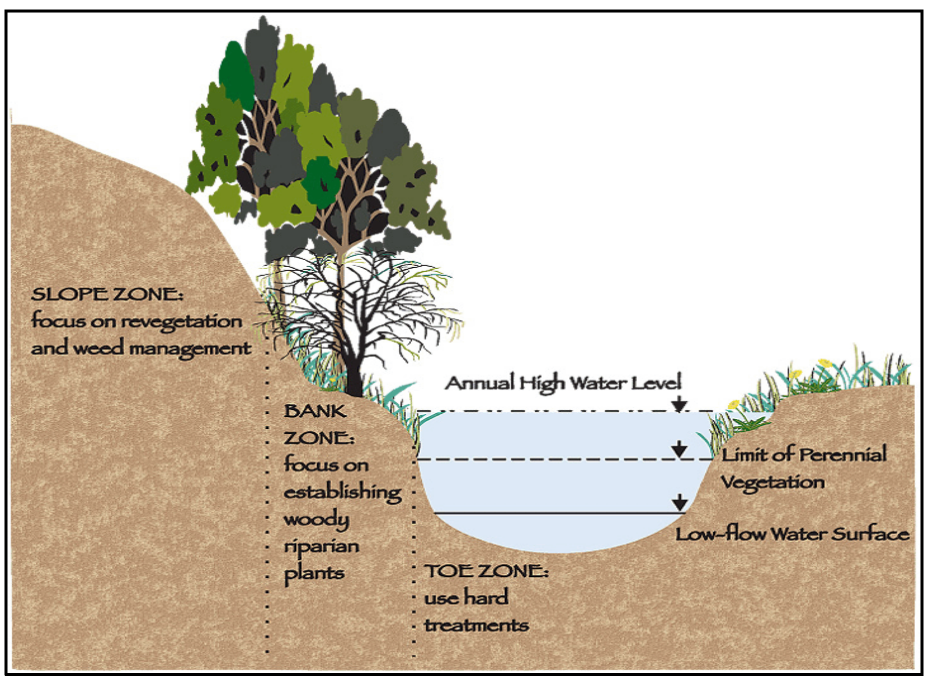


Figure 4.3. **Schematic illustration of toe, bank, and upper slope zones and recommended treatment approaches.**

Biotechnical slope stabilization is recommended as a general type of project when implemented in areas above the AHWL where any underlying causes of disturbance have been addressed. Appropriate areas for general application of biotechnical measures include the slope zone and upper portion of the bank zone as identified in Figure 4.3 . If stability problems at a specific location are associated with stream erosion or undercutting of the bank toe, biotechnical slope-stabilization projects should be implemented at the reach scale and should incorporate toe protection and grade control, as appropriate. Relevant State, County, and City permits are required for most biotechnical slope-stabilization projects occurring within the riparian corridor.

Specific types of biotechnical slope-stabilization techniques recommended for use within the Red Butte Creek riparian corridor include:

- vegetated soil lifts
- vegetated rock revetment using live stakes, pole plantings, and/or brush layering
- vegetated modular block retaining walls
- vegetated crib retaining walls
- vegetated gabion basket retaining walls

Figure 4.4. Photographs of revegetation and biotechnical slope-stabilization techniques. (Top left: erosion-control blanket and live stakes [image from FISRWG 1998]. Top right: live pole plantings [image from FISRWG 1998]. Bottom left: containerized cottonwood (*Populus* sp.) planting protected from herbivory with wire mesh cage. Middle right: installation of live plant posts to create vegetated rock revetment [image from NRCS 2007]. Bottom right: vegetated soil lifts with live plant stakes and rock toe protection.)

Photographs illustrating some of these techniques are provided in Figure 4.4, and selected detail drawings are provided in Appendix B, drawings 1–5. This list is not intended to be exhaustive. Biotechnical planting techniques are adaptable and can readily be combined in creative ways to meet site-specific needs. Other techniques such as willow bundles, brush mattresses, live fascines, vegetated rock walls, and coir fiber rolls are also recommended for use within the study area. Comprehensive discussion of individual techniques is beyond the scope of this document, but more detailed information is readily available in existing publications such as those listed to the right.

Local-Scale Projects

Storm Drain Outlet Protection

The use of vegetated rock is recommended as outlet protection for new storm drain outfalls installed within the riparian corridor and as a retrofit measure to correct erosion problems at existing outfalls. A vegetated, rock-lined swale should be installed to convey runoff from the protected outlet to Red Butte Creek. Use of these techniques avoids the erosion and scour problems commonly associated with concrete outlet protection structures and provides enhancement of the riparian functions of wildlife habitat, streambank stability, and filtration of pollutants, sediment, and nutrients.

Photographs illustrating these techniques are provided in Figure 4.5, and detail drawings are provided in Appendix B, drawings 6 and 7. Installation of storm drain outlet-protection measures requires relevant State, County, and City permits. In some locations where existing drain outfall systems appear to be inadequate for runoff volume, outlet protection measures should be accompanied by measures to improve storm water management (e.g., installation of retention basins, flow spreaders, French drains, or additional drain pipes).

Stream Crossings and Culvert Replacement

This recommended improvement measure involves installing bridges and open-bottom box culverts where roads and trails cross Red Butte Creek. The bridge and box culvert structures should have relatively wide spans equal to or greater than the wetted width of the stream channel during high-flow conditions. The use of these wide-span crossing structures with natural-substrate bottoms allows for continued transport of sediment and debris, and eliminates the deposition and scour problems associated with flow constriction at narrow-diameter culvert crossings. Hence new crossings should be designed as bridges or open-bottom box culverts and existing culvert crossings replaced with these wider-span structures, as feasible. Implementation of this measure will improve the riparian functions of stream stability, connectivity for fish and wildlife, aesthetics, and floodplain storage, and will reduce the maintenance needed to prevent culverts from clogging.

Publications that provide detailed descriptions of slope stabilization and stream repair techniques (complete references are provided in the References section of this document):

- CFWP. 2004. Urban subwatershed restoration manual 4: urban stream repair practices. Available at: www.cwp.org/Store/usrm.htm#4/.
- Gray and Sotir. 1996. Biotechnical and soil bioengineering slope stabilization: a practical guide for erosion control.
- FISRWG 1998. Stream corridor restoration: principles, processes, and practices. Available at: www.nrcs.usda.gov/technical/stream_restoration/.
- NRCS. 2007. National engineering handbook part 654: stream restoration design. Available at: policy.nrcs.usda.gov/viewerFS.aspx?hid=21433.
- NCHRP. 2005. NCHRP report 544: environmentally sensitive channel- and bank-protection measures.

Photographs of these techniques are provided in Figure 4.5. Stream-crossing projects will typically require site-specific professional engineering design as well as relevant State, County, and City permits.

Figure 4.5. Photographs of outlet protection and stream crossing techniques. (Top left: rock outlet protection. Top right: stream crossing using a bridge made from a recycled railroad flatcar. Middle left: vegetated rock-lined swale immediately following construction. Middle right: stream crossing using an open-bottom box culvert. Bottom left: vegetated rock-lined swale in second growing season. Bottom right: tailwater pool at culvert outlet.)

Culvert Outlet Protection

Where replacement of existing stream-crossing culvert pipes is not feasible in the near future, outlet protection improvements (FHWA 2006) are recommended as a short-term measure until funding becomes available for replacement. Installation of a rock-lined tailwater pool, in combination with vegetated rock bank protection and/or rock step-pool features, is recommended for protection of existing culvert outlets. The use of these techniques will improve the riparian functions of stream stability and aesthetics. However, these efforts will not improve riparian connectivity and will not resolve problems with sedimentation or deposition at culvert inlets.

The purpose of these recommended outlet protection measures is to reduce culvert outlet velocities, dissipate energy, create a stable streambed elevation that will not be susceptible to scour, and create stable streambanks adjacent to the culvert outlet. Culverts with especially high outlet velocities may require the installation of a series of step-pool features below the initial rock-lined tailwater pool to ensure a stable transition to the natural channel and to limit the likelihood of bed and bank scour. Detail drawings are provided in Appendix B, drawings 8–10. As with culvert replacement, culvert outlet-protection projects require site-specific professional engineering design as well as relevant State, County, and City permits.

Stream Daylighting

Where feasible, daylighting selected portions of Red Butte Creek that are currently piped is recommended as a riparian corridor improvement measure. Returning piped stream sections to the landscape as natural channel features is potentially one of the most valuable types of improvement projects. Daylighting projects can improve habitat connectivity, aesthetics, filtration, floodplain storage, recreational opportunities, and overall habitat quality and area. Because these projects convert straight, narrow pipes to more sinuous, wider open-air channels, downstream erosive velocities are also reduced, leading to additional stability benefits. Stream daylighting projects involve the use of heavy equipment and require site-specific professional design as well as relevant State, County, and City permits.

No-trespassing Signage

During RCS subcommittee meetings and public workshops, stakeholders emphasized concerns regarding trespassing onto private property from publicly owned portions of the riparian corridor. To address this issue, the creation of standardized no-trespassing signs is recommended. The signs could either be installed at public-private land interfaces throughout the corridor, or they could be made available to property owners by request.

Figure 4.6. Photographs of grade-control, bank-stabilization, and access-control techniques. (Top left: construction of a vortex rock weir. Top right: A-jacks toe protection [image from Schueler and Brown 2004]. Bottom left: downstream view of two vortex rock weir structures. Bottom right: steps that provide stabilized stream access.)

Reach-Scale Projects

Grade Control

Comprehensive installation of grade-control structures is recommended for stream reaches where streambed lowering was observed to be a problem. By stabilizing the streambed profile, grade-control projects can reduce bank erosion problems associated with undermining of the bank toe. In addition to improving bank stability, grade-control projects can also enhance aquatic habitat by creating pool features. Because grade-control structures influence channel shape and flow hydraulics, they have the potential to destabilize upstream and downstream areas if they are not implemented correctly and comprehensively. Therefore, it is important to install grade-control devices as a series throughout an entire stream reach.

The use of vortex rock weirs is recommended as the primary grade-control technique for the Red Butte Creek riparian corridor. These structures use two offset layers of immobile boulders arranged in a “V” shape to create a stable hard point in the streambed profile that will resist future scour. Photographs of vortex rock weirs are provided in Figure 4.6, and a detail drawing is provided in Appendix B, drawing 11.

Because the horizontal spacing between the upper layer of rocks is fairly wide, sediment being transported downstream is able to pass through the weir without becoming trapped. Vortex rock weirs are also relatively low-profile structures that do not alter flow hydraulics to the same extent as other types of grade structures that function more like small dams. Because large-size boulder materials are required, installation of vortex rock weirs will generally involve the use of heavy equipment. In stream reaches where heavy equipment access is not possible, other grade-control techniques, such as rock riffles, may need to be used. Rock-riffle installation involves the engineered placement of cobble-sized rock into a channel-spanning "ramp" feature to increase streambed resistance to scour. Additional details regarding this technique can be found in Technical Supplement 14G of NRCS (2007). Vortex rock weirs are recommended instead of rock riffles wherever possible because they have greater anticipated longevity and overall effectiveness.

Grade-control projects require site-specific professional design to determine required rock sizes, structure spacing, and weir dimensions. Relevant State, County, and City permits are needed for grade-control projects. Such projects also require that precautions, such as flow diversion or temporary dewatering, be taken to limit disturbance during construction and reduce potential impacts to water quality and fish.

Bank Stabilization

In reaches where excessive bank erosion poses a risk to adjacent infrastructure, comprehensive bank stabilization is recommended as a reach-scale improvement project. Reach-scale bank stabilization efforts involve the installation of treatment measures within the AHWL and affect the bank and toe zones (Figure 4.3). These types of efforts affect the shape and flow hydraulics of the active stream channel and have the potential to destabilize upstream and downstream areas if not implemented correctly and comprehensively. Therefore, to maximize long-term effectiveness and minimize future maintenance costs, bank-stabilization projects should be implemented at the reach scale.

As a general principle, bank treatments that protrude into the active channel or floodplain should be avoided whenever possible. To improve bank stability, channel width should be maintained or expanded wherever possible to allow flood flows to spread out, reduce downstream velocities, and dissipate erosive energy. In situations where infrastructure constraints on a given

Material suppliers for improvement projects: [a]

- www.contech-cpi.com (bridge, drainage, stabilization, storm water)
- www.thebmpstore.com (erosion control, inlet protection, slope stabilization)
- www.maccaferri-northamerica.com (erosion control, retaining walls, bioengineering)
- www.rolanka.com (erosion control, sediment control, soil bioengineering)
- www.geovireo.com (erosion control, sediment control, soil bioengineering)
- www.horizononline.com (erosion control and landscaping)
- www.herculesmfg.com (modular retaining walls)
- www.skipgibbs.com (recycled railroad car bridges)
- www.americanexcelsior.com (erosion control solutions)

[a] This list is partial, provided for reference only, and does not constitute an endorsement by Salt Lake City.

streambank require that treatment measures protrude beyond the existing bank location, concurrent measures should be taken to re-establish accessible floodplain area on the opposite bank to maintain flood conveyance capacity and avoid increasing downstream flow velocities.

Bank stabilization projects require site-specific professional design to determine scour depth, required rock sizes, structure spacing, and dimensions. Relevant State, County, and City permits are needed for bank-stabilization projects. These projects also require that precautions, such as flow diversion or temporary dewatering, be taken to limit disturbance during construction and reduce potential impacts to water quality and fish. Some specific bank-stabilization techniques are discussed below (detail drawings are provided in Appendix B, drawings 12–14).

Toe Protection

Because of the erosive flow velocities associated with the urbanized condition of the Red Butte Creek corridor, bank-stabilization projects should incorporate the use of hard treatments within the toe zone (Figure 4.3) where the resistive strength of vegetation alone is typically not adequate. Above the toe zone, the treatment emphasis should focus on the establishment of vegetation using the revegetation and biotechnical stabilization techniques described above in the General Projects section.

Toe protection using large, immobile rock installed to the maximum depth of scour is recommended for areas where heavy equipment access is possible (see toe protection component of drawings 1–4 in Appendix B). In areas where access is more limited, the use of A-jacks® toe protection is recommended as an alternative to large rock. A-jacks® are concrete, three-dimensional, cross-shaped devices that can be assembled onsite to create a stable “cage” to hold cobble-sized rock that would otherwise be mobile (see Figure 4.6 and Appendix B, drawing 12). As with rock toe protection, A-jacks® toe protection should be trenched in below the channel bed to the depth of maximum scour. Toe protection can be combined with any of the biotechnical slope stabilization techniques described previously to design a reach-appropriate comprehensive bank stabilization project.

Redirective Techniques

Redirective techniques involve installing measures to redirect flow away from an eroding bank, typically at the outside of a bend. Because of the risk that the redirected flows could cause erosion on the opposite bank or adjacent channel areas, these techniques should always be designed by qualified professionals and special caution must be used to ensure that all susceptible bank areas are adequately protected. Specific types of redirective techniques include wing deflectors, log or rock vanes, root wads, and spur dikes (Schueler and Brown 2004, McCullah and Gray 2005, NRCS 2007). Rock vanes with J-hooks are a recommended technique for appropriate locations in the Red Butte Creek corridor (Appendix B, drawing 14). The specific recommended design involves keying-in the hook structure to the bank opposite the vane structure to reduce the risk of erosion.

Access Control and Trail Stabilization

Implementation of measures to control foot traffic and stabilize access trails is recommended in stream reaches that receive heavy recreational use. Such measures can reduce soil compaction, enhance vegetation quality, and improve stream stability. Access needs should be assessed and planned at the reach scale so that control measures do not simply shift erosion and soil compaction problems elsewhere. Specific recommended measures include the installation of split rail fencing to focus and direct foot traffic and installation of pervious steps to provide stream access (Figure 4.6 and Appendix B, drawing 15).

Watershed-Scale Projects

Manage and Reduce Impervious Surfaces

This improvement measure involves taking steps to limit the adverse hydrologic effects of increased impervious-surface associated with new construction. Retrofit measures could also be implemented to reduce existing impervious surface acreage and increase stormwater infiltration. The use of low-impact development techniques and long-term storm water BMPs should be encouraged within the study area. Managing and reducing impervious surfaces would help return the creek's hydrology to a more natural pattern. This in turn would reduce erosive storm-flow velocities, improve water quality and channel stability, and increase summertime base flows.

Specific techniques could include runoff disconnection and infiltration practices, green roofs, installation of bio-swales instead of curb and gutter/raised median systems, and use of alternative paving techniques. An in-depth discussion of specific techniques is beyond the scope of this document, but detailed information is readily available in existing publications (Schueler and Brown 2004, SLCO 2009) and at web sites identified in the sidebars in this document section. Coordination with the existing Stormwater Coalition group, a City-County partnership, is also recommended.

Within the Red Butte Creek watershed, future development activities are most likely to affect the areas managed by the University of Utah and VA Medical Center. Meetings should be held regularly with these entities to ensure good communication regarding planned construction projects and ways to reduce the hydrologic impacts of new construction.

Explore Instream Flow Opportunities

This recommended improvement measure involves exploring opportunities to secure and manage water rights for instream flows. As discussed previously, maintenance of summertime base flows is a high-priority issue for stream-side residents. Meetings should be held with the Utah Division of Water Rights (DWRT) to clarify which types of

Internet resources for storm water management:

- www.cwp.org
- www.epa.gov/owow/nps/lid/
- www.stormwatercoalition.org
- www.seattle.gov/UTIL/About_SPU/Drainage_&_Sewer_System/NaturalDrainage_Systems/Natural_Drainage_Overview/index.asp

organizations are eligible to lease water rights for instream flows under recently passed legislation.

In addition to exploring possibilities associated with water rights, measures to increase infiltration and groundwater recharge within the watershed should also be explored. Increased instream flows would enhance riparian corridor aesthetics, water quality, and aquatic habitat conditions.

Increase Public Awareness

Improving conditions within the Red Butte Creek riparian corridor will be a long-term effort that will require continued awareness, interest, and support from stakeholders and the community at-large. To achieve this type of support, public awareness of the Red Butte Creek riparian corridor and its ecological functions will need to increase. Therefore, a public awareness campaign should be implemented. Elements of this campaign could include installation of signs identifying neighborhoods and parks as being within the Red Butte Creek watershed. Signs saying "crossing Red Butte Creek" could also be installed where roads and trails cross the stream.

Currently, the creek is rarely identified on existing maps or signs, and most City residents are not well informed of its location. Many opportunities to increase awareness through signs and interpretive displays exist in locations such as the University of Utah, VA Medical Center, Sunnyside Park, Miller Park, and Bonneville Glen. The interpretive signs currently located within the Red Butte Garden portion of the creek could be used as a model for displays in other stream reaches. Other public awareness efforts could include sponsoring stream cleanups, storm drain stenciling projects, weed pulls, field trips, and educational workshops. Such efforts could be coordinated with existing outreach campaigns such as Salt Lake City's "Water Week" event and the annual Salt Lake Countywide Watershed Symposium.

Permitting Requirements

Depending on the nature of a specific improvement project, permits may be required prior to initiating work in or near the stream channel. Information on the jurisdictions and the requirements of relevant permitting authorities is provided below. Permit requirements are summarized by project type in Table 4.5. Where jurisdictions overlap, separate permits from all relevant agencies are required.

State Stream Alteration

The State of Utah's DWRT administers a stream alteration program through the office of the State Engineer. Under Section 73-3-29 of the Utah Code, authorization is required prior to initiating alterations to the bed or banks of a natural stream channel. The intent of the program is to limit adverse impacts to the natural stream environment and associated natural resources. State jurisdiction generally includes those areas within a distance of two times the bankfull width of the channel, up to a maximum of 30 feet beyond bankfull on either side of the channel. In most cases for streams within the City, the bankfull channel width is roughly equivalent to the AHWL channel width used to establish setback distances under the City's RCO ordinance. Therefore, State stream alteration jurisdiction typically includes the channel itself, RCO Area A, and up to a 5-foot extent of RCO Area B (Figure 1.3). If a project will impact jurisdictional wetlands, a Federal permit from the U.S. Army Corps of Engineers (ACOE) may be required under Section 404 of the Clean Water Act in addition to the State Stream Alteration permit. Where this is the case, the DWRT would typically forward an application to the ACOE and the two agencies would issue separate permits.

County Flood Control

The County's Public Works Department, Engineering and Flood Control Division administers a flood-control permit program under Title 17 of the County code. The focus of the County program is to ensure that activities do not increase

Table 4.5. Summary of permit requirements for recommended types of improvement projects.

	IMPROVEMENT PROJECT	PERMITS REQUIRED[a]				
		State Stream Alteration	County Flood Control	City Riparian Protection - Developed Lots		
				Area A (25 feet)[b]	Area B (50 feet)	Area C (100 feet)
GENERAL PROJECTS	Stream Cleanup (manual)	N	M	N	N	N
	Mechanized Trash Removal	Y1	Y2	Y	Y	Y
	Removal of Invasive Plants	N	Y2	M1	M1	M1
	Revegetation (seed or plantings, no grading)	N	N	N	N	N
	Biotechnical Slope Stabilization	Y1	Y2	Y	Y3	N
	Slope flattening or terracing	Y1	Y2	Y	Y3	N
	Vegetated soil lifts	Y1	Y2	Y	Y3	N
	Vegetated rock revetment	Y1	Y2	Y	Y3	N
	Vegetated modular block retaining wall	Y1	Y2	Y	Y3	N
	Vegetated crib retaining wall	Y1	Y2	Y	Y3	N
	Vegetated gabion basket retaining wall	Y1	Y2	Y	Y3	N
LOCAL PROJECTS	Storm Drain Outlet Protection	Y1	Y2	Y	Y	Y
	Outlet protection using vegetated rock	Y1	Y2	Y	Y	Y
	Vegetated rock-lined swale	Y1	Y2	Y	Y	Y
	Stream Crossings and Culvert Replacement	Y	Y	Y	Y	Y
	Full-span bridge	Y	Y	Y	Y	Y
	Open-bottom box culvert	Y	Y	Y	Y	Y
	Culvert Outlet Protection	Y	Y	Y	Y	Y
	Rock-lined tailwater pool	Y	Y	Y	Y	Y
	Rock step pool	Y	Y	Y	Y	Y
	Stream Daylighting	Y	Y	Y	Y	Y
REACH-SCALE PROJECTS	Grade Control	Y	Y	Y	Y	Y
	Vortex rock weirs	Y	Y	Y	Y	Y
	Constructed rock riffles	Y	Y	Y	Y	Y
	Bank Stabilization	Y	Y	Y	Y	Y
	Toe protection	Y	Y	Y	Y	Y
	Redirective techniques	Y	Y	Y	Y	Y
	Floodplain re-establishment	Y	Y	Y	Y	Y
	Access Control and Trail Stabilization	N	Y2	N	N	N
	Split rail fence	N	Y2	N	N	N
	Access steps	N	Y2	Y	N	N

[a] N = not required, M = may be required, Y = required, Y1 = required if work occurs within two times the bankfull width of the channel, Y2 = required if work occurs within 20 feet of accessible top of channel bank, Y3 = required if work involves heavy equipment, M1 = removal of live, invasive trees greater than 2 inches caliper requires (1) approval by the Salt Lake City Department of Public Utilities and (2) replacement with approved tree species.

[b] On undeveloped land Area A extends to 100 feet.

Internet resources for more detailed permitting information:

- State Stream Alteration: www.waterrights.utah.gov/strmalt/default.asp
- County Flood Control: www.pweng.slco.org/flood/html/permits/permits.html
- City Riparian Protection: www.slcgov.com/Utilities/Stream Study Website/ud_rcs_Ordinance.htm

Common items required in a permit application submittal:

- project location and responsible party information
- narrative project description
- site plan
- design drawings (cross section, plan, profile views)
- hydrologic and hydraulic calculations
- soils and slope steepness data
- channel size and slope data
- scour and rock sizing calculations
- information on proposed BMPs to protect water quality

flooding risk or restrict the County's access to channels for flood-control purposes. The creeks within the City are considered county-wide flood-control facilities and are subject to the County requirements under Title 17. Jurisdiction includes those areas within a distance of 20 feet of the top of the accessible channel bank. The accessible channel bank is defined as the point beyond which slopes become too steep for access by vehicles or equipment. Where a stream channel is bordered by relatively flat surfaces, the accessible channel bank location may be similar to the AHWL, but where the channel is entrenched between steep slopes County jurisdiction may extend well beyond RCO Area A and into Areas B and/or C. Because of this variability, the extent of County jurisdiction should be determined on a site-specific basis.

City Riparian Protection

Salt Lake City's RCO ordinance (Ordinance 62) establishes restrictions and provisions for activities occurring within setback areas extending 25 feet (Area A), 50 feet (Area B), and 100 feet (Area C) from the AHWL (Figure 1.3) of above-ground streams. The intent of the RCO ordinance is to protect and preserve the City's streambed corridors and associated natural resources. The City requires that a Riparian Protection Permit (RPP) be obtained for certain activities occurring within the relevant setback area. The RPP program is administered through the Department of Public Utilities.

Relative Costs of Improvement Projects

Estimated unit cost information for different types of improvement projects is summarized in Table 4.6. These costs are approximate and were obtained from various sources including price estimates from manufacturers, reference documents (Schueler and Brown 2004, SLCO 2009), previous improvement projects designed by BIO-WEST, Utah Department of Transportation bid summaries from 2008 and 2009 (UDOT 2008 and 2009), and DPU engineering staff.

Total costs for implementation of specific projects will be variable depending on project scale and the specific treatment practices involved. Many projects will include a combination of techniques based on the needs of a given site or reach. The unit costs listed in Table 4.6 can be used as a basis from which to develop more complete cost estimates for specific efforts as funding sources, lead entities, and detailed work scopes are defined. It is important to bear in mind that many projects will also involve costs associated with preconstruction planning tasks such as detailed topographic surveys, permits, applications,

Table 4.6. Approximate unit cost information for improvement projects.

	TYPE OF PROJECT	UNIT	UNIT COST [a]	SOURCE OF COST INFORMATION
GENERAL PROJECTS	Removal/control of invasive plants	acre	$600–900	BIO-WEST (2009)
	Revegetation using custom seed mix	acre	$2,000–4,000	BIO-WEST (2009)
	Erosion control blanket	square yard	$2–5	UDOT 2008 and 2009
	Revegetation - live plant stakes	per stake	$2–5	supplier estimate, BIO-WEST (2009)
	Revegetation - 1-gallon containerized plants	per plant	$9–17	UDOT 2009, BIO-WEST (2009)
	Revegetation - 5-gallon containerized plants	per plant	$15–80	UDOT 2009, BIO-WEST (2009)
	Revegetation - 2-inch caliper trees	per plant	$175–325	UDOT 2009, BIO-WEST (2009)
	Slope flattening or terracing	square yard	$3–10	UDOT 2008 and 2009 [b]
	Vegetated soil lifts	linear foot	$30–60	DPU (2009)
	Vegetated rock revetment	linear foot	$50–80	DPU (2009)
	Vegetated modular block retaining wall	linear foot	$120–160	supplier estimate, DPU (2009)
	Vegetated crib retaining wall	linear foot	$250–300	Schueler and Brown 2004
	Vegetated gabion basket retaining wall	linear foot	$70–110	DPU (2009)
LOCAL PROJECTS	Outlet protection using vegetated rock	square yard	$70–120	DPU (2009)
	Vegetated rock-lined swale	linear foot	$60–85	DPU (2009)
	Railroad flatcar bridge (89 feet long x 8.5 feet wide)	each	$50,000–90,000	supplier estimate, BIO-WEST (2009)
	Pre-fabricated truss pedestrian bridge (30 feet long x 6 feet wide)	each	$30,000–100,000	supplier estimate, BIO-WEST (2009)
	Open-bottom box culvert (10–12 feet wide x 4–6 feet high)	linear foot	$2,500–6,500	DPU (2009)
	Rock-lined tailwater pool	cubic yard	$70–120	DPU (2009)
	Rock step pool	each	$2,000–6,000	Schueler and Brown 2004
	Stream daylighting	linear foot	$100–300	Schueler and Brown 2004
REACH PROJECTS	Vortex rock weirs	each	$1200–2100	Schueler and Brown 2004
	Constructed rock riffles	cubic yard	$70–110	DPU (2009)
	A-jacks toe protection	linear foot	$65–85	Schueler and Brown 2004
	Rock toe protection	cubic yard	$70–110	DPU (2009)
	Rock vanes with J-hooks	cubic yard	$150–250	SLCO 2009
	Floodplain re-establishment	cubic yard	$5–20	UDOT 2008 and 2009 [c]
	Split rail fence (minimum 1,500 feet, 10 feet on center)	linear foot	$8–15	supplier estimate, BIO-WEST (2009)
	Access steps	linear foot	$25–75	BIO-WEST (2009)

[a] Unit costs will typically be on the low end of the indicated range for large-scale projects that involve large quantities and on the high end of the range for small-scale projects.

[b] Cost reported for clearing/grubbing and landscape grading.

[c] Cost reported for excavation.

and site-specific design. In addition, most projects will also require expenditures for postconstruction maintenance and monitoring.

Although it is not possible to quantitatively distinguish total costs for the different improvement techniques in a general sense, relative costs can be evaluated qualitatively (Table 4.7). At one end of the spectrum, costs for stream-cleanup and -adoption efforts, which are typically done by volunteers with donated supplies, will be very low. Public awareness, invasive plant removal, revegetation, and mechanized trash-removal efforts can also often incorporate the use of volunteer labor and donations. These types of efforts will typically fall in the low-to-moderate range in terms of relative cost depending on the scale and complexity of the specific effort. Projects involving access control, trail stabilization, and storm drain outlet protection will typically fall in the moderate range. These techniques require preconstruction planning and site-specific design but materials costs will typically be in the moderate range.

Costs for relatively small-scale biotechnical slope-stabilization efforts that are implemented only in areas above the AHWL will also typically be in the moderate range. Biotechnical stabilization projects that involve work within the AHWL will also require toe protection, and possibly grade control, as well as more involved permitting and design work: These will be high-cost efforts. For the same reasons, comprehensive bank-stabilization, grade-control, culvert outlet-protection, and stream-daylighting projects will generally be high in cost. Costs to replace culvert crossings with bridges or box culverts will generally be high to very high, depending on the size of the culvert to be replaced, the size of the specific road or trail crossing, and traffic volume of the affected road or trail.

Different types of improvement practices also vary in terms of the range of potential riparian function benefits they provide (Table 4.7). For example, efforts to increase public awareness and encourage stream adoption will help generate long-term support, commitment, and interest in the Red Butte Creek riparian corridor. This support and commitment, in turn, have the potential to lead to implementation of a variety of improvement measures that could potentially benefit all the identified riparian functions. Other types of projects target a more specific subset of riparian functions. The information provided in Table 4.7 can be used to help guide decisions about the types of projects to pursue based on stakeholders' priorities for different sites and stream reaches within the study area.

Maintenance and Monitoring Considerations

Costs associated with long-term maintenance and monitoring are important to consider when planning, designing, and implementing riparian corridor improvement projects. Maintenance and monitoring considerations for different types of projects are summarized in Table 4.8.

For many of the recommended improvement measures, maintenance costs can be reduced by up-front investments to ensure that projects are initially designed well, implemented at the appropriate scale, and installed correctly. As discussed, many observed problems within the riparian corridor are associated with stabilization efforts that were installed without proper attention to toe protection, grade control, reach-scale hydraulics, natural channel dimension, or bed scour. Lack of attention to these items often results in projects that fail after only a few years—or, worse, projects that cause new stability problems in other nearby channel locations.

For some types of projects such as invasive plant control, access control, or stream-cleanup projects, long-term monitoring and maintenance requirements are inherently relatively high. Because litter, foot/dog traffic,

Table 4.7 Summary of relative project costs and potential riparian function benefits.

IMPROVEMENT PROJECT	APPROXIMATE RELATIVE COST	POTENTIAL RIPARIAN FUNCTION BENEFITS									
		Habitat	Shading and Water - Temperature Control	Aesthetics	Recreation	Floodplain Storage	Connectivity	Organic Matter Inputs	Filtration of Sediments and Pollutants	Streambank Stability	Stormwater Conveyance
Stream Cleanup (manual)	very low	x		x							
Mechanized Trash Removal	low to moderate	x		x					x	x	
Stream Adoption	low	x	x	x	x	x	x	x	x	x	x
Removal of Invasive Plants	low to moderate	x							x	x	
Revegetation with Native Plants	low to moderate	x	x	x		x		x	x	x	
Biotechnical Slope Stabilization	moderate to high	x	x	x		x		x	x	x	
Storm Drain Outlet Protection	moderate	x		x					x	x	x
Culvert Replacement with Bridge or Open-Bottom Box Culvert	high to very high	x		x		x	x			x	x
Culvert Outlet Protection	high			x						x	
Stream Daylighting	high	x		x	x	x	x	x	x		
Grade Control	high	x	x	x		x		x	x	x	
Comprehensive Bank Stabilization	high	x	x	x		x		x	x	x	
Access Control and Trail Stabilization	moderate	x		x	x				x	x	
Manage & Reduce Impervious Surfaces	variable	x		x		x			x	x	x
Explore Instream Flow Opportunities	variable	x		x			x				
Increase Public Awareness	low to moderate	x	x	x	x	x	x	x	x	x	x

Table 4.8. Summary of maintenance and monitoring considerations for various improvement projects.

IMPROVEMENT PROJECT	MONITORING MEASURES	MAINTENANCE MEASURES	NOTES
Stream Cleanup (manual)	Report any observed illegal dumping to authorities	Hold a cleanup event once a year	Areas that receive heavy use may require more frequent cleanups
Mechanized Trash Removal	Inspect once a year; note/photograph/report locations of any new over-sized items; report dumping to authorities	Schedule removals as needed based on monitoring observations	Monitoring could be completed in conjunction with annual stream cleanup event
Removal/ Control of Invasive Plants	Inspect treated areas for control effectiveness 1 month after each treatment; monitor/map invasive plants once every 3 years in conjunction with general riparian vegetation monitoring	Three treatments during year 1; one to three treatments per year during years 2–5; one treatment every 2 years during years 6 and beyond	Invasive plant control cost is approximately $250/acre/treatment
Revegetation with Native Plants	Inspect revegetated areas monthly during first 6 months; inspect twice per growing season during years 2 and 3	If needed, irrigate during initial establishment period; after first growing season replace any dead plants and spot-apply new seed as needed	Based on typical plant mortatily rates, budget for replacement of 25% of initial plantings
Biotechnical Slope Stabilization	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; monitor revegetation success; inspect project after major floods	If needed (following first high flow period), make adjustments/repairs to any "hard" elements (rock etc.) to ensure project is performing as intended; replace dead or dying vegetation as needed	Long-term maintenance typically minimal once vegetation becomes well established [a]
Storm Drain Outlet Protection	Monitor during construction to ensure correct installation; inspect during/after first major storm event following installation; monitor revegetation success	If needed (following post-storm inspection), adjust/repair rock to ensure structure is performing as intended; replace dead or dying vegetation/reseed as needed	Long-term maintenance typically minimal once vegetation becomes well established; may need maintenance when storm drain pipe reaches end of life span and is replaced
Culvert Replacement with Bridge or Open-Bottom Box Culvert	Monitor during construction to ensure correct installation; inspect during/after first high flow period following installation; throughout life of structure inspect periodically and after major floods for channel stability and for signs of structural degradation	Repair channel stabilization treatments in vicinity of structure as needed/relevant; replace the bridge or box culvert at the end of its life span (estimated at approximately 35–65 years)	Because they are more efficient at passing debris and sediment, these wide-span crossing structures should require significantly less maintenance during high flow periods than existing smaller-diameter culvert pipes
Culvert Outlet Protection	Monitor during construction to ensure correct installation; inspect during/after first high flow period following installation; monitor revegetation; inspect outlet and inlet for stability after major floods	If needed (following first high flow), adjust/repair rock to ensure structure is performing as intended; replace dead or dying vegetation/ re-seed as needed; culvert inlet will still require ongoing maintenance to remove debris etc.	Outlet protection may need maintenance/ replacement when culvert pipe reaches end of life span and is replaced
Grade Control	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; inspect after major floods	If needed (following first high flow period), adjust/repair to ensure structure is performing as intended	No special long-term maintenance typically required [a]
Comprehensive Bank Stabilization	Monitor during construction to ensure correct installation; inspect during and after first high flow period following installation; monitor revegetation success; inspect project after major floods	If needed (following first high flow period), make adjustments/repairs to any "hard" elements (rock etc.) to ensure project is performing as intended; replace dead or dying vegetation as needed	Long-term maintenance typically minimal once vegetation becomes well established [a]
Access Control Fencing	Monitor monthly for damage/vandalism during first year following installation; inspect twice a year during following years	Repair as needed based on monitoring observations; add deterrents such as brush barriers, signs, etc. as needed in chronic problem areas	Budget additional $1/linear foot/year for expected repair costs; more in highest-use areas

[a] Major floods on the order of 100-year recurrence interval events may result in channel changes that may require maintenance or re-installation of stabilization measures.

and invasive plant problems are chronic/ongoing by nature, they cannot be fixed through a one-time investment alone. Stream reaches affected by these issues require vigilance and regular maintenance; without follow-up, any benefits from a one-time effort will likely be short-lived despite high initial investment. Invasive plant control projects, in particular, should not be implemented unless plans are in place to insure that funding and labor will be available for needed long-term maintenance.

Grant Resources for Funding Improvement Projects

Implementing the recommended riparian corridor improvement projects will require significant financial investment. A variety of resources for financial assistance via grants and loans are available from Federal, State, and private sources. Information on specific relevant funding programs is summarized in Table 4.9.

Table 4.9. Information on funding programs to support riparian corridor improvement projects.

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Five Star Restoration Grant	EPA [b]	grants for collaborative community-based riparian, coastal, or wetland restoration projects	partnership of government, nonprofit, academic, private, and community interests	mid February	\$5,000–\$20,000	66.462	www.epa.gov/wetlands/restore/5star/ *Emphasis on collaborative efforts with educational, training, and scientific merit.*
State Revolving Fund/American Recovery and Reinvestment Act	Utah DWQ [c]	Federal stimulus funds to address demonstrated water quality needs	open	June 1	\$4 million total available	N/A	Shelly Andrews, Leah Ann Lamb, or Ed Macauley: 801-538-6146 www.waterquality.utah.gov/stimulus/ *Project must address demonstrated water quality need in nonpoint source pollution, water or energy efficiency, or green infrastructure/environmental innovation.*
Financial Assistance Program	Utah DWQ [c]	grants and 0% and low-interest loans for projects to address water quality needs, provide environmental education, and improve water resources	open	none	\$20 million total available	N/A	801-538-6146 www.waterquality.utah.gov/FinAst/NPSFinAid.htm *Eligible projects include runoff reduction, water-resource conservation, groundwater quality, water quality, nonpoint source pollution prevention, and environmental education.*

Table 4.9. Information on funding programs to support riparian corridor improvement projects (cont.).

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Project Assistance Program	Utah DWQ [c]	collaboration and funding for water quality improvement projects through grants and low-interest loans	community	none	variable	N/A	801-538-6146 www.waterquality.utah.gov/FinAst/Comgd1.htm *Project must result in a water quality benefit. Stream bank restoration projects are eligible.*
ACORN Foundation Grant	ACORN Foundation	grants for community-based projects to preserve and restore habitats, advocate for environmental justice, or prevent/remedy pollution	nonprofit grassroots organizations working in low-to-moderate-income communities	January 15, June 15	$5,000–$10,000	N/A	510-834-2995 grantsadmin@commoncounsel.org www.commoncounsel.org/Acorn%20Foundation *Letters of inquiry are accepted but full applications are by invitation only. Projects require a strong community focus, especially low-to-moderate income and leadership development.*
Blue Water Community Action Grant	Royal Bank of Canada	grants for nonprofit grassroots initiatives (including municipalities) for watershed protection and drinking water access	nonprofit 501c(3) organizations	March 6 (rolling)	$1,000–$5,000	N/A	www.rbc.com/donations/blue-water.html *Project must be involved in watershed protection or drinking water access. Online applications are available.*
Riverway Enhancement Grant	Utah DPR [d]	grants for the enhancement of river and stream corridors, including recreation and flood control	cities, counties, and special-service districts	May 1 (annually)	$50,000–$100,000 (50% matching)	N/A	Lyle Bennett: 801-538-7354 www.governor.state.ut.us/rplr/rdcc/2001webfolders/dnr/riverway-enhanc.pdf *While use of assistance may only include river and stream corridors prone to flooding, it may include a variety of outdoor recreation development.*
Nonpoint Source Implementation (Clear Water Act Section 319) Grant	Utah DWQ [c]	funding to address nonpoint source pollution	state and tribal agencies and municipalities	variable	variable (typical range $30,000–$50,000)	66.460	Michael Reichert: 801-538-6954 www.epa.gov/owow/funding.html
Watershed Protection and Flood Prevention/ Small Watershed Protection Program	NRCS [e]	technical and financial assistance to help communities protect, improve, and develop land and water resources in watersheds	any entity with state authority to carry out, maintain, and operate proposed improvement, including nonprofit groups	none	$650,000 average total amount available per state	10.904	Norm Evenstad: 801-524-4550 www.ut.nrcs.usda.gov/programs/pl566.html *Eligible projects include flood prevention, public recreation, groundwater recharge, and watershed protection.*
Plant Materials for Conservation	NRCS [e]	provision of (1) plant materials for use in restoration and (2) breeder stock and seed for use by commercial growers	cooperating state and Federal agencies and commercial growers	none	plant materials	10.905	NRCS [e] office: 801-524-4550 *Emphasis on field-testing and plant-material technology*

Table 4.9. Information on funding programs to support riparian corridor improvement projects (cont.).

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
Watershed Surveys and Planning	NRCS [e]	technical and advisory assistance for watershed planning	open (includes nonprofit organizations, private entities may not be eligible)	none	technical and advisory assistance	10.906	NRCS [e] State Conservationist Sylvia Gillen: 801-524-4551 sylvia.gillen@ut.usda.gov www.ut.nrcs.usda.gov
Wildlife Habitat Incentive Program	NRCS [e]	assistance for protection, restoration, development, or enhancement of habitat for wildlife, threatened and endangered species, and fisheries, as well as other types of wildlife	landowners meeting highly erodible land/wetland conservation and adjusted gross income requirements	none	5–10 year cost share (NRCS [e] 75%)	10.914	www.ut.nrcs.usda.gov Tooele Service Center: 435-882-2276 *Apply at a local USDA [f] service center or location found at www.sc.egov.usda.gov. (Form NRCS-CPA-1200). Applicant must remain in control of land for duration of assistance contract.*
Fish, Wildlife, and Plant Conservation Management	BLM [g]	grants for fish, wildlife, and plant conservation on BLM [g] lands and other public or private lands	open	1 fiscal year prior to need	$1,000–$100,000 (average award less than $10,000)	15.231	801-539-4001 www.blm.gov/ut/st/en.html *Cost match increases likelihood of an award.*
Wildlife Restoration	FWS [h]	Federal aid for a broad range of activities to restore, conserve, manage, or enhance wild bird and mammal populations and support public use of these resources	state agencies with lead fish and wildlife management responsibilities	none (30-day processing)	$2,750,000 average award	15.611	wsfrprograms.fws.gov/subpages/toolkitfiles/toolkit.pdf *Funds dispensed only to state wildlife agencies; requires legislation prohibiting use of hunting fees for nonhunting agency purposes.*
North American Wetlands Conservation Fund	FWS [h]	funding for acquisition and management, enhancement, and restoration of wetlands	public or private organizations with wetland conservation projects in Canada, the United States of America, and Mexico	March and July	up to $75,000 (small); $75,000–$1 million (standard) (requires 1:1 non Federal match)	15.623	www.fws.gov/birdhabitat/Grants/NAWCA
Wildlife Conservation and Restoration	FWS [h]	aid to states for efforts to benefit wildlife and habitat	state agencies with lead fish and wildlife management responsibilities	none	$904,000 average award	15.625	wsfrprograms.fws.gov/subpages/toolkitfiles/toolkit.pdf *Includes projects to benefit species that are not hunted or fished.*
Partners for Fish and Wildlife	FWS [h]	assistance for restoration and improvement of habitat	private landowners, local government entities, and nongovernmental organizations	none	$200–$25,000 (average $5,400); seeks 50% cost share	15.631	www.fws.gov/partners *Project must be located on private land, including lands held by individuals, local governments, nongovernmental organizations, and tribes.*
Challenge Cost Share	FWS [h]	grants for projects that encourage partnerships with non-FWS [h] groups for conservation, protection, and enhancement of fish, wildlife, and plants	open	variable by region	$300–$25,000 (average $7,800); requires 50% non Federal match	15.642	801-975-3330 *Submit proposals to a cooperating service office.*

Table 4.9. **Information on funding programs to support riparian corridor improvement projects (cont.).**

PROGRAM NAME	AWARDING ENTITY	DESCRIPTION	AVAILABILITY	DEADLINE	AWARD AMOUNT	CFDA [a] NUMBER	CONTACT INFORMATION, WEBSITE, AND NOTES
National Wetland Program Development Grant	EPA [b]	grants to help build programs to protect, manage, and restore wetlands	nongovernmental organizations, interstate agencies, and intertribal consortia	contact for information	$25,000–$225,000 per fiscal year	66.462	www.epa.gov/owow/wetlands/initiative/#financial *Priority areas are monitoring/assessment, improving wetland mitigation effectiveness, and refining protection of vulnerable wetlands and aquatic resources.*
Water Quality Cooperative Agreement	EPA [b]	grants for innovative efforts related to prevention, reduction, and elimination of water pollution	open (may exclude businesses, but open to individuals)	proposal requests	$15,000–$270,000	66.463	requests for proposals: https://www.grants.gov *Funding priorities include storm water control for targeted watersheds and urban wet weather watershed protection.*
Targeted Watershed Grant	EPA [b]	grants to support innovative community-based watershed approaches aimed at reducing water pollution	excludes for-profit enterprises, Federal agencies, and lobbying groups	variable (contact EPA [b])	$100,000–$1,000,000; requires 25% non Federal match	66.439	Eric Steinhaus: 303-312-6837 steinhaus.eric@epa.gov www.epa.gov/twg *Emphasis on monitoring, outreach/education, and demonstration of tangible environmental improvement.*
Patagonia Environmental Grant	Patagonia	grants to support action-oriented efforts to address root causes of environmental problems and protect local habitat	nonprofit 501c(3) organizations	contact for information	$3,000–$8,000 (typical)	N/A	www.patagonia.com/web/us/patagonia.go?slc=en_US&sct=US&assetid=2942 *Contact local retail store. Emphasis on measurable goals and objectives.*
Community Forestry Partnership Grant	Utah FFSL [i]	funding to support urban and community forestry projects	open	September 14, 2009	$1,000–$5,000; requires 1:1 match	N/A	Meredith Perkins: 801-538-5505 www.ffsl.utah.gov/grants/grants.php#urbangrants *Cities must achieve Tree City USA status to be eligible.*

[a] Catalog of Federal Domestic Assistance.
[b] U.S. Environmental Protection Agency.
[c] Division of Water Quality.
[d] Division of Parks and Recreation.
[e] Natural Resources Conservation Service.
[f] U.S. Department of Agriculture.
[g] U.S. Bureau of Land Management.
[h] U.S. Fish and Wildlife Service.
[i] Division of Forestry, Fire, and State Lands.

5.0 RIPARIAN CORRIDOR VISION

Summary of Stakeholder Input

This section provides a summary of the input received during public outreach activities throughout the 12-month planning process. Because the RCS public outreach activities centered around a series of four public workshops, the input received is summarized below according to public workshop.

Public Workshop 1

During the first public workshop, much of the input received focused on questions and concerns regarding the Riparian Corridor Overlay Ordinance that was enacted by the City. A number of residents complained about the regulations being too onerous and not allowing for enough individual site variance. Property owners were very concerned about the continuing loss of streambank area to erosion and the threat to individual property improvements from streambank instability. Residents are keenly aware of erosion problems associated with storm drain outfalls and stream culverts, and they are concerned about water quality issues. Concerns about reasonable use of private property and the privacy of residents were also expressed by those who attended. Workshop attendees also asked questions about the cost of the RCS study, the funding for the study, the composition of the RCS subcommittee, and whether the study will result in changes to the RCO ordinance.

Residents also provided a number of suggestions for consideration in the RCS management plan. These included suggestions for specific restoration projects, as well as requests for information on how to implement them on individual properties. A number of participants recommended that water rights be obtained to help maintain stream flow throughout the year. Residents were encouraged to provide permission for project team members to access private property along the creek.

The following is a summary of the questions asked and the responses received on the workshop response forms that were distributed at the first public workshop.

What Riparian Corridor Functions Are Important To You?

- Streambank stability
- Wildlife habitat
- Aesthetics
- Water quality
- Control of my own property

What Concerns Do You Have For The Riparian Corridor?

- Streambank erosion
- Storm water affecting water quality
- Reasonable use of my property
- Trespassing
- Debris blockages

What Suggestions Do You Have For Restoration?

- Redesign of storm drains
- Revegetation of streambanks
- Maintain water in stream channel
- Install signage to reduce trespass
- Educate property owners on solutions

Public Workshop 2

During the second public workshop there were a number of questions regarding what data were collected and how (e.g., wildlife use, water quality, and vegetation). Participants suggested that information on firewise landscaping, vegetation management, where to find native plants, control of nuisance wildlife species (racoons, rats, etc.), and ecosystem services be included in the management plan. Participants also asked questions specific to their individual property and whether project team members could help make recommendations for fixing specific problems. Other questions related to revisions to the Riparian Corridor Overlay Ordinance, the effects of Red Butte Dam, participation by the University of Utah in the study, instream flows, and public access to the riparian corridor.

The following is a summary of the questions asked and the responses received on the workshop response forms that were distributed at the second public workshop.

The Red Butte Creek riparian corridor is . . .

- a place for migratory birds and other creatures
- a vital component of our community providing us with ecosystem services and allowing nature to exist within our City
- very important and is worth devoting time, effort, resources and money to help preserve and improve
- a valuable natural ecosystem that sustains birds, fish, wildlife, and vegetation with opportunities for recreation and open space places within our City
- great to have above-ground water in the City

We envision a riparian corridor that . . .

- is thick with native plants, has clean water, provides nesting areas
- is clean, pastoral, and reflects a native vegetation oasis in the City
- serves the community and environment with an appropriate balance
- is something that attracts and supports wildlife
- has clean water, trees, wildlife, flood control

Together, we value the following riparian corridor functions:

- habitat
- a green zone, peaceful, quiet, natural
- clean water, trees, wildlife, flood control

Public Workshop 3

During the third public workshop, participants requested that information be included in the management plan that identifies native plants to use, where to buy them, and how much they may cost. Some concerns were expressed for how to deal with those segments of Red Butte Creek where there is limited floodplain because of the deep, incised stream channel and vertical streambanks. Participants also asked questions about the potential effects of climate change on the riparian corridor, invasive species control measures, off-leash dog concerns, and where funding would come from and how projects would be prioritized.

Suggestions that were provided by participants at the third public workshop included working with volunteer organizations on clean up projects, engaging forestry and wildlife agencies in specific rehabilitation projects, improving access opportunities within the publicly owned portions of the corridor upstream of Sunnyside Avenue, and making specific changes to the draft vision statement. Participants also expressed frustration with the University of Utah and the VA Medical Center for problems along Red Butte Creek under their management control. One workshop participant suggested that the City may be able to improve their public relations by going door to door to meet one-on-one with residents and discuss riparian corridor issues and solutions. This technique has been successfully used by agencies such as the Natural Resources Conservation Service to establish cooperative relationships with private landowners in rural areas and improve stream conditions.

Public Workshop 4

During the final public workshop, participants asked questions regarding the costs for recommended projects and how they would be funded. Concerns were expressed about the degradation of downstream riparian corridor functions caused by development projects that are being implemented on larger properties in the upper portion of the study area (e.g., Veteran's Administration and the University of Utah). Several workshop participants expressed interest in seeing greater involvement by these entities in the RCS planning process, recognizing that what happens on their lands affects those who live downstream. One suggested that Red Butte Garden should play a more active role in the implementation of recommended projects throughout the riparian corridor because they have expertise in the areas of weed control and native plant restoration.

During public workshop 4, maps of individual stream reaches were posted around the room. Participants with interest in specific reaches were asked to review the relevant maps and provide reach-specific input on comment forms attached to the maps. The comment forms asked the question "What riparian functions, values, or improvement projects do you think are high priority within this stream reach specifically?" Input gathered during this exercise is included in Appendix C, which also provides maps, data, and recommendations for individual stream reaches.

Meetings with University of Utah and VA Medical Center

Because both the University of Utah and VA Medical Center manage large portions of Red Butte Creek within the RCS study area, specific meetings were held to facilitate their input into the management planning process. DPU and BIO-WEST met with University of Utah facilities management staff as well as Red Butte Garden staff on June 22, 2009. As a state government entity, the University is not legally required to follow the requirements of the City's RCO ordinance. However, staff expressed an interest in the RCS study and in potential opportunities to collaborate with the City on improvement projects. Red Butte Garden indicated particular interest in opportunities to coordinate on grant applications for projects with educational or interpretive components. At this time, the University of Utah does not have an administrative structure that would allow them to actively pursue riparian corridor improvement projects. Currently, no specific plan is in place to guide or manage uses and practices within the riparian corridor portions of the University campus. University staff did indicate that they recently made improvements to a maintenance and storage facility adjacent to the creek.

BIO-WEST and DPU met with VA Medical Center staff on September 29, 2009. As a federal entity, the VA Medical Center is not legally required to follow the requirements of the City's RCO ordinance. However, staff expressed interest in the RCS project and recognize the creek as a potential amenity for VA patients and employees. In addition to the federal VA, the Utah State Veteran's Nursing Home and the Boyer Company also manage portions of the riparian corridor between Foothill Drive and Sunnyside Park. There is currently no specific plan in place to guide or manage the riparian corridor in this area. Years ago some preliminary work was done on a potential trails plan to facilitate commuting through the corridor by bicycle or by foot, but because of the challenges associated with steep slopes, tight infrastructure, and security concerns no trails have been developed. Recently, the VA has upgraded their storm drain system such that much of

Red Butte Creek vision statement:

The Red Butte Creek riparian corridor is a highly valued and unique natural resource in Salt Lake City that provides a refuge from the urban environment for people, plants, and wildlife. Our community appreciates the corridor for its relaxing and peaceful atmosphere, as well as for the visual and auditory benefits of the riparian area and free-flowing stream. Through on-going cooperative efforts, the riparian ecosystem is restored to the extent possible and provides many of the functions of a healthy natural ecosystem including wildlife habitat, aesthetic, water quality, and educational benefits.

To reach this vision, the following riparian corridor functions must be realized:

- *A well-connected vegetative corridor provides a diverse habitat for native wildlife and migrating bird species*
- *Healthy, mature vegetation provides a canopy to cool air and water temperatures; mid level vegetation and ground cover allow for diverse wildlife habitat, erosion control, and filtration of sediment and pollutants*
- *An uninterrupted flow of clean, clear water supports a healthy cold water fishery in the naturally perennial segments of the creek*
- *Streambanks are stable but allow for natural stream dynamics within acceptable limits for property owners*
- *The stream is recognized as a valuable asset by the community, with trash or debris and noxious weeds kept out of the streambed and riparian corridor*
- *Public open space compliments the riparian corridor while allowing for accessible enjoyment of the stream environment by city residents*
- *Storm water conveyances are upgraded to improve stream stability and water quality*
- *Culverts along the stream are replaced to reduce stream channel constrictions, provide energy dissipation, and improve streambed and streambank stability*

These goals will be achieved with cooperation between the City and the community, with property owners being given significant opportunities for input on rehabilitation projects. Accomplishment of projects will depend on their prioritization and available funding. Grant funding opportunities for implementation of rehabilitation projects will be pursued through collaborations between the City, community members, property owners, and agency stakeholders. Improvement measures will use progressive approaches and the best available science.

the runoff from the complex is now primarily routed to an off-stream detention basin rather than discharging directly into Red Butte Creek. The VA staff also explained that they frequently receive inquiries from boy scouts about possible Eagle Scout projects, and indicated a willingness to direct scouts to some of the projects recommended in the RCS management plan.

Red Butte Creek Riparian Corridor Vision Statement

Stakeholder input was used to develop a vision statement for the Red Butte Creek riparian corridor. The vision statement uses introductory text that describes the desired future condition of the corridor, followed by supporting text that identifies more specific targets and objectives. The closing text of the vision statement provides general guidance on how to achieve the desired future condition for the corridor.

Riparian Corridor Priorities

As evident from the input received during the RCS stakeholder outreach efforts, there is broad interest in the Red Butte Creek corridor and the various different riparian functions it provides. Three specific functions that stakeholders frequently identified as being important were habitat for wildlife and birds, water quality (including instream flows), and streambank stability. Projects that enhance these riparian functions and resources are likely to be broadly supported by the community and should be considered high priority for implementation. Additional studies to learn more about wildlife use of the corridor and water-quality conditions would also be of interest to stakeholders.

Residential property owners within the portions of Red Butte Creek downstream of Sunnyside Avenue would also be likely to support corridor improvement projects within the stream reaches above Sunnyside Avenue. Measures to improve water quality and reduce erosive flow velocities would be of particular interest, as downstream residents expressed concern that they "inherit" water quality and flow problems from the areas upstream. At the RCS workshops, some attendees emphasized that issues and opportunities are different in the reaches upstream of Sunnyside Avenue than in downstream reaches, and implementation approaches and priorities should vary accordingly.

Priorities for funding and implementing improvement projects will vary depending on perspective, scale, and anticipated implementation approach. For example, in a stream reach that currently is in good condition except for the presence of a small amount of trash, stream cleanup may be the highest-priority project for the reach. However, when considered from the perspective of the entire riparian corridor, other reaches that have more substantial trash problems may be higher-priority areas for stream cleanup efforts.

In Table 5.1 relevant improvement projects are summarized by reach, and relative needs are identified by project type from the perspective of the entire riparian corridor. For example, baseline assessment results suggest that some of the worst invasive species problems in the corridor occur in reaches LRB_R04C, LRB_R05A, and LRB_R07. Therefore, these reaches are identified as the highest-need reaches for implementation of invasive plant removal measures (Table 5.1). As another example, reaches LRB_R04A and LRB_R05A were identified as having the most significant amounts of over-sized, heavy litter items; hence, these reaches are noted as the highest-need reaches for mechanized trash removal efforts within the corridor. Similar guidance regarding corridor-scale priorities for culvert-replacement projects is provided in Table 5.2. If funding were to become available for a specific type of improvement measure (e.g., storm drain outlet improvements), the information in Tables 5.1 and 5.2 could be used to help decide where within the corridor to focus efforts.

In some cases support and funding for improvement efforts may develop for a specific stream reach or property within the riparian corridor. In these cases information about reach-specific priorities and needs will be necessary to help guide project choices. Toward this end, the information gathered during the baseline assessment and stakeholder outreach activities was used to identify recommendation lists for improvement efforts for individual stream reaches. Constraints and opportunities unique to individual reaches were also defined. Where stakeholders provided reach-specific input, their priorities for those stream reaches were also summarized. This reach-specific information is provided in Appendix C. Cost estimates for reach-specific recommendations are provided in Appendix D.

Riparian Enhancement Potential

An important consideration when selecting projects for implementation is the potential for a given study reach to fully meet certain riparian enhancement functions or objectives. This "riparian enhancement potential" varies depending on the position of the reach in the watershed, the extent of infrastructure development adjacent to the

Table 5.1. Relative need for various improvement measures by reach. [a]

REACH NUMBER	REACH DESCRIPTION	IMPROVEMENT MEASURE										
		Stream Cleanup - hand	Mechanized Trash Removal	Invasive Plant Removal	Revegetation - Canopy	Revegetation - Shrub	Revegetation - Understory	Restoration of Native Understory Plants	Storm Drain Improvement	Grade Control	Bank Stabilization	Access Control/ Trail Stabilization
URB_R09	Upper Red Butte Garden	-	low-medium	low-medium	-	-	-	-	-	low	low	low
LRB_R01	Lower Red Butte Garden	low	-	-	-	-	-	-	-	-	-	-
LRB_R02	University - Below Red Butte Garden	low	low	low	-	high	high	-	-	-	high	high
LRB_R03	University - Above Chipeta Way	-	-	low	medium	-	low	-	-	medium	medium	-
LRB_R04A	University - Below Chipeta Way	high	high	medium	medium	-	-	-	medium	low	medium	-
LRB_R04B	University - Near Tennis Courts	-	-	-	-	-	medium	-	high	medium	medium	-
LRB_R04C	University - Above Foothill Drive	medium	medium	high	high	low	low	medium	medium	medium	medium	-
LRB_R05A	VA Medical Center - Below Foothill Drive	low	high	high	-	high	low	-	-	medium	high	-
LRB_R05B	VA Medical Center - Above Sunnyside Park	-	-	low-medium	-	medium	medium	-	medium	medium	medium	-
LRB_R05C	Sunnyside Park	-	-	medium-high	-	low	high	medium	-	medium-high	medium	medium
LRB_R07	Miller Park/Bonneville Glen	low	low-medium	high	-	medium	low	high	-	high	high	high

[a] Relative needs are identified from the perspective of the entire riparian corridor; e.g., the highest-need reaches for stream cleanup are those assessed as having the worst trash problems in the corridor.

reach, and the frequency/ proximity of road crossings or other features that interrupt longitudinal connectivity. Projects intended to enhance the riparian functions of wildlife habitat, floodplain storage, travel corridors/ connectivity, water quality, or streambank stability will typically be the most effective and provide the greatest benefit-to-cost ratio when they are implemented in reaches with high riparian enhancement potential.

One important factor affecting riparian enhancement potential is impervious cover percentage. As discussed in Chapter 3, the conversion of watershed area to impervious surfaces results in reduced groundwater infiltration and increased, more rapid surface runoff. These changes tend to cause increased erosion, degraded water quality, and reduced baseflow. Impervious cover is commonly used as an index of the extent of urban

Table 5.2. **Relative needs for stream crossing culvert replacement and improvement projects within the Red Butte Creek riparian corridor.**

CROSSING LOCATION/ DESCRIPTION	REACH NUMBER(S)	APPROXIMATE CULVERT LENGTH (feet)	RELATIVE NEED FOR IMPROVEMENT	PREFERRED TYPE OF IMPROVEMENT	ALTERNATIVE TYPE OF IMPROVEMENT
Trail at south end of Red Butte Garden	between LRB_R01 and LRB_R02	50	low	replace with full-span prefabricated bridge	-
Chipeta Way	between LRB_R03 and LRB_R04A	108	low	replace with bridge or open-bottom box culvert	-
Crossing near tennis courts	between LRB_R04A and LRB_R04B	90	medium	remove	replace with open-bottom box culvert
Crossing near Marriot	between LRB_R04B and LRB_R04C	72	medium	remove	replace with open-bottom box culvert
Foothill Drive	between LRB_R04C and LRB_R05A	192	high	replace with open-bottom box culvert	install outlet protection and stabilize fill slopes
Hall Street	between LRB_R05A and LRB_R05B	128	medium	replace with bridge or open-bottom box culvert	install outlet protection and stabilize fill slopes
Crossing within VA Medical Center complex	near downstream end of LRB_R05B	20	high	remove	replace with open-bottom box culvert
Sunnyside Avenue	between LRB_R05C and LRB_R06	180	low [a]	replace with open-bottom box culvert	-
900 South	between LRB_R06 and LRB_R07	210	medium-high [b]	replace with open-bottom box culvert	install outlet protection
Trail in Miller Park	middle of LRB_R07	16	no improvements needed	-	-
1500 East	between LRB_R07 and LRB_R08	400	low [a]	replace with open-bottom box culvert	explore potential to daylight portion under parking lot
1300 East	between LRB_R09 and LRB_R10	260	unknown [a b]	replace with open-bottom box culvert	-
1100 East	between LRB_R10 and LRB_R11	90	no improvements recommended	-	-

[a] Outlet condition not assessed.
[b] Inlet condition not assessed

development and as a predictor of stream health (Schueler and Brown 2004). Within the Red Butte Creek RCS study area, the relative amount of impervious cover increases with distance downstream as the creek exits the less-developed canyon area and flows through the urbanized city. Therefore, the relative hydrologic integrity of the stream is greatest within upstream reaches and lowest at the downstream end of the study area (Table 5.3). Another advantage of project implementation within upstream reaches is that many project benefits (e.g., water quality, floodplain storage, streambank stability, invasive species removal) translate into downstream improvements well beyond the localized implementation area.

Table 5.3. **Factors affecting relative riparian enhancement potential by reach. (table key : + = high relative to other study reaches; o = average relative to other study reaches, – = low relative to other study reaches).**

REACH NUMBER	REACH DESCRIPTION	FACTORS AFFECTING RIPARIAN ENHANCEMENT POTENTIAL		
		Relative Hydrologic Integrity [a]	Relative Extent of Undeveloped Corridor Width [b]	Relative Longitudinal Integrity/ Connectivity [c]
URB_R09	Upper Red Butte Garden	+	+	+
URB_R10	Middle Red Butte Garden	+	–	– [d]
LRB_R01	Lower Red Butte Garden	+	o	–
LRB_R02	University - Below Red Butte Garden	+	–	+
LRB_R03	University - Above Chipeta Way	+	+	+
LRB_R04A	University - Below Chipeta Way	+	–	o
LRB_R04B	University - Near Tennis Courts	o	o	–
LRB_R04C	University - Above Foothill Drive	o	+	o
LRB_R05A	VA Medical Center - Below Foothill Drive	o	+	–
LRB_R05B	VA Medical Center - Above Sunnyside Park	o	–	o
LRB_R05C	Sunnyside Park	o	+	o
LRB_R06	Sunnyside Avenue to 900 South	–	–	– [d]
LRB_R07	Miller Park/ Bonneville Glen	–	o	+
LRB_R08	Below 1500 East	–	+	+ [d]
LRB_R09	Above 1300 E ast	–	+	+ [d]
LRB_R10	1300 East to 1100 East	–	–	o [d]
LRB_R11	Below 1100 East	–	o	– [d]

[a] Qualitatively assessed based on relative percentage of impervious cover within contributing drainage area for each Red Butte Creek study reach.
[b] Qualitatively assessed based on relative amount of existing infrastructure within 50 and 100 feet of the annual high water level on at least one streambank; see infrastructure tables in Appendix C.
[c] Qualitatively assessed based on relative length of uninterrupted channel connected to the reach.
[d] Reach not fully assessed.

Another factor affecting riparian enhancement potential is the lateral extent of undeveloped corridor width. In some study reaches, infrastructure has been built very close to the streambanks, limiting the width of the naturally-vegetated riparian corridor. Reaches tightly confined by infrastructure will have relatively limited potential for floodplain re-establishment, floodplain storage, or natural channel migration. The overall area of high quality habitat for riparian-dependent wildlife and bird species will also be limited relative to study reaches with wider undeveloped corridor widths. Improvement projects focused on enhancing these types of riparian functions will tend to be most effective in reaches with minimal infrastructure constraints. Reaches assessed as having relatively wide undeveloped corridor widths (Table 5.3) should be protected from future development to the extent possible.

Longitudinal integrity also influences riparian enhancement potential within the Red Butte Creek corridor. Existing stream crossing culverts create barriers that interrupt the free migration of wildlife and fish through the riparian corridor. Therefore, reaches with short channel lengths between culverts will have lower habitat potential than reaches that are connected to long sections of uninterrupted channel. Well-connected reaches also have greater potential in terms of the riparian functions associated with transport and storage of woody debris, nutrients, and organic matter. The longitudinal connectivity of some reaches can be improved by replacing culverts with wider-span structures that allow unrestricted passage of wildlife, fish, woody debris, sediment, and organic matter.

The factors affecting riparian enhancement potential for the different study reaches are summarized in Table 5.3. This information can be used to help guide decisions regarding improvement efforts in hopes of achieving the greatest relative benefit for a given implementation investment. However, significant and important benefits can be achieved even in study reaches rated as having relatively low enhancement potential. The rankings in Table 5.3 should be used as just one piece of information along with other factors such as community interest and support, funding availability, and relative project need (Table 5.1) when selecting efforts for implementation.

Implementation Approaches

Implementation of the recommended riparian corridor improvement projects will be a long-term effort that will require continued awareness, interest, and support from stakeholders and the community. It will also require significant financial investment. As described in the vision statement, the intent is to pursue funding through collaborations between the City, community members, property owners, and agency stakeholders.

To help guide, coordinate, and support the long-term implementation of enhancement efforts, the establishment of Red Butte Creek riparian corridor working group or watershed committee is recommended. Ideally, membership in this working group would include representatives from the City, as well as State, County, and federal government entities, local property owners and community residents, and nonprofit environmental groups. The working group could be a forum for continued involvement by interested members of the existing RCS Subcommittee and RCS workshop attendees.

Because of the mix of property ownership within the Red Butte Creek corridor, it will not be possible to achieve the riparian corridor vision statement objectives through a purely top-down, government-driven approach. Some projects will likely evolve from residents joining together around shared interests. An established riparian corridor working group or watershed committee would be helpful in facilitating such community-driven efforts by serving as a clearinghouse for the sharing of technical information and providing technical resources to help obtain and administer grant funds.

One local example of a successful "working group" approach to achieving watershed enhancement goals is the East Canyon Watershed Committee (www.eastcanyoncreek.org). This committee consists of a group of stakeholders interested in the health of East Canyon Creek and its watershed. The group has been in existence for more than 10 years and includes representatives from State, County, municipal, and regional government entities, local property owners and community residents, nonprofit environmental groups, and the Snyderville Basin Water Reclamation District. The committee essentially functions as an "umbrella" organization to help coordinate, facilitate, support, and guide improvement efforts, and also provides an information-sharing forum. The East Canyon Watershed Committee has successfully guided and coordinated a wide variety of watershed and stream improvement efforts, including several recent streambank stabilization projects. Grant funds from a number of sources (Nonpoint Source Implementation [Clean Water Act Section 319] Grant Program, Natural Resources Conservation Service (NRCS) Wildlife Habitat Incentive Program, and Environmental Protection Agency Water Quality Cooperative Agreement program [Clean Water Act Section 104 (b)(3)]) have supported their efforts. The East Canyon Watershed Committee currently includes education, monitoring, and stream restoration working groups that focus on projects addressing those specific issues.

Another example of an established working group is the Jordan River Watershed Council (www.waterresources.slco.org/html/jwrc/jrwc.html). This group also consists of a broad mix of stakeholders, and the Jordan River Watershed Council has helped coordinate riparian enhancement efforts along the Jordan River. It may be possible to establish an Red Butte Creek-specific subgroup as a component of this council. The results of the on-going Jordan River Total Maximum Daily Load project may also spur interest in improvement projects on tributary streams that would provide water quality benefits.

Certain riparian corridor improvement efforts could be modeled on existing partnering approaches that have proven successful. For example, each spring Salt Lake City partners with the Bonneville Cooperative Weed Management Area (CWMA) and environmental groups to encourage volunteers to participate in weed pulling efforts in the City Creek watershed. A similar approach could be used to implement invasive plant removal projects within the Red Butte Creek riparian corridor.

Native plant exchanges are another partnering approach that could be applied to the Red Butte Creek corridor. For the past several years, the Salt Lake County weed control program has worked with the Utah Native Plant Society, local businesses, the Salt Lake Conservation District, and Bonneville CWMA to sponsor plant-exchange events where homeowners who bring in the noxious weeds they remove from their yards receive free native plants in exchange. At RCS workshops, attendees indicated an interest in these types of approaches that would help defray some of the costs of revegetation efforts. One possibility in the Red Butte Creek corridor would be to target a single invasive plant species each year.

During RCS subcommittee meetings and public workshops, attendees provided suggestions for several other types of implementation approaches. One suggestion was to use the establishment of "special improvement districts" to generate funds for riparian improvements in specific privately owned portions of the corridor. Another suggestion was to pursue a personalized, one-on-one outreach effort where City or agency staff would visit individual homeowners to discuss improvement options for their properties. Soil Conservation Districts and the NRCS have employed this type of personalized approach for many years to facilitate stream corridor and riparian enhancements on privately owned agricultural lands. In New York State, the NRCS has established an "Urban Resources Partnership" program (www.ny.nrcs.usda.gov/programs/#urp) to help community organizations implement resource-enhancement projects in certain designated cities. This program has facilitated successful riverbank stabilization, wetland restoration, and habitat improvement projects on the Bronx River in New York City. Establishment of a similar type of program by the Utah NRCS could be encouraged.

Action Items

A variety of specific action items are recommended for implementation. These items are grouped by overall goal and listed below. Following the adoption of a working group or other organizational framework, more detailed project priorities will be determined, allowing for development of funding approaches and grant applications. The DPU will include riparian corridor projects in annual budgets based on available funding and system needs, and by referring to the prioritized lists in this document. Priorities established in this Red Butte Creek study will be included, along with priorities on other streams, to provide direction for City project implementation. To the extent possible, DPU's implementation efforts will be balanced among all four of the City's creeks (City, Red Butte, Emigration, and Parleys) and the Jordan River.

Goal: Continue public outreach and establish implementation working group

- establish organizational structure to guide implementation of riparian corridor improvement efforts
- promote involvement of multiple agencies/ organizations in working group to facilitate communication regarding project ideas and potential funding sources (e.g., schools with needs for volunteer projects, ACOE in-lieu mitigation funds, etc.)
- encourage community/ school groups, residents, and local businesses to participate in the Utah "Adopt a Waterbody" program
- prepare and install standardized no-trespassing signage in collaboration with interested property owners

Goal: Increase public awareness

- design and install signs at road and trail crossings (e.g., "Crossing Red Butte Creek") to increase public awareness and knowledge of where the City's creeks are located
- stencil storm drain inlets using lettering that includes stream names (e.g. "Do not dump: drains to Red Butte Creek"); coordinate this effort with the established Salt Lake County Stormwater Coalition
- prepare informational insert to distribute in utility bills; insert should include a map of stream corridors and public access points and information on riparian corridor functions and the RCS process
- conduct a riparian corridor-focused activity during the City's established annual "Water Week" event

Goal: Manage and reduce impervious surfaces

- protect existing undeveloped watershed areas within City municipal boundaries through pursuit of open space and conservation easement acquisitions and/or appropriate re-zoning efforts
- promote/require use of progressive long-term stormwater BMPs that reduce the hydrologic impacts of new developments; coordinate this effort with the Salt Lake City Division of Sustainability and Environment
- coordinate and partner with existing organizations involved with storm water management

Goal: Explore instream flow opportunities

- develop a more complete understanding of current water rights, uses, and conservation potential

- explore potential for purchase or lease of instream flow water rights under State water law through coordination with groups such as DWRT, Trout Unlimited, Utah Rivers Council, Utah Division of Wildlife Resources, and Utah Division of State Parks and Recreation

- pursue measures to increase infiltration and groundwater recharge

Goal: Improve riparian corridor aesthetics

- promote volunteer stream cleanups

- remove over-sized trash items from publicly owned riparian corridor areas

Goal: Improve riparian habitat through control of invasive plant species and restoration of native plant communities

- promote invasive plant removal by targeting and publicizing one high-priority species per year

- initiate invasive plant removal/control efforts in City-owned riparian corridor areas, beginning upstream and working downstream, utilizing an integrated weed control strategy

- ensure funding and labor will be available for multi-year follow-up treatments and long-term maintenance/monitoring of revegetated areas

Goal: Improve streambank and streambed stability through correction of localized infrastructure-related erosion problems

- budget for and implement identified high-priority stream crossing culvert replacement/ improvement projects

- budget for and implement identified storm drain outfall improvement projects

The Red Butte Creek riparian corridor currently provides a wealth of riparian functions and community benefits. Many opportunities exist to enhance these functions and benefits. With dedication on the part of all stakeholders, the vision for the corridor can be achieved.

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GLOSSARY OF TERMS

Acre-foot: the volume of water that will cover a 1-acre area to a depth of 1 foot.

Alluvial Deposits: sediments deposited by flowing water. Along the Wasatch Front, thick deposits of sediment, often referred to as alluvial fans, are commonly found at canyon mouths where channels enter the broad Salt Lake Valley.

Alluvial River: a river with a channel formed entirely within sediments deposited by flowing water; a self-formed channel not constrained by bedrock, hillslope deposits, or other external controls unrelated to the current streamflow regime and sediment load.

Annual High Water Level (AHWL): the water level, or stage, in Red Butte Creek during typical high flow conditions. The AHWL also demarcates the point from which Salt Lake City's Riparian Corridor Overlay Zone ordinance 100-foot riparian corridor is measured. Annual high flow typically occurs during the spring snowmelt runoff season. Based on analysis of available streamflow gage data, the average annual high flow value on Red Butte Creek is 22 cubic feet per second. Wetted channel width at annual high water varies throughout the study area based on local channel geometry and slope, and needs to be determined on a site-specific basis.

Culvert: a pipe, arch, or box structure that conveys Red Butte Creek underneath a road, utility, or trail crossing. Typically made of metal or concrete.

Embedded: refers to a condition wherein coarser-grained streambed material (gravel, cobble, or boulders) is surrounded by fine sediment (sand, silt, or clay) that fills the voids between the coarser particles and makes them difficult to pick up. Highly embedded sediments have reduced void space available as habitat for aquatic insects, and are not suitable as spawning gravels for fish. High degrees of embeddedness may indicate degraded watershed conditions and excessive delivery of fine sediment to the channel.

Entrenched: refers to a channel shape that is inset between tall slopes that vertically confine the channel and limit width of inundation during flooding. Entrenched channels occur naturally where streams have carved through steep canyons or glacial lake deposits, and can also occur as a result of fill placement or human-induced streambed lowering (incision) associated with land use changes, channel straightening, altered flood flows, reduced sediment supplies, and removal of in-channel woody debris.

Impervious: incapable of being penetrated by water.

Low bank/root zone erosion: a term that refers to erosion within the lower, toe area of the streambank. Streambanks affected by this type of erosion are characterized by exposed, bare roots. Low bank/root zone erosion may be caused by flashy urban hydrology that produces frequent, erosive runoff events, and can also result from toe failure caused by streambed lowering/incision.

Polygon (also referred to as "**vegetation polygon**"): an area delineated during field mapping as having vegetation community characteristics (i.e., plant species, density, structure) distinct from adjacent areas.

Riffle: a portion of stream channel—typically 15 to 30 feet long—characterized by choppy water, steep grade, and relatively coarse bed material. In natural streams, riffles often occur in an alternating sequence with flatter-gradient features such as pools or runs.

Riparian: an ecological term referring to the area located between aquatic (in-stream) and upland habitats.

Riparian Corridor (also referred to as "**corridor**" or "**stream corridor**"): a term used in a general sense in this document to describe the active stream channel plus the areas on both sides of the channel within 100 feet of the annual high water level. The term riparian corridor is also a specific legal term describing those areas subject to regulation under Salt Lake City's Riparian Corridor Overlay Zone ordinance.

Storm Drain Outfall: the outlet point where a storm drain enters Red Butte Creek. Storm drains are typically pipes (metal, concrete, or plastic) or concrete box structures that capture and convey storm water runoff from streets, gutters, and rooftops.

Streambank: a term used in a general sense to describe the vertically sloping sides of a stream channel.

Streambed: a term used in a general sense to describe the relatively flat, unvegetated bottom of a stream channel. Streambed material typically consists of unconsolidated sediments (i.e., clay, silt, sand, gravel, cobble, boulders), but can also be composed of bedrock or artificial materials such as concrete.

Study Reach (also referred to as "**stream reach**" or "**reach**"): a specific portion of the Red Butte Creek stream channel, typically 300 to 1,400 feet long, commonly bounded by a road crossing, property boundary, or geologic break. For this study, stream channel conditions were evaluated and described for each individual study reach.

Terrace: a flat, bench-like landform originally created by floodplain or lake bed deposits, but subsequently abandoned when the lake receded and/or the stream cut itself a deeper channel. Terraces are essentially relict depositional features that are no longer inundated by the modern flow regime. In this document, the term **terrace erosion** refers to erosion that occurs where a stream has migrated laterally into a terrace deposit. Banks affected by terrace erosion are typically tall, nearly vertical, and bare.

Toe: the lowest portion of the streambank between the low-flow water surface and the start of perennial vegetation. In urban stream channels, the toe area is subject to frequent, flashy, erosive flows associated with storm water runoff. Erosion of the toe area can undermine higher bank areas and cause slumping. **Toe protection** refers to the placement of resistant materials in the toe area to prevent erosion.

Watershed: the land area drained by a river system, bounded by a drainage divide, and converging at a specific outlet point. For the riparian corridor study, the Red Butte Creek watershed includes the land area that drains to the downstream end of the study area near 1100 East.

SALT LAKE CITY STREAM ASSESSMENT DATA FORM

Stream (cir): UCC LCC URB LRB UEM LEM UPC LPC	Date & Time:
Location/ Reach #:	Weather Now: ☐ rain ☐ clear
Observer(s):	Weather Past 24 hrs: ☐ rain ☐ clear
Water Appearance (cir): clear, slightly cloudy, v.cloudy	Stream Stage (cir): Flood High Mod Low Dry

Stream Bed Material Information
Dominant Type(s) (cir): bedrock, boulder, cobble, gravel, sand/silt (note pool vs Riffle differences)
Clay Shelf Present? ☐Y ☐N; if Y describe % channel width affected: _________________________
____

Bed Hardening or Grade Structures present (cir): none, concrete sill, rock weir, other
Diversion (headgate, etc.) at Bed Structure ☐Y ☐N Scour evident? ☐N ☐Y scour depth:________ft
☐Photo(s) ☐GPS or ☐map locations Condition:____
Notes: ____

Stream Bank Material Information
Dominant Type (cir): bedrock, boulder, cobble, gravel, sand/silt DESC:___________________________
Bank Erosion (cir): none, low, mod, high ☐GPS or ☐map locations of erosion problem areas
Bank Hardening Types present (cir): none, gabions, rip rap, concrete, asphalt chunks, stone or brick wall,
other__________ ☐GPS or ☐map locations Condition:________________________________

Channel and Floodplain Habitat Information
Sediment Deposits and/or Bars: absent/occasionally present/abundant Type: sand, gravel, cobble
Undercut Banks: absent/occasionally present/abundant
Accessible Flat Floodplain Surfaces: absent/occasionally present/abundant
In-channel Woody Debris: absent/occasionally present/abundant
Evidence of Reach-Scale Channel Degradation (“tipping” trees, excessive scour, etc.)? ☐N ☐Y
Notes:____

Storm Drain Outfall(s) ☐N ☐Y #_______ ☐GPS or ☐map locations ☐Photo(s)
Condition/Notes____

Exposed Pipe Crossing(s) ☐N ☐Y #_______ ☐GPS or ☐map locations ☐Photo(s)
Type (cir): sewer, water, gas, unknown, other______
Condition/Notes____

Eroded Access Trail(s) ☐N ☐Y #_______ ☐GPS or ☐map locations ☐Photo(s)
Condition/Notes____
Heavy Dog Use evident? ☐Y ☐N

Culvert Information *(note scour, deposition, debris blockages, unstable sills/walls etc.)*
Crossing # ________ ☐GPS or ☐map location Road Name or Other Desc.:_____________________
Type (cir): round pipe, arch, box, other________ Size (ft): H_____ W_____ Diam._____
☐Photo of upst. side ☐Photo of dst. side
Condition upst. side: ____
Condition dst. side: ____

Crossing # ________ ☐GPS or ☐map location Road Name or Other Desc.:_____________________
Type (cir): round pipe, arch, box, other________ Size (ft): H_____ W_____ Diam._____
☐Photo of upst. side ☐Photo of dst. side
Condition upst. side: ____
Condition dst. side: ____

Other Features (cir): seep/spring, tributary, other_____ ☐GPS or ☐map location
Notes:____
☐GPS or ☐map location of Pebble Count and Cross Section Measurements

Cross Section Survey Data *(note LEP, REP, LEW, REW, AHWL, BK, FP, TOPBK, IC)*

LEP tag desc: ☐LEP photo ☐Photo # of XS looking d.s. BM nail desc:			REP tag desc: ☐REP photo ☐Photo of XS looking u.s. ☐BM nail photo		
STA. (ft)	ROD VAL.(ft)	DESC.	STA. (ft)	ROD VAL.(ft)	DESC.

Slope Survey Data

Long. Dist. from XS (ft)	ROD VAL. (ft)	DESC.
		TW at upst. riffle
0		TW at cross section
		TW at dst. riffle

NOTES on reach type, condition, rec. management actions to improve condition, etc.:_________________
____
____
____
____

SKETCH of cross section *(show loc. of endpoint tags relative to lower & upper banks, etc.)*

Salt Lake City Riparian Vegetation Mapping Data Form

Date__________________ Data Recorders________________________________

Stream: UCC LCC URB LRB UEM LEM UPC LPC Photo(s) ________________________________

Polygon_______________ Stream Reach #___________

Stratum:

Canopy (>15 ft tall): total % cover >75% 25-50% <25%

spp1		cover1		spp2		cover2		spp3		cover3		spp4		cover4	

Shrub (3 ft-15 ft tall): total % cover >75% 25-50% <25%

spp1		cover1		spp2		cover2		spp3		cover3		spp4		cover4	

Understory (<3 ft tall): total % cover >75% 25-50% <25%

spp1		cover1		spp2		cover2		spp3		cover3		spp4		cover4	

Invasive species present? (y/n)	
Invasive species dominant? (y/n)	
Control recommended? (y/n)	
Active recruitment evident? (y/n)	

%Bare Ground/Rock	
%Leaf Litter	
Standing/Fallen Dead Logs on banks/floodplain (cir): absent sparse moderate dense	

Notes/Specific Issues:____

____

SALT LAKE CITY RIPARIAN STUDY - HIGH FLOW DATA FORM

Stream and Reach: ____________________ Sampling Party: ______________________________

Date (mm/dd/yy): ____________________ Time (24 hour): ____________________

Weather Now: ______________________________ Weather Past 24 hr.: ____________________

Water Appearance (circle one): Clear slightly cloudy very cloudy

Bedload Transport (describe sound): ____

____

Inundated Vegetation (describe): ____

____

____

High Water Data	
Location	Rod Height
WS Nail	
LEW	
REW	

Photos	
Direction	Number
US	
DS	
RB	
LB	

Taken by: ______________________________

General Notes: ____

____

____

____

____

____

____

____

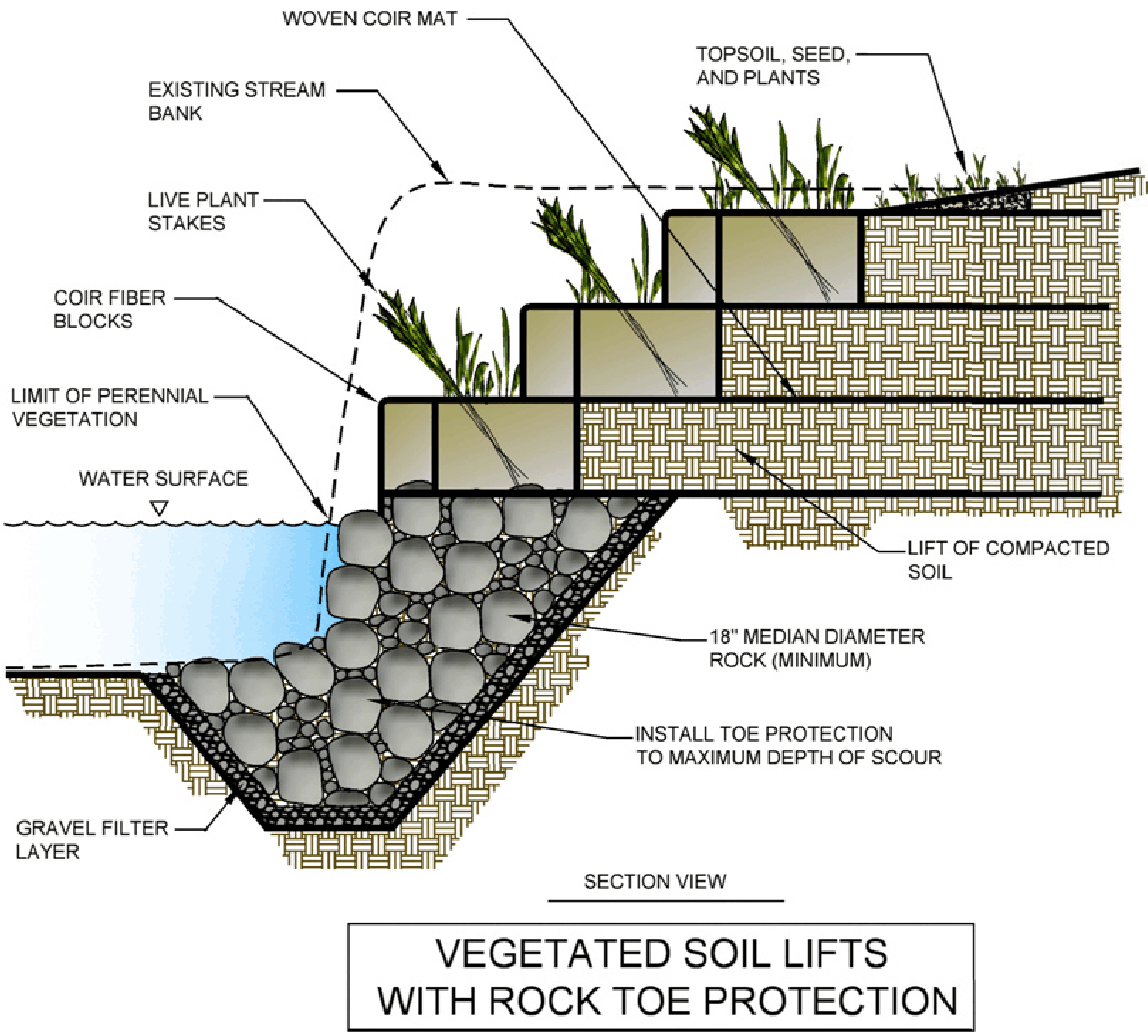
____

APPENDIX B: DETAIL DRAWINGS OF SELECTED IMPROVEMENT TECHNIQUES

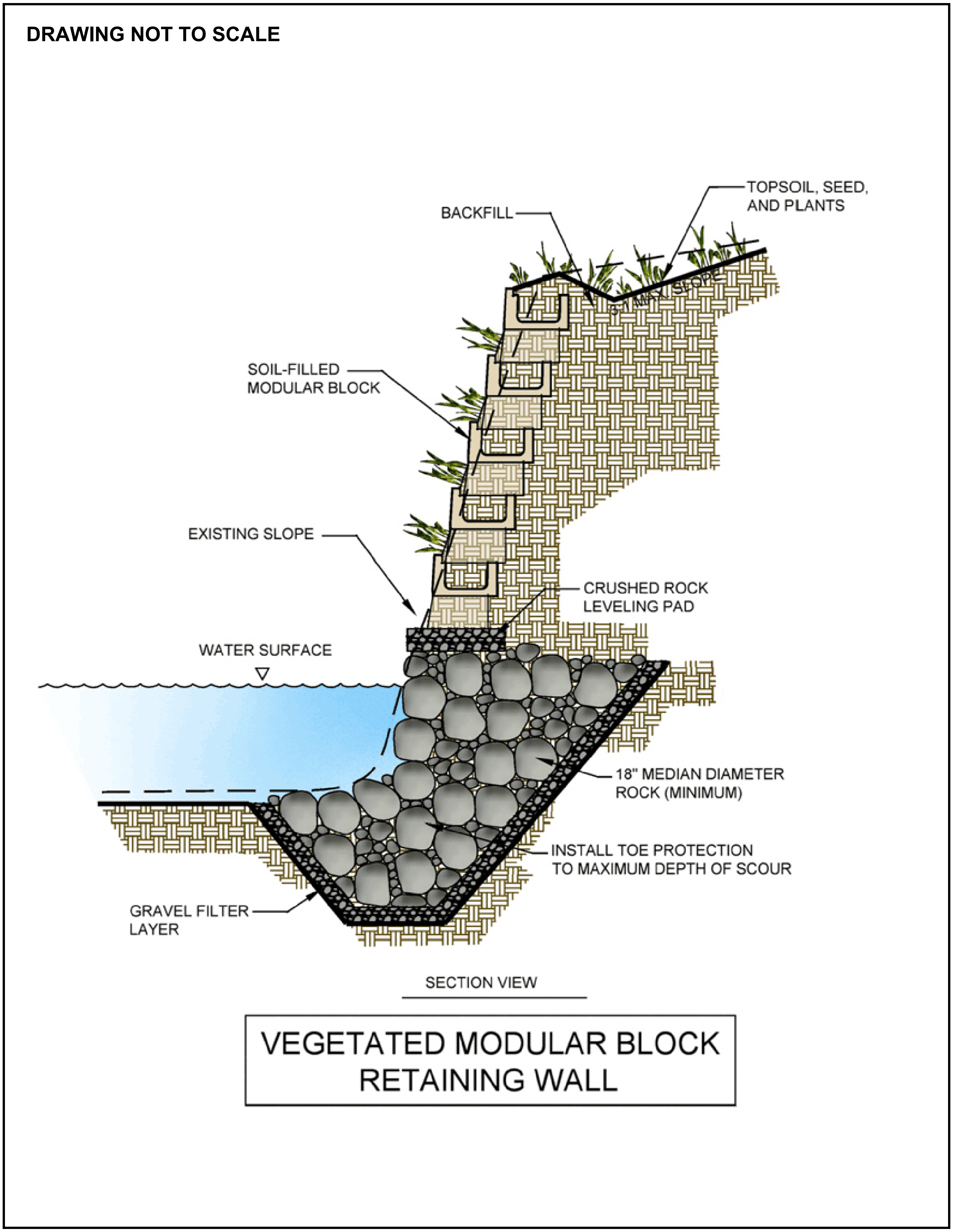
This appendix provides schematic drawings (not to scale) that illustrate the materials, form, and construction of selected improvement techniques. These drawings are not intended to substitute for site-specific engineering design. Site-specific calculations should be completed by a qualified hydrologist, engineer, and/or landscape architect to determine appropriate rock sizing, structure dimensions, etc. for installation in a particular location. In most cases, installation of these types of projects will require relevant State, County, and City permits. It is recommended that the publications, tables, and resources provided in chapter 4 of this document be consulted prior to designing or constructing any of these improvement measures. Particular care should be exercised when construction involves disturbance of areas within the annual high water level of any stream.

List of Drawings:

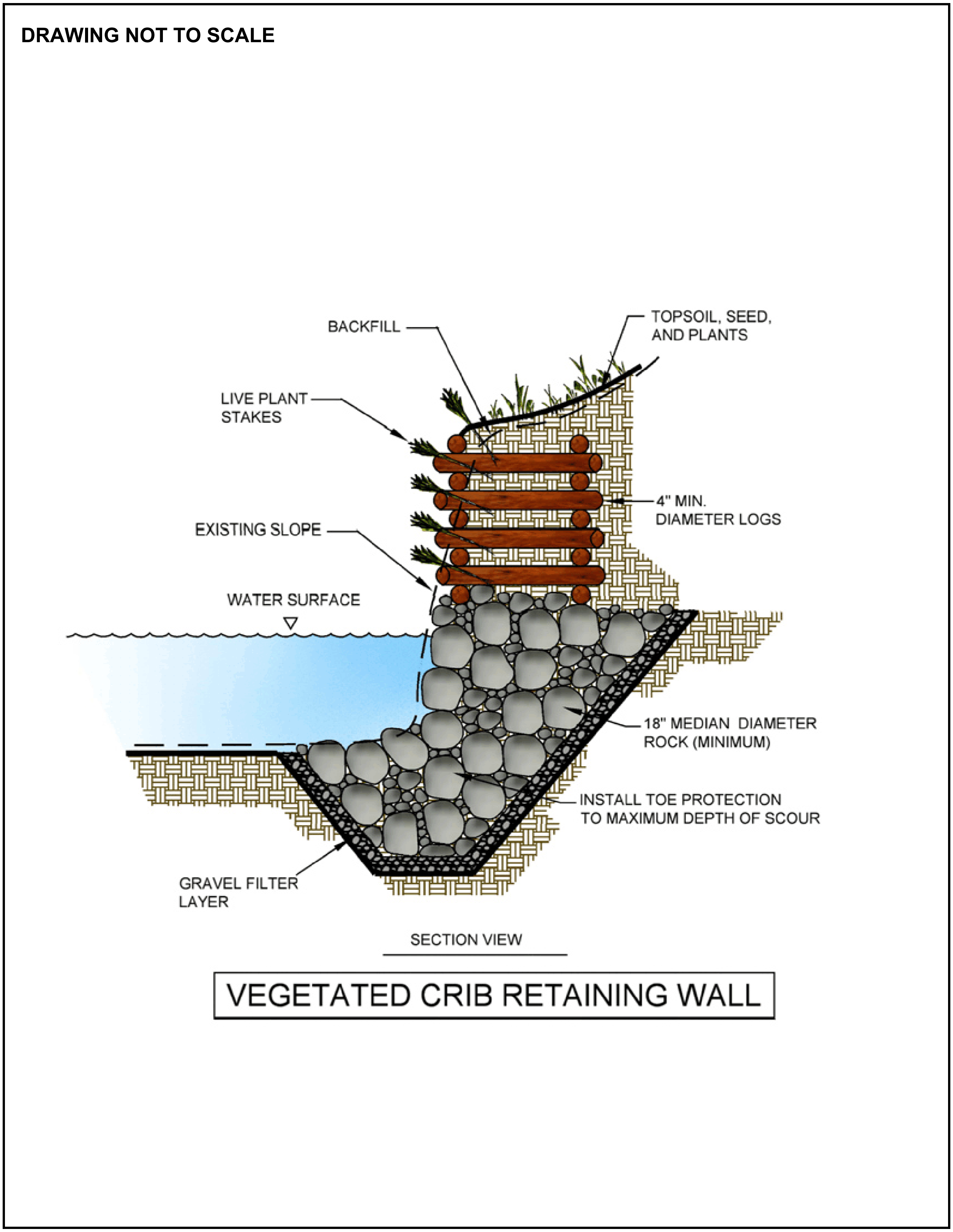
DRAWING NOT TO SCALE



Drawing 1. Vegetated soil lifts with rock toe protection.

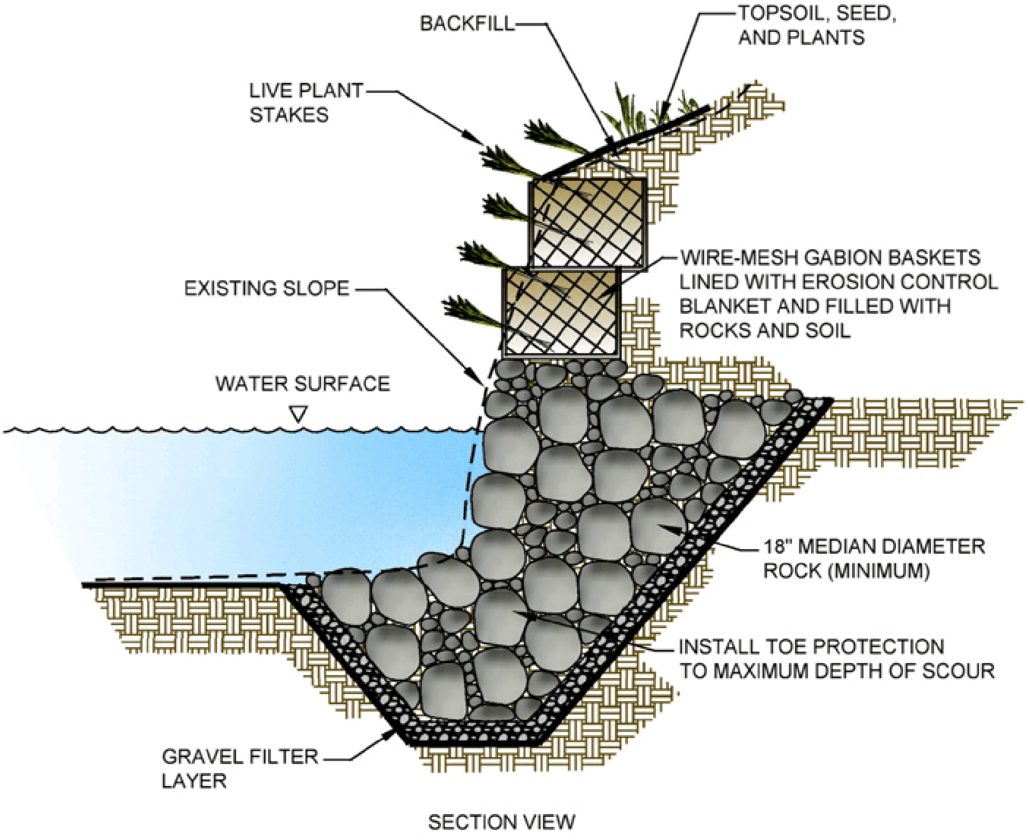


Drawing 2. **Vegetated modular block retaining wall.**



Drawing 3. Vegetated crib retaining wall.

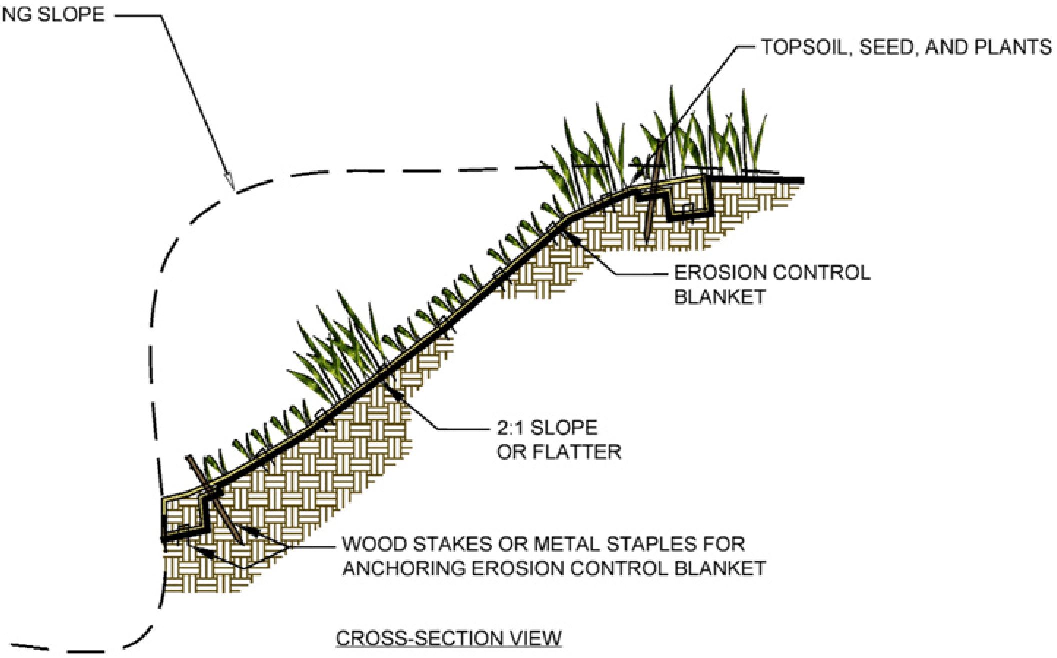
DRAWING NOT TO SCALE



VEGETATED GABION BASKET RETAINING WALL

Drawing 4. Vegetated gabion basket retaining wall.

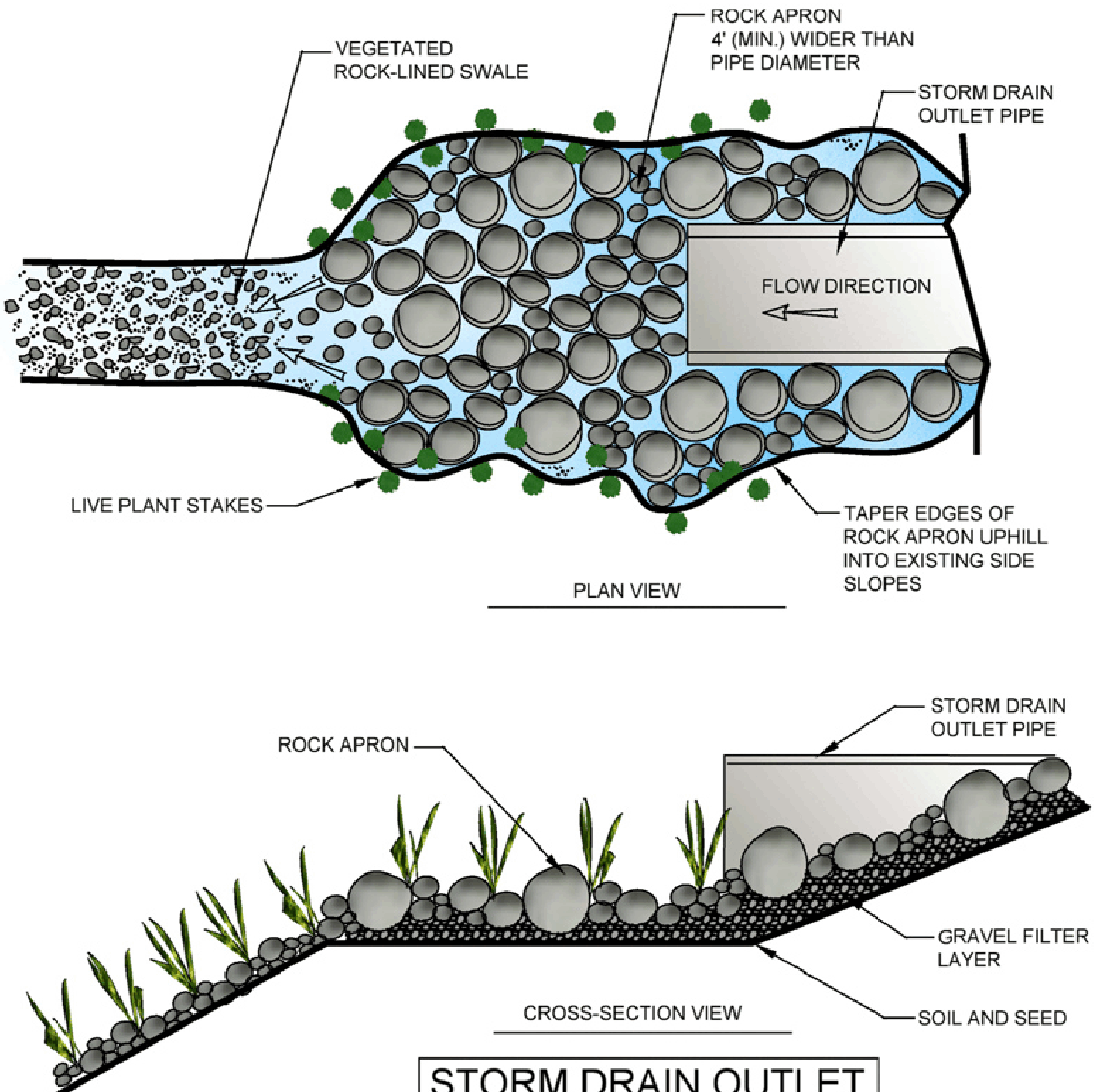
DRAWING NOT TO SCALE



SLOPE FLATTENING

Drawing 5. Slope flattening.

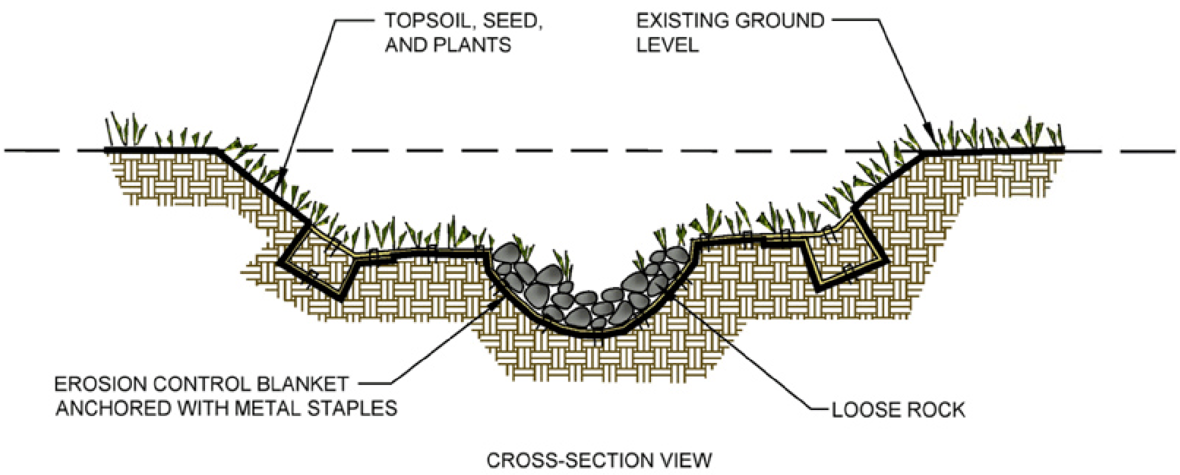
DRAWING NOT TO SCALE



STORM DRAIN OUTLET PROTECTION USING VEGETATED ROCK

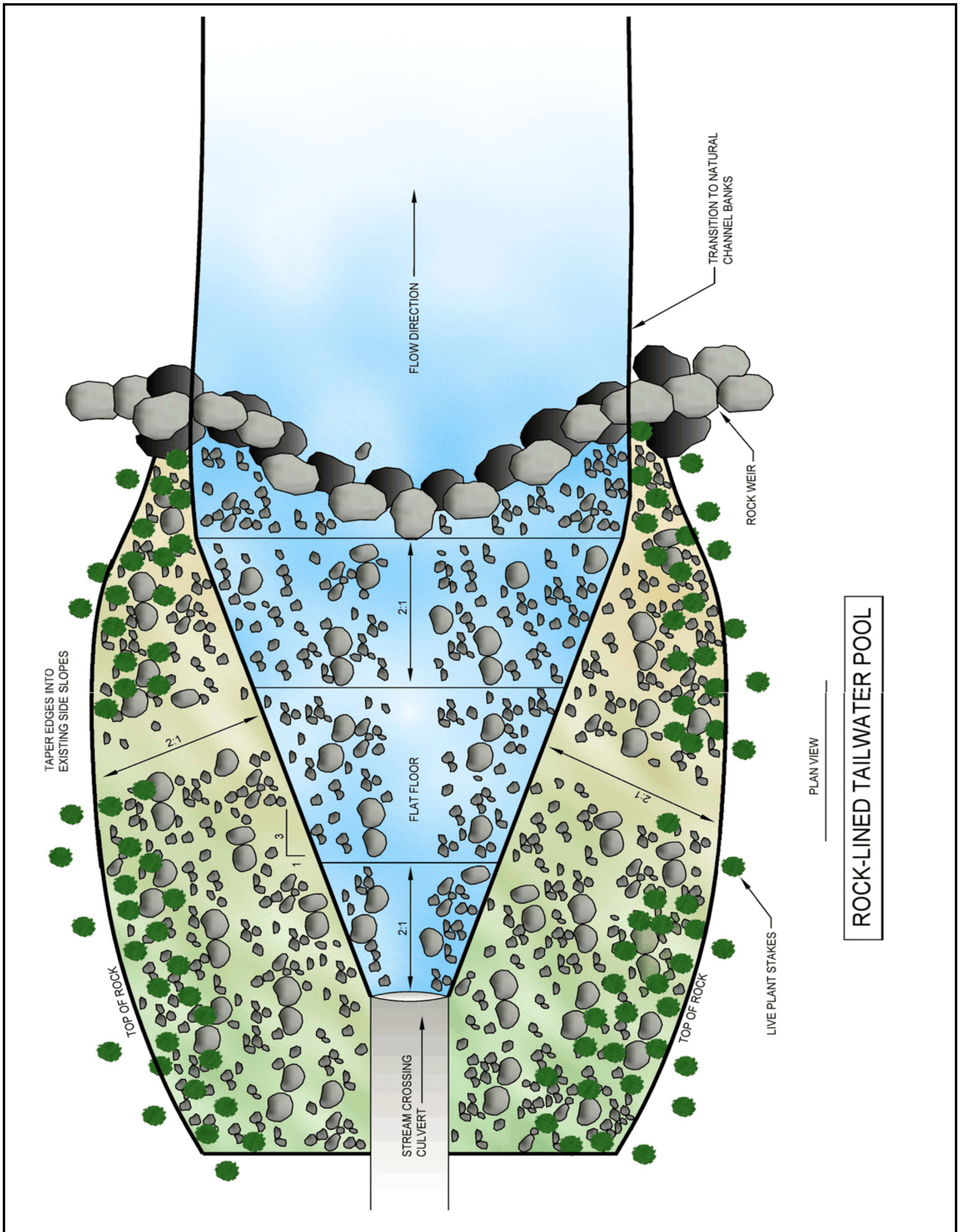
Drawing 6. Storm drain outlet protection using vegetated rock.

DRAWING NOT TO SCALE



VEGETATED ROCK-LINED SWALE

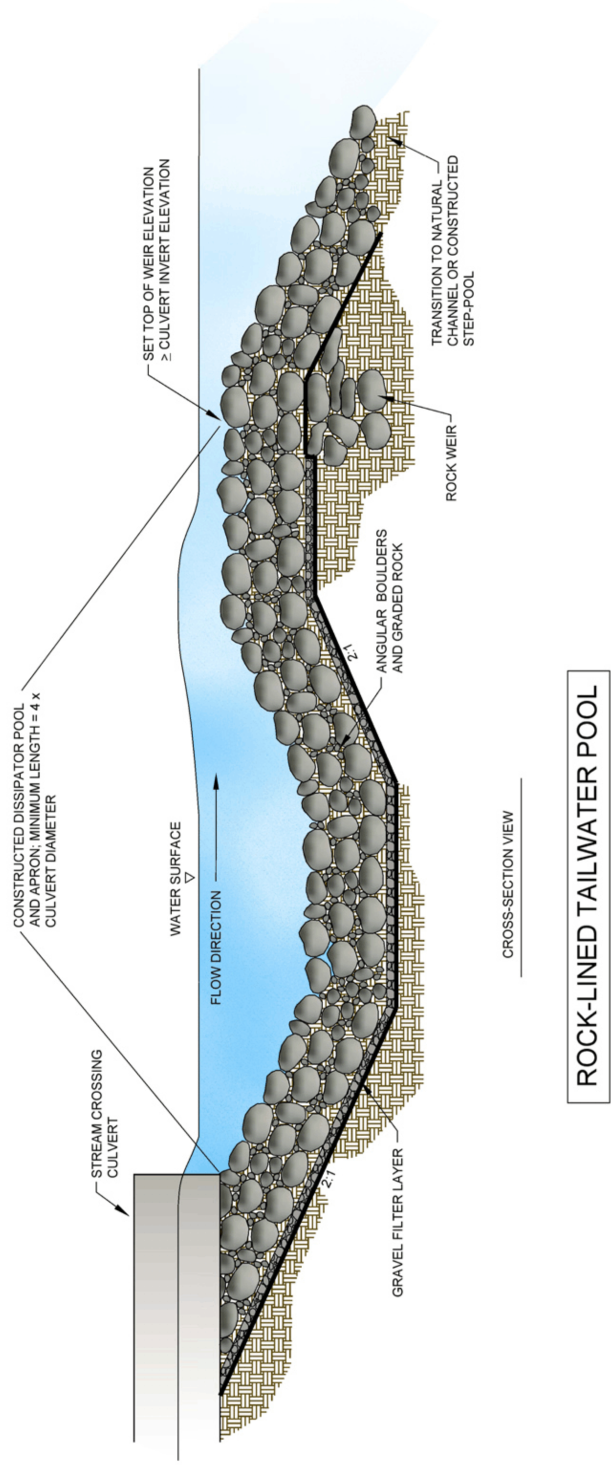
Drawing 7. Vegetated rock-lined swale.



DRAWING NOT TO SCALE

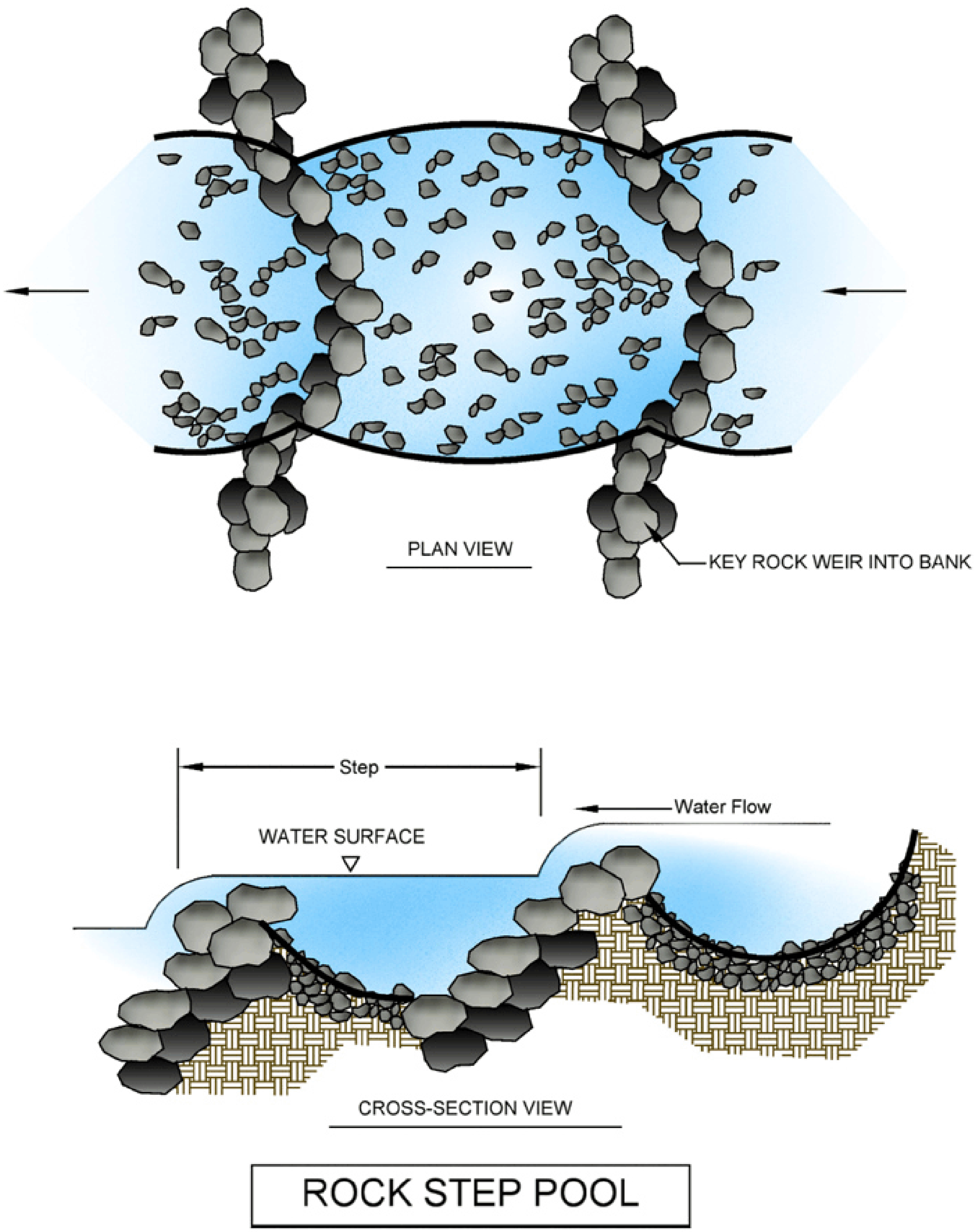
Drawing 8. Rock-lined tailwater pool (plan view).

DRAWING NOT TO SCALE

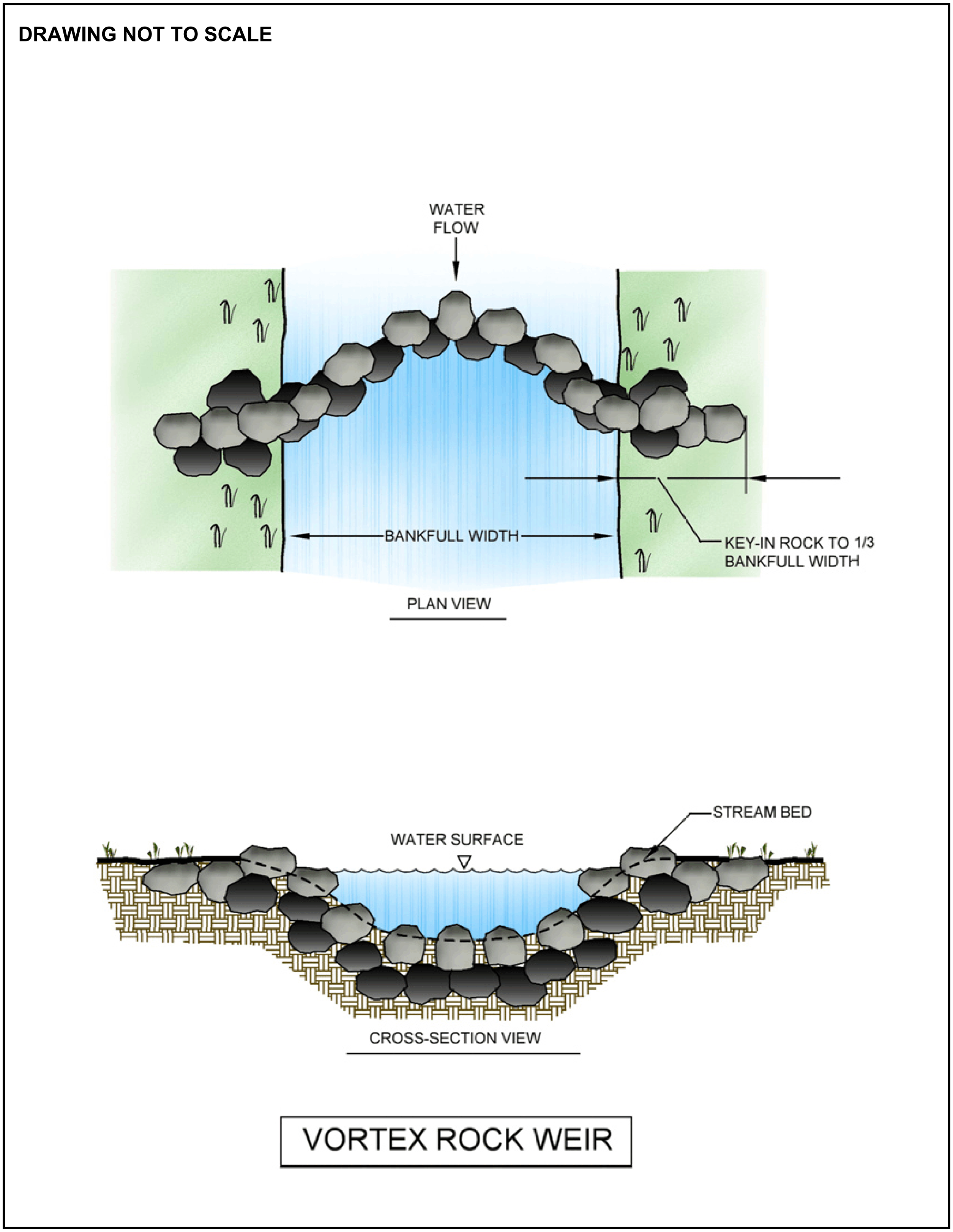


Drawing 9. Rock-lined tailwater pool (cross-section view).

DRAWING NOT TO SCALE

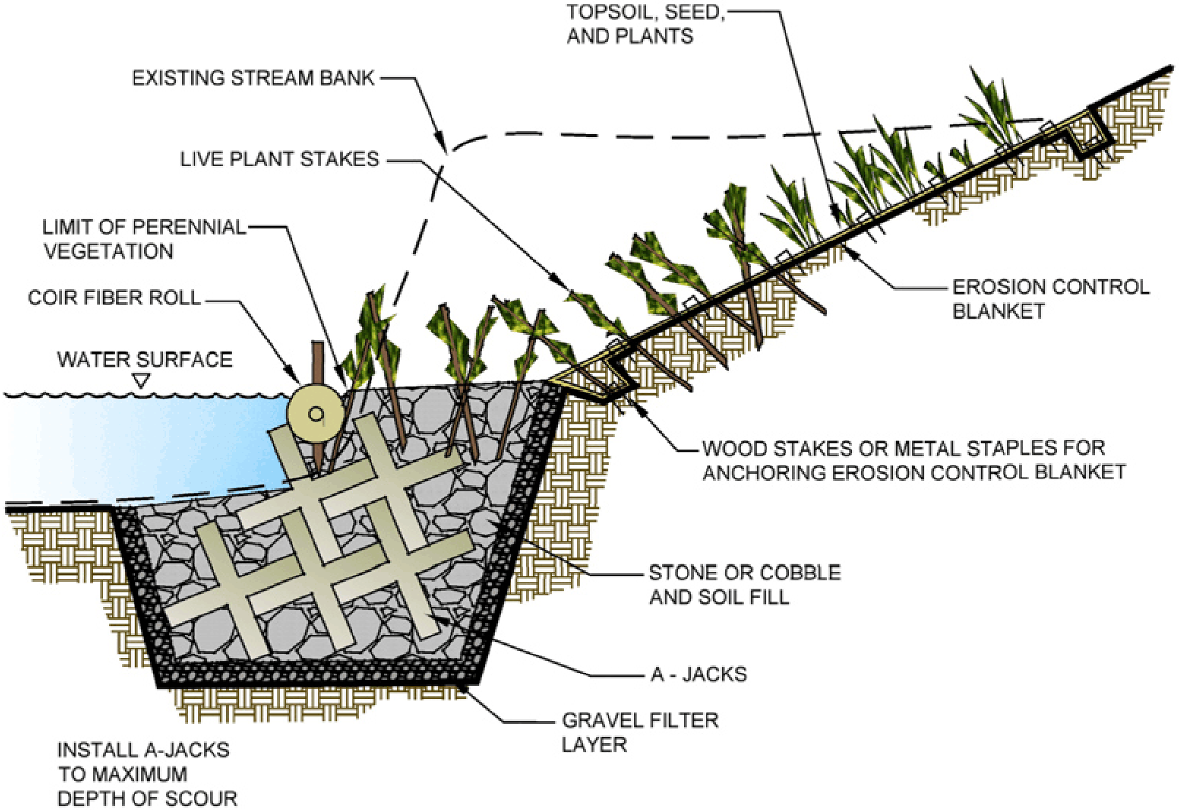


Drawing 10. Rock step pool.



Drawing 11. Vortex rock weir.

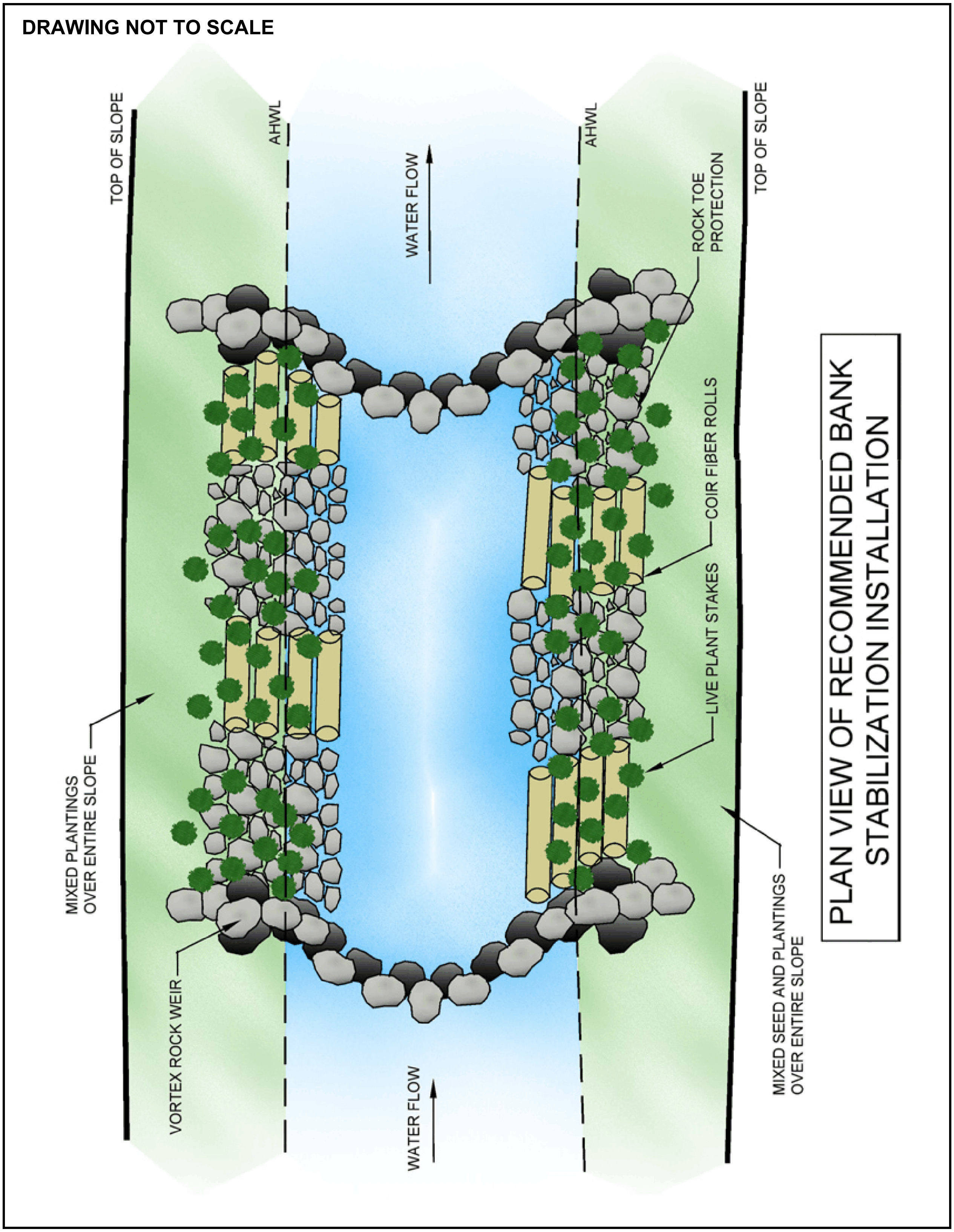
DRAWING NOT TO SCALE



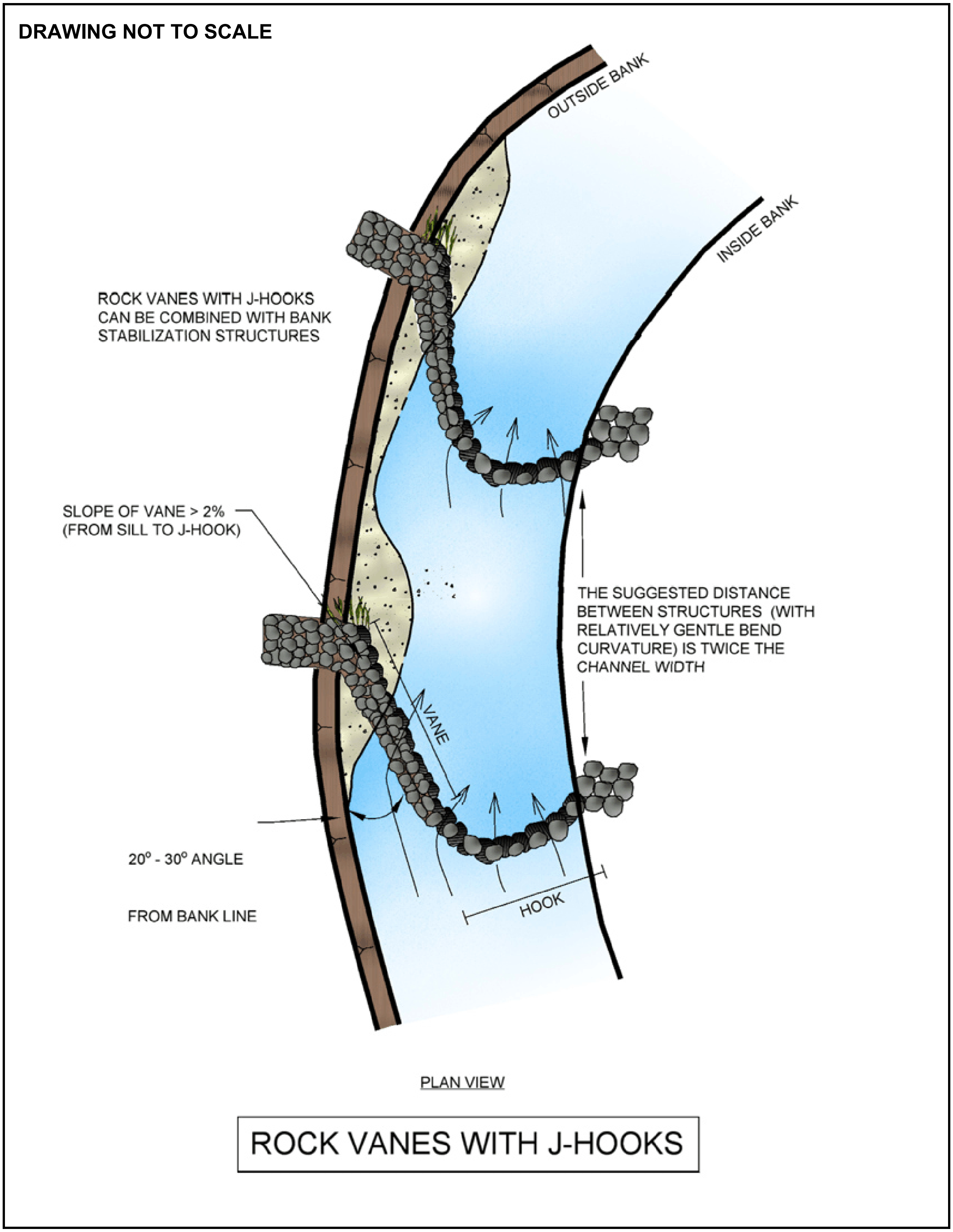
CROSS-SECTION VIEW

A - JACKS TOE PROTECTION

Drawing 12. A-jacks toe protection.

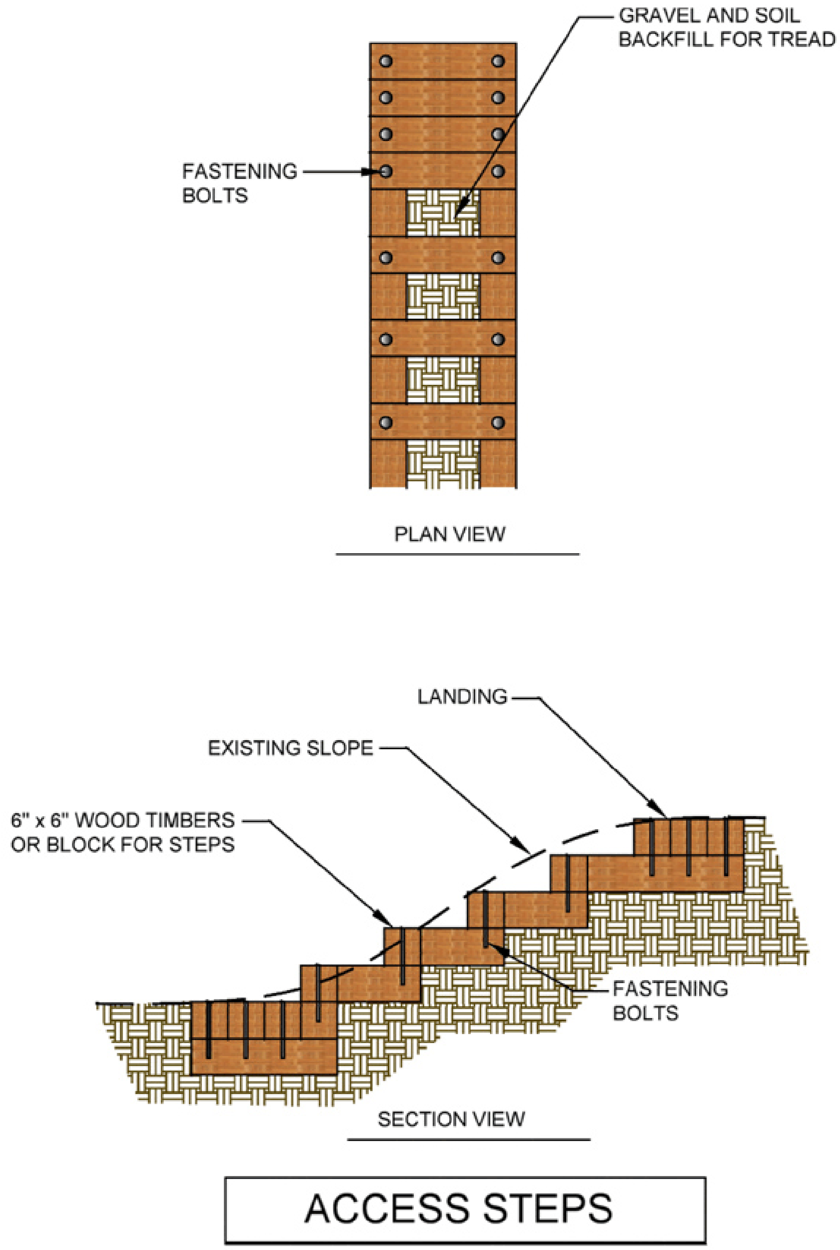


Drawing 13. Plan view of recommended bank stabilization installation.



Drawing 14. Rock vanes with J-hooks.

DRAWING NOT TO SCALE



Drawing 15. Access steps.

APPENDIX C: STUDY REACH MAPS, SUMMARIES, AND RECOMMENDATIONS

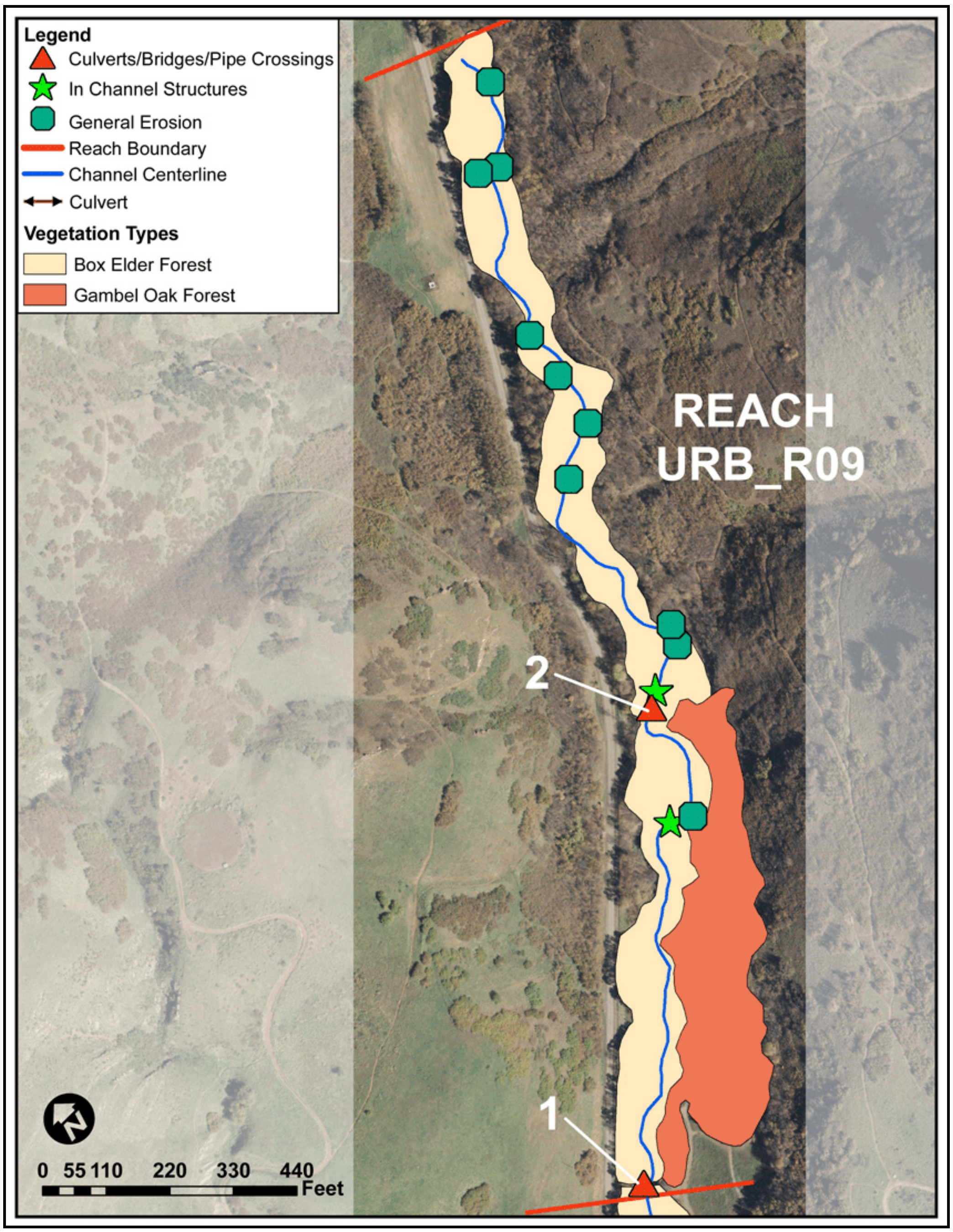
This appendix provides summary information and maps for each of the fully-assessed study reaches. These summaries are not intended to comprehensively provide all the information collected for each reach; rather, they are meant as a reference that provides a brief characterization and overview of existing conditions, issues, and recommendations for each assessed reach. The maps in this appendix include vegetation community types and locations of features such as litter areas, storm drain outfalls, culvert crossings, access trails, artificial bank treatments, and erosion areas. A brief description and selected photos are also provided, along with tables summarizing stream channel data and vegetation characteristics. For each reach, a table is also provided that lists appropriate types of improvement measures for the reach and describes where within the reach the measures should be applied. Measures identified for implementation at the reach-scale will typically require additional detailed site-level design work and engineering to determine specific locations and combinations of treatment techniques.

Approximate cost estimates for the items identified in the recommendations tables are provided in Appendix D. The recommendations included in this appendix are not exhaustive; as priorities evolve and funding becomes available for specific reaches or treatment techniques, it may be appropriate to implement measures not included in the tables at this time.

On Red Butte Creek, many study reaches are privately owned. Assessments in these reaches were only completed at properties for which specific access permission was obtained, and therefore were not comprehensive. Brief descriptions and photos of these partially-assessed reaches are provided at the end of this appendix.

REACH URB_R09: UPPER RED BUTTE GARDEN

This reach flows through the downstream portion of Red Butte Canyon, and the channel is confined by steep hillslopes. The reach is in relatively natural condition, and although some trail and picnic facilities are present, recreational use does not appear to be negatively affecting riparian condition. Channel and bank slopes are steep, and the reach shows evidence of low bank/root scour, terrace/high bank erosion, hillslope slumping, and apparent bed incision. Vegetative structure and cover are generally excellent in this reach.



Issues affecting riparian function:

- low bank/root zone erosion
- terrace erosion
- eroded access trails (minor)
- invasive species (whitetop, lesser burdock, Siberian elm)
- bed incision

Constraints/ opportunities:

- location offers educational/ interpretive opportunities
- connected to a large area of natural open space

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
2297	0.051	boulder, sand/silt	cobble, gravel, silt	occasionally present	abundant	occasionally present

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Gambel Oak Forest	76–100+	6–25	51–75	low	moderate
Box Elder Forest	76–100+	76–100+	51–75	moderate	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	none	moderate (road)	low

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Invasive plant removal	within vegetation type(s)
Removal of concrete/asphalt on bank	point 1 on map
Biotechnical slope stabilization	point 1 on map
Revegetation of low bank at picnic area	point 2 on map

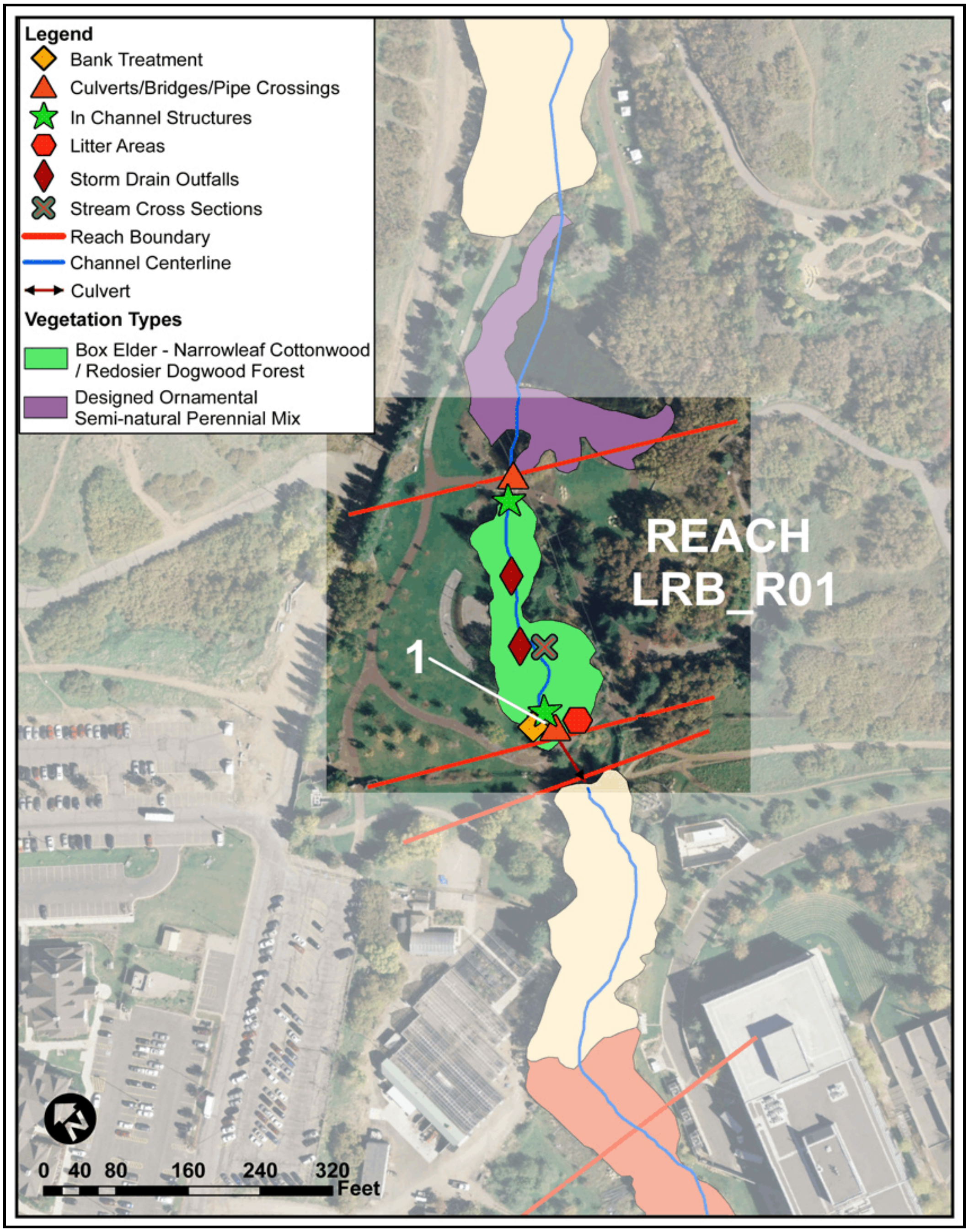
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- restoration of "renegade" trails with native vegetation
- interest in publicly accessible trail system with proper erosion controls and stream crossings
- general study area priorities (habitat, water quality, bank stability) also apply

REACH LRB_R01: LOWER RED BUTTE GARDEN

This is a short reach downstream of the ponds in Red Butte Garden. At the time of field assessment, the riparian corridor was affected by construction activities associated with renovation of the Red Butte Garden concert venue. The banks through this reach are much lower and less confining than in Reach URB_R09, and several grade control structures are present. A narrow but thick buffer of riparian vegetation with excellent shrub density limits direct access to the stream. No invasive plant species were noted in this reach.

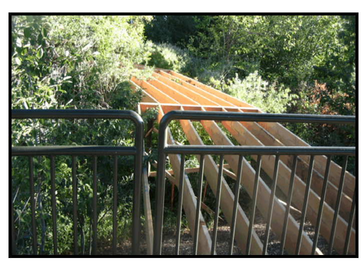


Issues affecting riparian function:

- affected by active construction at time of assessment

Constraints/ opportunities:

- location offers educational/ interpretive opportunities
- total width of natural riparian vegetation limited by developed concert venue



REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
281	0.043	fill on right bank	cobble, silt	abundant	absent	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder - Narrowleaf Cottonwood / Redosier Dogwood Forest	76–100+	76–100+	0	none	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	low	moderate	low

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Stream cleanup	point 1 on map
Monitor/protect riparian corridor	reach-scale

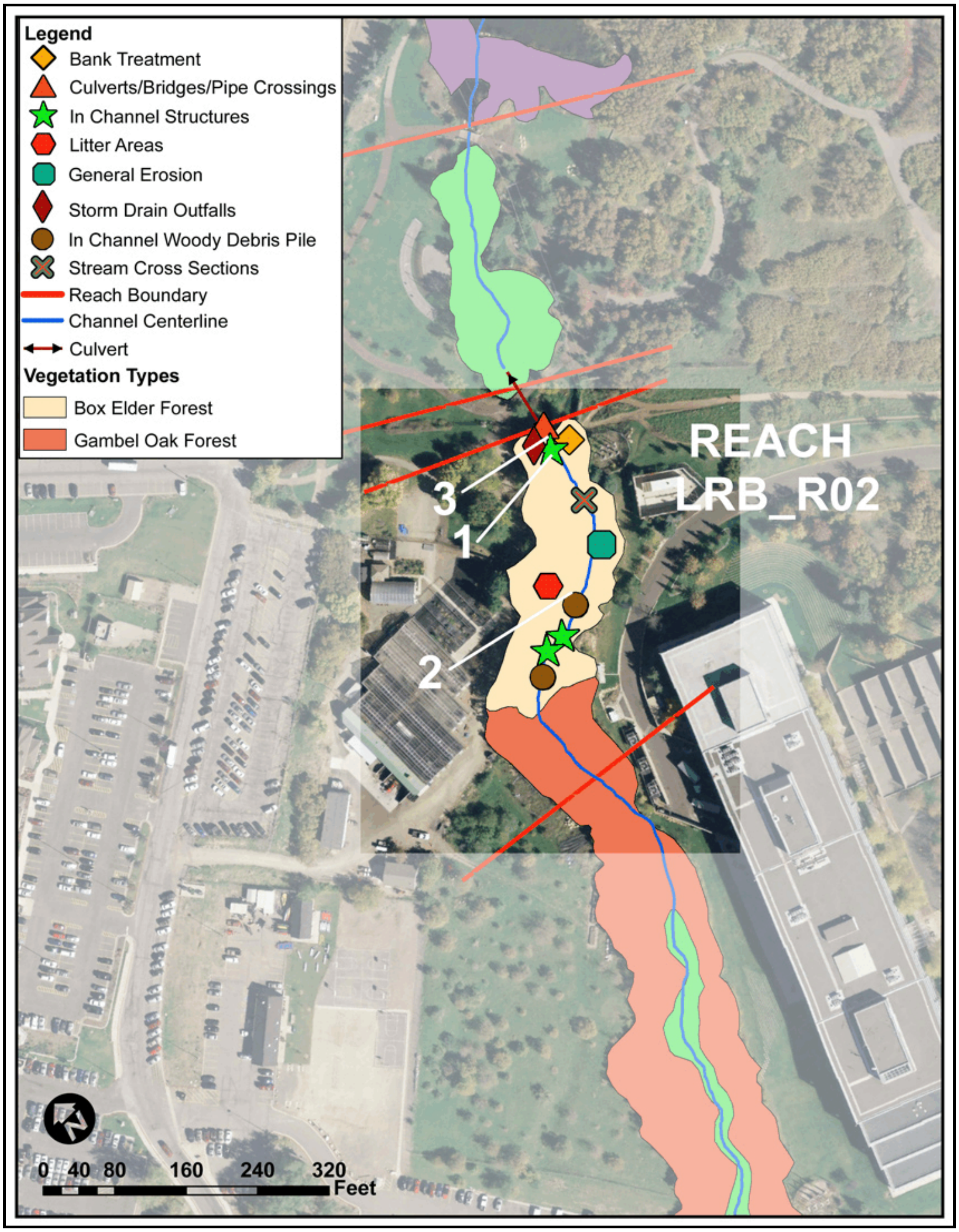
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- no reach-specific items identified
- general study area priorities (habitat, water quality, bank stability) apply

REACH LRB_R02: UNIVERSITY - BELOW RED BUTTE GARDEN

On the southeast side in this reach, the channel is confined by a tall bank that in some areas appears to have been affected by fill placement. The riparian area is impacted by heavy foot traffic that has compacted the soil and reduced understory vegetation cover. Rock and concrete pieces have been placed in several bank and in-channel areas; otherwise, bed material is dominantly sand and small gravel. Vegetation diversity is generally poor in this reach.



Issues affecting riparian function:

- heavy foot traffic/soil compaction
- lack of shrub cover
- lack of understory cover
- low bank/root zone erosion
- trash (minor)

Constraints/ opportunities:

- university location offers educational/ research opportunities
- confined by buildings/access roads

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
451	0.053	cobble, soil	gravel, sand/silt	occasionally present	occasionally present	occasionally present

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Gambel Oak Forest	76–100+	51–75	1–5	low	moderate
Box Elder Forest	76–100+	0	0	none	sparse

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	low	high	high

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Access control	reach-scale
Revegetation - understory layer	within vegetation type(s)
Biotechnical slope stabilization	reach-scale
Revegetation - shrub layer	within vegetation type(s)
Bank stabilization	reach-scale
Mechanized trash removal (concrete pieces)	point 1 on map
Stream cleanup	point 2 on map
Invasive plant removal/control	within vegetation type(s)
Culvert replacement with bridge	point 3 on map

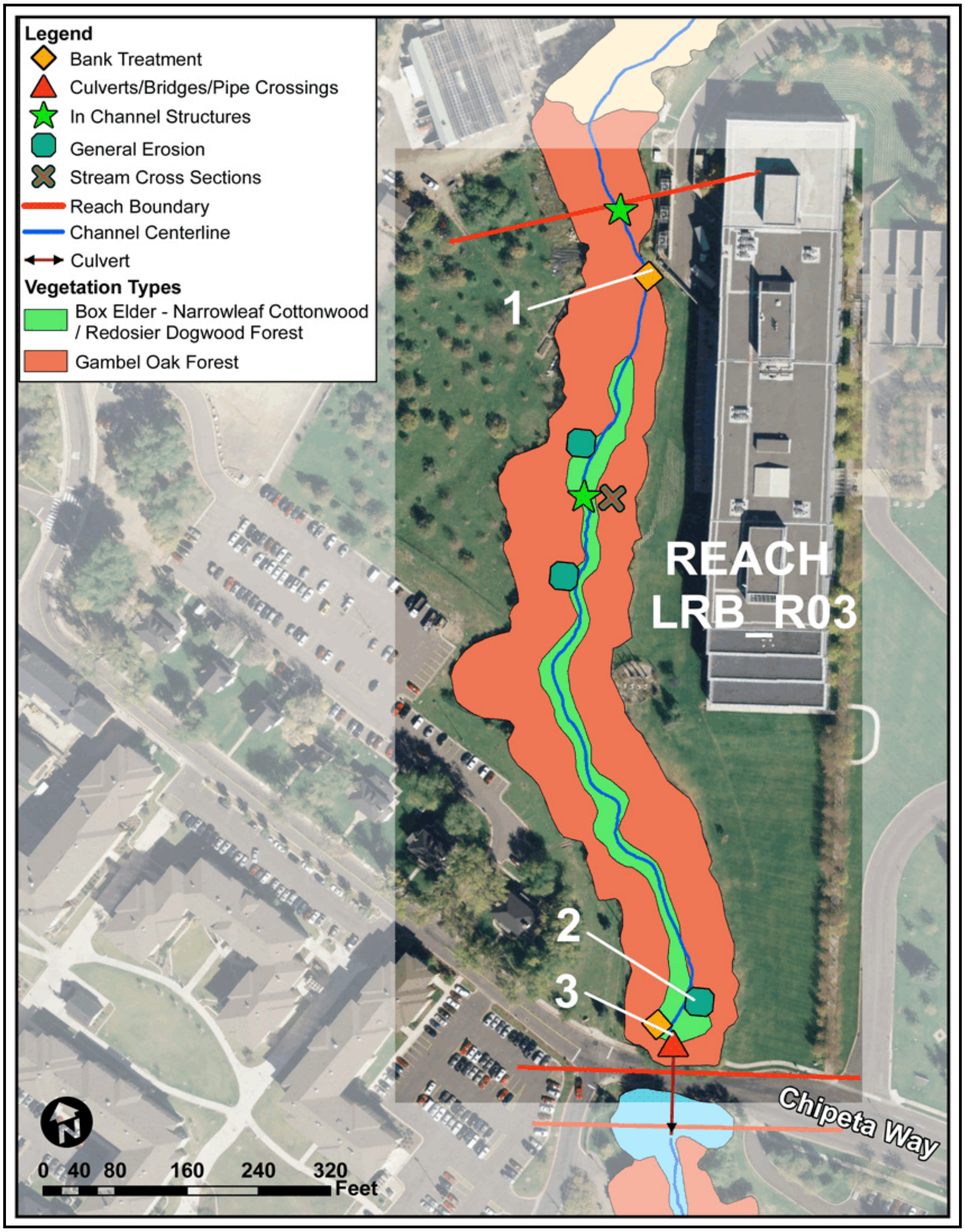
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- interest in public access/potential for trail
- general study area priorities (habitat, water quality, bank stability) also apply

REACH LRB_R03: UNIVERSITY - ABOVE CHIPETA WAY

Although this reach is generally steep, rock grade control structures have created small sections with flat, slow-moving water and wetland vegetation. Tree cover is poor on the east bank at the upstream end of the reach where a building/access road extends to within 16 feet of the channel centerline. The channel is confined by tall, steep banks through much of the reach. Poorly designed gravel and concrete brick wall bank protection features are contributing to erosion on adjacent/opposite banks.



Issues affecting riparian function:

- invasive species (Russian olive, lesser burdock)
- terrace erosion
- low bank/root zone erosion
- deposition/clogging at culvert inlet
- failing bank revetment
- limited tree cover

Constraints/ opportunities:

- university location offers educational/ research opportunities

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
1041	0.062	boulder, soil	boulder, cobble	occasionally present	abundant	occasionally present

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Gambel Oak Forest	76–100+	51–75	1–5	low	moderate
Box Elder - Narrowleaf Cottonwood / Redosier Dogwood Forest	51–75	51–75	26–50	low	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
none	low	low	moderate

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Invasive plant removal	within vegetation type(s)
Removal/improvements to gravel bank protection	point 1 on map
Revegetation - canopy layer	point 1 on map
Removal/improvements to concrete brick wall	point 2 on map
Avoid placing yard waste on banks/leave “no-mow” buffer at edge of turf	reach-scale
Bank stabilization	reach-scale
Grade control	reach-scale
Culvert replacement/improvement	point 3 on map

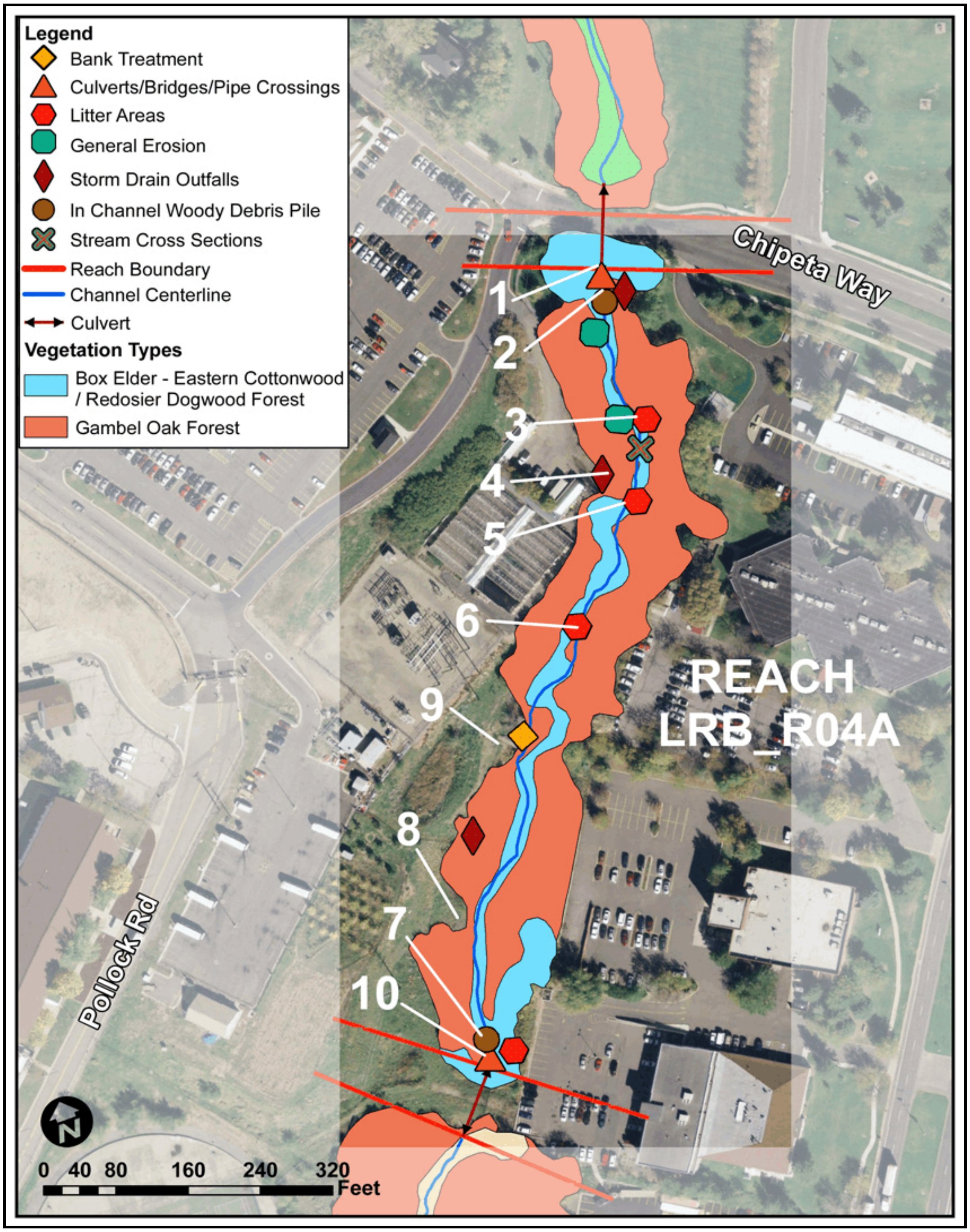
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- interest in public access/potential for trail
- general study area priorities (habitat, water, quality, bank stability) also apply

REACH LRB_R04A: UNIVERSITY - BELOW CHIPETA WAY

Banks are generally steep and tall in this reach, which flows between University parking lots and maintenance facilities. Significant amounts of trash were noted in the reach. Vegetative structure is relatively good; however, total forested width is limited in some areas. Poison ivy dominates the understory cover. Heavy root scour and significant bank erosion are prevalent within the reach.



Issues affecting riparian function:

- terrace erosion
- storm drain outfall erosion
- low bank/root zone erosion
- trash
- invasive species (Siberian elm)
- narrow forested corridor
- bed incision

Constraints/ opportunities:

- university location offers educational/ research opportunities
- potential may exist to remove culvert at rarely used crossing at downstream end of reach and daylight 90 feet of channel

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
961	0.053	boulder, cobble, soil	cobble, gravel	occasionally present	abundant	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder - Eastern Cottonwood / Redosier Dogwood Forest	76–100+	51–75	51–75	moderate	moderate
Gambel Oak Forest	76–100+	0	26–50	none	moderate
Gambel Oak Forest	76–100+	51-75	26–50	none	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	low	moderate	high

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Stream cleanup	points 2, 3, 5, 6, and 7 on map
Mechanized trash removal	points 3 and 6 on map
Storm drain improvement	point 4 on map
Culvert replacement/improvement/removal	points 1 and 10 on map
Revegetation to increase total forested width	points 8 and 9 on map
Invasive plant removal	within vegetation type(s)
Bank stabilization	reach-scale
Grade control	reach-scale

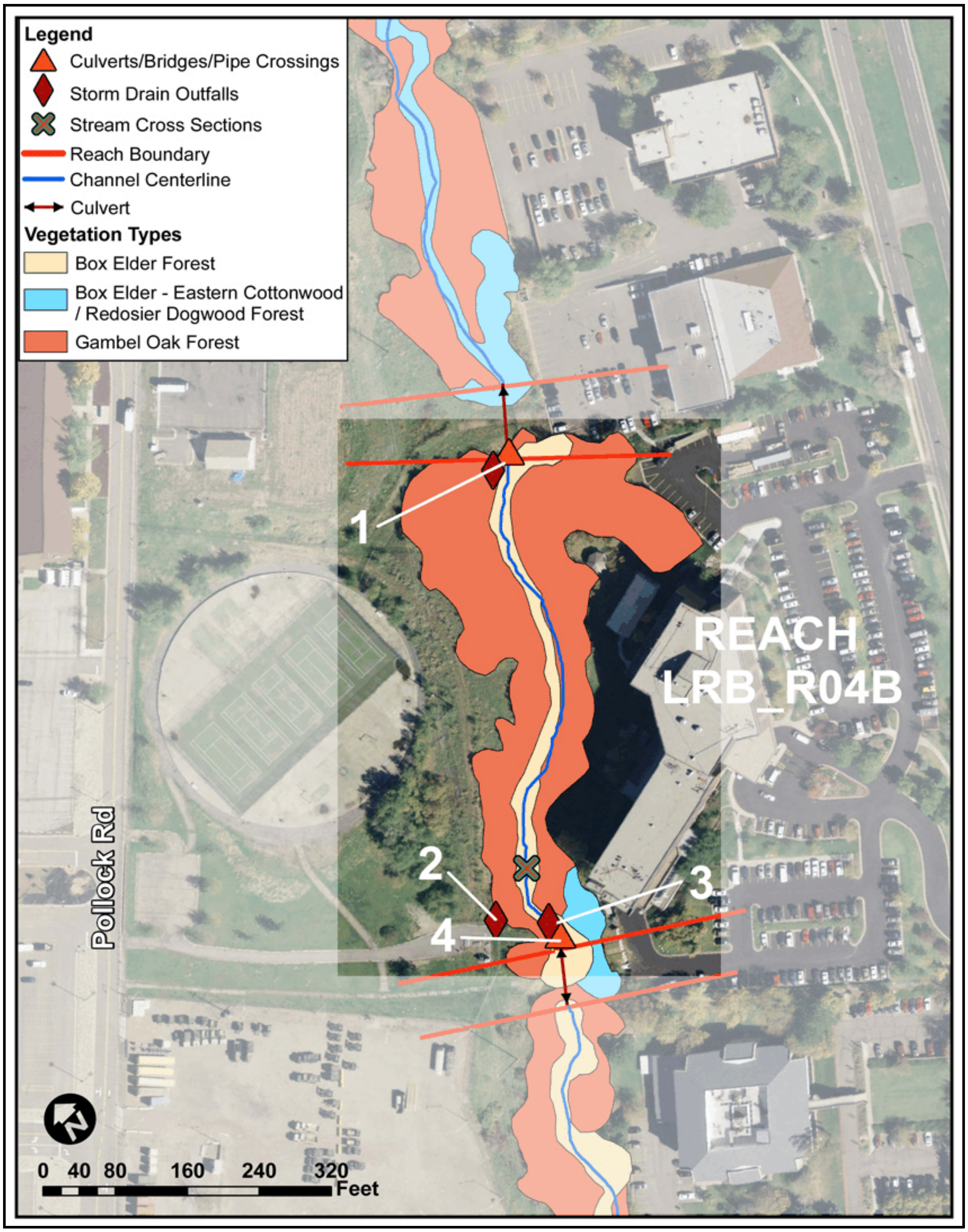
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- interest in public access/potential for trail
- general study area priorities (habitat, water quality, bank stability) also apply

REACH LRB_R04B: UNIVERSITY - NEAR TENNIS COURTS

This reach is located between tennis courts on the west and a hotel building on the east. As with the upstream reaches, banks are generally tall and steep and terrace erosion is prevalent. Several storm drain outfalls are causing erosion within the reach. Understory cover and species diversity are somewhat limited, with poison ivy dominant.



Issues affecting riparian function:

- terrace erosion
- storm drain outfall erosion
- limited understory cover
- deposition/clogging at culvert inlet

Constraints/ opportunities:

- university location offers educational/ research opportunities
- potential may exist to remove culverts at rarely used crossings at top and bottom of reach and daylight up to 160 feet of channel

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
595	0.040	boulder, cobble, gravel	cobble, gravel	occasionally present	occasionally present	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder Forest	76–100+	51–75	6–25	none	moderate
Box Elder - Eastern Cottonwood / Redosier Dogwood Forest	76–100+	6–25	0	none	sparse
Gambel Oak Forest	76–100+	26–50	6–25	none	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	low	low	moderate

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Storm drain improvement	points 2 and 3 on map
Culvert removal	points 1 and 4 on map
Revegetation - understory layer	within vegetation type(s)
Biotechnical slope stabilization	reach-scale
Bank stabilization	reach-scale
Grade control	reach-scale

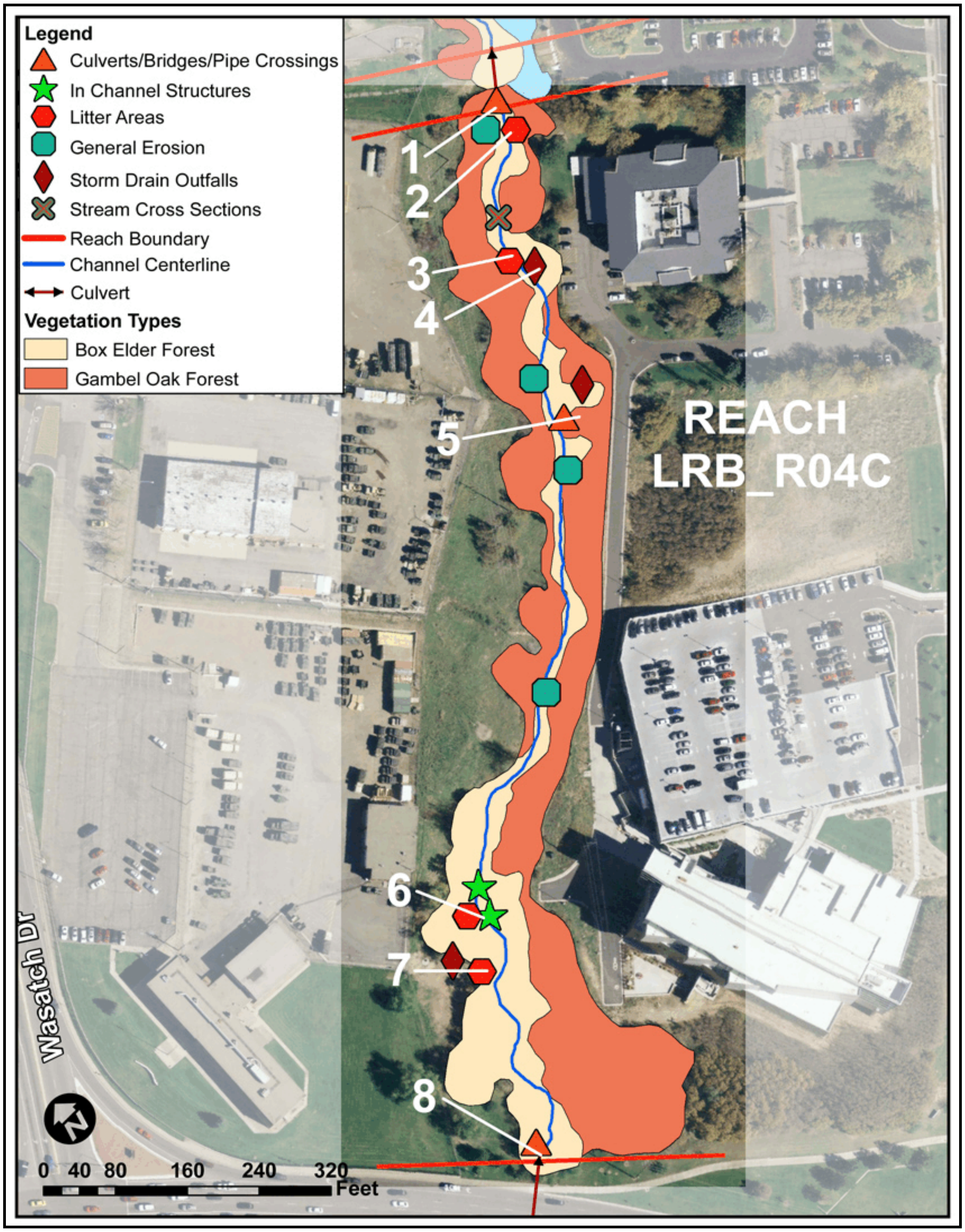
[a] See Appendix D for estimated costs.

Priorities identified by stakeholders:

- interest in public access/potential for trail
- general study area priorities (habitat, water quality, bank stability) also apply

REACH LRB_R04C: UNIVERSITY - ABOVE FOOTHILL DRIVE

This reach flows between U.S. Army facilities on the west and University of Utah research park buildings on the east. Several litter areas including broken pieces of concrete, pipe, chain link fence, and silt fence are present. Bank erosion is evident primarily in the upper and lower portions of the reach. This reach contains several storm drain outfalls and a wooden grade control structure. Forested width and canopy cover are limited in some areas.



Issues affecting riparian function:

- trash
- storm drain outfall erosion
- terrace erosion
- invasive species (whitetop, quackgrass)
- low bank/root zone erosion
- narrow forested corridor
- understory dominated by nonnative species
- bed incision
- limited shrub

Constraints/ opportunities:

- university location offers educational/ research opportunities
- potential may exist to remove culvert at rarely used crossing at top of reach and daylight up to 70 feet of channel

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
1294	0.032	cobble, gravel, soil	cobble, gravel	occasionally present	abundant	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder Forest	51–75	26–50	26–50	none	moderate
Gambel Oak Forest	76–100+	26–50	76–100+	high	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
none	low	low	high

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Restoration of native understory plants	within vegetation type(s)
Invasive plant removal	within vegetation type(s)
Mechanized trash removal	points 3 and 6 on map
Stream cleanup	points 2, 3, and 7 on map
Revegetation - canopy layer	within vegetation type(s)
Storm drain improvement	points 4 and 5 on map
Culvert removal	point 1 on map
Biotechnical slope stabilization	point 8 on map
Bank stabilization	reach-scale
Grade control	reach-scale

[a] See Appendix D for estimated costs.

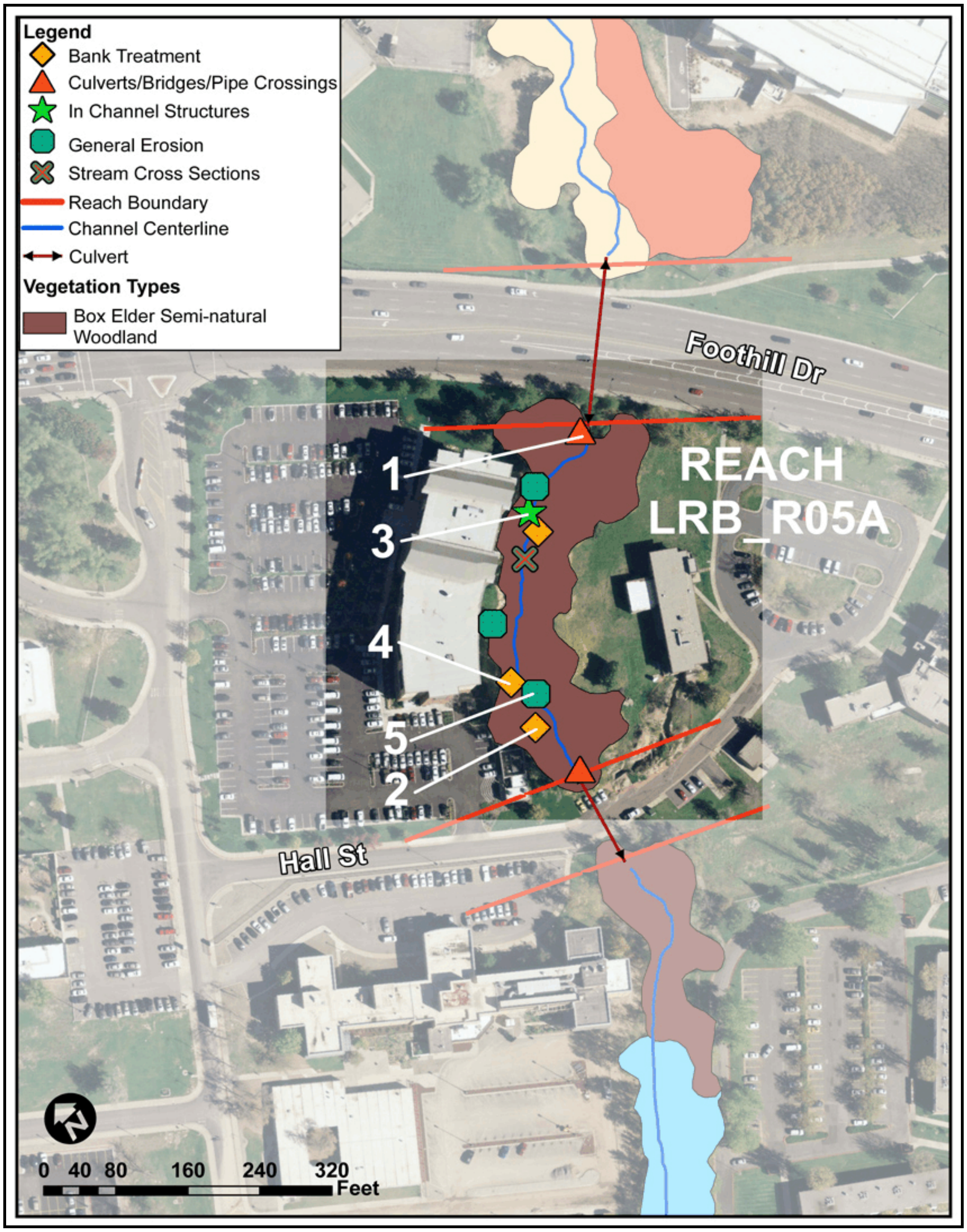
Priorities identified by stakeholders:

- interest in public access/potential for trail
- general study area priorities (habitat, water quality, bank stability) also apply



REACH LRB_R05A: VA MEDICAL CENTER - BELOW FOOTHILL DRIVE

This is a steep, short reach that is heavily impacted by development. Bank areas contain significant amounts of asphalt and concrete pieces that have failed to stabilize the banks and currently degrade aesthetics and limit vegetation establishment. The reach contains a concrete wall/weir/outfall structure that contributes to erosion and appears to be obsolete. Bed incision, root scour, and bank erosion are also ubiquitous through the reach. Shrub cover is lacking.



Issues affecting riparian function:

- scour/erosion at culvert outlet
- storm drain outfall erosion
- poor revegetation/ stabilization practices
- bed incision
- failing in-channel infrastructure
- failing bank revetment
- low bank/root zone erosion
- terrace erosion
- trash
- invasive species (Siberian elm)
- lack of shrub cover

Constraints/ opportunities:

- confined by infrastructure

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
433	0.055	cobble, soil	cobble, gravel	absent	occasionally present	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder Semi-natural Woodland	76–100+	0	26–50	high	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
moderate	none	high	none

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Invasive plant removal	within vegetation type(s)
Revegetation - shrub layer	within vegetation type(s)
Culvert replacement/outlet protection	point 1 on map
Stream cleanup	point 5 on map; reach-scale
Mechanized trash removal	points 2 and 4 on map; reach-scale
Replace/improve obsolete concrete structure	point 3 on map
Bank stabilization	reach-scale
Grade control	reach-scale

[a] See Appendix D for estimated costs.

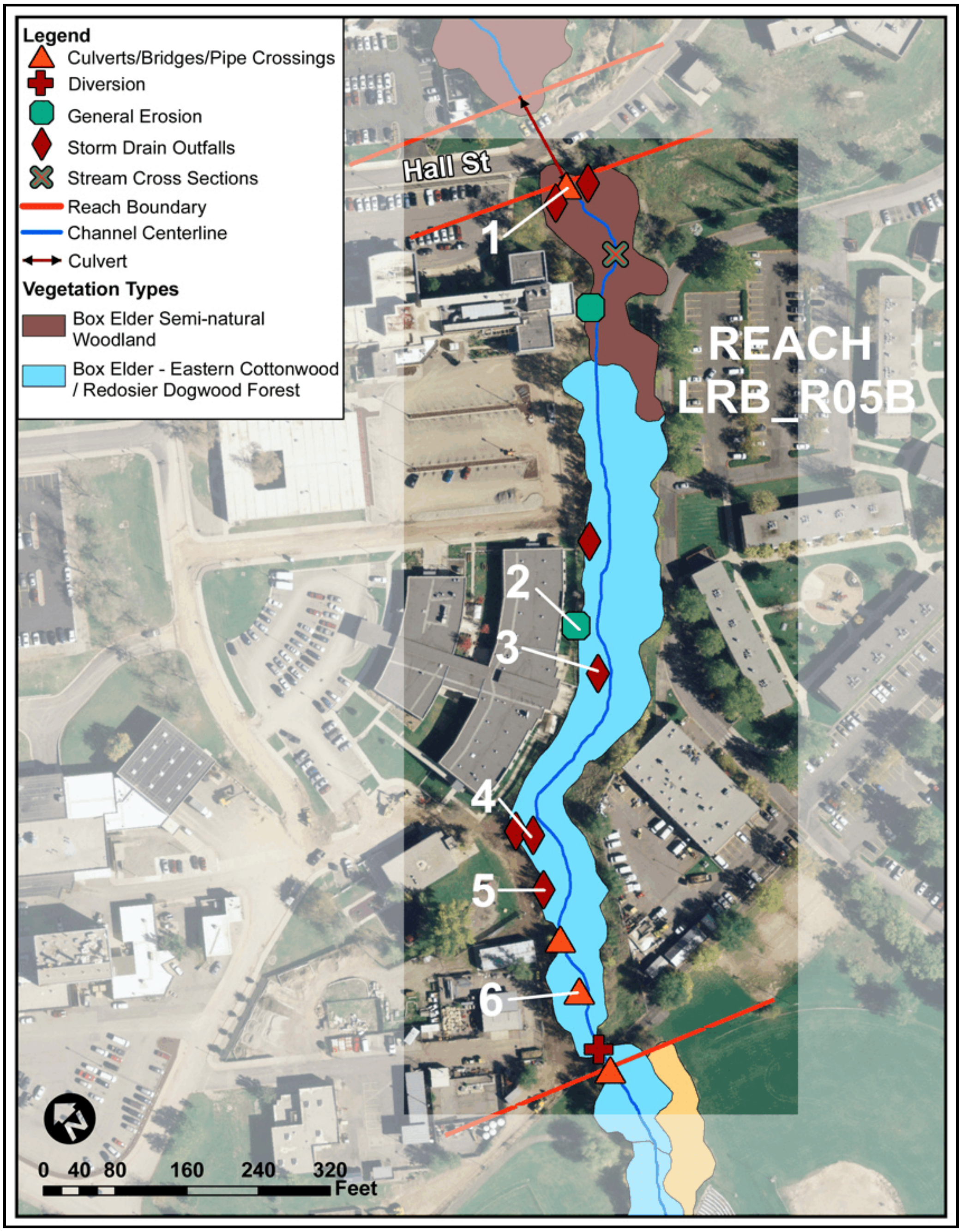
Priorities identified by stakeholders:

- interest in connecting small walking trail to Sunnyside Park trails
- interest in establishing bicycle commuting trail that would link to University of Utah
- general study area priorities (habitat, water quality, bank stability) also apply




REACH LRB_R05B: VA MEDICAL CENTER - ABOVE SUNNYSIDE PARK

This reach flows between Veteran's Administration and University of Utah facilities, ending at a diversion structure and bridge at the upstream end of Sunnyside Park. The reach contains seven storm drain outfalls, a utility pipe crossing, and a nearly clogged culvert at a trail crossing that does not appear to receive much use. Portions of the reach are in good condition.



Issues affecting riparian function:

- deposition/clogging at culvert
- bed incision
- terrace erosion
- storm drain outfall erosion
- limited shrub cover
- limited understory cover
- invasive species (Siberian elm, Russian olive)
- low bank/root zone erosion

Constraints/ opportunities:

- confined by infrastructure

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
1081	0.031	cobble, soil	cobble, gravel	occasionally present	occasionally present	occasionally present

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder Semi-natural Woodland	76–100+	6–25	6–25	moderate	moderate
Box Elder - Eastern Cottonwood / Redosier Dogwood Forest	76–100+	6–25	6–25	low	moderate

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
moderate	low	high	high

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Culvert replacement/outlet protection	point 1 on map
Culvert removal	point 6 on map
Storm drain improvement	points 3, 4, and 5 on map
Revegetation - shrub layer	within vegetation type(s)
Revegetation - understory layer	within vegetation type(s)
Invasive plant removal	within vegetation type(s)
Bank stabilization	reach-scale
Grade control	reach-scale
Biotechnical slope stabilization	point 2 on map

[a] See Appendix D for estimated costs.

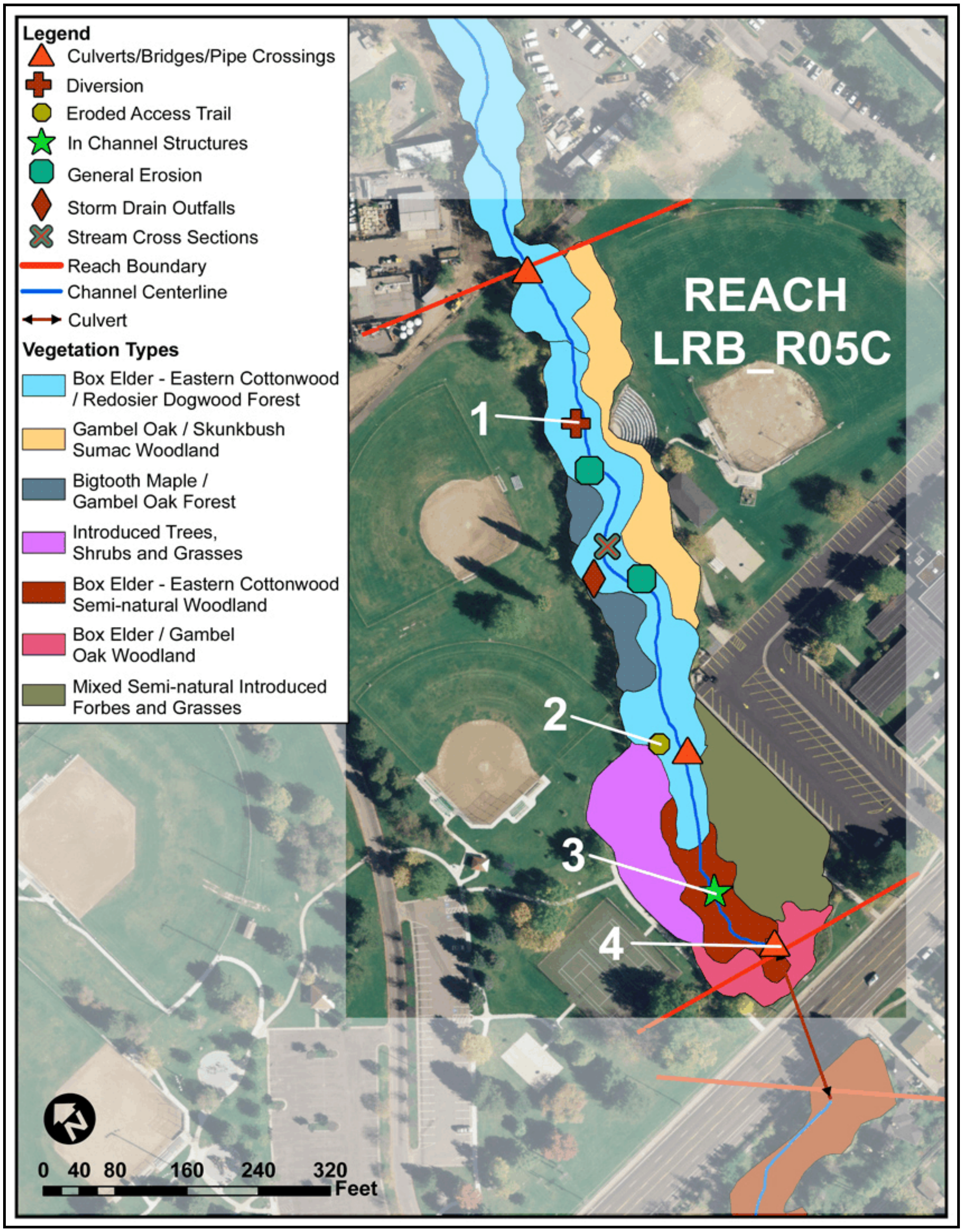
Priorities identified by stakeholders:

- interest in connecting small walking trail to Sunnyside Park trails
- interest in establishing bicycle commuting trail that would link to University of Utah
- interest in access deck that would allow nature appreciation/bird watching by State Nursing Home patients
- general study area priorities (habitat, water quality, bank stability) also apply




REACH LRB_R05C: SUNNYSIDE PARK

This reach contains a number of in-channel structures including a concrete diversion/weir structure and broken trash grate. The reach also contains several pedestrian access trails. Root zone scour and bank erosion are evident, particularly in the lower portions of the reach. Banks become less steep in the lower portion of the reach. Minimal understory vegetation cover is present.



Issues affecting riparian function:

- scour/erosion below concrete diversion weir
- low bank/root zone erosion
- eroded access trail
- bed incision
- invasive species (Russian olive, Siberian elm, houndstongue, whitetop)
- lack of understory cover
- failing in-channel infrastructure

Constraints/ opportunities:

- park location offers educational/ interpretive opportunities
- minimal infrastructure
- potential to reconnect broader floodplain near downstream end

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
887	0.037	cobble, gravel	cobble, gravel	occasionally present	occasionally present	absent

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Box Elder - Eastern Cottonwood / Redosier Dogwood Forest	76–100+	26–50	0	moderate	dense
Box Elder - Eastern Cottonwood Semi-natural Woodland	76–100+	51–75	6–25	moderate	moderate
Introduced Trees, Shrubs, and Grasses	26–50	0	76–100+	high	absent
Box Elder / Gambel Oak Woodland	76–100+	0	76–100+	high	absent
Mixed Semi-natural Introduced Forbes and Grasses	26–50	0	76–100+	moderate	absent
Bigtooth Maple / Gambel Oak Forest	76–100+	26–50	6–25	moderate	absent
Gambel Oak / Skunkbush Sumac Woodland	76–100+	26–50	6–25	low	dense

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
none	low	low	low

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Scour protection at diversion weir	point 1 on map
Revegetation - understory layer	within vegetation type(s)
Access trail stabilization	point 2 on map
Invasive plant removal	within vegetation type(s)
Remove/repair trash grate	point 3 on map
Bank stabilization	reach-scale
Grade control	reach-scale
Establish "no-mow" buffer at edge of turf	reach-scale
Culvert replacement	point 4 on map

[a] See Appendix D for estimated costs.

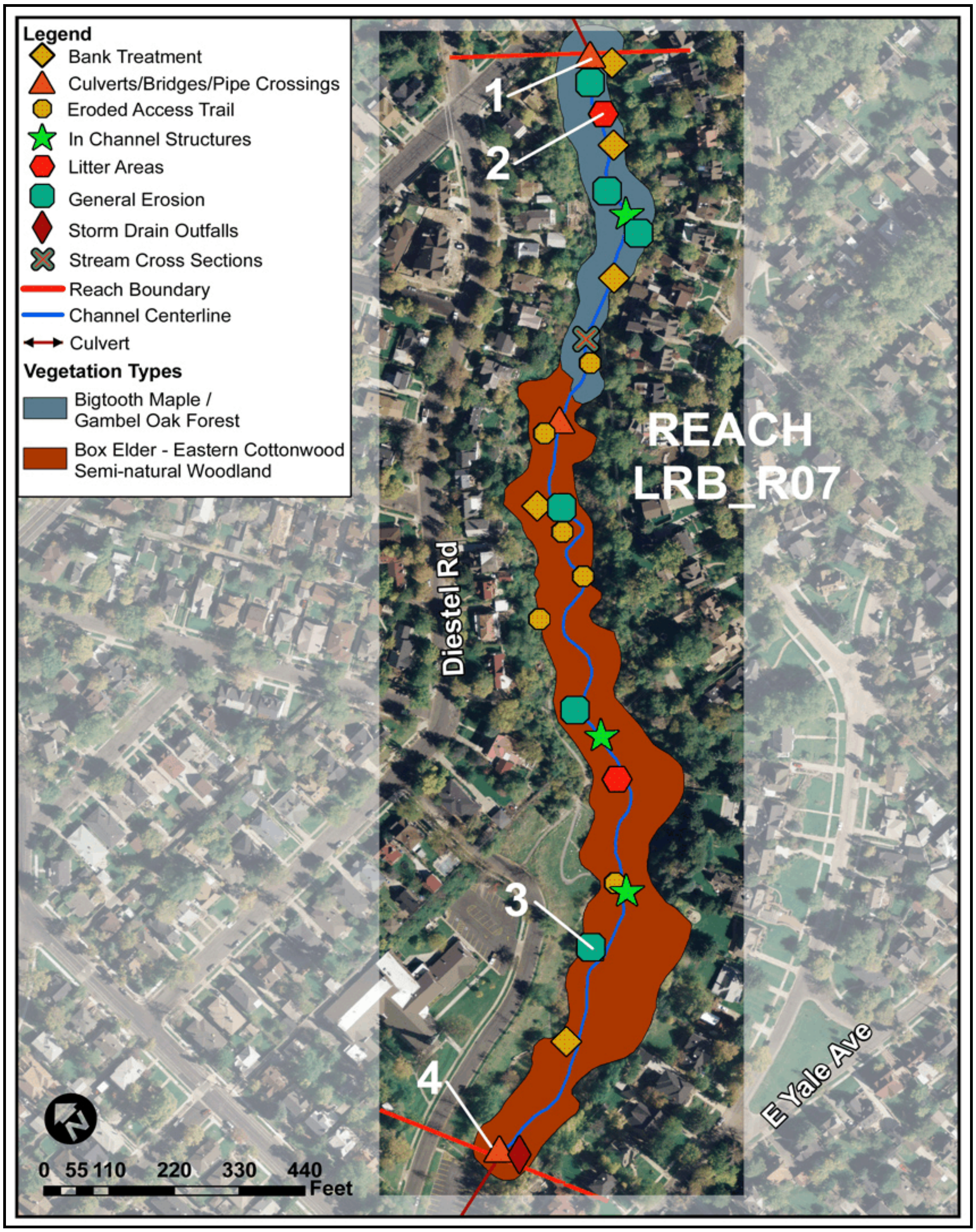
Priorities identified by stakeholders:

- no reach-specific items identified
- general study area priorities (habitat, water quality, bank stability) apply



REACH LRB_R07: MILLER PARK/BONNEVILLE GLEN

This reach encompasses Miller Park and Bonneville Glen, a church-owned park area. Bank erosion and bed incision are issues within the reach. Various rock and concrete bank/ bed hardening structures are present in the reach, but in some areas the structures are failing or causing erosion on opposite/ adjacent banks. Established and user-created trails are prevalent throughout the reach, limiting shrub and understory cover and contributing to erosion. Invasive periwinkle and English ivy comprise much of the understory vegetation.



Issues affecting riparian function:

- bed incision
- failing in-channel infrastructure
- failing bank revetment
- invasive species (English ivy, periwinkle, Scotch thistle, cheatgrass, Siberian elm, tree of heaven)
- low bank/root zone erosion
- scour/erosion at culvert outlet
- eroded access trails
- heavy foot traffic/soil compaction from dogs and people
- understory dominated by nonnative species
- lack of shrub cover

REACH CHARACTERISTICS						
LENGTH (feet)	SLOPE (feet/feet)	BANK MATERIAL	BED MATERIAL	FLAT FLOODPLAIN SURFACES	WOODY DEBRIS IN CHANNEL	BAR DEPOSITS
2084	0.036	cobble, gravel, soil	cobble, gravel	occasionally present	occasionally present	occasionally present

VEGETATION CHARACTERISTICS					
COMMUNITY TYPE	PERCENT COVER			INVASIVE SPECIES CLASS	WOODY DEBRIS ON BANKS
	Canopy	Shrub	Understory		
Bigtooth Maple / Gambel Oak Forest	76–100+	0	26–50	high	sparse
Box Elder - Eastern Cottonwood Semi-natural Woodland	76–100+	26–50	76–100+	majority	sparse

EXISTING INFRASTRUCTURE			
WITHIN 50 FEET OF AHWL		WITHIN 50–100 FEET OF AHWL	
Northwest Bank	Southeast Bank	Northwest Bank	Southeast Bank
low	low	low	moderate

RECOMMENDATIONS	
IMPROVEMENT MEASURE [a]	LOCATION
Invasive plant removal	within vegetation type(s)
Restoration of native understory plants	within vegetation type(s)
Revegetation - shrub layer	within vegetation type(s)
Access control	reach-scale
Access trail stabilization	reach-scale
Bank stabilization	reach-scale
Grade control	reach-scale
Culvert replacement/outlet protection	points 1 and 4 on map
Mechanized trash removal	point 2 on map
Remove partial rock wall	point 3 on map

[a] See Appendix D for estimated costs.

Constraints/ opportunities:

- potential may exist to daylight part of culverted section downstream
- upstream portion is publically owned
- tall, steep banks may limit large equipment access

Priorities identified by stakeholders:

- bird habitat/bird watching
- concern about dog-use impacts on wildlife
- instream flows
- general study area priorities (habitat, water quality, bank stability) also apply

PARTIALLY ASSESSED STUDY REACHES

Reach URB_R10: Middle Red Butte Garden

In this reach Red Butte Creek flows through a series of constructed, landscaped ponds within the formal portion of Red Butte Garden. The stream channel is in stable condition, and wetland plant species such as bullrush and common reed are present along the shoreline of some of the ponds. A moderate amount of houndstongue, a noxious weed, was noted in the corridor within the upstream portion of this reach.

Reach LRB_R06: Sunnyside Avenue to 900 South

This reach flows through a privately owned residential area. Conditions were qualitatively evaluated from a property near the upstream end of the reach and also from the culvert inlet at the downstream end of the reach. Banks are steep in this reach, and the channel has been artificially stabilized in a number of areas with a variety of structures including boards, concrete walls, rock weirs, and gabion baskets. Understory vegetation is dominated by invasive English ivy and periwinkle vine. Whitetop, a noxious weed, was also noted as present in the reach. Opportunities are somewhat limited in this reach due to infrastructure constraints, but improvements to habitat and filtration functions could be attained through restoration of native understory plants and biotechnical stabilization of steep upper slope areas. Installation of stabilized, pervious access steps could also improve stability and reduce potential erosion in areas where access trails currently consist of bare dirt.

Reach LRB_R08: Below 1500 East

This reach was not assessed because access permission from property owners was not obtained. Riparian conditions are assumed to be similar to upstream and downstream reaches. Projects involving restoration of native understory plants and biotechnical stabilization of upper slope areas would likely be appropriate in this reach.

Reach LRB_R09: Above 1300 East

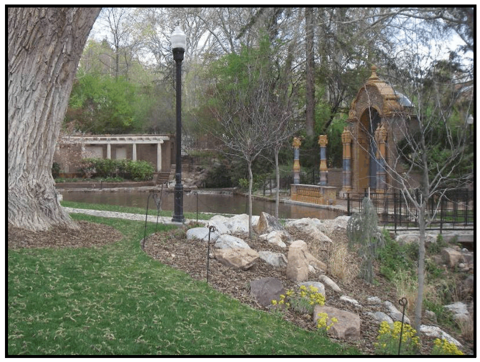
This reach was qualitatively evaluated from one property located near the middle of the reach. As in most of the study area, banks are steep and tall. The channel is well shaded by trees; understory vegetation is dominated by English ivy and periwinkle vine in some areas. Woody debris adds to in-channel habitat complexity. Streambanks have been hardened with grouted rock on some properties, and footbridges and fences occasionally cross the channel. Springs and seeps appear to be common in this reach and help to maintain baseflows while adding to habitat and vegetation diversity. Some of these springs have been developed with pipes and/or rocked spring heads. In several areas within the reach, small cottages are present immediately adjacent to or directly above the stream channel. These historic structures were built to provide cool places to sleep during the summer. Recommended projects for this reach include restoration of native understory plants, biotechnical stabilization of upper slope areas, and replacement of dirt access trails with stable, pervious access steps.

Reach LRB_R10: 1300 East to 1100 East

In this reach the Red Butte Creek channel drops below the lowest Bonneville bench level, bank height and steepness decrease, and the channel becomes less confined. This reach is completely within private property and was evaluated only in two locations where access was specifically permitted. In the areas assessed, the stream is channelized within artificially stabilized banks consisting of grouted rock walls, metal, or other hard structures. Fences commonly cross the stream at property lines, creating potential barriers to the transport of woody debris. As with reach LRB_R09, springs occur within the reach and footbridges have been constructed in several locations. Vegetation conditions vary among properties depending on landscaping, with natural vegetation in some areas and mowed grass in other areas. Within the historic Garden Park Ward property, the creek flows through a constructed pond. Opportunities within this reach are limited by the urbanized hydrology, infrastructure constraints, and

Reach LRB_R10: 1300 East to 1100 East (cont.)

"formal" landscaped use of streamside areas. Restoration of native shrubs, understory plants, and trees along the streambanks would improve the riparian functions of shading, filtration, and habitat in this reach.


Reach LRB_R11: Below 1100 East

This is a short reach that is tightly confined by residential buildings. The channel has been stabilized with concrete walls and, during high flow periods, velocities are very high due to the lateral confinement of the channel. Opportunities are limited in this reach due to the urbanized hydrology and tight infrastructure constraints.

APPENDIX D: COST ESTIMATES FOR STUDY REACHES

This appendix provides approximate quantity and cost information for the improvement measures identified in the reach tables in Appendix C. These estimates are for materials and installation costs only. They are approximate and should be considered order-of-magnitude level estimates. Project implementation will entail expenses for site-level plan design, engineering, permitting, monitoring, and maintenance in addition to the costs provided below. Additionally, the improvement measures included in the following tables are not intended to be exhaustive. It is anticipated that quantities and approaches may vary once site-specific design work is initiated for a given project or study reach.

Cost Assumptions

Estimates for each study reach are based on the unit cost assumptions listed in Table D1. The Table D1 values were derived from the unit costs listed in Table 4.6. Unit cost and quantity assumptions for specific improvement measures are described below.

Stream Cleanup

The unit costs listed in Table D1 assume that cleanup events are completed using volunteer labor; the listed unit cost values are intended to partially cover the cost of supplies, disposal/landfill fees, and mileage to/from disposal sites. Low, moderate, and high cost values are provided to reflect the difference in expected disposal costs for reaches assessed as having low, moderate, or high amounts of trash.

Mechanized Trash Removal

The unit costs listed in Table D1 assume the use of paid labor; costs could be reduced via the use of in-kind government labor/equipment, or donated supplies. The "low" cost value reflects efforts that could be completed in less than 1 day and would not involve significant disturbance for access. The "moderate" cost value reflects efforts that would require 2–3 work days to complete, involve use of heavy equipment, and require a moderate level of disturbance and revegetation. The "high" cost value reflects efforts that would require up to 1 week of work, extensive heavy equipment use, and extensive revegetation/stabilization measures after accessing the channel.

Invasive Plant Removal/Control

The average per-acre unit cost from Table 4.6 ($750/acre) was used for the "moderate" cost value in Table D1. This cost was assumed to be appropriate for vegetation communities mapped as having a "moderate" invasive species class. Lower and higher costs ($600/acre and $900/acre, respectively) were assigned for use in areas with mapped invasive species classes of low or high/majority, respectively. Unit costs represent per-acre costs assuming three site visits (i.e., three separate mechanical and/or chemical treatments), which would cover 1 year of invasive plant removal/control work. Successful invasive plant removal and control typically requires 5–10 years of annual treatments.

Table D1. Unit cost assumptions used to generate cost estimates for each study reach.

IMPROVEMENT MEASURE	UNIT	UNIT COST			SOURCE OF COST INFORMATION [a]
		Low	Moderate	High	
Invasive plant removal/control	acre	$600	$750	$900	BIO-WEST (2009)
Revegetation (seed)	acre	N/A	$3,000	N/A	BIO-WEST (2009)
Revegetation (erosion control blanket)	square yard	N/A	$3	N/A	UDOT [b] 2008
Revegetation - live plant stakes	per stake	N/A	$3	N/A	BIO-WEST (2009)
Revegetation - 1-gallon containerized plants	per plant	N/A	$12	N/A	UDOT [b] 2008
Revegetation - 5-gallon containerized plants	per plant	N/A	$75	N/A	UDOT [b] 2008
Revegetation - 2-inch caliper trees	per plant	N/A	$250	N/A	UDOT [b] 2008
Slope flattening or terracing	square yard	N/A	$5	N/A	UDOT [b] 2008
Vegetated soil lifts	linear foot	N/A	$45	N/A	DPU [c] (2009)
Vegetated rock revetment	linear foot	N/A	$65	N/A	DPU [c] (2009)
Stream cleanup	per event	$125	$250	$500	BIO-WEST (2009)
Mechanized trash removal	per event	$500	$3,000	$7,500	DPU [c] (2009)
Storm drain improvement (rock outlet and swale)	per outfall	$900	$1,800	$2,800	DPU [c] (2009)
Runoff management (vegetated rock-lined swale)	linear foot	N/A	$77	N/A	DPU [c] (2009)
Runoff management (grading)	cubic yard	N/A	$10	N/A	UDOT [b] 2008
Pre-fabricated bridge (30 to 45 feet long, 6 to 15 feet wide)	each	N/A	$70,000	N/A	supplier estimate, BIO-WEST (2009)
Open-bottom box culvert (12 feet wide or greater)	linear foot	N/A	$4,500	N/A	DPU [c] (2009)
Rock-lined tailwater pool	each	N/A	$20,000	N/A	DPU [c] (2009)
Rock step pool	each	N/A	$4,000	N/A	Schueler and Brown 2004
No-trespassing signage	each sign	N/A	$200	N/A	UDOT [b] 2008, BIO-WEST (2009)
Stream daylighting	linear foot	N/A	$200	N/A	Schueler and Brown 2004
Bank stabilization	linear foot	$35	$75	$110	DPU [c], BIO-WEST (2009)
Grade control (1 vortex rock weir every 100 linear feet)	each	N/A	$2,100	N/A	Schueler and Brown 2004
Floodplain re-establishment	cubic yard	N/A	$10	N/A	UDOT [b] 2008
Access control (split rail fence)	linear foot	N/A	$10	N/A	supplier estimate, BIO-WEST (2009)
Access trail stabilization (steps)	linear foot	N/A	$50	N/A	BIO-WEST (2009)

[a] See Table 4.6 and text above for more details.
[b] Utah Department of Transportation.
[c] Salt Lake City Department of Public Utilities.

Storm Drain Improvement

The Table 4.6 unit costs for "outlet protection using vegetated rock" and "vegetated rock-lined swale" were used to calculate approximate per-outfall costs for low, moderate, and high-cost storm drain improvements. For each outfall, the relevant per-outfall cost was assigned based on the assessed size and condition of the outfall. A low-cost outfall improvement includes 10 linear feet of swale and 1.25 square yards of vegetated rock outlet protection; a moderate-cost improvement includes 20 linear feet of swale and 2.5 square yards of vegetated rock outlet protection; a high-cost outlet improvement includes about 30 linear feet of swale and 5 square yards of vegetated rock outlet protection.

Pre-fabricated Bridge

The materials-only cost for either a railroad flatcar (89 feet long x 8.5 feet wide) or pre-fabricated pedestrian truss bridge (30 feet long x 6 feet wide) is about $23,000; this value was multiplied by three to provide an approximate order-of-magnitude estimate for materials and installation of this type of bridge. This value ($70,000/bridge) also includes removal of the old culvert, fill dirt excavation, and needed channel and bank work associated with bridge installation.

Open-bottom Box Culvert

Based on price estimates from suppliers, the materials-only cost for a 12-foot by 6-foot box culvert is about $625/linear foot. However, based on the experience of DPU engineering staff with a 2009 culvert replacement project on Emigration Creek, material costs tend to be a relatively minor proportion of the total project cost relative to installation costs. Installation costs at most crossings will be very high due to the depth of the existing culvert pipes; amount of fill material; challenging access conditions; and constraints associated with existing sewer lines, storm drain pipes, water lines, and other infrastructure. Therefore, based on input from DPU, a materials and installation unit cost of $4,500/linear foot was used for culvert replacement cost estimates (Table D1).

Rock-lined Tailwater Pool

The Table 4.6 per-cubic-yard costs for “rock-lined tailwater pool” and “vegetated rock revetment” were used to calculate an approximate per-pool cost for this improvement measure. The Table D1 value of $20,000 per pool assumes installation of 60 linear feet of vegetated rock revetment and about 170 cubic yards of excavation and rock installation (adequate for a rock-lined tailwater pool approximately 30 feet long and wide). For culvert outlets assessed as having particularly high outlet velocities and scour/erosion problems, one to two additional rock step-pools at $4,000/step-pool (Table 4.6) were included in the culvert outlet protection cost estimate for the reach.

Bank Stabilization

Bank stabilization projects should be implemented at a reach-scale and require site-specific design and engineering to select the most appropriate combination of techniques. Selection of specific techniques is beyond the scope of this study; therefore, some general assumptions were used to generate the cost estimates provided in Table D1. For reaches identified as having relatively minor stability problems that do not threaten infrastructure, a “low” unit cost value of $35/linear foot was used, and it was assumed that 10% of the total bank length (left plus right banks) would require stabilization measures. The $35/linear foot value is in the cost range for “softer” stabilization techniques such as soil lifts or slope terracing. For reaches assessed as having moderate stability problems that would likely require incorporation of “harder” techniques such as toe protection, a “moderate” unit cost value of $75/linear foot was used, and it was assumed that 25% of the total bank length would require stabilization measures. For reaches where infrastructure is threatened by bank erosion and stability is compromised by high-velocity urban storm flows, a “high” unit cost value of $110/linear foot applied to half of the total bank length was used. This value is in the cost range for techniques such as vegetated gabion basket or modular block retaining walls (Table 4.6).

Cost Estimates by Reach

The following tables (D2–D12) provide approximate cost information for each study reach. As discussed above, the cost values provided in this appendix include materials and initial installation but do not include site-specific design, engineering, permitting, monitoring, or maintenance costs. Maintenance and monitoring costs can be significant, particularly for projects involving invasive species control and revegetation (see Table 4.8). The tables below provide costs for each type of improvement measure and are also totaled for each reach. For reaches where replacement of stream crossing culverts is recommended, total costs are provided with and without the culvert replacement costs included.

Table D2. Estimated approximate costs for Reach URB_R09 (upper Red Butte Garden).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Invasive plant removal	6.41	acres	$4,480
Removal of concrete/asphalt on bank	1	event (moderate cost)	$3,000
Biotechnical slope stabilization (terracing)	200	square yards	$1,000
Biotechnical slope stabilization (rock revetment)	40	linear feet	$2,600
Revegetation of low bank at picnic area	20	1-gallon plants	$240
		TOTAL	**$11,320**

Table D3. Estimated approximate costs for Reach LRB_R01 (lower Red Butte Garden).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Stream cleanup	1	event (low cost)	$125
Monitor/protect riparian corridor	N/A	N/A	N/A
		TOTAL	**$125**

Table D4. Estimated approximate costs for Reach LRB_R02 (below Red Butte Garden).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Access control (fence)	450	linear feet	$4,500
Access trail stabilization (steps)	30	linear feet	$1,500
Revegetation - understory layer (seed)	0.96	acre	$2,880
Revegetation - understory layer (erosion control blanket)	300	square yards	$900
Revegetation - shrub layer	140	1-gallon plants	$1,680
Bank and slope stabilization	450	linear feet	$49,500
Mechanized trash removal (concrete pieces)	1	event (low cost)	$500
Stream cleanup	1	event (low cost)	$125
Invasive plant removal/control	0.28	acre	$170
Culvert replacement with bridge (trail crossing)	1	pre-fabricated bridge	$70,000
		TOTAL (with culvert replacement)	**$131,755**
		TOTAL (no culvert replacement)	**$61,755**

Table D5. Estimated approximate costs for Reach LRB_R03 (University - above Chipeta Way).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Invasive plant removal	2.86	acres	$1,720
Removal/improvements to gravel bank area (seed)	0.02	acre	$60
Removal/improvements to gravel bank area (erosion control blanket)	80	square yards	$240
Revegetation - canopy layer	7	trees	$1,750
Removal/improvements to concrete brick wall	1	event (high cost)	$7,500
Bank stabilization	520	linear feet	$39,000
Grade control	10	vortex rock weirs	$21,000
Culvert replacement/improvement (Chipeta Way)	108	linear feet	see Table D6
Avoid placing yard waste on banks	N/A	N/A	N/A
Establish “no mow” buffer at edge of turf	N/A	N/A	N/A
		TOTAL	**$71,270**

Table D6. Estimated approximate costs for Reach LRB_R04A (University - below Chipeta Way).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Stream cleanup	1	event (high cost)	$500
Mechanized trash removal	1	event (high cost)	$7,500
Storm drain improvement	1	outfall	$1,800
Culvert replacement with open box (Chipeta Way crossing)	108	linear feet	$486,000
Revegetation to increase total forested width	40	trees	$10,000
Invasive plant removal	0.74	acres	$560
Bank stabilization	480	linear feet	$36,000
Grade control	9	vortex rock weirs	$18,900
		TOTAL (with culvert replacement)	**$561,260**
		TOTAL (no culvert replacement)	**$75,260**

Table D7. Estimated approximate costs for Reach LRB_R04B (University -near tennis courts).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Storm drain improvement	3	outfalls	$6,400
Culvert replacement with open box (crossing near tennis courts) [a]	90	linear feet	$405,000
Revegetation - understory (seed)	0.17	acre	$510
Revegetation - understory (erosion control blanket)	790	square yards	$2,370
Bank and slope stabilization	300	linear feet	$22,500
Grade control	6	vortex rock weirs	$12,600
		TOTAL (with culvert replacement)	**$449,380**
		TOTAL (no culvert replacement)	**$44,380**

[a] Complete removal of culvert recommended if possible.

Table D8. Estimated approximate costs for Reach LRB_R04C (University - above Foothill Drive).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Restoration of native understory plants (seed)	1.0	acre	$3,000
Invasive plant removal	1.98	acres	$1,780
Mechanized trash removal	1	event (moderate cost)	$3,000
Stream cleanup	1	event (moderate cost)	$250
Revegetation - canopy layer	50	trees	$12,500
Storm drain improvement	2	outfalls	$4,600
Culvert replacement with open box (crossing near Marriot) [a]	72	linear feet	$324,000
Biotechnical slope stabilization (terracing)	40	square yards	$200
Biotechnical slope stabilization (erosion control blanket)	40	square yards	$120
Bank stabilization	650	linear feet	$48,750
Grade control	13	vortex rock weirs	$27,300
		TOTAL (with culvert replacement)	**$425,500**
		TOTAL (no culvert replacement)	**$101,500**

[a] Complete removal of culvert recommended if possible.

Table D9. Estimated approximate costs for Reach LRB_R05A (VA Medical Center - below Foothill Drive).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Invasive plant removal	1.04	acres	$3,120
Revegetation - shrub layer	170	1-gallon plants	$2,040
Stream cleanup	1	event (low cost)	$125
Mechanized trash/obsolete concrete structure removal	1	event (high cost)	$7,500
Replace obsolete concrete structure	1	step-pool	$4,000
Bank stabilization	430	linear feet	$47,300
Grade control	4	vortex rock weirs	$8,400
Culvert replacement with open box (Foothill Drive crossing)	192	linear feet	$864,000
Culvert outlet protection (no replacement)	1	rock-lined tailwater pool plus 1 step-pool	$24,000
		TOTAL (with culvert replacement)	**$936,485**
		TOTAL (culvert outlet protection only)	**$96,485**

Table D10. Estimated approximate costs for Reach LRB_R05B (VA Medical Center - above Sunnyside Park).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Storm drain improvement	3	outfalls	$3,600
Revegetation - shrub layer	220	1-gallon plants	$2,640
Revegetation - understory (seed)	0.43	acre	$1,290
Revegetation - understory (erosion control blanket)	720	square yards	$2,160
Invasive plant removal	1.72	acres	$1,100
Bank stabilization	540	linear feet	$40,500
Grade control	11	vortex rock weirs	$23,100
Biotechnical slope stabilization (soil lifts)	30	linear feet	$1,350
Removal of clogged arch culvert (crossing within VA complex)	1	removal	$7,500
Culvert replacement with open box (Hall Street crossing)	128	linear feet	$576,000
Culvert outlet protection (no replacement)	1	rock-lined tailwater pool	$20,000
		TOTAL (with Hall Street culvert replacement)	**$659,240**
		TOTAL (Hall Street culvert outlet protection only)	**$103,240**

Table D11. Estimated approximate costs for Reach LRB_R05C (Sunnyside Park).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Scour protection at diversion weir	1	rock-lined tailwater pool	$20,000
Revegetation - understory (seed)	1.10	acres	$3,300
Revegetation - understory (erosion control blanket)	850	square yards	$2,550
Restoration of native understory plants (seed)	0.66	acres	$1,980
Access trail stabilization (steps)	40	linear feet	$2,000
Access control (fence)	200	linear feet	$2,000
Invasive plant removal	2.55	acres	$1,910
Remove broken trash grate	1	event (high cost)	$7,500
Establish/maintain "no mow" buffer at edge of turf	N/A	N/A	N/A
Bank stabilization	440	linear feet	$33,000
Grade control	9	vortex rock weirs	$18,900
Culvert replacement with open box (Sunnyside Avenue crossing)	180	linear feet	$810,000
		TOTAL (with culvert replacement)	**$903,140**
		TOTAL (no culvert replacement)	**$93,140**

Table D12. Estimated approximate costs for Reach LRB_R07 (Miller Park/Bonneville Glen).

IMPROVEMENT MEASURE	QUANTITY	UNIT	APPROXIMATE COST
Invasive plant removal	5.07	acres	$4,563
Restoration of native understory plants (seed)	5.07	acres	$15,210
Restoration of native understory plants (erosion control blanket)	1,390	square yards	$4,170
Revegetation - shrub layer	250	1-gallon plants	$3,000
Access control (fence)	4,170	linear feet	$41,700
Access trail stabilization (steps)	150	linear feet	$7,500
Bank stabilization	2,084	linear feet	$229,240
Grade control	20	vortex rock weirs	$42,000
Mechanized trash removal	1	event (low cost)	$500
Remove partial rock wall	1	event (moderate cost)	$3,000
Culvert replacement with open-bottom box (900 South crossing)	210	linear feet	$945,000
Culvert outlet protection (900 South crossing)	1	rock-lined tailwater pool plus 1 step-pool	$24,000
Culvert replacement with open-bottom box (1500 East crossing) [a]	400	linear feet	$1,800,000
		TOTAL (with replacement of culverts)	$3,095,883
		TOTAL (culvert outlet protection only)	$374,883

[a] Culvert length and cost would be reduced if it were possible to daylight part of existing culvert.

Cost Summaries

Total costs for each reach are summarized in Table D13. Table D14 provides a summary of stream crossing culvert replacement costs and priorities for the Red Butte Creek corridor.

Table D13. Summary of estimated approximate costs for improvement measures by reach.

REACH NUMBER	REACH DESCRIPTION	REACH LENGTH (feet)	APPROXIMATE COST ESTIMATE FOR INITIAL IMPLEMENTATION OF IMPROVEMENT MEASURES [a]	
			With Culvert Replacement and/or Daylighting	Without Culvert Replacement and/or Daylighting [b]
URB_R09	Upper Red Butte Garden	2,297	N/A	$11,320
URB_R10	Middle Red Butte Garden	827	reach not fully assessed	reach not fully assessed
LRB_R01	Lower Red Butte Garden	281	N/A	$125
LRB_R02	University - Below Red Butte Garden	451	$131,755	$61,755
LRB_R03	University - Above Chipeta Way	1,041	N/A	$71,270
LRB_R04A	University - Below Chipeta Way	961	$561,260	$75,260
LRB_R04B	University - Near Tennis Courts	595	$449,380	$44,380
LRB_R04C	University - Above Foothill Drive	1,294	$425,500	$101,500
LRB_R05A	VA Medical Center - Below Foothill Drive	433	$936,485	$96,485
LRB_R05B	VA Medical Center - Above Sunnyside Park	1,081	$659,240	$103,240
LRB_R05C	Sunnyside Park	887	$903,140	$93,140
LRB_R06	Sunnyside Avenue to 900 South	492	reach not fully assessed	reach not fully assessed
LRB_R07	Miller Park/ Bonneville Glen	2,084	$3,095,883	$374,883
LRB_R08	Below 1500 East	1,059	reach not assessed	reach not assessed
LRB_R09	Above 1300 E ast	633	reach not fully assessed	reach not fully assessed
LRB_R10	1300 East to 1100 East	1,449	reach not fully assessed	reach not fully assessed
LRB_R11	Below 1100 East	301	reach not fully assessed	reach not fully assessed
TOTAL FOR RED BUTTE CREEK CORRIDOR			**$7,162,643**	**$1,033,358**

[a] Estimated cost values include materials and installation but do not include site-specific design, engineering, permitting, monitoring, or maintenance costs.

[b] If culvert outlets are protected but culverts are not removed or replaced with wider-span/open-bottom structures, stream stability is expected to improve but the additional benefits associated with replacement (improved connectivity, habitat, conveyance, reduced risk of clogging, etc.) will not be gained.

Table D14. Relative priorities and estimated costs for stream crossing culvert replacement/improvement projects in the Red Butte Creek riparian corridor.

CROSSING LOCATION/ DESCRIPTION	REACH NUMBER(S)	CULVERT LENGTH (feet)	RELATIVE PRIORITY FOR REPLACEMENT/ IMPROVEMENT	TYPE OF REPLACEMENT STRUCTURE	ESTIMATED REPLACEMENT COST [a]	PRIMARY BENEFITS OF REPLACEMENT	ALTERNATIVE TYPE OF IMPROVEMENT	ESTIMATED COST FOR ALTERNATIVE MEASURE [a]	PRIMARY BENEFITS OF ALTERNATIVE MEASURE	POTENTIAL TO DAYLIGHT/ REDUCE LENGTH OF CULVERT
Trail at south end of Red Butte Garden	between LRB_R01 and LRB_R02	50	low	full-span pre-fabricated bridge	$70,000	improved connectivity; reduced risk of clogging	N/A	N/A	N/A	no
Chipeta Way	between LRB_R03 and LRB_R04A	108	low	bridge or open-bottom box culvert	$486,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	N/A	N/A	N/A	no
Crossing near tennis courts	between LRB_R04A and LRB_R04B	90	medium	bridge or open-bottom box culvert	$405,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	remove [b]	$50,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	maybe - crossing not part of trail or road network
Crossing near Marriot	between LRB_R04B and LRB_R04C	72	medium	bridge or open-bottom box culvert	$324,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	remove [b]	$35,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	maybe - crossing not part of trail or road network
Foothill Drive	between LRB_R04C and LRB_R05A	192	high	open-bottom box culvert	$864,000	improved connectivity, habitat, stream stability, conveyance	install outlet protection	$24,000	improved stream stability	no
Hall Street	between LRB_R05A and LRB_R05B	128	medium	bridge or open-bottom box culvert	$576,000	improved connectivity, habitat, stream stability, conveyance	install outlet protection	$20,000	improved stream stability	no

Table D14. Relative priorities and estimated costs for stream crossing culvert replacement/improvement projects in the Red Butte Creek riparian corridor (cont.).

CROSSING LOCATION/ DESCRIPTION	REACH NUMBER(S)	CULVERT LENGTH (feet)	RELATIVE PRIORITY FOR REPLACEMENT/ IMPROVEMENT	TYPE OF REPLACEMENT STRUCTURE	ESTIMATED REPLACEMENT COST [a]	PRIMARY BENEFITS OF REPLACEMENT	ALTERNATIVE TYPE OF IMPROVEMENT	ESTIMATED COST FOR ALTERNATIVE MEASURE [a]	PRIMARY BENEFITS OF ALTERNATIVE MEASURE	POTENTIAL TO DAYLIGHT/ REDUCE LENGTH OF CULVERT
Crossing within VA Medical Center complex	near downstream end of LRB_R05B	20	high	bridge or open-bottom box culvert	$90,000	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	remove [b]	$7,500	improved connectivity, habitat, conveyance; reduced risk of clogging/ flooding/ structure failure	maybe - crossing not part of trail or road network
Sunnyside Avenue	between LRB_R05C and LRB_R06	180	low [c]	open-bottom box culvert	$810,000	improved connectivity, habitat, conveyance	N/A	unknown - outlet condition not assessed	unknown - outlet condition not assessed	no
900 South	between LRB_R06 and LRB_R07	210	medium-high [d]	open-bottom box culvert	$945,000	improved connectivity, habitat, stream stability, conveyance	install outlet protection	$24,000	improved stream stability	maybe (downstream side) - currently developed trailhead area
Trail in Miller Park	middle of LRB_R07	16	no improvements needed	N/A	N/A	N/A	N/A	N/A	N/A	no
1500 East	between LRB_R07 and LRB_R08	400	low [c]	open-bottom box culvert	$1,800,000	improved connectivity, habitat, conveyance	install outlet protection	unknown - outlet condition not assessed	unknown - outlet condition not assessed	maybe (upstream side) - currently parking area
1300 East	between LRB_R09 and LRB_R10	260	unknown [c / d]	open-bottom box culvert	$1,170,000	unknown - inlet/ outlet not assessed	install outlet protection	unknown - outlet condition not assessed	unknown - outlet condition not assessed	no
1100 East	between LRB_R10 and LRB_R11	90	no improvements recommended	N/A	N/A	N/A	N/A	N/A	N/A	no
				TOTAL	$7,540,000					

[a] Estimated cost values include materials and installation but do not include site-specific design, engineering, permitting, monitoring, or maintenance costs.
[b] Removal recommended instead of culvert replacement, if possible.
[c] Outlet condition not assessed.
[d] Inlet condition not assessed.