RIPARIAN ECOSYSTEM RESTORATION EFFECTIVENESS FRAMEWORK

Tracking the Benefits of Stream and Floodplain Restoration in the Lake Tahoe Basin

Environmental Incentives

2NDNATURE
ecosystem science + design

RIVER RUN

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Riparian Ecosystem Restoration Effectiveness Framework

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produced by:

2NDNATURE LLC
w 2ndnaturellc.com

River Run Consulting
mkiesse@hughes.net

Environmental Incentives, LLC
w enviroincentives.com

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EXECUTIVE SUMMARY

2NDNATURE, River Run Consulting and Environmental Incentives collaborated on the completion of a SNPLMA Round 8 research grant (original proposal attached as Appendix A) to focus and improve the quality of stream restoration effectiveness evaluations in the Lake Tahoe Basin. The research team coordinated and solicited feedback from a Technical Advisory Committee (TAC) consisting of Lake Tahoe stream restoration practitioners from California State Parks, California Tahoe Conservancy, US Forest Service Lake Tahoe Basin Management Unit, Lahontan Regional Water Quality Control Board (LRWQCB), Tahoe Regional Planning Agency (TRPA) and a design engineer consultant.

A preliminary Inventory (attached as Appendix B) of available documentation and effectiveness reports on riparian ecosystem restoration projects conducted to date (winter 2009) in the Lake Tahoe Basin led to the conclusion that the documentation of a clear process and format would greatly benefit the future development of riparian restoration effectiveness evaluations. The 2NDNATURE team developed a recommended Riparian Ecosystem Restoration broad goal statement and conceptual model to focus the Lake Tahoe Basin-wide discussions. The Riparian Ecosystem Restoration and Effectiveness Framework (Framework) was developed to focus the process and improve the communications when stream restoration practitioners are implementing specific restoration projects. The Framework process is expected to simplify the summary of existing (impaired conditions), the development of testable restoration project objectives, improve the quality of restoration project monitoring strategies and actualize the adaptive management process. This document contains a number of specific recommendations and guidelines on how to improve the quality of protocol and metric selection, analysis and reporting to increase the confidence in effectiveness monitoring results. A completed channel realignment project in South Lake Tahoe is used as a hypothetical example riparian restoration project to illustrate the format and potential Framework content. The Framework development for future riparian restoration projects can build upon a number of the attributes, metrics and protocols recommended in the tangible example developed by the 2NDNATURE team. The final products of the Framework will increase consistency of the documentation of the restoration team intentions to interested parties many years following the completion of the restoration actions, thereby directly improving the availability and quality of the data and information available to make long-term adaptive management decisions.

FRAMEWORK

The four components of the Framework are:

- Existing Conditions Summary
- Project Objectives
- Monitoring Strategy and
- Adaptive Management Plan.

The Framework is a process composed of four steps that will greatly improve the ability of the restoration team to develop and communicate the hypothesized linkage between restoration actions and observed ecosystem impairments. This document defines a process that guides the restoration team through the development of each Framework component. The Framework will focus restoration practitioners to develop clear testable project objectives which directly lead to a focused and effective monitoring strategy to test specific hypotheses. Guidance is also provided on how to define and select appropriate protocols and metrics for specific project objectives. The products of the Framework assist the project team in communicating the planned, and eventually monitored, response of specific ecosystem attributes to the implemented restoration actions. The Adaptive Management Plan provides a strategy for the restoration team to establish clear milestones when monitoring data will be synthesized and evaluated in the context of the project objectives in the form of an Effectiveness Evaluation Report. It is recommended that the Effectiveness Evaluation Report is reviewed and discussed with a collection of appropriate agency personnel to evaluate the post project restoration effectiveness and consider potential adaptive management decisions. The Framework components are summarized below.

EXISTING CONDITIONS SUMMARY DEVELOPMENT

The existing conditions summary documents the primary impairments and effects on ecosystem function in the project area as potential restoration solutions are being explored. This step should be informed by the findings of a watershed assessment and more detailed data collection and site evaluation effort pre-restoration project. The final products that comprise the existing conditions summary are:

- A diagram that summarizes and organizes ecosystem attributes that are impaired in their existing (pre-project) conditions.
- A supporting narrative description of the diagram that explains the processes linking impaired attributes and the chain of cause and effect among them.

PROJECT OBJECTIVES DEVELOPMENT

Project objectives succinctly and clearly describe the hypothesized effects of the primary restoration actions on identified ecosystem attributes. The expected responses to ecosystem classes are restoration project goals. The expected ecosystem attribute responses are expressed as measurable project objectives. Similar to the existing conditions summary, the final products are:

- A diagram that summarizes the expected results of the restoration project on ecosystem attributes.
- A supporting narrative description of project goals and objectives that includes expected directional changes and measurable, quantitative targets.

MONITORING STRATEGY DEVELOPMENT

The purpose of the monitoring strategy is to identify and select the protocols and metrics that adequately measure progress towards project objectives with the resources available. The Monitoring Strategy products include:

- A table of the selected goals, objectives, metrics and expected years of sampling.
- A narrative stating monitoring budget, monitoring duration and party responsible for ensuring implementation. The narrative includes any additional information necessary to justify the rational for the strategy selected. The narrative also includes a statement of each selected metric, protocol, general spatial and temporal frequency of sampling and the post restoration years when the results of the specific metric are recommended to be evaluated.

The monitoring strategy provides the main content for the development of a detailed Monitoring Plan that contains all of the detailed logistics, techniques, methods and directions to ensure consistent and reliable data collection and management throughout the planned monitoring effort.

ADAPTIVE MANAGEMENT PLAN DEVELOPMENT

The adaptive management plan is a process that ensures that evaluation effectiveness results are produced and incorporated into future management of the project site and restoration designs. The products of the adaptive management process include:

- The creation of a short Adaptive Management Plan (Plan) developed pre-project construction.
- The development of a Project Effectiveness Evaluation Report (Report) created at designated milestones post-project, summarizing monitoring results.
- An Adaptive Management Meeting (Meeting) to review the contents and findings of the Report.

- A documented summary of the Meeting discussions and outcomes in a Memo.

One primary goal of the Framework is to simplify the communication and documentation process for stream practitioners so that each effectiveness evaluation development team does not have to re-create the wheel. We believe the Framework process and the final products provide significant progress towards this goal. An obvious need for stream restoration practitioners is a clear and consistent definition of terms to improve communications. Therefore, this document contains a complete an ecosystem attribute glossary (*Chapter 11*) that defines each of the attributes used by the 2NDNATURE team is also included. It is strongly recommended that Framework documents created for future restoration projects are accompanied by a project specific Attribute Glossary to continue the clarity of communication.

LESSONS LEARNED AND RECOMMENDATIONS

Chapter 10 Lessons Learned and Recommendations is a reflection by the research team on the lessons learned from the process of completing the original research objectives and the role the Framework tool could play in the larger Lake Tahoe Environmental Improvement Program (EIP) and other programmatic and research areas. *Chapter 10* also clarifies a number of objectives outlined in the original research proposal (Appendix A) and how this final deliverable meets the original intentions and where subsequent efforts will need to continue to meet the specific needs of a one-size-fits-all rapid assessment methodology (RAM) and the Lake Tahoe Total Maximum Daily Load (TMDL) with respect to riparian ecosystem restoration.

DOCUMENT USE

This document is designed to contain all of the pertinent content of this research project in a single file so that components are not separated over time and they can be easily accessed. Upper-management can limit their review to a few chapters while practitioners and researchers are intended to read larger portions of the document. Upper-managers of resource management organizations are the intended audience of *Chapter 3 Lessons Learned from Lake Tahoe Stream Restoration Inventory* and *Chapter 4 Riparian Ecosystem Goal and Conceptual Model.* Practitioners, who will be implementing the Framework on future stream restoration project, will benefit from a thorough understanding of the complete document and associated terminology.

CHAPTER 2: RESEARCH INTRODUCTION

Millions of dollars have been spent on stream and meadow restoration projects in the Lake Tahoe Basin over the past 2 decades, but there has been little to no consistency in planning, tracking and evaluating the effectiveness of these restoration efforts. The 2NDNATURE research team employed Southern Nevada Public Lands Management Act (SNPLMA) Round 8 funding to propose a clear process to planning and developing effectiveness evaluations for riparian ecosystem restoration projects within the Lake Tahoe Basin. The original proposal is attached as Appendix A.

RESEARCH GOAL

Identify and document a consistent approach to plan, evaluate, track and report stream restoration projects. The approach was to be developed following the compilation of existing restoration project documentation and a subsequent lessons learned analysis.

RESEARCH OBJECTIVES

1. Establish a comprehensive qualitative and quantitative inventory of current and completed stream restoration projects that have been reported through early 2009, including information on the ways restoration effectiveness has been evaluated for each previous restoration project.
2. Synthesize findings from the restoration project inventory to determine consistent ways to define and evaluate restoration benefits and lessons learned from past project experiences.
3. Collaborate with resource managers, in the form of a technical advisory committee (TAC), to develop conceptual models and the associated process-oriented approach to evaluating the intended fluvial, water quality and ecological benefits of stream restoration efforts.
4. Build upon existing efforts to refine and document a collection of potential tools, protocols and metrics to measure stream and meadow restoration effectiveness in the Lake Tahoe Basin.
5. Document how the products of this research can inform policy and regulatory objectives in the Basin.

EFFECTIVENESS MONITORING FOCUS

The research products are focused on effectiveness monitoring as opposed to implementation or status and trends monitoring as defined in the Tahoe Science Consortium's Tahoe Science Plan (TSC) (Hymanson and Collopy 2009). Effectiveness monitoring is defined as the ability of management practices, including restoration projects, to achieve the agreed upon ecosystem goals of the Tahoe Basin such as the TRPA Threshold Standards and Tahoe Pathway desired conditions. The products herein could be applied to the monitoring of mitigation projects as well.

RESEARCH APPROACH

The 2NDNATURE research team completed the general steps below. The details and associated outcomes of these steps are provided in the remainder of this report.

1. Compiled the Lake Tahoe Stream Restoration Inventory

Monitoring reports for existing stream restoration projects (as of early 2009) were collected from project team libraries and TAC suggestions. The inventory includes maps, reach impairments, project objectives, size/magnitude of project and a summary of the effectiveness evaluation strategies. The complete Lake Tahoe Stream Restoration Inventory is attached as Appendix B.

2. Analyzed inventory and synthesized lessons learned

Chapter 3 provides a number of lessons learned as a result of the inventory development. Each primary lesson was used to define an objective for the research team to improve the quality, focus and standardization of future stream restoration effectiveness evaluations.

3. Proposed a riparian ecosystem restoration goal statement and conceptual model for the Lake Tahoe Basin

Chapter 4 provides a recommended goal statement and supporting conceptual model for the practitioners of Lake Tahoe riparian ecosystem restoration efforts. The goal specifically focuses upon the improvement of ecosystem processes, a key component of Lake Tahoe stream restoration. The basin-wide conceptual model communicates a basic summary of actions, drivers and desired ecosystem improvements to upper-management and the public.

Construction of log structure at Blackwood Creek Fish Ladder (2003)

4. Developed the Effectiveness Evaluation Framework for Riparian Ecosystem Restoration

Chapters 5-9 provide clear guidelines and recommended products to increase the consistency in defining existing (impaired) conditions, developing restoration project goals and objectives, designing a monitoring strategy and employing the monitoring results to make adaptive management decisions.

5. Reviewed research products with TAC

At three points during the research process the TAC was consulted for feedback on the project approach, interim products and the draft final report. These consultations guided the project team as well as vetted the new ideas proposed by the research team to develop the final document.

6. Submitted final report

This document is the final report for the SNPLMA Round 8 research effort and will be published on the SNPLMA web site and Tahoe Integrated Information Management System (TIIMS) at www.tiims.org.

CHAPTER 3. LESSONS LEARNED FROM LAKE TAHOE STREAM RESTORATION INVENTORY

The 2NDNATURE team conducted a review of available information regarding effectiveness evaluations for Lake Tahoe stream and meadow restoration projects in early 2009. The final product is the Lake Tahoe Stream Restoration Inventory (Inventory) included as Appendix B to this document. *Chapter 3* contains a brief analysis of the final inventory; five distinct lessons learned from the exercise of obtaining, synthesizing and creating the Inventory; and the refined research objectives of the 2NDNATURE research team. Based on the results of the Inventory, the 2NDNATURE team has developed a clear process to greatly improve the quality of future stream restoration effectiveness evaluations.

Restoration assessment shortcomings encountered in the Tahoe Basin are found state (Kondolf et al 2007) and nationwide (Bernhardt et al 2005) and are reflective, at least partly, of the difficult task of measuring complex and dynamic riparian ecosystems. Other factors which can confound effectiveness evaluations include lack of funding and time-frames for monitoring that are driven by regulatory or funding constraints rather than by response times of the ecosystem. These issues and others are discussed in *Chapter 3*, as well as our recommendations for improving riparian ecosystem restoration effectiveness evaluations in the Tahoe Basin. Our recommendations focus on the creation of a specific process to define and communicate complicated ecosystem processes and linkages that should form the basis of restoration project effectiveness evaluations.

INVENTORY METHODS

The 2NDNATURE team identified 11 streams within the Lake Tahoe Basin that had some restoration projects previously, with 19 independent restoration projects in the ground by early 2009. Over the course of two months the 2NDNATURE team contacted numerous agencies, consultants and regulators either by phone, email or internet searches (i.e. TIIMS) to obtain any documentation on the goals, objectives and/or effectiveness evaluations of the 19 identified projects. Due to the potential volume of information, lack of digital design records and potential lengthy review and evaluation considerations construction design plans were not requested nor obtained. A total of 21 project summary and/or monitoring reports were compiled as a result of these efforts. Each report obtained was evaluated by a 2NDNATURE science associate with no previous knowledge of the specifics of these Lake Tahoe stream restoration projects. This was to ensure that the information within the inventory was extracted from written reports and communications available and not from prior conversations.

The purpose of the Inventory was to integrate and compile effectiveness evaluation information from the 19 restoration projects in a standardized format for subsequent analysis. A strategy for information extraction from the available reports was developed prior to the review of all documents. 2NDNATURE identified 5 common stream reach impairments that impact the natural riparian function (degraded floodplain function, erosion/bank instability, fish barriers, straightened channel, and water quality impairment) and categorized each project under one of the 5 impairments based on the information provided. Similarly, 9 common project objectives of stream restoration efforts were defined by the 2NDNATURE team. If the existing site impairment or objective was not clearly communicated in the report, 2NDNATURE staff inferred impairments and objectives by the metrics and protocols used for the monitoring and evaluations that were conducted. Details on the effectiveness evaluations included attributes evaluated or monitored in each restoration project, if both pre- and post-project evaluations were conducted, the protocols used, and the duration of monitoring post-project.

2NDNATURE developed a rating system (ranging from 1-3) to compare the effectiveness evaluation quality for each of evaluation metrics used. A metric rating of 1 equated to a below acceptable effectiveness evaluation due to the lack of pre and post project monitoring of the metric and the inability of the dataset generated to evaluate the objectives of the restoration project. A score of 3 was given to monitoring metrics that were comparable pre and post project, reasonably

quantifiable, directly addressed a clear project objective, and had been completed and analyzed in the available report such that it was apparent the analysis included reasonable natural variability and other sources of error in results obtained. Metrics given a value of 2 fell between the one and three categories, or the monitoring had not yet been completed and thus the analysis of the effectiveness evaluation results was not available for review by the 2NDNATURE team. The complete Inventory is attached as Appendix B to this document.

LESSONS LEARNED FROM INVENTORY

The 2NDNATURE team identified 5 distinct lessons learned from the exercise of obtaining, synthesizing and integrating existing effectiveness evaluation information. Simple statistics are provided to support each lesson. Each lesson learned is followed with a 2NDNATURE research objective in an effort to directly improve the quality of future restoration effectiveness evaluations. Note that each lesson learned is numbered for reference, not to indicate importance or priority.

Lesson #1

Effectiveness documentation for past restoration projects were challenging to obtain and often contained inconsistent or incomplete information. In some instances no documentation was available.

The 2NDNATURE team identified 26 stream restoration monitoring reports but five were never located. Of the 21 reports obtained, 18 were available in electronic format but many required significant effort to locate the correct person to provide the document to 2NDNATURE. Of the 21 collected reports, 85% contain some level of data by which the stream restoration effectiveness was intended to be evaluated. These findings are similar to the struggles by Kondaulf et al (2007) during the development of a database of California riparian ecosystem restoration project conducted in California since the 1980s.

STUDY OBJECTIVE: DEVELOP A FRAMEWORK TO ASSIST IN CREATING PROJECT-LEVEL RIPARIAN RESTORATION PROJECT EFFECTIVENESS EVALUATIONS

We believe the creation of a specific process to guide the development of effectiveness evaluations will greatly assist project proponents in producing clear, concise, consistent project effectiveness evaluations. We term this process the Riparian Ecosystem Restoration and Effectiveness Framework (Framework). The Framework is intended to be both a process for the development, as well as the format of communications for future effectiveness evaluations. The Framework consists of four primary components or phases:

- Existing conditions summary development to identify the primary impairments and their ecosystem effects of a pre-restoration site. A process diagram (a.k.a. attribute linkage diagram) is created to describe cause and effects linkages between impairments and ecosystem attributes. The existing conditions diagram is supported by a narrative.
- Project objectives development to improve the documentation of assumed linkages between restoration project actions and their hypothesized effects on specific ecosystem attributes. Specific statement of how priority attributes are expected to either directly or indirectly respond to restoration actions help and inform project objectives. A set of clear testable objectives greatly enhances the development of a robust monitoring strategy. The final products to communicate project objectives also consist of an attribute linkage diagram and supporting narrative.
- Monitoring strategy development to identify the specific data collection (protocols) and data reporting (metrics) components that will be collectively implemented to evaluate the effectiveness of the restoration action(s). Each metric selected will be either hypothesized and/or documented in scientific literature to be a reliable proxy for one or more of the project objectives. The final monitoring strategy includes a table and narrative that specifically links project objectives with specific metrics and protocols.

- Adaptive management process development to outline the logistical process including milestones of Effectiveness Evaluation Reports and subsequent meetings to inform management decisions based on monitoring results.

Lesson #2

There have been incomplete or inconsistent definitions of the goal of stream restoration efforts in Lake Tahoe riparian ecosystems.

Ninety percent of the existing reports contained stated goals of restoration, but goals vary from process restoration to regulatory targets.

STUDY OBJECTIVE: DEVELOP A CLEAR GOAL FOR TAHOE BASIN RIPARIAN ECOSYSTEM RESTORATION

The 2NDNATURE team and the Technical Advisory Committee (TAC) collectively developed an over-arching, basin-wide goal for Lake Tahoe riparian ecosystem restoration projects. The goal is ecosystem and process based. A programmatic conceptual model was developed to visually articulate the linkage between Lake Tahoe stream restoration strategies and the resulting improvement in riparian ecosystem function.

The recommended goal statement, conceptual model and associated narrative are presented in *Chapter 4*. The goal statement and conceptual model are intended to guide and inform all phases of the Framework.

Lesson #3

Within many restoration project reports, the impairments, existing conditions and project objectives are missing or unclear.

Analysis of the Inventory indicates that 71% of reports included some summary of the existing conditions and identification of the site impairments. Of these, only 29% included set statements of hypothesized outcomes of the planned restoration action that could be directly tested, i.e. project objectives.

Without context for existing conditions and ecosystem impairments it is difficult to understand the objectives of the specific restoration project. In many cases it is unclear why project actions were chosen or how they were expected to improve specific ecosystem attributes, structure or function. There has also been a lack of understanding of the difference between a project goal and a project objective by restoration practitioners. Goals are general intentions, broad in scope, and not detailed enough to be measurable. In contrast, valuable objectives are specific, tangible, directly measurable (Margoluis and Salafsky 1998) and should be considered testable hypotheses of the expected response of the riparian ecosystem to restoration actions. For example, the Incline Creek Restoration Final Report indicates the projects goals as; “Increase SEZ area, filter sediment and aid floodplain development, improve floodwater retention and groundwater recharge, and improve fisheries through restoration of migratory fish habitat.” There were no specific project objectives. The example above is an intertwining of project goals and objectives. “Increase SEZ area” is a measurable and tangible restoration objective that can be tested, however “filter sediment and aid floodplain development” is a process oriented goal that cannot be directly measured as stated, and thus is not a testable objective.

STUDY OBJECTIVE: DEVELOP PROCEDURES FOR SUMMARIZING EXISTING CONDITIONS AND DEVELOPING TESTABLE PROJECT OBJECTIVES

These procedures will establish a standardized format to document existing (pre-project) conditions and restoration project objectives. Documentation produced by implementing the Framework procedures will include a description of the project area, human impairments within the watershed, impaired local attributes of the ecosystem, restoration actions and the linkages to desired outcomes. A key part of these protocols will be the development of process diagrams designed to illustrate cause and affect linkages between impairments or restoration actions and key ecosystem attributes and associated processes. The attribute-linkage diagrams will provide a simple visual tool to communicate the primary chains of cause and effect within the riparian ecosystem. The diagrams will be supported by more detailed narratives that are created using a standardized procedure. These procedures will form two components of the Framework: Existing Conditions Summary and the Project Objectives. *Chapter 5* clarifies the terminology and concepts of the Framework. *Chapters 6* and *7* provide detailed guidance on how to develop the Existing Conditions Summary and the Project Objectives, respectively.

Lesson #4

Few effectiveness monitoring efforts have demonstrated a clear linkage between monitoring results and project objectives.

Few monitoring efforts have included both pre-restoration and post-restoration monitoring of the same metric to provide an evaluation of project effectiveness. In many instances, post-implementation evaluations have not continued beyond two years, limiting the value of the observations to confidently assess the restored condition. In addition, previous evaluations have not been able to confidently attribute changes in ecosystem conditions to project actions rather than data noise from sampling error or natural variability. Seventy-four percent of the effectiveness evaluations included both pre and post project evaluations, but only 1 of these were determined to properly account for natural sampling variability and subsequently yield reasonably comparable data.[1] This failure includes lack of consideration for hydrologic or climate variations that result in differences in the analysis of pre and post observations (e.g. lack of consideration when comparing wet and dry year groundwater elevations, poor sampling), and designs that fail to constrain natural variability to the extent possible.

STUDY OBJECTIVE: PROVIDE GUIDANCE ON THE DEVELOPMENT OF A MONITORING STRATEGY TO EVALUATE THE EFFECTIVENESS OF A RIPARIAN RESTORATION PROJECT

The research provides a clear process for using the project objectives developed in the previous Framework components to select appropriate metrics and data collection protocols. The integration of the all of the Framework components allows a clear linkage between restoration actions and anticipated ecosystem responses, and guides the user on how to select appropriate metrics and protocols to evaluate the expected responses (i.e. project objectives). *Chapter 8* provides guidelines to focus and improve future, sampling design, protocols and metric selection, analysis and reporting. Clear guidelines are provided to improve the sampling design and data analysis approaches to constrain inherent natural variability. The Monitoring Strategy documents the protocols and metrics selected based on project priorities, available resources and other constraints. *Chapter 8* includes a collection of robust protocols and metrics for Lake Tahoe riparian ecosystems that will likely be applicable for monitoring future ecological restoration projects.

[1] Two monitoring plans were being implemented in 2009 and therefore the effectiveness evaluations were not available for review.

Lesson #5

Even with the best planning and documentation, some projects have not been able to produce the desired benefits as designed and implemented.

Given that restoration of riparian ecosystems is extremely complex and a relatively new science, all restoration projects are not likely to attain all objectives. Adaptive management (the process of integrating design, management and monitoring in order to adapt and learn) substantially lessens and mitigates the risk of poor future conditions and provides valuable information for future projects. However, existing Lake Tahoe projects seldom incorporate adaptive management. Not one of the 21 effectiveness evaluation reports contained any components of an adaptive management plan.

STUDY OBJECTIVE: DEVELOP A PROCESS FOR ACTUALIZING ADAPTIVE MANAGEMENT

This final component of the Framework focuses on a process for actualizing adaptive management. While the entire Framework is intimately tied to the adaptive management process, actualizing adaptive management will require a schedule for regular assessment of focused monitoring results and a clear process for determining future actions based on the data analysis.

While this portion of the Framework is focused on actualizing adaptive management, a major feature and clear benefit of the entire Framework is that it contains all information, documentation, and planning steps necessary to realize adaptive management process. This is consistent with the well accepted basic steps in the adaptive management process as defined by Salafsky et al (2001). Under each of the Salafsky et al (2001) steps in this list, the corresponding component of the Framework is listed.

START: Clarify group's mission

FRAMEWORK: Lake Tahoe Goal Statement and Conceptual Model

STEP A: Design a conceptual model based on local site conditions

FRAMEWORK: Existing Conditions Summary

STEP B: Develop a management plan: goals, objectives, and activities

FRAMEWORK: Project Objective Development

STEP C: Develop a monitoring plan

FRAMEWORK: Monitoring Strategy Development

STEP D: Implement management and monitoring plans

FRAMEWORK: Execute Monitoring Plan; draft Effectiveness Evaluation Report

STEP E: Analyze data and communicate results

FRAMEWORK: Adaptive Management Plan

ITERATE: Use results to adapt and learn

FRAMEWORK: Actualize adaptive management

Applying the Framework to a riparian ecosystem restoration project is expected to result in a complete adaptive management process. The Framework provides a consistent evaluation development process that will result in more consistent, comparable effectiveness evaluations. The Framework will provide a process to help assure that project effectiveness is given due consideration in all future riparian restoration projects, and will therefore reduce the incidence of non-reporting. Documentation concerning the strategy and approach to restoration effectiveness will be standardized and therefore easier to store and access. Several more specific or technical potential benefits are described in following pages.

CHAPTER 4: OVERARCHING RIPARIAN ECOSYSTEM RESTORATION GOAL AND CONCEPTUAL MODEL

The Riparian Ecosystem Restoration Conceptual Model illustrates, in a general way, the primary chains of cause and effect within riparian ecosystems at the Tahoe Basin-wide scale. The overarching riparian ecosystem restoration goal provides agreed on, general guidance for riparian ecosystem restoration. The Basin-wide conceptual model and goal provide a point of entry for upper management and the public to understand restoration strategies, their benefits and desired outcomes.

CONCEPTUAL MODEL BACKGROUND

Conceptual models have been created for many of the Lake Tahoe desired conditions defined by the Pathway strategic planning effort.[1]

The conceptual model provided in this chapter is similar to conceptual models developed for Pathway desired conditions by the Lake Tahoe Status and Trend Monitoring and Evaluation Program (M&E Program) because it links restoration strategies to the primary drivers that determine achievement of the Tahoe Basin's desired environmental and socioeconomic conditions. This conceptual model is slightly different than the M&E Program's conceptual models, such as the Biological Integrity Conceptual Model, because it is focused on the processes driving riparian ecosystem function rather than status and trend monitoring of regional ecosystem conditions.

TARGET AUDIENCE

Upper-level Managers are the intended audience of the conceptual model. This audience is familiar with the environmental management issues of the Tahoe Basin, but does not specialize in stream restoration efforts. These people need an easy way to understand a subject that is important, but one of many they must understand at a moderate level of detail. A deep understanding of all drivers and process interactions is not feasible for this audience. Examples of upper-level managers include programmatic decision makers and advisors to executives.

USES

- Communicate the current understanding of the primary chains of cause and effect in the system
- Ensure restoration project actions are aligned with Basin-wide, planning goals and objectives
- Prioritize important restoration strategies and identify links to the Lake Tahoe Environmental Improvement Program (EIP) Action Priorities

PRESENTATION

Conceptual models are described from right to left, progressing from the planning-oriented desired outcomes for the region and working back through the cause-and-effect linkages of the system. The right to left method focuses the audience on the desired outcomes of riparian ecosystem restoration prior to understanding the primary drivers of ecosystem conditions and finally the management strategies employed to restore them. This method keeps upper-level mangers and practitioners focused on the desired outcomes rather than the tools and techniques of restoration. Item names in the conceptual model diagram are **bolded** in their first appearance within the text to provide a clear point of reference. This structure and presentation approach is consistent with the M&E Program's conceptual model approach.

[1] Pathway Tahoe is an inter-agency collaborative planning program with the intent of establishing the long term direction and goals for resource management within the Lake Tahoe Basin. Detailed information is available at http://www.pathwaytahoe.org/

DESIRED OUTCOMES

Desired outcomes consist of an **overarching riparian ecosystem restoration goal** (**overarching goal**) developed with assistance from this effort's Technical Advisory Committee (TAC) and a subset of the **desired conditions** that were developed through the Pathway strategic planning process. Achievement of the Overarching Goal will result in direct and indirect benefits for the desired conditions identified.

Functional stream channel morphology of restored Trout Creek (2005)

OVERARCHING RIPARIAN ECOSYSTEM RESTORATION GOAL

The Overarching Goal is proposed as a consistent guide for practitioners to reference when broad direction is needed during planning, design and construction of riparian restoration projects. The Overarching Goal is a broad statement of the purpose of restoration actions. It is important to note that the Overarching Goal focuses on the valuable biological endpoints of the system.

The Overarching Goal of Lake Tahoe Riparian Ecosystem Restoration is to mitigate and/or alleviate the historic and present human impacts to the extent feasible, through the re-establishment of physical, chemical and biological processes that naturally sustain desired biological components of Lake Tahoe riparian ecosystems, including riparian vegetation communities, aquatic species and terrestrial wildlife.

DESIRED CONDITIONS

Efforts toward the Overarching Goal will directly and indirectly benefit several of the desired environmental and socioeconomic conditions that were developed through the Pathway strategic planning process. Desired conditions are a slightly different planning tool than the Overarching Goal in that they are descriptions of a state to be achieved rather than purpose of actions that should be undertaken. The desired conditions affected by riparian ecosystem restoration generally include the Wildlife and Fish (W/F), Stream Environment Zone (SEZ), Water Quality (WQ), Forest and Vegetation (F/V) and Soil resource areas.

It is possible to define three categories of desired conditions that may benefit from effort toward the Overarching Goal; directly benefiting, indirectly benefiting and potentially benefiting. The directly connected desired conditions are expected to improve because the Overarching Goal is very closely aligned with the desired condition description. It is considered very likely that the project team will select numeric objectives that can quantitatively show improvements to desired conditions. Indirect, but potentially substantial, benefits can accrue toward other desired conditions through re-establishment of

natural processes at sustainable equilibria or through anticipated changes to the riparian ecosystem which can later enhance the primary ecological drivers of the desired condition. Potentially benefiting desired conditions are considered likely to benefit in some way, but to a much smaller degree or at a localized scale. Potentially benefiting desired conditions are not included in the conceptual model diagram to maintain clarity and focus on the desired conditions that are most likely to be enhanced. Table 4.1 provides the name and description of each desired condition within the categories defined.[2]

Table 4.1. Desired conditions (DCs) benefiting from effort toward the overarching goal

DCs Directly Benefiting	DCs Indirectly Benefiting	DCs Potentially Benefiting
W/F DC-1. Biological Integrity of Aquatic Ecosystems: The functional, physical, chemical and biological integrity of the Basin's aquatic ecosystems are maintained at or above a sustainable level.	**WQ DC-1. Lake Tahoe Clarity**: Restore and then maintain the waters of Lake Tahoe for the purposes of human enjoyment and preservation of its ecological status as one of the few large, deepwater, ultra-oligotrophic lakes in the world with unique transparency, color and clarity.	**W/F DC-2. Sustainability of Special Status Species:** Populations of, and environmental conditions and processes important to native threatened, endangered, rare, special interest or sensitive species are maintained at a level which insures sustainability.
W/F DC-3. Biological Integrity of Terrestrial Ecosystems: The functional, physical, chemical and biological integrity of the Basin's aquatic ecosystems are maintained at or above a sustainable level.	**SEZ DC-7. SEZ Societal Values:** Beneficial uses of SEZ lands for water management, cultural and scientific purposes, limited agriculture, and recreation are compatible with the proper functioning conditions, as stated by desired conditions for physical, chemical and biological functioning.	**Soil DC-3. Forest Soil Function:** Soils function commensurate with their land use to sustain native plant and animal life, regulate water flow, flooding and infiltration, cycle nutrients, and filter pathogens, excess nutrients and other pollutants.
SEZ DC-4. SEZ Physical and Chemical Function: SEZ physical and chemical processes function properly within the constraints and dynamics of the watershed, including, but not limited to, natural hydrologic processes, water quality, and stormwater treatment capacity.		**F/V DC-2. Plant Communities of Concern:** The natural conditions and functions of plant communities of concern are sustained.
SEZ DC-5. SEZ Biological Function: SEZ biological processes function properly within the constraints and dynamics of the watershed. Vegetation, terrestrial wildlife, and aquatic communities are healthy and sustainable.		**F/V DC-3. Special Status Species:** Populations of, and environmental conditions and processes important to native threatened, endangered, rare, special interest or sensitive species are maintained at a level which insures sustainability.
SEZ DC-6. Watershed Function: Watershed characteristics, such as hydrologic, fluvial and littoral geomorphic processes, approximate natural conditions where attainable.		**F/V DC-4. Hazardous Fuels:** Fuel conditions pose low wildfire risk to communities.

[2] Pathway desired condition names and descriptions are referenced from Chapter 1 of the 2006 Threshold Evaluation Report published by TRPA in November 2007. Accessed 1/8/10 via www.tiims.org/Data-Repository/Documents/Lake-Tahoe-Basin/Science-and-Reporting/Data-Synthesis,-Reporting,-and-Management/Reporting/TRPA/2006/2006-TRPA-Threshold-Evaluation---Chapter-1-Introdu.aspxand-Reporting/Data-Synthesis,-Reporting,-and-Management/Reporting/TRPA/2006/2006-TRPA-Threshold-Evaluation---Chapter-1-Introdu.aspx.

DCs Directly Benefiting	DCs Indirectly Benefiting	DCs Potentially Benefiting
Soil DC-1. Land Coverage and Disturbance: Land coverage, on a watershed basis, does not exceed the capability of the soil resources to offset the effects of impervious cover. The effects of impervious cover and disturbance are fully mitigated on a storm water zone basis.		**Scenic DC-1. Natural Environment:** Scenery viewed from Lake Tahoe and the Basin's major roadways, public recreation areas, trails, and urban centers predominantly displays natural appearing forest, meadows, mountains, and the shoreline of Lake Tahoe. Development, where visible, complements the natural setting.
		Recreation DC-1. Opportunity: Provide a suitable spectrum of high-quality recreational opportunities while sustaining Lake Tahoe's natural setting as an outstanding recreation destination.

PRIMARY ECOSYSTEM DRIVERS

Primary ecosystem drivers in the riparian ecosystem create a chain of cause and effect that must be understood to effectively plan restoration projects that achieve the desired outcomes. Primary ecosystem drivers are shown in Figure 4.1 as orange, tan or green rectangles depending on the level of control and the self-sustainability of related processes.

Habitat quantity and habitat quality for flora and fauna are the primary drivers of biological community success. Larger habitat extents provide more opportunity for species abundance and reproduction. In many cases there is a minimum threshold of habitat extent needed to maintain a biologically viable population.

Fluvial morphology strongly affects water supply and transport, which are major contributors to the complex physical and chemical processes that drive habitat quality. The appropriate fluvial morphology of a stream reach is characteristic of a proper balance between the reach-specific **hydrology** and **sediment load**. The primary components of fluvial morphology are **channel capacity, channel stability, bank stability, and channel complexity**. Channel capacity determines the degree of floodplain connectivity, which determines the **shallow groundwater connection and levels**. Many impaired streams possess much higher channel capacities than ideal natural channels in functional riparian ecosystems. Channel complexity includes plan form and cross-section components that make a channel more variable, such as riparian cover, woody debris, overhanging banks, channel substrate sorting, pool and riffle sequences, sinuosity and other factors. Specific stream systems and locations within stream systems will have different types and levels of complexity, but channel complexity in general provides a diversity of ecological niches, directly increasing habitat quality. Bank stability is the relative potential source of the sediment the banks may provide to the stream system and channel stability refers to the longitudinal stability of the bed. Thus fluvial morphology strongly affects **stream** and **floodplain vegetation condition** which are key components of riparian ecosystem habitat quantity and quality.

Fluvial morphology is driven by two main natural drivers and many human-caused **watershed impairments**. **Geology** is a natural, non-controllable driver of sediment load; it determines the baseline **sediment load** as well as the plan view pattern of the channel. **Climate** is another natural driver than cannot be controlled by actions within the Tahoe Basin. Climate and catchment area drive the baseline **hydrology** of the system and have a major influence on the natural fluvial morphology. Human disturbances cause **reach-scale impairments** that also affect fluvial morphology. Bridges and culverts constrain the channel either vertically or horizontally. **Dams/flood control** or **channelization** will modify channel capacity, slope, channel complexity, and all of the other primary geomorphic processes. Humans also impact the watershed uplands through (1) **land coverage and disturbance** caused by development of roads and homes, (2) some types of **forest management and logging** that increase sediment load and modify the catchment hydrology and (3) problematic **grazing** that removes vegetation in riparian areas and mechanically erodes stream banks thereby increasing sediment loads.

ACTIONS AND MANAGEMENT STRATEGIES

Actions and management strategies can be used to alleviate or mitigate human-caused disturbances at both the reach and watershed scales. Many of the possible actions and management strategies have been named in the EIP as Action Priorities[3]. The conceptual model shows actions and strategies that are EIP Action Priorities in a darker shade of yellow. Some Action Priorities have been combined when they describe the same strategy applied to different features. For instance, **reduce stormwater pollution from local roads, state highways and forest roads** is a combination of three Action Priorities which all focus on reducing stormwater pollution from the named road types.

Reach actions are the physical techniques used within restoration projects to restore a more functional geomorphology at particular stream or floodplain sites. **Adjusting cross-section geometry** encourages more frequent overbank flows**,** **protecting banks** and **controlling grade** dissipate energy that might have otherwise disturbed the sediment load balance. **Buffering riparian corridor** through acquisitions, grazing protections or other land use changes can reduce direct erosion of banks and filter sediment before it reaches the stream channel. Specific reaches may also include treatment basins and other facilities that **reduce stormwater pollutants from local roads, state highways and forest roads**.

Watershed management actions and strategies are indirect or long-term actions that protect streams by taking action in the uplands or by changing land use in environmentally sensitive areas. Impervious surfaces and disturbed soil contribute to pollutant loads and hydrologic changes in stormwater runoff that are of great concern in Tahoe. This creates a need for best management practices that **reduce stormwater pollution from local roads, state highways and forest roads** and to **retrofit public and private facilities** to reduce pollutant loads in stormwater. Many planned projects within the EIP focus on **restoring Upper Truckee or other priority watersheds** in the interests of reducing fine sediment that degrades fish/wildlife habitat (such as that of the Lahontan cutthroat trout) and mitigating urban development impacts on the ecosystem. Watershed restoration will also have several indirect benefits such as protecting lake clarity, recreational enhancements and others listed in the *Desired Outcomes* section above. **Acquisition of environmentally sensitive lands** is used to site stormwater treatment facilities, reduce impervious surfaces and buffer riparian corridors. **Protection of sensitive species** is accomplished through habitat preservation and enhancement, and through **controlling invasive aquatic and terrestrial species**.

[3] EIP Action Priorities were referenced from the most recent review draft of the EIP update document that is available to the public. This document is titled "Restoration In Progress: Environmental Improvement Program Update- Planning Horizon 2008-2018" and references a draft date of 7/15/09 on the cover. This file was accessed via http://www.trpa.org/default.aspx?tabindex=12&tabid=227 on 1/11/10.

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.421.9023
www.2ndnaturellc.com

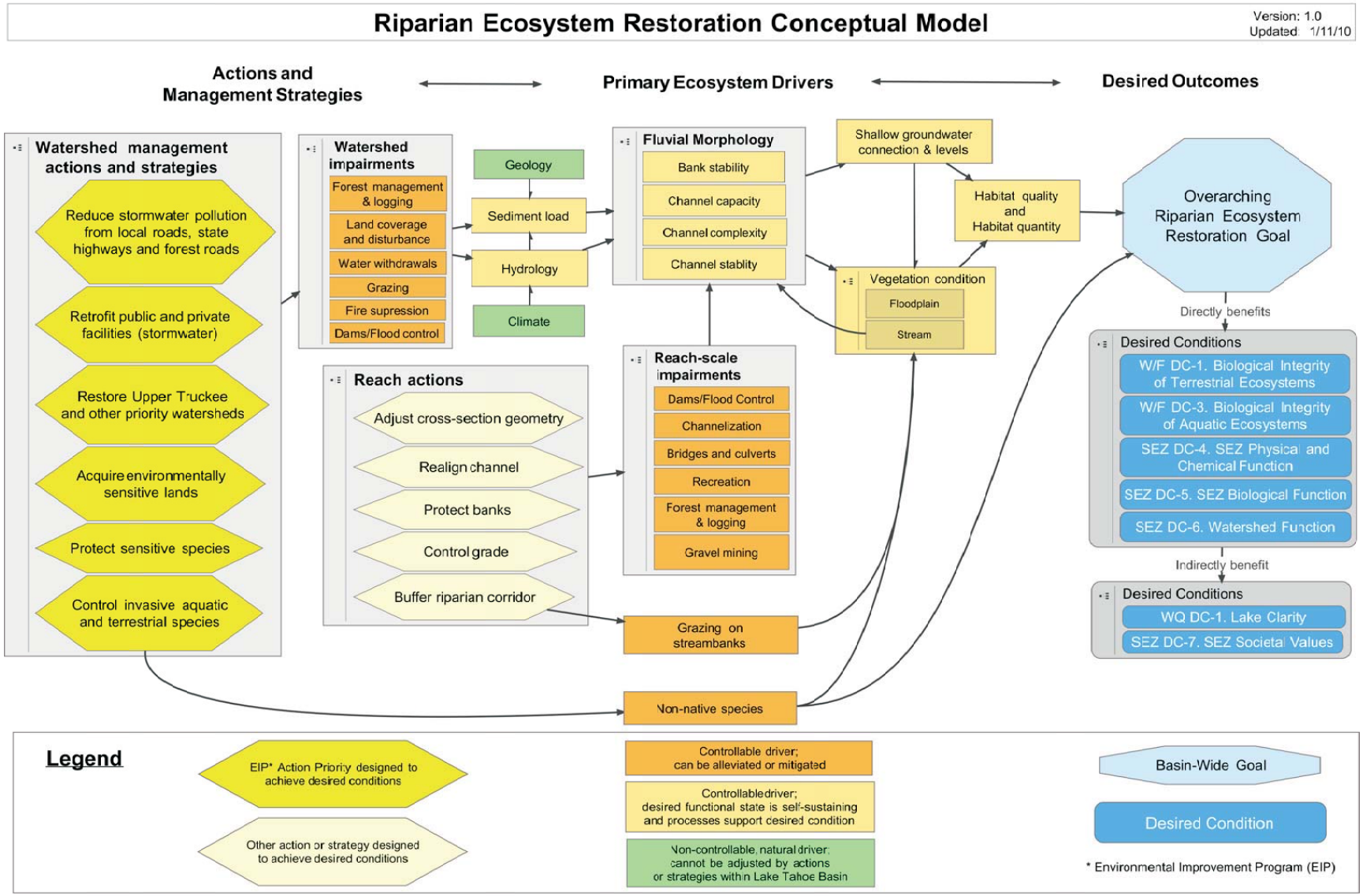

Figure 4.1: The Riparian Ecosystem Restoration Conceptual Model representing Tahoe Basin-wide policy goals (right side), the most important drivers within the riparian ecosystem (middle section) and the strategies that can be taken to restore riparian ecosystem function (left side).

FIGURE 4.1

CHAPTER 5. FRAMEWORK OVERVIEW AND TERMINOLOGY

The Riparian Ecosystem Restoration and Effectiveness Framework (Framework) is a clearly defined process for developing robust effectiveness evaluations for riparian ecosystem restoration projects. Information from the Framework process includes existing (pre-project) conditions, project-level objectives, data collection protocols and reporting metrics, and a recommended process for actualizing adaptive management. The Framework can solve the challenges identified in *Chapter 3: Lessons Learned from Lake Tahoe Stream Restoration Inventory* that are repeatedly faced by restoration efforts in the Tahoe Basin.

TARGET AUDIENCE

Riparian Ecosystem Restoration Practitioners such as geomorphologists, hydrologists, design engineers, ecologists, biologists and project managers are the primary target audience of the Framework. This audience is familiar with most technical aspects of riparian ecosystem restoration and they are most likely to implement the Framework on specific restoration projects.

Other people involved in riparian ecosystem management such as regulators, funders, permitters and other resource managers will find the products created by Framework implementation extremely valuable communication tools.

FRAMEWORK COMPONENTS

The Framework is a four-step process that restoration practitioners can undertake to develop a complete effectiveness evaluation and adaptive management plan. Each step will result in a set of specific products that illustrate key hypotheses, approaches and concepts of the restoration project for future reviewers. In addition, the Framework development process and the products created will provide an invaluable communication tool for each restoration project, clarifying the intentions and hypotheses of the variety of experts from different disciplines typically involved. Implementing the Framework will improve project-site management decisions and the quality of future restoration designs.

Building upon the principles described in *Chapter 4: Riparian Ecosystem Goal and Conceptual Model*, the Framework provides a systemized process for stream restoration practitioners to complete the following for each specific restoration project:

1. Existing Conditions Summary Development
2. Project Objectives Development
3. Monitoring Strategy Development
4. Adaptive Management Process

Detailed guidelines, considerations and the recommended final products of each Framework component are provided in the following *Chapters 6-9*. Hypothetical examples of the final products have been developed and used to improve the understanding and application of the Framework concepts.

KEY TERMS

Many of the terms used in this document have precise definitions to improve communication consistency and are important in understanding the material that follows. Key terms are defined below.

Riparian Ecosystem: A term used within the Framework to encompass the complete stream channel and floodplain area hydrologically influenced by the stream waters directly. Hydrologic influence within the stream channel includes the riparian corridor and extends laterally from the thalweg of the stream outward to the riparian and floodplain complex both via surface and subsurface hydrologic interactions.

Restoration: The collective actions conducted within a riparian ecosystem to restore the natural processes to the extent possible given existing and future constraints. Restoration actions are typically discrete physical modifications to riparian system that are hypothesized to improve ecosystem function thereby improving and/or increasing habitat quality and quantity. Isolated species eradication or revegetation efforts such as planting of natives or removal of exotic vegetation species may also be considered restoration actions.

Ecosystem Category: Any one of the four primary aspects of riparian ecosystem structure including geomorphic form, vegetation structure, habitat and biological communities. Ecosystem categories help define the general cause and effect linkages of the ecosystem and provide a systematic way of categorizing ecosystem attributes.

Ecosystem Attribute (Attribute): An ecosystem attribute is a form or structure of the riparian ecosystem. Attributes are observable and measurable characteristics of a riparian ecosystem such as sinuosity, willow distribution, water temperature or trout abundance. Specific attributes are used to define existing (pre-project) conditions and document testable project objectives.

Ecosystem Attribute Class: Defined by the Framework as a higher-level organization of attributes that describe a specific characteristic of the ecosystem category. Attribute classes can be described in a general sense, but require a collection of specific statements about a number of attributes to be clearly measured. For instance, floodplain vegetation community condition is an attribute class and a general statement can be made to infer the existing condition of the floodplain vegetation community at a specific location, such as; "The floodplain vegetation community condition has declined." However, this statement of attribute class can only be evaluated by the condition of a collection of specific attributes such as distribution of sedge plant species and/or diversity of floodplain vegetation species.

A statement of the anticipated restoration action effects on an ecosystem attribute class is a restoration project specific goal statement (e.g. a goal of this project is to increase floodplain vegetation community condition). A statement of the anticipated restoration action effects on an attribute is a restoration project objective (e.g. a project objective is to increase the distribution of sedge plant species within the floodplain area by 20% from existing [pre-restoration] conditions).

Goal: The purpose toward which an endeavor is directed. Goals are general intentions, broad in scope, and not detailed enough to be measurable. The riparian ecosystem framework includes a Lake Tahoe basin-wide restoration goal (see *Chapter 4*) as well as project specific goals (expressed using attribute classes) for independent restoration actions.

Objective: Something that one's efforts or actions are intended to attain or accomplish. Objectives are less broad than goals in scope. Objectives are specific and directly measurable. Objectives should be clearly stated and testable hypotheses of the expected response of the system in question as result of specific actions.

Effectiveness Evaluation: All of the information required to evaluate the success of a riparian ecosystem restoration project. An effectiveness evaluation must include a description of the existing (pre-project) conditions; clear objectives of the project actions (this includes a precise statement of quantitative targets); a set of monitoring protocols and reporting metrics; and an adaptive management strategy of collected data with respect to the specific objectives. The Framework in its entirety will improve effectiveness evaluations in the Lake Tahoe Basin.

Metric: A metric is the form of quantitative expression for specific physical, chemical or biological attribute of the ecosystem. Metrics included in a monitoring strategy are expected to respond in a predictable direction if restoration actions are successful. A restoration target is a quantitative measureable difference in a specific metric when comparing pre and post restoration values.

Protocol: A description of the techniques and methods employed to generate data and calculate a metric value. A monitoring strategy is detailed by protocols used to describe the precise techniques required to collect data and analyze it.

Attribute Linkage Diagram (Diagram): A one-page conceptual model that organizes attributes and attribute classes according to general cause and effect linkages among ecosystem categories of the riparian ecosystem. Diagrams are used within the Framework to summarize both Existing Conditions and Project Objectives of a specific riparian reach targeted for restoration actions.

THE ROLE OF ECOSYSTEM ATTRIBUTES

The identification of key ecosystem forms and structures that are impaired and will be targeted by restoration actions is the foundation of a valid restoration project effectiveness evaluation. In order to provide a reliable effectiveness evaluation, the existing condition of the ecosystem (pre-restoration) must be characterized. Once summarized, the existing (impaired) conditions provide a clear context for the expected riparian ecosystem response to restoration actions. In the context of the Framework, ecosystem attributes are used to characterize both the pre and post restoration condition of the subject riparian ecosystem.

Ecosystem attributes are specific and measurable characteristics of a riparian ecosystem which identify key ecosystem forms and structures that are impaired and may be targeted by restoration projects. Attributes are used to summarize existing conditions and provide a clear context for the expected riparian ecosystem response to restoration actions. Thus, well-defined attributes will focus the development of the monitoring strategy and lead to the most reliable post-project effectiveness evaluations.

A series of examples can make the progression from a general ecosystem attribute, to an existing condition statement, to a project objective. A geomorphic attribute is “channel slope” which is defined as the elevation change divided by length of the reach. This attribute can be used to describe existing conditions in a statement such as:

> *Channel slope is higher than the pre-impairment slope and higher than the expected slope given the valley slope due to the elimination of historic meanders.*

The existing condition statement can then be used to define a clear statement of the hypothesized effects of restoration actions. A testable statement of the hypothesized effects of the restoration action on a specific ecosystem attribute is a statement of a project objective such as:

> *Channel reconstruction will decrease the average channel slope from 0.05 to 0.01 within the subject reach.*

The use of ecosystem attributes to describe existing condition and generate robust project objectives is critical to the development of a strong effectiveness evaluation. In order to fulfill this role, ecosystem attributes used in the Framework should have the following characteristics:

- The attribute should have relevance to the impairments (pre-restoration) and restoration actions of the specific project.
- Attributes should be carefully defined and attribute definitions should accompany the final Framework documents. (Definitions of the attributes used by the 2NDNATURE team for the example restoration project are included in the *Chapter 11: Attribute Glossary*.)
- Attributes should be specific enough that cause and effect relationships with other attributes can hypothesized and supported by literature references, be reasonably inferred and/or clearly stated.
- Attributes must be measurable and should be specific enough to articulate a quantitative target.

For use in this Framework, an attribute is typically a statement of physical form (e. g. channel sinuosity, streambank slope, shrub height) or a vegetation or biological community structure (e. g. fish species abundance or distribution of willows). Attributes are limited to form and structure in the Framework because forms and structures (rather than processes) are the

characteristics typically measured to evaluate a specific process and/or ecosystem function. For example, consider a stream impaired by high sediment load to the channel. High sediment load results in altered bedload sediment transport, scour and deposition, all complicated processes regarding sediment dynamics. The banks of the subject channel are highly unstable due in part to dysfunctional sediment transport as a result of increased aggradation within the stream reach. Evaluation of restoration project effectiveness is much more likely to quantify the channel form (streambank height, stream bank angle, stream bank stability, etc), rather than measuring and setting quantitative targets for a complicated dynamic fluvial process (bedload transport). A streambank stability index can be assumed to be a reasonable proxy to infer the relative functionality of the sediment transport process.

This does not mean that the Framework ignores ecosystem process descriptions. In some cases, simple processes may be reliably measurable and could be used as attributes (e.g. rates of sediment deposition on the floodplain). Moreover, processes are critical in describing how the project will bring about changes in ecosystem attributes, and processes are fundamental in the successful restoration of a riparian ecosystem. In many instances, the interactions of multiple attributes within and across attribute classes and ecosystem categories are, in fact, ecosystem processes.

ATTRIBUTE CLASSES

Attribute classes are groups of ecosystem attributes that can be used to make general statements of both the existing conditions and the restoration project goals. Attribute classes are useful in three ways. First, they can help identify the cause of impairments in a general way. Second, they can be used to broadly describe the anticipated effects of restoration projects on physical, chemical and biological attributes of the riparian ecosystem. Third, they help to define the difference between project goals and objectives at the scale of the typical restoration project. A key difference between attributes and attribute classes is that attribute classes are not directly measurable via a known protocol or single measurement.

A series of examples can demonstrate the progression from an attribute class to a broad existing condition statement to a project goal. “Channel stability” is an attribute class which cannot be quantified via a single metric. This attribute class can be used as the basis for a broad statement of the impact the impairment is assumed to have on the geomorphic form of the stream. For example, a broad existing conditions statement based on this attribute class could be:

> Channel stability has decreased as a result of channel incision.

A project goal of a restoration action targeted to mitigate channel incision would be the inverse, clearly stating the anticipated effect of the restoration actions:

> Channel realignment will increase channel stability.

At first glance, statements about the anticipated effects of the project on the functional categories themselves may appear to be project objectives. For example:

> Channel reconstruction will improve aquatic habitat.

For the purposes of effectiveness evaluation, however, this statement cannot function as a project objective. It is not directly measurable because there is no widely accepted single index of aquatic habitat quality. In addition, habitat quality characteristics are significantly different depending upon the specific aquatic biological species considered. There is no way to set a quantitative target for habitat quality. In the context of effectiveness evaluation, this statement is more accurately described as a project-specific goal, a generalized statement of what the restoration project is intended to achieve.

Consider, on the other hand, the following statement of an attribute within the aquatic habitat quality class:

> Channel reconstruction will increase substrate D50 from 2mm to 25mm.

This statement is specific, measurable, and contains a quantitative target, all necessary features of a project objective. More importantly for a robust effectiveness evaluation, it is a testable scientific hypothesis. Thus the best project objectives, which are the anticipated project outcomes of using attribute statements, are actually testable scientific hypotheses. Within any category, the measured effectiveness of a restoration action to achieve specific project objectives (i.e. increase in D50 or decrease channel slope) demonstrates tangible progress toward broader project goals (i.e. improve aquatic habitat or increase channel stability).

ATTRIBUTE SELECTION

It cannot be understated that the application of the Framework by practitioners will require careful selection of the ecosystem attributes most relevant to the impairments and restoration approach of the specific riparian ecosystem in question. The collection of attributes defined in *Chapter 11: Attribute Glossary* is merely a selection of those potentially definable. While these may be some of attributes more pertinent to most Lake Tahoe Basin projects, people who implement the Framework in the future are urged to explore other potential attributes that may be more meaningful or relevant to their stream reach, its impairments, and anticipated restoration activities.

ECOSYSTEM CATEGORIES: STRUCTURING ATTRIBUTES AND THEIR CLASSES

Ecosystem categories help define the general cause and effect linkages of the ecosystem and provide a systematic way of categorizing ecosystem attributes. For the purposes of the Framework there are four primary categories that define the riparian ecosystem structure: geomorphic form, vegetation structure, habitat and biological communities.

Ecosystem categories are organized via a top-down format based on the fundamental premise that the processes controlled by the physical attributes of a riparian ecosystem have a significant influence on the habitat quality and quantity available for riparian flora and fauna, and ultimately on the community condition of the valued biological species. This fundamental concept is represented in Figure 5.1.

Both the Existing Conditions and Project Objective components of the Framework embrace the ecosystem category organizational structure to focus and simplify the development and communication of the complex cause and effect relationships within a riparian ecosystem in the context of a specific restoration project.

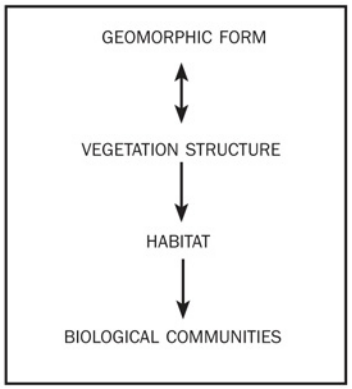

Figure 5.1. Ecosystem categories organized in the general chain of cause and effect within a typical riparian ecosystem.

THE ATTRIBUTE LINKAGE DIAGRAM (DIAGRAM)

An Attribute Linkage Diagram (Diagram) is a one-page conceptual model that organizes attribute classes and attributes according to general cause and effect linkages among ecosystem categories of the riparian ecosystem. The structure of the Diagram is not intended to represent importance of the attributes in any sense, but rather to facilitate understanding and improve communications about how the impairments and restoration actions are expected to affect key ecosystem attributes.

In the Diagram, ecosystem categories are structured from top to bottom. Although there are innumerable ways to characterize the structure of attributes in a riparian ecosystem, this structure (see Figure 5.2) has a logical grounding in riparian ecosystems: physical geomorphology and associated form provides the groundwork for vegetation establishment as well as the dominant vegetation types. Vegetation structure in conjunction with channel form is the basis of aquatic and terrestrial riparian habitat, and habitat is the integrated characteristics of the system that support the resident biological communities and associated function. Restoration actions modify the geomorphic form of stream systems to restore the processes that support the vegetation and biological structures.

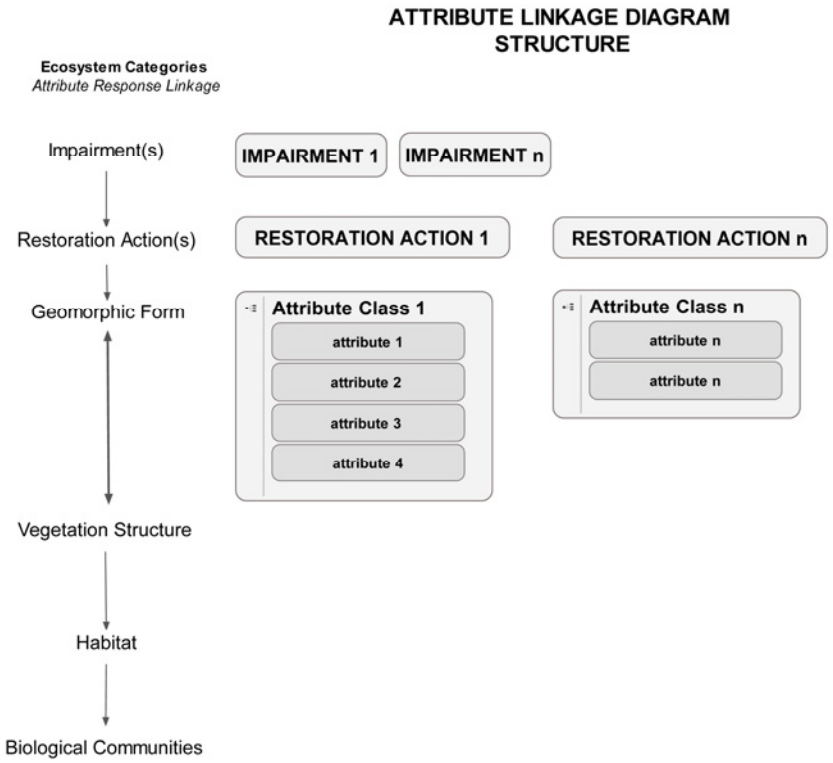

Figure 5.2. The general structure of an Attribute Linkage Diagram, showing the linkage between the identified impairments, restoration action, and the geomorphic effect. The attribute class and attributes continue for the remaining three ecosystem categories.

As with any conceptual model of complicated ecosystems, the Diagram structure is a necessary but extreme simplification of the real world. For instance, there is substantial feedback between attributes associated with an ecosystem category in the diagram and also substantial feedback between attributes associated with different ecosystem categories. These feedback loops are most apparent between vegetation and geomorphic/physical attributes such that geomorphic form and streambank vegetation condition are highly interrelated (Hupp and Osterkamp 1996, Mount 1995, Gurnell et al 2006). For example, a high level of channel entrenchment will increase the stream bank slope and reduce stream bank stability which in turn will reduce the ability for bank vegetation to remain intact or subsequent riparian plants to establish. The lack of bank vegetation also reduces stream bank stability because the soils are more exposed to erosion during high flow conditions. The Diagram structure infers these feedback loops and the cause and effect details can be described systematically in the supporting Narrative. The development of an Attribute Linkage Diagram can greatly increase the identification and communication of the most important links in the chain of cause and effect between attributes. This is particularly valuable for describing the way impairments are affecting attributes during analysis of existing conditions and describing the anticipated restoration project effects when developing project objectives.

ECOSYSTEM ATTRIBUTE NARRATIVE (NARRATIVE)

While the Diagram can summarize the chain of cause and effect on specific attributes and provides a valuable talking tool, by itself it says nothing about specifically **HOW** the effects occur. The primary role of the Narrative is to more deeply explain the ecosystem processes at work and explain the feedback loops between various ecosystem attributes and attribute classes.

The Narrative is the place to describe the processes involved in ecosystem function. For example, straightening a stream increases channel slope, resulting in higher shear stress on the streambed, increased channel scour, and channel incision (Leopold et al 1964). As streambanks become higher and water availability to the bank vegetation is reduced, the vegetation root strength and rooting depth both decrease (Gurnell et al 2006). These geomorphic changes result in an increase in the shear stress acting on the channel bed, causing the channel cross-sectional area to enlarge, which continues to increase scour and erosion at the toe of the streambank. Through these processes, a higher proportion of streambanks within the subject reach begins to actively erode.

The basic organization of the Narrative is to describe each attribute and the effects upon it by other attributes that are in higher ecosystem categories or other attribute classes. *Chapter 6: Existing Conditions Summary Development* and *Chapter 7: Project Objectives Development* provide more detailed guidance on the content, format and process necessary to compose the Narrative for the first two steps of the Framework.

Blackwood Creek (2003)

CHAPTER 6: EXISTING CONDITIONS SUMMARY DEVELOPMENT

The purpose of the Existing Conditions Summary is to summarize the primary impairments to ecosystem function in the project area, and their perceived ecosystem effects. The Existing Conditions Summary should be informed by the findings of a watershed assessment and a more detailed data collection and site evaluation effort. The final products that comprise the Existing Conditions Summary are:

- An Existing Conditions Diagram that summarizes causes and effects among ecosystem attributes resulting from impairments
- A supporting Narrative that explains the processes linking impaired attributes and the chain of cause and effect among them

This step of the Framework is best used to focus the critical thinking of the design team and clarifying their understanding of the existing (pre-project) conditions in project area. The final Existing Conditions Summary has the following key uses:

- Guides consistent documentation of the high-priority attributes of the specific riparian ecosystem
- Communicates the design team's hypotheses about the linkages between the impairment and the observed existing condition of priority ecosystem attributes
- Informs the selection of appropriate restoration actions
- Focuses the definition of project objectives

EXISTING CONDITIONS SUMMARY DEVELOPMENT GUIDELINES

The Existing Conditions Summary is used to document existing hypotheses of how historic and current impairments have resulted in the observed degraded conditions at the site. The Existing Conditions Summary does not take the place of a detailed watershed assessment, but rather provides a simple and standardized communication tool to summarize the primary findings of all previous assessment efforts. Site specific data should be used where available to justify existing condition statements and hypothesized cause-effect linkages stated in the Existing Conditions Summary.

The Existing Conditions Diagram and Narrative are developed simultaneously. The process is highly iterative and likely will require multiple versions that are reviewed and modified by the project team. The simple products created (Diagram and Narrative) will significantly improve communication between the project team. The final products will provide clear communication to other stakeholders about the understanding, observations and assumptions made by the project team. The Existing Conditions Summary should be developed according to the following principles and general guidelines:

1. The overarching principle for organizing the Existing Conditions Summary is based on the fundamental premise that ecosystem categories are affected by historic and current impairments whose influence can cascade through the ecosystem's physical attributes, vegetation, habitat quality and quantity available for riparian flora and fauna, and ultimately on the community condition of the valued biological species (see Figure 5.1). This structure is based on the general attribute linkage diagram structure described in *Chapter 5: Riparian Ecosystem Restoration and Effectiveness Framework Overview.*

2. The Diagram should be developed from top to bottom, identifying the stream reach specific impairment(s) (e.g. straightened channel) and the placement of the corresponding node at the top of the Diagram. Both watershed and local impairments should be considered (Figure 6.1).

3. The team adds the primary attribute class and specific attributes that are observed to be degraded in their existing condition, and this degradation is hypothesized to be either directly or indirectly the result of one or more of the documented impairments. The team should identify attributes and attribute classes for each ecosystem category.

4. A directional statement of each attribute/attribute class used in the Existing Conditions Diagram is added to indicate how it has either been observed or is hypothesized to deviate from the pre-disturbance conditions (e.g. high surface water temperatures or low channel complexity).

5. Linkages are assumed within attribute classes, as well as from attribute classes and specific attributes above and below, though arrows are eliminated to visually simplify the Diagram. The details of these linkages are outlined in the supporting Narrative.

6. The project team should maintain a complete attribute glossary during the process to be sure all members of the team agree on attribute definitions. *Chapter 11: Attribute Glossary* is an example.

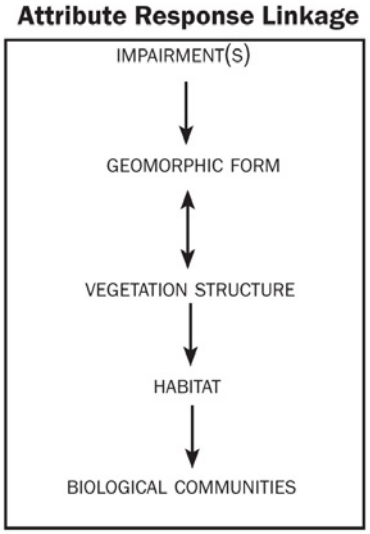

Figure 6.1. Existing conditions attribute linkage diagram structure, organized by ecosystem categories.

The Narrative consists of concise statements regarding each of the existing condition attribute and attribute class. The Narrative statements are developed in concert with the Diagram, such that each attribute class existing condition, function and state is described using specific cause and effect statements of attribute interactions. The Narrative should follow these guidelines:

7. Narrative statements are limited to the condition of the subject attribute and the causal influences that are hypothesized to have directly resulted in the current state of the subject attribute.

8. The Narrative statements for each attribute/attribute class should describe the effect of previous attributes/attribute classes on the attribute that is the subject of the paragraph. The Narrative statements refrain from discussing the effects of the subject attribute on the condition of the attributes located lower in the Diagram. This general rule narrows the focus of the developer and will help the reader understand the structure of ecosystem cause and effect.

9. Site specific data should be used where available to justify the observed degraded conditions as well as the hypothesized cause and effect statements included in the Narrative.

EXISTING CONDITIONS SUMMARY DEVELOPMENT EXAMPLE

This section details the process and the format for creating both the Existing Conditions Summary Diagram and Narrative. This section contains excerpts from the Existing Conditions Summary example created by the 2NDNATURE team for the Angora Sewer Reach to illustrate the guidelines described above. The complete Angora Sewer Reach Existing Conditions Summary is provided in *Chapter 6.1*.

IMPAIRMENTS

The statement of the impairment can be one or many, but should be specifically hypothesized to have direct influence on the observed impaired ecosystem attributes below it. The more specific and focused the impairments statements are, the more the existing conditions summary will inform the selection of appropriate restoration actions to mitigate the impairment(s).

GEOMORPHIC FORM

The geomorphic attributes include a statement of the existing condition relative to what is expected to be the conditions prior to the impairments that resulted in modifications. In some instances, restoration to pre-disturbance conditions is not feasible due to existing constraints. In these cases, the statements of existing attribute condition are relative to what is likely achievable if restoration actions improve fluvial processes. Figure 6.2 provides an example of the upper portion of the existing conditions Diagram for Angora Sewer Reach.

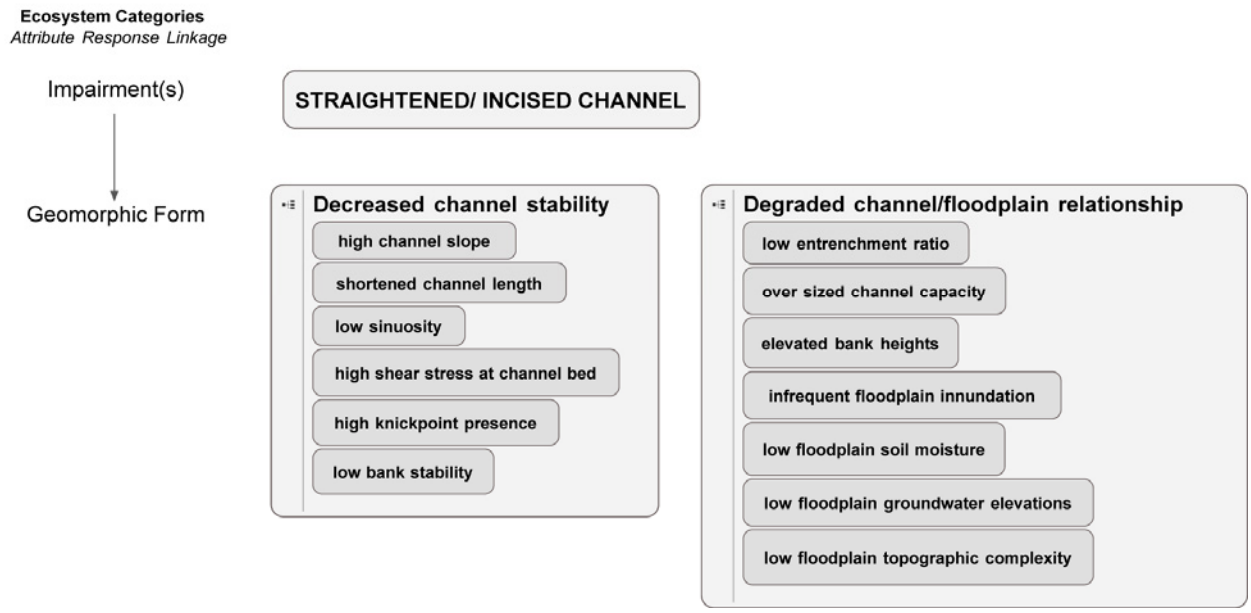

Figure 6.2. Angora Sewer Reach; existing conditions diagram with impairment and geomorphic attributes.

In this example, the primary classes of geomorphic form attributes are channel stability and channel/floodplain relationship. Within the Diagram, statements are made on the relative direction of each attribute class in their existing degraded conditions compared to what is hypothesized to be the pre- disturbance condition and/or

achievable future stable condition, e.g. decreased channel/floodplain relationship. These are general qualitative directional statements to articulate the interacting processes that have resulted in the observed condition of the attribute class.

For example, in Figure 6.2 the subject Angora Sewer Reach (pre-project) is determined to have a degraded channel/floodplain relationship (attribute class). The term "channel/floodplain relationship" is defined in *Chapter 11, Attribute Glossary* as:

> *Fluvial ecosystem processes are dependent upon the hydrologic connection between the floodplain and the stream channel. Annual floodplain inundation supplies soil and nutrients to the floodplain (Schumm 1977). Appropriate floodplain connection between the stream and the associated floodplain maintains an elevated adjacent shallow groundwater table that significantly increases vegetation success and vigor (Hauer and Lamerti 1996). The extent, depth and duration of flooding, as well as the depth of floodplain groundwater, are dependent on the channel capacity of the stream channel.*

Below each attribute class in the diagram is a collection of specific attributes. The Diagram includes statements of the relative deviation of each specific attribute compared to hypothesized pre-impairment and/or future stable conditions. Figure 6.2 states the Angora Sewer Reach has a low entrenchment ratio and an oversized channel capacity, in addition to 4 other observed degraded channel/floodplain relationship attributes in existing (pre-restoration) conditions. There is an inherent linkage between each of these attributes within this class and across classes. In an effort to simplify the visual display of the attribute linkage diagrams, specific arrows are not included.

The existing conditions narrative provides the detailed explanation to support these attribute statements and explain the assumed linkages implied in the Diagram. The Narrative is organized by attribute class, and then the condition of each attribute in the Diagram is systematically described to substantiate the cause and effect linkages in a systematic manner. **The format for the Narrative is as follows:**

ATTRIBUTE CLASS (TITLE)

> ATTRIBUTE (TITLE): *Narrative qualitative description of attribute existing condition and assumed* **causes** *of this existing condition as a result of other attributes within this or any other class. Include quantitative expression of attribute condition whenever possible. Narrative can include statements of how attribute is assumed to* ***affect*** *other attributes within the same class, but should refrain from discussing the effect of this attribute on others outside its respective class. References that strengthen the cause and affect linkages should be provided whenever possible.*

Each attribute contained within the Diagram is described in detail, following the guidelines provided above. In order to simplify and focus the Narrative, each attribute discussion is restricted to the effects **on** the attribute being discussed from other attributes within and/or above, and avoids discussing the effects **of** the subject attribute on other attributes below it.

Using the same two geomorphic attributes of the Angora Sewer Reach existing conditions Narrative statement for channel/floodplain relationship as an example:

CHANNEL/FLOODPLAIN RELATIONSHIP

> ENTRENCHMENT RATIO*: The existing channel has a lower entrenchment ratio than the pre-disturbance channel due to incision. The width of the channel at a depth 2 times bankfull depth is currently the same as the bankfull width.*

CHANNEL CAPACITY: *Channel capacity is increased as a result of channel straightening and the resulting increased slope and reduced channel length. Flows well exceeding the estimated bankfull discharge (10-12 cfs) are currently carried entirely within the channel and do not inundate the adjacent floodplain.*

Notice that the channel/floodplain relationship Narrative above addresses the specific impairment and the other geomorphic attributes that have a functional influence on entrenchment ratio and channel capacity. The Narrative also addresses specific geomorphic or physical attributes that are the result of a degraded hydrologic connection between the stream channel and its associated floodplain. The Narrative, however, does not discuss the hypothesized impacts channel capacity (for instance) may have on the ecosystem categories or attributes below, even though it is hypothesized that the meadow vegetation community condition has been impaired as a result of the degraded channel/floodplain relationship. The recommended Narrative format allows these statements under the vegetation structure narrative section. This format of the Narrative allows a clear and consistent procedure and format for the developers to follow, reducing repetition.

VEGETATION STRUCTURE

The Diagram continues to link geomorphic form with vegetation structure attributes along the bank of the channel and within the associated meadow complex (i.e. floodplain). The channel bank and meadow are hypothesized to be impaired as a direct and/or indirect result of the existing geomorphic form. Using Angora Sewer Reach as an example, the primary vegetation structure attributes are streambank vegetation community condition and meadow vegetation community condition, defined by a collection of specific attributes of the vegetation system (Figure 6.3). Again the definition of one of the attribute classes (streambank vegetation community condition) is provided in the Attribute Glossary (*Chapter 11*):

> *Streambank vegetation is rooted on the channel bank that directly affects the stream channel. Bank vegetation effects on the channel include shading, root structures providing bank stability and promoting channel complexity and channel stability (Hauer and Lamberti 1996, Simon et al 2009). Simon et al (2006) conducted an analysis of the hydrologic and mechanical effects of existing riparian vegetation on streambank stability on the Upper Truckee River and found that stream bank vegetation, especially Lemmon's willow can significantly increase bank strength, reduce the frequency of bank failures and decrease the generation of fine grained sediment to channel. A well established, diverse and successional bank vegetation community supplies wood, leaf litter and detritus to the aquatic system.*

The Narrative format and guidelines remains consistent as outlined above. An insert from the supporting Angora Sewer Reach existing conditions Narrative statement for streambank vegetation community conditions is:

STREAMBANK VEGETATION CONDITION

STREAMBANK VEGETATION COVER: *Streambank instability has contributed to a loss of cover provided by streambank vegetation. Channel incision has also affected bank vegetation as available soil moisture has decreased. There is a feedback loop between the loss of vegetation cover and bank stability, where reduced rooting strength and vegetation presence on the stream bank directly reduces streambank stability, which exacerbates the loss streambank vegetation and limits seedling regeneration (Dunne and Leopold 1978, Simon et al 2006, Langendoen et al 2009).*

Notice that the vegetation structure narrative is limited to discussions of attributes within and above the vegetation structure category of the diagram and refrains from addressing the impacts of the vegetation structure on the habitat quality or the biological communities.

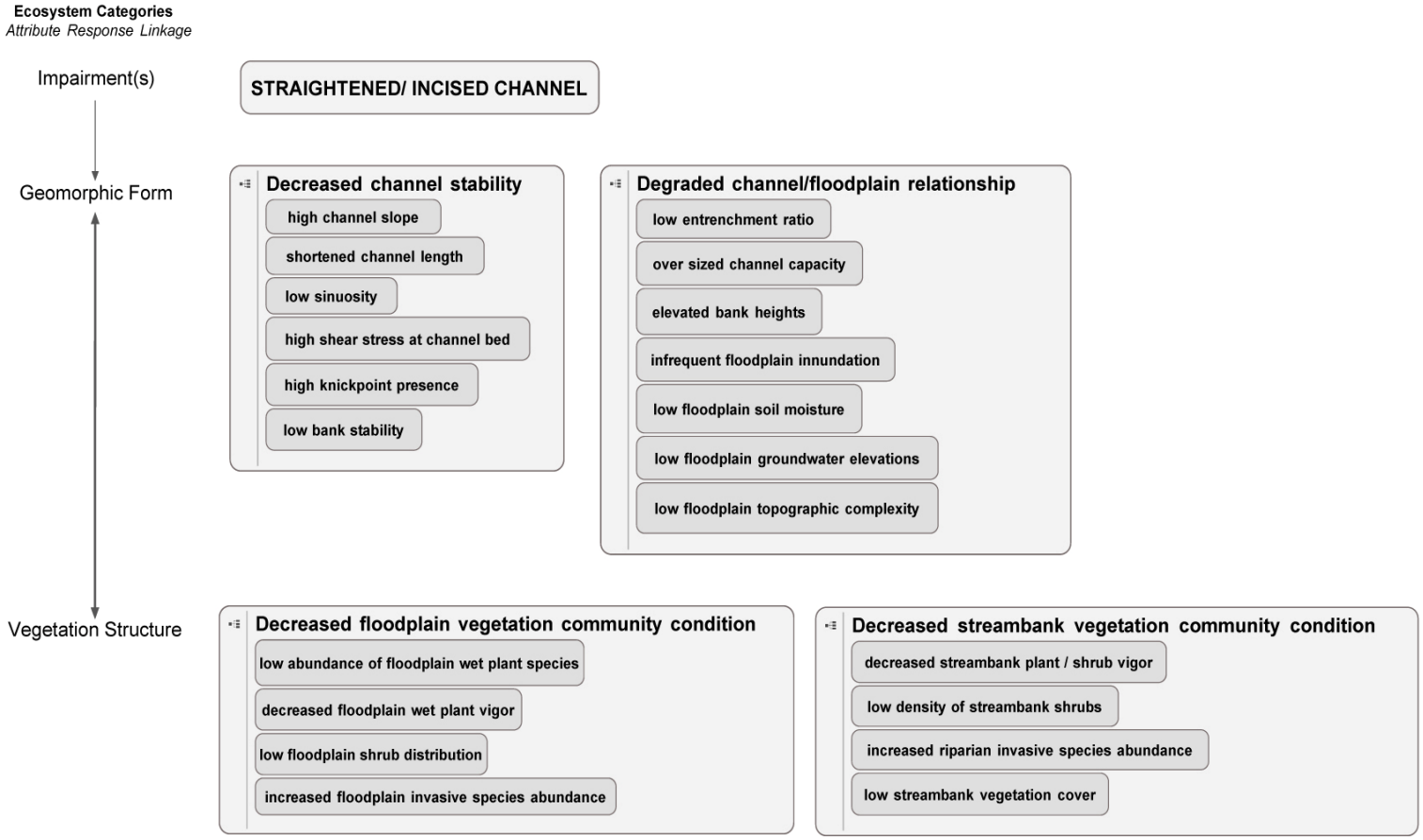

Figure 6.3. Angora Sewer Reach; Existing conditions diagram with impairment, geomorphic form and vegetation structure

HABITAT

The habitat attribute classes for Angora Sewer Reach are aquatic habitat quality, terrestrial habitat quality and downstream water quality (Figure 6.4), all of which have been degraded as result of the poorly functioning processes and the reduced condition of the ecosystem categories indicated above. Using terrestrial habitat

quality as the habitat attribute class example, terrestrial habitat quality is defined in the Attribute Glossary (*Chapter 11*)

> *Terrestrial habitat quality encompasses a wide range of specific physical, chemical and biological conditions that directly affect habitat for fauna in the riparian ecosystem. The specific habitat needs vary for terrestrial wildlife species and specific life stage requirements. These physical, chemical, biological habitat relationships are exceedingly complex and cannot be simply depicted in a diagram. However, qualitative statements about terrestrial habitat quality are often possible, especially in a relative sense (before-after a disturbance, for example). Habitat quality attributes are best expressed as either specific measurable characteristics of the streambank/meadow system (i.e. shrub abundance) or as a statement of the life stage habitat requirements for target species that is either desirable or undesirable within the subject terrestrial ecosystem (i.e. willow flycatcher nesting habitat).*

Notice that some of the terrestrial habitat quality attributes in Figure 6.4 are statements of the habitat quality of a particular terrestrial species at a specific life stage (e.g. willow flycatcher nesting habitat). The reason for this deviation from the guidelines of attribute definitions in the habitat category is two-fold. First, terrestrial habitat requirement vary greatly for the range of potential terrestrial species within a riparian ecosystem. Birds, insects, small mammals, amphibians, etc, all have very different life histories and associated habitat requirements. The statement of habitat quality for a specific species life stage maintains the commitment to keep the attribute linkage Diagram graphically simple, but provides a clear statement of priority/target species for the subject site. Second, the statement of species and life stage is precise enough to be measured by a species expert and the details of the specific habitat requirements are detailed in the Narrative.

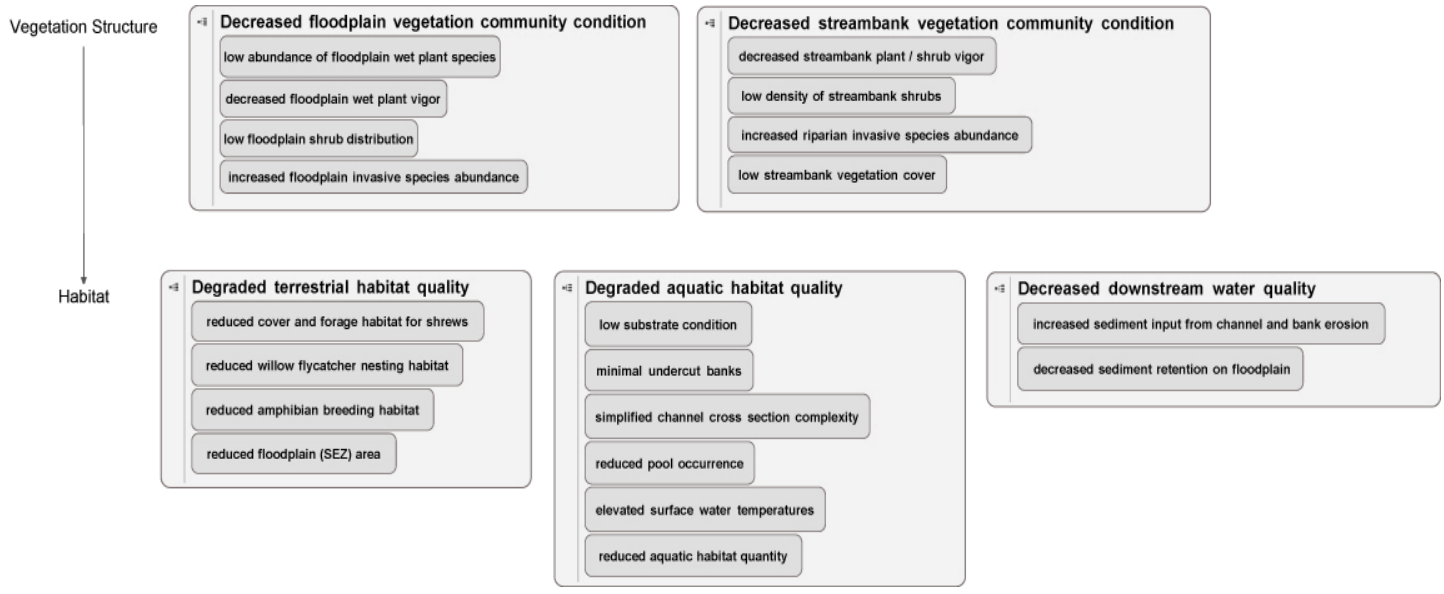

Figure 6.4. Angora Sewer Reach: Existing Conditions Diagram including vegetation structure and habitat attributes.

For example, a specialist measuring nesting willow flycatcher habitat will evaluate the abundance of shrubs in the meadow and the presence of standing water during the spring breeding season. A portion of the terrestrial habitat quality narrative for the Angora Sewer Reach states:

TERRESTRIAL HABITAT QUALITY

WILLOW FLYCATCHER NESTING HABITAT: *The reduction in floodplain inundation and decreased abundance of shrubs in the floodplain has reduced the nesting habitat for willow flycatchers. Impaired stream systems can display a reduced absolute abundance of willows and other riparian shrubs, reducing habitat for a variety of biological communities (Bombay et al 2000). Willow flycatchers require standing water on the floodplain in close proximity to mature shrubs during the spring breeding season (Green et al 2003). Complete Angora Sewer Reach Existing Conditions Narrative provided in Chapter 6.1.*

Also included in the habitat level of the existing conditions Angora Sewer Reach Diagram is the attribute class: *downstream water quality*, described by two specific attributes. Water quality has been included in the habitat ecosystem category, because indirectly water quality can be a specific component of habitat quality for select aquatic species (such as substrate condition influences on invertebrate communities). More specifically the combination of attributes and associated processes that comprise aquatic and terrestrial habitat quality directly influence the downstream water quality for the Lake Tahoe pollutants of concern, nutrients and sediment species.

The decision to include water quality attributes in the linkage Diagram as a priority attribute should be determined on a site by site basis. Water quality is included in the Angora Sewer Reach Diagram because it is assumed that the water quality from the Angora Sewer Reach (a tributary to the largest sediment loading stream to Lake Tahoe, the Upper Truckee River) is potentially a measureable water quality signal to the overall stream loading to Lake Tahoe. Each specific riparian stream reach should be considered in the context of the overall loading of pollutants of concern to Lake Tahoe and as well as the true water quality risks of the subject site.

BIOLOGICAL COMMUNITIES

The complete existing conditions Diagram for Angora Sewer Reach is presented in Figure 6.5. The biological communities are separated into two attributes: aquatic wildlife community condition and terrestrial wildlife community condition. Terrestrial wildlife community condition is defined by the Angora Sewer Reach attribute glossary (*Chapter 11*) as:

> *The terrestrial wildlife community consists of all animals found in the riparian ecosystem, including terrestrial insects, reptiles, amphibians, birds and mammals. Certain species may be more susceptible to perturbations of the riparian ecosystem and would be ideal candidates for evaluating biological condition and/or restoration success.*

The terrestrial wildlife attributes include specific community, species and life stage attributes that are hypothesized to be impaired as a result of the degraded ecosystem process and habitat quality and quantity all outlined above this level of the Diagram. The biological community attributes should be limited to a collection of target species and life stages to focus on a selection of representative and priority indicator species. The biological attributes should be measurable statement of wildlife community characteristics such as presence, diversity or population. The supporting Angora Sewer Reach existing conditions Narrative statement for terrestrial wildlife community condition is provided in *Chapter 6.1*.

DEVELOPMENT CONSIDERATIONS

The integration of the geomorphic, chemical and flora attributes and associated processes collectively represent the aquatic and riparian habitat that supports the highly valued biological communities (e.g. fish or bird communities), located at the bottom of the diagrams but at the top of the food chain. Site specific data should be used where available to justify hypothesized cause-effects included in the Existing Conditions Summary. The development team should continue to probe the questions of what are the specific and measurable attributes hypothesized to be degraded relative to pre-disturbance conditions. The more specific and tangible the narrative and attributes can be in the Existing Conditions Summary, the more informative the Existing Conditions Summary will be in selecting the appropriate restoration actions and design components. Similarly, the development of measurable project objectives will also be improved as illustrated in *Chapter 7: Project Objectives Development.*

Inherently there is no correct or perfect Existing Conditions Summary, and it is highly likely that two different development teams, summarizing the same impaired stream reach may develop and focus upon slightly different collections of attributes. However, the critical thinking stimulation, hypothesis formation and resulting communication tools that result from the process of developing an Existing Conditions Summary is as valuable to a restoration project as the final communication products that are created from the efforts.

The draft Existing Conditions Summary can be conducted early in the watershed assessment process to assist with the identification of information gaps, clarify current hypotheses of impairment effects on observed ecosystem attribute responses, and provide a consistent communication tool between the diverse group of technical experts on the restoration design team. The Existing Conditions Summary draft can be revisited regularly as new information is gained to improve the accuracy of the summary and reprioritize information gaps. The iterative use of the Existing Conditions Summary development by a design team will focus data collection efforts and reduce potentially costly miscommunications. The final Existing Conditions Summary will document the project team's understanding and prioritization between known impairments and the existing physical, chemical and biological conditions of the site to be restored.

Pool at Blackwood Creek (2003)

CHAPTER 6.1 EXAMPLE EXISTING CONDITIONS ANGORA SEWER REACH

Lead Agency: California State Parks

Existing Conditions: estimated late 1990's

The subject reach is located on California State Parks lands approximately three miles upstream of the confluence with the Upper Truckee River. The valley is broad and has a low slope, with extensive native sedge and rush vegetation on the floodplain. Based on historical aerial photographs and remnant geomorphic indicators, the pre-disturbance channel was highly meandering.

Note: Any quantitative attribute values provided below are for illustrative purposes only and DO NOT reflect actual conditions of the Angora Sewer Reach prior to the implementation of restoration in 2000.

Existing Conditions attribute linkage diagram for Angora Sewer reach is included as Figure 6.5

IMPAIRMENT(S)

In the 1960's, a sewerline was constructed in the floodplain to serve subdivisions to the west. The installed sewerline trench was not manually revegetated to protect against erosion. During floods, water flowed down the sewerline trench and began to develop a channel. Over time, the sewerline trench eventually captured the subject reach of Angora Creek, becoming the low flow channel. The existing channel (1990's) has a much lower sinuosity, higher slope and larger channel capacity than the pre-disturbance channel.

Primary Impairment(s): Straightened/ Incised Channel

KEY ECOSYSTEM ATTRIBUTES

CHANNEL STABILITY

Channel stability has decreased with capture of the stream by the linear sewerline.

CHANNEL SLOPE

The existing channel has a slope of 0.05. This is estimated to be 30% greater than the pre-disturbance channel due to a loss of channel length resulting from capture by the sewerline.

CHANNEL LENGTH

The existing channel is over 300 ft shorter than the pre-disturbance channel due to a loss of channel length resulting from channel capture by the sewerline.

SINUOSITY

The existing channel has a lower sinuosity than the natural channel based on aerial photo review due to sewerline capture.

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2NDNATURE LLC
TEL: 831.426.9119 FAX:831.421.9023
www.2ndnaturellc.com

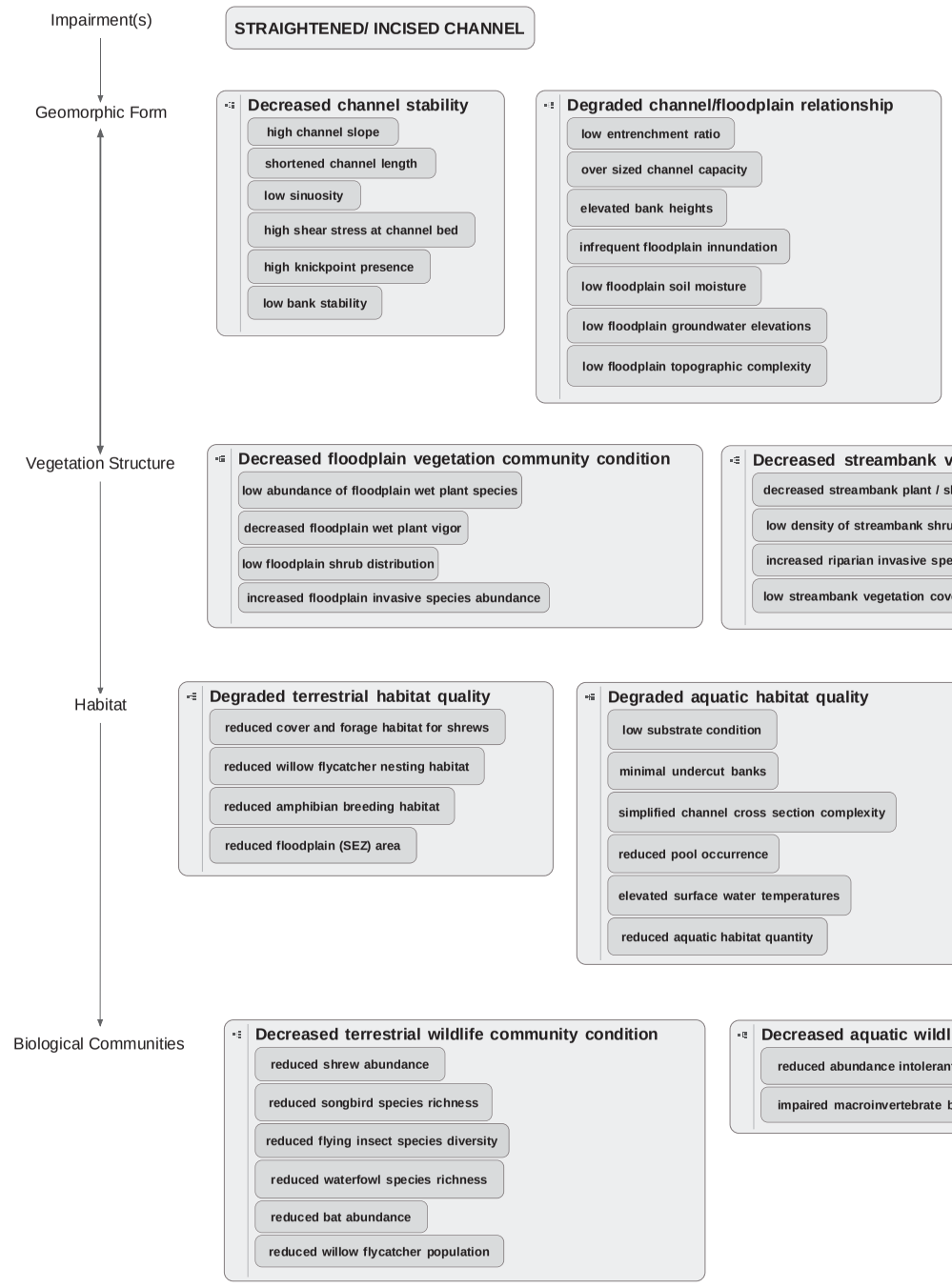

Figure 6.5: **Existing Conditions Diagram**
Angora Creek and Washoe Meadows Enhancement
Project Phase IV Sewer Meadow Reach
Ecosystem Categories (Angora Sewer Reach)
Hypothetical example of Angora Sewer Reach

FIGURE 6.5

SHEAR STRESS

The existing channel has higher shear stress acting on the bed than the pre-disturbance channel due to increased slope and enlarged channel capacity thus more energy during higher flows is applied to the channel bed, thereby exacerbating channel erosion (Leopold et al 1964).

KNICKPOINT PRESENCE

Several mobile knickpoints are present in the existing channel, due to an increase in bed erosion resulting from additional shear stress and the channel incision response. Prior to disturbance, knickpoints were probably not present in the project area.

BANK STABILITY

Bank stability in the existing channel is lower than the pre-disturbance channel due to increased shear stress and the resulting incision response increasing bank heights and bank angles. As the channel bed incised, bank height increased and water availability for streambank vegetation has decreased resulting in a reduction in the abundance and vigor of vegetation on the streambank which in turn has exacerbated bank instability (Schumm 1977, Mount 1995, Simon et al 2006).

CHANNEL/FLOODPLAIN RELATIONSHIP

The channel/floodplain relationship has been degraded as a result of channel straightening from the sewerline capture.

ENTRENCHMENT RATIO

The existing channel has a lower entrenchment ratio than the pre-disturbance channel due to incision. The width of the channel at a depth 2 times bankfull depth is currently the same as the bankfull width.

CHANNEL CAPACITY

Channel capacity is increased as a result of channel straightening and the resulting increased slope and reduced channel length. Flows well exceeding the estimated bankfull discharge (10-12 cfs) are currently carried entirely within the channel and do not inundate the adjacent floodplain.

BANK HEIGHT

The bed incision and reduced channel length has significantly increased the average height of the streambanks.

FLOODPLAIN INUNDATION

The increased channel capacity has resulted in a significant reduction in the frequency, duration and extent of floodplain inundation.

FLOODPLAIN SOIL MOISTURE

Floodplain soil moisture, especially during spring and summer, has decreased due to channel incision and increased channel capacity directly reducing the frequency of floodplain inundation and a relative lowering of the local shallow groundwater elevation.

FLOODPLAIN GROUNDWATER ELEVATION

Floodplain groundwater elevation has decreased due to channel incision and lowering of the channel bed, thereby reducing the seasonal elevation of the adjacent shallow groundwater table (Fetter 1994). This effect is most prominent during the dry season when stream base flow is the primary source of water to the shallow groundwater system.

FLOODPLAIN TOPOGRAPHIC COMPLEXITY

Floodplain surface has minimal irregularity and limited woody debris, likely, due to historic land use disturbances and lack of overbank flooding in recent years. Floodplain topographic complexity within the project reach is below achievable conditions.

FLOODPLAIN VEGETATION COMMUNITY CONDITION

The floodplain vegetation community condition has decreased as a result of decreased channel stability and a decline in the channel/floodplain connectivity.

WET PLANT SPECIES ABUNDANCE

Channel incision has reduced flooding frequency and has caused a lowering of the late season shallow groundwater elevation. This has reduced the soil moisture and nutrient content of the meadow soils (Hauer and Lamberti 1996, Schumm 1977), both of which influence wet species plant growth (Kaufman et al 1997). Undisturbed analog floodplains are dominated by sedges adapted to wet conditions. The floodplain has responded with a decline in the relative abundance of plants that require high soil moisture conditions (especially sedges).

WET PLANT VIGOR

The average height and % of new growth each June of the wet plant species in the floodplain has decreased as a result degraded channel/floodplain relationship.

FLOODPLAIN SHRUB DISTRIBUTION

Historic aerials suggest a relatively higher abundance of shrubs (particularly willows) in Lake Tahoe low energy floodplain environments. Shrub establishment in this matrix was likely facilitated by moist floodplain soils (Fry and Quinn 1979), a functional channel/floodplain relationship and regular disturbances such as fire or by deposition of sediment on the floodplain during floods (Gurnell et al 2006). With the reduced disturbance on the floodplain and reduced water availability, shrub recruitment, establishment and distribution have all decreased.

INVASIVE FLOODPLAIN SPECIES ABUNDANCE

Tolerant species within the restoration area are more abundant than desired. Tolerant vegetation species, such as Scotch Broom, can thrive in the Sierra Nevada soils with low nutrients and low moisture content (Kattelman and Embury 1996).

STREAMBANK VEGETATION COMMUNITY CONDITION

The streambank vegetation community condition has decreased as a result of decreased channel stability and a decline in the channel/floodplain connectivity.

STREAMBANK PLANT VIGOR

The average height and % new growth of streambank wet plant species is lower than expected if the channel/floodplain relationship were not degraded.

STREAMBANK SHRUB DENSITY

The high erodibility of streambanks and the reduced water availability have minimized the establishment of riparian shrubs, whose abundance, density and spatial distribution have been reduced. Shrubs provide streambank stability (Simon et al 2006) due to rooting strength, thus the reduced density of shrubs exacerbates bank erosion and channel instability.

INVASIVE RIPARIAN SPECIES ABUNDANCE

Unstable streambanks have caused a simplification of the riparian plant community, giving way to invasive species capable of withstanding high rates of disturbance and lower water requirements (Dunaway et al 1994). As a result, the relative abundance of invasive tolerant grass and forb species has increased on the streambanks.

STREAMBANK VEGETATION COVER

Streambank instability has contributed to a loss of cover provided by streambank vegetation. Channel incision has also affected bank vegetation as available soil moisture has decreased. There is a feedback loop between the loss of vegetation cover and bank stability, where reduced rooting strength and vegetation presence on the stream bank directly reduces streambank stability, which exacerbates the loss streambank vegetation and limits seedling regeneration (Dunne and Leopold 1978, Simon et al 2006, Langendoen et al 2009).

TERRESTRIAL HABITAT QUALITY

Terrestrial habitat quality encompasses a wide range of specific physical, chemical and biological conditions that directly affect habitat for fauna in the riparian ecosystem. The specific habitat needs vary for different terrestrial wildlife species and specific life stage requirements. The terrestrial habitat quality has declined due to the integrated impacts of the attributes and associated interactive functional processes described above.

COVER AND FORAGE HABITAT FOR SHREWS

Reduction in low lying shrubs and standing water within the floodplain has caused the shrew habitat within the flood plain to decline. Shrews require low lying shrubs and grass for habitat and rely on macroinvertebrates often found associated with standing water for food (Jameson and Peeters 2004). While shrews are not sensitive or threatened species the presence of these small mammals within a floodplain would indicate a more functional channel/floodplain relationship.

WILLOW FLYCATCHER NESTING HABITAT

The reduction in floodplain inundation and decreased abundance of shrubs in the floodplain has reduced the nesting habitat for willow flycatchers. Impaired stream systems can display a reduced absolute abundance of willows and other riparian shrubs, reducing habitat for a variety of biological communities (Bombay et al 2000). Willow flycatchers require standing water on the floodplain in close proximity to mature shrubs during the spring breeding season (Green et al 2003).

AMPHIBIAN BREEDING HABITAT

Standing surface water storage on the floodplain is important breeding habitat for several amphibian species (including tree frog and long-toed salamander (Jenning and Hayes 1994, Manley and Lind 2005) and thus the amphibian breeding habitat has been reduced. Standing water is less common on the floodplain due to the decreased channel/floodplain connectivity.

FLOODPLAIN (SEZ) AREA

The floodplain and/or stream environment zone (SEZ) area has significantly declined with the decreased elevation of shallow groundwater as a result of the reduced channel/floodplain relationship. The reduced frequency and duration of overbank flows and the lower groundwater table have also contributed to a significant narrowing of the areal extent of the floodplain and the increased presence of a mesic meadow surrounding the stream channel.

AQUATIC HABITAT QUALITY

The specific habitat needs vary for different aquatic wildlife species and specific life stage requirements. The aquatic habitat quality has declined due to the integrated impacts of the attributes and associated interactive functional processes described above.

SUBSTRATE CONDITION

Substrate condition declined with incision due to increased erosion of the bed and banks causing increased loads of fine sediment (< 2mm) to the reach. The enlarged channel resulting from instability tends to retain sediment, particularly fine sediment, decreasing the formation of stable riffle and bar features (Leopold et al 1964, Mount 1995).

UNDERCUT BANKS

Incision and loss of vegetation, particularly shrubs, on streambanks have reduced the ability of streambanks to form undercuts, thus minimal presence of undercut banks is observed.

CHANNEL CROSS SECTION COMPLEXITY

Channel incision and erosion of streambanks has tended to promote a uniformly shallow low flow channel, with a high width-depth ratio. The current average channel section is greatly simplified in width, depth and flow variability.

POOL OCCURRENCE

Pool occurrence has decreased as the channel and meander length decreased and slope increased as a result of capture. The straightened channel did not possess the complex and cross-sectional variability in hydraulic conditions necessary for pool development. The incised channel possesses a more uniform longitudinal hydraulic condition and tends to export sediment, which does not allow for the development of bars, riffles and pools.

SURFACE WATER TEMPERATURES

Loss of vegetation cover on the streambanks has decreased shading, resulting in increased surface water temperature, especially during the summer. The shallow, wide low flow channel also increases solar input to the stream and contributes to increased water temperatures (Dunne and Leopold 1978).

AQUATIC HABITAT QUANTITY

The reduced sinuosity and channel length significantly reduced the areal extent and volume of aquatic habitat. The oversized channel capacity has resulted in many locations where water depths during the dry months may be too shallow to likely support an abundance larger fish species such as trout. The loss of pools in the straight channel also reduced the water volume within the channel, and therefore aquatic habitat, contained within the reach.

DOWNSTREAM WATER QUALITY

Due to lower channel stability, downstream water quality has declined, particularly with respect to increased sediment loads.

CHANNEL SEDIMENT INPUT

Sediment generation from the project reach has increased as a result of chronic bed and bank erosion. The channel erosion is greater due to the array of degraded geomorphic attributes outlined above.

FLOODPLAIN SEDIMENT RETENTION

The disconnection of the channel from its floodplain has reduced the frequency, duration and extent of floodplain inundation. The loss of floodplain activation has reduced the retention of sediment on the floodplain during floods, causing a reduction in the potential total and fine sediment sink that could be treating upstream sources. Floodplain activation, sediment retention and floodwater infiltration will also result the removal and retention of nutrient species on the floodplain as well, potentially improving downstream water quality (Noe and Hupp 2009).

TERRESTRIAL WILDLIFE COMMUNITY CONDITION

The terrestrial wildlife community condition has decreased.

SHREW ABUNDANCE

Reduction of floodplain habitat has contributed to reduced abundance of shrews, which are highly dependent on frequently inundated floodplains and shrubs for cover and foraging (Jameson and Peeters 2004).

SONGBIRD SPECIES RICHNESS

The species richness of songbirds within the subject riparian ecosystem area is expected to be higher in floodplain (SEZ) areas with greater distribution of shrubs, such as willows. Reduction of shrub abundance, wet meadow habitat and standing water on the floodplain during the spring have contributed to reductions in number of songbird species utilizing the project area.

FLYING INSECT DIVERSITY

The diversity of the adult flying insect community had decreased as a result of the degraded channel/floodplain relationship, reduction of standing water on the floodplain, and reduced wet meadow habitat.

WATERFOWL SPECIES RICHNESS

Due to the enlarged channel morphology, loss of pools, and reduction of standing water on the floodplain, number of waterfowl species utilizing the area in the spring is expected to have declined (Siegel and DeSante 1999).

BAT ABUNDANCE

Lower abundance and diversity of flying insects has reduced bat foraging opportunity and reduced bat presence.

WILLOW FLYCATCHER POPULATION

Degradation of the floodplain habitat and riparian shrub abundance has contributed to the reduction of willow flycatcher population (Greene et al 2003).

AQUATIC WILDLIFE COMMUNITY CONDITION

The aquatic wildlife community condition has decreased.

INTOLERANT FISH SPECIES ABUNDANCE

The aquatic habitat quality and quantity degradation in Angora Creek has reduced the relative abundance of fish species relatively intolerant to the degraded aquatic habitat such as sculpin and trout. The degraded aquatic habitat quality attributes that are hypothesized to negatively impact the intolerant fish species include:

- Reduced channel complexity, impairing spawning, rearing and cover habitat (Knapp et al 1998).
- Loss of quality pools minimizing refuge.
- Reduced streambank vegetation reduces shading, increasing surface water temperatures (Matthews et al 1997).
- Reduced substrate condition by increased presence of fines (<2mm), reducing spawning success (Furniss et al 2007).
- Reduced abundance, diversity and integrity of macro invertebrates limiting fish food supply.

MACROINVERTEBRATE BIOTIC INTEGRITY

The existing macroinvertebrate community is impaired due impaired aquatic habitat conditions, including the following:

- Increased distribution of sand sized (< 2mm) or smaller material in the channel bed. (Karr and Chu 1999, Herbst 2009).
- Reduction in bank vegetation distribution and density reduces the wood, leaf litter and organic material supply to stream (Entrekin et al 2008).
- Reduction in bank vegetation distribution and density reducing the shade cover and increasing maximum daily water temperatures (Meehan et al 1977).
- Reduction in channel complexity has reduced the distribution of sediment sorting.

The macroinvertebrate community can be quantified using locally developed indices of biological integrity that incorporate species diversity, presence of intolerant species, etc (Herbst and Silldorff 2004).

CHAPTER 7: PROJECT OBJECTIVES DEVELOPMENT

The purpose of the Project Objectives Development is to summarize the hypothesized effects of restoration action(s) on the ecosystem attributes and document specific project objectives that can either be measured directly or through proxies. The final Project Objectives documents will also consist of an attribute linkage Diagram and associated supporting Narrative that contains project objectives and specific directional and measurable metrics that could be used to evaluate the response of the ecosystem to restoration.

The Project Objectives development will focus the project team on translating their understanding of the ecosystem into specific, measurable outcomes of the restoration project. The final Project Objectives Diagram and Narrative can be used to:

- Define and communicate the project specific goals and testable objectives of the restoration effort.
- Clarify the intended vegetation structure, habitat and biological improvements expected as a result of geomorphic modifications.
- Simplify selection of metrics and protocols for future monitoring that are directly relevant to the priority attributes and project objectives.
- Align specific project goals and objectives with Lake Tahoe Environmental Improvement Program (EIP) Action Priorities and Performance Measures

To illustrate the development process and final product of this step in the Framework, Angora Sewer Reach Project Objectives example is used as an example throughout this chapter. The complete Angora Sewer Reach Project Objectives documents are included as Chapter 7.1 and may provide valuable context to follow while the reader seeks to comprehend this chapter.

DEVELOPMENT GUIDELINES

The Project Objectives Attribute Linkage Diagram (Project Objectives Diagram) directly builds upon the diagram created in *Chapter 6: Existing Conditions Summary Development.* The Narrative is created to support the diagram and contains both general project goals and specific project objectives. Where possible the project objective statements include quantitative statements of the existing condition (pre-project) for each attribute and quantitative project objective targets.

The Project Objectives Diagram and Narrative should be developed according to the following principles and general guidelines:

1. Inherently implied in the project objectives diagram is the design team's specific hypotheses of the directional and predicted changes expected to be iterated through the ecosystem as a result of the restoration action(s). The project objectives diagram visually communicates the goals and objectives of a reach specific restoration project, by articulating the desired ecosystem attribute responses as a result of the restoration actions.

2. Restoration action(s) are inserted directly below the impairment in the existing conditions attribute linkage diagram, suggesting the intended direct mitigation of the impairment by the selected restoration action(s) (Figure 7.1).

3. The project objective attributes are reworded to respond in the opposite direction to the impairment as phrased in the Existing Conditions Summary. Thus they become the "mirror image" of the existing condition attributes.

4. Each attribute class box from the Project Objectives Diagram becomes a project specific goal. Each goal is a directional statement of how the related attribute class is expected to respond over time to restoration. However, the goals are typically not directly measurable, but rather can be quantitatively described by a collection of project objectives.

5. Each attribute box from the Project Objectives Diagram becomes a measurable project objective. The Narrative clarifies the ecosystem linkages implied in the diagram and defines the expected responses of the primary attributes as a result of the restoration. These statements are quantitative, testable and contain specific measurable targets whenever possible.

6. Some of the attributes that are included in the Existing Conditions Summary may not be included in the Project Objectives Diagram if the project team's critical evaluation of their expected response or measurability lead to the conclusion the restoration action(s) will not be able to distinctly prove anticipated effects.

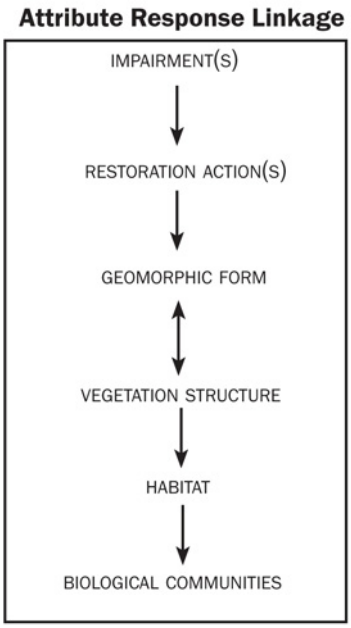

Figure7.1 Project objectives attribute linkage diagram structure, organized by ecosystem categories.

7. The Diagram summarizes the changes expected to specific attributes and attribute classes and the Project Objectives Narrative systematically explains how these changes are expected to migrate through the linked ecosystem attributes. Following the same guidelines outlined in the Existing Condition Narrative, the Project Objectives Narrative is a collection of project objectives which outlines the design team's hypotheses on how the restoration project will alleviate the existing stressors, restore functional ecosystem processes, and ultimately improve the desired biological communities at the base of the attribute diagram.

8. Special consideration should be given to inclusion of project goals and objectives (i.e. attribute classes and attributes) that align with EIP Action Priorities and EIP Performance Measures. There are 30 Action Priorities in most recent version of the EIP update on the TRPA website [1] and a few potentially related Action Priorities are: Enhancing Fish and Wildlife Habitat, Restoring the Upper Truckee Watershed, Managing Invasive Aquatic Species, Reducing Stormwater pollution from Forest Roads, etc. The alignment of attribute classes and/or attributes with EIP Performance Measures will improve the linkage between the EIP accomplishments and project specific objectives. While some creativity will be required to ensure directly measurable and testable project objectives, draft Performance Measures that may be applied to riparian ecosystem restoration project objectives include:
    - Linear feet of stream habitat restored or enhanced
    - Acres of Environmentally Sensitive Land Acquired
    - Acres of habitat protected
    - Acres of habitat restored or enhanced
    - Sensitive species sites protected or re-established

[1] At the time of this writing the current draft document is titled "Restoration In Progress: Environmental Improvement Program Update- Planning Horizon 2008-2018" draft 7/15/09. http://www.trpa.org/default.aspx?tabindex=12&tabid=227. The complete list of operational EIP Performance Measures and procedures for using them will be available from TRPA Environmental Improvement Branch staff in late 2010.

- Acres treated for invasive species
- Fine sediment load reduction achieved
- Nitrogen load reduction achieved
- Phosphorous load reduction achieved
- Tons of carbon sequestered or emissions avoided

PROJECT OBJECTIVES DEVELOPMENT EXAMPLE

Building upon the Angora Sewer Reach example in *Chapter 6: Existing Conditions Summary Development,* the Angora Sewer Reach project objectives Diagram is included as Figure 7.2. The restoration actions are channel realignment and revegetation. One project goal of the implementation of restoration is improve the channel/floodplain relationship. According to Figure 7.2, the specific attributes within this class suggest the restoration team hypothesized that restoration actions will specifically result in a measurable increase in the entrenchment ratio and a reduction in the channel capacity. Referring to the example from Project Objectives Narrative in *Chapter 7.1:*

CHANNEL/FLOODPLAIN RELATIONSHIP

The channel/floodplain relationship will be restored to a more functional condition given the reach hydrology and sediment load as a result of channel realignment and restoration. [A general goal statement]

ENTRENCHMENT RATIO: *Due to incision, the channel is currently has a very low entrenchment ratio. When the stage of the reach is 2 times bankfull discharge stage, flow is still entirely contained in the channel and the entrenchment (the ratio of bankfull width to width at 2 times bankfull stage (Rosgen 1996) is low, between 1 and 2. Following channel restoration, flows above bankfull will inundate the floodplain. Width at 2 times bankfull stage will be greater than ten times bankfull and the average reach entrenchment ratio will be >10 post project.*
[An objective statement with supporting explanation of cause and effect and a numeric target value]

CHANNEL CAPACITY: *The channel realignment design flow is 10-12 cfs, a reduction of 25-40% from the existing conditions channel capacity. Channel cross sectional area will be reduced to 7.5 sq ft from a pre-project average of about 20 sq ft. The average channel width will be 8 ft. This capacity will better approximate functional bankfull channel conditions, thereby improving the channel/floodplain relationship*.
[An objective statement with supporting explanation of cause and effect and a numeric target value]

DEVELOPMENT CONSIDERATIONS

The Project Objectives should be completed and readily available with the final restoration design plans prior to construction. The Project Objectives and other Effectiveness Evaluation documents should be continually reviewed throughout the Effectiveness Evaluation process.

The process of developing the existing conditions analysis and project objectives is intended to encourage critical thinking and is expected to be iterative, with the process of development equally as valuable as the final communication products. The creation of the project objectives diagram may result in new insight by the development team that perhaps some of the attributes included in the existing conditions analysis may not be expected to respond to the selected restoration action and spur revisions in the restoration design and/or strategy.

There is no inherently correct or perfect set of Project Objectives, and it is highly likely that two different development teams summarizing the same restoration project may develop and focus upon slightly different collections of project goals and objectives. However, the critical thinking stimulation, hypothesis formation and the development of clearly articulated Project Objectives that are each independently stated and testable hypotheses will greatly improve the development and execution of the Monitoring Strategy and future Effectiveness Evaluations.

CHAPTER 7.1 EXAMPLE PROJECT OBJECTIVES ANGORA SEWER REACH

Lead Agency: California State Parks

Restoration Action: completed 2000

SEE CHAPTER 11: ATTRIBUTE GLOSSARY for definition of attribute terms.

Note: Any quantitative attribute or objective values provided below are for illustrative purposes only and DO NOT reflect actual conditions of the Angora Sewer Reach prior to the implementation of restoration in 2000.

Project Objectives attribute linkage diagram for Angora Sewer reach is included as Figure 7.2

RESTORATION ACTION(S)

Approximately 3,000 linear feet of the channel will be reconstructed to mimic the natural, meandering alignment to mitigate the incised and straightened channel. The channel capacity will be sized to accommodate 10-12 cfs (the estimated 2 year recurrence interval flood) determined using geomorphic indictors, historic aerials and other available information. The newly constructed channel banks will be revegetated with native plants per the final designs and revegetation plan.

Primary Restoration Action(s): Channel Realignment; Revegetation

PROJECT GOALS AND OBJECTIVES

The ecosystem attribute class statements are specific restoration goals. Each ecosystem attribute class statement is a specific project objective. Each project objective will include the existing (pre-restoration) quantified metric as appropriate.

CHANNEL STABILITY

Channel stability, which had been compromised by the construction of the sewer line, will be restored through channel realignment. The reconstructed channel will increase channel stability by reducing channel slope and shear stress on the bed, primarily through the constructed increase in sinuosity.

CHANNEL SLOPE

The existing channel has a slope of 0.005. The restored channel will reduce the slope to approximately 0.0026, in order to recreate a slope similar to pre-disturbance slope.

CHANNEL LENGTH

The restored channel will integrate a natural meandering shape resulting in an increase in channel length from 2,400 feet to 3,400 feet. The restored channel length is analogous to, and will be used to quantify, the EIP Performance Measure; “linear feet of stream habitat restored or enhanced”.

SINUOSITY

The channel realignment will increase the sinuosity of the channel from 1.1 to 1.6.

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.421.9023
www.2ndnaturellc.com

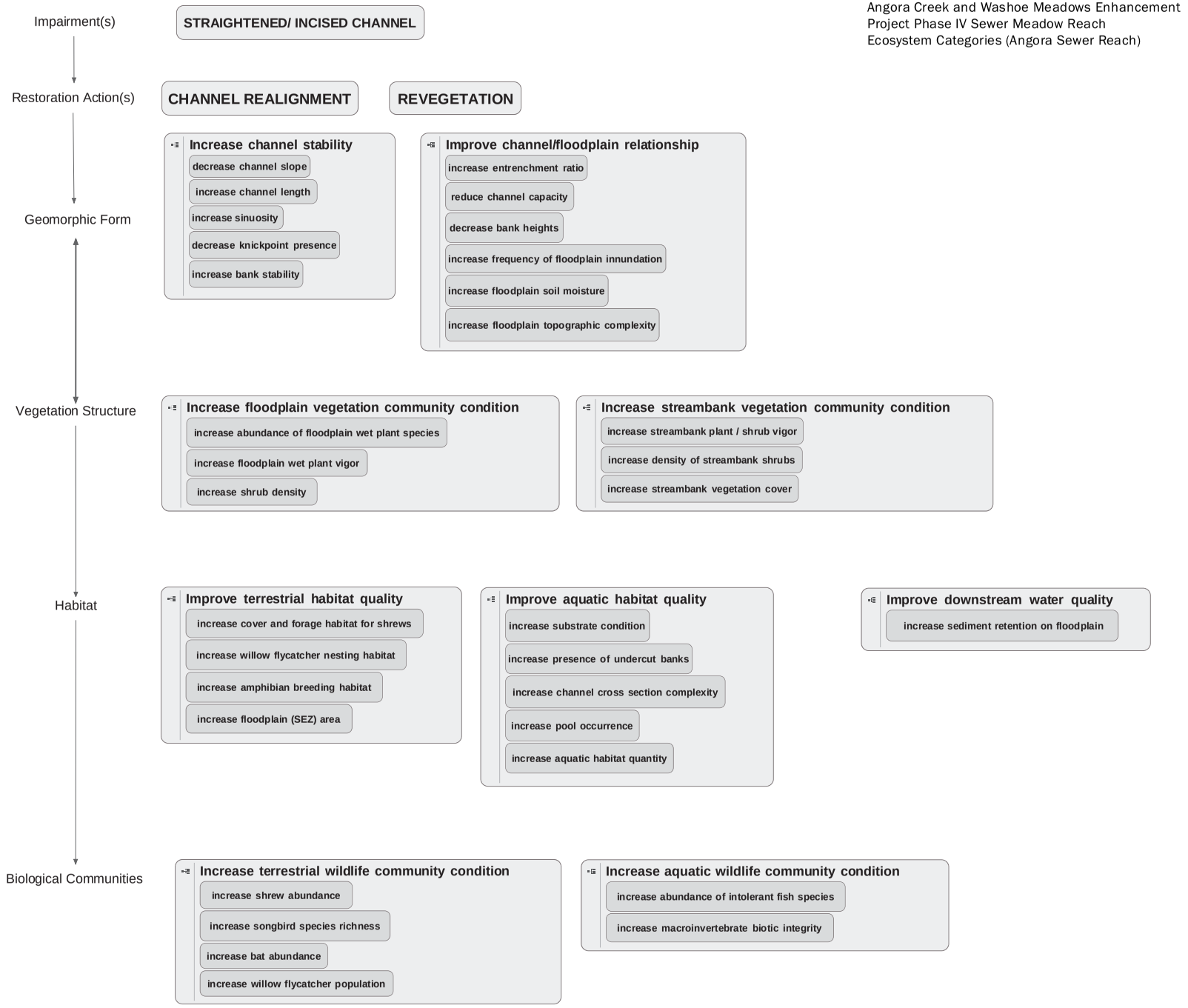

Figure 7.2: Project Objectives Diagram
Angora Creek and Washoe Meadows Enhancement
Project Phase IV Sewer Meadow Reach
Ecosystem Categories (Angora Sewer Reach)

FIGURE 7.2

KNICKPOINT PRESENCE

Knickpoints formed in the existing channel as a result of bed erosion, shear stress and the channel incision response. The reconstructed channel will remove knickpoints and minimize the potential of knickpoint formation. The existing channel has an average of 3 knickpoints per 1000 ft of stream, the channel realignment will reduce knickpoints to <1/1000 ft.

BANK STABILITY

Channel realignment will increase bank stability, due to lower streambank height, lower velocities within the channel and lowered shear stress acting on the banks during high flows. Bank stability has a positive feedback with bank vegetation condition, where stable banks will increase the recruitment and survival of streambank vegetation communities, which, in turn, protect the streambanks from erosion during higher flow conditions (Hauer and Lamberti 1996, Simon et al 2006, Simon et al 2009). Currently, approximately 50% of streambanks are actively eroding. Based on analysis of undisturbed streams in similar setting, less than 10% of streambanks will be actively eroding post-project.

CHANNEL/FLOODPLAIN RELATIONSHIP

The channel/floodplain relationship will be restored to a more functional condition given the reach hydrology and sediment load as a result of channel realignment and restoration.

ENTRENCHMENT RATIO

Due to incision, the channel is currently has a very low entrenchment ratio. When the stage of the reach is 2 times bankfull discharge stage, flow is still entirely contained in the channel and the entrenchment (the ratio of bankfull width to width at 2 times bankfull stage (Rosgen 1996) is low, between 1 and 2. Following channel restoration, flows above bankfull will inundate the floodplain. Width at 2 times bankfull stage will be greater than ten times bankfull and the average reach entrenchment ratio will be >10 post project.

CHANNEL CAPACITY

The channel realignment design flow is 10-12 cfs, a reduction of 25-40% from the existing conditions channel capacity. Channel cross sectional area will be reduced to 7.5 sq ft from a pre-project average of about 20 sq ft. The average channel width will be 8 ft. This capacity will better approximate functional bankfull channel conditions, thereby improving the channel/floodplain relationship.

BANK HEIGHT

Channel realignment will restore streambank height to values measured in functional analogs. The restored channel will have a lower streambank height and lower flow and velocities, minimizing the potential of future incision (Leopold et al 1964). Streambank height will be reduced to an average of 2 ft at riffle sections from the current 3-5 ft.

FLOODPLAIN INUNDATION

With a lower streambank height and a reduced channel capacity, the frequency, extent and duration of floodplain inundation will increase. In existing conditions, the subject reach does not get out of bank when the discharge is less than the 10 year recurrence interval. Post-project, the floodplain will be inundated when discharge exceeds the recurrence interval of 2 years or >12 cfs and the duration of floodplain inundation for each water year type (dry, moderate, wet) will increase by 50% or more.

FLOODPLAIN SOIL MOISTURE

Floodplain soil moisture will increase due to more frequent out of bank flooding. The raised channel bed and increased channel stability will elevate the local groundwater table causing an increase in soil moisture available for the roots of vegetation (Fetter 1994). Post-project, soil moisture > 25% saturation is expected to be found in the upper four feet of the soil profile throughout the growing season (May-July) in the entire floodplain area. Currently, soil moisture >5% saturation is found in only 25% of the floodplain area in the top four feet of the soil profile throughout the growing season.

FLOODPLAIN TOPOGRAPHIC COMPLEXITY

The existing topographic complexity in the floodplain will be improved by increasing the irregularity of the currently uniform surface which lacks surface depressions and mounds. The restored floodplain will increase the roughness and surface complexity of the floodplain by 20% through the random placement of wood, sod and other natural material on the floodplain. The topographic complexity will continue to increase as the floodplain vegetation community improves.

FLOODPLAIN VEGETATION COMMUNITY CONDITION

The floodplain vegetation community condition will improve as a result of increased channel stability and channel/floodplain connectivity.

FLOODPLAIN WET PLANT SPECIES ABUNDANCE

An increase in floodplain inundation and local groundwater elevation will increase soil moisture providing an adequate growing environment, especially later in the growing season, for wet plant species, such as sedges (Kattlemann and Embury 1996). Frequent over bank flow will also transport more nutrient rich soils to the floodplain (Noe and Hupp 2009). These factors will increase the abundance of plants adapted to wet meadow landscapes. In drier peripheral areas of the floodplain 50% of the plants are currently wet meadow species. Five years post-project, based on the wet plant relative abundance of functional analogs, wet meadow species will comprise 90% of floodplain vegetation.

FLOODPLAIN WET PLANT VIGOR

Floodplain inundation increases nutrient rich sediment deposition on the floodplain, improving the overall health and growth of wet plants. In addition to an increase in abundance of shrubs and willows, within the project reach, the average height of sedge species will increase by 20%.

FLOODPLAIN SHRUB DENSITY

Floodplain inundation increases nutrient rich sediment deposition on the floodplain, increasing the establishment of shrubs and their success in expanding on the floodplain. Sediment deposition also provides disturbed areas for shrub establishment, encouraging shrub recruitment (Rood et al 2005). These factors, complemented by manual revegetation efforts, will increase the density of shrubs on the floodplain. Currently, shrub density averages 1 plant /100 yd^2. Following channel restoration, this will increase to 5/100 yd^2. It is anticipated that this change in density will require several years post-project, and the occurrence of at least one large flood that deposits new sediment on the floodplain.

STREAMBANK VEGETATION COMMUNITY CONDITION

The streambank vegetation community condition will increase as a result of increased channel stability and channel/floodplain connectivity.

STREAMBANK PLANT VIGOR

An increase in streambank stability and improved channel/floodplain relationship will lead to increases in the riparian plant community vigor (Rowntree and Dollar 1999). Due to increased water availability, reduced bank erosion and increased soil porosity (Kattleman and Embury 1996) native forbs, sedges and rushes will not only become more abundant, but will also increase in average height by 15%.

STREAMBANK SHRUB DENSITY

The higher streambank stability and improved channel/floodplain relationship will increase the density of riparian shrubs due to increased water availability and soil development on the streambanks (Simon et al 2006, Barbour et al 2007). Currently, shrub density is about 1/100 lineal ft of channel. Post-project estimates of shrub density based on undisturbed streams in a similar setting is expected to average 10/100 lineal ft.

STREAMBANK VEGETATION COVER

The reconstructed channel will increase stream bank vegetation cover as a result of greater water availability to riparian vegetation by the lowering streambank height and reducing channel capacity. The reduction of shear and erosive stresses on the streambank will reduce instability and promote bank vegetation reestablishment. Currently, vegetation covers less than 50% of the streambanks. Analysis of undisturbed channels in similar settings suggests that streambank cover should increase to over 90%. Increases in vegetation cover should occur in the first year post-project as a result of manual revegetation efforts, but the target 90% streambank cover may not be realized until 8 years post-project.

TERRESTRIAL HABITAT QUALITY

Terrestrial habitat quality will improve due to the restored attributes and associated interactive functional processes described above.

COVER AND FORAGE HABITAT FOR SHREWS

Increases in riparian shrub abundance, wet plant species abundance and floodplain standing water distribution and floodplain inundation frequency will improve the quality of foraging and cover habitat for shrews (Frey 2003).

WILLOW FLYCATCHER NESTING HABITAT

Regular floodplain inundation will increase the area and duration of standing water on the floodplain. Also, an increase in riparian shrub abundance and complexity within the meadow will result in more occurrences of mature shrubs near standing water, the primary component of nesting habitat for willow flycatchers (Greene et al 2003).

AMPHIBIAN BREEDING HABITAT

Amphibian breeding habit improves as a result of the reconnection between the channel and floodplain. Frequent floodplain inundation will lead to an increase in the area of standing surface water on the floodplain, as well as in increase in the duration of standing water, creating important breeding habitat for native amphibian species such as the Pacific tree frog (Stebbins 2003) and increasing the amphibian population by 20%.

FLOODPLAIN (SEZ) AREA

The floodplain (SEZ) area will increase due to the hydrologic reconnection between the channel and floodplain. An increase in the shallow groundwater elevation will increase the frequency and seasonal persistence of adequate soil moisture, especially later in the growing season, benefiting plant species adapted to regularly inundated floodplains. More frequent flooding will transport more nutrients onto the floodplain soils (Schumm 1977, Noe and Hupp 2009). As a result, it is

anticipated that about 25% of the floodplain area will transition from mesic meadow to wet meadow, similarly the SEZ area restored will be a 25% increase from the pre-project SEZ area (approximately 12 acres). The floodplain (SEZ) habitat area will also be used to quantify and report the EIP Performance Measure; "Acres of habitat restored or enhanced".

AQUATIC HABITAT QUALITY

The aquatic habitat quality will improve due to the restored attributes and associated interactive functional processes described above.

SUBSTRATE CONDITION

The substrate condition will be increased by a reduction in the contribution of sand sized sediment (< 2 mm) in the channel substrate. The increase in substrate size will increase channel stability, promoting functional sediment transport processes, and allowing for riffle and bar development and regular scour during floods (Leopold et al 1964, Knighton 1998). These processes will more effectively sort and store channel substrate, reducing the distribution and amount of sand stored in the channel and increasing the mean particle size in riffles. Improved bank stability will also improve substrate condition by reducing the chronic bank source of sand sized sediment to the channel (Simon et al 2006).

Substrate D50 is expected to increase from 1 to > 3mm. Percent of sand sized sediment or finer is expected to decrease from 50% to less than 25%. Improvements in substrate should be seen immediately post-project. However, monitoring following floods in subsequent years will be required to assess if improvements are sustained.

UNDERCUT BANKS

An increase in streambank stability, coupled with increased vegetation cover, will allow for the development of undercut streambanks. Currently, about 5% of outside bends have undercut development. This is expected to increase post-project to over 50%, based on measurements of undisturbed streams in similar settings. Because undercut streambanks require robust vegetation for their development, undercut banks may require several years post-project to develop.

CHANNEL CROSS SECTION COMPLEXITY

The channel realignment will result in an increase in channel complexity both within the cross section and longitudinally. Higher sinuosity and higher variability in the longitudinal profile and planform pattern will increase hydraulic diversity along the stream reach. The resulting variable scour will promote increased cross-sectional variability in width and depth (Leopold et al 1964). Increased channel and bank stability will also contribute to increased channel complexity by promoting variable patterns of scour and deposition. Channel complexity will provide more spawning, rearing and cover habitat for aquatic organisms. Currently, cross section depth standard deviation at bankflow stage averages less than 5% for ten points across the section. Post-project depth variability is anticipated to be over 20%. Improvements in cross section variability should occur immediately post-project, and should improve with channel-forming flows in subsequent years.

POOL OCCURRENCE

Improved planform (higher sinuosity), a stable profile, and improved streambank stability will improve the development and stability of pools. The result will be an increase in pool frequency and average depth. Currently, pool frequency is approximately 1/500 lineal feet of channel, with an average maximum depth of 0.7 ft. Post-project, pool frequency will increase to approximately 1/100 lineal ft, with an average maximum depth of 1.5 ft. Pool occurrence improvements will occur immediately post-project, and should continue with subsequent channel-forming flows.

AQUATIC HABITAT QUANTITY

The restored channel will be longer, as a result of the increased sinuosity, and consist of a greater area than the existing channel. Total length, surface area, and water volume will increase by approximately 25% as measured during September low flow conditions.

DOWNSTREAM WATER QUALITY

Downstream water quality will improve, particularly with respect to decrease sediment loads.

FLOODPLAIN SEDIMENT RETENTION

The increased floodplain connectivity will directly result in flood waters inundating the floodplain more frequently. Noe and Hupp (2009) found that floodplains retain a significant fraction of the annual stream sediment (119%), nitrogen (24%) and phosphorous (59%) loads and larger floodplain areas and longer floodplain inundation retained a greater fraction of the annual loads. The magnitude of sediment deposited within the floodplain was found to be dependent on micro-topographical features and the nature of the vegetation, with densely vegetated areas being particularly effective at trapping sediment (Brunet and Astin 2008). Thus, the restoration of the channel/floodplain relationship attributes will result in an observable increase in sediment volume being deposited and stored on the floodplain. Currently, sediment is deposited on the floodplain only during 10-year recurrence interval floods or larger. Post-project, sediment is expected to be deposited on the floodplain when discharge exceeds approximately 20 cfs.

TERRESTRIAL WILDLIFE COMMUNITY CONDITION

The terrestrial wildlife community condition will increase.

SHREW ABUNDANCE

Improved habitat conditions for shrews will result in increased abundance (Gardner et al 2005). Currently, shrew abundance is about 0.8 individuals per 100 yd^2. Based on Tahoe Basin data, shrew abundance in excellent habitat averages about 1.3 individuals per 100 yd^2, which is the target population post-project. Habitat improvements will rely on vegetation establishment, which may take several years. Some improvement in the shrew abundance should occur rapidly, but the full effects of the project may not be apparent for several years.

SONGBIRD SPECIES RICHNESS

Increased bank and meadow vegetation complexity, and increased floodplain surface water storage, will improve songbird foraging, cover and escape habitat and will correspond to an increase in the number of songbird species utilizing the project area. Pre-project songbird surveys indicated a total of 7 species common to the project reach, and based on observations in undisturbed Tahoe Basin riparian meadows we expect as many as 20 species to utilize the restored riparian area. Songbirds are dependent on well-developed mature vegetation community structure, which will require several years to mature post-project.

BAT ABUNDANCE

An increase in the insect abundance and diversity is expected, providing a greater food source for local bats (Reid 2006). Currently, bat detections average 2.5 bats per detection evening. Data from other Tahoe meadows suggest detection rates in functional ecosystems should be approximately 10 per detection evening. This increase should occur relatively rapidly post-project.

WILLOW FLYCATCHER POPULATION

Increased abundance of riparian shrubs and overall meadow vegetation complexity will improve the habitat condition and the abundance of the willow flycatcher population (Bombay et al 2000). Due to degraded riparian shrub habitat and lack of appropriate willow flycatcher habitat there are few willow flycatchers observed at the project site (Green et al 2003). Following habitat improvement and vegetation establishment, which could take several years, we expect to detect a significant increase in the number breeding pairs as well as an increase in the overall population within the project reach.

AQUATIC WILDLIFE COMMUNITY CONDITION

The aquatic wildlife community condition will increase.

INTOLERANT FISH SPECIES ABUNDANCE

The relative abundance of intolerant fish species, such as sculpin and trout, will increase as a result of the following improvements in habitat (Stead 2007):

- Channel complexity will provide more spawning, rearing and cover habitat
- The presence of relatively deep, cool pools will provide quality refuge
- Bank vegetation will provide shading and reduce surface water temperatures (Matthews and Berg 1997)
- Bank vegetation will promote undercutting of banks and provide quality refuge
- Improved substrate condition will increase spawning success (Furniss et al 2007)
- Increase in abundance and species diversity of macro invertebrates will increase food supply (Karr and Chu 1999, Herbst 2004)

Trout abundance is currently 0.25/sq m, and is expected to increase to 0.75/sq m based on density estimates in similar streams. Trout biomass is expected to increase from 7.5g/sq m to 15g/sq m. Sculpin abundance is expected to increase from 0.5/sq m to 1/sq/m, and biomass from 3g/sq m to 6g/sq m. It is expected that these changes will occur over a period of several years, as habitat develops and populations expand through increased spawning success and survival.

MACROINVERTEBRATE BIOTIC INTEGRITY

The condition of the macroinvertebrate community will improve, with an estimated 25% increase in IBI value, due to improved aquatic habitat conditions, including the following:

- Decreased fine sediment distribution in the substrate (Karr and Chu 1999, SWAMP 2007, Herbst and Silldorff 2009)
- An increase in streambank vegetation cover, providing feeding, cover and resting habitat for adults and maintaining lower maximum water temperatures (Matthews and Berg 1997)
- An increase in vegetation cover will also increase the supply of wood, leaf litter and organic material to the stream (Entrekin et al 2008)
- An increase in channel complexity, resulting in more habitat complexity

IBI should increase substantially one year post-project, as macroinvertebrates tend to respond relatively quickly due to rapid reproduction and colonization by drift from upstream. Subsequent monitoring should be conducted to assure that community condition is maintained following channel-forming flows.

CHAPTER 8: MONITORING STRATEGY DEVELOPMENT

A monitoring strategy describes the basic approach for monitoring project effectiveness with respect to stated project objectives and showing progress toward project goals. The Monitoring Strategy Development describes the process and tools necessary for the project team to identify, select and develop the metrics and protocols that provide quantitative evidence of project effectiveness. The central building blocks of a Monitoring Strategy are the metrics and protocols used to express effectiveness. A metric is the form of quantitative expression for a specific physical, chemical or biological characteristic of the ecosystem. Protocols are the specific techniques and methods employed to collect and analyze datasets to obtain the metric of interest. After the Framework process is complete, the Monitoring Strategy should be detailed in a Monitoring Plan that can be used by field personnel to ensure consistent and reliable implementation of the monitoring strategy developed.

MONITORING STRATEGY BENEFITS

The benefits of the Monitoring Strategy include:

- Prioritize project goals and objectives with respect to effectiveness evaluations. The process of developing a Monitoring Strategy will assist project proponents in selecting indicators and protocols that are most feasible, cost-effective, and most likely to provide reliable and informative results.

- Document and evaluate potential metrics and protocols for the prioritized objectives. The final Monitoring Strategy will guide the acquisition of data in the field, and subsequent analysis.

- Guide project teams on how to select metrics and protocols given monitoring, resource, climatic and other constraints.

DEVELOPMENT PROCESS

Monitoring Strategy development takes place in three distinct phases that include documenting options, selecting metrics and protocols, and developing the Monitoring Strategy. In Phase I: Documenting Options, a number of potential metrics and protocols for each of the project objectives are identified, and their relative cost and effectiveness analyzed. In the selection phase, the design team must select metrics and protocols based on the monitoring budget, priority project objectives and associated data needs. In the initial development phase, basic details relating to protocols and metrics are described.

PHASE I: DOCUMENTING OPTIONS

Several specific metrics and associated protocols should be identified and considered for each project objective. The project team should systematically identify the potential metrics and associated protocols for each project goal and objective included in the Project Objective Diagram. For each objective there are likely a number of different potential metrics and protocol pairs that range in cost and precision based on the necessary level of data collection details. The initial list of potential metrics and protocols should not be influenced by objective priorities or potential costs, meaning the team should strive to identify a range of metrics and protocols that would be reasonable to evaluate if the project met the specific objective. This exercise of considering the protocols necessary to evaluate each project objective may result in a refinement and revision of the Project Objectives if some objectives are not clearly measurable or if this exercise results in the consideration that the specific project objective may not be a priority with respect to the overall restoration effectiveness.

The continued iteration of the Framework components is encouraged as the process of restoration design and Framework development continue.

METRIC AND PROTOCOL SELECTION CRITERIA

The selection of the metrics and protocols for consideration will rely on many factors which vary from project to project. A multitude of potential protocols exist to quantify any one specific project objective and likely each project team will have a set of preferred protocols based on experience, familiarity and previous use. The intent of the Framework is not to select the best, or provide an exhaustive listing of all possible protocols for each potential attribute for use in the Lake Tahoe Basin. Nor is the intent of Chapter 8 to provide a recommended collection of protocols to be used to evaluate all projects. Rather, the Framework provides a process by which project proponents could be more effectively determine which protocol, and collection of protocols, would be most effective for use in their project. It is recommended, though not essential, that the monitoring strategy rely upon existing and documented protocols. Some example protocols and references have been provided in Chapter 8. In some instances the protocol deemed appropriate to quantify a specific objective may be a modification of existing protocols, tailored by the project team to test a site specific objective. It is recommended that the final Monitoring Plan, which details the data collection, data management and data analysis protocols, is properly reviewed and accepted by technical reviewers outside the immediate project development team.

The following criteria should be considered when developing and selecting appropriate metrics and protocols:

ABILITY TO REPEAT PRE AND POST PROJECT- An imperative component of any effective monitoring strategy is the quantification of the metric both pre and post project. As protocols and associated metrics are contemplated to test each project objective, the project team should consider the ability and limitations of repeating the protocols in a manner that would yield comparative results and minimize sampling error to the extent possible.

MAGNITUDE OF PROJECT EFFECT- If the anticipated project effect is large the precision of the metric can be relatively low. For example, if 90% of streambanks are currently eroding (pre-project) and the project objective target is to achieve streambank erosion coverage of 10%, a simple visual field survey protocol may be adequate and is a significantly cheaper alternative to a complete bank stability survey. On the other hand, if percent fines in the stream bed are currently (pre-project) 40% and the project objective target is to achieve 30% fines, a technique such as visual surveys of embeddedness protocol is unlikely to provide adequate resolution. In this instance, a more complicated technique such as bulk sediment sampling and sieve size analysis would be necessary.

PRECISION OF THE METRIC - Precision is defined as the repeatability of two independent monitoring efforts to obtain the same value. Error and/or lack of precision can be due to either user error or lack of definitive protocols to determine metric value. In some instances, a less precise and rigorous protocol will satisfy the needs of the team if the magnitude of the project effects is expect to be large. The increased precision of the protocol selected is necessary when the anticipated measurable project effect decreases.

SENSITIVITY TO ENVIRONMENTAL VARIABILITY- What is the influence of natural variability on the signal of the metric and how can this variability best be controlled? For example, depth to shallow groundwater is a selected metric and is expected to decrease by 30% as a result of a restoration action. Depth to shallow groundwater is inherently influenced by seasonal and climatic variability and data collection and data analysis must constrain for these influences to best isolate the signal due to the restoration actions. Monitoring should occur at the same months each year, and data analysis and metric interpretation should consider the type of water year and seasonal precipitation patterns for each year evaluated when calculating % decrease of

shallow groundwater depth. In other words, what are the data collection considerations including locations and timing of data collection that will increase confidence that the changes in the metric over time are due to restoration action benefits and not sampling, climatic or other inherent variability in the metric values?

RESPONSE TIME- Referring to the Attribute Linkage Diagram structure, attribute response to restoration action(s) generally tends to be more rapid in the ecosystem categories at the top of the diagram, and longer at the bottom. Some geomorphic changes to the system are rapid and may be portions of the actual restoration action, such as channel capacity or bank heights. Geomorphic attributes may continue to evolve and likely the most significant adjustments can be measured following flood events. Pool development or undercut bank formation, for example, may take several high flows. Vegetation, habitat and biological community response times are typically longer than geomorphic changes due to the inherent reliance of these ecosystem categories to the geomorphic form. Some aspects of vegetation community structure respond rapidly to restoration actions, while others may take substantially longer. Meadow grasses, sedges and other plants were documented to respond rapidly to the increase in shallow groundwater elevation within the restored Trout Creek reach, while willow recruitment and establishment has progressed more slowly (Western Botanical Resources 2003). Macroinvertebrate community will respond rapidly as soon as their primary physical habitat (substrate condition) improves, but subsequent increases in the sand distribution of the stream bed can reduce biotic integrity as measured by the macroinvertebrate community equally as rapidly.

RELATIVE COST- Cost will have a significant influence on the final selection of metrics to comprise the Monitoring Strategy. Once the list of potential metrics is developed, the team will have to prioritize the metric combinations that are expected to provide the most effective evaluation of the project objectives to adequately inform the adaptive management process.

COST EFFECTIVENESS- Many metrics may be cost effective because multiple metrics may be calculated with the employment of one single protocol. For example, aerial photos can provide information on channel geometry, shrub community distribution, and floodplain inundation (if taken at the correct time). Although aerial photos are expensive, they may be cost effective if several metrics can be derived from them.

ESTABLISHED PROTOCOLS – The use of documented and tested protocols should be a priority wherever possible, this will reduce the level of detailed protocol development work to be done by the project team. References of protocols should be provided. However, in many instances, the best protocol to evaluate a specific project objective may not exist, and yet be relatively simple to create assuming they meet the criteria above. For example, the project objective; “increase aquatic habitat quantity”. There is likely not a published protocol, yet the quantification of the reach water volume on September 1st each year can be standardized and repeatable if the method by which the quantification is conducted is well documented. The project team encourages the future development of cost-effective yet scientifically valid and defensible protocols.

EIP AND STATUS AND TREND MONITORING ALIGNMENT- Additional consideration should be given to including metrics that relate strongly to Lake Tahoe Environmental Improvement Program (EIP) Performance Measures because these metrics are of particular interest to funders of riparian ecosystem restoration projects and they can be used to report progress of the overall EIP. See the *Development Guidelines* section of *Chapter 7: Project Objectives Development* for a list of relevant EIP Performance Measures.

The identification of potential metrics and protocols should be presented in a table format that includes project goal, project objective, possible metrics and associated protocols, relative cost and relative precision. The cost and precision comparisons should be conducted within each specific restoration project goal, thus providing a range of metrics available to evaluate each of the identified project goals.

EXAMPLE: PROTOCOL AND METRIC OPTIONS TABLE
ANGORA SEWER REACH

Table 8.1 provides a hypothetical example of the recommended protocol and metric options table for a subset of the Angora Sewer Line restoration project goals to illustrate the recommended table format. A complete table would include potential metrics and associated information for each restoration goal and objective that would be considered for inclusion in the future restoration project monitoring efforts. The project team should have specific protocols (and associated references if applicable) in mind for each of the metrics suggested. The documentation of the specific protocols are not necessarily required at this screening stage. Relative precision and cost should be used to compare across potential protocols within the same restoration goal and do not have comparative relevance across goals. *Note: content is not necessarily recommended for Angora Sewer Line monitoring and is merely for illustrative purposes of recommended format while providing potential metrics and protocols for listed objectives.*

Project Objective	Potential Metric (units)	Protocol (details)	Relative Precision	Relative Cost
Restoration Goal: Improve channel/floodplain relationship				
Increase entrenchment ratio	Entrenchment ratio	Topographic Surveys	High	$$
	Entrenchment ratio	Geomorphic field survey (Field tape survey)	Mod	$
Decrease channel capacity	Cross-sectional area (ft^2)	Topographic Surveys	High	$$
	Estimated cross-sectional area (ft^2)	Geomorphic field survey (Field tape survey)	Low	$
Decrease bank heights	Bank height (ft)	Topographic Surveys	High	$$
	Estimated bank height (ft)	Geomorphic field survey (Field tape survey, stadia rod, GPS)	Mod	$
Increase floodplain inundation frequency	Inundation frequency and duration (# of days/yr)	Floodplain inundation monitoring (Continuous stage, continuous discharge, topographic cross section survey)	High	$$$
	Inundation area (ft^2)	Floodplain inundation monitoring (Continuous stage, continuous discharge, topographic cross section survey)	Mod	$$$
	Out of bank observed (y/n)	Floodplain visual survey (during storm events)	Low	$
Increase floodplain soil moisture	Relative soil moisture (1-5)	Floodplain visual survey (visual field survey, transects)	Low	$
	Soil moisture (%)	Floodplain visual surveys (GPS, moisture probe in transects)	Mod	$$
	Soil moisture (%)	Floodplain visual surveys (GPS, soil sample to submit in transects)	High	$$$

Project Objective	Potential Metric (units)	Protocol (details)	Relative Precision	Relative Cost
Restoration Goal: Improve terrestrial wildlife community condition				
Increase shrew abundance	Shrew abundance (# of individuals per unit area)	Biological Surveys (Trap, mark and repeat 2 consecutive days)	High	$$
Increase songbird species richness	Songbird species richness (# of species)	Biological surveys (Visual/acoustic survey by bird biologist)	Mod	$
Increase bat abundance	Bat presence and density	Biological surveys (Visual/acoustic survey by biologist)	Mod	$
Increase willow flycatcher population	Willow flycatcher population (# of individuals)	Biological surveys (Mist net surveys; trap, band, and recapture conducted 3 times per year, 4+ years)	High	$$$

PHASE II: SELECTING METRICS AND PROTOCOLS

The project team will need to collaborate and screen the potential metric and protocol list to prioritize the priority objectives, select the adequate metrics and determine the most effective Monitoring Strategy to meet the project needs within the monitoring resources available. The selection of the final metric list will be difficult, but inherently not everything can be monitored. Some key considerations for the selection of individual metrics are in the *Metric and Protocol Selection Criteria* section above. The project team should focus on cost, signal to noise, precision and response time criteria when selecting the combination of metrics and protocols. In addition the team should consider the collective ability of the final metric combination to evaluate the riparian ecosystem improvements as a whole, including all ecosystem categories.

In some instances, resources or time may not be available to allow adequate evaluations of the ecosystem categories that are expected to have longer response times (e.g. biological community metrics) or may require evaluations annually over many years to smooth natural variability in the datasets (e.g. water quality metrics). The project team should discuss these limitations and attempt to find workable solutions that are possible within resource constraints. If the limitations are insurmountable, they should be documented in the Monitoring Strategy.

ATTRIBUTE LINKAGE DIAGRAMS AND METRIC CHARACTERISTICS

As noted in previous chapters, the Attribute Linkage Diagrams are laid out with cause and effect relationships running from the top of the diagram (geomorphic and physical attributes) down through vegetation community attributes, habitat attributes, and biological community attributes. Several general characteristics of metrics for specific attributes also display trends along this gradient, including monitoring costs, expected response time and susceptibility to environmental noise. Thus the Attribute Linkage Diagram structure can be useful tool when selecting metrics and protocols. Expanding upon the *Metric and Protocol Selection Criteria* section, below are examples and additional considerations for the project team to consider as they select the final metrics and protocols.

Monitoring cost for most metrics tends to be less expensive at the top of the attribute linkage diagram (physical/ geomorphic), and more expensive at the bottom (biological community monitoring). This relative cost difference is

primarily due to the high natural variability of biological communities and the long anticipated response to restoration actions. These characteristics result in greater temporal and spatial sampling frequency to increase the statistical confidence and constrain natural and sampling error from a measured response as a result of the restoration action(s). A number of metrics can be used to evaluate more than one project objective and this overlap can be a cost-effective approach to focus the data that is collected. In the Angora Sewer Line Monitoring Strategy example (below), the metric floodplain inundation frequency (# of days/yr) is a metric that can directly evaluate three project objectives; increase floodplain inundation frequency, increase breeding habitat for amphibians and increase cover and foraging habitat for shrews. Cost-savings can also be actualized by the use of specific field data for a multiple metric calculations. Notice in the Angora Sewer Line Monitoring Strategy example that the topographic survey data and the continuous water stage data are utilized in some capacity to calculate a number of different metrics.

Attribute response generally tends to be more rapid in the ecosystem categories at the top of the Attribute Linkage Diagrams, and longer at the bottom. For example, changes in bird communities may only occur following vegetation responses, which themselves may take several years, while the physical changes in the landscape are rapid. However, there are several exceptions and considerations (examples from the Trout Creek (South Lake Tahoe) restoration project that was constructed in summer 2001 are given as this restoration project has received intensive and long-term monitoring):

- Macroinvertebrate community response is generally rapid, as their primary physical habitat (substrate) is usually in place immediately following implementation. In the Trout Creek project, substantial changes to the macroinvertebrate community were documented one-year following the project (Herbst 2004).
- Some aspects of vegetation community structure respond rapidly to restoration actions, while others may take substantially longer. In the Trout Creek project, meadow grasses, sedges and other plants were documented to respond rapidly (1 yrs) to the increase in shallow groundwater elevation, while willow recruitment and establishment was expected to require more time to establish (Western Botanical Resources 2003).
- Constructed projects are likely to adjust following floods, and those designed with geomorphic function are likely to continually evolve, with responses highest following significant flows. In Trout Creek, streambank stability was highest one year following construction, but has likely decreased in a few locations following several flood events (Matt Kiesse pers. obs.). Long-term monitoring of even rapidly responding metrics is necessary to catch these trends.
- Biotic integrity was high following construction, but has been reduced by an influx of sand from upstream in samples taken eight years following construction (Herbst 2009).

- One year pre-project and two years of post-project water quality monitoring using continuous turbidity probes yielded inconclusive results that were likely due in part to the inability of the monitoring duration to properly constrain the natural variability of hydrologic and water quality parameters and teh inherent complexity in measuring a distinct annual pollutant load reduction signal (Smolen et al 2002, Smolen 2004).

Another important consideration in selecting metrics is their susceptibility to environmental noise. This characteristic shows a general trend in relationship to ecosystem attribute categories in the diagrams, with higher susceptibility to noise in metrics for ecosystem attributes at the bottom of the diagram. Environmental noise is especially a problem with biological populations, where year-to-year climatic variability may have significant impacts on the plant or animal community of interest. Drought, for example, may significantly affect plant community conditions. This problem is especially pronounced in migratory animals, whose population structure in Lake Tahoe may be altered by climatic conditions in areas far away. The effect of environmental noise may be mitigated in biological studies, to some extent, through the use of a control site to evaluate regional climatic influence. For some highly mobile wildlife population, such as fish, mammals or birds, sampling error is significantly influenced by the coincidence of observations and wildlife presence.

Environmental noise may also be important in many physical and chemical metrics, especially detailed, precise measurements associated with discharge or water quality. For the Trout Creek project, suspended sediment entering and leaving the project area was measured for one year pre- and two years post-project. The results suggested that sediment load in the project area may have increased somewhat the year following construction, and remained comparable the following year, but these results are inferred as environmental noise was far larger than any project effects (Smolen 2004). These data suggest that several years of pre-and post-project data may be required to conclusively demonstrate project effects or the lack thereof when monitoring water quality. Environmental noise can be high in more simplistic metrics such as groundwater elevation; sophisticated analysis was required to analyze three years of data for Trout Creek, even though project effects were relatively large (Tague 2008).

PHASE III: DEVELOPING THE MONITORING STRATEGY

Developing the monitoring strategy involves refinement of the metrics, description and reference specific protocol to be used, general sampling temporal frequency and spatial distribution, and descriptions of some of the general considerations involved in monitoring effectiveness of the project. The Monitoring Strategy products describe the final combination of goals, objectives, metrics and protocols that have been selected. The Monitoring Strategy products include:

- A table summarizing the selected goals, objectives, metrics, protocols and expected years of sampling.
- A narrative stating monitoring budget, monitoring duration and party responsible for ensuring implementation.

The table is a concise summary of the metrics used to evaluate each priority project objective that collectively will provide a reliable restoration effectiveness evaluation. The narrative should include introductory discussion of available resources, duration of monitoring and milestones for evaluations of data and any additional information necessary to justify the rational for the strategy selected. The narrative includes a statement of each selected metric, protocol and associated references, general spatial and temporal frequency of sampling and the post restoration years when the results of the specific metric are recommended to be evaluated. Additional details should be provided for each protocol to be implemented to ensure clear communication of general monitoring techniques (i.e. protocol), spatial resolution of monitoring, timing and frequency and specifically which metrics (and reporting units) will be calculated from the data obtained from each protocol. The protocols are presented in the Monitoring Strategy Narrative by general discipline such that trained field personnel in such discipline are likely capable (surveyors, geomorphologists, botanists, biologists, etc) of completing all surveys and/or detailed monitoring necessary to derive the associated metrics. References of the specific protocol to be used should be included in the narrative. Notes can provide additional details as necessary to ensure the general monitoring strategy is well communicated.

The Monitoring Strategy provides enough information to clearly communicate the approach, but does not contain the high level details necessary for the field personnel to implement the monitoring. These details will be subsequently documented in a detailed Monitoring Plan.

EXAMPLE: MONITORING STRATEGY TABLE
ANGORA SEWER REACH

A hypothetical example of a Monitoring Strategy is provided in **Table 8.2** for the Angora Sewer Reach restoration project. *Please note that the content is for illustrative purposes only and merely provides a clear example of the recommended content and format and not necessarily recommended for Angora Sewer Reach effectiveness evaluations.*

Project Objective	Metric (units)	Protocol	Pre-project	Post-project
Restoration Goal: Increase channel stability				
Reduce channel slope	Slope (unitless)	Topographic surveys	1x	3x; 3 events
Increase channel length	Channel length (ft)	Geomorphic field survey (Field tape survey)	1x	1x; 1 yr
Reduce knickpoint presence	# of knickpoints/ 1000 linear ft	Geomorphic field survey (Visual survey and GPS)	1x	3x; 3 events
Restoration Goal: Improve channel/floodplain relationship				
Increase entrenchment ratio	Entrenchment ratio (unitless)	Topographic surveys	1x	3x; 3 events
Reduce channel capacity	Cross-sectional area (ft^2)	Topographic surveys	1x	3x; 3 events
Decrease bank heights	Bank height (ft)	Topographic surveys	1x	3x; 3 events
Increase floodplain inundation frequency	Inundation frequency (# of days/yr)	Floodplain inundation monitoring (Continuous stage, continuous discharge, topographic cross section survey)	1 yr	continuous; 5 yrs
Restoration Goal: Improve floodplain vegetation community condition				
Increase floodplain shrub density	Shrub density (# of shrubs/100 yd^2)	Geomorphic field survey (Visual and GPS)	1x	3x; 5 yrs
Increase floodplain wet plant vigor	Average wet plant height (ft)	Floodplain visual surveys (GPS and vegetation transects)	1x	3x; 5 yrs
Restoration Goal: Improve streambank vegetation community condition				
Increase streambank shrub density	Shrub density (# of shrubs/100 yd of stream bank)	Geomorphic field survey (Visual and GPS)	1x	3x; 5 yrs
Restoration Goal: Improve terrestrial habitat quality				
Increase breeding habitat for amphibians	Inundation frequency (# of days/yr)	Floodplain inundation monitoring (Continuous stage, continuous discharge, topographic cross section survey)	1 yr	continuous; 5 yrs
	Standing water distribution (%)	Floodplain visual surveys (GPS and stadia rod)	1yr	3x; 5 yrs

Project Objective	Metric (units)	Protocol	Pre-project	Post-project
Increase cover and forage habitat for shrews	Inundation frequency (# of days/yr)	Floodplain inundation monitoring (Continuous stage, continuous discharge, topographic cross section survey)	1 yr	continuous; 5 yrs
	Standing water distribution (%)	Floodplain visual surveys (GPS and stadia rod)	1yr	3x; 5 yrs
	Shrub density (# of shrubs/ 100 yd of stream bank)	Floodplain visual surveys (GPS)	1x	3x; 5 yrs
Restoration Goal: Improve aquatic habitat quality				
Increase undercut bank presence	# of undercut banks per stream bank	Geomorphic field survey (Visual survey, stadia rod and GPS)	1x	3x; 5 yrs
Increase pool occurrence	Pool occurrence (average # of pools/ 1000 ft of channel)	Geomorphic field survey (Visual survey, stadia rod and GPS)	1x	3x; 5 yrs
Increase aquatic habitat quantity	Aquatic habitat volume (cf)	Channel length and average wetted area in September	1x	3x; 5 yrs
Restoration Goal: Improve downstream water quality				
Increase sediment retention on floodplain	Annual sediment load retention (kg/yr)	Floodplain sediment sampling and floodplain inundation frequency and duration monitoring	1 yr	8 yrs
Restoration Goal: Improve terrestrial wildlife community condition				
Increase shrew abundance	# of individual/100 yd^2 (# of species)	Pit fall traps, mark and repeat 2 consecutive days	6x; 2yr	24x; 8 yrs
Increase songbird species richness	Species richness (# of species)	Visual/acoustic survey by bird biologist	6x; 2yr	24x; 8 yrs
Increase bat abundance	Bat presence (# of individuals)	Visual surveys by biologist	6x; 2yr	24x; 8 yrs
Restoration Goal: Improve aquatic wildlife community condition				
Increase abundance of trout	Trout abundance (# of individuals)	Snorkel surveys	6x; 2yr	24x; 8 yrs

EXAMPLE: MONITORING STRATEGY NARRATIVE
ANGORA SEWER REACH

Angora Sewer Reach: South Lake Tahoe
Date prepared: February 1999 *(pre-restoration implementation)*
Prepared by: 2NDNATURE

AVAILABLE RESOURCES AND MILESTONES

State Parks has approximately $50,000 to complete a detailed monitoring plan, implement data collection, manage data and produce the Year 1 post project effectiveness evaluation report. State Parks will retain a consultant to develop and implement the data necessary to complete the Year 1 report, thereby establishing detailed and repeatable data collection and data management protocols. Two additional Effectiveness Evaluation Reports will be completed following Year 3 and Year 8. State Parks personnel will conduct the majority of annual effectiveness evaluation data collections from Year 2 - Year 8 to reduce consultant costs. State Parks estimates an annual cost in consultant fees and equipment maintenance to be $10,000 and has secured the necessary $150,000 to implement this monitoring strategy annually for 8 years post project.

PROTOCOLS SELECTED

Given available resources, direct evaluation of each project objective to determine project effectiveness is not feasible. The design team has prioritized the project objectives below that will be directly evaluated using specific metrics to determine restoration effectiveness. The metrics and protocols have been selected to collectively evaluate a collection of the project objectives based on the prioritization of the goals and objectives by the team. The majority of monitoring resources will be allocated to geomorphic form monitoring during the initial 3-5 years post project to validate that the geomorphic improvements met objectives. The other largest monitoring expenditure is willow-flycatcher population monitoring to both evaluate this project objective as well as inform a greater scientific hypothesis that riparian ecosystem restoration is having a measurable benefit to willow flycatcher populations in the Lake Tahoe Basin.

Topographic Surveys

The topographic surveys are focused upon the establishment and repeated survey of channel cross-sections using accurate topographic survey methods as outlined in PACFISH/INFISH effectiveness monitoring program (PIBO) stream monitoring protocols (Heitke et al 2008).

Location of evaluation: 8 well-distributed cross sections extending entire reach.
Pre-project evaluation frequency: 1 time
Post-project evaluation frequency: annually (yr 1 - yr 8)
Time of year monitored: June
Notes: GPS locations of all cross section endpoint monuments and thalweg locations at a minimum.

Metric: Slope
Reporting unit: unitless
Notes: thalweg elevation at upper and lower cross-section/channel length, per gradient calculations outlined in Roper et al (2002).

Metric: Entrenchment ratio
Reporting unit: unitless
Notes: cross-section data analysis includes stage to channel geometry (Leopold et al 1964, Rosgen 1996, California Wetlands Monitoring Group 2009)

Metric: Cross-sectional area
Reporting unit: ft^2
Notes: average cross-sectional area over the reach (8 cross-sections) will be calculated per protocols outlined in the monitoring plan.

Metric: Bank height
Reporting unit: ft
Notes: average bank heights for each bank (total 16) over reach will be calculated per protocols outlined in the monitoring plan.

Geomorphic Field Survey

The geomorphic field surveys will include visual observations and/or simple rapid field measurements that can be obtained using a stadia rod or survey tape. The precision of these techniques is lower than more rigorous protocols, however the below metrics have been determined to be adequate for the subject restoration project due to the expected signal of geomorphic response to restoration.

Location of evaluation: entire reach as appropriate
Pre-project evaluation frequency: 1 time
Post-project evaluation frequency: annually (yr 1 - yr 8)
Time of year monitored: June
Notes: conducted while on site completing topographic surveys, GPS locations as appropriate.

Metric: Channel length
Reporting unit: ft
Notes: estimate entire reach length using survey tape along the thalweg.

Metric: # of knickpoints
Reporting unit: average # of knickpoints/ 1000 ft of channel
Notes: vertical height of each knick point measured and recorded using stadia rod and GPS locations.

Metric: # of undercut banks
Reporting unit: # of undercut banks per stream bank
Notes: stream bank length is 2*channel length. Width of overhang should be measured using stadia rod and GPS locations. An undercut bank had an angle less than 90 degrees and an undercut depth of greater than 5 cm (Roper et al 2002).

Metric: # of pools
Reporting unit: average # of pools/ 1000 ft of channel
Notes: maximum depth of each pool measured and recorded using stadia rod per the PIBO stream pool residual depth measurement protocols (Heitke et al 2008). Locations will be determined using GPS.

Floodplain Inundation Monitoring

The primary components of this protocol include the installation of stage recorders surveyed and tied to topographic elevations, development of stage-discharge curves, and installation of staff plates to QA/QC stage data. The stage recorders will be set to 15-min intervals and provide a continuous time-series of stream stage over the duration of monitoring. The field data collection protocols are detailed in the Monitoring Plan as developed by the project team.

Location of evaluation: 3 established cross sections representative of entire restored reach
Pre-project evaluation frequency: at least 1yr with event Q > bankfull if possible
Post-project evaluation frequency: continuous with focus during events Q> bankfull (yr 1 - yr 5)
Time of year monitored: continuous/event focused

Metric: Inundation frequency
Reporting unit: # of days/yr
Notes: calculated by # of days out of bank/# of days Q>bankfull using the continuous stage time series to constrain for annual hydrologic variations. Rating curve developed to compare event duration out of bank with peak stage/discharge. All calculations will be conducted per the protocols developed by the project team and contained in the Monitoring Plan.

Metric: Aquatic habitat volume
Reporting unit: ft^3
Notes: calculate September average water depth (continuous stage) * topographic cross-section surveys to estimate average cross-sectional area of channel with water in September * reach channel length (ft) = estimated aquatic habitat volume over entire reach. All calculations will be conducted per the protocols developed by the project team and contained in the Monitoring Plan.

Metric: Floodplain sediment retention estimates
Reporting unit: kg/yr
Notes: floodplain sediment sampling protocols developed by 2NDNATURE (http://www.fs.fed.us/psw/partnerships/tahoescience/stream_sediment.shtml), including passive sediment samplers placed along surveyed cross-sections in floodplain and samples submitted to laboratory for analysis. Elevation and locations tied to stage records. Analytical results are extrapolated based on 3-D terrain model and hydrologic records to estimate annual loads by water year type. All calculations will be conducted per the protocols developed by the project team and contained in the Monitoring Plan.

Streambank and Floodplain Visual Surveys

Location of evaluation: walk perimeter of floodplain and channel and conduct appropriate observations to obtain below metrics
Pre-project evaluation frequency: 1x
Post-project evaluation frequency: 3x between yr 1 - yr 5
Time of year monitored: varies by metric

Metric: Shrub density (floodplain and stream bank)
Reporting unit: average # of shrubs/100 yd^2 of floodplain or # of shrubs/100 yd of stream bank
Time of year monitored: August
Notes: Shrubs must exceed 2 ft in height to be counted.

Metric: Average wet plant height
Reporting unit: ft
Time of year monitored: August
Notes: using 1 x 1 square, complete 20-30 observations in randomly distributed locations that represent overall floodplain surface expected to have increased wet plant vigor as a result of restoration. Measure plant height using stadia rod placed vertically from base of plant. GPS location of observations and repeat observations in same locations over course of monitoring. Performed later in the year than other vegetation survey observations, such as September, should resources allow.

Metric: Standing water distribution
Reporting unit: % cover
Time of year monitored: 14 days post snow melt peak
Notes: GPS locations and extent of ponded water on floodplain, measure maximum depth using stadia rod. Data analysis will consider spring peak discharge and floodplain inundation frequency and duration for each year evaluated to constrain results based on climatic conditions for each water year. All calculations will be conducted per the protocols developed by the project team and contained in the Monitoring Plan.

Biological Surveys

Location of evaluation: point locations representative of restored stream and floodplain extent
Pre-project evaluation frequency: 6x over 2 yrs
Post-project evaluation frequency: 24x between yr 1 - yr 8,
Time of year monitored: varies by metric
Notes: Biological response not evaluated until 3+ years post restoration. Three evaluations should be conducted per year of selected observations during similar season to inform the precision of biological community metrics.

Metric: Shrew abundance
Reporting unit: # of individuals/100 yd^2
Time of year monitored: to be determined by biologist
Notes: 3 transects are established within the project area and 100yd^2 sample areas are equipped with pit fall traps to capture resident shrews at night (Rudran and Foster 1996). Observations repeated for two consecutive nights. Each individual captured marked and released following guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists (1998). The number of individuals per 100yd^2 sampling area is recorded. Locations of research plots are mapped using GPS and used to repeat location over monitoring duration (8yrs).

Metric: Songbird species richness
Reporting unit: # of species
Time of year monitored: to be determined by biologist
Notes: Species composition of birds is assessed using point counts surveys following well accepted protocols adapted from the US Forest Service (Ralph et al 1993). A minimum of 6 survey points are located within the project area. Species are recorded by either visual or acoustic confirmation. Observations begin at 0700 hours. Survey dates and locations of survey points are standardized by biologist to instruct bird enthusiasts on proper field survey and data collection protocols. The number of species during each survey will be tracked over the monitoring duration (8 yrs).

Metric: Bat abundance
Reporting unit: # of individuals per survey evening
Time of year monitored: to be determined by biologist
Notes: Daytime observations will be conducted to look for bat roosting sites as while following protocols outlined by the American Society of Mammalogists (1992). Dusk surveys will be also be conducted using point count surveys. Season and locations of evening observations will be standardized by biologist following guidelines provided by Barclay and Bell (1988). Surveys will provide qualitative estimates of bat presence and abundance over monitoring duration (8yrs).

Metric: Trout abundance
Reporting unit: # of individuals
Time of year monitored: to be determined by biologist
Notes: Snorkel surveys conducted by trained fish biologist as adapted from the US Forest Service's protocols on underwater surveys for trout (Thurow 1994). Time of day, season and locations of observations will be standardized by biologist to provide qualitative estimates of trout presence and relative density over monitoring duration (8yrs).

MONITORING PLAN OUTLINE

The Monitoring Plan should have all of the necessary operational and method details for the field and office personnel to implement the Monitoring Strategy as intended. The Monitoring Plan should be carried into the field with personnel and referred to by all members of the monitoring team to ensure consistency is being maintained over the course of many years of data collection. A clear and comprehensive Monitoring Plan will preserve the quality of the data obtained and provide consistency if personnel changes occur within the monitoring organizations and provide documentation for future reviews of monitoring results and data interpretations.

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CHAPTER 9: ADAPTIVE MANAGEMENT PROCESS

In the final component of the Riparian Ecosystem Restoration Effectiveness Framework (Framework), project proponents define the process to periodically review synthesized monitoring results and make adaptive management recommendations. The purpose of the adaptive management process is to guide incorporation of monitoring results into future management decisions about the project and communicate findings that may be helpful for future project designs.

The adaptive management process is used to:

- Motivate the development and critical review of effectiveness evaluation reports post-project implementation.
- Facilitate programmatic decision makers in their use of scientific findings to inform and support future management decisions.
- Encourage continued adaptive management of existing restoration projects
- Communicate lessons learned from a specific restoration project to improve future restoration strategies and project designs in this aspect of the Environmental Improvement Program (EIP)

Figure 9.1 summarizes the products of the adaptive management process.

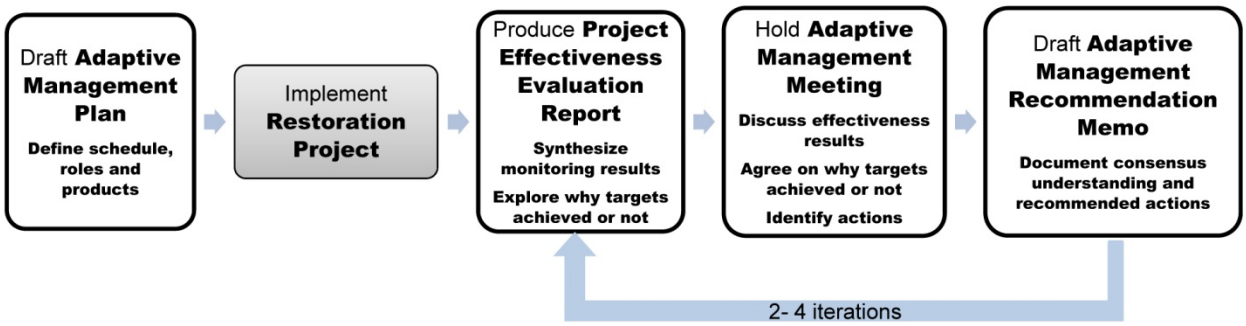

Figure 9.1. The adaptive management process highlighting key components that are outlined in the Adaptive Management Plan.

The Adaptive Management Plan is created prior to implementation of the restoration project and guides the effectiveness evaluation process after the project is constructed. The pre-determined number of Project Effectiveness Evaluation Reports are created after project implementation at defined milestones when new monitoring information becomes available and is analyzed. Each report is reviewed at an Adaptive Management Meeting and the meeting outcomes are summarized in the Adaptive Management Memo.

The project proponent should be responsible for directing the process and maintaining these products during and after the adaptive management period that may stretch as long as 10 years. The final Framework and adaptive management documents should be submitted to www.TIIMS.org for public access.

ADAPTIVE MANAGEMENT PLAN (PLAN)

The Plan defines when effectiveness monitoring and other data from a particular project should be reviewed and who should be involved. The Plan should be brief and used by the project proponent to schedule and implement the adaptive management process. The Plan should be a single reference for the project proponent to organize and guide the adaptive management process. The Plan should include the following information:

- Schedule
- Report content guidelines
- Meeting guidelines
- Memo content guidelines

The Plan should develop an adaptive management schedule for the project which specifies milestones when Reports should be produced and the subsequent Meetings will be scheduled for to review and discuss the restoration effectiveness. These milestones should be selected based on the anticipated response times for key metrics selected to evaluate geomorphic form, vegetation structure and biologic communities are expected to display a measurable response to the restoration actions.

The Plan should also include all relevant guidance regarding Report content, Meeting planning and Memo content. The following sections provide details describing each of these elements. Each of the following sections can be pasted directly into the Plan and edited to align with an individual project's needs. Once complete, the Plan can act as a single point of reference to guide the project proponent through the adaptive management process.

PROJECT EFFECTIVENESS EVALUATION REPORT (REPORT)

A Report will synthesize the results of the monitoring information collected to date. These Reports should be detailed enough that they bring together all available information, but brief enough that they can be reviewed in the time available to the primary audience: agency program managers and decision makers. It is expected that 2-4 Reports will be produced over the 5-10 year adaptive management period. Each successive Report should build on the content of previous Reports to summarize the response of the riparian ecosystem over time.

A recommended Report outline is provided below.

1. **Executive summary -** Synthesize main findings based on monitoring data relative to project objectives available and key recommendations or next steps.

2. **Introduction -** State the milestone for which this report has been produced and this reports respective context in the overall Plan. Provide details regarding who was responsible for the implementation of the Monitoring Strategy and the generation of the Report.

3. **Project Context -** Provide a summary of the implementation schedule and actions that have occurred since design was completed. The Project Objectives Diagram and Narrative and the Monitoring Strategy should be included for simple reference by the reviewers of the report.

4. **Monitoring results -** The results section should systematically and simply review each project goal and supporting objectives. For each objective provide the metric values obtained over time, a review of the performance relative to previously defined targets and a discussion of potential considerations or other factors that may have influenced results. The recommended results section outline includes:
    a. Climatic summary: graphical precipitation, temperature, discharge time summaries for all years of monitoring that provide complete context of both pre- and post-project climatic conditions
    b. Goal 1
        i. Objective 1
            1. Metric 1A
                a. Pre Project Value
                b. Post Project Value
                c. Response interpretation: compare observed value to the target value documented in the Project Objectives Narrative Analysis
                d. Considerations of metric signal: this would include potential climatic variability, hydrologic conditions, sampling error or complications, number of observations or other factors that may have influenced metric values that are beyond just restoration project effects

e. Appropriateness of target: consider the original rationale for selection of the target value and consider justifiable change recommendations
f. Ability of current restoration action to meet specific objective at this time
g. Recommendations for future monitoring of the metric

2. Metric 1B…

ii. Objective 2…

c. Goal 2…

Data graphics can be used to illustrate achievement of targets grouped by project objective or project goal. The findings should focus on how the existing data informs how specific project goals and/or objectives may or may not have been achieved; findings should attempt to explain why a target value for specific metrics may or may not have been achieved. Data results and interpretations should be given careful consideration to causes such as weather conditions, sampling design or restoration design ineffectiveness; findings should be clear and brief; findings should reference supporting data.

5. **Discussion and Conclusions -** Present bulleted findings and recommendations that are not necessarily related to a specific goal but may help with future project designs or management topics of particular interest.

ADAPTIVE MANAGEMENT MEETING (MEETING)

The Meeting is the opportunity to gather relevant stakeholders to revisit and discuss previous riparian ecosystem restoration projects. The Meetings are scheduled and organized by the project proponent. The Meeting is informed by the contents and findings of a recently developed Report, thus facilitating decision makers to use scientific findings to support and inform management decisions.

Recommended Meeting objectives are:

1. Review and understand the Report.
2. Discuss and identify why metrics may or may not have achieved targets.
3. Make decisions regarding additional management actions at the project site.
4. Designate a person to produce the Memo.

We recommend participants include a representative from each of the following: project proponent, funding organization(s), individual(s) who analyzed the monitoring data and drafted the subject Effectiveness Evaluation Report, regulating agencies and major stakeholders such as landowners. Whenever possible, representatives should include some personnel who worked on the project and are familiar with its objectives, as well as personnel who were not involved in the project and can objectively review the information without bias.

A facilitator who does not provide significant content on any discussion topic can assist with achieving the objective of reaching agreement on target attainment and decisions about additional management actions. The facilitator should be unbiased towards particular outcomes and should encourage all stakeholders to share their perspectives at the beginning of any discussion topic. As discussion progresses the facilitator should help participants find common ground and achieve consensus about outcomes. In cases where there is near-consensus, the facilitator should describe the majority opinion as the primary outcome but record minority opinion and then move the group forward to additional discussion topics.

ADAPTIVE MANAGEMENT RECOMMENDATIONS MEMO (MEMO)

The Memo is the documentation of Meeting outcomes and recommendations that documents knowledge gained through the adaptive management process so that it can inform future decisions. The content of the Memo should include the basics of the Meeting and agreed-upon findings resulting from the review of the effectiveness monitoring results. The

Memo should be brief and provide a clear summary of the discussion and any consensus recommendations reached regarding:

- The current state of understanding of the restoration project successes.
- Specific success of the restoration design that may be applicable to future design techniques in other similar and applicable riparian ecosystems.
- The potential components of the restoration or specific locations within the restoration area that may require additional evaluation or consideration because responses may be below expectations.
- Potential recommended changes to the existing monitoring strategy to either eliminate previous metrics or make additions of new metrics. Potential reasons to eliminate a metric may be due to consensus that either: (1) the objective has been clearly achieved, or (2) the metric is unable to evaluate the objective appropriately. Potential reasons to add a new metric include: the need to fill an existing data gap, or (2) better assess achievement of specific goals or objectives.

Responsibility for drafting the Memo should be given to one person who attended the Meeting. In many cases a neutral participant such as the facilitator or note taker is the best person to accept this responsibility. The drafted Memo should be circulated to the participants for review and their comments should be incorporated. After the final Memo is circulated to the participants, it should be appended to the Report and maintained by the project proponent.

CHAPTER 10: FRAMEWORK LESSONS LEARNED AND RECOMMENDATIONS

One of the objectives of this research was to improve the linkage of riparian ecosystem restoration projects and Lake Tahoe Basin planning and regulatory efforts. A few strategies included in the original 2NDNATURE team SNPLMA Round 8 proposal have been much better defined by the Lake Tahoe resource managers since 2007 when this SNPLMA proposal was developed. Clarification of these concepts is provided below. The project team also provides a number of recommendations based on the development and completion of the Framework that may improve the communication and consistency of riparian ecosystem restoration benefits into the future.

LINKAGES OF RIPARIAN ECOSYSTEM RESTORATION TO THE LAKE TAHOE TMDL

One of the current challenges of water quality management in the Tahoe Basin is to develop consistent and standardized linkages between riparian ecosystem restoration efforts and the Lake Tahoe TMDL. In a general context, linkages between the Framework and the TMDL in terms of conceptual sediment source and fate processes are implicit in the current version of the Framework. For example, the Framework includes a conceptual model of the effects of human disturbance on riparian ecosystem processes (Figure 4.1). This model is consistent with the Lake Tahoe TMDL approach to stream channel pollutant inputs (LRWQCB and NDEP 2008, LRWQCB and NDEP 2009a), which assumes human disturbance is likely to increase sediment generation from riparian ecosystems due to channel erosion and incision. While the TMDL research indicates that loading of fine sediment particles (FSP <16µm) is relatively low from stream channels erosion relative to urban and atmospheric sources (LRWQCB and NDEP 2009a), Framework conceptual models hypothesize that effective stream restoration can reduce sediment generation from eroding beds and banks of stream channels. In addition to reducing sediment/nutrient generation from the channel itself, Framework conceptual models hypothesize that geomorphically functional meadow systems may significantly increase total and fine sediment and nutrient removal from upstream sources as a result of increased channel/floodplain connectivity and floodplain deposition.

While the potential benefits of restoring wetland function on sediment generation and sequestration are well-documented (Phillips 1989, NRC 200, Noe and Hupp 2009, California Wetlands Monitoring Workgroup 2009), quantitative validation of these hypotheses has remained elusive in the Tahoe Basin. The most comprehensive study of pre- and post- stream restoration particle flux to date on the Trout Creek restoration (Smolen 2004), failed to measure water quality improvements as a result of restoration. This study had several potential flaws, including short post-project monitoring duration, and it is unclear whether the results are reflective of project performance or monitoring and analysis deficiencies.

Development of the TMDL, in response to enormous concern for water clarity of Lake Tahoe, has led to a quantitative emphasis on managing and protecting fine sediment loading to the Lake (LRWQCB and NDEP 2009a). This creates the need to quantitatively assess potential water quality effects of riparian restoration actions. However, it must be recognized that a quantitative measure of pollutant load reduction may be one of the most difficult attributes to evaluate for riparian restoration projects, due to substantial hydrologic variability, seasonal variability in pollutant generation and transport from upstream sources and the long ecosystem response times of attributes that may increase pollutant retention on the floodplain. In response to this inherent complexity and uncertainty, the project team offers the following recommendations:

1. A tool kit should be developed to estimate and validate the quantitative benefits of riparian restoration projects, aligned with the water quality accounting framework already in place for the TMDL. These tools are best developed through analysis of existing projects with substantial existing data, augmented by additional data collection. This recommendation is further discussed in the following section.

2. It may be necessary to quantitatively document particle flux over long time periods for restoration actions. This intensive water quality research will probably be cost-prohibitive for all riparian restoration projects in the Basin. The alternative to costly and time intensive detailed water quality monitoring of all implemented riparian

restoration projects is detailed pollutant fate and transport research from a small subset of applicable systems. Any detailed water quality and associated load reduction research within Lake Tahoe streams will significantly benefit from the continuous discharge data provided by the existing (and future) USGS stream gage stations. Further recommendations for addressing long-term research needs are discussed in the final section of this chapter.

QUANTITATIVE ALIGNMENT OF RIPARIAN RESTORATION ACTIONS WITH THE TMDL: DEVELOPMENT OF A STREAM LOAD REDUCTION TOOL

The 2007 SNPLMA research proposal suggested that information resulting from this research could be fed into the Lake Tahoe TMDL management system. However, the TMDL was in early stages of development at that time and the appropriate relationship of benefits of riparian restoration to the TMDL was not obvious. Today, it is clear that this linkage to the TMDL management system is via the TMDL Accounting & Tracking Tool developed for the LRWQCB and NDEP to support the Lake Clarity Crediting Program (LRWQCB and NDEP, 2009b). In order to meet this need, a water quality benefit tool (pollutant load reduction estimate) calculation methodology that estimates Lake Clarity Credits for riparian and SEZ restoration projects and is consistent with the format of the TMDL Accounting & Tracking Tool (LRWQCB and NDEP 2009c) is needed. This TMDL-specific tool was not scoped in the original 2007 research proposal and thus not developed. However, the development of a methodology to estimate the pollutant load reductions of specific riparian restoration actions (Stream Load Reduction Tool) is included the 2NDNATURE team's Trout Creek Project scope funded through SNPLMA Round 9 and scheduled to be completed by 2012.

The Stream Load Reduction Tool (SLRT) will provide a consistent and standardized methodology to estimate the average annual load reductions as a result of riparian restoration projects. The methodology will incorporate existing floodplain and terrain modeling such as HEC-RAS, ARC GIS or other widely available fluvial modeling platforms to form the basis of the mass balance approach. User inputs will include a number of hydrologic, geomorphic, physical and vegetation attributes of the riparian reach and contributing catchment in question. Hypotheses of physical dynamics such as particle fractionation, settling rates or adsorption kinetics will be based on best available data and/or existing literature. The SLRT will integrate simple and complex observations of a stream reach to characterize pre and post-restoration pollutant loading, allowing local resource managers to predict the relative water quality benefits (total and fine sediment (FSP < 16μm) load reductions) resulting from stream morphologic modifications and floodplain restoration efforts. The SLRT will enable load reductions from stream restoration to be accounted for in the Lake Tahoe TMDL and potentially the Lake Clarity Crediting Program. The SNPLMA Round 9 scope of work will produce a clear and repeatable methodology to estimate the pollutant load reduction benefits, but the existing resources will not result in an automated stand alone model with a user interface such as the Pollutant Load Reduction Model (PLRM) version 1 (http://www.tiims.org/TIIMS-Sub-Sites/PLRM.aspx).

While the SLRT will provide estimates of load reduction for riparian restoration projects, additional evaluation will be required to document that implemented projects reflect assumptions made in the SLRT. Since the development of the Lake Clarity Crediting Program and supporting urban stormwater tools, the Lake Tahoe community now has a clear vision of rapid assessment tools for this purpose in urban settings; the Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) (2NDNATURE 2009) (http://www.swrcb.ca.gov/rwqcb6/water_issues/programs/tmdl/lake_tahoe/index.shtml) and the Road RAM (to be released Spring 2010). The upcoming development of the SLRT methodology by the project team with SNPLMA Round 9 funding will identify the primary attributes and processes of a riparian system that will be critical to achieving pollutant load reductions as a result of stream restoration actions. These attributes and processes will directly inform the future development of a water quality-focused Stream RAM that could be used to verify the long-term SLRT estimates.

As part of the SNPLMA Round 9 scope, the 2NDNATURE team will provide a set of recommendations for the future development of a RAM for verification of water quality benefits from riparian restoration projects. These recommendations will be derived from the process of developing the SLRT, including the implementation of the SLRT methodology on the restored reach of Trout Creek as a tangible example. We anticipate that the development of a verification RAM in the future will require a detailed knowledge of the functional assumptions and structure of the SLRT. To that end, all data

collection and data analysis protocols used to create the pre- and post-restoration SLRT scenarios for Trout Creek will be documented and provided. Furthermore, the research team will use the Trout Creek evaluation to document recommendations for improving the way pre- and post-project data is collected with respect to populating SLRT scenarios.

A future water quality based stream RAM would verify restoration project performance predicted by the SLRT through evaluation of geomorphic functional processes critical to pollutant load reduction with less intensive data collection requirements than those for the SLRT. For example, the initial SLRT model will likely require detailed stream topographic surveys to define a collection of the required design parameters. However, verification of project function in the future could be based on geomorphic attributes requiring less intensive data collection efforts, such as width to depth ratio, bank heights, bank angle or channel width. Once the SLRT is developed, the potential necessary field observations to rapidly verify the condition of the riparian system in question will become much more apparent. These recommendations of rapid observations, along with the final SLRT methodology, will be documented and will form the basis for a future stream RAM that is comparable to the Urban RAM tools, should such a tool be desired in the future.

DEVELOPMENT OF RIPARIAN ECOSYSTEM ASSESSMENT TOOL

The original research proposal (Appendix A) states that "tools" will be provided to help resource managers track and report the benefits of stream restoration and that these tools could be used to prioritize, select and plan future projects. The Framework is intended to be this "tool." Over the course of the two years since the 2007 research proposal, the Framework has evolved into a complete process that will help managers better identify measurable project objectives for an array of ecosystem attributes, measure progress toward these objectives, and track and report the physical, chemical and biological effectiveness of riparian ecosystem restoration projects. This approach builds on discussions already underway at UTRWAG and, if the Framework is followed, will significantly advance the way stream restoration projects are evaluated and results are communicated.

DEVELOPMENT OF A STREAM RAPID ASSESSMENT TOOL

The research proposal (Appendix A) states that a rapid assessment methodology (RAM) would be developed for Lake Tahoe riparian ecosystems. At the time of 2007 research proposal development, the project team's concept of a rapid assessment method was to assess the function of the riparian ecosystem function as a whole. Through the development of the Framework, the project team, in consultation with TAC members, determined that the more comprehensive Framework tool itself would provide a greater value than a broad riparian ecosystem RAM for the specific objective of project effectiveness evaluation.

To evaluate the reasons for this decision, it is important to understand the differences between the Riparian Ecosystem Restoration Framework and a broad riparian ecosystem RAM. The U. S. Environmental Protection Agency (EPA) has defined a structure for the monitoring and assessment of wetland resources. The EPA approach has 3 levels (CWMW 2009):

- Level 1: consists of map-based inventories of wetlands and related habitats, including rivers, streams, and riparian areas, plus related projects that have a direct effect on the distribution and abundance of wetlands and related habitats. Level 1 maps can serve as the basis for landscape and watershed profiles of wetland systems, and as sample frames for surveys of wetland condition based on Level 2 and Level 3 tools.

- Level 2: consists of rapid, field-based assessments of the overall condition or functional capacity of wetlands and/or their likely stressors. Level 2 results can be used to cost-effectively survey the overall condition of wetlands across landscapes, watersheds, and regions.

- Level 3: consists of quantitative measurement of specific wetland functions or stressors. Level 3 results can be used to calibrate and validate results from Level 2 assessments.

The Framework developed under this research is best described as a process for identifying, planning, implementing and evaluating the results of Level 3 (and potentially Level 2) assessments as defined by the EPA. Rapid assessments are strictly Level 2 assessments. It is important to recognize that the Framework and rapid assessments are not merely the same tool with different levels of intensity. They are quite different tools, with different structures and objectives. The Framework is a comprehensive guide and process for developing and communicating effectiveness evaluations for specific restoration efforts. Rapid assessments are a specific, detailed technique for rapidly gathering and evaluating data, with well-defined protocols for data collection and analysis.

Both tools have strengths and weaknesses. The Framework provides guidance and structure to practitioners for project objective and hypothesis development, and formats for communicating project development, assessment, and evaluation. One weakness in the Framework is that it provides little guidance in the specific protocols to be used. The detailed Level 3 data to be obtained by users of the Framework tend to be very discipline-specific and the while Chapter 8 provides some examples, the project team decided it was not valuable to summarize a number of protocols already established in specific disciplines such as fisheries biology, entomology or botany. In Lake Tahoe projects, experts in these disciplines are typically included on restoration design teams and should assist in protocol development appropriate for the specific restoration project. Conversely, the primary strength of rapid assessment tools is lower cost, lower technical training required, the protocols are specific, and the results repeatable and comparable across users. However, these characteristics of RAM tools result in a significant reduction in the quantitative resolution of the data than the Level 3 assessments derived from the Framework, making the ability analyze specific functions and processes of riparian ecosystems very limited.

The Framework tool better meets the research objectives of the SNPLMA Round 8 proposal of improving the assessment of riparian ecosystem restoration project success in Lake Tahoe than an ecological RAM for several reasons. First, the Framework structure is broader and applicable to the entire project planning process. In addition to aiding in project evaluation, application of the Framework will assist project planners in identifying key ecosystem processes and structures that are impaired, developing specific, well-defined project objectives, and developing restoration approaches based on an understanding of underlying physical and biological processes. These functions were incorporated into the Framework based on the lessons learned from the inventory of existing restoration efforts (Chapter 3). For example, the development of robust project objectives was generally limited in existing stream restoration effectiveness evaluations. Broad rapid assessments are not structured to address these issues: for example, the CWMW (2009) indicates that while some parts of the California Rapid Assessment Methodology (CRAM) could be used as general restoration design guidelines, CRAM does not account for site-specific constraints and opportunities or design objectives.

Second, the Framework focuses on standardized reporting of virtually every aspect of restoration project development. Again, this was in response to the lessons learned (Chapter 3) that formats for describing evaluation techniques and results for current Tahoe Basin riparian restoration projects vary so widely that reviewer understanding is hindered. While rapid assessments like CRAM provide some direction for presentation of results, the Framework is very specific in the products created. We believe the standardized format will greatly assist in the dissemination of important evaluation results.

Finally, given the enormous amount of effort directed at riparian ecosystem function in the Tahoe Basin, it seems appropriate that a greater level of detail and effort is warranted in the assessment of stream restoration effectiveness. The detail of Level 3 assessments recommended in the Framework address this need. In fact, the California Wetlands Monitoring Workgroup (CWMW 2009) noted in a recent technical publication regarding the use of the California Rapid Assessment Method (CRAM; http://www.cramwetlands.org/) for individual projects that while CRAM might be part of a project assessment, "*in many cases, CRAM will need to be used in conjunction with Level 1 and 3 methods to support the assessment of wetland condition for decision-making purposes.*" The Level 3 type assessments which are the focus of the Framework thus appear to be justified as an integral part of the evaluation package for most large-scale restoration projects.

In addition to the higher value provided by the Framework in these areas, it is also important to note that rapid assessments have important limitations. Because most if not all rapid assessments are calibrated over a broad geographic region, they may not reflect or recognize the fairly unique conditions of the Tahoe Basin. CRAM, for example, is calibrated

using streams throughout California, many of which are in very highly degraded urban settings uncommon in Lake Tahoe. Stressor-response relationships used to develop and calibrate these models may not be represented in Tahoe. It is unclear that results from the current CRAM modules would be meaningful in Tahoe, or if the assessment would be sensitive to local impairments and the ecosystem response to restoration activities.

Another serious shortcoming of Level 2 type rapid assessments is that they lack the detail to address many important management questions at Lake Tahoe. The CWMW (2009) notes that the following are inappropriate uses of CRAM:

- focused species or threatened or endangered species monitoring
- evaluation of compliance with water quality objectives

As these are important management issues in Lake Tahoe, it is clear that rapid assessment alone will not fulfill the requirements of restoration project evaluation.

For these reasons, the project team believes that the Framework developed has more value than a rapid assessment in light of the current needs of the Tahoe Basin for the specific objective of project effectiveness evaluation. At the September 2009 TAC meeting the TAC members agreed with this conclusion, and suggested that the completion of the Framework tool will achieve the most important goals of this research, to improve the quality and communication of effectiveness evaluations of stream restoration projects.

This is not to suggest there is no place for rapid assessment in the management of Tahoe Basin riparian ecosystems. It is our opinion that rapid assessment is highly suited to evaluation of riparian ecosystem condition and trends at the watershed and Lake Tahoe Basin scales, particularly for identifying impairment. Rapid assessment may also have high value for establishing management goals and objectives at watershed and the Basin scales, and measuring progress or effects of multiple activities over longer temporal scales.

The project team does believe that rapid assessment may have a valuable role within individual restoration project effectiveness evaluations, specifically with respect to geomorphic and/or water quality specific attributes. Chapter 8 guides Framework users to determine if cost-effective and rapid techniques to evaluate specific project objectives are appropriate. CRAM, for example, focuses on confinement and entrenchment ratios to assess relative channel stability. In the context of a project effectiveness evaluation based on Framework guidance, well-constructed rapid assessments could potentially be an important tool in evaluating progress toward, and attainment of, specific project objectives.

Given the current interest in CRAM in the Lake Tahoe Basin, the 2NDNATURE team may choose to allocate Round 9 resources to evaluate its performance to provide an effectiveness evaluation on Trout Creek. Specifically, we propose to use pre-project data, to the extent feasible, in conjunction with current field data, to simulate pre-and post-project CRAM assessments using existing CRAM riverine module. The results of this exercise would then be compared and contrasted with a similar exercise to develop Framework products. A discussion of the strengths and weaknesses of CRAM in project evaluation, relationship of CRAM to the Framework, the potential for CRAM calibration with Lake Tahoe Level 3 applicable data, and recommendations for possible adjustments in metric and attribute definitions or weighting will be included in research reporting. The inclusion of this evaluation into the Round 9 Trout Creek research will be reviewed with our Technical Advisory Committee (TAC) in the coming months.

LONG-TERM RESEARCH RECOMMENDATIONS

The development of the Framework reinforces the need for long-term effectiveness monitoring. Throughout this report the research team identifies the limitation of previous effectiveness evaluations to provide meaningful results due to short monitoring time-frames. This is due to three major factors:

- *Inherently long response times of several ecosystem categories to the physical restoration actions*. Biological populations, especially wildlife and fish, may require several years to respond to physical restoration actions. While

vegetation may respond more rapidly, 5 years or more may be required for measurable responses in many key characteristics (establishment of mature willows, for example).

- *High natural variability in attributes of interest*. Many attributes of interest naturally vary widely in response to dynamic environmental conditions. High year to year variations in sediment yield are documented for Lake Tahoe streams (simon, LTIMP). Biological populations also exhibit enormous seasonal and yearly variability in response to climatic fluctuations and inherent population dynamics.

- *Post-implementation project adjustment*. Given the inherent complexity of geomorphic design and the natural tendency of a fluvial system to reach an energy equilibrium all implemented restoration projects are likely to go through a period of adjustment following completion.

It is clear that the focus of project evaluation must be on multi-year to decadal time-scales to address these factors. Short time-frames, however, were not the only limitation of current project evaluations. We also noted that data collection and analysis efforts were often not intensive enough. Biological community monitoring and species population estimates are costly and require technical expertise and at times species specific handling permits. Robust water quality monitoring strategies to quantify sediment load reductions require continuous discharge and turbidity meters for a wide range of both pre and post project water year types, representative water quality samples to create turbidity to sediment concentration rating curves and advanced data management and analysis expertise.

Effective evaluations of many ecosystem attributes of interest therefore requires both long-term and intensive monitoring. Whether this effort is described as monitoring or research, the level of effort is certainly similar to research. For many attributes, the cost and necessary monitoring duration may be prohibitive for individual riparian restoration projects. Furthermore, single projects are not likely to be capable of evaluating all project objectives or attributes hypothesized to respond to project effects. To address these concerns, we offer the following recommendations, many of which are stated earlier in Framework documents but reiterated here.

1. Evaluation time-frames should be expanded. Currently, most projects in the Tahoe Basin tend to focus on two-year post-project time evaluation windows. The evaluation window should be substantially expanded, to several years if not decadal time-scales. This recommendation creates conflicts with administrative schedules and time-frames for restoration projects that have already been implemented that will need to be resolved. Most funding for project evaluation is based on shorter time periods. Also, project proponents may have disincentives to manage projects over longer time-frames. However, it must be recognized that ecosystem change does not occur on administrative time-scales, and effective evaluation and adaptive management of restoration projects will require longer management time-frames.

2. Monitoring effort should be more efficiently allocated over the life of the effectiveness evaluation. Monitoring efforts can be optimized by focusing effort early in the evaluation period on attributes with short response times, and focusing effort later in the evaluation period on attributes with long response times. For example, geomorphic attributes which respond rapidly should be monitored early in the evaluation period, while songbird populations, with long response times dependent on the establishment of mature vegetation, should only me monitored later in the evaluation period. A substantial amount of time and effort may be conserved by carefully designing observation periods to align with expected attribute response.

3. Sub-sets of attributes should be selected for long-term, intensive effort. Framework guidance includes the development of attribute linkage diagrams to depict hypothesized cause and effect relationships between various attributes of the riparian ecosystem, i.e. project objectives. It will not be possible for every project to monitor the entire universe of ecosystem attributes potentially affected by restoration actions. However, evaluation of a selection of a sub-set of attributes, distributed across several ecosystem categories, will validate conceptual model assumptions for some attributes, substantially contributing to the inference that model assumptions and hypotheses are valid for all attributes.

4. Projects in close proximity should coordinate and collaborate on monitoring efforts. This is the basic assumption of the UTRWAG for the Upper Truckee River. Intensive, long-term monitoring effort can be shared by several individual projects for many ecosystem attributes. Application of the Framework by all projects in a specific geographic area would assist greatly in this goal by allowing for standardized, effective communication of objectives, attributes of interest, and hypothesized effects of restoration actions between projects.

5. Standardized, basin-wide dissemination of monitoring results and coordination of monitoring efforts will improve the effective allocation of monitoring resources. For example, the results of intensive monitoring may be inferred to be applicable for similar restoration actions in similar geomorphic settings. Subsequent projects could thus concentrate effort on other ecosystem attributes of interest. Again, the project team believes that consistent application of Framework guidance will greatly assist in implementation of this recommendation, by allowing for effective communication of project objectives, hypothesized effects of restoration actions, and evaluation of results.

6. The availability of long-term contiguous datasets is severely limited in the environmental field. The USGS surface water stream gauging program is an invaluable tool for watershed science. The basin wide conceptual model (Figure 4.1) indicates that the two main uncontrollable factors influencing fluvial geomorphology are the hydrology and sediment load delivered to the reach of interest. Continuous time series of hydrologic records are an integral and imperative component to inform riparian ecosystem restoration design. The historic time series provides an endless amount of insight to scientists, practitioners and the public on climatic patterns, regional comparisons, water quality modeling inputs, water budgets, urban development impacts, flood hazards, future climatic predictions, etc, etc. As the questions of global climate change impacts on Lake Tahoe aquatic resources are increasingly addressed, the value of historic, present and future meteorological and hydrologic datasets will form the scientific basis by which predicted system responses are theorized.

CHAPTER 11: ATTRIBUTE GLOSSARY

GEOMORPHIC ATTRIBUTE CLASSES

CHANNEL STABILITY

Geomorphically functional natural channels are generally considered to be in dynamic equilibrium between sediment supply and sediment transport over medium time frames (decades) and reach spatial scales. At discrete locations, the channel bed may aggrade (increase in elevation by accumulating sediment) or degrade (decrease in elevation) following individual floods, but the mean elevation over longer time periods remains relatively stable. Thus, over longer timeframes, the sediment flux through a stable stream reach is at steady state (input = output) (Dunne and Leopold 1978). The term dynamic implies that in event or annual time frames, aggradation or degradation can occur in specific locations, but the sediment input and output are balanced on multiple year time scales within a stable channel reach.

This dynamic equilibrium is often impaired in disturbed channels or watersheds. Increased erosion from the watershed, for example, will cause higher sediment supply to the channel, resulting in net aggradation in downstream reaches (Mount 1995). Straightening of the channel itself often increases erosive power, and will result in degradation of the channel bed. Sustained aggradation or degradation in a stream reach are both indicative of a loss of sediment transport equilibrium and the disruption of steady state with respect the sediment balance of the fluvial system. Channel instability can be observed through a time series of longitudinal profiles, or may be expressed as knickpoints or slope breaks in the existing profile (Leopold et al 1964). High rates of bank instability are also indicative of perturbations to dynamic equilibrium.

CHANNEL/FLOODPLAIN RELATIONSHIP

Fluvial ecosystem processes are dependent upon the hydrologic connection between the floodplain and the stream channel. Annual floodplain inundation supplies soil and nutrients to the floodplain (Schumm 1977). Appropriate floodplain connection between the stream and the associated floodplain maintains an elevated adjacent shallow groundwater table that significantly increases vegetation success and vigor (Hauer and Lamerti 1996). The extent, depth and duration of flooding, as well as the depth of floodplain groundwater, are dependent on the channel capacity of the stream channel.

Floodplain connectivity is a description of the functionality of the stream-floodplain relationship. It is important to note that the degree of connectivity varies by channel type and geomorphic setting. In some geomorphic settings, inundation of the floodplain may occur at lower flood recurrence intervals than in others. The highly connected floodplains of undisturbed streams exhibit flooding dynamics typical for the geomorphic setting. Human modifications of stream systems can result in a significant alteration of hydrologic connection between the channel and its associated floodplain (Mount 1995). Incision is a common response in disturbed channels resulting in the hydrologic disconnection of the channel from the floodplain. When the floodplain connectivity is reduced the extent, duration and frequency of flooding all decrease.

GEOMORPHIC FORM ATTRIBUTES

CHANNEL SLOPE

Elevation change divided by length of reach. The slope of a straightened, incised channel will be higher than the same channel that possesses meander patterns (Mount 1995). Protocols to quantify slope include any variety of topographic surveying techniques using a hand level with field mapping and GPS, or total station.

CHANNEL LENGTH

Linear flow path distance of thalweg (the deepest portion of the channel) of subject reach. Straightened channels will have a shorter channel length than a meandering channel within the same valley.

SINUOSITY

The ratio of the channel length between two points on a channel to the straight-line distance between the same two points; a measure of meandering (Leopold et al 1964). Straightened channels will have a lower sinuosity than a meandering channel within the same valley.

SHEAR STRESS

Shear stress is defined as a stress which is applied parallel or tangential to the channel bed or channel banks, as opposed to a normal stress which is applied perpendicularly. Increased shear stress will increase erosion potential of the channel and will increase when slope of the channel increases (Leopold et al 1964).

KNICKPOINT

A distinct point of sudden or abrupt steepening in the longitudinal gradient or slope of a streambed. Prior to asserting that knickpoint stability is an attribute of geomorphic impairment; bed substrate, relative mobility of the knickpoint (potential active headcut) and stream channel slope relative to valley slope must be considered (Leopold et al 1964).

BANK STABILITY

In undisturbed, geomorphically functional stream channels, the proportion of unstable stream banks is generally related to stream type (Rosgen, 1996). In stable low energy stream channels with low rates of bedload transport, the proportion of unstable stream banks is relatively low. In higher gradient streams with high rates of bedload transport, especially coarse bedload, unstable banks are relatively more common. For any particular reach, the geomorphically functional proportion of unstable banks should therefore be estimated based on the expected natural slope and fluvial morphology of the stream channel, and a comparison of the stream setting with other similar undisturbed channels, or other criteria. Some bank erosion is normal in a functional stream as meandering streams continue to erode at the outer bend and deposit material in the point bar (Knighton 1998; Florsheim et al 2008). Human disturbances to the channel or watershed perturbation tend to increase the proportion of unstable banks. Multiple processes interact to exacerbate bank erosion. Channel reach degradation will increase channel capacity and bank height, both of which result in high steep banks that are more susceptible to erosion and collapse. The deterioration of riparian vegetation condition, as a result of increased channel capacity and bank collapse will also exacerbate bank instability (Mount 1995; Hauer and Lamberti 1996; Knighton 1998; Florsheim et al 2008; Simon et al 2009).

ENTRENCHMENT RATIO

The computed index used to describe the vertical containment of a stream channel. Entrenchment ratio = flood prone width /bankfull width where the flood prone width is water depth at 2x bankfull depth (Rosgen 1996; CWMW 2009).

CHANNEL CAPACITY

Channel capacity refers to the cross-sectional capacity of the stream channel in a specific location and/or over a subject stream reach. A low energy stream channel in natural balance with the characteristic hydrologic conditions and sediment load tends to have a capacity on the order of the 1.5-2 yr recurrence interval discharge in lower gradient alluvial channels (Leopold et al, 1964; Williams 1978; Dunne and Leopold 1978), but substantial variations in this average have been noted (Williams 1978). In other channel types the geomorphic functional capacity may vary such as higher gradient step-pools. The functional channel capacity of a particular reach should be determined by analyzing the capacity of similar streams that are undisturbed, or by geomorphic and hydrologic analysis of the stream reach in question. Identification of the appropriate channel capacity or bankfull discharge must include an investigation of the overflow surface in the field where bankfull channel indictors such as changes in bank slope, or active floodplain elevations can be identified. A correlation of these features with the discharge necessary to fill the bankfull channel can be conducted a number of ways (Dunne and Leopold 1978; Williams 1978). Difficulty in recreating the functional capacity of a highly modified channel is inherent and requires reliance on discharge records, historic aerials, analog stream reaches and other sources of information (Mount 1995; Rosgen 1996). Flows exceeding the functional capacity begin to inundate the adjacent flood plain if the channel cross-sectional morphology approximates a natural form, though variability throughout the stream is expected.

BANK HEIGHT

The vertical distance from the channel bed to the top of the channel bank. Bank height will increase as channel capacity increases and channel bed incises.

FLOODPLAIN INUNDATION

The inundation of the adjacent floodplain as a result of a discharge event exceeding the capacity of the channel and resulting in surface water covering normally dry areas with flood waters. Inundation frequency, duration and extent are important components of this attribute. The extent of hydrologic connectivity can be viewed as operating in longitudinal, lateral, and vertical dimensions and over time (Schumm 1977; Ward 1989). Floodplain inundation frequency, duration and extent will all decrease as channel capacity increases and the channel/floodplain relationship declines.

FLOODPLAIN SOIL MOISTURE

Soil moisture is the water content of the soil, ranging from 0-100%, and should be measured from soil collected about 12 inches beneath the surface (Environmental Laboratory 1987). Soil moisture is a key attribute necessary for meadow vegetation conditions, particularly in the spring growing months and will be reduced as attributes of channel/floodplain relationship decline (Hauer and Lamberti 1996).

FLOODPLAIN GROUNDWATER ELEVATION

Floodplain groundwater elevation refers to the elevation of the shallow groundwater table in the land (meadow/floodplain) adjacent to the active stream channel. Shallow groundwater is strongly influenced by the channel capacity and channel complexity characteristics. A functional fluvial morphology in an historic meadow complex will possess a relative high shallow groundwater table adjacent to stream channel, particularly during the

spring growing season (Fetter 1994). The late fall groundwater table is expected to be also be relatively higher adjacent to a geomorphically functional stream. Typical local reach impairments, such as channelization and flood control, disconnect the stream channel hydrologically from the floodplain and result in lower groundwater elevations, lower soil moisture and less frequency of floodplain inundation (Mount 1995). This has negative effect on the floodplain ecosystem, which requires functional hydrologic characteristics to support the desired flora species.

FLOODPLAIN TOPOGRAPHIC COMPLEXITY

Floodplain topographic complexity refers to the topographic variability of the surfaces adjacent to and potentially inundated by, the stream. The floodplain topographic complexity will result in natural variability in over bank flow patterns, sediment deposition distribution and surface water storage on the floodplain. Topographic complexity adds roughness to the flat floodplain surface thereby promoting variability of both physical processes such as sediment deposition and water retention, as well vegetation structure.

VEGETATION STRUCTURE ATTRIBUTE CLASSES

FLOODPLAIN VEGETATION COMMUNITY CONDITION

Floodplain vegetation condition refers to the distribution, diversity, vigor and/or species of flora rooted beyond the channel bank but within the hydrologic influence of the stream channel, within the floodplain. The floodplain vegetation is directly influenced by the stream during overbank flow events when the stream supplies water, sediment and nutrients to the floodplain meadow complex. Meadow vegetation is also strongly influenced by shallow groundwater elevation and other channel/floodplain relationship attributes (Kaufman et al 1997).

STREAMBANK VEGETATION COMMUNITY CONDITION

Streambank vegetation is rooted on the channel bank that directly affects the stream channel. Bank vegetation effects on the channel include shading, root structures providing bank stability and promoting channel complexity and channel stability (Hauer and Lamberti 1996, Simon et al 2009). Simon et al (2006) conducted an analysis of the hydrologic and mechanical effects of existing riparian vegetation on streambank stability on the Upper Truckee River and found that stream bank vegetation, especially Lemmon's willow can significantly increase bank strength, reduce the frequency of bank failures and decrease the generation of fine grained sediment to channel. A well established, diverse and successional bank vegetation community supplies wood, leaf litter and detritus to the aquatic system. There are several characteristics to evaluate of bank vegetation condition, including cover, community structure and complexity, and vigor. In undisturbed systems, these characteristics are influenced by the landscape setting, and will vary substantially both among and within watersheds. In disturbed systems, cover, complexity and vigor all tend to decline.

VEGETATION STRUCTURE ATTRIBUTES

WET PLANT SPECIES ABUNDANCE

Wet plant species include plant species known to require greater amounts of water and soil moisture to survive. The abundance of wet plant species is expressed as the relative percent of wet plant species composition in the floodplain or streambank vegetation community. Wet plants include, but are not limited to; native perennial sedges and grasses, interspersed with a high diversity of native perennial forbs (Kattelmann and Embury 1996).

PLANT VIGOR

The vigor of vegetation, measured as the plant height and % of new growth in June of the existing plant or shrub species, can be reduced when soil moisture and water limitations exist, especially for wet plant species.

SHRUB DENSITY

The relative density of shrub vegetation species, particularly willow, expressed as the # of established individuals per 100 yd reach. Shrubs along a streambank provide bank stability (Simon et al 2006) due to rooting strength and also provide habitat to desired avian species including willow flycatchers (Greene et al 2003).

INVASIVE SPECIES ABUNDANCE

Invasive species are usually, but not necessarily, non-native species to the area in question. Invasive species often have higher tolerance than many natives for reduced soil nutrients and soil moisture content (characteristics of disturbed riparian soils). The abundance of invasive species is expressed as the relative percent of invasive species composition in the floodplain or streambank vegetation community. Invasive species in a Lake Tahoe degraded riparian ecosystem include but are not limited to; higher occurrences of non-native perennial grasses, introduced forbs such as wooly mullen, and native lodgepole pine saplings (D'Antonio et al 2004). Unstable streambanks can simplify the riparian plant community, giving way to invasive species capable of withstanding high rates of disturbance and lower water requirements (Dunaway et al 1994).

STREAMBANK VEGETATION COVER

Vegetation cover is amount of shading the adjacent streambank vegetation provides to the surface of the stream waters. This is measured as the extent of relative cover over a pre-determined streambank length. A well developed streambank vegetation canopy will reduce maximum daily temperatures, provide allochthonous organic material to the stream ecosystem, serve as a source of woody debris to the stream, assist with overhanging bank development, and provide food supply as well as predation protection to aquatic wildlife (USFWS 1992, Entrekin, 2008).

HABITAT ATTRIBUTE CLASSES

TERRESTRIAL HABITAT QUALITY

Terrestrial habitat quality encompasses a wide range of specific physical, chemical and biological conditions that directly affect habitat for fauna in the riparian ecosystem. The specific habitat needs vary for different terrestrial wildlife species and specific life stage requirements. These physical, chemical, biological habitat relationships are exceedingly complex and cannot be simply depicted in a diagram. However, qualitative statements about terrestrial habitat quality are often possible, especially in a relative sense (before-after a disturbance, for example). Habitat quality attributes are best expressed as either specific measureable characteristics of the streambank/floodplain system (i.e. shrub abundance) or as a statement of the life stage habitat requirements for target species that is either desirable or undesirable within the subject terrestrial ecosystem (i.e. willow flycatcher nesting habitat).

AQUATIC HABITAT QUALITY

Aquatic habitat quality encompasses a wide range of specific physical, chemical and biological conditions that directly affect habitat for fauna in the riparian ecosystem. The specific habitat needs vary for different aquatic wildlife species and specific life stage requirements. Many specific aquatic attributes can be integrated to express aquatic habitat

quality including: pool depth/abundance; percent fines in substrate; variability of width or depth; riparian vegetation cover; woody debris in channel; water temperature; width-depth ratio, etc.. The deposition of fines amidst interstitial streambed gravels can pose hazards to fish and communities of benthic macro-invertebrates by disrupting habitats, degrading spawning habitat and reducing the flow of oxygen through gravel beds.

DOWNSTREAM WATER QUALITY

Streams subjected to reach and/or watershed impairments typically have relatively increased sediment loads introduced to and contained within the fluvial system (Dunne and Leopold 1978, Mount 1995). Disturbed channels will have a higher proportion of the source of total and fine sediment loads generated from streambank erosion (Simon et al 2006). Watershed impairments can result from landslides, irresponsible grazing, roads and ski trails, etc., and these can result in increased sediment delivery to a stream.

Downstream water quality refers to the expected total and fine sediment load downstream of the subject stream reach. It is assumed that the implementation of restoration actions will result in a quantifiable improvement in downstream total and fine sediment loads as the combined result of reducing the streambank source of sediment and increasing the floodplain depositional sink of sediment loads delivered from upstream sources. The actual measure of the average annual sediment load reduction as a result of stream restoration efforts is costly and will require long-term observations to appropriately constrain hydrologic and climatic variability.

HABITAT ATTRIBUTES

COVER AND FORAGE HABITAT FOR SHREWS

Shrews are small mammals, common in healthy riparian ecosystems in the Sierra Nevada. Shrews require moist soil conditions and riparian shrubs to hide from predators and forage for food. While shrews are not sensitive or threatened species the presence of these mammals within a floodplain would indicate a functional channel/floodplain relationship (Jameson and Peeters 2004).

WILLOW FLYCATCHER NESTING HABITAT

Nesting willow flycatchers require standing water in the meadow during the spring nesting season and a well developed riparian shrub community (Green et al 2003).

AMPHIBIAN BREEDING HABITAT

Breeding amphibian species require soil moisture and standing water on the floodplain and a hydrologic connection between the stream and meadow (Manley and Lind 2005).

FLOODPLAIN (SEZ) AREA

Mesic meadows are characterized by lower soil moisture, a decreased channel/floodplain relationship and higher occurrences of non-native perennial grasses, introduced forbs such as wooly mullen, and native lodgepole pine saplings (D'Antonio et al 2004). Wet meadows are characterized by higher soil moisture, frequent floodplain inundation, and higher occurrences of native perennial sedges and grasses, interspersed with a high diversity of native perennial forbs (Kattelmann and Embury 1996). Wet meadow characteristics are similar to stream environment zones (SEZ). An SEZ is defined as land hydrologically influenced by the stream and is identified by the presence of key indicators such as the evidence of surface water flow, riparian vegetation, near-surface ground water, designated floodplain, and alluvial soils (Cobourn 2007). The Tahoe Regional Planning Agency (TRPA) has set restoration targets to increase the acreage of

naturally functioning SEZs in the Tahoe Basin (EIP 2008). Often, the transition to upland communities is gradual and difficult to pinpoint precisely, and may change over longer time frames due to climatic variation. However, in disturbed streams the area of riparian habitat quantity is often significantly reduced due to hydrologic disconnection of the stream from the floodplain and the resulting transformation of riparian vegetation to upland vegetation communities.

SUBSTRATE CONDITION

Substrate condition refers to the sediment grain size distribution of the stream bed. Geology of the contributing watershed strongly influences the nature of the sediment supplied to the channel, and specific substrate characteristics therefore vary from watershed to watershed. Good substrate condition would apply to an undisturbed watershed and stream, where sediment size and distribution on the streambed is representative of the geomorphic setting.

Substrate condition is often highly altered in disturbed channels with excessive bank and bed erosion. A substantial increase in the proportion of fine sediment in the streambed is typical in channels with high erosion and/or increased fine sediment source supply from the contributing watershed. Embeddedness is one technique to measure the degree to which gravel and cobble substrate are surrounded by fine sediment (SWAMP 2007). An increase of fines or embeddedness directly reduces the suitability of the stream substrate as habitat for macroinvertebrates, fish spawning and fish egg incubation.

UNDERCUT BANKS

Streams with appropriate channel geometry and a well established streambank vegetation community, with large rooting structures, will result in water surface elevation during common annual discharge conditions to erode material from the intermediate stream bank. The result is overhanging banks which provide physical complexity to the channel, provide shade and predation protection for aquatic species. The loss of streambank vegetation reduces the cohesiveness of bank material and its resistance to scour, which leads to elimination of undercut banks (Mount 1995).

CHANNEL CROSS SECTION COMPLEXITY

Channel cross section complexity is the variability in physical morphologic characteristics within the stream channel itself, including width, depth, velocity and substrate. It includes both longitudinal and cross-sectional variability. Longitudinal complexity includes meanders, pool/riffle sequences and planform irregularity. Cross-sectional variability includes asymmetric depth, velocity and substrate conditions. The distribution of energy within a balanced stream reach will include variability in flow patterns, depth and substrate sorting within the channel cross-section (Leopold et al 1964). A simplified channel tends to have a reduced frequency of pools, a straightened planform and significant reductions in variability of both width and depth (Mount 1995). Geomorphically-functional channels tend to have higher hydrologic flow pattern variability and thus more physically complex than disturbed channels.

POOL OCCURRENCE

A stream pool is stretch of a river or creek in which the water depth is above average and the stream velocity is quite low. Pool frequency can be important for juvenile fish habitat, especially where many stream reaches attain high summer temperatures and very low flow dry season characteristics.

SURFACE WATER TEMPERATURE

The temperature of the water in the stream, measured in ^{o}F. Elevated surface water temperatures in a stream can have deleterious effects on sensitive aquatic species.

AQUATIC HABITAT QUANTITY

Aquatic habitat quantity is the total volume of the active channel during baseflow conditions. Direct channel disturbance in the Lake Tahoe area has often included channel straightening, resulting a shorter stream and a reduction in habitat area.

SEDIMENT INPUT FROM CHANNEL AND BANK EROSION

An oversized, straight, and eroding channel results in a significant contribution of sediment downstream from channel and bank erosion. Restoration actions that improve the balance between the geomorphic form and the contributing hydrology and sediment load will significantly reduce the sediment input from the channel bed and banks (Simon et al 2006, Simon et al 2009).

FLOODPLAIN SEDIMENT RETENTION

Floodplain connectivity results in flows exceeding bankfull discharge to inundate the adjacent floodplain. Sediment retention on the floodplain is the result of sediment deposition during overbank flows. Sediment deposited on the floodplain settles into the floodplain which serves a sediment and nutrient sink and reduces the total and fine sediment loads transported downstream (Noe and Hupp, 2009).

BIOLOGICAL COMMUNITIES ATTRIBUTE CLASSES

TERRESTRIAL WILDLIFE COMMUNITY CONDITION

The terrestrial wildlife community consists of all animals found in the riparian ecosystem, including terrestrial insects, reptiles, amphibians, birds and mammals. Certain species may be more susceptible to perturbations of the riparian ecosystem and would be ideal candidates for evaluating biological condition and/or restoration success.

AQUATIC WILDLIFE COMMUNITY CONDITION

The aquatic wildlife community condition includes any aquatic species and/or trophic levels of concern that can be used to describe the health of the aquatic wildlife community. Riparian ecosystem disturbance and poor substrate conditions can alter aquatic habitat structure by decreasing channel depth, changing substrate composition and burying woody debris and these changes have been documented to change aquatic community assemblage (Howson et al 2009).

BIOLOGICAL ATTRIBUTES

SHREW ABUNDANCE

Shrews are small mammals, common in healthy riparian ecosystems in the Sierra Nevada. Shrews require moist soil conditions and riparian shrubs to hide from predators and forage for food. While shrews are not sensitive or threatened species the presence of these mammals within a restored floodplain with a functional channel/floodplain relationship would indicate wet meadow/floodplain habitat improvements (Jameson and Peeters 2004). Shrew abundance is measured as the total number of individuals estimated per 100 yd^2 study reach.

SONGBIRD SPECIES RICHNESS

The species richness of songbirds within the subject riparian ecosystem area is expected to be higher in floodplain (SEZ) areas with greater distribution of shrubs, such as willows. Species richness is measured as the total number of songbird species recorded in the study area.

FLYING INSECT SPECIES DIVERSITY

Flying insects are abundant in functional riparian ecosystems and the diversity of flying insect species is expected to be higher in functional low energy riparian ecosystmes. The Simpson Index of Diversity will be used as a metric to evaluate flying insect species diversity. Value ranges from 0-1 where the higher the value the more diverse the sample. This calculation takes into account both number of species (species richness) and number of individuals of each species (species evenness). Defined as 1-D where D is Simpson Index defined as $D=[\Sigma\, n(n-1)]/[N(N-1)]$, where n is the total number of organisms of a particular species and N is the total number of organisms of all species.

WATERFOWL SPECIES RICHNESS

We expect an increase in the frequency, duration and extent of standing water on the floodplain would result in an increase in waterfowl species richness within the project area (Siegel and DeSante 1999). Waterfowl species richness is measured as the total number of species recorded in the study area.

BAT ABUNDANCE

Bats feed on terrestrial insects and benthic macroinvertebrates typically in the dusk hours and visual observations can confirm activity, thus bat presence is expected to be higher in riparian ecosystems with more abundant insect populations (Reid 2006). Bat abundance is measured as the total number of individuals observed from 1 hour pre-dusk to 1-hour post-dusk.

WILLOW FLYCATCHER POPULATION

The number of willow flycatcher individuals estimated per unit area within the subject riparian ecosystem area. Willow flycatcher population is expressed as the absolute number of individuals as well as presence/absence of breeding and nesting activity (Green et al 2003).

INTOLERANT FISH SPECIES ABUNDANCE

The fish community consists of all fish species which utilize the stream for all or a portion of their life cycle. Fish community assemblage has been documented to respond to aquatic habitat improvements (Howson et al 2009) as a result of stream restoration. Intolerant fish species, including trout and sculpin, do not survive or reproduce well in impaired streams that have low macroinvertebrate abundance, elevated surface water temperatures, low pool frequency or other characteristics of a simplified stream ecosystem (Stead 2007). Intolerant species abundance is expressed as the number of intolerant species individuals relative to the total number of individual fish observed within the study reach, i.e. the percent contribution of intolerant species individuals to the overall number of fish observed.

MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (IBI)

Benthic macroinvertebrate are small organisms that live at least part of their life cycle within the stream. These are primarily the larval or immature form of insects, but also included are other types of organisms such as worms.

Macroinvertebrate health in a stream system is greatly influenced by the presence of downed woody vegetation, decomposing organic matter and substrate condition. Therefore, streams systems that have the ability to retain organic matter will possess a more diverse, and productive aquatic ecosystem (Entrekin 2008). Substrate condition has been identified as a critical stream component to support healthy macroinvertebrate populations and many have identified the % of fines, degree of embeddedness or other substrate condition metrics as predictive stressors of IBI values (Karr and Chu 1999, Herbst and Silldorff 2004, Ode et al 2005). A reduced biotic integrity of the benthic invertebrate community can be observed in some disturbed systems due to a reduction in aquatic habitat quality

The health of this community is typically assessed with an index of biotic integrity, which evaluates community structure relative to undisturbed or reference conditions (SWAMP 2007). The SWAMP bioassesment procedures produce quantitative and repeatable measures of a stream's physical/habitat condition and benthic invertebrate assemblages. Furthermore, SWAMP (2007) is a well accepted IBI for California streams that includes complete field collection, data analysis and IBI calculations. Improvements to SWAMP IBI calculations are currently being developed by Herbst and Silldorff (2009).

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APPENDIX A

A comprehensive integration of past stream restoration efforts and future tools to evaluate and track the multitude of benefits provided by streams and meadows in the Lake Tahoe Basin.

Justification Statement

Millions of dollars have been spent on stream and meadow restoration projects in the Lake Tahoe Basin over the past 2 decades, but there has been little to no consistency in tracking and evaluating these projects. One of the primary unresolved, and most high profile, questions related to the Lake Tahoe Total Maximum Daily Load (TMDL) analysis concerns the potential for stream and meadow restoration to prevent fine sediment and nutrient pollutants from entering the Lake during high flow events. Much can be learned from a broader evaluation of constructed stream and meadow restoration projects, the intended benefit(s) of each project and how the design and implementation aimed to achieve these benefits. A synthesis of past projects, as well as consistent effectiveness evaluation techniques, will provide the needed direction for future stream restoration project performance evaluations and identify where technical data gaps lie.

Background and Problem Statement

There are 3 primary problems this research will address:

1. *A lack of an available comprehensive inventory of existing stream and meadow restoration efforts including intended benefits, design objectives, design criteria, construction details, effectiveness monitoring techniques and associated results.*

The proposed efforts will provide a comprehensive inventory of existing stream restoration projects completed in the Lake Tahoe Basin. The proposed effort will systematically organize and document the location, intended benefits, and key technical physical design characteristics of each of the stream restoration projects conducted in the Basin. In addition, this effort will document and analyze the specific effectiveness evaluation techniques and associated findings employed on previous restoration projects. This effort will also systematically catalog the experiences of the people engaged in designing, managing, constructing and evaluating the projects. The inventory will result in a reporting template by which all past projects will be integrated and then compared. The reporting template and database will be tools to improve the consistency of problem statements, intended benefits, design approach and other details of stream and meadow restoration projects conducted in the Tahoe Basin. The techniques and format developed will facilitate continued integration and comparative technical analyses of projects into the future, forming the backbone of the adaptive management process.

2. *A lack of a process-oriented approach to consistently identify project goals and intended benefits, and then track and report effectiveness of constructed stream and meadow restoration projects both within individual projects and across all projects.*

The majority of stream and meadow restoration projects in the Lake Tahoe Basin has been implemented without standardized protocols for effectiveness monitoring and results dissemination to other implementing agencies or members of the research community. Where effectiveness monitoring has been conducted, standardization of observations, reporting metrics and data collection protocols across projects has not been a priority. The lack of standardized project effectiveness evaluations is not limited to Lake Tahoe; Bernhardt et al. (2005) found that only 10% of the 37,099 projects in the National River Restoration Science Synthesis (NRRSS) database indicated an assessment or monitoring plan had been conducted, and of those the majority did not critically evaluate the consequences of restoration activities nor disseminate the monitoring results. This lack of consistency and synthesis of stream restoration data collection is resulting in the loss of valuable stream process data even while millions of dollars continue to be invested in stream and meadow restoration efforts in the Lake Tahoe Basin. Standardized information integration can significantly improve the value of information and data available, as well as illuminate data gaps and

future research needs. This standardized data can be fed into the TMDL management system and provide necessary information for resource managers to prioritize, select and plan future projects funded through the Environmental Improvement Program (EIP).

The proposed research includes the development of conceptual models. These models will provide basin resource managers with a clear direction on the conceptual relationship between the intended benefits of stream restoration efforts and how restoration actions are assumed to achieve these benefits. Specifically, these models will address how geomorphic modifications of the stream channel affect vegetation characteristics, water budget, biogeochemical cycling, habitat quality and other components of stream ecology. The research team will use the understanding gained from past experience, scientific literature and the review of effectiveness information to develop representative conceptual models for marsh and stream restoration projects (Task 2).

The research team will more clearly define effectiveness monitoring approaches for the Lake Tahoe Basin (Task 4). The Upper Truckee River Watershed Advisory Group has made considerable strides recently in defining guidelines for general monitoring plans to evaluate stream restoration projects on the Upper Truckee River (UTRWAG 2007). The researchers will build upon the efforts and guidelines produced by UTRWAG to further define these effectiveness approaches. The research team assumes there are two distinct categories of effectiveness monitoring to standardize future performance evaluations: rapid assessment and long-term evaluations. The team will define a rapid assessment methodology (RAM) for stream and meadow systems, a set of cost-effective and repeatable tools to evaluate, compare and track all stream restoration projects in the Basin. The information gained from the rapid assessments will inform project-specific performance evaluations, as well as facilitate comparative condition evaluation across projects in the Lake Tahoe Basin. The second category of effectiveness parameters, long-term evaluations of stream restoration projects, will be more costly to implement, require multiple measurements and observations during storm conditions, and may require the techniques to be further tested and refined by research scientists. Due to high effort and cost, it is anticipated that the long-term evaluations would focus on a subset of projects. Research areas for long-term monitoring would include complicated processes such as sediment transport dynamics, nutrient cycling or ecological benefits of stream and meadow restoration efforts.

3. *A lack of clear understanding of how stream restoration benefits relate to the intended long-term water quality goals of the TMDL, beneficial uses of the LRWQCB and the Pathway 2007 thresholds.*

Stream restoration projects are undertaken in the Lake Tahoe Basin to fulfill a number of desired conditions developed through the multi-agency Pathway planning process. These conditions are expected to satisfy Lahontan Regional Water Quality Control Board (LRWQCB) Beneficial Uses, the United States Forest Service (USFS) Desired Conditions and the Tahoe Regional Planning Agency (TRPA) Environmental Threshold Carrying Capacities. The intended benefits of physically modifying incised, sediment-ridden and simplified streams into “more functional” geomorphic systems include improvements in downstream water quality, soil stability, ecological health, wildlife habitat, etc. The conceptual models (Task 2) and standardized monitoring techniques will assist in the understanding and evaluation of how projects support multiple ecosystem goals and EIP programmatic objectives.

One of the most important Desired Conditions for the greater Lake Tahoe Basin and the focus of the TMDL is the restoration of Lake Tahoe clarity through the significant reduction of sediment and nutrients (Roberts and Reuter 2007). The recent release of the Pollutant Reduction Opportunity Report (LRWQCB and NDEP 2007) for the TMDL focuses upon the specific reduction of sediment sources generated within the stream channels themselves (i.e., bank erosion and bed scour). This narrow context allows for only minimal water quality benefit as a result of stream channel restoration. The TMDL evaluation does not consider the multitude of ecological and water quality benefits that functional stream and meadow systems can provide

to the Lake Tahoe Basin as a whole. This information gap has been one of the most noted points in the agency and public review of the TMDL analysis to date and is a high priority scientific research need to inform TMDL implementation planning.

Urbanized lands in the Basin have been identified as the primary source of fine particles and phosphorous loads (Roberts and Reuter 2007), and a significant fraction of urban stormwater is routed to the local stream systems prior to delivery to Lake Tahoe. While pollutant control options (PCOs) were not evaluated across source category groups (SCGs) in Phase II of the TMDL, functional stream morphology provides a significant opportunity to act as a sink for urban stormwater pollutants. A restored and functional stream and meadow system may consistently remove nutrient and sediment sources introduced to the stream system from bank failures or fire scars on forested lands or from urban activities such fertilizer applications and roadway activities. The research team will provide the tools to resource managers to track and report the benefits of stream restoration efforts in the broader context of the TMDL, Pathway 2007 and LRWQCB beneficial uses.

Research Hypothesis, Goal, and Objectives

Hypothesis A focused integration of past actions and lessons will inform the definition of future stream and meadow condition evaluations thereby providing a clear process to define, track and evaluate the benefit and effectiveness of restoration efforts.

Goal Compile existing stream restoration efforts and associated monitoring data to synthesize and disseminate existing knowledge. Building upon past and current efforts, the research team will identify and document reliable methods to prioritize, evaluate, track and report stream restoration effectiveness efforts at achieving multiple ecosystem benefits into the future.

Objectives

1. Establish a comprehensive qualitative and quantitative inventory of current and completed stream restoration projects and how effectiveness has been evaluated for each project,
2. Synthesize findings from the inventory to determine consistent ways to define and evaluate project benefits and lessons learned from past project experiences,
3. Collaborate with resource managers (in the form of a TAC) to develop conceptual models and the associated process-oriented approach to evaluating the intended fluvial, water quality and ecological benefits of stream restoration efforts (see the cover of the proposal for an example),
4. Build upon existing efforts to refine and document standardized rapid assessment tools, protocols and metrics to measure stream and meadow condition by which effectiveness of projects can be evaluated and tracked throughout the Lake Tahoe Basin,
5. Prioritize long-term research and data collection priorities to quantify fine particle and nutrient load reductions and the ecological benefits of the stream systems, and
6. Document how these tools can inform policy and regulatory objectives in the Basin.

Approach, Methodology, and Location of Research

The project consists of 4 main tasks detailed below that will be completed in succession as outlined in the project schedule. The primary deliverable for this research (Task 5) will be a Technical Report that contains the information, observation, results and findings from the project.

Project Team

The project's primary personnel include Nicole Beck, PhD of 2NDNATURE, Matt Kiesse of River Run Consulting and Jeremy Sokulsky of Environmental Incentives. Dr. Beck will serve as the principal

investigator. 2NDNATURE was funded by SNPLMA in Round 7 to implement site-specific data collection techniques to quantify the sediment load reductions predicted as a result of stream restoration efforts. 2NDNATURE has also completed a number of effectiveness evaluations in Lake Tahoe, including a recent synthesis of the research on stormwater BMP water quality performance for the USFS LTBMU in 2006. For the BMP Synthesis 2NDNATURE distilled key pieces of information from a wide variety of EIP projects into a common format for comparison and analysis. Dr. Beck was the technical lead for the Lake Tahoe TMDL Groundwater Source Category Group (SCG) and has participated in all aspects of the combined Urban Upland/Groundwater SCG PCO development, screening and load reduction quantification process (LRWQCB and NDEP 2007). 2NDNATURE also provided technical assistance to the stream channel SCG for the TMDL.

Matt Kiesse of River Run has led the technical assessment and design teams for projects in all of the major Lake Tahoe watersheds, including Trout Creek, Upper Truckee River, Meeks Creek, Ward Creek, Cold Creek, Incline Creek, etc. Mr. Kiesse's wealth of knowledge of fluvial geomorphic and ecological processes, coupled with his intimate participation in the design and construction of so many of the stream restoration projects to be analyzed during this research, makes him an invaluable member of this team.

Jeremy Sokulsky of Environmental Incentives (EI) will complete the link between science and policy. EI has been intimately involved with and extremely knowledgeable about the ongoing Lake Tahoe TMDL and Pathway planning processes. EI has served as the programmatic liaison and project manager for the development of the Pollutant Reduction Opportunities Report (LRWQCB and NDEP 2007) and the development of an integrated water quality management strategy for the past 2 years. EI recently completed the design of a multi-agency management system for the Pathway agencies, namely LRWQCB, TRPA, USFS LTBMU, and NDEP. The generalized management system developed through this project will be the starting point for developing a TMDL-specific management system.

Location of Research

The majority of the effort involves the synthesis of existing information and data from completed stream restoration projects throughout the Lake Tahoe Basin. The focus of this research is not to collect new data and will rely on the existing data sets generated for the variety of stream systems in the Basin. However, we do intend to conduct rapid field observations of each of the restored stream reaches included in the synthesis. The field observations' purpose and intent will be refined following the existing report and data review and conducted to allow a comparison using rapid assessment methods of the physical and chemical processes currently acting at each restored site.

Methodology

Task 1. Compilation of Stream Restoration Projects and Effectiveness Information

The research team will obtain and compile all available and relevant information on completed stream and meadow restoration projects. Information will include a comprehensive inventory of all stream and meadow restoration projects displayed spatially in GIS. Relevant qualitative and quantitative information and data will be extracted from available project designs reports, publications, articles and monitoring studies. The research team will interview key agency staff, contractors and investigators who have participated on past projects to gain an understanding of the success factors and road blocks related to project planning, construction and maintenance. Matt Kiesse's (River Run) extensive involvement in past stream restoration projects will be extremely valuable in the completion of Task 1. The synthesis will document the state of the existing knowledge, assumptions and approaches on what stream and meadow restoration projects' intended benefits have been over the past 20 years and the key successes and failures from these efforts. The team will compile information into an inventory in database format that will be made available to agencies and researchers. The inventory will facilitate a simple comparison of the key components of the restoration projects, including but not limited project goals and objectives; stakeholder process and community support information; stream hydrologic, geomorphic, sediment load, bank stability indices and

other site physical and chemical setting conditions quantified pre-project; engineering solutions selected to meet the goals and objectives of the stream reaches restored; pre-project condition evaluation approach and select data; post-project condition evaluation approach and select data; approach to document project effectiveness, including processes, techniques, protocols and metrics; findings and conclusions from effectiveness evaluations; recommendations from effectiveness evaluations for future monitoring, site maintenance, project modifications; and lessons learned and findings from review of project planning, stakeholder engagement, and project construction and maintenance.

The inventory of information will be developed into a comprehensive summary of each project completed to date. This summary will provide a framework for evaluation of past restoration efforts and allow a comparison of site characteristics, project goals and objectives, restoration project planning, design, implementation and effectiveness monitoring.

Task 2. Conceptual Models of Stream Restoration Processes

Stream and meadow restoration efforts in the Tahoe Basin have focused on reestablishing pre-disturbance geomorphic function. However, the links between geomorphic process and other characteristics of the fluvial system are often poorly understood. To effectively evaluate the effectiveness of restoration efforts, it is important to more clearly define the specific mechanisms through which restoration actions provide the intended benefits, and how physical changes in the stream channel and floodplain relate to, and influence, other specific physical, chemical and biological processes and conditions. Some effort has already been made to develop simplified conceptual models of these relationships; an example of these is shown on the cover of this proposal. We propose to further develop a conceptual model of the role of restoration in fluvial processes. The conceptual models will simply communicate the scientific processes and potential indicators of stream function that explicitly link restoration actions to intended benefits for stream and marsh restoration projects in the Tahoe Basin. The conceptual models will illustrate direct linkages between actions, natural processes and parameters of measure that are expected to track condition and effectiveness.

These conceptual models will be developed with engagement from agency staff and researchers in the form of a TAC. A broad acceptance of the basic conceptual models will help guide future design efforts and provide a basis for monitoring and project evaluation. A maximum of four formal interactions will be conducted at critical milestones between the research team and the TAC. The TAC will consist of individuals intimately involved in stream restoration, members of UTRWAG, Pathway 2007, TMDL or other key programs in the Basin. The TAC will provide feedback to the scientists to ensure the products are technically sound and meet the needs of the Basin managers.

Task 3. Analysis of Stream Restoration Effectiveness and Synthesis of Findings

In the context of the conceptual models and process relationships outlined in the conceptual models (Task 2), the research team will evaluate past stream restoration achievements and how well past projects have achieved the intended benefits. The ability of the techniques utilized by past projects to evaluate effectiveness will be assessed and directly related to the process linkages outlined in the conceptual models. Rapid site evaluations of past projects will be performed by the research team. The purpose of the site evaluations will be to supplement the available information of each project by providing a standardized, yet rapid, observational survey of the completed projects using consistent criteria across all projects. The RAM observation methods and results will be well documented. The analysis of documented effectiveness and the results of rapid site observations will illuminate specific data gaps in our current understanding of project effectiveness and where our techniques to evaluate effectiveness have failed.

Task 4. Recommended Approach to Evaluating Stream and Meadow Restoration Effectiveness

The primary goal of Task 4 is to build upon previous and existing efforts (particularly UTRWAG) to evaluate

stream restoration effectiveness. The goal will be to recommend tools and a framework to monitor and track the effectiveness of stream and meadow restoration projects for multiple benefits. As mentioned above, the recommendations will fall into two categories: 1) rapid assessment methods that can be conducted on 1-3yr repeat frequency on all projects and 2) scientific areas of stream restoration benefits that are more complex, costly, and require consistently higher temporal resolution datasets collected long-term.

The cost-effective protocols will provide agency resource managers and researchers with a method to document pre-project conditions and provide definitive evidence within a short period of time (1-3 yrs) following project completion as to whether a stream restoration project was built to specifications and if the geomorphic function of the stream system has appropriately responded to the restoration actions. The selected protocols will directly link to processes contained within the conceptual models, thus illustrating a predictive response of the system as a result of the intended actions of the restoration. As a collective whole, the parameters will address the physical and chemical function of the system relative to desired conditions. Individually the parameters will provide specific process-response information on physical conditions, chemical processes and biological habitat quality at the site. The data set generated from these evaluations over time will provide a process to compare the conditions of the stream systems throughout the Basin. Explicit steps will be described regarding how rapid assessment methods can be integrated into the operations of both the TMDL pollutant reduction tracking system and the Water Quality Crediting and Trading Program that are being developed under current contracts.

The research team will also identify and recommend specific areas of research and data collection techniques that may provide the greatest insight about how to better quantify the more complex, long-term benefits of stream restoration. Existing and future research needs in Lake Tahoe streams will be evaluated as they relate to empirical models of channel evolution, water quality and/or sediment floodplain deposition. The research team's recommendations will focus on areas of stream ecosystem processes and function to provide direction for basin managers who are considering the multitude of research, modeling, policy and regulatory ongoing efforts and future needs. The team intends to create a recommended list of research and long-term monitoring priorities that should be conducted on one or two streams to validate conceptual models of geomorphic and restoration function, refine and test monitoring techniques, and assist with quantifying the benefits of stream restoration projects with respect to the Lake Tahoe clarity, ecology and the community as a whole.

Task 5. Deliverables

The specific deliverables for the research are outlined below. The below schedule clarifies the process and key milestones of these efforts.

Task 5A. Quarterly progress reports

As required by the contract, quarterly progress reports will be created and submitted to the USFS by the 1st of March, June, September and December.

Task 5B. Coordinate TAC, lead workshops and presentations

The research team will assist with the coordination of the technical advisory committee and ensure milestone meetings and presentations are met. No more than four (4) workshops will be conducted at key milestones to present progress and solicit input and comments from the TAC.

Task 5C. Draft and Final Technical Report

Efforts from Tasks 1-4 will be integrated and submitted as technical report that will include all details and key products outlined in Tasks 1-4. A draft will be provided and presented to the client and TAC for

review and comment. Following integration of any comments, a final technical report will be completed and released.

Strategy for Engaging with Managers

The research team will engage agency resource managers and interested researchers in the form of a TAC. The TAC will allow mangers to provide input and feedback to the research project and ensure that each task of this research is widely accepted and useful as tools for future project planning and evaluations (Task 5B).

Deliverables/Products

Information on the project's deliverables and products is presented in Task 5.

Schedule of Milestones/Deliverables

Task		Begin: (time since contract award)	End: (time since contract award)
1	Obtain and compile existing documentation/data on stream restoration efforts and monitoring plans	0 months	3 month
	Develop inventory of information and data	0 months	3 months
	Synthesize projects, approach, effectiveness monitoring, etc	2 months	3 months
2	Develop draft conceptual models	1 months	3 months
	Revise and create final conceptual models following TAC input	4 months	6 months
3	Develop, implement, and analyze preliminary RAM	5 months	7 months
	Quantitatively and qualitatively analyze restoration project effectiveness	7 months	12 months
4	Identify cost-effective parameters for stream restoration evaluations on all streams	6 months	12 months
	Identify long-term parameters and research needs for stream restoration effectiveness evaluations	6 months	12 months
	Document protocol guidelines, metrics and reporting framework	8 months	12 months
	Programmatically integrate into TMDL, EIP, Pathway 2007	10 months	12 months
5	Produce quarterly progress reports	1st of March, June, September, and December throughout project	
	Coordinate TAC, lead workshops and make presentations	1 months	18 months
	Produce Draft Technical Report	12 months	15 months
	Produce Final Technical Report	15 months	18 months
	Invoicing	1 month	18 months

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APPENDIX B

Task 1. Existing Stream Restoration Inventory - Summary

Stream	Restoration Project Name	Restoration Location	Project ID	Project Monitoring Report(s)	Project Monitoring Duration	Author	Channel Restored (Linear ft)	Area Restored (Acres)	Estimated Restoration Cost ($Thousands)	Estimated Monitoring Cost ($Thousands)
Angora Creek	Angora Creek and Washoe Meadows Wildlife Enhancement Project Golf Course and Historic Meadow Reach	3 miles S of South Lake Tahoe, adjacent to Lake Tahoe Golf Course	ANG_01	Angora Creek and Washoe Meadows Wildlife Enhancement Project Golf Course and Historic Meadow Reach, 2001	1995-1998	CDPR	2600	12	600	50
	Angora Creek and Washoe Meadows Enhancement Project Phase IV Sewer Meadow Reach	2.5 miles SW of South Lake Tahoe, within Washoe Meadows State Park	ANG_04	Angora Creek and Washoe Meadows Enhancement Project Phase IV Sewer Meadow Reach, 2004	2001-2005	CDPR	3800	20	700	50
	Angora Creek Stream Restoration Project: County Reach									
Big Meadow Creek	Cookhouse Meadow Restoration Project	4 miles S of Meyers, Highway 89 at Upper Truckee Rd.	CKHS_06	Cookhouse Meadow Restoration Monitoring Plan, March 2006 (Draft)	2005-2011	USFS	1100	20		
Blackwood Creek	Blackwood Creek Fish Ladder Removal and Stream Restoration Project	2.5 miles NW of Homewood, off Barker Pass Rd.	BLKWD_03	Phase I: Blackwood Creek Fish Ladder Removal and Stream Restoration (Draft)	2003-2008	USFS	310	1.5	1,100	50
	Blackwood Creek Barker Pass Road Crossing Replacement and Stream Restoration Project	2.5 miles NW of Homewood, off Barker Pass Rd.	BLKWD_06	Phase II: Barker Pass Road Crossing Replacement (Draft)	2006-2014	USFS	580	4	2,000	25
	Blackwood Creek Phase III Stream Restoration Project	2 miles NW of Homewood, off Barker Pass Rd.	BLKWD_08	Phase III: Blackwood Creek Channel Design and Floodplain Restoration (Draft)	2008-2028	USFS	2000	8		
Burke Creek	Burke Creek Stream Restoration Project	1 mile N of Stateline, adjacent to Tahoe Shores Mobile Home Park	BRK_98	Burke Creek Stream Channel Restoration Monitoring Report 1990-1998	1990-1998	USFS	2,920			
Cold Creek	Cold Creek Stream Restoration Project	South Lake Tahoe, between Pioneer Trail and the confluence with Trout Creek	*CC_94*	*Cold Creek Stream Restoration 1994*	*do not have report*		5500	15	600	50

Stream	Restoration Project Name	Restoration Location	Project ID	Project Monitoring Report(s)	Project Monitoring Duration	Author	Channel Restored (Linear ft)	Area Restored (Acres)	Estimated Restoration Cost ($Thousands)	Estimated Monitoring Cost ($Thousands)
Griff Creek	Griff Creek Stream Environment Zone Watershed Restoration Project	Kings Beach, between Highway 267 and Secline Rd north of Lake Tahoe Blvd.	GC_96	Griff Creek Stream Environment Zone Watershed Restoration Project	1991-1996	NTPUD	200	2	500	50
Incline Creek	Incline Creek Restoration Project	Incline Village, between Lakeshore Blvd and Incline Way	INC_05	Incline Creek Restoration 2005	2005-2020 ? (15 yrs of maintenance were assigned. *Do not have final report*)	NTCD	2200	2.1	1,900	30
Lonely Gulch Creek		1.5 Miles S of Meek's Bay, between Glen Drive and Highway 89	LG_00			TCPUD	200	0.5	450	30
	Lonely Gulch Stream Restoration Project	1.7 miles S of Meek's Bay, between Glen Drive and Highway 89	LG_06	Lonely Gulch Watershed Restoration Monitoring Report, 2002-2006	2002-2006	USFS	350			
Rosewood Creek	Rosewood Creek Restoration Project	Incline Village, between Highway 28 and Lakeshore Blvd.	RSW_04	Rosewood Creek Restoration Project Final Report, 2004	2004-2006	NTCD	2700	1	1,400	
	Lower Roseweed Creek Restoration Project	Incline Village, between Highway 28 and Lakeshore Blvd.	RSW_07	Lower Rosewood Creek Restoration Project: Suspended Sediment Loads and Particle Size, 2002-2007	2002-2007	DRI	3,200			
Trout Creek	Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project	South Lake Tahoe, between Pioneer Trail and the confluence with Cold Creek	TRT_03	Trout Creek Meadow Restoration 2001-2003 Geomorphic Monitoring	2001-2003	Swanson Hydrology + Geomorphology	10000	40	2,000	200
				Final Fisheries Monitoring Report. Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project, March 2006	1999-2004	River Run				
				Sediment and Nutrient Monitoring and Modeling in Lake Tahoe Basin, California, U.S.A., March 2002	2000-2001	DRI				

Stream	Restoration Project Name	Restoration Location	Project ID	Project Monitoring Report(s)	Project Monitoring Duration	Author	Channel Restored (Linear ft)	Area Restored (Acres)	Estimated Restoration Cost ($Thousands)	Estimated Monitoring Cost ($Thousands)
Trout Creek	Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project	South Lake Tahoe, between Pioneer Trail and the confluence with Cold Creek	TRT_03	Draft Trout Creek Restoration Project Wildlife Monitoring Report	2000-2004	Wildlife Resource Consultants	10000	40	2,000	200
				Trout Creek Restoration Monitoring: Assessment of Channel Reconstruction Using Benthic Invertebrates as Indicators of Ecological Recovery, June 2004	1999-2003	Sierra Nevada Aquatic Research Laboratory				
				Post Construction Vegetation Monitoring Report, April 2003	2000-2002	Western Botanical Services				
				Draft Trout Creek Stream Restoration Monitoring Plan, July 1999	Did not include in inventory because this monitoring report had no data collection	Watershed Restoration Associates				
				Effect of geomorphic channel restoration on streamflow in a snowmelt-dominated watershed, October 2008	1999-2004	Tague, Valentine, Kotchen				
Upper Truckee River	Upper Truckee River Restoration Project: Washoe Meadows State Park	2.5 miles S of South Lake Tahoe, Lake Tahoe Golf Course near Country Club Dr.	UTR_94	UTR Restoration Project 1994 Monitoring Report	1994-1995	CSP	1000		90	15
	Upper Truckee River Restoration Project: Lower West Side	South Lake Tahoe, adjacent to Marina and Sailing Lagoon	UTRM_05	Lower West Side Monitoring Reports, 2005	2005-2007	Entrix	1600	16		
		1 mile S of South Lake Tahoe, adjacent to Lake Tahoe Airport	*UTR_08*	*UTR Restoration (Airport Reach)*	*do not have report*		3500			

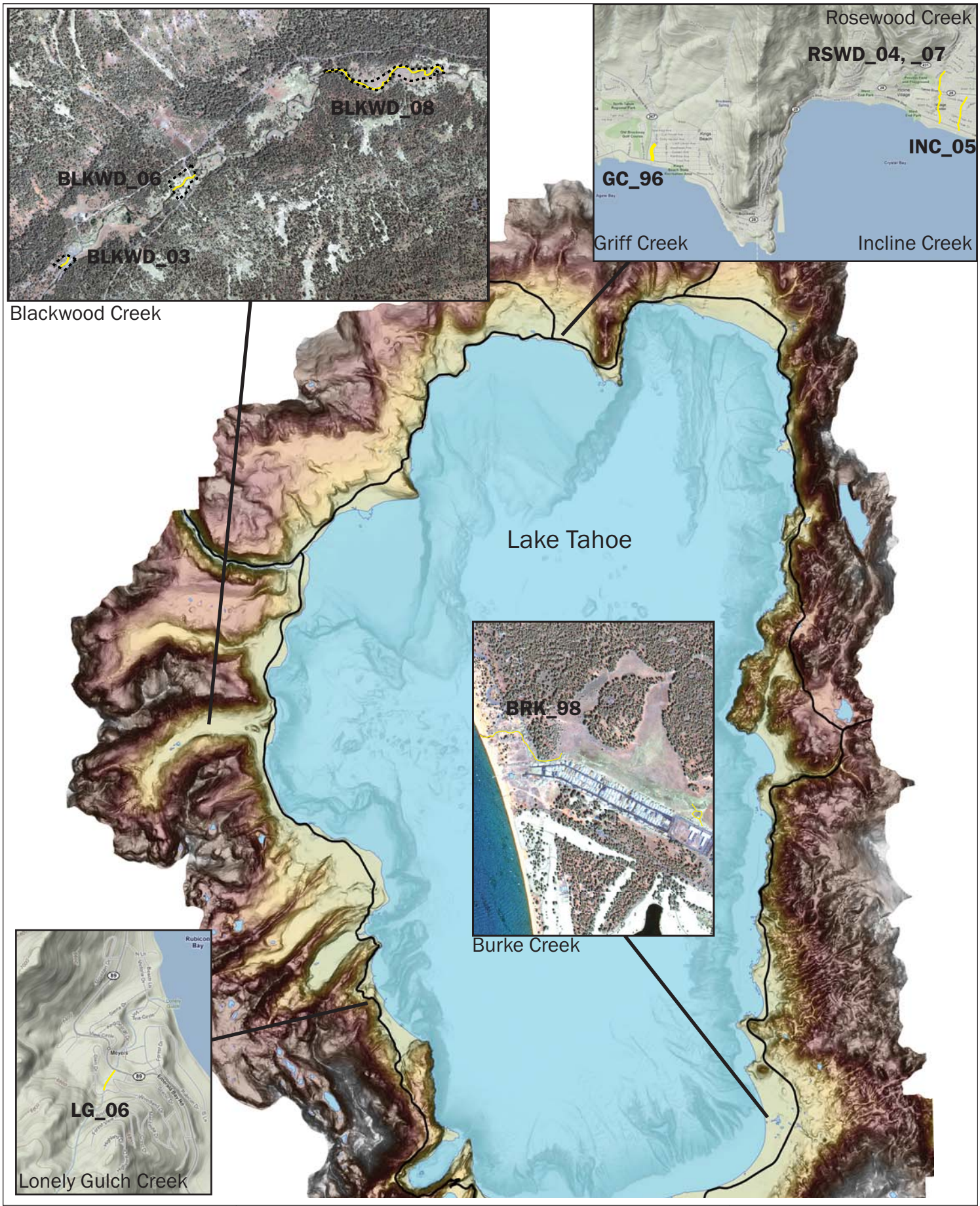

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FIGURE 1: **Lake Tahoe Stream Resoration Locations, North Shore.** Lake Tahoe Basin aerial view of shaded and colored Digital Elevation Model (DEM). Yellow highlighted streams indicate restored reaches and dashed lines indicate restored area, with stream name and site code.

miles
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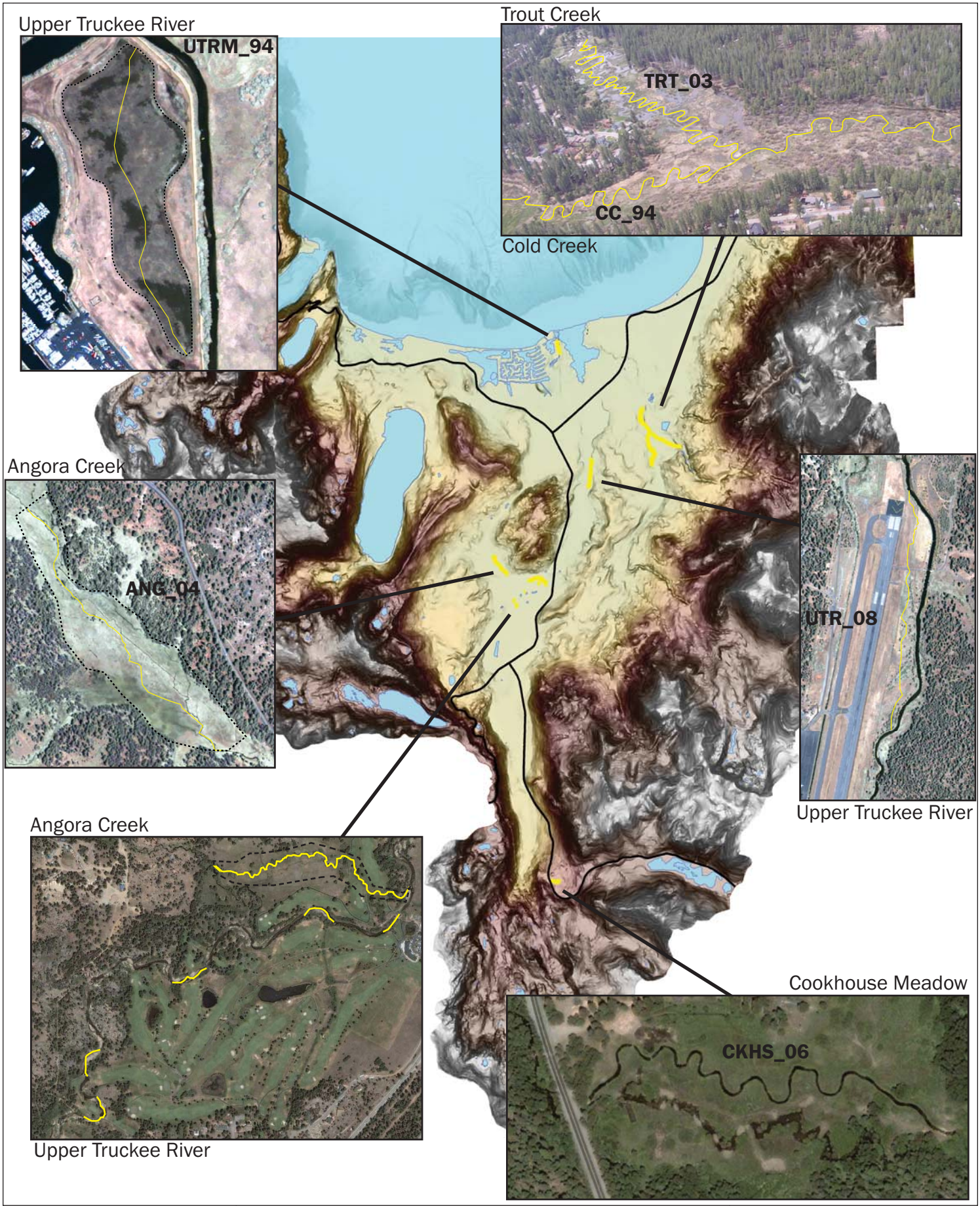

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FIGURE 2: **Lake Tahoe Stream Restoration Locations, South Shore.** Aerial view of South Lake Tahoe DEM. Yellow highlighted streams indicate restored reaches and dashed lines indicate restored area, with stream name and site code.

miles
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Task 1. Existing Stream Restoration Inventory

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Angora Creek	ANG_01	Angora Creek and Washoe Meadows Wildlife Enhancement Project Golf Course and Historic Meadow Reach, 2001	Degraded Meadow Function	Reconnect Floodplain	Groundwater Elevation	Discrete Depth to Groundwater	Pre and Post Comparison	1	X		2
				Improve Water Quality	Sediment	None	None				
				Revegetation	Vegetation (Distribution and Survival)	Photo points	Pre and Post Comparison	2	X		1
				Improve Fish Habitat	Fish Habitat	None	None				
			Straightened Channel (Planform)	Improve Channel Planform	Planform	Aerial Photo Overlay	Pre and Post Comparison	1	X		2
					Channel Geometry	Cross Section Time Series	Pre and Post Comparison	1	X		2
	ANG_04	Angora Creek and Washoe Meadows Enhancement Project Phase IV Sewer Meadow Reach, 2004	Erosion and Bank Instability	Reduce Bank Erosion	Channel Geometry	Cross Section Time Series	Pre and Post Comparison	1	X		2
			Straightened Channel (Planform)	Improve Channel Planform	Planform	Sinuosity	Post Monitoring Only	1		X	1
			Degraded Meadow Function	Reconnect Floodplain	Groundwater Elevation	Discrete Depth to Groundwater	Pre and Post Comparison	3	X		2
				Improve Water Quality	Sediment	None	None				
				Revegetation	Vegetation	Photo points	Pre and Post Comparison	1	X		1

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Big Meadow Creek	CKHS_06	Cookhouse Meadow Restoration Monitoring Plan, March 2006	Erosion and Bank Instability	Reduce Bank Erosion	Channel Substrate	Photo Points (Document Bank Changes)	Pre and Post Comparison	3	X		2
						Visual Survey (Determine % Scour)	Post Monitoring Only	5	X		2
						% Pools (SCI_05)	Post Monitoring Only	2	X	X	1
						Pebble Counts (SCI_05)	Post Monitoring Only	3	X	X	2
						Pool Riffle Ratio (SCI_05)	Post Monitoring Only	3	X	X	2
						Macroinvertebrate (SCI_05)	Pre and Post Comparison	5	X	X	2
			Incised Channel (Planform)	Improve Planform	Planform	Cross Section Time Series	Post Monitoring Only	5	X		2
						Longitudinal Profile	Post Monitoring Only	2	X		1
						Aerial Photos (Track Channel Changes)	Pre and Post Comparison	2	X		2
			Degraded Meadow Function	Revegetation	Vegetation	Transects (Wexelman Trend)	Pre and Post Comparison	2	X	X	2
						Transects (Sod Point Intercept)	Pre and Post Comparison	2	X	X	2
						Transects (% Ground Cover)	Pre and Post Comparison	2	X	X	2
						Aerial Photos (Distribution)	Pre and Post Comparison	2	X		2
						Photo Points (Distribution)	Pre and Post Comparison	5	X		2
				Reconnect Floodplain	Frequency and Duration of Overbank Flow	Automated Stage Recorder	Post Monitoring Only	5	X	X	2
					Groundwater Elevation	Discrete Depth to Groundwater	Pre and Post Comparison	5	X		2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Blackwood Creek	BLKWD_03	Phase I: Blackwood Creek Fish Ladder Removal and Stream Restoration (Draft)	Straightened Channel (Planform)	Reconnect Floodplain	Channel Geometry	Photo Points (Document Bank Changes)	Pre and Post Comparison	5	X		2
						Aerial Photos (Track Channel Changes)	Pre and Post Comparison	1	X		2
						Longitudinal Profile	Post Monitoring Only	2	X		1
				Improve Fish Habitat	Fish Habitat	Visual Assessment (Document Fish Habitat Conditions)	Post Monitoring Only	1	X		1
						Macroinvertebrate Samples (SCI_05)	Pre and Post Comparison	5	X	X	2
Blackwood Creek	BLKWD_06	Phase II: Barker Pass Road Crossing Replacement (Draft)	Degraded Meadow Function	Reconnect Floodplain	Channel Geometry	Photo Points (Document Bank Changes)	Pre and Post Comparison	8	X		2
						Aerial Photos (Track Channel Changes)	Post Monitoring Only	2		X	1
						Longitudinal Profile	Post Monitoring Only	2	X		1
						Cross Section Time Series	Post Monitoring Only	2	X		1
				Revegetation	Vegetation	Transects (% Ground Cover)	Post Monitoring Only	2	X	X	1
						Transect (Woody Species Regeneration)	Post Monitoring Only	2	X		1

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Blackwood Creek	BLKWD_08	Phase III: Blackwood Creek Channel Design and Floodplain Restoration (Draft)	Straightened Channel (Planform)	Improve Channel Planform	Channel Geometry	Aerial Photos (Track Channel Changes)	Pre and Post Comparison	4	X	X	2
						Cross Section Time Series	Post Monitoring Only	6	X		2
						Width to Depth Ratios (SCI_05)	Post Monitoring Only	6	X	X	2
			Degraded Meadow Function	Revegetation	Vegetation	Transects (% Ground Cover)	Pre and Post Comparison	6	X	X	2
				Reconnect Floodplain		Photos Points (Distribution)	Pre and Post Comparison	9	X		2
			Erosion Bank Instability	Reduce Bank Erosion	Streambank stability	Entrenchment Ratio (SCI_05)	Post Monitoring Only	6	X	X	2
						Bankfull Stage (SCI_05)	Post Monitoring Only	6	X	X	2
						Streambank Stability (SCI_05)	Post Monitoring Only	6	X	X	2
					Channel Substrate	Pebble Count (SCI_05)	Post Monitoring Only	6	X	X	2
				Improve Fish Habitat	Fish Habitat	% Fines (SCI_05)	Post Monitoring Only	6	X	X	2
						Pool Riffle Ratio (SCI_05)	Post Monitoring Only	6	X	X	2
						Macroinvertebrate Samples (SCI_05)	Post Monitoring Only	6	X	X	2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Burke Creek	BRK_98	Burke Creek Stream Channel Restoration Monitoring Report 1990-1998	Erosion and Bank Instability	Reconnect Floodplain	Channel Geometry	Cross Section Time Series	Pre and Post Comparison	2	X		2
						Width to Depth Ratios (SCI_96)	Pre and Post Comparison	3	X	X	3
						Bank Angle (SCI_96)	Post Monitoring Only	2	X	X	2
					Vegetation	Photo Points (Monitor Revegetation Success)	Pre and Post Comparison	2	X		1
				Improve Fish Habitat	Channel Substrate	% Fines (SCI_96)	Post Monitoring Only	2	X	X	1
					Fish Habitat	Residual Pool Depth (SCI_96)	Post Monitoring Only	2	X	X	1
						% Shade (SCI_96)	Post Monitoring Only	2	X	X	1
						Pool Riffle Ratio (SCI_96)	Post Monitoring Only	2	X	X	1
			Water Quality Impairment	Improve Water Quality	Nutrients, TSS, Turbidity	Discrete Samples (Surface Water)	Pre and Post Comparison	3	X	X	2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Griff Creek	GC_96	Griff Creek Stream Environment Zone Watershed Restoration Project	Erosion and Bank Instability	Reduce Bank Erosion Improve Channel Planform	Channel Geometry	Cross Section Time Series	Pre and Post Comparison	3	X		2
						Longitudinal Profile	Pre and Post Comparison		X		2
						Photo Points (Document Bank Changes)	Post Monitoring Only		X		2
					Channel Substrate	Visual Survey (Documented Streambank Stability)	Post Monitoring Only		X		2
						Pebble Count (Wolman, D50)	Post Monitoring Only		X	X	2
				Revegetation	Vegetation	Photo Points (Monitor Revegetation Success)	Pre and Post Comparison		X		2
						Transects (% Cover Ground, Point Intercept Method)	Pre and Post Comparison		X	X	3
Incline Creek	INC_05	Incline Creek Restoration 2005	Erosion and Bank Instability	Reduce Bank Erosion	Do not have final report to evaluate						
				Revegetation							
				Improve Fish Habitat							
			Water Quality Impairment	Improve Water Quality							
			Degraded Meadow Function	Reconnect Floodplain							
				Improve Channel Planform							

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Lonely Gulch Creek	LG_06	Lonely Gulch Watershed Restoration Monitoring Report, 2002-2006	Erosion and Bank Instability	Reduce Bank Erosion	Channel Geometry	Cross Section Time Series	Pre and Post Comparison	2	X		2
						Photo Points (Document Bank Changes)	Pre and Post Comparison	3	X		2
					TSS, Turbidity	Discrete Samples (Surface Water)	Pre and Post Comparison	3	X	X	2
				Improve Biological Integrity	Fish Habitat	Macroinvertebrate Samples (MMI)	Post Monitoring Only	1	X	X	2
				Reconnect Floodplain	Vegetation	Photo Points (Monitor Revegetation Success)	Pre and Post Comparison	3	X		2
Rosewood Creek	RSW_04	Rosewood Creek Restoration Project Final Report (2004)	Erosion and Bank Instability	Reduce Bank Erosion	Channel Stability	Visual Survey (Monitor Bank Stabilization)	Post Monitoring Only	3	X		2
				Revegetation	Vegetation	Transects (% Ground Cover, Point Intercept Method)	Post Monitoring Only		X	X	2
						Transects (Survival Rate, Point Intercept Method)	Post Monitoring Only		X	X	2
						Photo Points (Monitor Revegetation Success)	Post Monitoring Only		X		2
				Improve Water Quality	Sediment	Visual Survey (Detention Basin Sediment Accumulation)	Post Monitoring Only		X		2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Rosewood Creek	RSW_07	Lower Rosewood Creek Restoration Project: Suspended Sediment Loads and Particle Size, 2002-2007	Water Quality Impairment	Improve Water Quality	TSS, Turbidity	Continuous Time Series	Pre and Post Comparison	5	X	X	3
						Event Sediment Loads	Pre and Post Comparison	5	X	X	3
			Erosion and Bank Instability	Reduce Bank Erosion	Channel Substrate	(Rosgen Bank Erosion Hazard Index)	Post Monitoring Only	2	X	X	2
Trout Creek	TRT_03	Trout Creek Meadow Restoration 2001-2003 Geomorphic Monitoring	Erosion and Bank Instability	Reduce Bank Erosion	Channel Substrate	Pebble Count (Wolman, D50)	Post Monitoring Only	3	X	X	2
			Straightened Channel (Planform)	Improve Channel Planform	Channel Geometry	Aerial Photo Overlay	Pre and Post Comparison		X		2
						Cross Section Time Series	Post Monitoring Only		X		2
						Longitudinal Profile	Post Monitoring Only		X		2
		Final Fisheries Monitoring Report. Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project, March 2006	Straightened Channel (Planform)	Improve Fish Habitat	Fish Habitat	Pool Riffle Ratio	Pre and Post Comparison	2	X	X	3
					Fish Population	Length-Frequency Distribution			X	X	2
						Population Estimates			X	X	2
						Biomass Estimates			X	X	2
		Sediment and Nutrient Monitoring and Modeling in Lake Tahoe Basin, California, U.S.A., March 2002	Water Quality Impairment	Improve Water Quality	TSS, Turbidity	Continuous Time Series	Pre and Post Comparison	1	X		2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Trout Creek	TRT_03	Draft Trout Creek Restoration Project Wildlife Monitoring Report	Degraded Riparian and Wetland Habitat	Improve Terrestrial Wildlife Habitat	Birds	Transects (Abundance of Species using Point Count Method)	Pre and Post Comparison	2	X		2
					Mammals	Transect (Abundance, Timed Surveys, Sherman Live Trap)			X	X	2
					Amphibians	Visual Survey (Distribution of Larvae)			X		2
					Macro Invertebrates	Transect (Abundance, Pitfall Traps)			X	X	2
		Post Construction Vegetation Monitoring Report, April 2003	Degraded Meadow Function	Revegetation	Vegetation	Visual Survey (Plant Diversity and Vigor)	Pre and Post Comparison	1	X		2
						Transects (Vegetation Cover, Point Intercept Method)			X	X	2
						Photo Points (Monitor Revegetation Success)			X	X	2
						Transects (Belt Line Measuring Willow Density)			X	X	2
					Floodplain Soils	Soil Moisture	Pre Monitoring Only	None	X		1
						Discrete Depth to Groundwater	Pre and Post Comparison	2	X	X	2

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Trout Creek	TRT_03	Trout Creek Restoration Monitoring: Assessment of Channel Reconstruction Using Benthic Invertebrates as Indicators of Ecological Recovery, June 2004	Degraded Riparian and Wetland Habitat	Improve Biological Integrity	Macro Invertebrates	Transects (Diversity and Abundance)	Pre and Post Comparison	2	X	X	3
		Effect of geomorphic channel restoration on streamflow in a snowmelt-dominated watershed, October 2008	Degraded Meadow Function	Reconnect Floodplain	Groundwater Elevation	Discrete Depth to Groundwater	Pre and Post Comparison	2	X		2
					Stream and Groundwater dynamics	Continuous Time Series and Analysis		4	X	X	3

Stream	Project ID	Project Monitoring Report(s)	Reach Impairment	Project Objectives	Attribute Evaluated	Effectiveness Reporting Metric	Timing of Observations	Years Evaluated Post Implementation	Quantitative Comparison		Metric Rank
									Within project	Across Streams	
Upper Truckee River	UTR_94	UTR Restoration Project 1994 Monitoring Report	Erosion and Bank Instability	Reduce Bank Erosion	Channel Stability	Photo Points	Post Monitoring Only	1	X		1
						Visual Survey (Document Active Erosion Areas)	Post Monitoring Only	1	X		1
					Channel Substrate	Pebble Count (Wolman, D50)	Post Monitoring Only	1	X	X	1
					Channel Geometry	Cross Section Time Series	Pre and Post Comparison	2	X		2
						Longitudinal Profile	Post Monitoring Only	1	X		1
				Revegetation	Vegetation	Transects (Survival Counts)	Post Monitoring Only	2	X	X	1
						Transects (% Ground Cover, Point Intercept Method)	Post Monitoring Only	2	X	X	1
						Photo Points (Document Revegetative Success)	Pre and Post Comparison	2	X		1
	UTRM_05	Lower West Side Monitoring Report, 2005	Water Quality Impairment	Improve Water Quality	Nutrients,TSS, Turbidity	Discrete Samples (Surface Water)	Post Monitoring Only	3	X	No Final Report to Evaluate	
						Discrete Samples (Groundwater)	Post Monitoring Only		X		
					Sediment	Sediment Disk	Post Monitoring Only		X		
						Photo Points (Document Sediment Distribution/Overbank Flow)	Post Monitoring Only		X		
			Degraded Meadow Function	Reconnect Floodplain	Groundwater Elevation	Continuous Depth to Groundwater	Pre and Post Comparison		X		

TABLE HD1
Inventory Header Definitions

Inventory Header	Definition/Explanation
Stream	Lake Tahoe Basin stream where restoration occurred.
Project ID	Assigned identification code for stream restoration action and/or associated report.
Project Monitoring Report	Report name used to populate inventory.
Reach Impairment	Based on existing communications and professional knowledge 5 common impairments were identified to impact the natural riparian function. The 2NDNATURE team believed all streams in Lake Tahoe Basin could be categorized under one or more of the 5 impairments. When the reviewed report did not state the impairment or problem, 2NDNATURE inferred the reach impairment by stated objectives or other statements.
Project Objectives	2NDNATURE identified 9 common objectives for stream restoration and enhancement projects based on the existing restoration documentation review. The reviewed report either directly stated the restoration objectives or the objectives were inferred based on reach impairment and/or restoration actions completed.
Attribute Evaluated	Stream channel attribute monitored to measure and track changes as a result of the restoration efforts.
Effectiveness Reporting Metric	Method/technique/value used to monitor and present the evaluated attribute.
Timing of Observations	Timing of attribute evaluations relative to restoration implementation. Options of timing of observations are: pre and post monitoring, pre monitoring only, post monitoring only, or none.
Years Evaluated Post Implementation	Number of years the attribute was monitored after implementation of the restoration.
Quantitative Comparison, Within Project	Attribute monitoring resulted in quantitative values and these values can be used to compare pre and post conditions of the attribute within the restoration project.
Quantitative Comparison, Across Projects	Quantitative values were produced from monitoring efforts and may be used to compare across stream conditions within the Lake Tahoe Basin.
Metric Rank	A numerical value of 1, 2, or 3 based on the type of monitoring that occurred. A rank of 1 is poor and 3, strong. See TABLE MR1 for more thorough definitions of scores.

TABLE MR1
Metric Rank Table

Metric Rank	Definition/Explanation
1	A. Qualitative observations **not** evaluated during **both** pre and post restoration conditions and post project condition evaluations of metric conducted for no more than 2 years. OR, B. Qualitative observations evaluated during both pre and post conditions but the observation interpretation left the reader to infer "effectiveness" of the restoration. OR, C. Quantitative metric **not** evaluated during **both** pre and post restoration conditions and post project condition evaluations of metric conducted for no more than 2 years.
2	A. Quantitative metric evaluated during **both** pre and post restoration conditions, but post project evaluations conducted for 1 year or less. OR, B. Quantitative metric **not** evaluated during pre restoration conditions, but post project condition evaluations of metric conducted for 3 years or more. OR, C. Cross section, longitudinal profile, or aerial photo overlay comparisons pre and post restoration conditions, but failed to include possible quantitative metrics (e.g. sinuosity, meander length (ft), channel capacity (ft^2), slope, etc.). OR, D. Quantitative metric evaluated during both pre and post restoration conditions, but the potential high natural variability in the metric signal is not constrained in the monitoring strategy and/or not adequately considered in the metric interpretation. OR, E. Standardized, well-developed protocol used to rapidly evaluate relative condition (typically geomorphic) at one snap shot in time, but not conducted during **both** pre and post restoration conditions. OR, F. The monitoring plan is currently (2009) being implemented and while the metric evaluation has the potential to be a 3, the effectiveness results are not yet available to interpret applied metric quality.
3	A. Quantitative metric evaluated during both pre and post restoration conditions. AND, B. The quantitative metric values allow reasonable temporal and spatial comparisons within the specific restoration project. AND, C. Monitoring strategy and metric interpretation were reasonably constrained for natural and/or sampling variability of metric signal.

Table RI. Reach Impairments

Degraded Meadow Function
Erosion/Bank Instability
Fish Barriers
Straightened Channel (Planform)
Water Quality Impairment

Table G. Project Objectives

Improve Biological Integrity
Improve Channel Planform
Improve Fish Habitat
Improve Terrestrial Wildlife Habitat
Improve Water Quality
Reconnect Floodplain
Reduce Bank Erosion
Reduce Channel Incision
Revegetation

Table AE. Attribute Evaluated

Channel Geometry
Amphibians
Birds
Channel Stability
Channel Substrate
Fish Habitat
Fish Population
Floodplain Soils
Frequency and Duration of Overbank Flow
Groundwater Elevation
Macro Invertebrates
Mammals
Nutrients
Planform
Sediment
Stream and Groundwater Dynamics
Streambank Stability
TSS
Turbidity
Vegetation

Stream	Project ID	Project Monitoring Report	Summary
Angora	ANG_01	Angora Creek and Washoe Meadows Wildlife Enhancement Project Golf Course and Historic Meadow Reach, 2001	In the 1940's diversion ditches and dams were built in the Washoe Meadow to support dairy operations. Angora Creek was diverted to meet the UTR at a confluence upstream of its natural confluence; this diversion stranded the meadow it once supported. The lower reach of the channel and meadow were destroyed by construction of the golf course in 1955. Restoration objectives were to return a naturally functioning stream and meadow system by restoring the stream to the pre-diversion location and recreating a stream channel that would flow across fairways 10 and 11. A new headgate diversion structure was built to control flows into the new channel. The reconstructed channel has a high flow channel (60 cubic ft. per minute) and a low flow channel (25 cubic ft. per minute), as well as a low slope and meandering pattern. Pre project monitoring included setting up photo points, monitoring depth to ground water in established monitoring wells and surveying a cross section. According to a report figure, 11 cross sections were created for this restoration reach; however the data collected and monitored is not clearly conveyed in the report. Restoration Cost: $596,000.
	ANG_04	Angora Creek and Washoe Meadows Enhancement Project Phase IV Sewer Meadow Reach, 2004	In the 1960's STUPD aligned a sewer straight down the meadow slope of Angora Creek. As a result, Angora Creek was deviated from its original meandering path to a straight incised channel. The restoration aimed to restore a functioning meadow and stream system along this impaired reach. Using historic aerial photos, a new channel was designed with a low slope and meandering path. The restored channel geometry is listed below: • Sinuosity 1.6, • Avg. width 8 ft, • Riffle depth: 1.0 to 1.2 ft. • Avg. Slope: 0.0256 3,800 linear feet and 20 acres of wetland were restored and the sewer line was filled and revegetated. Pre project monitoring included setting up photo points, monitoring depth to ground water and establishing cross sections. According to a report figure, 22 cross sections and 18 monitoring wells were monitored in the restored reach, however, only the data of 1 cross section survey and 1 MW pre and post were presented in the report. Restoration Cost: $550,000.

Big Meadow Creek	CKHS_06	Cookhouse Meadow Restoration Monitoring Plan, March 2006	Cookhouse meadow spans 25 acres of wet meadow along Big Meadow Creek. The habitat began being degraded in the 1850's with European settlement and grazing. In 1963 Big Meadow Creek was relocated for the construction of Highway 89. A box culvert was installed under the highway to allow passage; consequently the historic streambed is now a deeply incised stream channel with no floodplain connectivity. The restoration aims to relocate the channel within meadow using a Rosgen "C Type" channel. Construction will be completed in the summer of 2005 and the abandoned channel will be filled in the summer of 2006. Project objectives are: 1) Restore natural over-bank flooding relationship 2) Raise seasonal groundwater table elevation 3) Reestablish natural sediment patterns 4) Reduce erosion 5) Restore natural soil moisture conditions to meadow 6) Maintain and increase wet meadow environment 7) Increase woody shrub area 8) Increase diversity and complexity of meadow. Pre restoration monitoring included stream flow levels, meadow plant and wildlife inventories. Groundwater elevations will be evaluated using existing groundwater wells monitored twice a month from September to March, and once a month at baseflow. Wexelman Trend Transects, photo points, and aerial photos will assess the vegetation changes in the meadow. Sod point intercept transects will track the sod placed along stream channel. Longitudinal and cross section surveys will track changes to the planform. Stream condition inventories will be conducted twice post restoration and will measure % pools, substrate size, and bar deposition. Macroinvertebrate sampling will occur each year to evaluate overall stream health.
Blackwood Creek	BLKWD_03	Phase I: Blackwood Creek Fish Ladder Removal and Stream Restoration	Land use impacts such as grazing, road building, and logging and channel modifications have worsened the condition of the Blackwood Creek watershed over time, causing an incised channel with a disconnected floodplain. The overall objective of the Blackwood Creek Restoration is to restore a natural geomorphic and hydrologic function to the channel and to restore the riparian area. The objective of Phase I was to improve the transport of sediment and flow in the upper reach and reconnect channel to the floodplain. Phase I of the Blackwood Creek Restoration removed a dilapidated fish ladder and replaced it with a naturalized step pool.
Blackwood Creek	BLKWD_06	Phase II: Barker Pass Road Crossing Replacement	The objective of Phase II was to improve the transport of sediment and flow in the upper reach and reconnect channel to the floodplain. Phase II of the Blackwood Creek Restoration removed the low water crossing and undersized culvert at Barker Pass Road Crossing and replaced it with a bridge and a step pool channel.

Blackwood Creek	BLKWD_08	Phase III: Blackwood Creek Channel Design and Floodplain Restoration	Restoration in Phase III is still under construction. The objective of Phase IIIA is to increase the sediment deposition within the restored reach. Phase IIIA involves the placement of 12 engineered rock and log deflection structures and 28 floodplain roughness structures to provide additional stability to the reach. Additionally, 2000 feet of new channel will be constructed and connected into the historic channel. Phase IIIB is located upstream of the fish ladder and involves filling a man made gully and reconnecting Blackwood Creek to its historic channel. The Blackwood Creek Restoration Monitoring Plan set the following quantitative objectives to achieve for the restoration: 50% or more vegetative cover, increase sinuosity to 1.6 or greater, increase bank stability to 80% stabilized within the restored reach.
Burke Creek	BRK_06	Burke Creek Stream Channel Restoration Monitoring Report 1990-1998	In 1992 the USFS reconstructed 2,920 ft reach of Burke Creek stream channel, and during the same time Douglas County implemented the Kahle Drive Erosion Control project at an adjacent urban area. This monitoring plan was implemented to monitor the effectiveness of the 2 restoration efforts and the impact these efforts had on water quality (sediments and nutrients), and to evaluate the channel stability and fish habitat characteristics. Water quality was monitored from 1990-1998 at 3 sites, one above the restored site, a second below the restored area, and a third at the outlet of a sediment basin implemented on the Kahle Drive ECP. Water quality sampling occurred pre-restoration (1990-1992), during restoration (1993-94) and post channel restoration (1996-98). Samples were collected weekly during spring flow and monthly during baseflow. During the monitoring period only one storm sample was collected. Water samples were analyzed for suspended sediment, turbidity, total phosphorus, dissolved phosphorus, and nitrate/nitrite. Average annual medians and means were calculated from the data set. 12 cross sections were established in the restored reach and were surveyed in 1992-1995, and 1997. Width to depth ratios were monitored in 1992, 1993, 1996, 1997, 1998. Stream condition inventories (according to SCI USFS 1996) were conducted post restoration in 1996 and 1998, which measured pool/riffle ratios, residual pool depth, bank stability, %fines, %shade, and width depth ratios. 5 photo points were established in 1992 and photos were taken in 1992, 1993, and 1997.
Cold Creek	CC_94	Cold Creek Stream Restoration, 1994	Restoration removed the Lake Christopher dam and converted the area into a meadow and constructed a new meandering channel stretching over a mile in distance. Restoration Cost: $1,400,000.

Griff Creek	GC_06	Griff Creek Stream Environment Zone Watershed Restoration Project	In the 1930's NTPUD constructed a concrete dam across Griff Creek, creating scour and sediment problems downstream. The active erosion area increased the load of sediment into Lake Tahoe and degrading fish and wildlife habitat. The primary objective of the restoration was to eliminate erosion hazards. Griff Creek Restoration Project aimed to remove the dam, fill in the section of eroding diversion ditch, revegetate dirt road leading to the site, improve fish habitat, and restore the drainage of the creek to the pre-dam conditions. As planned, the restoration removed the dam and installed and restored the stream through the dam footprint as well as the installation of a series of jump pools for fish passage. Revegetation occurred in any pre-existing disturbed areas and any area that was disturbed during construction. To monitor the restored floodplain and stream channel, cross sections transects were established. 7 floodplain transects and 3 stream transects were established. Floodplain transects include the restored stream and areas of the diversion ditch, while stream transects include the area adjacent to Griff Creek. Wolman pebble counts were conducted instream at the location of each stream survey transect. In addition to transects, ocular surveys and established photos points were conducted at the restored site to document conditions of active erosion areas of the stream channel and banks. Written observations were documented on a standardized report form. Vegetative cover was monitored using the point intercept method (Buckner 1985) in the 8 established transects. Canopy cover was also measured using a "Cover-Point Optical Point Projection Device" instrument. Restoration Cost: $430,500
Incline Creek	INC_05	Incline Creek Restoration 2005	Objectives of the Incline Creek were to increase SEZ area, filter sediment and aid in floodplain development. The project involved the restoration of 1.5 acres, construction of a new 1200 ft channel, improvement of current channel stabilization, and the construction of the Village Green detention basin. Rosgen's (1996) stream classification was used in constructing mostly a Rosgen "B2 Type" and some "B3 Type" channel. The restored channel geometry is listed below: • Gradient: 2.1% • Bankfull: 28 cfs • Sinuosity: < 1.2 • Overbank Flow Occurrence: 13 days/year Restoration Cost: $1,897, 288.00

Lonely Gulch Creek	LG_06	Lonely Gulch Watershed Restoration Monitoring Report, 2002-2006	A 350 foot reach at Lonely Gulch Creek was vulnerable to erosion due to excessive tree fall of conifer lining the banks. Restoration removed trees, placed some in the stream bed to and keying them into the banks to provide extra stability. Objectives of the project were to clear the downed trees, reduce bank angle, revegetate channel edge, and embed woody debris to bank and streambed to provide stabilization. 4 metrics were created to track the performance of this restoration. 1) Stream flow turbidity and suspended sediment samples to track changes in the water quality entering and exiting the site 2) Photo points to be used as a qualitative measure of streambed and bank stability 3) Cross sections to measure changes in stream banks and bank stability 4) Macroinvertebrate inventory to compare against other Tahoe streams. Water samples were collected from a designated site upstream and downstream of the restored reach. Samples were evaluated for turbidity and suspended sediment. Samples were taken weekly during spring runoff and monthly during baseflow. Median annual turbidity and suspended sediment were calculated from the collected dataset. 7 photo points were established and photos were taken annually from 2002-2006. 4 cross sections were established in the reach and were surveyed in 2003, 2004, 2006. Macroinvetebrates were sampled once after the restoration and the Lonely Gulch reach received a score of 80.7 out of 100 based on the multi metric index (MMI).
Rosewood Creek	RSW_04	Rosewood Creek Restoration Project Final Report (2004)	The Rosewood Creek watershed is highly urbanized impacting the quality and quantity of water entering Rosewood Creek. The human and land use impacts on Rosewood Creek have lead to channelization, degraded riparian habitat, and increased amount of sediment and nutrients flowing in and it is not being treated before entering Third Creek. Rosewood Creek was removed from its historic channel and prematurely feeds into Third Creek just south of Hwy 28. The objectives of the restoration are to restore flows to historic reach, improve riparian habitat, and improve water quality by increasing overbank flow and sediment deposition. The restoration involved constructing a new stream channel moving the confluence of Rosewood Creek and Third Creek downstream to Lakeshore Blvd. Additionally, 5 flood spreading basins, and a storm detention basin were built to reduce sediment loads. The restoration increased the overall length of the Creek 3,200 linear feet consisted of mostly Rosgen Type “E” channels and some Type “A” channels. The restoration was expected to improve water quality and decrease sediment loads. After the implementation of the restoration, flow was managed not to exceed 14 cfs from 2004-2006, through the usage of the diversion structure. The Operations and Maintenance Report Plan documents the inspection and monitoring on the restored creek. Streambank stability in “Type E” channels should be monitored by observing the condition of the coir fabric, in “Type A” channels, the stability of the rock will be inspected. Flood spreading basins should be inspected for accumulated sediment and vegetation growth is anticipated. The detention basin will be inspected for sediment accumulation, and the basin should be cleaned after 2 ft of sediment has accumulated. Revegetated areas will be monitored by establishing transects and measuring % cover and % survival using the line intercept technique. Restoration Cost: $1,423,179.87

Rosewood Creek	RSW_07	Lower Rosewood Creek Restoration Project: Suspended Sediment Loads and Particle Size, 2002-2007	The Rosewood Creek Restoration was completed in the Summer of 2003 (see above for restoration details). The objectives of this research study were to assess the impact of Rosewood Creek has on suspended sediment delivery into Third Creek and determine the effectiveness of the restoration on mass and particle size distribution. Monitoring occurred between Nov 2002-Oct 2007 which included In-situ measurements of conductivity, water temperature, water discharge and turbidity. Discrete water samples were taken by an automated sampler triggered by turbidity and analyzed for suspended sediment concentration and particle size distribution. 2 monitoring sites were established, 1 above the restored creek, and a second below the restoration. In addition to continuous sampling at stations, 60 storm events were sampled.
Trout Creek	TRT_03	Trout Creek Meadow Restoration 2001-2003 Geomorphic Monitoring	Trout Creek has sustained human and land use impacts for over 100 years. Human and land use disturbance has lead to streambed and bank erosion, straightening the stream channel and impairing the overall habitat and floodplain of Trout Creek. The objectives of the Trout Creek restoration were aimed to restore the natural geomorphic processes to the stream and floodplain. A new channel was constructed between Pioneer Trail and Martin Avenue and reconnected with the original Trout Creek planform. The new channel dimensions reduced width and depth to increase overbank flow and reduce the erosive forces moving through the channel. 6 reaches were identified to monitor restoration effectiveness. Within each reach, a longitudinal profile was used to monitor each reach's thalweg, 4 cross sections were established that included 2 riffles and 2 pools, and pebble counts were conducted using the Wolman pebble count method to determine particle size distribution. In all, 2,560 linear feet were monitored.
		Final Fisheries Monitoring Report. Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project, March 2006	The objective of the Trout Creek restoration was to restore a natural geomorphic function to the stream and floodplain. A more specific objective under restoring geomorphic function was to improve wildlife habitat and fisheries. The restoration of the stream channel increased the sinuosity and increased the pool riffle ratio to 50%. The "Final Fisheries Monitoring Report. Trout Creek Stream Restoration and Wildlife Habitat Enhancement Project" evaluated the changes in fish habitat and population as a result of the various restoration techniques implemented. Monitoring of fish habitat and population was conducted 3 years pre restoration (1999, 2000, 2001) and habitat was monitored for 2 season post implementation (2002, 2003), and population was monitored once after implementation in 2004. Habitat was monitored by evaluating pool/riffle ratio within a habitat unit (defined length of habitat by 2-3 bankfull widths). Salmonid habitat, identified by spots of small to medium gravel, velocity of 0.5-2.0tf/sec, and a depth of 0.5-2.0 ft.,was surveyed and mapped in 2001. Population monitoring was conducted via electrofishing at 2 sites along Trout Creek. All fish captured were weighed and measured. Results show the restoration improved habitat by increasing the pool riffle ratio, and while the population did not necessarily increase, the post restoration populations were higher in density and biomass.

Trout Creek	TRT_03	Sediment and Nutrient Monitoring and Modeling in Lake Tahoe Basin, California, U.S.A., March 2002	Currently we only have the pre restoration monitoring report conducted by DRI. DRI objectives of monitoring Trout Creek were to compare the nutrient and sediment loads at inflow and outflow points before and after stream restoration. Monitoring included the deployment of turbidity loggers collecting continuous data at 3 sites in Trout Creek, at the inflow, at the confluence with Cold Creek, and at the outflow. The instruments deployed were equipped with a pressure transducer, turbidimeter, conductivity probe, temperature probe, and a vacuum automated sampler. The automated sampler took water samples which were analyzed for TKN, NO3, TPO4, OP, TSS, Tu. Nutrient and sediment loads were derived by continuous turbidity measurements. The pre restoration monitoring took place from August 2000-June 2001.
		Draft Trout Creek Restoration Project Wildlife Monitoring Report	Wildlife monitoring data were collected on terrestrial invertebrates and four classes of vertebrates: birds, mammals, amphibians, and reptiles. The purpose of the wildlife surveys was to provide data that could be used to evaluate the effectiveness of the project in improving wildlife habitat and enhancing biological diversity. One year of pre-project (2001) and two years of post-project wildlife monitoring surveys (2002, 2003) were performed to monitor changes in species compositions.
		Post Construction Vegetation Monitoring Report, April 2003	Vegetation surveys documented baseline vegetation and site conditions in 2000 prior to restoration. Depth to ground water elevation was also monitored to determine whether or not changes in groundwater elevation can be detected by changes in vegetation species composition over the course of several years. The surveys documented species richness (diversity) and the amount of vegetative cover throughout the project area and soil moisture within transects sampled. Vegetation surveys were conducted at 17 transects included: • qualitative ocular surveys • vegetative cover sampling (transects) • soil moisture and ground water monitoring (CTC wells) • photo-monitoring • willow density of planted cuttings
		Trout Creek Restoration Monitoring: Assessment of Channel Reconstruction Using Benthic Invertebrates as Indicators of Ecological Recovery, June 2004	Benthic invertebrates serve as an indicator for water quality and habitat, making invertebrates a key attribute in evaluate the success of stream restoration. 3 sites were sampled at Trout Creek, one upstream of Pioneer Trail to serve as the control, one upstream of the Cold Creek confluence and a third below the Cold Creek confluence. Two years of pre project monitoring was conducted in late September of 1999 and 2000. Additionally, 2 years of post project monitoring were conducted in late September of 2002 and 2003. At each of the of the 3 sites 5 transects were sampled and the invertebrates collected were evaluated for the following: • Body length to quantify frequency and diversity • Diversity (taxonomic richness) • Sensitive indicator groups • Small bodied midges • Dominance of species Results show the post project samples had an increase in abundance, diversity, and frequency of larger sizes of invertebrates in Trout Creek.

Trout Creek	TRT_03	Effect of geomorphic channel restoration on streamflow in a snowmelt-dominated watershed, October 2008	This study analyzed the effectiveness of restoration by comparing streamflow data from pre and post restoration to determine changes in hydrology. USGS gages located at the upstream and downstream ends of the project were utilized as well as 20 GW monitoring wells were monitored from 1999-2003. Using the collected date, the % gain in streamflow was calculated before and after the restoration and graphically compared.
Upper Truckee River	UTR_94	UTR Restoration Project, 1994 Monitoring Report	The monitoring report does not state the goals or objectives of the restoration completed. Monitoring of the restoration involves assessing performance of the channel stability and revegetation. Channel stability was monitored through visual surveys documenting active erosion areas, photos and cross sections (31). Pebble counts were conducted at the established cross sections. A longitudinal profile was conducted on the restored reach. Revegetation was evaluated by establishing transects and monitoring % ground cover and survival counts.
	Lower West Side (UTRM_05)	Lower West Side Monitoring Reports, 2005	The Lower West Side Restoration Project is part of the larger restoration project "Cove East Restoration Project" at the mouth of the Upper Truckee River. The CTC has plans to conduct the larger restoration project from Hwy 50 to Lake Tahoe, but due to land purchases, the larger project has been delayed. The Lower Side restoration is one phase of the larger restoration with an objective to restore sections of fill near Tahoe Keys Marina. Removal of dams in the marsh and hydraulic reconnection to the UTR occurred in 2003. More frequent overbank flow within restored reach is anticipated post restoration. The objective of this restoration is to restore a naturally functioning marsh which would increase the uptake of sediments and nutrients and ultimately improve water quality of runoff into the lake. In spring of 2004, 5 surface water quality stations were installed with a staff gauge to monitor stage and water quality. A sedimentation disc was also installed to monitor the effectiveness of overbank flow and gauge the amount of sediment settling in the floodplain. Surface and groundwater samples were analyzed for TSS, turbidity, conductivity; nitrate/nitrite, TKN, iron, and TP. Monitoring also involved taking discrete water quality samples from monitoring wells and maintaining dataloggers taking continuous groundwater level data from groundwater wells.