Burke Creek Restoration Potential and Design Concepts

For Portions Both Inside and Outside the Sierra Colina Parcel
and for
Consideration in the TRPA Burke Creek EIP #161 Study

Final Memorandum

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1.0 Purpose, Scope, and Background

At two locations, Burke Creek crosses the Sierra Colina parcel (APN #1318-23-301-001) in Stateline Nevada, as shown in Figure 1. The portion of the channel nearest Highway 50 on the Sierra Colina property was realigned by adjacent commercial and public property owners, primarily in the 1970s and 1980s, to the north of its historical location and onto the Sierra Colina parcel. This work resulted in a constructed channel that runs near the southern boundary of the parcel. Restoration of the Burke Creek channel, including this realigned portion, has been the subject of several previous studies, and is the focus of an ongoing project by the Tahoe Regional Planning Agency (TRPA) as Environmental Improvement Project (EIP) #161.

Sierra Colina, LLC acquired the parcel in April 2005, and is interested in completion of planning and implementation of improvements for EIP #161, which it understands will aim to preserve and enhance Burke Creek. Sierra Colina, LLC retained Northwest Hydraulic Consultants (**nhc**) to conduct a reconnaissance of Burke Creek for two purposes: 1) to identify problems and evaluate restoration potential within the boundaries of the Sierra Colina parcel; and 2) to identify problems and evaluate restoration potential outside the perimeter of the Sierra Colina parcel for consideration by the TRPA, the U.S. Forest Service and the other institutional partners and consultants involved with the EIP #161 study. With these two purposes in mind, **nhc** reviewed background information and conducted a reconnaissance of Burke Creek between Highway 50 and the Lower Kingsbury residential development upstream (east) of the Sierra Colina parcel.

The Sierra Colina Village project application to the TRPA contains a proposal for approximately 70% of the Sierra Colina parcel to remain preserved open space, possibly through a charitable land conveyance or open space easement, and the portions of Burke Creek inside the Sierra Colina parcel will not be directly affected by construction of Sierra Colina Village. However, Sierra Colina, LLC has indicated a willingness to consider potential restoration actions for the portions of Burke Creek on its property, or a proportionate contribution to the overall Burke Creek restoration effort, if this is associated with an approved Sierra Colina Village project.

The Sierra Colina Village project is in the preliminary design phase and will proceed to environmental review prior to completion of planning for EIP #161. The preliminary design shows the Sierra Colina Village improvements situated to north and west of the SEZ. All proposed buildings and the road are located outside the SEZ boundary and due to the natural topography of the parcel the majority of storm water runoff will drain away from the SEZ. A small portion of the total building area is tributary to the SEZ in the northeastern corner of the parcel. A separate analysis for water quality design to address runoff from the proposed Sierra Colina Village is currently being prepared by **nhc** independent from potential future restoration contemplated by the EIP #161 study. The water quality design will minimize and mitigate effects on Burke Creek from the proposed Sierra Colina development.

In addition to the analysis provided in this document, Sierra Colina retained **nhc** and the Nevada Tahoe Conservation District (NTCD) to conduct a year long water quality monitoring study of Burke Creek in the vicinity of the Sierra Colina property. The monitoring effort is designed to provide baseline data and assess the current function of the Burke Creek Stream Environment Zone (SEZ) with respect to water quality on the Sierra Colina property and in the vicinity of Sierra

Colina. The monitoring workplan and two quarterly status reports are currently available for review separate from this document.

Section 2 of this memorandum provides a brief review of background information on Burke Creek to provide historical perspective. Section 3 describes **nhc's** field observations. Section 4 presents some preliminary restoration concepts based on **nhc's** observations. Restoration concepts are offered for further consideration and study as part of EIP #161. Although a purpose of the reconnaissance was to develop recommendations for potential independent restoration work on the Sierra Colina parcel, our observations indicate that restoration activities should be conducted as a coordinated project for a larger reach of stream. The basis for this recommendation is also included in Section 4. Recommended next steps for Sierra Colina, LLC include: 1) participation in the TRPA EIP #161 project to identify potential collaborative efforts, and 2) deference of specific designs or restoration activities until a more comprehensive plan is developed.

Figure 1. Approximate Alignment of Burke Creek Looking Upstream

2.0 Burke Creek Background

A brief overview of Burke Creek historical disturbance and more recent restoration efforts provides context for considering the current potential restoration opportunities and design considerations for Burke Creek. Historically, the Burke Creek watershed was subject to both logging and grazing disturbances. The watershed was logged extensively in the late 1880s, like much of the surrounding area in the Lake Tahoe Basin, to supply timber to mining and development during the Comstock Era. The Burke Creek meadow was used intermittently for cattle grazing until about 1978 when the US Forest Service (USFS) acquired the majority of land

within the Burke Creek watershed. With the exception of two 1,500 foot reaches across private property, Burke Creek now flows across USFS land.

Table 1 provides a list of some of the more significant disturbances and restoration projects within the Burke Creek watershed from the 1950s to the present. In the past, the channel was modified and moved in multiple locations to accommodate land use changes. Subsequently, a number of restoration projects have been conducted to mitigate the effects of urban development, including restoration of the channel in the Burke Creek meadow by the USFS.

Table 1. Timeline of Burke Creek Activities

Approximate Date	Activity
Late 1950s	Tahoe Shores Mobile Home Park constructed - downstream of Highway 50
Mid 1970s	Proposed Jennings Casino construction activity
1970s	Burke Creek in the vicinity of Sierra Colina was realigned and channelized when the Nugget Casino and parking lot were constructed (now Burger King)
1970s	Lower Kingsbury Development
1980s	Douglas County Kahle Park recreational fields constructed
1981	USFS implemented the Jennings Casino Site Restoration Project
1992	USFS and Douglas County reconstruct 2,000 feet of Burke Creek from Lake Tahoe to Kahle Ditch
October 2003	Kingsbury Village Erosion Control Project (Kingsbury North - EIP #240) completed in the upper Burke Creek watershed.
October 2004	Lower Kingsbury Erosion Control Project Phases I and II (EIP #239) completed in the Lower Kingsbury residential development. Project construction includes roughly 3,000 square feet of Burke Creek SEZ restoration.

Figure 2 shows a comparison of the historical (1950s) and existing conditions for Burke Creek, indicating extensive channel relocation and modification of the SEZ. The reach downstream of the highway has been the subject of an extensive restoration effort by the USFS following construction activities for the Jennings Casino near Highway 50. The highway culvert crossing and a portion of the channel located along the parking lot upstream of Highway 50 (including a portion of the channel on the Sierra Colina property) were modified and relocated some time in the 1970's. The channel in this area was relocated to the north, and the original SEZ excavated for construction of a commercial parking lot adjacent to the Sierra Colina southern property line. Just upstream of the parking lot, the SEZ was later altered and affected by fill for construction of the Douglas County Kahle Park Community Recreation Center and ballfields. A slope failure in this fill material occurred during the January 1997 flood event, and filled the channel with sediment. The section of the Burke Creek channel between Highway 50 and Kahle Park is among the most highly affected by past disturbances. Upstream of the Kahle Park, historical modification is less obvious, but includes a berm in the SEZ near the upstream end of the Sierra Colina property, with probable straightening or confinement of the channel upstream.

Figure 2. Comparison of Historical and Existing Conditions

3.0 Field Observations of Existing Conditions

nhc conducted field observations of Burke Creek on May 9, 2006, from Highway 50 to the Lower Kingsbury residential development (Figure 3).

3.1 Objectives

Multiple environmental objectives typically intersect in Lake Tahoe Basin SEZs, including restoring natural stream morphology and geomorphic processes, protection or improvement of water quality, protection or enhancement of riparian and aquatic habitat, and improvement of recreational or environmental education opportunities. The first three categories of objectives (geomorphic processes, water quality, and riparian and aquatic habitat) were used to make a preliminary evaluation of the existing state of Burke Creek during the field visit. Brief descriptions of these three categories of objectives are provided below. Recreational and educational opportunities were not evaluated, but should be considered eventually as part of the restoration plan because the Sierra Colina parcel, Douglas County facilities, and USFS land will all ultimately be accessed and used by community residents and visitors.

3.1.1 Geomorphic Processes

Natural stream morphology reflects geologic, hydrologic, and biological characteristics of the watershed and the stream corridor. Normal variability in the transport of water and sediment results in geomorphic processes along the stream corridor that forms and transforms the channel and floodplain. These processes are closely linked to the biological and ecological characteristics of the channel and SEZ. When disturbance occurs, imbalances in the hydrologic or sediment transport properties of the channel may result in reduced channel stability, long-term stream bed degradation and bank erosion, and associated degradation of biological and ecological function.

Therefore, restoration of natural channel and floodplain morphology and normal geomorphic processes, where feasible, is a key factor in achieving water quality and biological objectives.

3.1.2 Water Quality

Pollutants of concern for Lake Tahoe include fine sediment and nutrients (phosphorous and nitrogen). Natural SEZs provide control on the transport of fine sediment during flood events and serve an important role in watershed nutrient cycling. Depending on the condition of a stream, it may serve as either a source or a potential control for transport of pollutants downstream. Characteristics that are considered desirable for control of pollutants include stable channels with riparian vegetation, wide vegetated floodplains, and meadow or wetland areas in the SEZ.

As described in Section 1.0, **nhc** and the Nevada Tahoe Conservation District are currently conducting a year-long water quality monitoring study on Burke Creek in the vicinity of Sierra Colina. The purpose of the study is to provide baseline data and assess the current function of the Burke Creek SEZ with respect to water quality. Preliminary data has shown that Burke Creek water quality has low concentrations for pollutants of concern for Lake Tahoe clarity (i.e. fine sediment, phosphorous, and nitrogen). All of the samples collected to date in Burke Creek for pollutants of concern have been below TRPA's maximum allowable concentrations for storm water constituents of concern for discharge to surface water.

These preliminary data are consistent with recent stream channel estimates of pollutant loading for Burke Creek, calculated by the Lake Tahoe Watershed Model (LRWQCB, 2006). The Watershed Model is the primary tool being developed and used to assess pollutant loads to Lake Tahoe. The Watershed Model estimates Burke Creek pollutant loads to be similar to some of the less disturbed streams in the Tahoe Basin (e.g., Lonely Gulch Creek, McKinney Creek, etc.), and much less than disturbed streams such as the Upper Truckee River, Blackwood Creek, and Ward Creek. For example, the estimated fine sediment load for Lake Tahoe's largest sediment input, the Upper Truckee River, is roughly 2,250 metric tons per year (MT/yr). Conversely, the estimate of fine sediment load from Burke Creek is roughly 0.1 (MT/yr). The trend is similar when analyzing pollutant loading on a unit area basis. Based on the above estimate of pollutant loading, the Upper Truckee River watershed contributes 132 pounds per year per acre (lbs/yr/ac) of fine sediment. Conversely, the Burke Creek watershed contributes 0.07 (lbs/yr/ac) of fine sediment.

Although Burke Creek may not be a large source of pollutants in the context of the Tahoe Basin, restoration of the creek can provide incremental benefits in reducing pollutant loads to Lake Tahoe. In addition to reducing pollutant loads to the lake, improved water quality in Burke Creek will positively affect other restoration objectives, such as improved aquatic habitat.

3.1.3 Riparian and Aquatic Habitat

Riparian vegetation provides habitat for birds, amphibians, and other species and serves important functions in fluvial ecosystems to provide inputs of organic material and food sources, cover and shade on the stream, and nutrient cycling. Aquatic habitat supports invertebrate, fish, amphibian, and bird populations. With respect to fish species, important stream habitat considerations include suitable conditions for passage, rearing, and spawning.

3.2 Field Observations by Reach

To assist in describing observed conditions, seven reaches were delineated based on stream morphology and other conditions relating to the objectives described above (Figure 3). Conditions in each reach are summarized in Table 2, and briefly described below. Initial field observations by reach are presented here; recommended restoration concepts are presented in Section 4. The reach designations are based on geomorphic characteristics. Land ownership within each reach is noted on Figure 3 and in parentheses in the text header for each reach. Each text header contains the approximate length of the delineated reach in Figure 3 by land owner.

Reach 1 - (1a - Sierra Colina [250 ft]; 1b – Private Owners/Douglas County [200 ft])

In Reach 1, the channel has been modified in morphology and location. The historical channel was apparently considerably south of its existing location (outside the Sierra Colina parcel), and was relocated in the 1970's for construction of the Nugget Casino. This location is presently occupied by Burger King. The original SEZ was excavated for construction of a commercial parking lot, and the stream moved into upland soils along the northern edge of the parking area near the southern boundary of the adjacent Sierra Colina parcel. The Reach 1 channel is perched above the adjacent commercial parking lot by as much as 10 feet, and overflowed into the parking lot during the 1997 event. The channel bed is partially armored with large rock and wood, and a small berm is constructed along the south edge of the stream in some locations to reduce the chance of overflow. Existing conditions present a potential risk of damage to the stream and adjacent land uses from flooding and erosion associated with large future flood events.

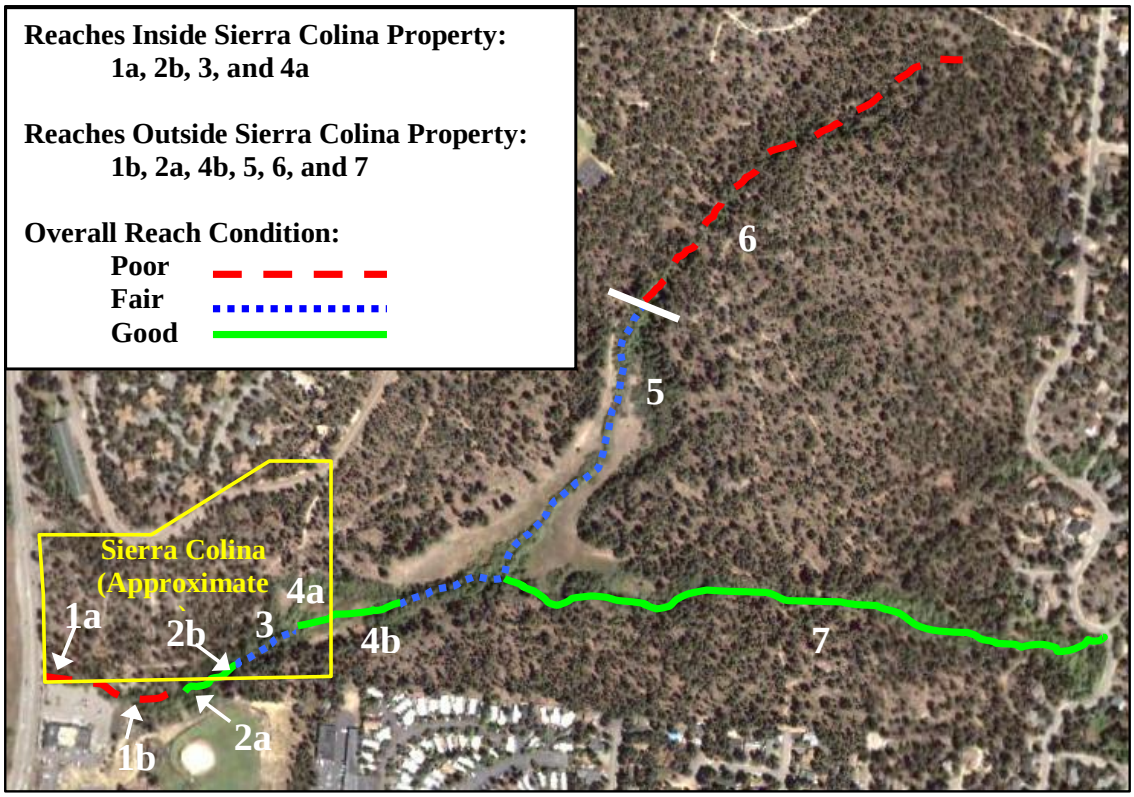

Figure 3. Reach Map

The channel is relatively steep, has several steps in profile, and has little floodplain area. Vegetation and instream wood appear to play a significant role in maintaining vertical stability in this reach. In normal flows, the channel appears to be relatively stable due to constructed stabilization features, but has a potential risk of avulsion out of the constructed channel during future flood events. A narrow band of riparian vegetation is established along the channel in some areas. Aquatic habitat is limited due to the steepness of the stream, and the steps in profile are likely fish passage barriers for some species. In the upper portion of this part of this reach, drainage flows from the Kahle Park Community Recreation Center are tributary to Burke Creek.

Reach 2 - (2a - Douglas County [100 ft]; 2b - Sierra Colina [150 ft])

Reach 2 has lower gradient than Reach 1, and has multiple channels distributed in a broader band of riparian vegetation. The channel form in this area may be partly the result of previous blockage from the landslide in the 1997 event, subsequent accumulation of sediment transported by the creek, and finally colonization by vegetation. In its present form, Reach 2 appears to meet water quality and habitat objectives fairly well, but it is a very short reach and differences from both upstream and downstream reaches suggest that evolution of the channel in this area needs to be considered.

Reach 3 - Sierra Colina (350 ft)

Reach 3 is slightly incised into its historical floodplain, and has some evidence of active bank erosion. Riparian vegetation is less dense than downstream, and several mature alders along the channel have died or appear to be dying. The channel is well shaded by the forest canopy and has a large accumulation of woody material from fallen trees, but little regeneration of stream bank vegetation appears to be occurring. The incision of the channel in this reach may have desiccated a previously wetter floodplain area. The upper end of this reach is defined by a head cut in the channel profile that is 3-4 feet high.

Reach 4 - (4a - Sierra Colina [100 ft]; 4b – USFS [350 ft])

Reach 4 is a more open wet meadow area in the vicinity of Reach 4b with multiple channels at the downstream end distributed in a relatively dense stand of riparian vegetation. Swanson (1999) notes a constructed berm near the upstream boundary of the Sierra Colina property and recommends its removal to restore more natural stream processes in the SEZ. The stream channels are presently located south of this berm and the area downstream of the berm in Reach 4a is much drier than adjacent meadow areas at similar elevation. A slight berm, probably the one referred to by Swanson, is discernable in the northern portion of this section of SEZ and near the Sierra Colina boundary (Reach4a/4b break). The berm slightly decreases the surface area (perhaps 0.5-1 acre) of the SEZ which receives surface flow from Burke Creek.

Reach 5 - USFS (1,200 ft)

Reach 5 of Burke Creek is on the northern tributary and has substantially more flow than the southern tributary (Reach 7). Reach 5 is incised through the meadow, with a narrow band of fairly

dense riparian vegetation (mostly willows). This reach appears straightened or confined from past activity, but **nhc** did not undertake a detailed historical analysis of Reach 5 for this review. Much of the Reach 5 meadow was relatively dry during our May 2006 site visit.

Reach 6 – USFS (1,200)

In Reach 6, the stream flows through a relatively narrow valley and is in direct contact with adjacent upland hillslopes. The floodplain is narrow or absent in most of Reach 6, and there is evidence of previous and possibly ongoing channel incision. Bank erosion is occurring in several locations, and riparian vegetation is relatively sparse in many locations. In the upstream portion of the Reach 6, dense stands of horsetail are located in and along some portions of the channel. The upstream end of Reach 6 is stabilized by a series of constructed drops and a previous revegetation project; in this area, the channel appears to be relocated from its historical course (which is now occupied by a residence).

Reach 7 – USFS (1,750 ft)

Reach 7 appears less disturbed from historical conditions than other reaches, and has a relatively stable active channel and well-vegetated floodplain. Although some encroachment is evident from adjacent land uses, relatively natural geomorphic processes appear to be contributing to recruitment of instream woody material and regeneration of riparian vegetation. Stream bank erosion is modest and there is little evidence of channel incision or instability in profile. The upstream end of this reach is defined by a road culvert crossing, with significant inflows of storm water from adjacent residential neighborhoods.

Table 2. Summary of Burke Creek Conditions by Reach

Reach	Geomorphic Function	Water Quality	Riparian and Aquatic Habitat	Overall Reach Condition
Reach 1	Poor: Constrained by necessity for fixed channel location and risks associated with flood flows	Fair: Bed and banks generally stable, but risk of avulsion in large storm event	Poor: Riparian width narrow, steps in profile may be fish passage barrier	Poor
Reach 2	Fair: Distributed flows, active floodplain, minor erosion and channel migration, but short reach dissimilar from upstream and downstream	Fair-Good: Well vegetated floodplain with shallow flow during floods, little erosion or incision, but short reach	Fair: Riparian vegetation and regeneration, overhead cover on stream, but limited instream cover and short reach	Fair-Good
Reach 3	Fair-Poor: Slightly incised and moderate bank erosion, relatively large amount wood in channel and on floodplain, floodplain becoming inactive and drier, headcut at upper end	Poor: Bank erosion and channel incision appears to be progressing, likely sediment and nutrient source	Fair-Poor: Instream wood and undercut banks for cover, but little bank vegetation or regeneration and mature riparian trees appear to be in decline	Fair-Poor
Reach 4	Fair: Downstream portion - multiple channels in well vegetated meadow floodplain, minor erosion and deposition. Portion of SEZ impacted by berm. Upstream portion - channel may be slightly incised and floodplain/meadow less frequently inundated.	Fair-Good: Distributed flows on wide, vegetated floodplain downstream, but upstream portion may be slightly incised	Good: Overhead and instream cover; wider band of riparian vegetation than downstream or upstream	Fair-Good
Reach 5	Fair-Poor: Slightly incised, possibly straightened or confined in the past; floodplain inactive, meadow may be desiccating	Fair: Bed and banks generally stable, but frequency of floodplain/meadow overflow probably low	Fair-Good: Continuous but narrow band of riparian vegetation, good cover over and in-stream, long reach	Fair
Reach 6	Poor: Incised and eroding, little active floodplain, confined by hillslopes	Poor: Likely sediment and nutrient source, actively eroding	Fair-Poor: Some riparian vegetation, stream cover fair, may be passage problems at upstream end	Poor
Reach 7	Good: Small channel and active floodplain, minor erosion and deposition, long reach, some encroachment/disturbance from adjacent residential areas	Fair-Good: Relatively stable, floodplain active and vegetated, but less wide (naturally) than downstream reaches	Good: Continuous riparian corridor, overhead and in stream cover	Good

4.0 Restoration Potential and Design Considerations

The restoration potential and design considerations provided in this section are based on **nhc**'s brief reconnaissance. More detailed analysis is expected as part of the Burke Creek Restoration Project being conducted by TRPA (EIP #161). **nhc**'s suggestions on restoration concepts are offered for the TRPA's consideration in more comprehensive study and design in the TRPA EIP #161 project.

Restoration plans should be developed based on characteristics of the entire watershed and should be designed to achieve specific functional objectives for habitat conservation and water quality protection in a watershed context. For Sierra Colina, **nhc** recommends cooperation and collaboration with the TRPA Burke Creek Restoration Project to ensure that any specific enhancements contemplated on the Sierra Colina property are consistent with this overall watershed approach. Implementation of any improvements on Sierra Colina should be conducted in a manner and sequence that is coordinated within the context of restoration for the Burke Creek watershed, and all parcels encompassed by EIP project #161.

At the time this reconnaissance was initiated, it was not clear whether any restoration activities inside the SEZ Burke Creek portion of the Sierra Colina parcel should be implemented by Sierra Colina as part of the "Sierra Colina Village" project, or if Sierra Colina's proportionate share of Burke Creek restoration should be implemented by Sierra Colina as part of its contribution to the multi-party larger EIP #161 plan to be determined in the future by the TRPA. However, it is clear that some alternatives can only be considered by the TRPA in cooperation with a group of stakeholders (of which Sierra Colina is only one small private entity). For example, re-alignment or substantial modification of the Reach 1 channel along the commercial parking lot (adjacent to Sierra Colina) may affect Nevada Division of Transportation (infrastructure at Highway 50), Douglas County (Kahle Park), US Forest Service (downstream of Highway 50) and adjacent private property owners on the site where the Burger King is now located. Restoration of other reaches would also involve the US Forest Service and other public agencies. For these reasons, we suggest that comprehensive restoration plans for the entire area covered by our field reconnaissance be developed as part of the TRPA EIP #161 project, with proportionate cooperation and participation of Sierra Colina (with respect to its own parcel) and other stakeholders (with respect to the other parcels through which Burke Creek flows). Specifics on implementation of particular improvements can then be developed by the TRPA, based on the overall plan that will emerge from the results of the TRPA study.

4.1 Recommendations by Reach

Brief discussions of restoration potential and design considerations for each reach are provided below and summarized in Table 3. Note that the recommendations below are concepts for each reach, and do not list specific activities to be performed by Sierra Colina or other property owners. Recommendations for Sierra Colina participation are provided at the end of this section.

Reach 1

Reach 1 presents an opportunity to reduce risk of potential flooding and erosion, and an opportunity for SEZ enhancement by improving continuity in riparian habitat, and fish passage. However, restoration of natural geomorphic processes is probably not feasible or desirable unless a significant change in property ownership and land use is made to accommodate major channel realignment. It seems highly improbable to restore historical conditions, given present land use (NDOT, commercial, USFS, etc). The existing adjacent Burger King parking lot and Douglas County Kahle Park fill slope both encroach on the historical SEZ; thus, complete recovery or relocation of this reach is not realistic. Even relatively modest restoration of a more natural stream channel would require significant expenditures and collaboration on the part of several private property owners and public agencies. In Reach 1, it is unlikely that the gradient can be significantly reduced, and design of a stable channel at this slope will limit opportunities to achieve all of the objectives listed in Section 3.

Therefore, restoration of Reach 1 should probably focus on reduction of existing problems (e.g., flooding, erosion, fish passage) and connectivity in riparian and aquatic habitat between the meadow downstream and higher value SEZ upstream, and less on restoration of geomorphic processes. In a watershed context, this approach would combine treatment of specific local problems or limiting factors (e.g., channel erosion, fish passage) in some areas with enhancement of functional SEZ values and geomorphic processes in the areas where restoration potential is highest (outside of Reach 1).

Although various options should be explored at the conceptual level, it is likely that a high gradient section will be required for at least a portion of Reach 1. Channel stability and fish passage are key concerns for design of a higher gradient section of stream. Previous conceptual designs (Swanson, 1999) recognized that restoration of the original Burke Creek channel location is not feasible without property acquisition on the parcel presently occupied by Burger King. Swanson (1999) proposed leaving the Reach 1 channel in its current alignment for a portion of its length, and then transitioning to a lower gradient section just upstream of the highway culvert. The reasoning behind the Swanson (1999) alternative should be considered in the current EIP #161 study and refined as necessary according to present day property constraints and uses. Limitations noted in the original Swanson (1999) concept development are that the transition to a lower gradient may lead to problems associated with sediment deposition, and a relatively small area of low gradient SEZ restoration would be created. In addition, there might be continued risk of overflow into the parking lot in large flood events unless the higher gradient channel upstream is enlarged.

An alternative for the TRPA to consider is reconstructing the entire length of channel along the commercial parking lot next to Sierra Colina, maintaining the existing stream gradient, but increasing the width of the channel/floodplain area. A modest reduction in parking lot size and installation of a retaining structure along the north margin of the lot would provide sufficient space for a vegetated channel and floodplain corridor to be developed. Due to the high gradient, stabilization of this area for large flood events would require installation of buried large rock grade controls or similar structures across the entire floodplain area. However, this concept might facilitate construction of a relatively small channel for fish passage within a broader riparian corridor, and provide increased reliability for passage of floods. Flood flows should be relatively shallow in this case, and the top of the retaining structure could be elevated somewhat above the stream profile to reliably contain flood events. This alternative would probably not include a sharp break in gradient until near the upstream end of the highway crossing, and the location of the crossing might be near the existing culvert, requiring some stream reconstruction downstream of the highway to join with the existing channel. This alternative suggestion would require the participation of private property owners on both sides of Reach 1 (with the Burger King center land owner needing to agree to sell or contribute land and forfeit existing commercial parking spaces), as well as the participation and funding of the Highway 50 culvert reconstruction on the part of the State of Nevada.

A break in stream gradient near the highway will likely be necessary. Provision for accumulation and removal of sediment at this location should be considered.

From a water quality perspective, Reach 1 has limited potential for water quality benefits, but provision of a stable channel will reduce sediment sources, especially the potential for episodic loads in large events. Storm water inflows from Douglas County property at Kahle Park occur near the upstream end of Reach 1. Douglas County should consider pre-treatment of these flows using structural BMPs in Kahle Park, potentially in combination with a designated section of the SEZ for biological treatment and vegetative filtering of tributary flows prior to entering the main channel. These measures would improve water quality in the creek and the chances for successful restoration.

Riparian and aquatic habitat improvements are also constrained by width and gradient of the stream, but construction of a wider floodplain could provide increased width and improved continuity in the riparian corridor. The largest potential benefit is probably fish passage, which should be designed, if feasible, to accommodate native species as well as introduced salmonids. This will require identification of target species and swimming abilities, and hydraulic analysis of the proposed channel over a range of flow conditions. Design of fish passage that incorporates hydraulic roughness and replicates natural stream hydraulics should be considered preferable to a fish ladder or structural fishway. Design of fish passage in this reach would ideally be combined with improved fish passage at the Highway 50 culvert crossing.

The overall potential for restoration benefits in Reach 1 is considered moderate – restoration of historical geomorphic processes is unrealistic, but measures can be implemented to address existing problems and provide stream stability, water quality, riparian habitat, and fish passage.

Reach 2

Reach 2 is very short. Its present characteristics seem at least partially the result of the slope failure that occurred in the 1997 event, blocking the stream. Subsequent colonization by vegetation and accumulation of sediment may have produced a short reach of stream that is lower in gradient than both upstream and downstream reaches. Reach 2 currently has relatively high value in meeting the objectives listed in Section 3, but EIP #161 restoration plans should consider Reach 2 in the overall context of the stream profile, including continuity in bedload transport. Reach 2 may presently serve as a trap for sediments generated in the upstream reach, and some potential for avulsion or long term channel erosion may exist if this sediment supply continues to be high. In this case, consideration of a main channel with sufficient bedload transport capacity is warranted.

An alternative is to consider Reach 2 as a suitable indicator for potential transformation of the upstream reach (see Reach 3 discussion below). In this case, conditions would need to be modified upstream to promote dense riparian vegetation reestablishment and regeneration and concurrent changes in the channel form, thereby reducing local sources of bed material and inflow of sediment to Reach 2. Vegetation appears to play an important role in stream morphology both here and upstream in Reach 4, indicating that regeneration of willows and alders in the SEZ, and their effects on channel form and sediment transport, are interdependent. Longitudinal profile information, cross section surveys, and hydraulic/sediment analyses would help to assess current conditions and potential actions.

From a water quality perspective little improvement is apparently necessary in Reach 2, although the potential for avulsion should be considered in the context of sediment transport continuity as noted above (with respect to the relationship between Reach 2 and Reach 3).

Riparian vegetation in Reach 2 appears to be relatively healthy with natural regeneration. A longer historical perspective will ultimately determine whether the current condition of Reach 2 is or is not a relatively short term response to the storm related disturbance in 1997. Initial observations indicate that aquatic habitat might be improved by addition of instream cover, but this may occur naturally as riparian vegetation matures, or if sediment supply from upstream were reduced and the channel form became less braided.

The overall potential for restoration benefits in Reach 2 is considered moderate.

Reach 3

Reach 3 is incised slightly into its historical floodplain and has evidence of active bank erosion. Control of the incision or restoration of the stream profile is needed to achieve geomorphic, water quality, and habitat objectives. Design alternatives might include re-establishment of the stream profile in place, construction of new channel segments at appropriate elevations, or stabilization of the existing channel. Because the incision is still modest, restoring the stream profile appears feasible, and would likely have the highest benefits in reactivating the floodplain for water quality and habitat objectives. This approach would also address the headcut at the upstream end of the channel without the need for constructed drops or steps.

A more detailed assessment of the riparian vegetation conditions is needed – mature alders and other riparian vegetation appear to be in poor health; many have died and toppled in the channel and on the floodplain. Although this process has added overhead and instream cover to the channel, it has not controlled incision, and little regeneration of riparian vegetation on the channel banks is occurring. An assessment is needed to determine the causes for the lack of healthy riparian vegetation, and conditions needed for reestablishment. Restoration design of the Reach 3 channel and regeneration/succession processes for riparian vegetation will need to be considered together with its potential impact on Reach 2.

Re-activation of the historical floodplain appears to be the most important factor in reducing sediment supply from Reach 3 and improving habitat.

Restoration potential in Reach 3 is considered high.

Reach 4

Reach 4 appears to be in good condition at its downstream end. A key objective here may simply be to preserve the existing functional SEZ. The feasibility of removing the berm noted in the Swanson (1998) report should be revisited in an effort to restore functional SEZ area in Reach 4a. At the upstream end of Reach 4b, the channel may be slightly more incised (more detailed stream profile and cross section information is needed), and meadow/floodplain inundation may be less frequent. In this area of Reach 4b, existing riparian vegetation is limited to a narrower corridor, perhaps due to past grazing or other activities. If these conditions are confirmed, minor controls on the channel profile (e.g., instream wood) might help to promote geomorphic processes that would in turn expand the riparian corridor.

Water quality and habitat conditions in this reach appear to be relatively good, and little besides protection of the SEZ may be necessary.

Restoration potential in Reach 4 is considered moderate, primarily associated with increasing functional SEZ area in Reach 4a and a potentially expanded riparian corridor in Reach 4b.

Reach 5

Reach 5 appears to have a relatively stable channel and a continuous, but narrow band of riparian vegetation. However, Reach 5 channel conditions were not reviewed in detail during our site visit, and should be checked to confirm the stability of the channel. In spite of fair existing conditions, Reach 5 appears to have high potential for restoration of the channel and meadow by reestablishing a higher stream profile and more sinuous planform. This reach may have been affected by historical confinement or straightening, resulting in slight incision. A higher stream profile might promote wetter meadow conditions and an expanded, more diverse riparian corridor. More frequent overflows of the channel also has potential water quality benefits.

Historical analysis, stream profile and cross-section surveys, groundwater monitoring in the meadow, and more detailed assessment of riparian and aquatic habitat conditions are needed to

assess the benefits and feasibility of this approach. Although construction of a new or modified channel would have temporary impacts on existing habitat, opportunities for wet meadow restoration in the Lake Tahoe Basin are relatively few and should be considered in this reach.

Restoration potential in Reach 5 is considered high.

Reach 6

Reach 6 is confined by a relatively narrow valley and has evidence of both channel incision and bank erosion into adjacent hillslopes. Reduction of sediment supply in this reach would likely have benefits for downstream reach stability and reduction of sediment loads to Lake Tahoe. A more detailed comparison of conditions in Reach 6 with those in Reach 7 might be informative to assess historical changes and develop design concepts. At a minimum, improvements in channel stability should be considered using a combination of vegetative features and structural (e.g., rock rip-rap) stabilization where necessary. A more aggressive approach, and substantially more difficult, might be to re-establish conditions similar to Reach 7, with a small active channel and narrow, well-vegetated floodplain. Historical analysis, stream surveys, and hydraulic/sediment analyses would be necessary to assess the feasibility of this approach. The costs of more aggressive channel reconstruction should be weighed against the relative costs and benefits of stabilization in place to develop a preferred approach.

In either case, a more stable channel appears to have substantial benefit in reducing sediment and nutrient supply, and ample opportunity exists for improvement of the riparian vegetation along the stream corridor. Additional riparian vegetation is need to improve overhead cover on the stream, and would likely also improve instream cover in the long term. A more detailed assessment of aquatic habitat is needed to assess whether suitable spawning habitat could be developed in this area. Existing constructed drops at the upstream end of Reach 6 might impact fish passage, but conditions upstream were not analyzed to determine if there is suitable or potentially suitable fish habitat.

Restoration potential in Reach 6 is considered high, primarily associated with reduction of sediment supply.

Reach 7

Reach 7 is in relatively good condition, and little work appears to be necessary based on our brief field review. Protection of the SEZ against further encroachment from adjacent land use and potential off-trail recreational impacts appear to be the highest priorities. Our field review did not include the lower portion of this reach in the meadow; this portion of the channel should be checked to see if the incision in Reach 5 is also present here.

Reach 7 is considered to have low restoration potential due to good overall existing conditions, but high value for preservation.

Table 3. Restoration Potential of Burke Creek by Reach

Reach	Overall Reach Condition	Overall Restoration Potential	Design Considerations
Reach 1	Poor	Moderate	1. Restoration of geomorphic processes probably not feasible - constrained by current commercial land use and private property ownership 2. Alternative development requires agency/private property owner collaboration 3. Stable channel/floodplain needed to allow for fish passage and improve reliability in floods 4. Consider widening stream corridor by modifying parking lot (requires willingness of land owners to sell or contribute property) 5. Provide for sediment accumulation/removal at grade break near highway 6. Combine with improved fish passage under highway 7. Pre-treatment needed for Douglas County Kahle Park inflows and with possible subsequent SEZ treatment 8. Limited water quality and habitat benefits are achievable – may be more effective in a watershed context to focus on upstream reaches for these objectives
Reach 2	Fair	Moderate	1. Need a better understanding of the evolution of this reach after 1997 storm event 2. Consider sediment transport continuity and effects of riparian vegetation on channel form and sediment transport 3. May be suitable as an indicator for upstream reach – need longitudinal profile and cross section information, hydraulic and sediment analyses
Reach 3	Fair-Poor	High	1. Re-activation of historical floodplain could provide significant benefits for water quality and habitat 2. Assessment of riparian vegetation regeneration/succession is needed 3. Adjustment of profile or repair of headcut is needed to protect against upstream degradation
Reach 4	Fair-Good	Moderate	1. Relatively good condition, preservation may be most important action 2. Removal of existing berm should be considered to re-water a portion of SEZ in Reach 4a 3. Upstream portion may be slightly incised – more information needed – if confirmed, control of stream profile might help promote overflows to meadow and expansion of riparian corridor in Reach 4b.

Reach	Overall Reach Condition	Overall Restoration Potential	Design Considerations
Reach 5	Fair	High	1. Potential for wet meadow restoration – would likely require reconstruction of channel at higher profile elevation and slightly more sinuous planform 2. Restoration of meadow stream could have significant water quality and habitat benefits
Reach 6	Poor	High	1. Stream stabilization needed to reduce sediment supply and allow enhancement of riparian corridor 2. Alternatives might include stabilization in place and reconstruction of stream/floodplain 3. Reach 6/7 comparison may be informative for historical perspective and to guide design 4. Riparian vegetation associated with stream stabilization would provide improved riparian and aquatic habitat
Reach 7	Good	Low - little necessary	1. Little work appears needed – preservation should be highest priority 2. Meadow section not visited – check for incision

The **nhc** observations above are based on our brief field reconnaissance. Additional information is needed to develop more detailed restoration objectives, assess restoration potential, and develop specific plans. This should include historical review, detailed stream surveys, biological assessments, and hydraulic/sediment transport/water quality analyses. The observations and suggestions provided here are offered to contribute to this process at its initiation.

4.2 Recommendations for Sierra Colina Actions

At present, we recommend that Sierra Colina, LLC participate in the TRPA EIP #161 study, and defer decisions on specific potential restoration activities on the Sierra Colina portions of the Burke Creek channel until a comprehensive restoration plan is developed. The reasoning for this is twofold. First, some restoration options (e.g., channel modifications in Reach 1) cannot be accomplished or even considered by Sierra Colina independently – they require agency/property owner collaboration and potential easement or land acquisition outside of Sierra Colina's control and responsibility. Second, measures adopted on one portion of the stream may affect others, especially with regard to sediment transport and water quality. Independent implementation of restoration measures on the Sierra Colina property might entail limitations on their success or potentially even failure due to upstream influences, especially inputs of sediment. This recommendation is predicated on the assumption that the TRPA project will proceed over time.

5.0 References

Swanson, 1998. Design Memorandum to Paul Kaleta, Basin Strategies, August 27, 1998.

Swanson, 1999. Design Memorandum to John-Paul Harries, January 28, 1999.

LRWQCB, 2006. Lake Tahoe Nutrient and Sediment Total Daily Maximum Load. Summer/Fall 2006 Newsletter. Lahontan Regional Water Quality Control Board and Nevada Division of Environmental Protection.

USDA Forest Service 1991. Burke Creek/Kahle Ditch Restoration Project. Prepared for Douglas County Public Works Department and USFS Lake Tahoe Basin Management Unit.

USDA Forest Service. 1999. Burke Creek Stream Channel Restoration Monitoring Report 1990-1998. USFS Lake Tahoe Basin Management Unit. Prepared by Susan Norman.