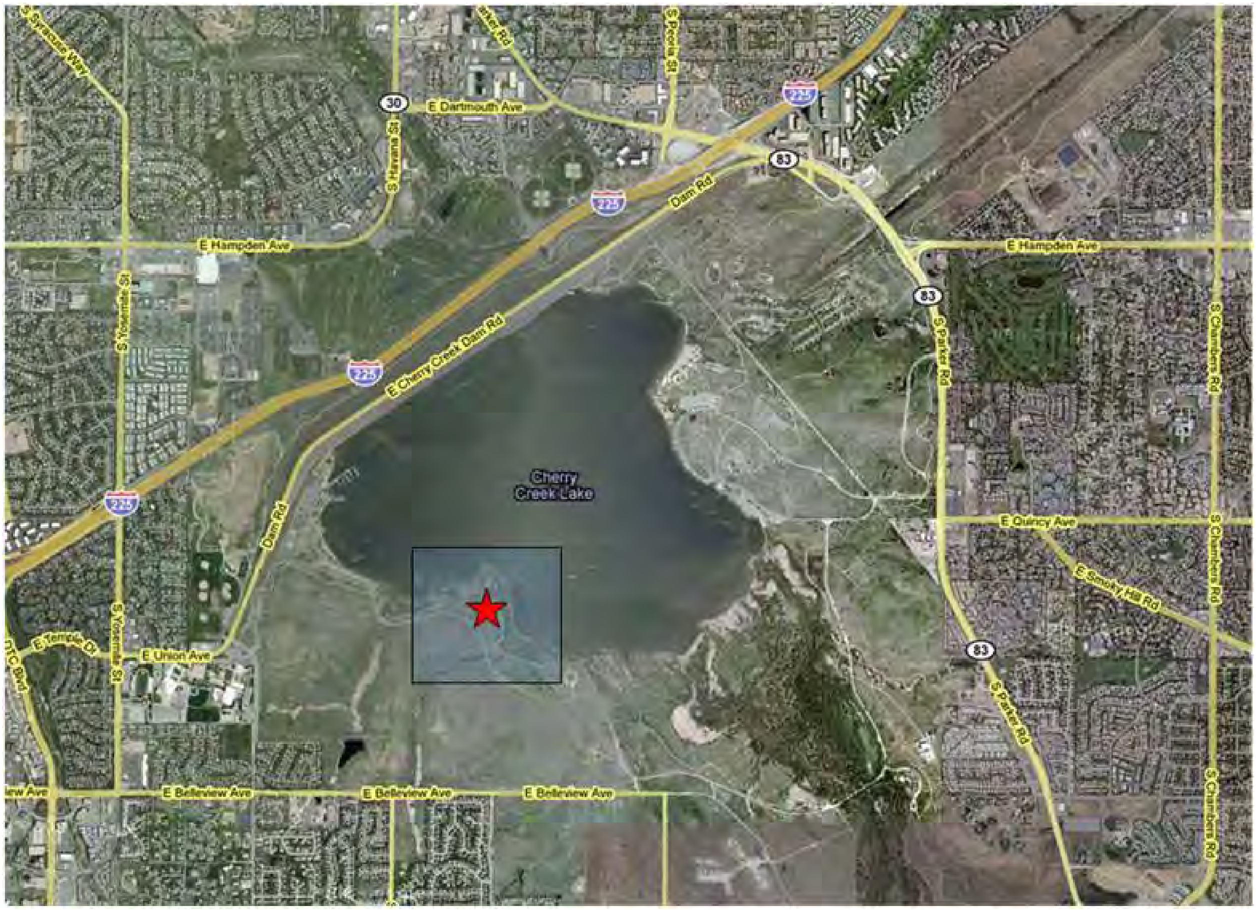

Cherry Creek State Park- Mountain and Lake Loop

Shoreline Stabilization and Water Quality Improvement

Preliminary Design Recommendations and Memorandum   December 1, 2008

Prepared for the Cherry Creek Basin Water Quality Authority by:

w e n k

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Contents

Design Team ... 1
Contents ... 2
Project Description ... 3
Scope ... 3
Key Water Quality Issues ... 4
- Shoreline erosion and instability ... 4
- Runoff Erosion and Concentrated Flows ... 5
- Anticipated Higher Levels of Activity ... 6

Assessment ... 7
- Social Trails ... 7
- Parking Areas ... 8
- Vegetation ... 9
- Historic Comparison ... 10
- Natural Process and ... 11

Conceptual Development ... 12
Conceptual Sections ... 15
Implementation Recommendations ... 18
Opinion of Probable Costs ... 20
Attachment A - Vegetation Survey ... 21
Attachment B – Water Quality Benefits of Shoreline Stabilization Memorandum ... 32
Attachment C – Water Surface Elevation Memorandum ... 37
Attachment D - Concept Development Drawing Set ... 11"x17" sheet set

Project Description

The Cherry Creek Reservoir *Shoreline Stabilization Mountain and Lake Loop Alternative Development and Analysis* (Project) is part of the Cherry Creek Basin Water Quality Authority's (the Authority)*2008 Capital Improvement Program* (2008 CIP) which was developed to identify and to prioritize activities and projects necessary to achieve water quality standards in Cherry Creek Reservoir. The 2008 CIP includes several measures or practices, called Pollutant Reduction Facilities (PRF), that reduce phosphorus loads to the Reservoir. PRFs include storm water storage, wetlands, shoreline and stream-bank stabilization, and other approaches to immobilize phosphorus or control algae in the Reservoir. The Project was evaluated by the Authority and others at the conceptual level and recommended for further consideration and inclusion on the 2008 CIP.

The Project area is located within Arapahoe County and Cherry Creek State Park and is located along West Lake View Road approximately 0.75 miles from the west (Dayton Street) Park entrance. The Project area includes approximately 6.5-acres including the area between the foot trail and the shoreline and approximately 2,300-feet of shoreline. Project objectives are to design improvements in order to construct shoreline and bank stabilization measures that:

Objective 1. *Protect existing shoreline from erosion and degradation due to ice, wind, wave action, and sheet flow runoff while developing and preserving beach areas.*

Objective 2. *Reduce surface erosion due to runoff and improve water quality of runoff from parking areas and trails before entering the reservoir.*

Objective 3. *Maximize preservation of existing vegetation capitalizing on the ecological and recreational values associated with it.*

Objective 4. *Integrate and enhance visitor experience and proposed uses while reducing operation and maintenance requirements.*

Scope

The Project is divided into three phases:

Phase I - Assessment.

- Compile physical information (i.e.; topography, recreation facilities, utilities, endangered species studies, etc) illustrating existing conditions.
- Evaluate project area for: a) shoreline stability, b) wind, rain, ice, pedestrian, and runoff related erosion, c) vegetation sustainability, and d) visitor use.

Phase II - Alternatives Development

- Develop alternate solutions which address issues and constraints identified during Phase I.
- Recommend Preferred Alternative Plan
- Develop preliminary opinion of probable costs and qualitative benefits of Recommended Alternative Plan.

Phase III - Preliminary Conceptual Design.

- Approval of Alternative Plan by the Technical Advisory Committee (TAC)
- Develop Conceptual Design (35%) Documentation including drawings and accompanying report to present project results.

Key Water Quality Issues

The Authority issued a memorandum summarizing its assessment of Water Quality Benefits of Shoreline Stabilization (Attachment B). The memorandum was reviewed and commented on by members of the Wenk Associates Design Team.

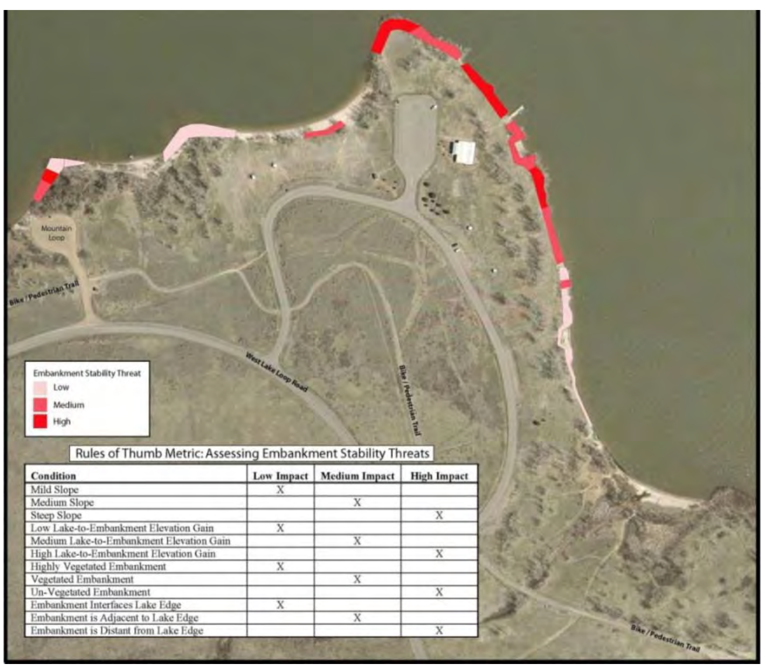
The proposed solutions are directed at resolving three key water quality issues that contribute to mobilizing sediment:

- Shoreline erosion and instability
- Runoff erosion and concentrated flows
- Anticipated higher levels of recreational activity

Shoreline erosion and instability

Wave action, wind, and ice "push" contribute to major cut bank conditions and erosion of shoreline. Cut banks range from 6 inches to more than 8 feet, averaging 2-3 feet.

Cut bank erosion examples at Lake Loop area



Condition	Low Impact	Medium Impact	High Impact
Mild Slope	X		
Medium Slope		X	
Steep Slope			X
Low Lake-to-Embankment Elevation Gain	X		
Medium Lake-to-Embankment Elevation Gain		X	
High Lake-to-Embankment Elevation Gain			X
Highly Vegetated Embankment	X		
Vegetated Embankment		X	
Un-Vegetated Embankment			X
Embankment Interfaces Lake Edge	X		
Embankment is Adjacent to Lake Edge		X	
Embankment is Distant from Lake Edge			X

Shoreline instability areas: Lake Loop Study Area Resource Management Plan- Stephen Hoover

Runoff Erosion and Concentrated Flows

Runoff from parking areas is not currently being treated for pollutants before entering the reservoir. Among pollutants commonly found in parking lot runoff, petroleum, rubber, and road grime are prevalent.

Existing social trails and concentrated flows are contributing to higher rates of surface erosion in areas where high levels of activity occur. Surface erosion contributes to higher particulate quantities in runoff and the loss of vegetation. Areas anticipating increased use are therefore vulnerable to the undesirable impacts of runoff erosion and concentrated flows.

Example of social trail and concentrated flows

Paved parking area at Lake Loop

Existing social trails are shown in red. Parking areas are shown in orange: Lake Loop Study Area Resource Management Plan- Stephen Hoover

Anticipated Higher Levels of Activity

According to Cherry Creek State Park officials, use is increasing beyond designed capacity at existing developed recreational areas around the reservoir forcing users to overflow into less developed areas of the Park such as the Lake Loop and Mountain Loop. These areas are experiencing increasing visitor days and higher usage levels. According to officials, these areas are expected to develop into "medium to high" use areas within the next 5-10 years creating concern for increased erosion due to loss of vegetation, compaction of soils, and concentrated use in areas like paths, fishing areas, and beaches and picnic areas.

Existing beach and recreation areas are crowding forcing overflow to move to less developed areas.

Existing activity areas expected to increase in utility are shown in blue. From Lake Loop Study Area Resource Management Plan- Stephen Hoover

Assessment

Site assessment/empirical analysis includes documented physical information and identified relationships between site conditions and shoreline stability; wind, rain, ice, pedestrian, and runoff related erosion; vegetation sustainability; and visitor use.

Social Trails

The diagram below illustrates the condition of an existing social trail system and prioritizes improvements as follows:

Green trails have generally shallow slopes and receive low to moderate volumes of foot traffic resulting in only minor erosion. *Green trails do not have recommended improvements under this scope of work.*

Yellow trails have moderate slopes and receive higher traffic volumes resulting in moderate erosion. *Minor improvements to Yellow trails are recommended under this scope of work.*

Red trails have steeper slopes, high volumes of social traffic and concentrated flows from adjacent impervious areas resulting in major erosion issues. *Major improvements to Red trails are recommended under this scope of work.*

**Social trails within the project boundary that are not illustrated in Green, Yellow, or Red should be considered for re-vegetation/ reclamation as part of this project.*

Parking Areas
The diagram below illustrates the existing parking areas.

The Lake Loop parking area (shown in green) is paved with asphalt. Drainage generally moves North and East towards the reservoir. *Improvements are not recommended to the parking surface itself, however, mitigation of runoff is recommended.*

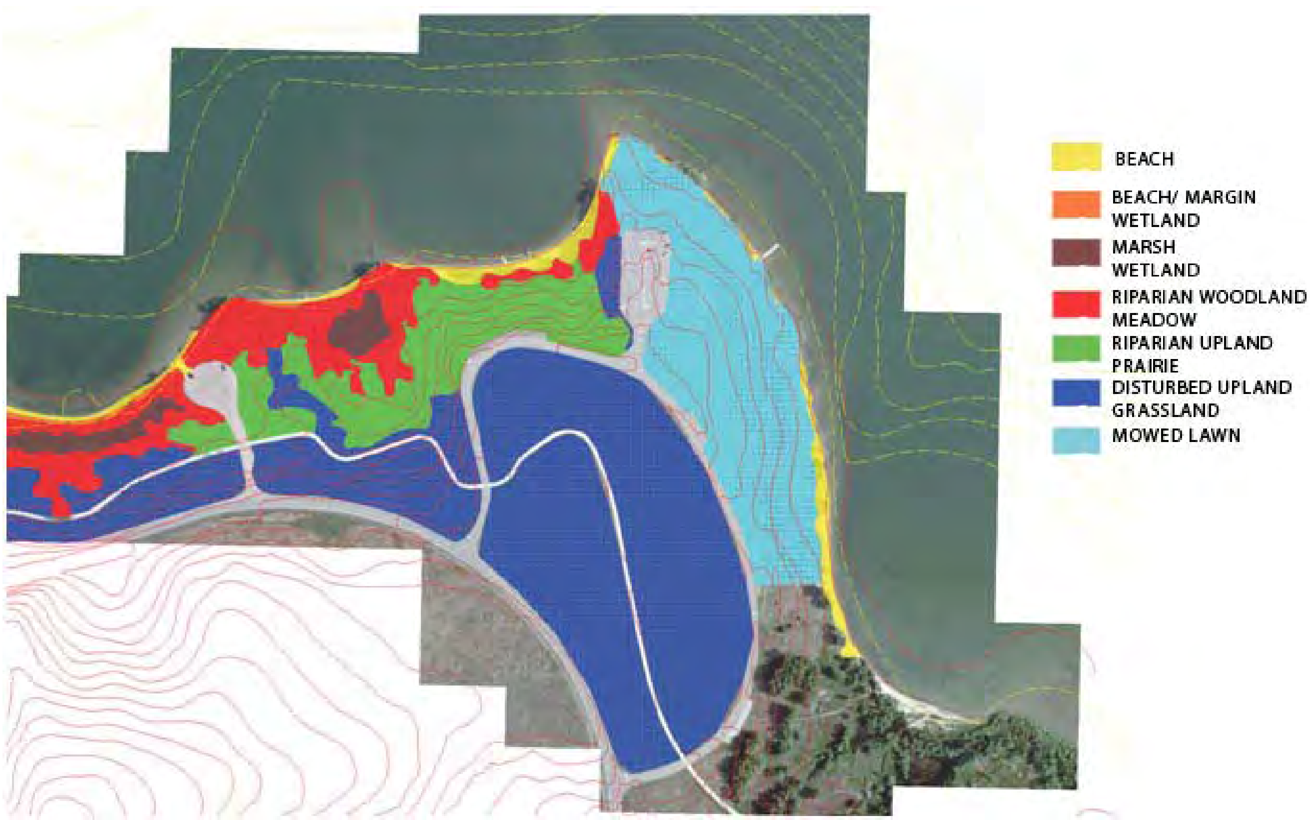
The Mountain Loop parking area (shown in red) is paved with gravel/road base. Drainage generally moves North and West toward the reservoir. This parking area is extremely close to the shoreline and runoff moves along social trails and without any buffer directly into the reservoir contributing to sediment loads. *Recommended improvements include reconfiguration of the parking area in order to provide buffer and mitigation of runoff.*

Vegetation

The diagram below illustrates the existing vegetation conditions.

Detailed survey, descriptions of vegetation types, and recommendations for construction, restoration, and preservation are included in *Attachment A- (Vegetation Survey by Restoration Ecology).*

In particular, care and attention should be paid to the preservation of *Remnant Upland Prairie, Riparian areas*, and *Beach Margin Wetland* areas during construction. Re-vegetation recommendations and strategies are included in *Attachment A.*



Historic Comparison

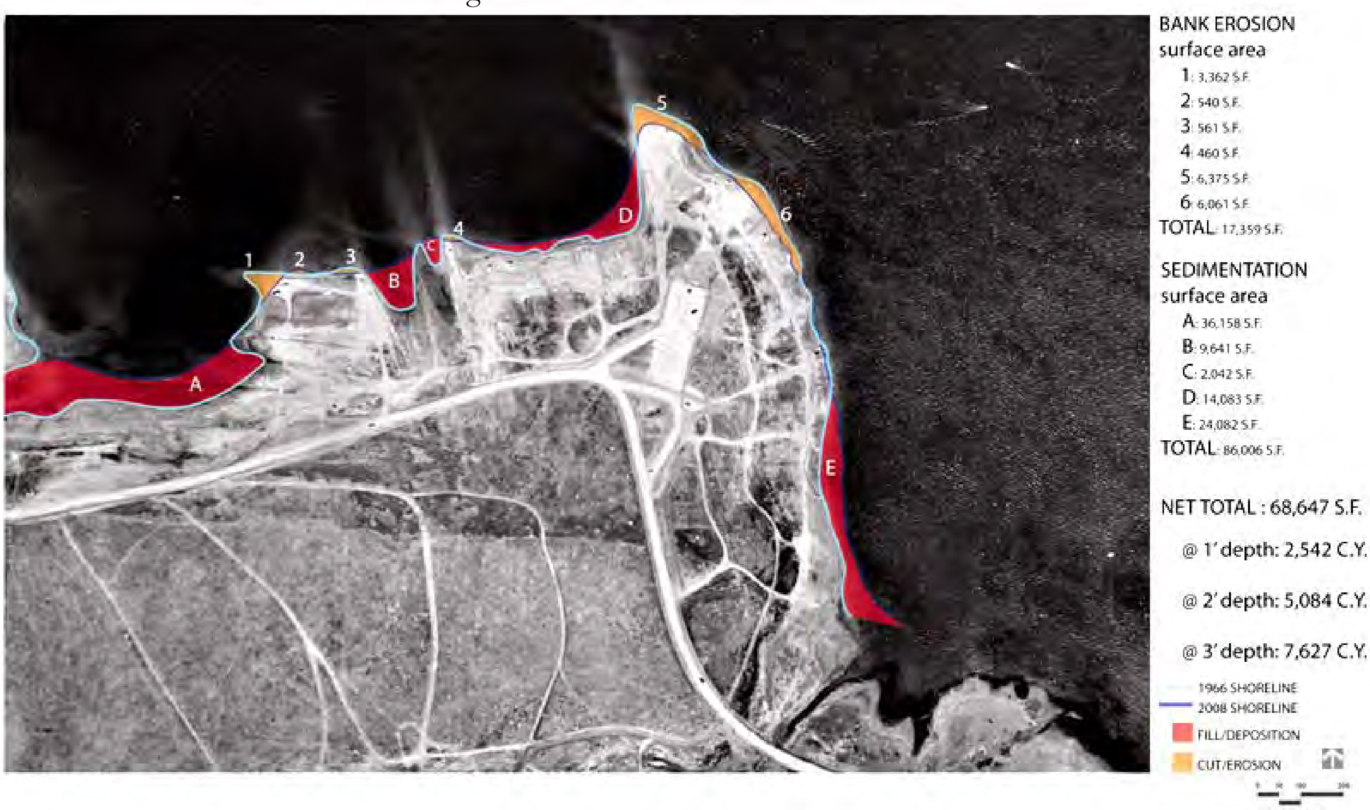
The images below illustrate changes in development, shoreline and vegetation over approximately 40 years.

Of particular interest, are noticeable differences in the formation of beaches that have developed from particulate movement due to erosion and deposition and resulting in a general "smoothing" of the shoreline.

Aerial photo of Mountain and Lake Loop area 1966.

Aerial photo of Mountain and Lake Loop area 2007.

In the diagram below an approximate calculation of particulate movement is shown by comparing the shoreline of the land mass in 1966 and that of 2007. If the average depth of erosion and sedimentation was 2 feet, the approximate net total of soil movement within the reservoir would be 5,084 cubic yards. This study assumes consistent water surface at or near elevation of 5550'in both images and does not consider surface erosion.



Natural Process and Patterns of Shoreline Erosion

The observed pattern of erosion at the site appears to differ from one side of the site to the other. As the diagram below illustrates, empirical analysis from site observations indicate that prevailing forces(wind and wave action) on the East side of the site tend to move from the East towards the site and are deflected to the North, whereas the forces impacting the West side tend to move from the West and also deflect to the North. It is therefore recommended that stabilization techniques should respond to differing force directions.

Many natural processes are visibly at work around the site. Specifically, there are several examples of bank stabilization as a result of established vegetation, and beach deposition occurring behind natural points created by established vegetation and debris like the stump shown below. These natural processes show the effectiveness of, and encourage the use of, stabilization strategies such as points and/or jetties which both stabilize shoreline and encourage the buildup of healthy beach areas by reducing sediment movement.

Conceptual Development

Based on natural processes found on site and strategies that have proven their effectiveness in other projects around the country, the Design Team has developed conceptual alternatives which replicate natural processes in shoreline stabilization and erosion control. These alternatives also enhance recreational opportunities at the site. With the guidance of the Basin Authority, the U.S. Army Corps of Engineers, and Cherry Creek State Park staff, the Design Team has developed the preferred alternative plan into a 35% level Concept Plan with appropriate typical sections and details. The Concept Plan addresses four main objectives and provides specific strategies and details which support these objectives.

Objective 1. *Protect existing shoreline from erosion and degradation due to ice, wind, wave action, and sheet flow runoff while developing and preserving beach areas.*

Strategy

- Utilize strategically placed "points" and/or jetties to maximize protection while reducing impact to existing shoreline and encouraging sand deposition in beach areas. (Concept Plan Figure 1)
  - *Solutions must provide protection for water surface elevations ranging from el. 5548-5552 per Aug. 1 2008 memorandum from Bill Ruzzo to Design Team (Attachment C).*

Details

- Bio-edge stabilization: Void-Filled Rip Rap (VFRR) beach points allow plant life to establish while stabilizing the shoreline in areas with lower activity and exposure. (Figure 3)
- Hard edge stabilization: Terraced stone boulders or integrated pre-cast concrete units provide a usable active edge while stabilizing the shoreline in areas with high activity and exposure (Figures 2 and 4)
- Beach cuts: A "scalloped" shoreline created by gently sloped beaches and hard points discourages shoreline erosion. Beach cuts will also help generate fill material for points and will be used to balance reservoir flood capacity**. (Figure 5)
- Breakwater point/jetty: VFRR or boulder edge protects points with high exposure and encourages sand deposition (Figures 2,3,4, and 6)

Objective 2. *Reduce surface erosion due to runoff and improve water quality of runoff from parking areas and trails before entering the reservoir.*

Strategy

- Utilize diversion and infiltration strategies to improve water quality of runoff from parking and hard-surface areas (Concept Plan Figure 1)
- Re-configure parking at Mountain Loop to provide buffer from reservoir and redirect flows through an infiltration area (Concept Plan Figure 1)
- Prioritize and improve trails to reduce concentrated flows by utilizing signage, fencing, stable walk surface materials, boardwalk type crossings(over wet infiltration areas) and waters bars (Concept Plan Figure 1)

Details

- Bio-swales and infiltration areas (Figure 7)

Objective 3. *Maximize preservation of existing desirable vegetation capitalizing on the ecological and recreational values associated with it.*

Strategy

- Place fill soils to create "points" in locations where desirable existing trees have exposed tree roots due to cut banks. (Concept Plan Figure 1)
- Reclaim un-desirable or weedy areas and promote healthy re-vegetation as recommended in the "Maintenance and Restoration Recommendations" section of the Vegetation Survey (Attachment A)
- Consider construction phasing and methods which preserve and restore desirable vegetation.

Details

- Fill at cut bank (Figures 3 and 4)

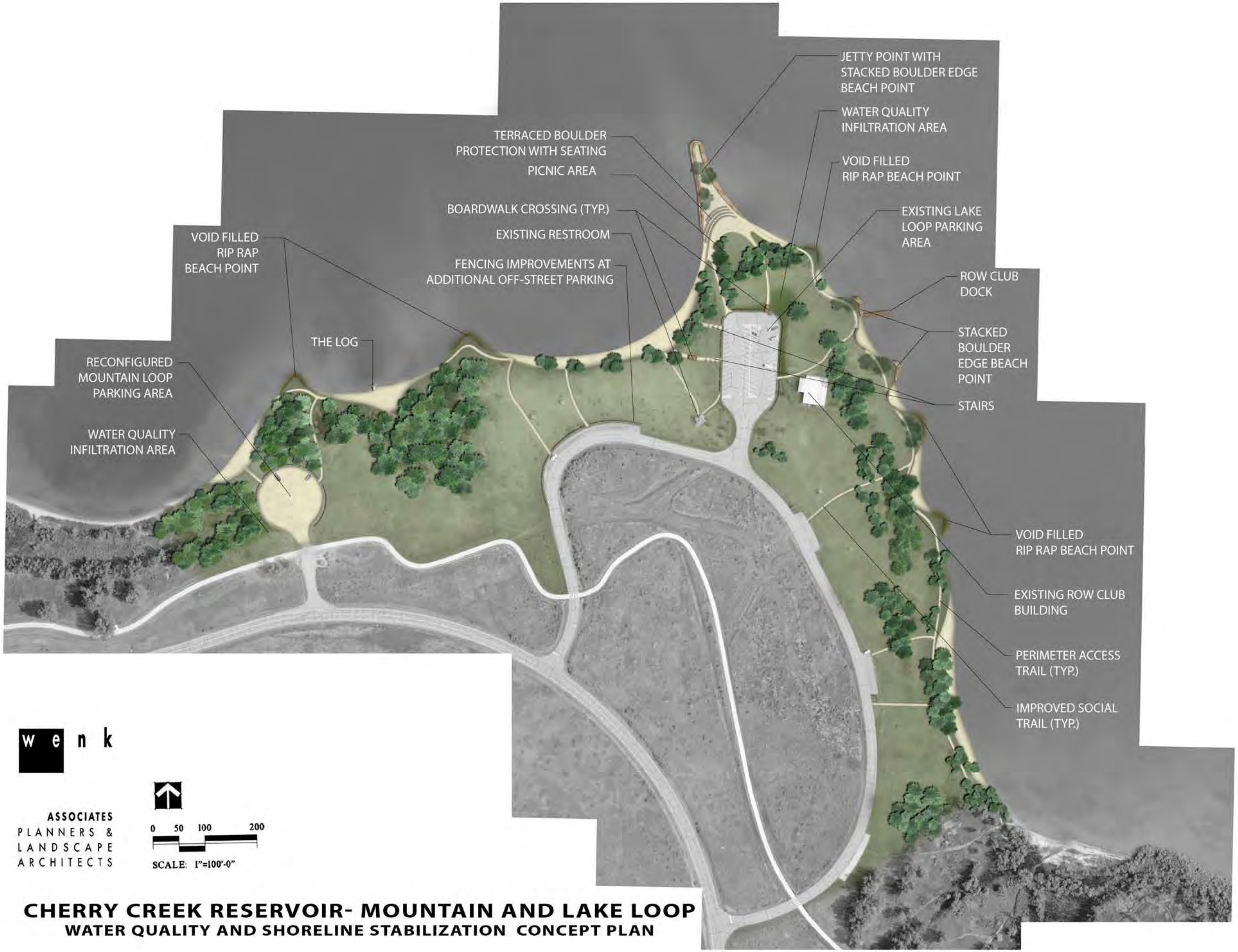
Objective 4. *Create multi functional solutions that enhance visitor experience and proposed uses while reducing operation and maintenance requirements.*

Strategy

- Integrate input and feedback from the Technical Advisory Committee (TAC), Cherry Creek State Park staff, Marina operators, Row club members, and other stakeholders to determine desirable recreational *and* operational requirements and outcomes.
- Provide (ADA) accessible routes and amenities in the Project where possible and appropriate.
- Provide new perimeter access trail for maintenance access and for enhanced pedestrian access
- Utilize construction methods and materials which recognize the importance of maintenance and operational requirements, yet provide for pleasant tactile and aesthetic experience for visitors.

*** The following pages contain conceptual rendered details of preferred alternatives for improvements. Please refer to the *Attachment B- (Concept Development Drawings)* for more detailed plans and information pertaining to the recommendations provided in this report.**

**** The Army Corps of Engineers requires balanced flood volume capacity in any project impacting the constructed reservoir.**



CHERRY CREEK RESERVOIR- MOUNTAIN AND LAKE LOOP
WATER QUALITY AND SHORELINE STABILIZATION CONCEPT PLAN

FIGURE 1 CONCEPT PLAN

Conceptual Sections

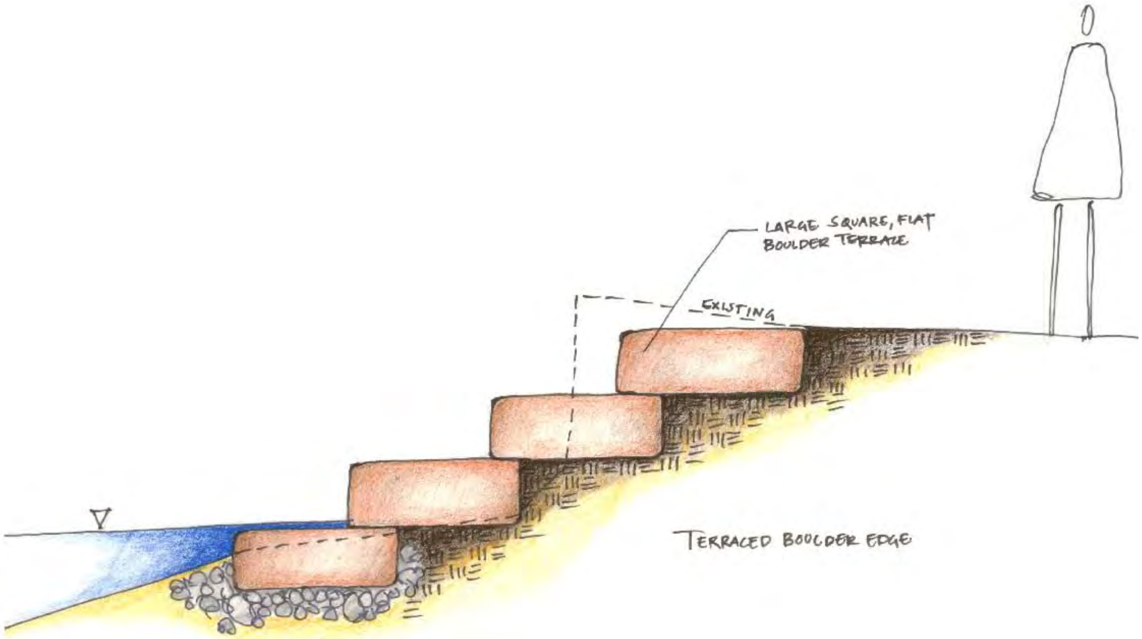


Figure 2 TERRACED BOULDER EDGE

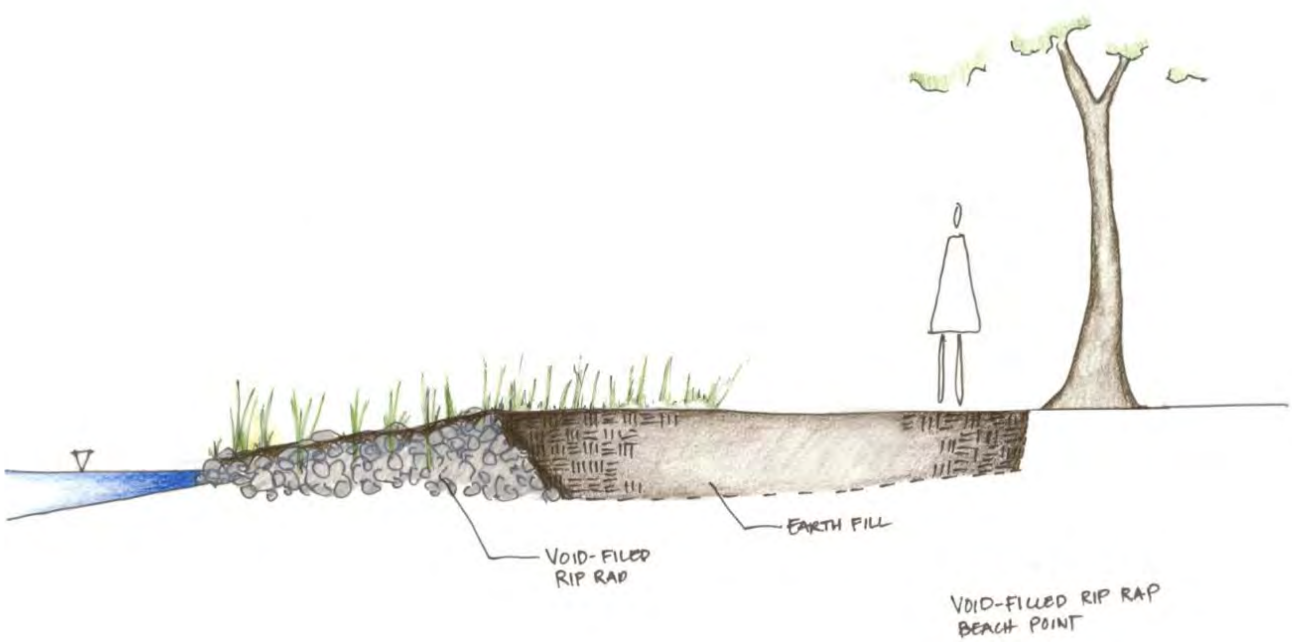


Figure 3 VOID FILLED RIP RAP BEACH POINT

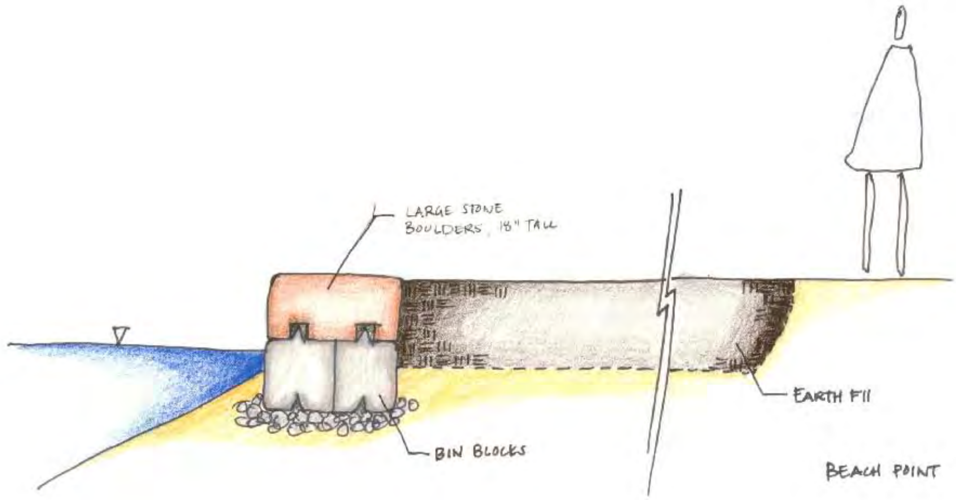


Figure 4 HARD EDGE BEACH POINT

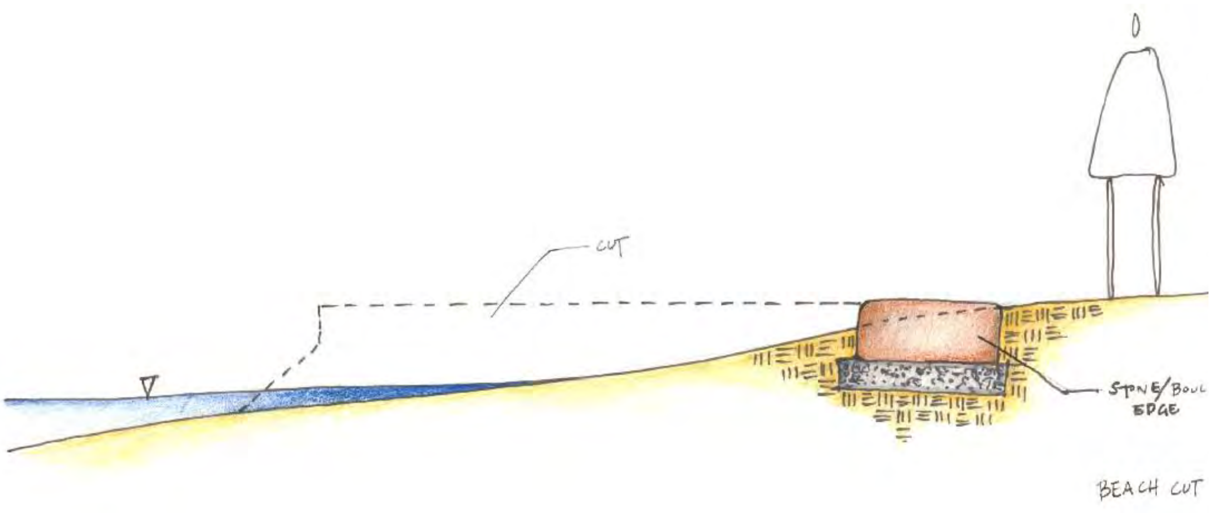


Figure 5 BEACH CUT

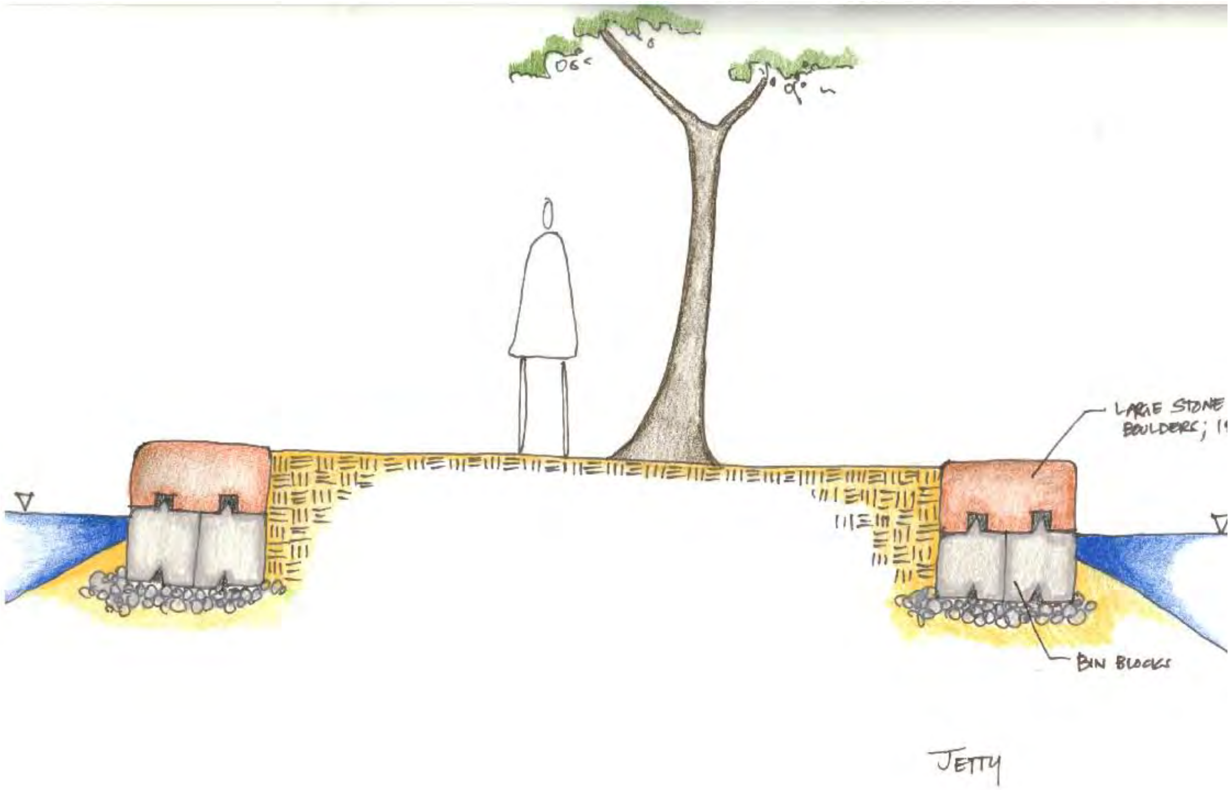


Figure 6 JETTY

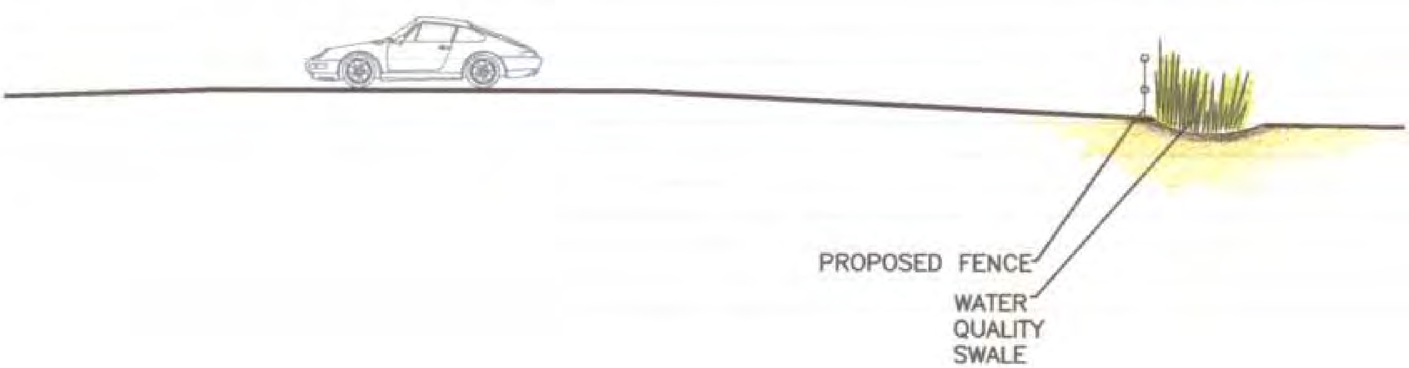


Figure 7 PARKING INFILTRATION SWALE

Implementation Recommendations

Due to the nature of the Project, the Design Team recommends a lower level of detail in Final Design (as compared to traditional "Final Design" and a proportionally greater investment in construction services (from the Design Team) in order to facilitate a higher quality and more cost effective approach as reflected in the *Opinion of Probable Costs* section of this report.

The Design Team has the following recommendations for progression and implementation of the stabilization project outlined in this report and the accompanying drawings.

1. **Additional investigations and data collection** are required for accurate and effective design solutions. These investigations will occur as part of, and prior to, the final design process and will include, but are not limited to, the following:
    1. *Horizontal and topographic survey-* Survey information provided for this Concept Development scope of work does not provide the level of detail required to produce accurate drawings for construction documents.
    2. *Geotechnical exploration-* As an optional item to be considered, an understanding of soil profiles may be necessary in order to make informed decisions regarding infiltration, cut/fill, and structural stabilization strategies (i.e. foundations etc.)

2. **Final Design** documents should include the following:
    1. *Existing conditions* plans and survey
    2. *Demolition and site preparation* plans
    3. *Layout plans* and *construction details*
    4. *Grading, Erosion, and Sediment Control (GESC)* plans
    5. *Cut/Fill calculations required to prove balanced flood volume capacity*
    6. *Planting and re-vegetation* plans
    7. *Specifications and materials selections*

3. **Review and Approval** of final design documents and implementation procedure by:
    1. Army Corps of Engineers
    2. Cherry Creek State Park

4. **Construction Services** will play an important role in the implementation of the design. The anticipated construction period will span between 24 and 36 weeks, therefore construction phasing and the contractor's experience and efficiency are critical for the Projects success. The following services should be included in the construction process:
    1. *Contractor selection-* The combination of unique stabilization techniques, natural resource protection, shallow water earthwork, and recreation development will require specialized experience which will require a rigorous contractor pre-qualification and selection process.
    2. *Bid Assistance* - The Design Team will prepare a comprehensive bid form and will assist in the contract bid process including RFI administration, the addendum process, and bid tabulation.

3. *Construction observation-* Layout assistance and availability of the landscape architect and engineer(s) for observation of construction processes will be critical in realizing the intent of the design. This recommendation is based on previous experience which indicates that site-layout, staking, and observation will be more accurate and responsive to the existing and rapidly changing site conditions of this project type. Tasks will include:
   - *Weekly construction and site coordination meeting attendance*
   - *Site layout for improvements*
   - *Construction observation which includes:*
     - *Pre-construction meeting*
     - *Submittal review*
     - *Site detail inspections*
     - *Final walk-through, punch list, and warranty inspections*

Opinion of Probable Costs

Cherry Creek Mountain and Lake Loop Shoreline Stabilization
Preliminary Opinion of Probable Construction Costs
September 2008

Description	Qty.	Unit	Unit Price	Total
Construction				
Earthwork-Cut/Fill	35,000	CY	$ 6.00	$ 210,000.00
PLD Material	350	CY	$ 100.00	$ 35,000.00
Void Filled Rip Rap	1,700	CY	$ 70.00	$ 119,000.00
Stacked Boulder 24"-36"	700	CY	$ 110.00	$ 77,000.00
Mountain Loop Parking re-configuration	1	LS	$ 30,000.00	$ 30,000.00
Path Improvements (includes perimeter access trail)	10,000	SF	$ 5.50	$ 55,000.00
Misc. Standard CCSP details(fencing, stairs, boardwalk crossings, etc)	1	LS	$ 40,000.00	$ 40,000.00
			Line Item Subtotal	*$ 566,000.00*
Contractor costs		LS		$ 50,000.00
Survey, Geotechnical		LS		$ 20,000.00
			Construction Subtotal	***$ 636,000.00***
Final Design (Design Team)	1	LS	$ 70,000.00	**$ 70,000.00**
*Includes Refined engineering and site design, GESC drawings, additional topo survey				
Construction Services (Design Team)	1	LS	$ 80,000.00	**$ 80,000.00**
*Includes Construction Observation services by the design team				
			Project Budget	**$ 786,000.00**

*** Construction cost opinion and estimate of construction services fee to be reassessed/refined during final design phase.**

Attachment A - Vegetation Survey

Cherry Creek Reservoir
Mountain and Lake Loop
The Restoration Group, Inc.
June 19, 2008

Introduction
This report describes the vegetation within the study area at Cherry Creek Reservoir, including Mountain and Lake Loops. Plant communities, distribution, derivation, soils, and ecological functions are discussed. A brief list of maintenance and restoration recommendations is included at the end of the report. This study was conducted in early June, 2008.

Background
Cherry Creek State Park, lying within Arapahoe County, is a large water storage facility with recreational access. The vegetation of the area at the time of reservoir construction consisted of a disturbed upland prairie straddling the historic creek channel. Most of the disturbance on the study site is derived from recent reservoir construction and the preceding hundred years of agricultural usage for grazing, small grain production, access roads and ranch yards. Prior to these impacts the site supported short and midgrass upland prairies with a narrow band of riparian meadows, woodlands and wetlands along the historic Cherry Creek Channel.

The upland soils are silt loam and deep silty clay loam of the Fondis series. Sandy alluvial soils occurred along the historic creek channel and very recent sandy deposits are present on the newer reservoir shoreline. The historic finer grained upland soils are reported to have fairly slow permeability and internal drainage with a high tendency for water and wind erosion (Arapahoe County Soils Survey, USDA).

Evidence of the historic vegetation and subsequent disturbance is reflected more or less in the current vegetation. Prior to western settlement of the area, the landscape probably consisted of a mosaic of shortgrass, midgrass and sand prairies with a narrow band of sub-irrigated vegetation lining historic Cherry Creek channel and its tributaries, consisting of a complex of lowland tallgrass prairie, marsh, and riparian shrublands and woodlands.

VEGETATION TYPES OF THE MOUNTAIN AND LAKE LOOPS STUDY SITE AT CHERRY CREEK RESERVOIR

The current plant communities of the Mountain and Lake Loops have been mapped (Maps 1-3, attached) in seven vegetation types. These vegetation units reflect the presence of the preexisting historic vegetation, past disturbance and reseeding with introduced Eurasian species, and current land use and management. The existing mapped vegetation types include:

VEGETATION TYPES
Beach (B)
Beach margin wetland (Wb)
Marsh wetland (Wm)
Riparian woodland and meadow (R)
Remnant upland prairie (P)
Disturbed upland grassland (D)
Mowed lawn area (L)

These units are delineated on the attached vegetation maps (maps 1-3) and are described below. Paved and unpaved paths, parking and pavement were mapped, but are not labeled.

Figure 1. A beach area east of the Lake Loop, with young cottonwood seedlings. These trees may be uprooted be wave or ice action before they can mature to saplings.

BEACH
Sandy beach areas are common along the shoreline at both Mountain and Lake Loops. These sands appear to be very recent shallow deposits, overlaying deep soils of silt loam and silty clay loams. Where the topography near the beach is steeper, the native soils are exposed as short vertical banks behind narrow sandy beach areas. Susceptible to wind and water erosion, these silt and clay banks appear to be easily cut by wave and ice action.

Where apparent excavation occurred along the shoreline, during reservoir development (possibly borrow sites) the excavation areas have gradually filled in with deeper sand deposits. In these areas the beaches tend to be flat and broad.

Heavily utilized beach areas tend to support scanty beach vegetation. Where lesser usage of the beach occurs, there may be a band of year old seedling cottonwood trees growing in the mid beach area. These small trees seem may be eliminated by wave or ice abrasion, as sapling trees have not colonized these sites. Little herbaceous vegetation occurs within the area of wave action on sand deposits. Where the silt loam and silty clay loam soils reach to the lake margin, woody vegetation can occur at the water's edge. These areas are discussed later in the riparian woodland and meadow vegetation type.

WETLANDS

Two kinds of wetland vegeation types occur in the study area. These are beach margin wetlands and marsh wetlands. These can occur is both the sandy and silty soil conditions as long as ground water level (determined by the reservoir fill height) lies near the surface.

Figure 2. Beach Margin wetland west of the Mountain Loop beach area. Bulrush and sandbar willows are visible on the low sandy berm at the rear of this beach.

Beach margin wetland

The first of these wetland vegetation types is the sandy **beach margin wetland**. These wetland areas are situated on low berms which have developed at the rear of some beaches. This wetland type occurs along both Mountain Loop and Lake Loop shoreline. These wetland areas occur along the reservoir edge in former dam construction borrow areas which were initially occupied by shallow water in the newly constructed reservoir. Over time, sand deposited by wind or wave action has filled the borrow areas, creatng the current shoreline.

Beach margin wetland vegetation which established on the moist edge of the new reservoir created and sustains the low sandy shoreline berm on which it grows in two ways. First, the above ground structure of the vegetation slows the winds and high waves at the reservoir edge, causing sand to drop out of suspension in the slowed air or water. In this way the wetland vegetation functions as living snow fence which continues to cause deposition of sand along the beach margin. Second, the below ground rhizomatous root mass typical of wetland vegetation is adapted to continually invade fresh sand deposits and quickly stabilize them, creating significant erosion protection for the shoreline areas. Gradually these low berms have aggraded to an elevation of 6-12 inches or more in height above the water table.

Deeply rooted species within the **beach margin wetlands** continue to thrive in the aggrading berms. Common species occurring within these areas include: American bulrush (*Schoenoplectus pungens*, aka *Scirpus americanus*), hardstem bulrush (*Schoenoplectus lacustris*), wooly sedge (*Carex lanuginosa*), inland saltgrass (*Distichlis strictus*), and sandbar willow (*Salix* exigua). In slightly higher sites, more mesic species occur, as well, including showy milkweed (*Asclepias speciosa*), perennial ragweed (*Ambrosia psilostachya*), peach leaved willows (*Salix amygdaloides*) and plains cottonwoods (*Populus deltoides* ssubsp. *monilifera).* These species are well adapted to these areas and will continue to survive as long as foot traffic is relatively light and a connection to the ground water beneath is retained. Species typical of the slightly drier moist meadow areas, such as the showy milkweed, may eventually become more common if the distance to the groundwater increases. Abrasion by heavy foot traffic will also cause some of these species to be lost. Trees rooted in these areas may not survive over the long term unless the soils aggrade significantly, as the shallow soils over the watertable offer little capacity to support the weight of a mature tree in strong winds.

Figure 3. Marsh wetland with narrow-leaved cattail in the wet central area, ringed by sandbar willows and riparian woodland. Mountain Loop.

Marsh wetland
The second wetland vegetation type, **marsh wetlands** occur behind the shoreline berm in the remaining portion of the former borrow areas and also in low portions of the pre-existing topography which now lie near the reservoir edge and are frequently saturated by the current ground water level. One long narrow **marsh wetland** occurs west of the Mountain Loop parking area just behind the beach margin berm. Its outlet opens to the reservoir at the western end of the study area. Two smaller marshes occur between Mountain Loop and along the eastern boundary of the study area, east of Lake Loop.

Lower areas of the marshes typically have standing water whenever the reservoir is full. Most of the vegetation in these areas was derived from wind or waterborne seed which colonized bare soil or sands in the former scrapes or replaced the drowned upland prairie in the areas of soil saturation. The wetter portions of these marshes are herbaceous, with woody vegetation occupying the slightly higher or marginal portions of these sites. Common species within the wetter portions are narrow leaf cattail (*Typha angustifolia*) and hardstem bulrush (*Schoenoplectus lacustris*). In the slightly higher portions of the **marsh wetlands,** where standing water occurs less frequently, the typical species include: Wooly sedge (*Carex lanuginosa*), inland saltgrass (*Distichlis strictus*), American bulrush (*Schoenoplectus pungens*), sandbar willow (*Salix* exigua), showy milkweed (*Asclepias speciosa*), and perennial ragweed (*Ambrosia psilostachya*). The edges of these marsh areas are nearly continuously lined by additional sandbar willows (*Salix* exigua), peach leaved willows (*Salix amygdaloides*) and plains cottonwoods (*Populus deltoides* ssubsp. *monilifera).* Common noxious weedy species found within the drier portions of these areas include Canada thistle (*Breea arvensis*) and Russian olive (*Eleaegnus angustifolia*), a small introduced tree species.

The **marsh wetlands** function as detention/retention basins and vegetated filter strips to upland area runoff, removing sediment and nutrients prior to slow release into the ground water or reservoir. These areas can provide nesting sites for regional birds such as Red winged and Yellow headed blackbirds, American Bittern and Marsh wrens. Foxes, raccoons, coyotes and owls likely hunt along the wetland margins.

Figure 4. Riparian woodland and meadow in the eastern portion of Lake Loop.

RIPARIAN WOODLAND AND MEADOW

Ringing the reservoir in a green band is the most recognizable vegetation cover types on the site: the moist **riparian woodland and meadow.** In this area, riparian woodlands intermingle with moist open meadows in a broad belt around the reservoir. These areas are directly connected to the riparian woodlands along the margins of the Cherry Creek channel upstream of the reservoir. The native vegetation here is largely derived from the upstream areas. Like the parent plant communities along the stream, the riparian woodlands and meadows are sub-irrigated by proximity to the ground water. Unlike the lower lying wetland types, the soils in these areas are seldom fully saturated. The **riparian woodland and meadow** vegetation type may occur along the margins and upper areas of former borrows, but is generally rooted within the finer textured silt loam and silty clay loam soils.

The native plains cottonwoods and peach leaved willows have colonized moist bare soil areas around the margins of the reservoir since it filled. The ribbons of mid-sized trees evidence former openings in the herbaceous plant cover, where bare disturbed areas or drowning historic prairie permitted tree seedlings to colonize. Seedling cottonwoods began as dense single age stands, and over time, most of the original trees, declined and were lost. These woodlands are still young and sorting out which trees will grow to full maturity. Many of the smaller trees in these areas are currently losing vigor, crowded and over shadowed by the healthier and larger individuals. Over time these stands will retain only a fraction of the current number of trees. But these surviving trees will be more widely spaced, much larger, and will likely provide as much or more canopy cover as the more numerous younger trees.

The **riparian woodlands** have low species diversity, typical of young riparian areas. Native riparian shrubs are only just beginning to appear in the understory, as the result of the 'natural recruitment' process. Natural recruitment occurs as birds and medium sized mammals, forging in older diverse neighboring woodlands, carry seeds (golden currant (*Ribes* *aureum*), chokecherry (*Prunus virginiana*), wild plum (*Prunus americana*), nannyberry (*Viburnum lentago*), and snowberry (*Symphoricarpos occidentalis*) into the young forests and leave them behind in their droppings, thus 'recruiting' greater native diversity to the younger woodlands. Over time, native shrubs establish in the understory, making these woodlands much better habitat. Currently, choke cherry is the only native understory shrub species observed within the study area. Russian olive, a small *non*-native tree, has colonized the woodlands as well. Planted in wind breaks, birds have spread them around. Now this species is listed as a noxious weed due to the competition they present to native riparian species.

Among the trees, moist meadows occur which are a mixture of native and introduced herbaceous species, and are evidence of recent disturbance and reseeding. Most of the species in the meadows are non-native or weedy exotic grasses, such as: smooth brome (*Bromus inermus*), Kentucky bluegrass (*Poa pratensi*s), and quackgrass (*Agropyon repens*). A few native species have also colonized these newly moist areas, including: western wheatgrass (*Pascopyrum* smithii), foxtail barley (*Critesian jubatum*), inland saltgrass, and showy milkweed. In spring, patches of the tall non-native yellow sweet clover (*Melilotus officinale*) are abundant, as are noxious weeds such as Canada thistle and leafy spurge (*Euphorbia esula*).

The **riparian woodlands and meadows** offer foraging areas for warblers and other migratory and resident birds, as well as potential nesting sites for Red-shafted flicker, Black-billed magpie, Great horned owls, Western screech owls, Red-tailed hawk, and other raptors, Wood ducks, and in larger trees, Great blue and Black-crowned night herons. The roots of cottonwoods and willows anchor the soils in place where they have established along the shoreline, slowing erosion by ice or wave action. Evapotranspiration from the dense canopy of leaves, humidifies and cools the adjacent air, by 5 to 10 degrees, and offering respite from the summer heat. Finally, mature cottonwoods can become truly huge, and are the largest single life form between the Mississippi River and the Sierras, making the species a kind of 'blue whale of the prairie'; thriving and towering over other more diminutive native regional vegetation. Half the dry weight of each tree (many tons), is stored carbon, an increasingly important consideration in our warming global climate).

REMNANT UPLAND PRAIRIE

The limited areas of native shortgrass and midgrass species which have avoided or recovered from grazing or reservoir construction traffic still occur on site. These native plant communities occur on silty clay loam and silt loam soils in upland sites between the two loop parking areas. This small prairie is a remnant of a plant community which has inhabited this area since the end of the last ice age 11,000 years ago; an *old growth* prairie.

Plant diversity of this prairie remnant has been reduced by a variety of recent disturbance events, but surviving species include: buffalograss (*Buchloe dactyloides*), blue grama (*Chondrosum gracile*), western wheatgrass (*Pascopyrum smithi,* aka *Agropyron*), sideoats grama (*Bouteloa curtipendula*), three awn (*Aristida purpurea*), green needlegrass (*Nasella viridula,* aka *Stipa*), needle-and-thread grass (*Hesperostipa comata*), golden aster (*Heterotheca villosa*), (*Psoralidium tenuiflorum*, aka *Psorlea*), scarlet globe mallow (*Sphaeralea cocinnea*), and rubber rabbitbrush (*Chrysothamnus nauseosus*). Numerous weedy species also are present, including: great mullein (*Verbascum thaspus*), leafy spurge, cheatgrass (*Anisthana tectorum* aka *Bromus*), and Japanese brome (*Bromus japonicus*). Two non-native grasses smooth brome and crested wheatgrass occur occasionally, probably due to interseeding. In places (especially just west of the lake

Loop Parking area) the moister edge near the reservoir is densely colonized by the introduced yellow sweet clover, which can grow up to 6 feet in height.

Figure 5. Native upland prairie in Mountain Loop, with the native bunchgrass needle-and–thread grass in the foreground.

DISTURBED UPLAND GRASSLAND

This is the most extensive of all the mapping units in the study area. Much of the upland areas south and west of Mountain and Lake Loop support this vegetation type. Reclamation activities following dam construction, inter-seeded with non-native grass species: smooth brome and crested wheatgrass. Soils here are the typical silt loams found elsewhere around the reservoir. A few native species persist where the exotic grasses failed. Species with windborne seeds have become established in the **disturbed upland grasslands,** including the native shrub, rubber rabbitbrush and the noxious weed, musk thistle (*Carduus nutans*). Leafy spurge, another noxious weed is also present.

While the non-native grasses which dominate the **disturbed upland grassland,** do provide cover for soil and forage for grazing animals, the lack of native prairie grasses and diverse wildflowers and shrubs greatly diminishes the habitat and aesthetic values of this largely disturbed cover type.

Figure 6. A weedy area within the disturbed upland grass vegetation type, showing weedy species: musk thistle and leafy spurge.

MOWED LAWN

The largest vegetation type is represented by the **mowed lawn** at the Lake Loop. The vegetation within this lawn area has species elements found elsewhere in riparian woodland and meadow, as well as remnant upland prairie and disturbed upland grassland cover types. The soils supporting this mowed vegetation are the typical native silt loam and silty clay loam. Scattered stands of mid-sized cottonwoods occur throughout, reaching to the shore where the native soils approach the water's edge. The cottonwood stands consist of closely spaced young trees, much as those found in the riparian woodlands elsewhere on the site. Stands of trees near the water occasionally have small peach-leaved willows, as well. Unmowed taller grasses under the trees, discourages foot traffic and picnicking, thus protecting the tree roots from excessive compaction, which can kill these trees. Some weedy non-native species are present, mostly represented by yellow sweet clover. Although the lawn *is not* irrigated Kentucky bluegrass, it serves well as a landscape for picnicking and other beach related recreational activities. This area is very important to the recreational users of the park.

Figure 7. Mowed lawn in the Lake Loop area showing diverse mowed species with closely growing mid-sized cottonwood trees.

MAINTENANCE AND RESTORATION RECOMMENDATIONS

The following is a very brief list of general recommendations related to management and restoration of native diversity to the state park in this location.

Control noxious and nuisance weedy species including: Canada thistle, musk thistle, leafy spurge, Russian olive trees, Tamarisk (near the boathouse) and yellow sweet clover.
Initiate a program of selective removal of stressed, sick or overly dense cottonwoods to allow space for individuals to mature and increase in size.
Augment riparian woodlands and meadows (or infiltration areas) with native shrubs such as wild plum, chokecherry, golden currant, nannyberry, and western snowberry. These species will provide cover to replace the Russian olive and far better habitat and aesthetic value. Systematically adding them to the site will speed the process of diversification and improve the passive recreational value.
Utilize native seed mixtures for repair and reseeding of any future disturbance to non-lawn areas. A broad range of native species could serve to add to the existing plant communities to strengthen and diversify areas within the park, which have only recently been converted to moist riparian conditions or which have been heavily impacted in the recent past.
Reservoir edge in the sub-irrigated lower portions of mowed lawn could be augmented with carefully selected well adapted native tubeling grasses. By selecting species suited to the site usage as well as the exiting soils and condition, it could be possible to support the recreational need of the area, while not compromising the native recovery of the state park landscape. In some areas, introduced lawn grasses may be the better selection.
Shoreline stabilization areas should be designed to sustain the anticipated impact by water, ice, wind, and users. Where these sites can be created to restrict or discourage easy access to

newly planted areas, or where user intense impact is unlikely, installation and establishment of adapted native vegetation should be encouraged.

Run off from parking areas and roofed areas may be utilized to augment nearby planting areas. Riparian shrubs and woodland species may be located in these moister infiltration sites to provide screening and diversity.

Deep planting and poling methods may be used to establish additional cottonwoods farther from the water's edge, if desired.

Figure 8. A quiet beach between Mountain and Lake Loops in Cherry Creek State Park.

Attachment B – Water Quality Benefits of Shoreline Stabilization Memorandum

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Memorandum

To: Jesse Clark, Wenk Associates

CC: Jim Wulliman, Muller Engineering Company

From: William P. Ruzzo, P.E.

Date: October 23, 2008

Re: Water Quality Benefits of Shoreline Stabilization

Presented in this memorandum is the Authority's assessment of the water quality benefits of shoreline stabilization.

What Causes Shoreline Erosion And What Are The Impacts To Reservoir Water Quality?

Wind, wave, ice, storm runoff, and recreation users cause surface soils to become "detached", allowing soil movement (sediment) and eventual discharge into the Reservoir. Sediment is a pollutant that impacts aquatic habitats. Sediment and stormwater runoff also include phosphorus, nitrogen, and other pollutants that encourage the growth of algae. Algae negatively impact beneficial uses of the reservoir, such as fishing, swimming, and boating.

How Does Stabilization Improve Water Quality?

Shoreline stabilization reduces the quantity of pollutants that enter the reservoir through stabilization techniques that:

a. Uses rock or other non-erodible materials to protect shoreline , which prevents or minimizes the amount of erosion that can occur and, therefore, the discharge of pollutants to the Reservoir.

b. Uses vegetation to naturally stabilize soils and also filter sediment from storm runoff, thereby immobilizing and trapping pollutants, preventing them from entering the Reservoir.

c. Encourages infiltration of storm water which reduces runoff volume and, therefore, quantities of pollutants entering the reservoir related to surface runoff and shoreline erosion.

Shoreline stabilization measures and related best management practices (BMPs) also reduce concentrated discharges and pollutants (sediment, nutrients, pesticides, oil/grease)[1] found in runoff from parking lots and other paved surfaces (i.e. roads, formal paths, and social trails). The BMPs use sedimentation, filtration, and infiltration techniques described above to immobilize and trap sediment before entering the Reservoir.

How Much Phosphorus Is In Watershed Soils?

A summary of phosphorus soil sampling from the watershed, and stream bed and banks is presented in the Table 1 on the next page. Evaluation of these data shows that:

1. Watershed soils tests resulted in average extractable phosphorus of 1.5-mg/kg (sample location 5), which puts these soils in the “very low” rating for available phosphorus. However, as the soil erodes and is transported downstream by storm runoff, some soil is deposited in the stream beds and along stream banks. This deposition results in an increase in soil phosphorus concentration, a phenomenon known as pollutant enrichment[2]. This enrichment is evident in tests at sample locations 2, 3, 4 and 6, all which show an increase in phosphorus concentration in soils as it is transported by storm water runoff.

2. The amount of phosphorus in soils is also dependent on the grain size, with coarser grain sizes (i.e.: fine sands and coarser) having significantly less phosphorus, as evidenced by sample location 4 in Cherry Creek. The soils along the reservoir shoreline are mostly silts, clays, and fine sands.

How Does the Authority Evaluate Water Quality Benefits of Shoreline Stabilization?

The Water Quality Control Commission (Commission) established a chlorophyll *a* standard as a measure of algae in the reservoir to protect the beneficial uses of the reservoir. The Commission also established a total maximum annual load (TMAL) for phosphorus as a goal meant to achieve the chlorophyll a standard. Therefore, controlling phosphorus loads to the Reservoir was established as the watershed management strategy.

In the past, the Authority has used *pounds* of phosphorus *“trapped” or “immobilized”* as a basis to evaluate projects. However, based on data collected by the Authority, phosphorus *concentration* in Cherry Creek and other tributaries was found to be the most reliable predictor of chlorophyll *a* concentrations in the Reservoir and therefore, is the proposed basis for evaluating the water quality benefits of shoreline and stream stabilization projects.

Quantification of phosphorus reduction from shoreline stabilization is different from stream bank stabilization, primarily because shorelines are impacted by additional erosive forces besides storm runoff, including wave and ice forces and recreation impacts. In addition, because storm runoff along the shoreline is more “dispersed” in nature, it is often impractical to measure

[1] Kadlec and Knight.1996. *Treatment Wetlands*. CRC Press LLC, p22.
[2] Novotny and Chesters, 1981. *Handbook of Nonpoint Pollution Sources and Management*. Van Nostrand Reinhold, p 215

phosphorus concentrations in the flows that enter the reservoir. Therefore, approximate methods are required to estimate the benefits of shoreline stabilization that rely on available data and engineering judgment.

Table 1 – Summary of Phosphorus Concentrations in Watershed Soils

Location	Total Phosphorus	Extractable Phosphorus
1. Shoreline bank materials at East Shade Shelter (CH2MHill[3])	500 mg/ kg or 1 -lb/ton	n/a
2, Cottonwood stream bank and stream bed results (GEI[4])	573 mg/kg or 1.15-lbs/ton	1.42 mg/kg or 0.2%
3. Cottonwood\Peoria accumulated sediment (GEI[5])	743 mg/kg or 1.49 lbs/ton	3-mg\kg or 0.4%
4, Cherry Creek Bed Sediment at Arapahoe Road (Tetra Tech[6])	36-mg/kg or 0.07-lbs/ton	n/a
5. Watershed soils investigations (Halepaska[7])	n/a	1.5-mg/kg or 0.003-lbs/ton
6. Cherry Creek Bed Samples (Halepaska[8])	n/a	Ortho P range 300 to 1,500 mg/kg

Since data for phosphorus contained in shoreline runoff is limited, the following analysis utilizes data from stream stabilization techniques to draw conclusions about benefits of shoreline stabilization.

Phosphorus loads, and to some extent concentrations, are dependent on the size of tributary areas to the shoreline, which are typically much smaller (i.e.: less than 100-acres) than for streams, such as Cherry Creek (365-square miles), Cottonwood Creek (18-square miles), and Shop Creek (550-acres). As the result, rainfall on shoreline tributaries can produce high runoff rates and erosion forces for short, more intense storms that would yield somewhat higher phosphorus concentrations in the runoff. For instance, phosphorus, event-mean-concentrations (EMC) for undeveloped land is around 0.40-mg/l[9] which is believed to be representative of the

[3] CH2MHill. Results of composite bank samples obtained during design of East Shade Shelter project.
[4] GEI 2008. Results of bank and bed sediment samples taken by the Authority in Cottonwood Creek upstream of Easter Avenue.
[5] GEI 2008. Results of samples obtained by GEI from Cottonwood\Peoria detention pond for 2007 CIP OM-8
[6] Tetra Tech 2006. Results of Cherry Creek bed samples obtained by Tetra Tech as part of the 2006 CIP CCB-5.1 project "Cherry Creek Sediment Basin at Arapahoe Road"
[7] J.C. Halepaska, December 9, 1999. *Cherry Creek Basin Soil Analysis Results*
[8] Ibid, quarterly bed sediment sample analysis from 1994 to 1999.
[9] UDFCD 2008. *Urban Storm Drainage Criteria Manual Volume 3 Best Management Practices*. Note that the Authority's watershed model used a value of 0.28 mg/l for undeveloped which included data from Colorado Springs area. The UDFCD value was selected here because the reservoir is in the metro area where the 0.40-mg/l was developed, whereas the watershed extends outside the metro area, almost to Colorado Springs.

runoff concentrations for the tributary areas along the reservoir shoreline from pre-project conditions.

The median phosphorus concentrations for Cottonwood Creek and Shop Creek where they enter the reservoir are 0.22-mg/l and 0.13-mg/l, respectively, which includes both base and storm flow measurements. Both Shop Creek and Cottonwood Creek have detention, wetlands, and stream stabilization measures that were constructed and, therefore, this data provides some indication of phosphorus concentrations that can be expected from BMP discharges. For comparison purposes, background phosphorus concentrations are estimated to be around 0.18- to 0.20-mg/l[10,] and the median discharge concentration from extended detention basins is 0.24-mg/l[11]. Phosphorous concentrations associated with the type of BMPs implemented as part of proposed shoreline stabilization improvements would be expected to be similar and possibly lower than the median discharge concentration from the above stream stabilization projects.

The conclusion from this comparison is that, over the long-term, shoreline stabilization is expected to reduce phosphorus concentrations into the reservoir from pre-project conditions and likely would reduce concentrations to a level consistent with the Authority's goal of 0.20-mg/l. [12]

[10] Cherry Creek Basin Water Quality Authority 2008. *Summary of Activities to Comply with Phased TMAL Requirements*

[11] American Society of Civil Engineers (ASCE) BMP database for extended detention basins

[12] CCBWQA 2008. Proposed phosphorus goal for control regulation 38 and 72 hearings in March 2009.

Attachment C – Water Surface Elevation Memorandum

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Memorandum

To: Jess Clark, Wenk LA

CC: Jim Wulliman, Muller Engineering Company

Tim Metzger, Manager, Cherry Creek State Park

Karen Sitoski, USACE

From: William P. Ruzzo, P.E.

Date: August 1, 2008

Re: Mountain Loop Shoreline Stabiliztion

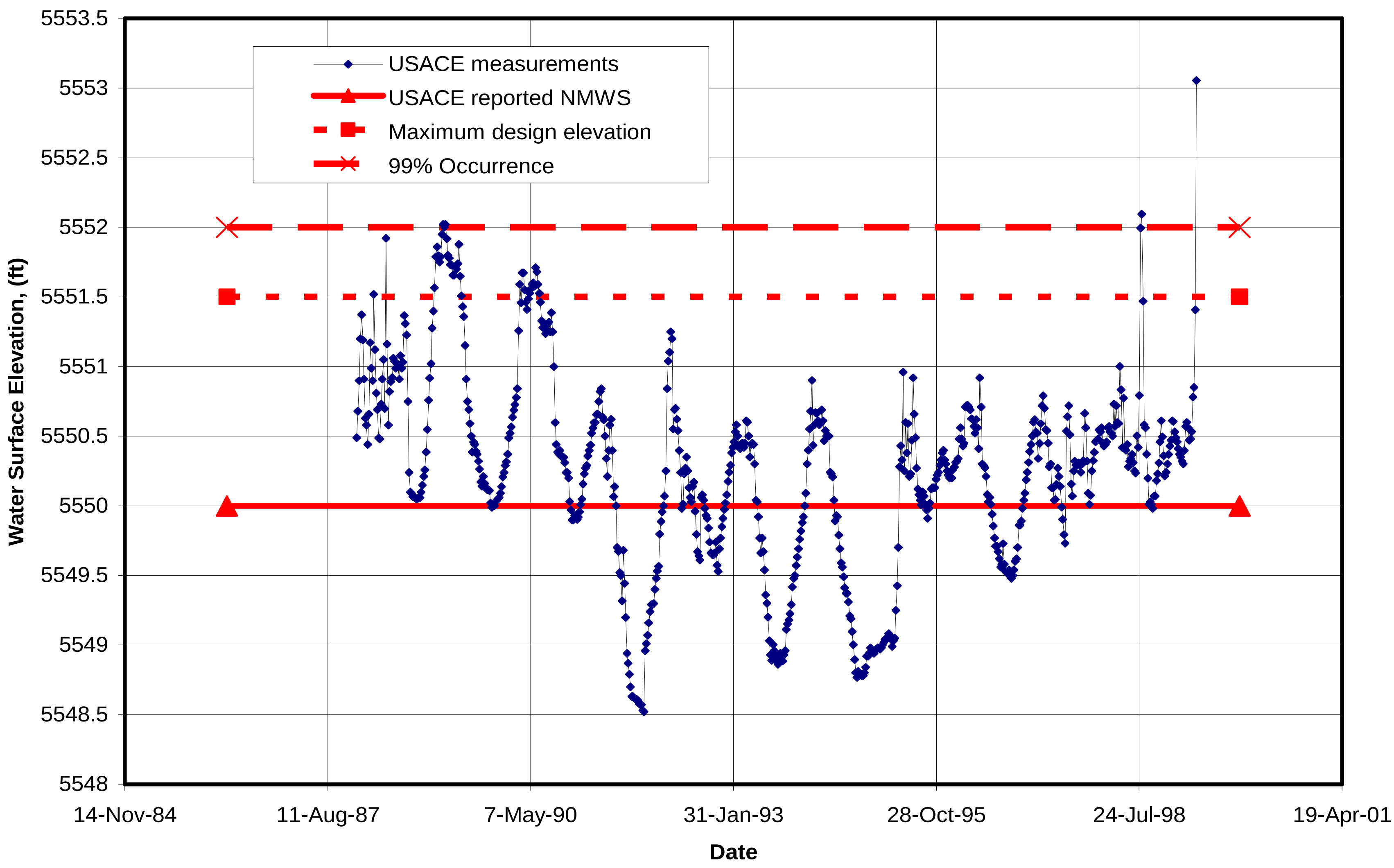
I reviewed my files for information relative to the variation in the Reservoir water surface elevation (WSE) for design purposes. The attached figure shows the variation in weekly reservoir WSE obtained from the USACE for 1986 through 1999. During that period the WSE statistics were:

Elevation Range	Number of Occurrences	Frequency of Occurrence (%)	Accumulative Frequency of Occurrence
Less than 5549	53	7.7	7.7
5549 to 5550	146	21.1	28.8
5550 to 5551	407	58.9	87.7
5551 to 5552	81	11.7	99.4
5552 to 5553	3	.4	99.8
Greater than 5553	1	.1	99.9

Because of the changes in water rights administration of the Reservoir and, perhaps the drought period, these statistics are no longer valid, but they do provide a basis for estimating the upper range in water surface elevation for design purposes. The lower WSE can only be approximated based on speculation.

My recommendation is to assume for design purposes, that the lower WSE is 5548 and the upper WSE is 5552.

CHERRY CREEK RESERVOIR WATER SURFACE ELEVATIONS



Attachment D - Concept Development Drawing Set