SWANSON HYDROLOGY + GEOMORPHOLOGY

draft final report

Upper Truckee River
Upper Reach Environmental Assessment

for the Bureau of Reclamation, Tahoe Resource Conservation District, and
Regional Water Quality Control Board - Lahontan Region

(cash match)

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I. Introduction and Problem Statement

The Tahoe Resource Conservation District (TRCD) and the U.S. Bureau of Reclamation (BR) are sponsoring this environmental assessment of the Upper Truckee River-Upper Reach to identify projects that reduce pollution discharged into Lake Tahoe and restore ecosystem function in the river and watershed. This effort is being completed in coordination with the programs of numerous agencies, other organizations and the public to implement environmental improvement projects in the Lake Tahoe Basin and to recover what has been lost to historic development and land use. This document provides the background for the development and assessment of environmental improvement alternatives, their costs benefits and impacts. Based upon the information provided herein and the agency and public planning processes, a set of recommended priority projects (priority list) will be produced for funding and implementation.

The Upper Truckee River (UTR) is the largest, longest water course, draining over 54 square miles in the Lake Tahoe Basin (Figure 1.1). The UTR originates in undeveloped wilderness, ten miles south of Lake Tahoe along the Sierra Nevada crest at Red Lake Peak (elevation 10,063 feet), then flows northward through a spectacular alpine terrain of lakes, meadows, forests and volcanic and granitic bluffs. It cascades down multiple waterfalls into the narrow, glacially-formed Christmas Valley and at that point enters the urban lands of Meyers and South Lake Tahoe. From South Upper Truckee Road crossing to Lake Tahoe, the UTR becomes more affected by roads, houses, bridges and other elements of urban landscape. The River flows over 15 miles through neighborhoods, old quarries, a golf course, an Airport and grazing lands before flowing away from its original delta lagoon system in the Barton Meadow. It then flows into a channelized section past the Tahoe Keys Project before discharging into Lake Tahoe.

The UTR has been identified as a major pollutant source of sediment and nutrients flowing into Lake Tahoe, owing largely to the large drainage area of urbanized land. Nutrients, including bioavailable nitrogen and phosphorous, have been identified as a major contributor to algae growth in Lake Tahoe, which has led to a significant decline in the clarity of the Lake since measurements began in the 1960s. Fine sediment contributes to lake clarity decline, as well as the degradation of aquatic habitat for fish and other wildlife in the UTR.

John C. Fremont was the first Anglo American to view Lake Tahoe (with the UTR in the foreground) from Red Lake Peak in February of 1844 (Figure 1.2). Although historical records do show that the native Washoe (Lindström, 2000) set fire to meadows to favor certain plants for food, baskets and medicine, major changes occurred to the UTR with the introduction of European-style land uses as early as the 1850s. An intensive period of change accompanied the development of the Upper Truckee River as the route to the Comstock Lode mining boom in Nevada of 1860-1890. With this boom, the UTR watershed became a major source of timber and grazing land, as timber harvest, road building and grazing in reclaimed marshes and throughout the watershed forever changed the landscape, wildlife and ecosystems in the region.

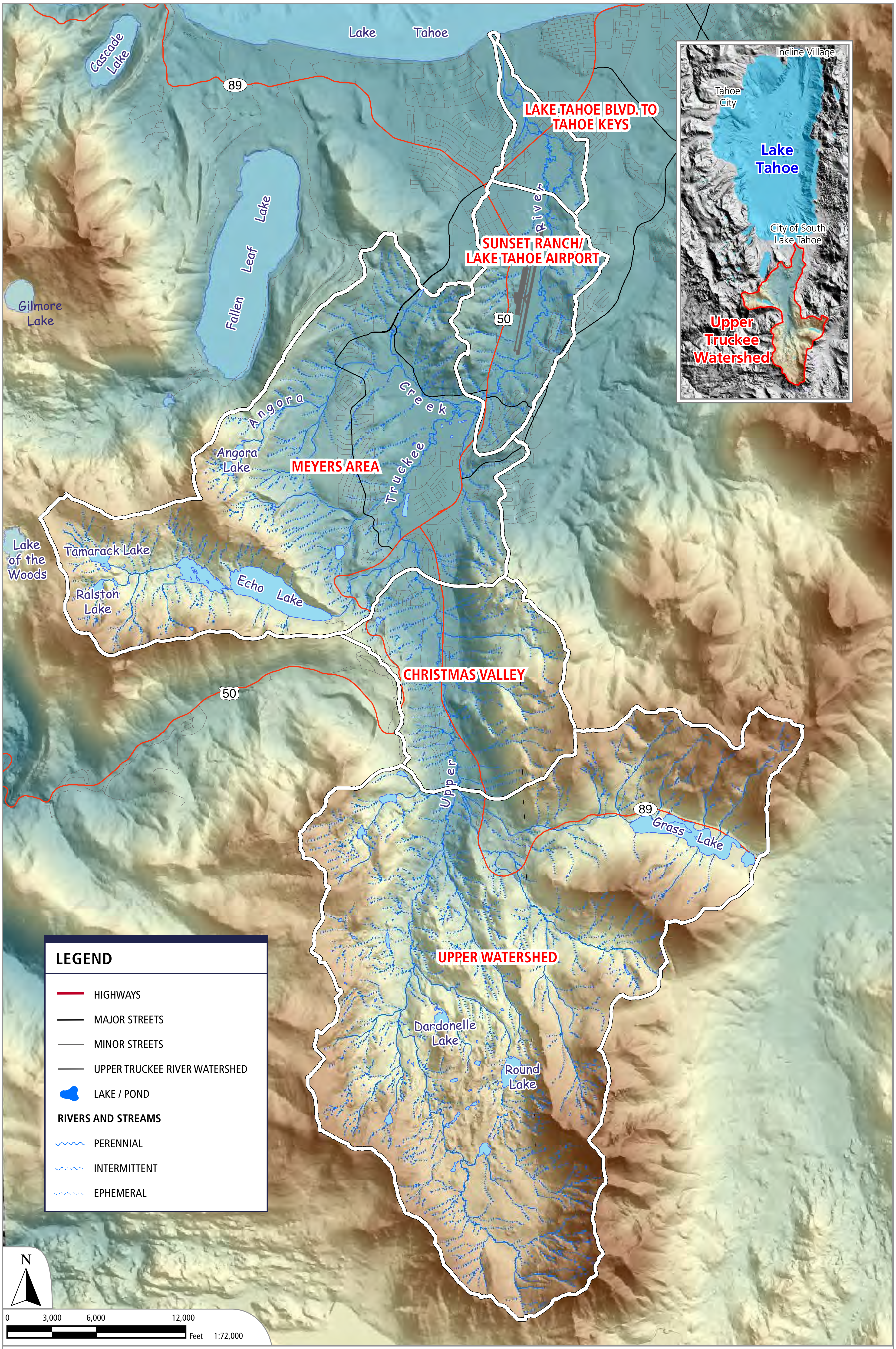

FIGURE 1.1: Project Location Map.

FIGURE 1.2: Photo of the Upper Truckee River Watershed looking north from above Red Lake Peak.

After a period of relatively little development between 1900 and 1950, an expanding tourism economy began to take hold, including expanded year-round and summer vacation populations. After the winter Olympics of 1960 at Squaw Valley, winter tourism expanded greatly, and Lake Tahoe became a world renowned destination. The UTR was a major focus of this change, as much of the surrounding valley floor, floodplains and meadows were converted to accommodate an airport, golf courses, subdivisions and supporting infrastructure (e.g. bridges, sewer lines, roads). The rapid development of the Basin began to take a toll on the environmental quality of the Lake, and in recognizing the need for control, the bi-state Tahoe Regional Planning Agency (TRPA) was formed in 1968. Immediate measures were set in place to minimize the effects of development, beginning with the export of all wastewater out of the basin in 1974, part of which flows through a major export line along the UTR southward over Luther Pass (Highway 89).

The dramatic environmental changes that have occurred over the past 150 years resulted in obvious physical changes to the UTR and its watershed: channels were straightened, natural floodplains were filled for roads, bridges and buildings, marshes were converted to grazing meadows and golf courses, etc. In addition, and perhaps most importantly, there was an underlying change to the natural processes that had formed and sustained the natural ecosystem and held the geologic landscape in equilibrium and relative stability over thousands of years. A primary example was the upset of the delicate hydrologic and geomorphic balance of the UTR, a balance that dictates the dimensions and form of the stream channel and floodplain. This balance was substantially changed by channel straightening which in turn led to the incision or lowering of its streambed, the lowering of the groundwater table, drying of floodplain areas, conversion of riparian vegetation to less erosionally resistant species, and the narrowing of the riparian corridor. Natural geomorphic processes resulting from stream flow, erosion and sediment transport today favor an eroding channel with a far less valuable ecosystem function. It will be necessary to modify the way the river works, as well as its physical form, in order to regain the natural equilibrium and natural stability.

The focus and nature of this assessment is to examine the UTR for opportunities to restore its natural function while addressing the land use and economic factors surrounding land uses to assess how restoration can occur. The condition of the UTR, with regard to ecosystem function and stability, is presently well below its potential. This is the result of a lack of coordination between development of land use and environmental protection of the river corridor and its water quality. This assessment presents an opportunity to examine the overall condition and improve the relationship between the watershed and its land use to the benefit of both. Formulation of environmental restoration measures for the UTR requires that the underlying nature of geomorphic processes be understood and modified in order to obtain the most favorable self sustaining conditions. Although the effects of past land use change cannot be fully undone to “restore” the UTR to historical conditions, the best solutions lie in modifying the river to approach its natural function and allow for adjacent land uses to compatibly exist.

I.1 PROJECT GOALS AND RESEARCH OBJECTIVES

I.1.A Project Goals

Project goals as defined here are desired outcomes of plan implementation. They are the yardsticks by which the success of the proposed restoration action is measured for its benefits, costs and impacts.

The following goals were developed with the policies and activities of multiple agencies, as well as private landowners and other organizations, in mind (a more detailed discussion of each agency's role in the watershed follows). These were presented and approved at agency and public meetings in July and September of 2003.

- Restore ecosystem function to the UTR in terms of riparian vegetation, ecological processes and natural geomorphic processes that sustain channel morphology.
- Reduce erosion and sediment input to pre-disturbance levels to the extent possible.
- Manage for beaver activity in a manner that meets ecosystem and sediment reduction goals and addresses land use impacts.
- Offset pre-1850s impacts to the extent possible, given desires of landowners and agencies; provide a constructive basis for resolution of conflicts.

I.1.B Research Objectives

Research objectives are specific products of the work completed to prepare the assessment and watershed plan. For example, a GIS database of bank erosion along the river was developed to aid spatial examination of erosion problems and development of solutions. The following are the research objectives for this project:

- Develop geomorphic data to estimate pre-disturbance (pre-1850) conditions.
- Develop a sediment source database to determine areas in need of treatment (main channel, tributaries and roads).
- Complete an assessment of channel stability on UTR mainstem.
- Compile existing data and proposed ecosystem restoration and water quality improvement projects in the Upper Reach and assess priorities.
- Develop a master list of recommended projects that can be implemented to meet project goals.

I.1.C Agencies Programs and Policies

Many agencies are involved in a coordinated effort to restore the environmental quality of the UTR, including efforts to restore streams and wetlands and reduce pollutant discharge into Lake Tahoe. Some agencies regulate activities of public and private landowners (e.g. TRPA and Regional Water Quality Control Board (RWQCB-Lahontan)), some provide technical and grant funding assistance (Tahoe Resource Conservation District (TRCD), Natural Resources Conservation Service (NRCS)), while others oversee public land and manage according to their agencies' specific policies (e.g. California Tahoe Conservancy (CTC), U.S. Forest Service (USFS) Lake Tahoe Basin Management Unit (LTBMU) and California Department of Parks and Recreation (CDPR)).

The primary drive for many restoration projects in the UTR originates from the long range Environmental Improvement Program (EIP) that was prepared, and is being implemented, by TRPA and many partners. The EIP identifies the projects necessary to improve the environmental quality of Lake Tahoe to an acceptable and self-sustaining level by meeting specific environmental "thresholds." The EIP includes erosion control, drainage and ecosystem restoration projects that address specific problems in forests, wetlands, streams and watersheds. TRPA requires that each local agency (County, City, transportation agency) develop and implement construction plans to implement the EIP. In the UTR watershed, this includes Caltrans, El Dorado County, El Dorado County Department of Transportation, CDPR and the USFS. The EIPs listed for the UTR project area under this assessment are shown in Table 1.1.

The Lahontan Regional Water Quality Control Board regulates pollution discharge to protect beneficial uses of water in streams, waterways and lakes in the eastern Sierra Nevada region, including the Lake Tahoe Basin. Lahontan is active in funding and overseeing water quality improvement research and planning projects (including a portion of this plan), as well as regulating water quality protection for development and construction activities; this includes permitting for stream restoration projects.

The LTBMU has its own planning direction resulting from the adoption of the Sierra Nevada Forest Plan Amendment (SNFPA), which specifies the return of functional ecosystem processes to lands under their management and the inclusion of the TRPA thresholds into the Forest Plan. This includes specific goals for aquatic ecosystem management and restoration that are aimed at restoring the geomorphic processes essential for habitat development and sustenance. The LTBMU oversees and actively manages many parcels along the Upper Reach study area and in the Upper Watershed lands south of South Upper Truckee Road. Presently the LTBMU is preparing restoration plans for the Big Meadow Creek watershed which drains 4.0 square miles of the Upper Watershed.

The CTC acquires and manages lands for the purpose of conservation, water quality, recreation and wildlife ecosystem restoration. This work includes funding many erosion control and stream restoration projects in the Lake Tahoe Basin. CTC has participated in many projects in the UTR, including restoration of lower Angora Creek with CDPR.

Program	Project Name	Proj #	Start Date	Implement/ Construction	Lead Agency	Description	Total Cost
FISHERIES	BIG MEADOW CREEK - STREAM HABITAT RESTORATION	407		6/1/2009	CTC	PROJECT: Remove the cows from meadow area, reconstruct bridge in order to increase stabilization of banks (not in USFS plan), stabilize head cuts, fly in cobble (USFS,CTC). *This project will not effect the fisheries threshold rating, but it will improve fish habitat condition	$50,000.00
FISHERIES	ANGORA CREEK THROUGH MEADOW - STREAM HABITAT RESTORATION (COMPLETE)	437		6/1/2000	CTC	1.7 miles of channel naturalization and meadow enhancement on lower reach of Angora Creek (CTC, C-parks) (linked to SEZ 949,559).	$433,000.00
FISHERIES	GRASS LAKE CREEK IMPROVEMENTS - STREAM HABITAT RESTORATION	886		10/1/2010	CTC	PROJECT: Facilitate improvement of this resident fisheries stream from good to excellent by stabilizing banks, removing barriers to fish movement and facilitating the exchange of stream diversions with some other source.	$146,000.00
FISHERIES	HABITAT RESTORATION-UPPER TRUCKEE/UPPER SECTION	908		10/1/2011	CTC	PROJECT: In the upper reaches of the Upper Truckee and its tributaries the main habitat improvement need is bank stabilization. Along many of these reaches past grazing practices have caused bank erosion. Hikers on some reaches have current impacts. *With the completion of phases I, II, and III will improve 21.8mi of stream	$852,000.00
FISHERIES	HABITAT RESTORATION-UPPER TRUCKEE/MIDDLE PHASE II	909		10/1/2003	CTC	PROJECT: Middle section includes work along the stream where it parallels Tahoe Paradise Park (Lake Baron) and by the gravel pit. There are some barriers to migration along this section formed by dams, felled trees and beaver dams. Section = 5 miles. *With the completion of phases I, II, and III will improve 21.8 miles of stream	$3,150,000.00
FISHERIES	COOKHOUSE	10132	6/1/2001	6/1/2003	USFS	PROJECT: Construct stream channel, improve habitat, increase streambank stabilization.	$700,000.00
FISHERIES	COOKHOUSE MEADOW	10133	6/1/2001	6/1/2003	USFS	PROJECT: Restore eroding stream banks on Big Meadow Crk., through Cookhouse Meadow. Possibly reconstruct section of channel, install grade control structures or build floodplains within the current incised profile to reconnect the stream with the floodplain.	$160,000.00
SCENIC RESOURCES	MEYERS HWY 50 CENTER LANDSCAPED MEDIAN	140	6/1/2000	6/1/2001	CALTRANS	Install intermittent center landscaped median, curb & gutter planting bed, drainage, turn pockets and stacking spaces on US 50 between Apache/Santa Fe and SR 89. This is Phase I of Roadway Unit #36 improvement project.	$600,000.00
SOIL CONSERVATION/SEZ	RESTORE 40 ACRES OF SEZ - EL DORADO COUNTY	650	1/1/1999	6/24/2000	CTC	If found to be in need, restore 40 acres of SEZ on lands that have been acquired by the public in the subdivided, developed, and disturbed areas within the limits of El Dorado County	$4,850,000.00
SOIL CONSERVATION/SEZ	UPPER TRUCKEE/MEYERS BRIDGE BANK STABILIZATION	937	1/1/2000	6/23/2004	CTC	Stabilize 800 feet of eroding bank with riparian vegetation revetments, floodplain benches, and lateral channel shifts. Alternative approach would be to widen existing floodplain through excavation of terraces.	$4,000,000.00
SOIL CONSERVATION/SEZ	ANGORA CREEK STREAM RE-DIVERSION OFF SEWER LINE AL (COMPLETE)	949		6/22/2001	C-PARKS	Project would re-divert stream back to its original channel. Angora Creek currently runs directly over a sewer line for approx. 900 feet. Restore 2 acres of SEZ, 0.5 acres of meadow habitat improvement, and 0.1 acres of riparian and stream habitat improvements.	$690,000.00
SOIL CONSERVATION/SEZ	UPPER TRUCKEE RIVER BANK STABILIZATION-LAKE VALLEY	950	1/1/2000	6/23/2004	C-PARKS	Implement a range of stabilization treatments along eroding stream banks. Treatments would include riparian plantings, native materials revetment, riprap revetment and retaining walls less than 0.2 acres of SEZ preservation.	$3,000,000.00
SOIL CONSERVATION/SEZ	GEOMORPHIC ANALYSES/MONITORING OF UPPER TRUCKEE	951		6/21/2001	CSLT	Perform comprehensive analyses of fluvial processes to document trends in both treated and untreated areas. Studies will result in initial reports, followed by monitoring and annual updates.	$450,000.00
SOIL CONSERVATION/SEZ	ANGORA CK. SUBDIVISION SEZ RESTORATION	985	6/1/2002	6/22/2002	EL DORADO	Four acres of hydrology and floodplain restoration, and channel stabilization on Angora Creek between Lake Tahoe Blvd. and View Circle. CTC funding included under #650, Restore 40 Acres SEZ in El Dorado County.	$1,215,267.00
WATER QUALITY	MEYERS RESIDENTIAL	191		6/1/2010	EL DORADO	Erosion source controls and stormwater treatment faculties associated with the grantees roadways. Improvements will include revegetation. of disturbed soils; drainage stabilization (e.g. paved gutters, rock lined channels), infiltration and sedimentation facilities (e.g. veg. treatment ponds and various sediment traps), subdivision roads near Meyers School.	$5,900,000.00
WATER QUALITY	UPPER TRUCKEE FOCUSED WATERSHED GROUP	630	1/1/1996	1/1/1996	LWQCB	The Upper Truckee Focused Watershed Group coordinates agency activities occurring or planned in the watershed. A major objective is to complete a Watershed Plan with assistance from the US Army Corps of Engineers. Knowledge gained from this group will be applied to other watersheds in the future. Project costs at this time only include matching funds to the USCOE for preparation of the Project Study Plan (PSP). Other costs include indirect services from agency personnel who participate on the group.	$150,000.00
WATER QUALITY	ANGORA HIGHLANDS/BOULDER MT	705		6/1/2006	EL DORADO	CTC has identified conveyance and treatment needs within Angora Highlands and on Boulder Mt. Drive. Revegetation, curbs, gutters, storm drains, retaining walls and rock slope protection needed. Sediment basins may also be required. CTC references are Angora Highland and Boulder Mtn. ECP's	$2,107,229.00
WATER QUALITY	CHRISTMAS VALLEY	708		6/1/2004	EL DORADO	CTC has identified 3 CIP'S in this area which need re-vegetating: rock lined ditches, curbs, gut, retaining walls, and rock slope protection. Treatment facilities (sediment basins) also likely required.	$2,628,145.00
WATER QUALITY	SOUTH UPPER TRUCKEE & GRASS LAKE ROAD	709		6/1/2004	EL DORADO	Erosion source controls and stormwater treatment faculties associated with the grantees roadways. Improvements will include revegetation. of disturbed soils; drainage stabilization (e.g. paved gutters, rock lined channels), infiltration and sedimentation	$3,159,344.00
WATER QUALITY	SR 89 LUTHER PASS TO HWY 50 JUNCTION	1012	6/1/2004	6/1/2007	CALTRANS	The project involves slope stabilization, water collection, and treatment improvements along 8.56 miles of road from El Dorado mile post 0.00 to mile post 8.56.	$8,000,000.00
	PROGRAMS					SUBTOTAL	$42,240,985.00
WILDLIFE	REVIEW & REVISE WILDLIFE DISTURBANCE ZONES	341	9/1/2002	9/1/2004	TRPA	PROGRAM. Review the current special interest species disturbance, influence zone language, ecologically significant areas, and revise as appropriate (based upon watershed assessment) to update for 2007 wildlife thresholds and Regional Plan.	$200,000.00
WILDLIFE	REVISE REGULATIONS REGARDING SNAG & DOWN WOODY DEBRIS	342	5/1/2000	5/1/2000	TRPA	PROGRAM. Revise regulations regarding snag and down woody debris to accommodate wildlife needs.	$20,000.00
WILDLIFE	BEAVER MANAGEMENT PLAN	586	1/1/2005	11/1/2005	USFS	PROGRAM. In coordination with land managers, resource agencies and TRG develop and implement a beaver management plan.	$50,000.00
WILDLIFE	WILDLIFE SPECIAL INTEREST SPECIES MAP & DATABASE	592			USFS	PROGRAM. Annually update special interest species maps and database, create a "real-time" monitoring database through this process. (On going program, $20,000 per year).	$20,000.00
WILDLIFE	ASPEN COMMUNITY SPATIAL DISTRIBUTION AND CONDITION ASSESSMENT	10029	5/1/2002	5/1/2002	TRPA	Using GPS, delineate all aspen stands in the Basin and import information into a GIS. Assess the condition of all aspen stands with respect to age, dbh, vegetation composition, soils, canopy cover, encroachment from conifers, biological activity, impact from roads and trails, pathogen levels, hydraulic and soil characteristics. Assessment should provide a measurable index of stand health so that managers are able to monitor aspen stand conditions in the future and prioritize stands for enhancements.	$100,000.00
WILDLIFE	WETLAND HUMAN DISTURBANCE BMP	10045	10/1/2000	5/1/2002	USFS	Assess current human movement and use patterns at wetland communities. Use assessment to redesign human movement by incorporating improved vegetation buffers and cover, set backs, fencing, interpretive signing, and improve or provide viewing platforms designed as blinds. The objective of this project is to reduce impacts to marsh associated species from disturbing human activities.	$16,000.00
WILDLIFE	ASPEN COMMUNITY RESTORATION PROJECTS	10080	12/1/2002	5/1/2003	MULTIPLE	On a landscape scale, aspen communities provide for habitat diversity. This project is intended to build from the "Aspen community spatial distribution and condition assessment". Restoration projects will focus on those aspen stands that have been identified as in a deteriorating condition. Restoration project should attempt to re-invigorate declining aspen communities using a variety of techniques such as conifer removal, mild burning, group selection thinning, and mechanical pushing. The goal of this project is to re-establish vigorous and self-sustaining, unevenaged stands of aspen throughout the region. Note** This project needs to be refined in terms of location for treatment and thus will effect the cost associated with this project.	$250,000.00
WILDLIFE	RIPARIAN WILDLIFE ENHANCEMENT: PHASE II	10142		7/1/2002	CTC	Regional riparian wildlife enhancement program. The objectives of this program are to identify disturbed riparian habitats and implement restoration and enhancement projects at identified sites. Program includes acquisition of riparian lands. This program directly relates to EIP # 1003.	$1,867,000.00
WILDLIFE	RIPARIAN WILDLIFE ENHANCEMENTS: PHASE III	10143		7/1/2005	CTC	Regional riparian wildlife enhancement program. The objectives of this program are to identify disturbed riparian habitats and implement restoration and enhancement projects at identified sites. Program include acquisition of riparian lands. This program directly relates to EIP # 1003.	$1,866,000.00
Total Cost (All Projects)							$46,629,985.00

TABLE 1.1: List of projects and programs located in the Upper Truckee River Watershed proposed in the Environmental Improvement Program. Note: This may not be an exhaustive list of every EIP project within the Upper Truckee River Watershed.

The CDPR owns a significant portion of the UTR and surrounding lands within the Lake Tahoe Golf Course (LTGC) and Washoe Meadows State Park. CDPR has been actively researching and implementing enhancement projects on the UTR and Angora Creek, having restored 7,000 linear feet of the latter over the past six years. CDPR is presently overseeing the design of a stabilization project in the LTGC at the crossings at Holes 6 and 7.

II. Historical Changes

II.1 UPPER TRUCKEE RIVER WATERSHED DESCRIPTION

The Upper Truckee River flows from Red Lake Peak near Carson Pass to Lake Tahoe near the Tahoe Keys Marina, a distance of over 20 miles. The watershed can be segmented into five distinct areas as shown in Figure 1.1:

- Upper Watershed
- Christmas Valley
- Meyers Area
- Sunset Ranch/Lake Tahoe Airport
- Lake Tahoe Blvd. to Tahoe Keys

This assessment is focused on projects that can be carried out within the UTR corridor from Elks Club Highway 50 crossing to a point about 2,000 feet upstream of South Upper Truckee Road, encompassing the Meyers Area, Christmas Valley, and a portion of the Upper Watershed. But it also addresses the watershed conditions affecting environmental quality system-wide, and several watershed issues have emerged from this assessment that are pertinent to the entire UTR and are discussed where appropriate.

The UTR watershed is an elongated basin draining over 54 square miles. The Upper Watershed varies in elevation from over 10,000 feet along the Sierra Nevada crest down to 6,500 feet above MSL at South Upper Truckee Road. The river originates in the steep volcanic bluffs of the Upper Watershed surrounding Meiss Meadow near Carson Pass. It then flows northward through meadows, forests, lakes and barren rocky areas in a terrain highly modified by repeated glaciations. The headwaters area is a bowl-shaped cirque that once held glaciers that formed and disappeared over the past 1.8+ million years. Glacial erosion processes carved the Upper Watershed and left large areas of bedrock scraped clean of soil. Other areas have glacial deposits of till and boulder erratics. Over ten perennial lakes, formed primarily by glacial processes, are found within the Upper Watershed. The northern end of these glacial deposits rests upon a prominent 800-foot high glacial step over which the Upper Truckee River cascades down in multiple waterfalls of bedrock and large boulders to the head of Christmas Valley.

The Upper Watershed is entirely owned by the USFS and is managed by the LTBMU. Only one public road, Highway 89, is open for vehicular access and crosses over Luther Pass along Grass Lake and Grass Lake Creek on the southeastern side of the watershed. The remaining area has foot trails, equestrian access, and some designated mountain bike trails.

Christmas Valley is a classic U-shaped glacial valley created during the earliest and largest glaciation of over 1.8 million years ago. Since that time, glaciers have not advanced past the Upper Watershed, and the ancestral and present UTR have transported remobilized glacial sediments, carved floodplains and terraces, and interacted with higher and lower stands of Lake Tahoe. The valley floor in Christmas Valley is relatively flat and bounded by valley walls on the east and west that rise steeply over 1,000 feet. The area has a conifer forest cover with areas of meadows and aspen groves situated along the UTR tributary streams and springs. The Upper Truckee River flows within a geologically incised corridor, down the middle of the valley for six miles to the Meyers Highway 50 crossing. Deep, boulder lined reaches are separated by wider, alluvial floodplain areas of meadows and aspen groves. The valley floor has been developed since the 1960s with residential housing and summer cabins, most on city-sized lots criss-crossed by numerous all-season roads. Land ownership in Christmas Valley is a mix of private residential and ranch lands with State and LTBMU holdings interspersed.

The Meyers Reach is situated between the Meyers and Elks Club Highway 50 crossings. At Highway 50, the UTR changes abruptly from a confined, boulder-lined and geologically incised channel of Christmas Valley to a wider, alluvial river/floodplain corridor, free of boulders and bedrock, contained within the wider floor of Lake Valley. The UTR flows within a 100 to 200 foot wide, recently formed channel/floodplain system, bounded by low terraces of recently abandoned floodplain and high terraces of ancient ice age glacial outwash. The UTR flows through a narrow band of mixed conifer and riparian forest, past the reclaimed gravel pits of Lake Baron and through Washoe Meadows State Park before emerging into a reach bounded by a former large meadow that is now the Lake Tahoe Golf Course (LTGC).

Angora Creek enters the UTR at the lower downstream end of the golf course. Angora Creek drains a 5.9 square mile watershed that originates at Angora Lakes before flowing through residential neighborhoods, large meadows and the LTGC. 7,000 linear feet of the lower reaches of Angora Creek have been restored, including the last 600 feet flowing through the LTGC.

A second unnamed tributary (0.81 square miles) flows northward from Meyers into the UTR at Hole 10 of LTGC. This highly altered stream originates in the Tahoe Paradise Golf Course in Meyers before flowing northward across Highway 50, through a channelized ditch in the Tahoe Paradise residential area, then emerging onto the LTGC. The stream flows for 3,000 feet between fairways before flowing into the UTR near the clubhouse.

The UTR in the Meyers Reach predominately flows through State of California owned land; the exceptions are the land east of the river near Lake Baron and part of the land north of the river at the upstream end of the golf course.

The downstream boundary of the Meyers watershed area and the Upper Reach project area is the Elks Club Highway 50 crossing.

Below the project reach the UTR flows through Sunset Ranch, Lake Tahoe Airport and the channelized section near the Tahoe Keys. Much of the lower UTR flows though broad meadows surrounded by urbanized land. Nearly all of the lower reaches were channelized to accommodate grazing in the 1860s and for the construction of the Lake Tahoe Airport in the early 1960s. Environmental conditions in these areas are being addressed through the preparation of earlier plans (Middle Reach UTR – January 2003) and ongoing planning efforts (Lower West Side – Barton Meadow – CTC).

II.2 ORIGINAL CONDITIONS

Understanding the current environmental condition of the UTR requires a comparison with the best estimation of the original river form and process prior to introduction of European land use in the 1860s. The original pre-1860s condition resulted from geologic forces and recent climatic history, within which native vegetation and wildlife communities evolved and adapted to the environment of the late Holocene Epoch (past 10,000 years). This followed the end of the last glacial period of 26,000 to 18,000 years before the present. In order to recover ecosystem function, it is important to understand recent geologic history, the land use changes and their effect on ecosystems, in addition to the hydrologic and geomorphic processes that create and sustain the ecological habitat.

The geology of the UTR has been highly influenced by the large scale tectonic interaction of the Pacific and North American Plates and the evolution of the west coast of North America and San Andreas Fault system to the west. The oldest rocks in the watershed date back to the Mesozoic Era (over 150 million years ago) when the west coast of North America was expanding westward by accretion of continental crust that floated in on eastward moving plates. At this time, the west coast of California was a subduction zone, similar to the present west coast of South America where denser, eastward moving plates of oceanic crust plunged under the lighter and more buoyant continental crust. The ubiquitous outcroppings of granite visible in the Sierra Nevada today originated through the partial melting of the consumed oceanic crusts in the upper mantle. The melted constituents were lighter and more buoyant. The crust began a long cooling period that allowed for the formation of crystalline granitic rocks; these granitic rocks were later exposed by tectonic uplift and erosion to form today's Sierra Nevada.

The present Sierra Nevada began uplifting 5.0 million years ago during the Pliocene Epoch, and since that time, the Sierra Nevada crest has risen over 5,000 feet in the UTR / Lake Tahoe area. As the Sierra Nevada uplifted, the land around Lake Tahoe stretched until three large blocks broke apart and formed, from west to east, the uplifted Sierra Nevada Crest, the down dropped Lake Tahoe graben and the uplifted Carson Range. Lake Tahoe was originally a northward sloping valley until volcanic flows and movement along faults formed the mountains along the north end of the Lake from Mount Rose to the Truckee River, which blocked drainage and created the Lake.

The UTR lies at the boundary of the Sierra Nevada and Basin and Range Provinces (Figure 2.1). The major faults that bound the three blocks originate in the UTR Upper Watershed and form the boundaries of Christmas Valley, before trending northward to Meyers where they split; the western fault continues north along the west shore of Lake Tahoe and the Sierra Nevada Front; the eastern fault bends eastward toward the Nevada side of Lake Tahoe and the Carson Range. These faults are still active and, in places, display ground breaks through sediments less than 10,000 years old.

The bedrock of the UTR watershed is predominately granitic; however there are significant outcroppings of highly erodible, tertiary-aged volcanic rocks that occur along the crest of the Upper Watershed. These were formed during the major volcanic eruptions of the Miocene period (5-24 million years ago) that covered the entire Sierra Nevada; subsequent erosion by glaciers and flowing water removed much of the original volcanic rock cover. A soils map is presented in Figure 2.2.

Geomorphology is concerned with recent and ongoing geologic processes of weathering, erosion and sediment transport and the development of landforms (e.g. hillslopes, valleys, streams, shorelines, etc.). The significant geomorphic events that formed the present UTR began over 2 million years ago when the first of four major glaciations occurred. Much of the evidence of the two earliest periods has been buried, re-worked or destroyed by the later two: the larger Tahoe period (60,000 to 90,000 years before present) and the later and smaller Tioga phase (18,000 to 26,000 years before present).

Birkeland (1963) identified limited exposures of the post-Plio-Pliestocene Hobart Till north of Lake Tahoe and in the Truckee River canyon below the Lake Tahoe outlet and postulated a pre-Wisconsian (pre-Tahoe) age well over 600,000 years before present. The second pre-Wisconsian was the “Donner Lake” glacial period 400,000 to 600,000 years ago, which at times blocked the Truckee River canyon north of Tahoe City with ice raising the level of Lake Tahoe by up to 600 feet above present levels (elevation 6800 feet above sea level). Periodic breaching of the ice dams caused large, catastrophic floods to spill down the Truckee River into the Truckee Meadows of present day Reno, carrying boulders as large as ten feet in diameter.

The later Wisconsian glaciations also raised Lake Tahoe to varying degrees. The earlier and larger Tahoe glacial period may have raised Lake Tahoe 90 feet above its present level; prominent shoreline terraces around the Lake indicate a constant level, 90 feet higher than present, but other shoreline terraces are found at 40 and 80 feet above present lake level.

Evidence for the Tahoe and Tioga period glaciers is well recorded on the south and west shore of Lake Tahoe (i.e. Fallen Leak Lake, Emerald Bay, Meeks Creek watershed), however the moraine deposits are not found north of the Upper Watershed of the UTR (i.e. the terminal moraines of recent times end at Cookhouse Meadow (elevation 7,000 feet)) and to the west. Terminal moraines from the Echo Lake area end just west of the Meyers Highway 50 crossing.

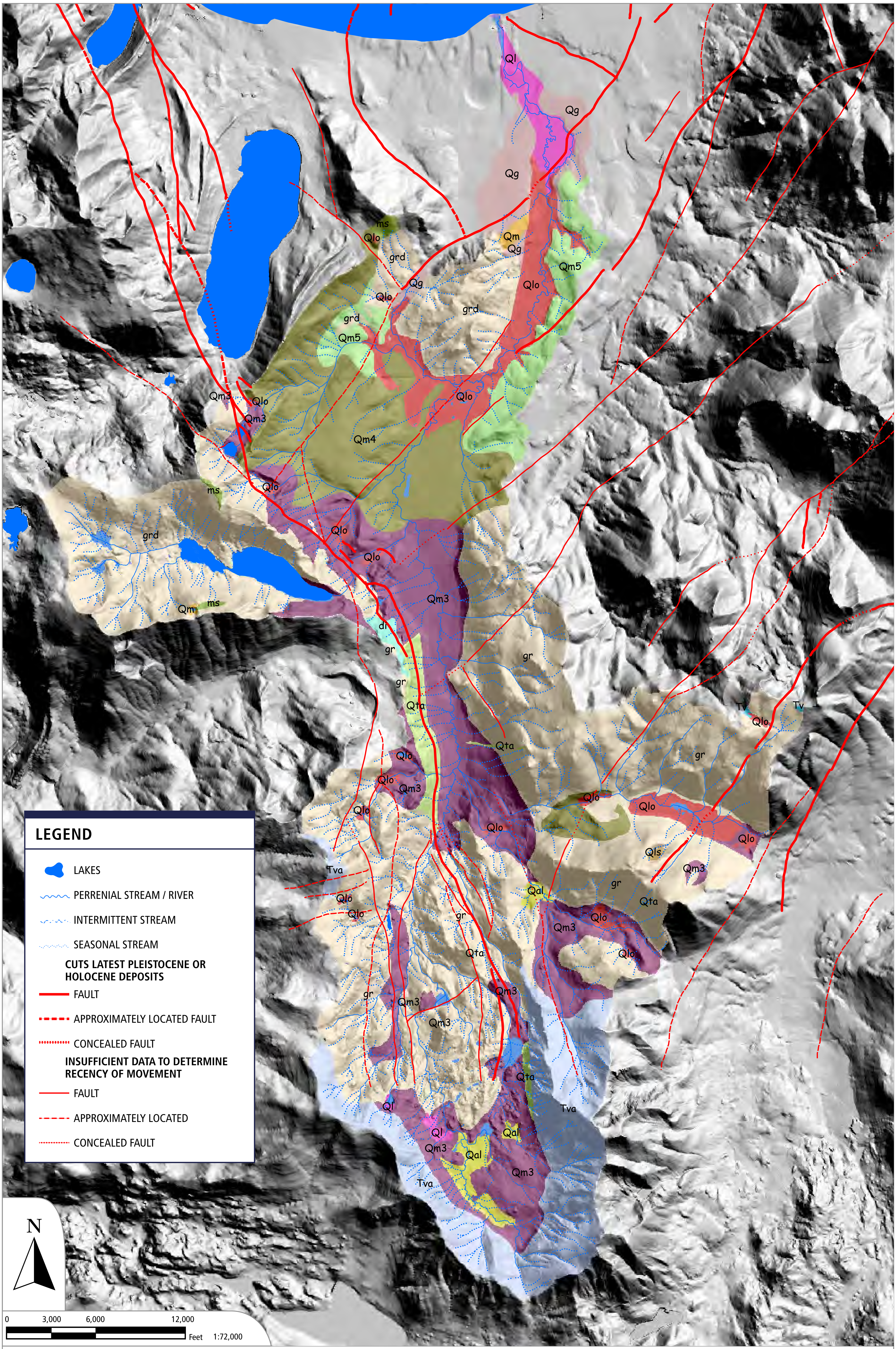

FIGURE 2.1A: Upper Truckee River Geology Units Map. Refer to Figure 2.1B for for geologic units legend and desription. Faults source data: R.A. Schweickert, et.al. 1999.

Geologic Formations

Qal	Lake and Stream Sediments/ Deposits/ Alluvium
Qg	Glacial Outwash Deposits
Ql	Older Lakebed Deposits
Qlo	Older Lake Sediments
Qls	Rockslides
Qm	Glacial Deposits/ Moraines Undifferentiated
Qm3	Tioga Till Glacial Moraines
Qm4	Tahoe Till Glacial Moraines
Qm5	Pre-Tahoe Till
Qta	Talus
Tv	Undifferentiated Volcanic Rocks
Tva	Dominantly Andesite Breccias
di	Intrusive Rocks (diorite)
gr/grd	Granite Rocks
ms	Metasedimentary Rocks

Soil Types

Ca	Cagwin Series	C	The Cagwin series consists of gently rolling to very steep, somewhat excessively drained soils that are 20 to 40 inches deep over granitic material, or grus.
Co	Celio Series	D	The Celio series consists of poorly drained soils that are 40 to 60 inches deep over a very gravelly hardpan strongly cemented with silica.
Eb	Elmira Series	Variations in A & D	The Elmira series consists of nearly level to moderately steep, somewhat excessively drained soils that are underlain by sandy granitic alluvium or highly weathered till.
Ge	Gefo Series	A	The Gefo series consists of nearly level to moderately steep, somewhat excessively drained soils that are underlain by sandy granitic alluvium.
Ja	Jabu Series	Variations in B, C & D	The Jabu series consists of nearly level to moderately steep, well drained to moderately well drained soils that are about 40 inches deep over a dense fragipan.
Mk	Meeks Series	B	The Meeks series consists of level to very steep, somewhat excessively drained , stony soils that are 40 to 71 inches deep over a hardpan cemented with silica.
Mx	Mies Series	D	The Mies series consists of strongly sloping to steep, excessively drained soils that are 10 to 20 inches deep over hard andesitic rock.
Tc	Tallac Series	Variations in B & C	The Tallac series consists of gently sloping to steep, well drained and moderately well drained soils that are 40 to 70 inches deep over a weakly silica cemeted hardpan.
Tr	Toem Series	C	The Toem series consists of strongly sloping to very steep, excessively drained soils that are 8 to 20 inches deep over decomposed granitic material.
Wa	Waca Series	C	The Waca series consists of hilly to steep, well drained soils that are 20 to 40 inches deep over andesitic tuff.
Gr	Gravelly Alluvial Land	D	Gravelly Alluvial Land consists of small areas of recent gravelly alluvium adjacent to stream channels and in meadows.
Lo	Loamy Alluvial Land	D	Loamy Alluvial Land consists of small areas of recent alluvium adjacent to stream channels and in meadows.
Mh	Marsh	D	Marsh is in the Upper Truckee Marsh and in very poorly drained and in ponded meadows.
Px	Pits & Dumps	D	Pits and Dumps consists of sand and gravel pits, refuse dups, and rockl quarries.
Sm	Stony Colluvial Land	C	Stony colluvial land occurs in areas of colluvium from granitic, metamorphic, and volcanic rock and from highly fractured volcanic flow.
Fd	Fill Land	A	Fill land is sandy material dredged from the Upper Truckee Marsh to form a pad for urban development, mainly in the Upper Truckee Marsh area.
Rx	Rock Land	D	Rock land is in areas of granitic, metamorphic, and volcanic rocks.

Figure 2.1B: Legend describing geologic formations and soil types in the Upper Truckee River Watershed (Hydrologic soil group noted in blue).

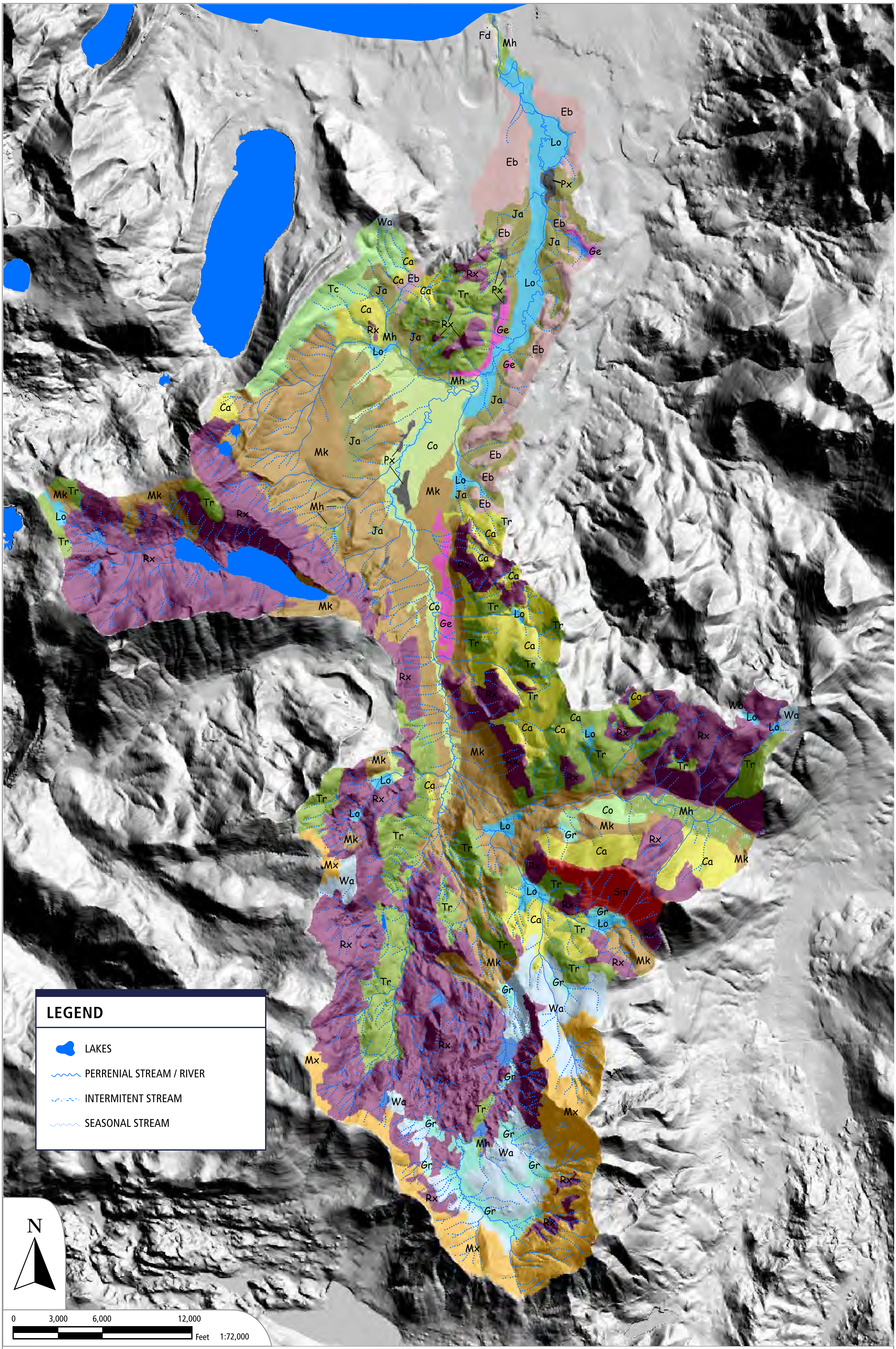

FIGURE 2.2: Upper Truckee River soils map. Refer to Figure 2B for legend and soil type descriptions.

The lack of glacial "till" deposits in Christmas Valley and downstream indicates that only the earliest glaciations could have carved Christmas Valley, Meyers and Lake Valley, and that the predominate geomorphic processes that formed the present landscape are related to active faulting, down-dropping valley floors, development of glacial outwash filled valleys and sub-aqueous glacial outwash deltas deposited below elevated stands of Lake Tahoe.

To understand the present UTR landscape and watershed, one has to imagine a dynamic sequence of rising and falling lake levels changing the base level for the UTR and the position of deltaic formation. Dramatic increases in sediment supply and stream flow during glacial periods were followed by drier interglacial periods, similar to present day conditions. Glacial outwash terraces, composed of large lag boulders, sand and gravel deposits, form the terraces along the floor of Christmas Valley and extending into Meyers; these outwash terraces merge into deltaic deposits in Meyers, which appear related to the 90 foot high Lake stand of the Tahoe glacial period. The boulders lining the bed of the UTR in many reaches of Christmas Valley may be the remnants of the early glaciations, and these end abruptly at the Meyers Highway 50 crossing. Older outwash deposits are found along the hills east of the Lake Tahoe Airport and west of the Lake Tahoe Golf Course.

Examination of aerial photographs and alluvial deposits along the UTR show evidence of the development of the modern, pre-disturbance UTR. Over the past 10,000 years, the UTR experienced a gradual drying, followed by a dry and warm period between 5,000 and 8,000 years before present. The present interglacial became slightly colder over the past 3,000 years and has remained fairly steady since. An investigation of pollen from Osgood Pond (Cushing, 1967), located just off Highway 50 near the Meyers Highway 50 crossing recorded this sequence of climatic change and vegetative response. In general, the pre-disturbance UTR was downcutting through the glacial outwash deposits, forming a meander belt and floodplain, riparian and wetland zone. There is evidence of past small lakes and ponds that have become meadows within the modern floodplain.

Figure 2.3 shows a geomorphic map of the UTR corridor and the delineation of glacial outwash terraces, deltaic deposits and the modern floodplain. The modern floodplain is the focus of attention with respect to estimating the pre-disturbance UTR ecosystem. It was formed in the present climate (past 10,000 years), as sediment supply and flow to the UTR from the watershed were greatly reduced. The UTR reworked and transported the materials in the outwash terraces and incised a narrow river corridor. There are places where erosion of the glacial outwash terraces continues and the UTR is slowly eroding through older outwash deposits but is geologically constrained.

II.2.A Geomorphic Variables Measuring Land Use Impacts

Examination of the physical form and processes of a river system falls within the study of fluvial geomorphology. To describe the original UTR system and the subsequent changes associated with land use effects, it is useful to define elements of river form.

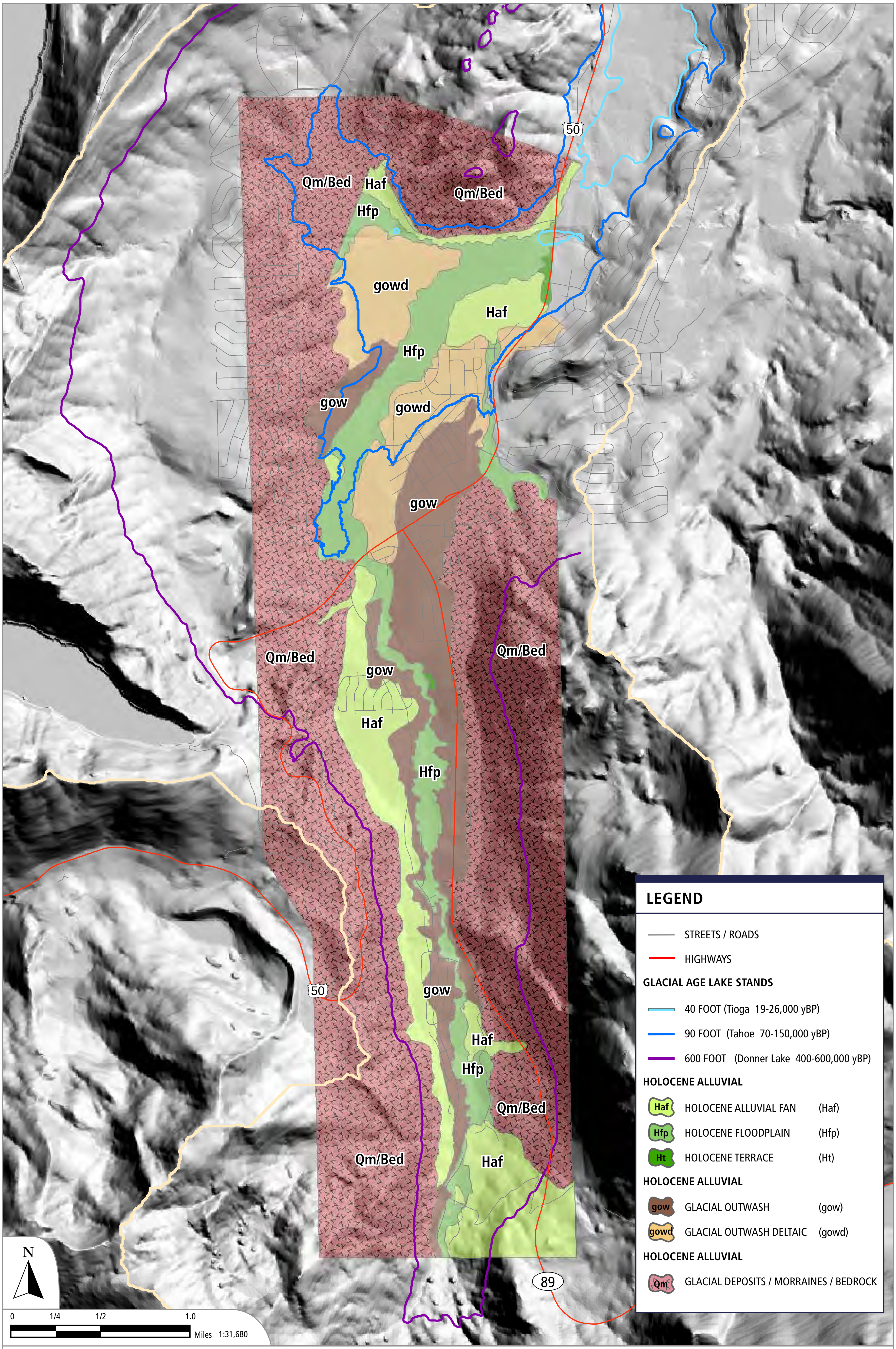

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FIGURE 2.3: Land form map of glacial age and Holocene units along Upper Truckee River, Upper Reach Project as mapped by SH+G. Lake stands reference: Birkeland, 1964 and Birkland, 1968.

Channel morphology refers to the geometric characteristics of the channel and the pattern of the river as viewed from above. Channel geometry refers to the width and depth of the channel as viewed in cross section. It is important to distinguish the signature of different flow levels and flood events and the features and associated hydrologic events between the various stages of a stream channel: the low flow channel contains the smallest flow events that generally occur over 90% of the time; the bankfull channel occurs less than 10% of the time and is associated with channel forming process such as sediment deposition on new floodplain, point bar development and outer bank erosion in a meandering stream. On the UTR annual snowmelt runoff events have the most frequent impact on channel morphology. The flood channel occurs at a stage that often fills the largest channel and spills out onto the valley floor or terraces; terraces are old floodplain surfaces originally constructed by the river at the bankfull stage that are now elevated and abandoned by the bankfull flows (Figure 2.4). The morphology of these features can vary, especially when the stream in question is not fully “alluvial” and has geologic controls such as bedrock or older resistant materials along its boundaries that limit erosion.

Channel pattern refers to the shape of the river’s path which generally falls into one of three categories: straight, meandering and braided. Generally, the pattern of interest is that of the bankfull channel, since it represents the present channel and floodplain forming processes. Most streams are meandering streams and sinuosity is the measure of curve of the river.

Finally, the channel longitudinal profile is of keen interest to tracking the impacts of historical land use effects. The longitudinal profile is a plot of the lowest points (i.e. thalweg or flow line) occurring along the path of the channel (Figure 2.5). The longitudinal profile exhibits the slope of the river and thus a measure of hydraulic energy grade of flows and erosive force.

The earliest aerial photograph available of the UTR is 1940 (Figure 2.6), which is 80 years following the introduction of intensive European land use during the Comstock Era. These photos show the river system already affected by grazing, reclamation, logging and roads and bridges. In order to estimate pre-1860 conditions, other indirect evidence must be used. Using a combination of aerial photographs and recent topographic data (1-foot contour LIDAR Map supplied by TRPA) an “original” channel pattern was developed (Figures 2.7A-D) along with the channel pattern shown in 1940 and 2003 aerials. The “original pattern” is that represented by drawing and connecting visible meander scars on Holocene floodplain areas, the 1940s from the 1940 aerial photographs, and 2003 from the LIDAR image and topographic map. The resultant channel pattern plot reveals an overall loss of pattern sinuosity of 20 percent in the Meyers Reach from 1.70 to 1.35; the loss in the Christmas Valley Reach is less, but measurable and significant in discrete reaches. A comparison of sinuosity of Reaches 1 – 4 in the original, 1940 and 2003 channels can be found in Table 2.1.

The loss of channel pattern sinuosity is related to the early European land use practices of land reclamation for grazing. Pattern sinuosity is a naturally developed characteristic of a stream, reflecting a balance of sediment supply, sediment sizes, flow and the natural tendency of a river

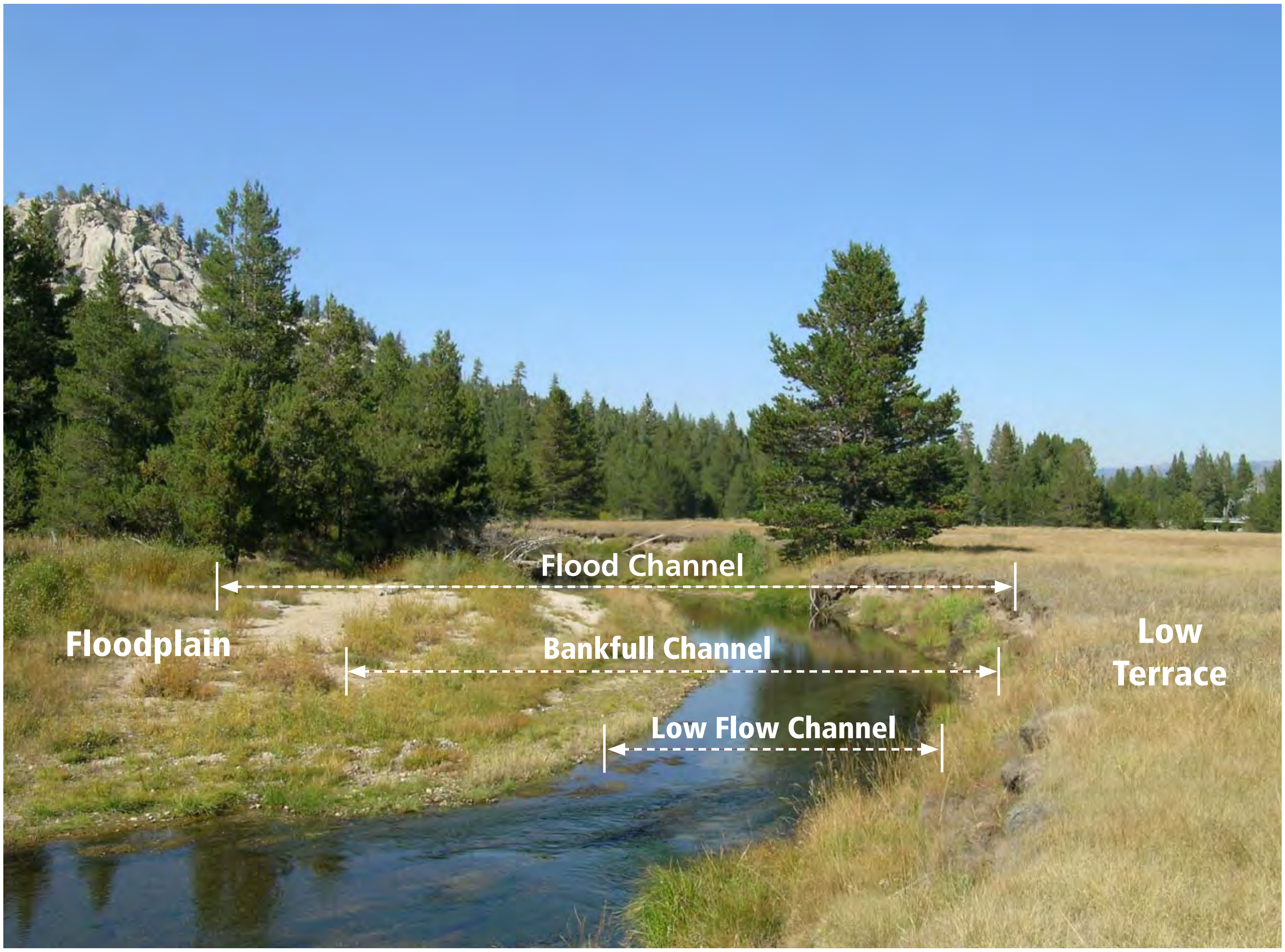

FIGURE 2.4: Photo of Upper Truckee River at SH+G river station 1800 indicating locations of flood channel, bankfull channel, low flow channel, floodplain and low terrace.

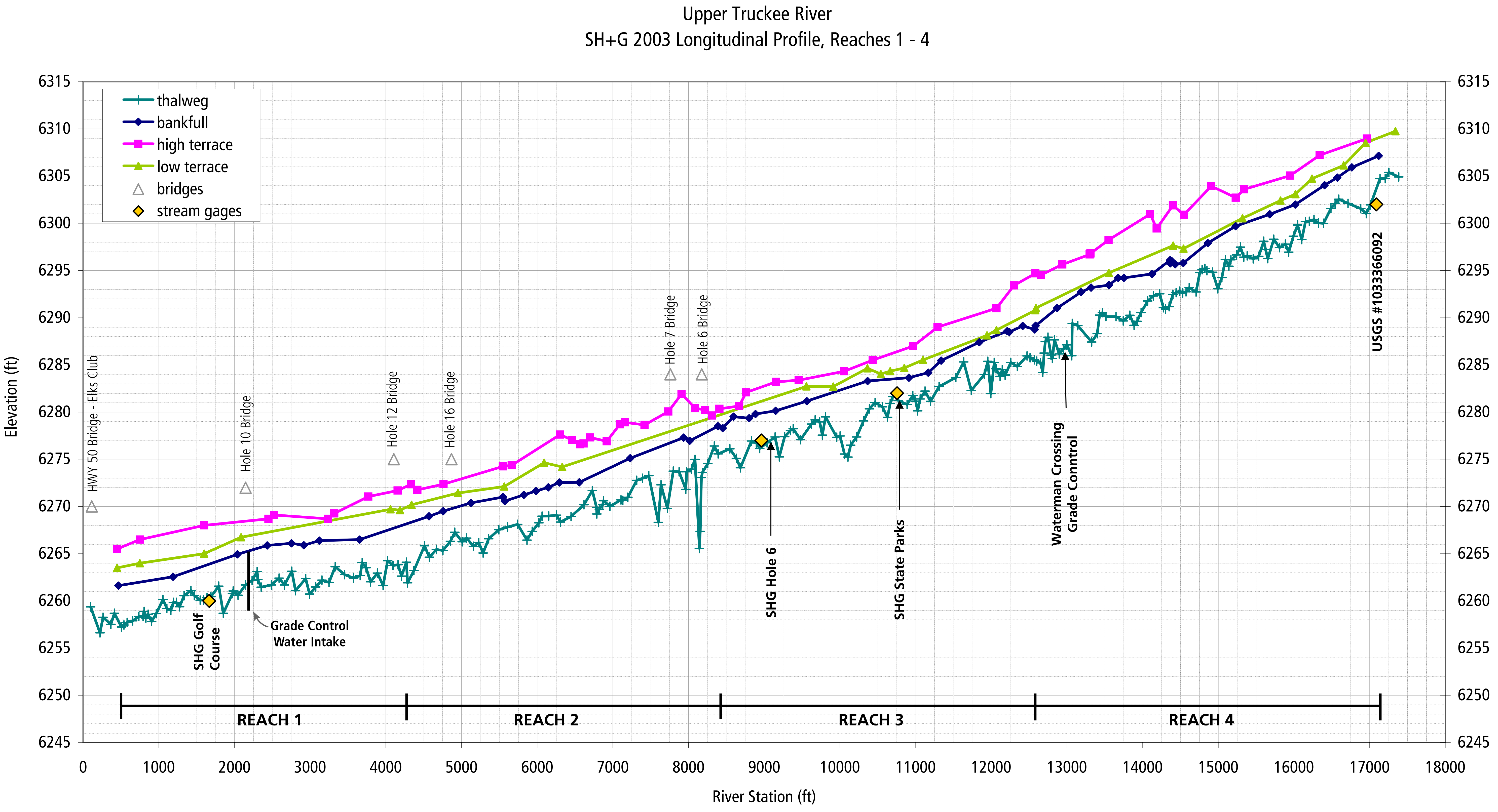

FIGURE 2.5: Longitudinal profile of Upper Truckee River from Elks Club Highway 50 crossing to Meyers Highway 50 crossing (Reaches 1-4). Bankfull, low terrace and high terrace features were also surveyed in the field.

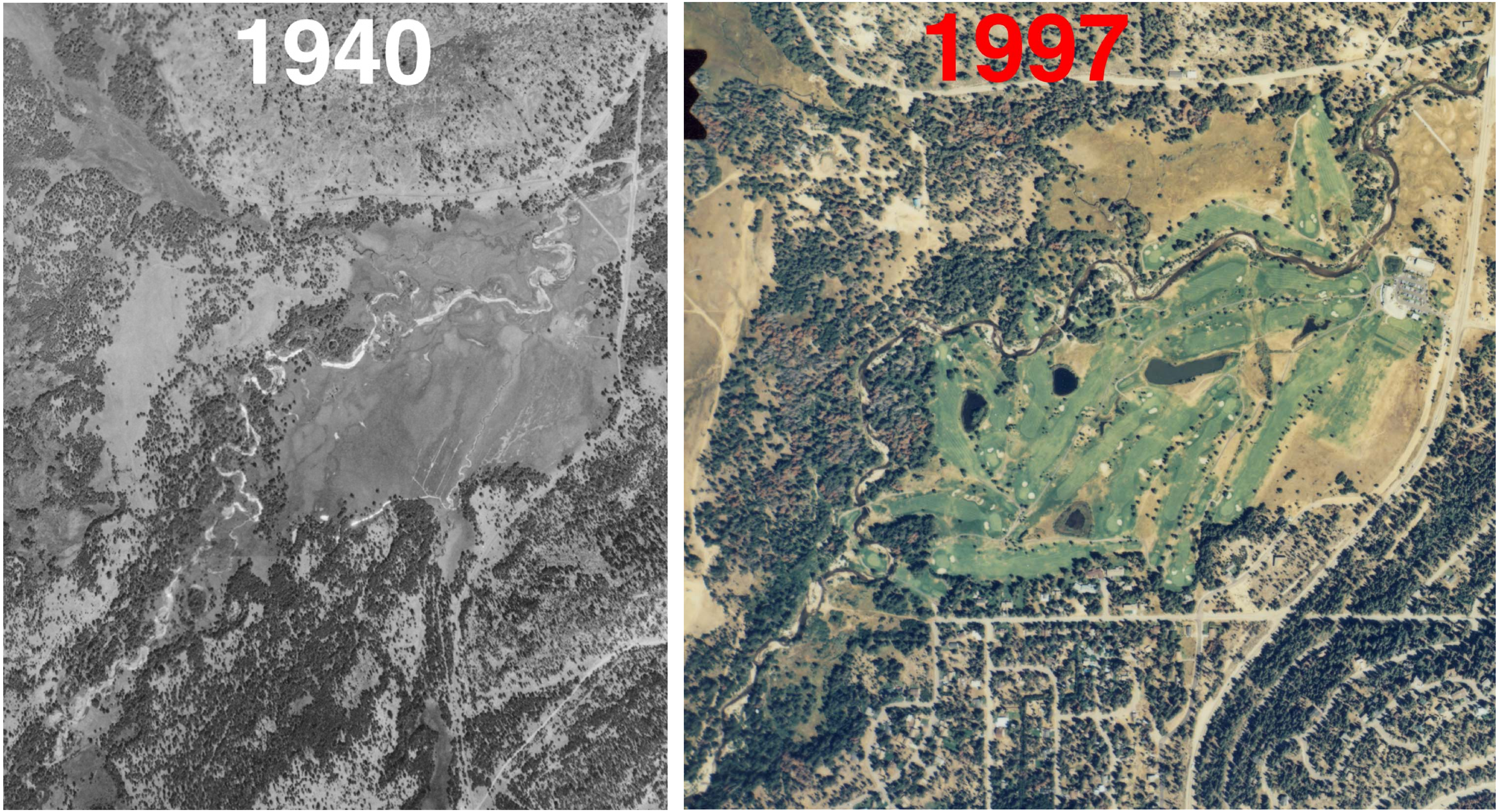

FIGURE 2.6: Aerial photographs of the Upper Truckee River from 1940 and 1997.

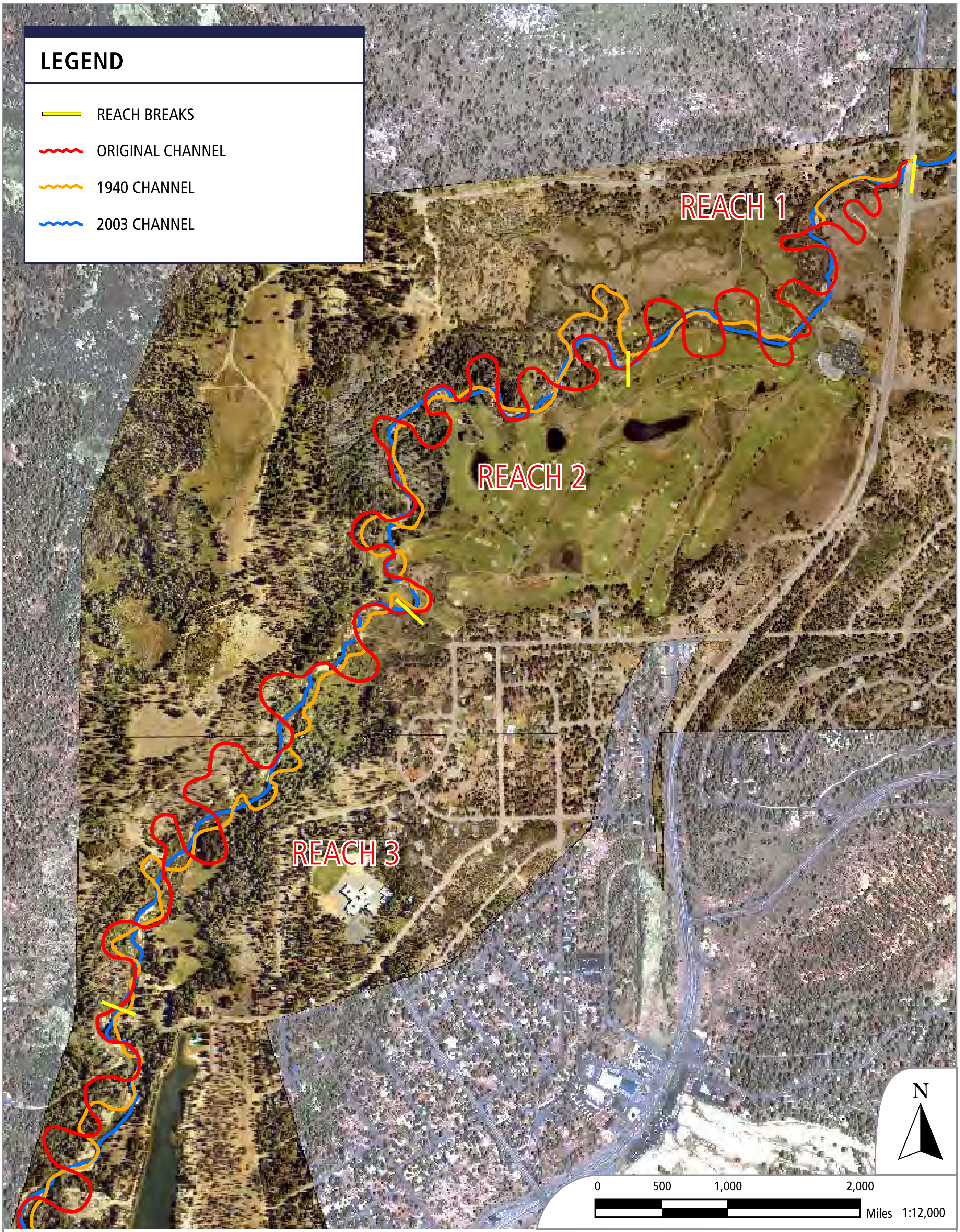

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FIGURE 2.7A: Illustration of channel pattern for the original interpreted channel, 1940 channel, and present day channel (2003 channel) in Reaches 1-3.

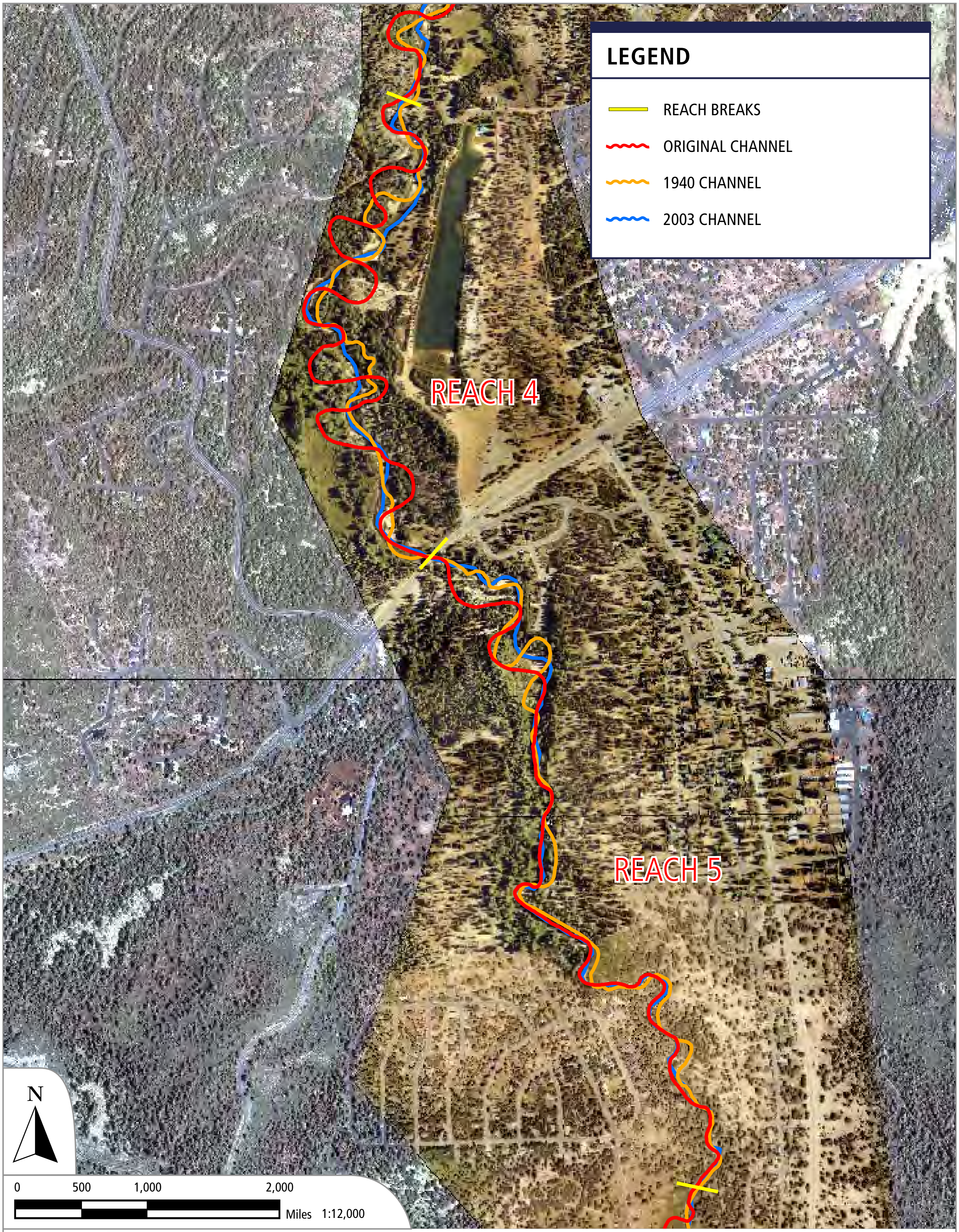

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FIGURE 2.7B: Illustration of channel pattern for the original interpreted channel, 1940 channel, and present day channel (2003 channel) in Reaches 4-5.

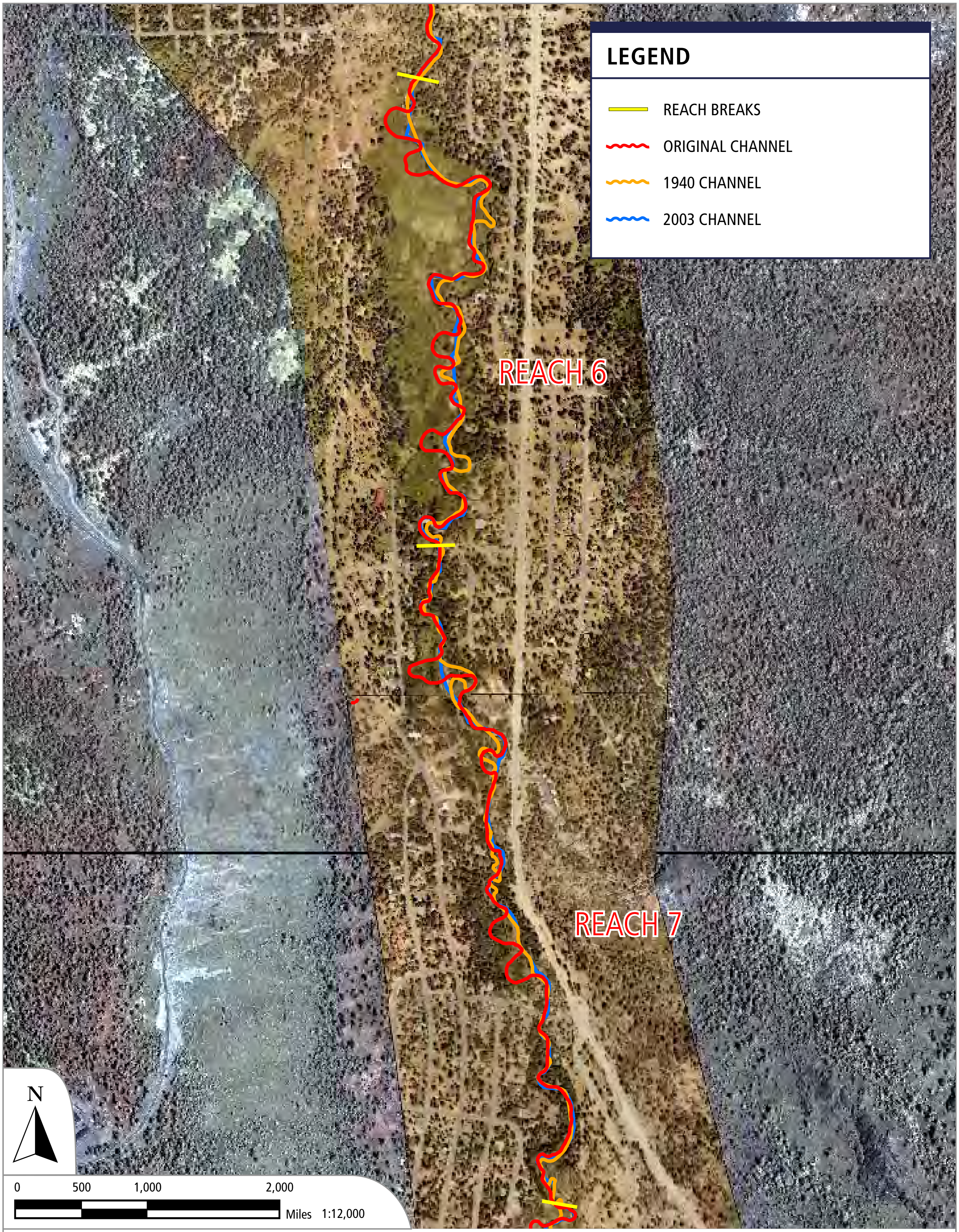

FIGURE 2.7C: Illustration of channel pattern for the original interpreted channel, 1940 channel, and present day channel (2003 channel) in Reaches 6-7.

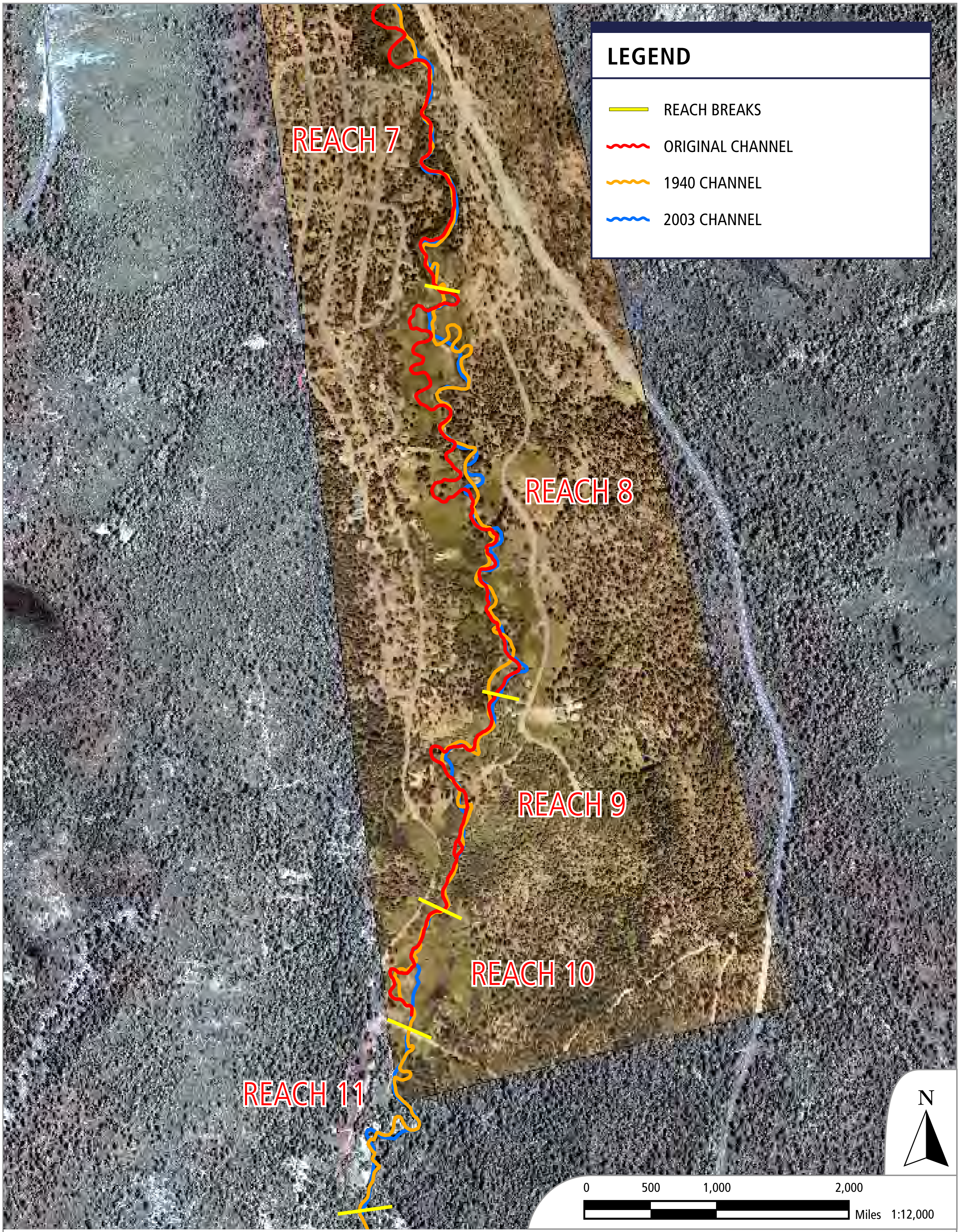

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FIGURE 2.7D: Illustration of channel pattern for the original interpreted channel, 1940 channel, and present day channel (2003 channel) in Reaches 7-11.

Sinuosity

Reach ID	Original Channel			1940 Channel			2002 Channel		
	Channel Length (ft)	Valley Length (ft)	Sinuosity	Channel Length (ft)	Valley Length (ft)	Sinuosity	Channel Length (ft)	Valley Length (ft)	Sinuosity
1	6721	2555	2.6	4603	2555	1.8	3650	2555	1.4
2	7229	2594	2.8	6597	2594	2.5	4383	2594	1.7
3	7239	3795	1.9	5329	3795	1.4	4425	3795	1.2
4	7432	3844	1.9	5202	3844	1.4	4745	3844	1.2
5	7442	5130	1.5	7941	5130	1.5	7245	5130	1.4
6	6845	3615	1.9	5449	3615	1.5	5362	3615	1.5
7	7557	5120	1.5	7016	5120	1.4	6162	5120	1.2
8	5443	3080	1.8	4843	3080	1.6	4922	3080	1.6
9	2279	1679	1.4	2315	1679	1.4	2148	1679	1.3
10	1345	938	1.4	1208	938	1.3	1096	938	1.2
11	1935	1427	1.4	2282	1427	1.6	1934	1427	1.4
Total	28621	12789	2.2	21730	12789	1.7	17202	12789	1.3

Meander Length

Reach ID	Original Channel		1940 Channel		2002 Channel	
	Average (ft)	Standard Dev.	Average (ft)	Standard Dev.	Average (ft)	Standard Dev.
1	423	161	433	72	341	N/A
2	423	97	366	145	361	92
3	563	90	289	81	383	81
4	577	74	276	105	509	233
5	397.5	98.5	385.1	85.5	353.1	66.6
6	249.3	70.5	187.0	51.5	320.9	125.9
7	270.1	76.2	142.0	51.3	358.6	120.4
8	197.6	32.8	190.2	43.7	204.2	36.3
9	262.4	n/a	209.9	70.1	265.7	9.3
10	203.4	37.1	111.5	n/a	124.6	17.0
11	246.0	n/a	115.6	52.0	177.1	n/a

Radius of Curvature

Reach ID	Original Channel		1940 Channel		2002 Channel	
	Average (ft)	Standard Dev.	Average (ft)	Standard Dev.	Average (ft)	Standard Dev.
1	122	68	165	48	113	9
2	109	39	107	43	108	40
3	137	26	82	42	163	56
4	134	29	73	34	172	91
5	99.1	23.9	103.8	39.8	103.6	19.7
6	63.6	23.5	41.5	15.2	100.5	51.6
7	68.3	27.6	35.6	28.1	114.0	30.4
8	48.2	11.4	46.6	20.3	56.2	16.5
9	111.5	32.5	68.6	43.2	99.6	30.0
10	64.8	8.7	36.9	12.8	42.4	12.6
11	121.4	9.3	28.5	10.1	86.1	54.5

TABLE 2.1: A comparison of planform characteristics for the original, 1940 and present (2002) Upper Truckee River channel. Channels shown on historical aerial photographs were analyzed in GIS to calculate measurements.

to transport sediment and flow in a manner that dissipates energy at an even rate. The interplay of pattern sinuosity, vegetation and small-scale erosion and sediment deposition patterns create hydraulic diversity in the channel, pools, riffles, undercut banks and well sorted coarse substrate – the medium for macroinvertebrates and salmonid spawning. Riffle elevations control surface water low flow elevations and the seasonal groundwater elevations in the surrounding floodplain areas. Groundwater elevation is a key physical factor for wetland and riparian vegetation growth on the adjacent floodplain areas.

The reduction of pattern sinuosity indicates a trend towards channel shortening, a steepening of channel slope and an increase in erosive force. Erosive force and the ability of the stream to move sediment is related to the product of flow depth and channel slope (i.e. mass of water times the energy slope). The overall effect is deepening or incision of the channel into the underlying substrate and a disruption of channel stability. Channel incision is self-feeding, in that channel deepening increases erosive force which in turn increases depth and so on. Deepening the channel also decreases bank stability by undercutting root strength of vegetation and increasing bank height. With channel deepening, there is a response towards forming a wider channel to reduce flow depth and erosive force; eventually the stream forms a new meander belt, lengthens and aggrades, if the independent variables of sediment supply and flow imposed by the watershed remain relatively constant.

Early historical land uses can account for the change in sinuosity between original and 1940. The onset of the Comstock Mining Boom to the east in Virginia City in 1860 led to the development of roads through the UTR watershed between Sacramento and San Francisco. This led to creation of toll houses along the way and the need for dairy and cattle products. The meadows along the UTR were ideal for grazing, and it is apparent that strategies of controlling snow melt runoff by increasing channel depth allowed for earlier seasonal grazing entry to meadows. Construction of diversion works enabled late season irrigation, extending the production of the meadows well into late summer. These practices are clearly visible on the 1940 and 1952 aerials in the lower project area at the present site of the Lake Tahoe Golf Course (Figures 2.6 & 2.8). The LTGC is the site of a former dairy (Lindström, 2003).

Other historic land use practices have contributed to channel straightening and incision. Bridge and road crossing construction often involves placing earthen fill along the approaching road, preventing flow from accessing the floodplain and creating a bottleneck. This change, although quite localized, can dramatically cause incision for considerable distances upstream and downstream of the crossing. Blocking the floodplain concentrates all of the hydraulic force through the bridge opening; in many cases, the channel is dredged within the local reach to maximize channel flood capacity and minimize flooding over the roadway. The presence of a bridge can create a deeper scour zone that may initiate a headcut that over time can migrate upstream. As described above, channel deepening increases hydraulic force for erosion and increases the ability of the flow to move more sediment (i.e. increased transport capacity) and larger sediment sizes (i.e. transport competence). Thus, channel deepening often increases the supply of sediment to downstream reaches and often in quantities and sizes that the normal

FIGURE 2.8: Aerial photograph taken in 1952 of Upper Truckee River upstream of the Elk's Club Highway 50 crossing (Reaches 1-3).