

FAN LAKE & FALL RIVER RESTORATION: SITE CHARACTERIZATION, DESIGN ELEMENTS, AND RECOMMENDATIONS



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Division**

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SUMMARY

In this report, we present the results of research conducted during 2005 in Horseshoe Park in the area impacted by Fan Lake, a water body formed following the 1982 failure of the Lawn Lake dam. The lake inundated an area of ~17 acres, drowning the riparian willow community dominant on the site. Rocky Mountain National Park is interested in restoring the communities and ecological functions lost or impaired by the formation of Fan Lake. However, to develop appropriate restoration goals and approaches, basic information is needed. Our work was intended to fill some of these information gaps by addressing the following questions: how does the site function hydrologically and are the current hydrologic regimes suitable for the restoration of riparian willow communities? Are there other constraints such as inadequate seed rain preventing natural recovery of the site? Where might willows be successfully planted across the landscape and are there differences in cutting survival among species or planting methods? What modifications to the site's topography and hydrologic regimes need to be undertaken to allow for reestablishment of the riparian shrub communities historically present in the site?

The main body of the report presents an overview of the baseline studies we undertook to answer these questions. We took several approaches including the installation of groundwater monitoring wells and staff gauges, installation and monitoring of a network seed rain traps providing information regarding the spatial and temporal patterns of seed rain across the site, and establishment of experimental cutting plots in a variety of hydrologic settings in order to evaluate the efficacy of planting pre-rooted and unrooted willows stakes from the dominant willows species in the area. Our results suggest that, although the lake was partially breached in 1995, it still floods extensively during the spring through the early summer, creating an environment unsuitable for willow establishment and favoring the dominance of herbaceous emergent marsh species. Data from cutting plots and well networks suggest that willow cover could be effectively increased in some areas under existing hydrologic regimes, but that absent redirecting the Fall and Roaring River channels into their historical paths, complete restoration would be difficult to impossible.

In the appendices, we detail specific restoration options and recommendations for the Fan Lake site. These include design specifications for restoration of the Fall and Roaring River channels, grading plans and earthwork calculations, suggested planting protocols and species lists. In addition, we outline approaches for plant installation, erosion control and sediment stabilization, and long-term monitoring of restoration success.

RESULTS OF SITE CHARACTERIZATION STUDIES

INTRODUCTION

Project overview

The 1982 breach of the earthen dam on Lawn Lake sent a torrent of water flowing down the channel of the Roaring River, eroding and transporting large quantities of sediment, much of which was deposited as an alluvial fan near the confluence of the Roaring and Fall Rivers in Horseshoe Park. The alluvial fan abutted a portion of a lateral moraine, impeding the flow of the Fall River and resulting in the formation of a small lake, hereafter referred to as “Fan Lake”. Fearing a catastrophic failure of the impoundment, in 1995, Rocky Mountain National Park staff created a breach at the head of the lake, partially draining areas to the west.

A variety of direct and indirect effects on the native riparian and wetland communities resulted. Most notably, large areas of riparian shrub communities were lost, converted to bare sediment, open water, or marsh-type wetlands. Natural recovery of the site has been slow in many areas, due in part to hydrologic and geomorphic changes to the area. In this report, we present the results of research aimed at identifying constraints on the natural recovery of impacted communities and the formulation of plans to actively restore the site.

Objectives

The primary goal of our research was to determine where suitable hydrologic conditions exist for the establishment of willows and sedges in the study area, to refine methods for plant establishment, and to develop planting maps to guide restoration activities. As originally conceived, the site

was to be restored as it presently exists, working within the constraints of existing landform configurations and hydrologic regimes. However, it became clear during initial field visits with NPS staff to the study area that the formation and persistence of Fan Lake has significantly altered topographic, soil, and hydrologic properties, making restoration to historic conditions impossible without more substantial changes to the site’s hydrologic regime. Therefore, we added an additional goal, that of developing the necessary design specifications for reestablishment of the Fall River channel configuration, hydrologic regimes and landform characteristics present prior to the formation of Fan Lake.

METHODS

Study area

Research was conducted in the western portion of Horseshoe Park, Rocky Mountain National Park, from the alluvial fan formed at the confluence of the Roaring and Fall Rivers west to the Endovalley picnic area. In this report, the *study area* includes both the impacted areas as well as relatively pristine riparian communities identified as reference areas. The *restoration area* includes the area impacted by the formation of Fan Lake and the alluvial fan and requiring direct actions such as earth moving, planting, or fencing (Figure 1).

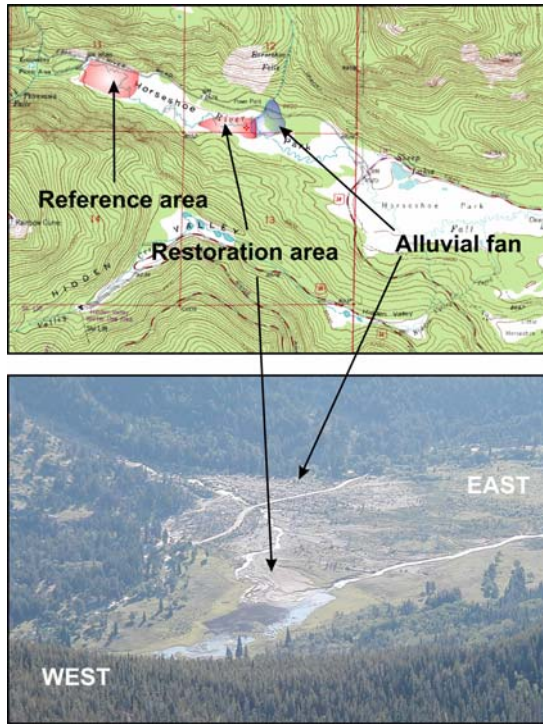


Figure 1. Overview of study area.

Impact analysis

We conducted an analysis of historic and contemporary aerial photographs and GIS data to estimate the extent and nature of impacts resulting from the formation of Fan Lake. Rectified aerial photographs of the Horseshoe Park area from 1937, 1946, 1990, and 2001 were examined in ArcView v.3.2 (ESRI, Inc., Redlands, CA). The extent of Fan Lake was digitized from the 1990 photograph and compared to digital vegetation cover maps predating and postdating the formation of Fan Lake developed by Peinetti et al. (Peinetti et al. 2002) and used for estimating

the area of different vegetation types impacted by the formation of Fan Lake.

Hydrologic analyses

We installed a network of groundwater monitoring wells and staff gauges across the restoration area in order to develop an understanding of the spatial and temporal dynamics of groundwater and surface water across the site. Wells were constructed from slotted PVC and installed in augured holes along a series of transects. In addition, we placed staff gauges in the Fall and Roaring Rivers to monitor seasonal fluctuations in stream stage. Wells and staff gauges were monitored approximately every week through mid-September.

Seed rain traps

To evaluate whether low willow seed levels may be constraining natural willow establishment, we installed a network of willow seed rain traps across the study site, from the alluvial fan west to the Endovalley picnic area (Figure 2). Traps consisted of 400 cm² plywood squares mounted horizontally above the ground surface and coated with Tanglefoot[®], a sticky, weather-proof substance used to capture passing seeds. We counted the number of willow seeds captured on traps on a weekly basis from late May to mid-July and converted trap counts to aerial estimates of seed rain. Seasonal seed rain totals were interpolated using the Spatial Analyst extension in ArcView and used to develop contour maps of seed rain density.

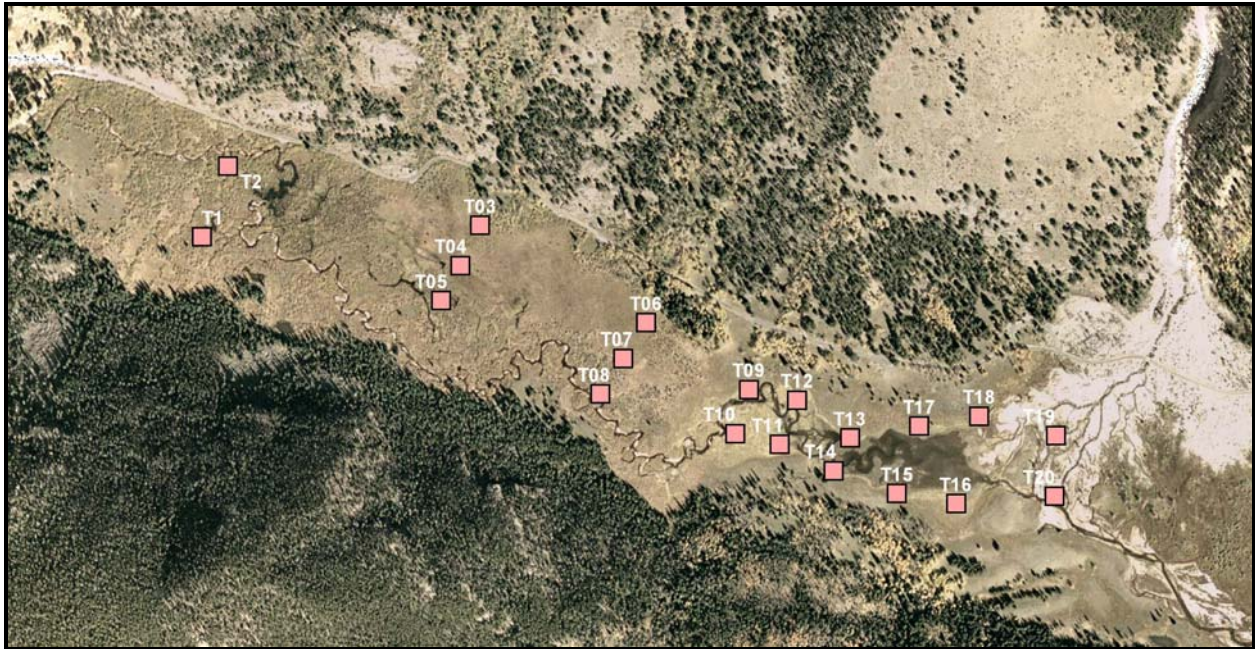


Figure 2. Layout of seed rain traps used in the study.

Reference area vegetation and hydrology

In August of 2005, we collected foliar canopy cover from vegetation plots along a transect through the Endovalley reference area. Our goal was to develop a better understanding of the species composition in riparian communities not impacted by Fan Lake. The percent cover of woody species was estimated in 2 x 5 m plots systematically placed at 10 m intervals along the transect from north to south. Herbaceous cover was estimated in three 1 m² subplots and averaged for analysis. Mean subplot elevation was measured in each subplot using a Topcon laser level.

RESULTS

Impact analysis

At its maximum extent, Fan Lake extended approximately 0.57 km to the west of the impoundment forming Fan Lake. Although the area inundated varied seasonally, the maximum extent indicated on available aerial

photographs and by erosional shorelines on the ground was approximately 17 acres. Historic aerial photographs from 1937 and 1946 clearly indicate that a large portion of the area impacted by Fan Lake once supported riparian willow communities. These communities, common elsewhere along streams throughout the elk winter range, provide essential habitat for beaver, whose presence is also indicated on the aerial photographs (Cottrell 1993, Baker et al. 2005).

Although the exact composition of these willow communities is unknown, previous research in the area (Peinetti et al. 2002) supports the conclusion that willows were common along the margin of Fall River. In our analysis of their data, we found that 9.6 acres of the nearly 16.9 acre area impacted by Fan Lake formerly supported riparian shrub communities; in 1996, this area had decreased to only 0.6 acres (Table 1, Figure 3). Anecdotal evidence such as dead willows within the boundary of Fan Lake also clearly shows that significant willow mortality has occurred.

Our GIS analyses indicate an increase in open water of nearly 600% relative to pre-lake conditions. Although this entire area is inundated in the spring and early summer, as stream and lake stage decrease over the summer, extensive emergent marsh communities are revealed. Although no data describing herbaceous communities prior to Fan Lake exist, these marsh communities are undoubtedly unrepresentative of the pre-lake vegetation. For example, the most common species in these areas is now *Glyceria elata*, a species characteristic of lacustrine rather than riparian environments, clearly indicating that significant changes in the hydrologic regime and vegetation patterns of the site have occurred.

Table 1. Comparison of 1937 and 1996 cover types for the restoration area (source data: Peinetti 2002).

Cover type	Area (acres)			% of 1937 area
	1937	1996	Difference	
Open water	2.0	11.7	9.6	578%
Riparian shrub	9.6	0.6	-9.0	6%
Meadow	5.1	4.5	-0.6	88%
Forest	0.1	0.0	-0.1	28%
Total	16.9	16.9		

Significant changes to the hydrologic functioning of the site are indicated from the aerial photographs. Prior to the formation of Fan Lake, the Fall River flowed north around the morainal lobe that, with the formation of the alluvial fan, ultimately impounded it. The Roaring River entered to the east of this feature, discharging into the Fall River near the middle of where the alluvial fan was deposited (Figure 4). Following the formation of the Fan Lake, the course of the Roaring River shifted, flowing west of the alluvial fan and moraine. Likewise, the contemporary path of the Fall River differs largely from its pre-lake configuration. It now flows through the middle of the moraine

where it was breached by NPS staff in 1995 (Figure 4).

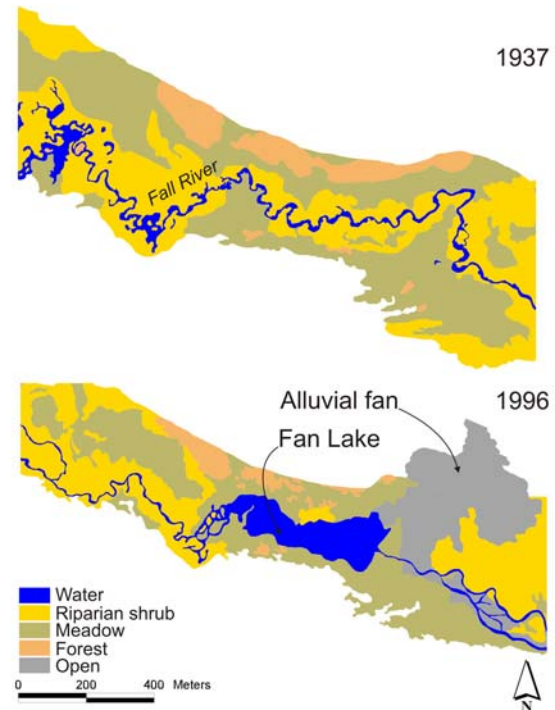


Figure 3. Comparison of major cover types in 1937 and 1996, as delineated via aerial photograph analysis by Peinetti (2002).

Groundwater and surface hydrology

Our analyses of monitoring well and staff gauge data reveal several general hydrologic environments. Some portions of the restoration area have seasonally stable water tables, driven by large inputs of groundwater from adjacent slopes. This is most pronounced in the alluvial fan area, where water tables were quite stable, varying over the study period by <15 cm (Figure 5). The stability of water tables observed in these areas was also indicated by the presence of a distinct clayed soil horizon seen when wells were installed. Although the mean water table depth in sites varied with relative elevation, water tables in all wells on the alluvial fan fluctuated little over the season.



Figure 4. Aerial photographs of study area from 1946, before the formation of Fan Lake, and in 2001, afterwards illustrating changes in the direction of flow for the Fall and Roaring Rivers. Note that the Roaring River now flows further west along or near the historic Fall River channel, while the Fall River now flows east, exiting the restoration area through breach in the morainal lobe created in 1995

Hydrologic cross-sections around the margins of Fan Lake suggest that water tables are effectively flat or slope slightly towards the lake. Thus, it appears that for planting purposes, relative elevation above stream stage, easily measured using staff gauges, is an effective indicator of water table depth. Groundwater and surface water gradients are more complex in the alluvial fan itself. Cross sections indicate groundwater radiates out from the head of the fan towards the Fall River. However, cross sections perpendicular to the main Roaring River channel indicate that most of the stream is losing with respect to groundwater. A comparison of survey data from 2005 to the 2001 aerial photographs indicate that the Roaring River channel has not stabilized and

has migrated west over the alluvial fan over time.

Spatial and temporal seed rain patterns

Willow seed rain was observed for approximately 6 weeks, from May 24 through July 18. Consistent with previous research in the area (Gage and Cooper 2005), we found steep seed rain gradients from the Endovalley reference area to the Fan Lake area. (Figure 6). The highest total seed rain values of 4675 seed/m² was observed near Endovalley, which supports tall willows with only moderate elk browsing. In contrast, seed rain totals on traps located on the east side of Fan Lake ranged from 0 to 75 seeds/m², a two-order of magnitude difference. Although some willow colonization has occurred on the alluvial fan since 1982, seed-producing plants were not observed, likely a result of the heavy elk browsing.

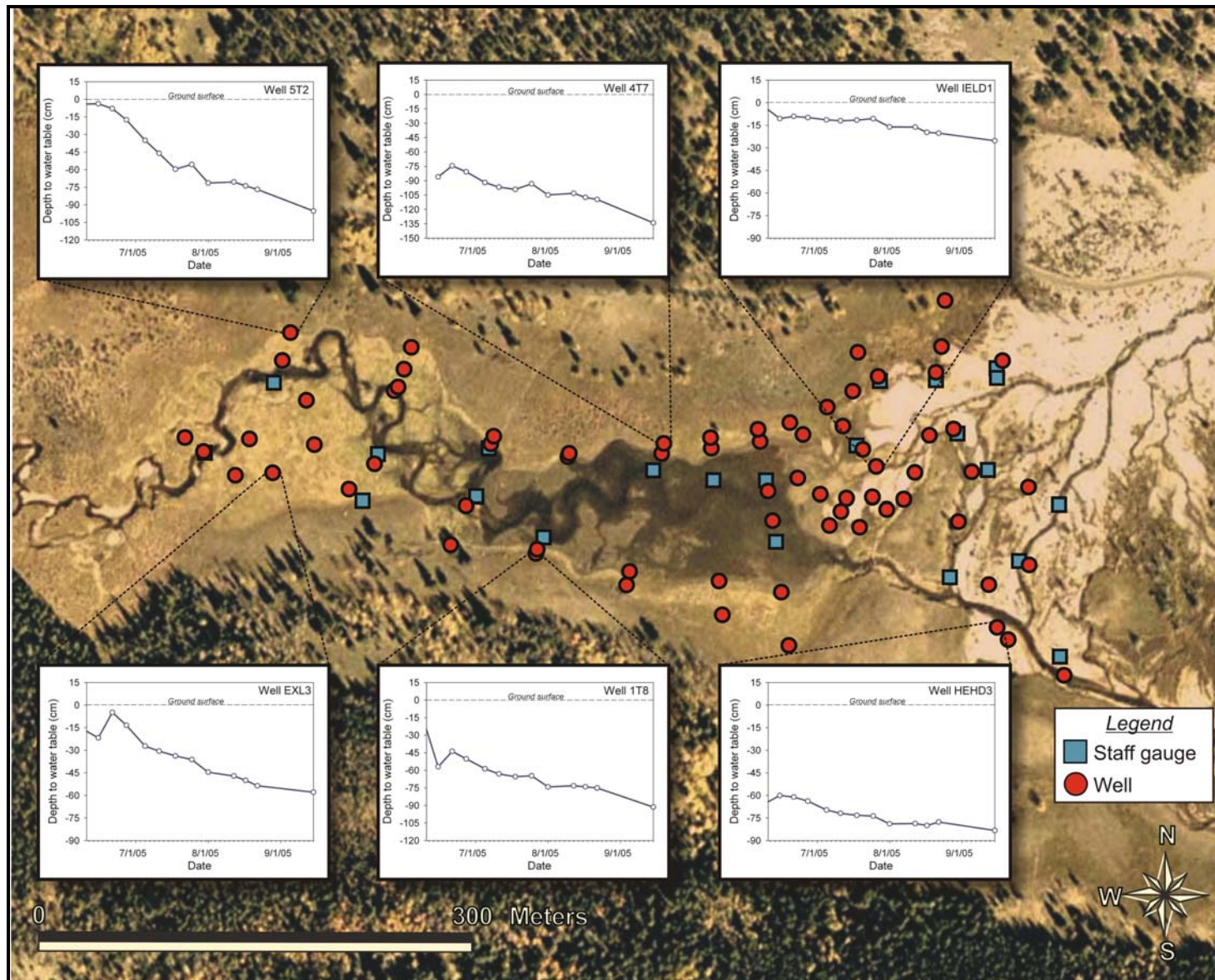


Figure 5. Layout of groundwater monitoring wells and staff gauges throughout the project area including hydrographs for selected wells.

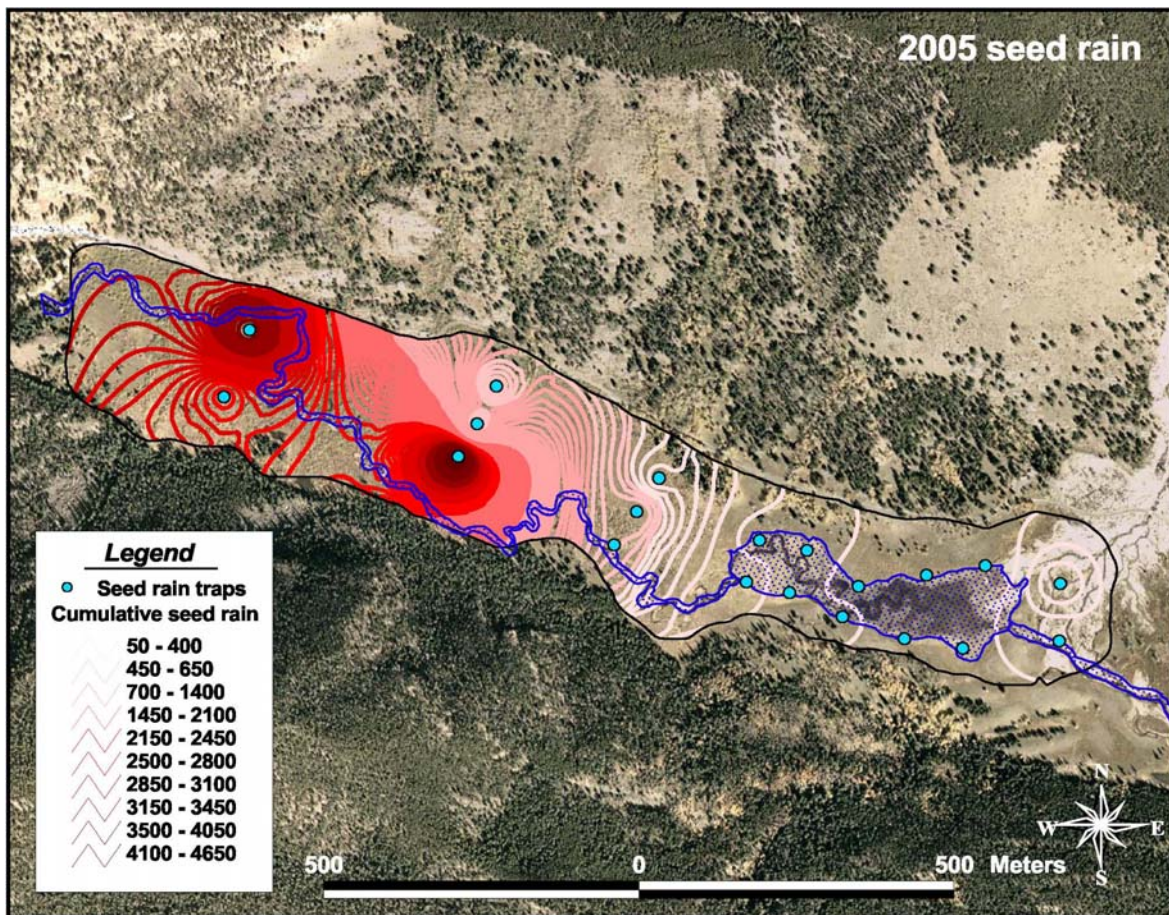


Figure 6. Interpolated seed rain values from traps installed across study area and monitored through early summer, 2005.

Project and reference area vegetation

The dominant overstory species in reference area macroplots in terms of both cover and frequency in plots was *Salix monticola*, followed by *S. drummondiana*, and *S. geyeriana* (Figure 7). Overall willow cover was high, averaging 35% (range: 0-90%), and 23 of 26 plots had at some willow cover. The only plots lacking willow cover fell in the center of old abandoned beaver ponds and were dominated by herbaceous species such as *Carex aquatilis* and *C. utriculata*.

Five of the six dominant herbaceous species in subplots were non-native species, specifically: *Agrostis gigantea* (80.8%),

Brexa arvensis (65.4%), *Poa pratensis* (61.5%), *Phleum pratense* (57.7%), and *Taraxacum officinale* (53.8%). *Calamagrostis canadensis* was the most abundant native species, occurring in 76.9% of macroplots. It was also the herbaceous species with the greatest mean cover (26.2%). Other species of note include *Carex aquatilis* and *C. utriculata*. The frequency of both was low, as was mean cover for all plots pooled together. However, when present in any given plot, each species had high cover. These species were always found in wet microsites, generally in former beaver ponds.

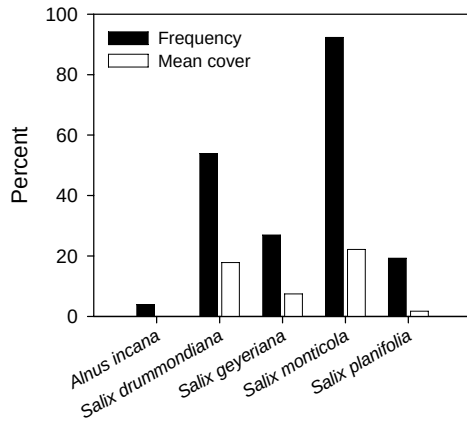


Figure 7. Mean cover and frequency of woody species in reference area macroplots.

Cutting experiment

In general, all cuttings survived at relatively high rates, although the patterns among treatments and sites were complicated. All main effects tests as well as several interaction terms were significant in the ANOVA (Table 2). The highest survival rate (94.2%) occurred with *Salix drummondiana* cuttings, followed by *S. monticola* (88%), *S. geyeriana* and *S. planifolia* (84.2%) and lastly, *S. bebbiana* (67.5%). Overall, pre-rooted cutting survived at a greater rate than unrooted cuttings, but the difference was relatively small (86.0% vs. 81.3%). Among hydrologic treatments, the highest survival rate was found in the intermediate elevation, low dynamic plots (97.3%), while the driest treatments had the lowest survival (56%).

Table 2. Results of Type III test of main effects (Proc MIXED, SAS, inc.); Variables included in analysis are hydrologic regime (hyd), rooting treatment (root), willow species (spp), and their interactions.

Effect	Den DF	Num DF	F value	P>F
hyd	3	64	74.26	<.0001
root	1	64	4.56	0.0366
hyd*root	3	64	2.82	0.0458
spp	4	64	16.49	<.0001
hyd*spp	12	64	2.91	0.0029
root*spp	4	64	1.07	0.3788
hyd*root*spp	12	64	2.12	0.0273

As indicated by the significant interaction terms in overall ANOVA, the relation between cutting survival in any particular species and rooting treatment depended on hydrologic setting. In general, *Salix bebbiana* did the poorest of all the species, regardless of other factors.

DISCUSSION

Past and current conditions

As revealed in our impact analyses, the formation of Fan Lake caused major changes to the hydrologic and ecological systems in the area. The changes in cover type are readily apparent when viewing the aerial photographs; less easy to quantify are the changes in function. Despite the partial breaching of Fan Lake in the mid-1990's, much of Fan Lake still floods for an extended portion of the growing season, limiting the suitability of the site for all but the most inundation-tolerant species. The emergent vegetation present in these areas is representative of lacustrine environments rather than riparian habitats. The site, as currently functioning hydrologically, is largely unsuitable for willows, the dominant cover prior to the Lawn Lake flood. Absent hydrologic restoration, reestablishment of a riparian community similar to that historically present is impossible.

Realignment of the Fall River and Roaring River channels should provide the necessary shift in hydrology to allow for reestablishment of a riparian willow community in the area. Although the volume of sediments deposited in the alluvial fan is huge, most of the sediments are east of the morainal lobe that demarks the eastern edge of Fan Lake. With only a relatively modest amount of excavation through the west portion of the alluvial fan deposits, restoration of the historical planform

geometry of the Fall and Roaring Rivers is achievable. Accomplishing this will help to divert water out of the Fan Lake “basin”, creating conditions more amenable to natural or assisted willow recovery.

Although our seed rain data do suggest that low propagule inputs into the restoration site may in part present an obstacle to natural recovery of willows, any such effect is secondary to the hydrologic limitations of the site. Willows enclosed by fencing can produce seeds within only a couple of years of protection, providing a localized source of seeds to promote further natural establishment (Kay and Chadde 1992, Gage and Cooper 2005). However, without the necessary hydrologic regimes, no amount of seed rain will improve establishment rates.

Although our hydrologic studies provide a good approximation of current groundwater and surface water dynamics essential to planning channel modifications, precise prediction of the hydrologic response to earthmoving activities is impossible. Since successful restoration of the site ultimately depends on the hydrological regime, we recommend that hydrologic monitoring be conducted for at least two years following the restoration effort is finished. This should be part of an adaptive management and monitoring program, whereby the success of plantings and natural recruitment are tracked following earthwork and planting.

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APPENDIX 1. RESTORATION DESIGN AND IMPLEMENTATION PLAN

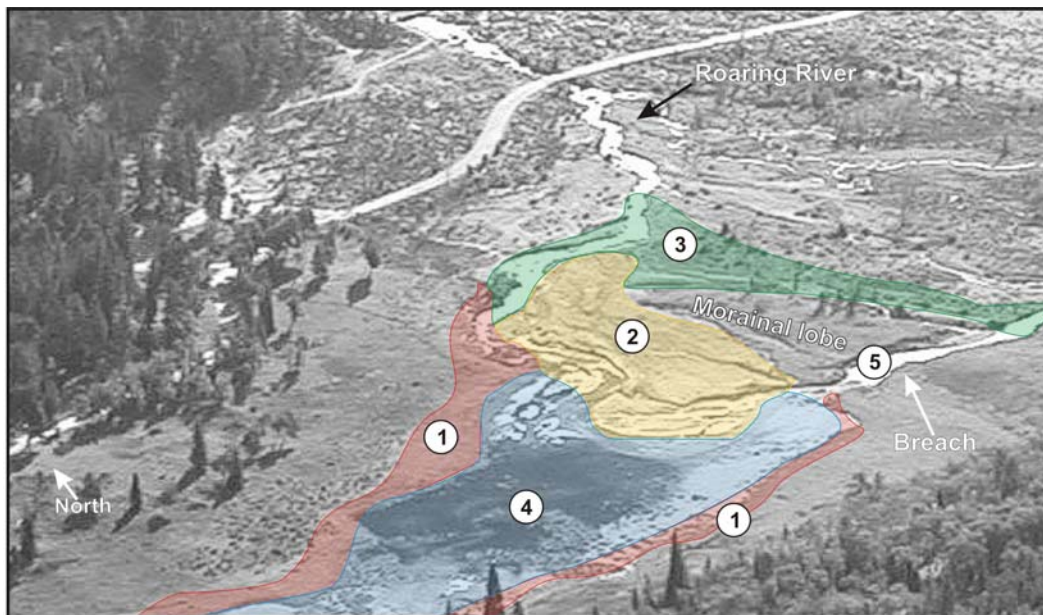
Overview

Based on discussions with NPS personnel, hydrologic restoration of the site has been identified as the first priority. Depending on resources remaining following earthmoving activities, revegetation of the site and protection of plantings will be pursued. Here, a range of different options are presented.

Site stratification

To facilitate analysis and evaluation of restoration options, we divided the restoration area into five zones, each differing in gross hydrology, soil characteristics, standing vegetation, and restoration potential (Table 3, Figures 8, 9). Zone 1 is a relatively narrow band extending from the upper shoreline of Fan Lake to the main area inundated during the spring and early summer (Zone 4) and is well vegetated, including a cohort of willows established following the 1995 breach. Zones 2 and 3

occur on the alluvial fan itself, and differ from one another primarily on the basis of soil characteristics and the amount of natural vegetation recovery that has occurred. Sediments in Zone 2 is are dominated by fine to coarse sand, and support relatively sparse vegetation cover, while soils in Zone 3, located east of the morainal lobe, are a more poorly sorted mix of sand, gravel, cobbles, and boulders. This area comprises the main body of the alluvial fan and has seen more natural establishment and recruitment of willows than zone 2. The extensive area of seasonal open water and emergent marsh in the center of Fan Lake comprise Zone 4. Most of this area supported willows prior to the formation of Fan Lake, but the site is too wet now for all but a handful of marsh species. Zone 5 consists of the 1995 breach through the morainal lobe. If closed, this area will need to be revegetated with an appropriate suite of upland species.



- ① Fan Lake margins ② Alluvial fan west ③ Alluvial fan east ④ Open water/marsh ⑤ Upland

Figure 8. Oblique photograph looking northeast across the restoration area depicting the location of the 5 different zones discussed in the text.

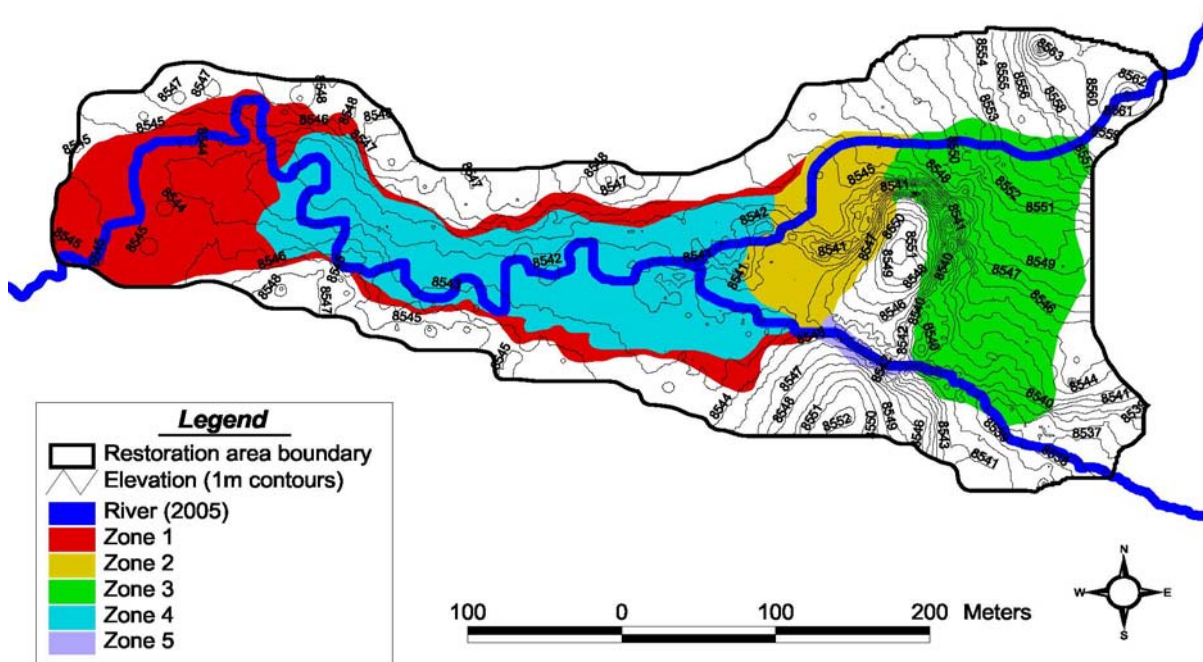


Figure 9. Map depicting locations of zones described in text.

Table 3. General characteristics of different zones delineated in the restoration area.

	<u>Soils</u>		<u>Hydrology</u>		<u>Vegetation</u>	
	Dominant soil texture	Organic matter	Water table depth range ¹	Water table dynamics	Existing	Willow establishment?
Zone 1	Silt loam to coarse sands	Intermediate to high	20 to 90cm	Low to high	Well established graminoid cover; heavily browsed and apparently even-aged cohorts of willows in bands along the erosional shoreline	limited
Zone 2	Fine to coarse sand	Low	15 to 45cm	Low	Sparse graminoid cover, abundant bare ground	limited
Zone 3	Coarse sand to cobbles	Low	10 to 90cm	Low	Sparse graminoid cover, abundant bare ground	limited
Zone 4	Silt to fine sand	Intermediate to high	-20 to 35cm	Low to intermediate	seasonally inundated	no
Zone 5	Coarse sand to cobbles as fill from earth moving	Low	40 to >150 cm	Unknown	Upland meadow	None

High grass and sedge cover and low levels of natural disturbance in the form of high energy spring floods are among the factors limiting opportunities for willow seedling germination and growth in zone 1. Although extensive areas of bare and wet sediment occur in zones 2 and 3, trampling from elk and humans limit natural willow establishment. Natural willow recovery in zone 4 is prevented primarily by hydrologic regime. The zone is typically completely underwater during the period of willow seed rain, thus offering no substrates for new establishment.

Hydrologic restoration

The primary objective of earthmoving activities is restoration of the pre-Fan Lake hydrologic regime. As discussed earlier, the site is currently too wet to support the riparian communities present before the Lawn Lake dam failure. To improve the hydrologic suitability of the site for these

communities, the Fall and Roaring Rivers should be moved to their approximate locations prior to the dam break.

Key questions that need to be addressed in developing design specifications for the channel restoration include: (1) Where did the channels occur historically? (2) What constraints on the design channel are imposed by current topography? (3) What gradients need to be achieved to ensure proper hydrologic functioning? (4) What cross-sectional design best replicates natural conditions? (5) What quantities of material will need to be added or removed from the landscape to achieve the desired configuration?

To obtain the locations of the Fall River and Roaring River channels, we digitized their locations on georectified aerial photographs from 1946. The length of the original Fall River channel, from its current confluence around the morainal lobe to the east end of the 1995 breach is approximately 471 m. The

Fall River's current course from the same start and endpoints is now only 212 m, a nearly 55% reduction in length. The length of the Roaring River that will need to be redirected to establish its pre-Fan Lake configuration is approx. 134 m.

Reference cross-sections were identified from survey data collected in 2002 by the authors and NPS staff (Figure 10). These data were used in the development of design cross-sections (Figure 11). Existing topography as well as proposed topographic surfaces for the restoration design are presented in the attached maps (Appendix 2).



Figure 10. Locations of reference cross-section used to develop design channel configuration. Red dots indicate location of survey point; the 1990 boundary of Fan Lake is also indicated.

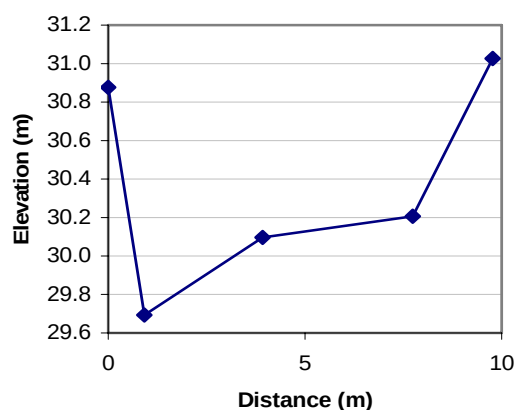


Figure 11. Example of reference cross-section from the Endovalley picnic area

Vegetation

Our reference area vegetation data provide a reasonable restoration target with regards to willow species composition. The establishment of tall, high density stands of willows such as *Salix drummondiana* and *S. monticola* will provide a long-term food source needed to support beaver, a keystone species now absent from the Fan Lake area itself.

Our results suggest that either rooted or unrooted cuttings can be used. Because of the relative ease of the latter, we suggest that this approach be taken for the bulk of revegetation purposes. Ideally cuttings should be taken while plants are dormant and installed in contact with the water table or capillary fringe; cutting lengths can be varied to achieve this. The majority of the cutting length should be underground, with only 10 cm or so of the cutting protruding. Although no precise ratios of species planted are recommended, the relative abundances of species in the reference area (*Salix monticola* > *S. drummondiana* >> *S. geyeriana* > *S. planifolia* > *S. bebbiana*) can be used to guide decisions about relative cutting numbers.

Because of the ease of collection and dispersal and the relatively low seed rain levels in the restoration area, broadcasting willow seeds is encouraged. Seeds from the dominant willows species can be collected in early spring or summer. Catkins should be monitored for maturity, and when ready for collection, they should be dried for 2-4 days in paper bags at room temperature. Seeds can then be hand broadcast over areas with bare, wet sediments such as the margin of the Fall and Roaring Rivers.

Fencing

Improving the suitability of the site for beaver by ensuring an adequate supply of tall morphotype willows for food and building needs should be an explicit long-term management goal. To accomplish this, establishment of willows through cuttings alone would likely be insufficient given the high elk densities present in the area and the vulnerability of new plantings to herbivory. Fencing is likely needed, at least for several years, to allow for willow establishment and growth.

The cost of different fencing treatments varies depending on the perimeter of areas protected and the specific materials and construction techniques used. ROMO staff will develop specific fencing plans depending on available funds following earth moving activities.

Monitoring

The effects of earthmoving activities on hydrologic regime should be followed using existing or newly installed wells. In addition,

we recommend development of a monitoring plan to track the success of plantings and natural re-colonization of the site.

With regards to herbaceous species, the high prevalence of non-native plants in our reference area highlights a key issue that needs to be addressed as restoration work proceeds. Relative to most other parts of ROMO, Horseshoe Park area has had a long and rather intensive history of human use resulting in high degrees of anthropogenic disturbance. Although most of the infrastructure associated with the areas historic occupancy have been removed, the dominance of meadow areas by non-native pasture grasses such as timothy (*Phleum pratense*) demonstrate the legacy of the area's early inhabitation. Because of the ready availability of propagules and the disturbance inevitable with any earth-moving activities, the site should be monitored for the development of any invasive species issues.

APPENDIX 2. SEDIMENT STABILIZATION AND EROSION CONTROL BEST MANAGEMENT PRACTICES

GENERAL DESIGN CONSIDERATIONS:

To minimize erosion and sediment inputs resulting from the earthmoving and restoration activities, several general design factors should be considered. These include:

- Project timing – Earthmoving should be done in either winter, early spring, or late fall when streamflow is low.
- Minimize project footprint – Constrain earthmoving equipment to the minimum area needed for work. Define a single access point of equipment.
- Include erosion control measures in construction oversight and follow-up monitoring.
- Minimize velocity of unavoidable runoff.
- Identify likely sources of erosion or sediment input to streams and select appropriate approach to mitigate (e.g. erosion control blankets, intensive planting, sediment fencing, etc.)
- Focus planting of willows in areas most in need of stabilization.
- When possible, work from above stream rather than in it.

EROSION CONTROL TECHNIQUES:

Select appropriate technique based on the challenges posed at a given site. Options, as outlined by Peale (1996), include:

Erosion control blankets – Appropriate for protecting and stabilizing slopes, for covering erosive soils prior to the establishment of vegetation, and protecting erosive soils in high-use areas.

- *Installation:*
 - Prepare and seed the area.
 - Unroll blankets in direction of water flow (90° to contour).
 - Bury upslope end in a 6 in. x 6 in. trench beyond crest of slope to avoid undercutting.
 - Overlap ends at least 6 in. and sides at least 4 in. Uphill strip overlaps downhill strip.
 - In channels, bury blanket in a 6 in. x 6 in. trench, at ends, and every 30'. Before backfilling,
 - staple across width of trench in zigzag pattern at 6 in. intervals. Backfill to grade and tamp by foot.
 - Use pins or staples made of 4.2 mm (0.162 in.) wire, or heavier. “U” staples must have 8 in. legs and 1 in. crowns.
 - “T” pins must be at least 8 in. long and 4 in. across the top. Triangular survey stakes may also be used.
 - Follow manufacturer’s recommendation regarding stapling pattern.
 - Monitor; re-anchor and replace as necessary.
-

Silt fences – Appropriate for areas subject to sheet and rill erosion, such as the toe of fills and transitions between cuts and fills. Useful for intercepting and detaining small amounts of sediments, for decreasing the velocity of sheet flows, where maximum slope above the barrier is 100 ft and maximum grade is 50%. Not appropriate for areas where surface flow above 1 cfs is expected.

- *Installation:*
 - Install fence on contour.
 - Ensure that the area below the fence is undisturbed or stabilized.
 - Position barrier at least 5 ft from base of slope greater than 7% to allow for runoff to pond and infiltrate, sediment to settle.
 - Select filter fabric in continuous rolls to minimize the need for joints.
 - Posts should be driven vertically at least 18 in. into the ground, at 6 ft intervals on contour.
 - Select fabric that is impregnated with UV inhibitors to provide a minimum life of 6 months.
 - Fences should be inspected immediately after each rainfall and at least daily during prolonged rainfall.
 - Damage should be repaired immediately.

Straw bale barriers – Appropriate for areas subject to sheet and rill erosion, for intercepting and detaining small amounts of sediment from disturbed areas of limited extent, for decreasing the velocity of sheet flows, in situations in which effectiveness is required for less than three months, in sites where maximum area is 0.5 acres/100 ft, maximum slope above the barrier is 150 ft, and maximum grade is 45%.

- *Installation:*
 - Position barrier at least 5 ft from base of slope greater than 7% to allow runoff to pond and infiltrate and sediment to settle.
 - Use certified weed-free materials only.
 - Place bales on contour, in a single row, lengthwise, with ends tightly abutting one another.
 - Place bales so that wire or twine bindings run around the sides rather than across top and bottom, to prevent deterioration of bindings.
 - Entrench bales at least 4 in.
 - Chink bales (fill gaps with loose straw) to prevent water from escaping between bales.
 - Backfill bales with excavated soil.
 - Fill to ground level on downhill side; build up 4 in. on uphill side.

Additional approaches should be considered where appropriate. Armoring of sites particularly vulnerable to erosion can be accomplished through the use of large diameter cobbles and boulders collected on site.

APPENDIX 3. DESIGN MAPS

Contour map of current topography of site [ATTACHED]

Contour map of design surface [ATTACHED]

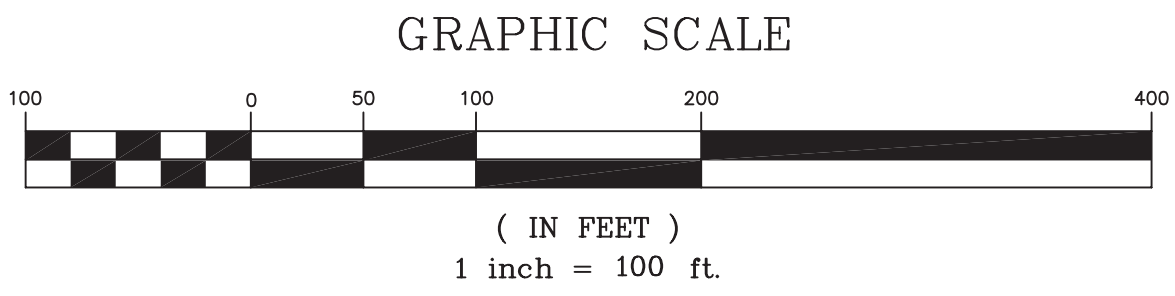
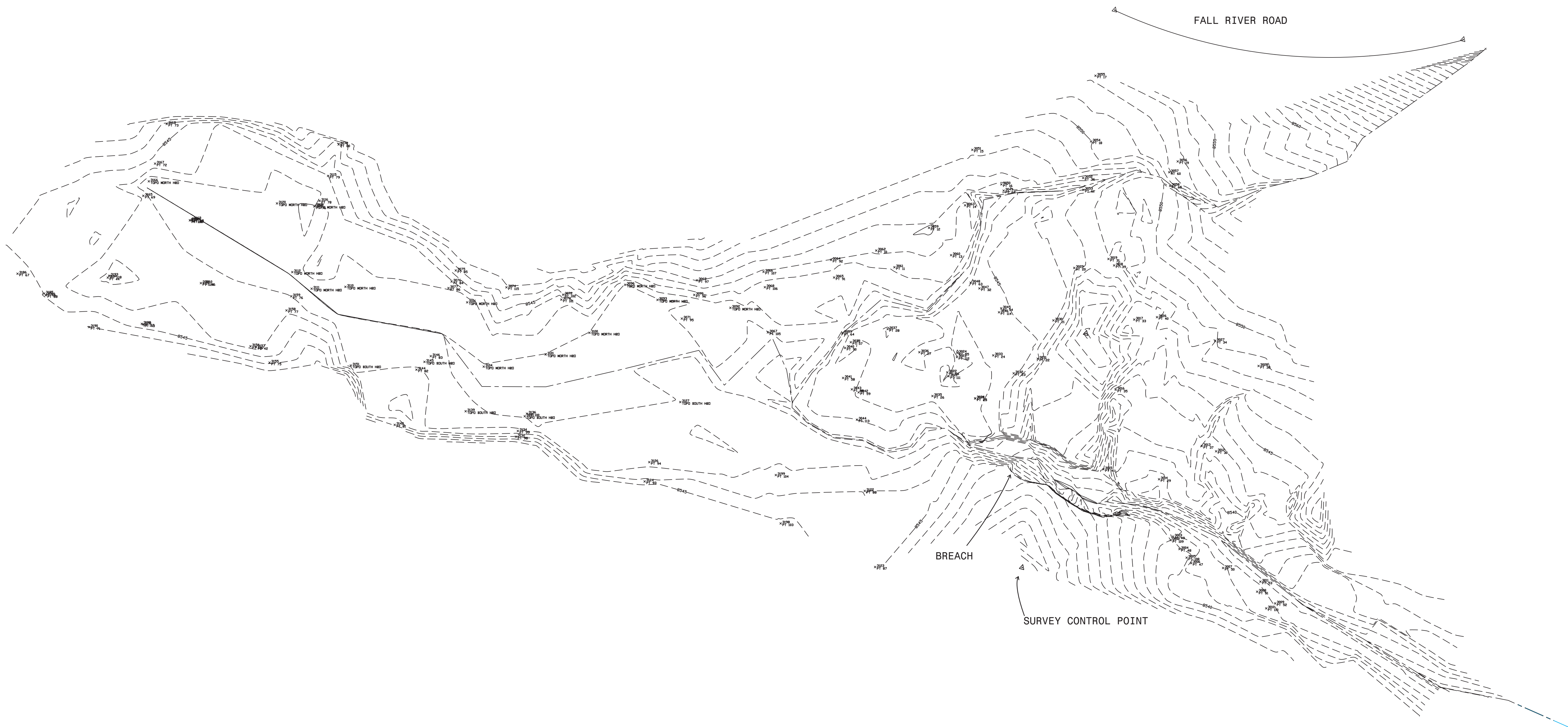
Cross-sections through design surface [ATTACHED]

Calculations of cut/fill quantities [ATTACHED]

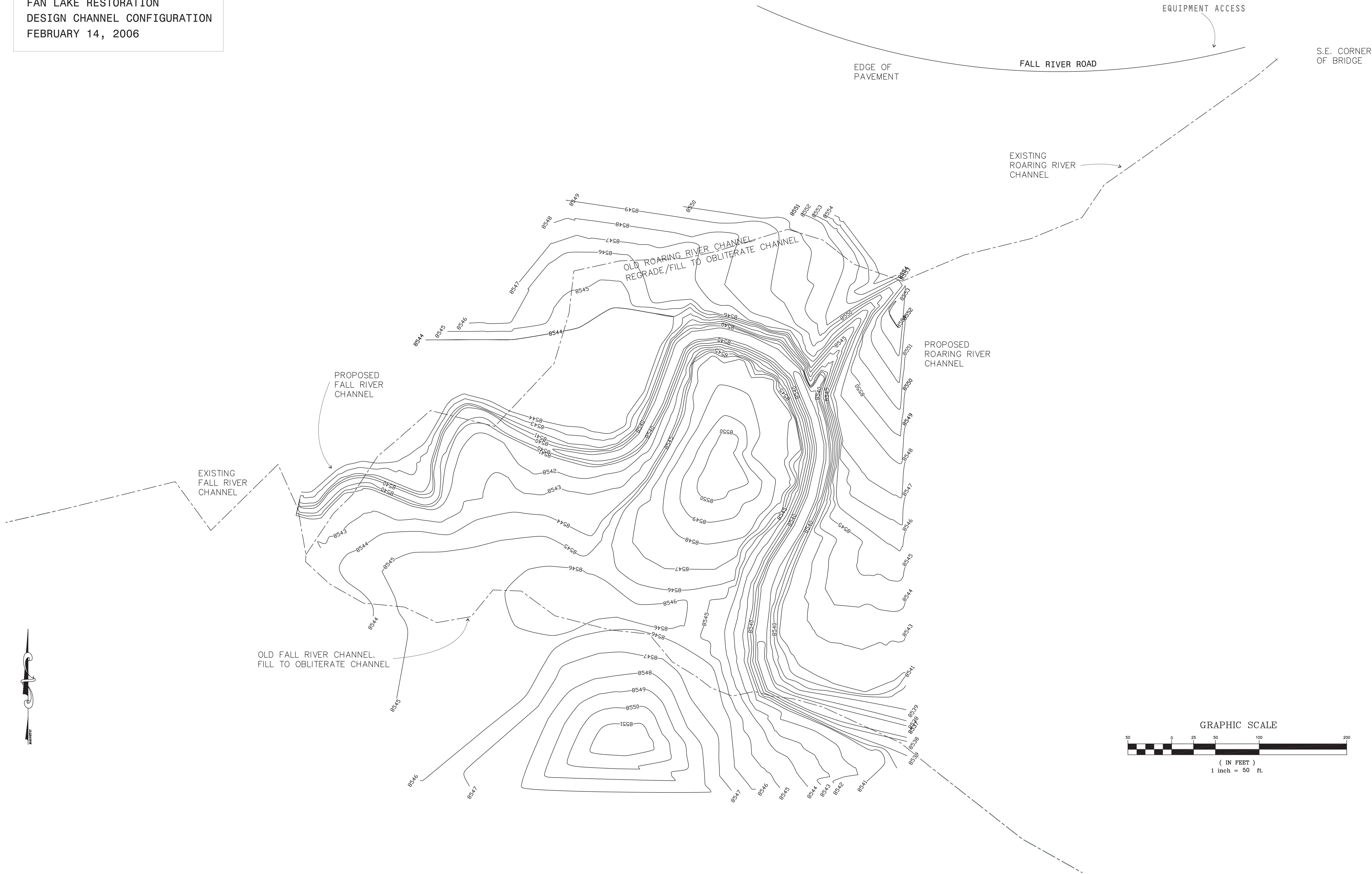
FAN LAKE RESTORATION
CURRENT TOPOGRAPHY
FEBRUARY 15, 2006



FAN LAKE RESTORATION
CURRENT TOPOGRAPHY
FEBRUARY 15, 2006

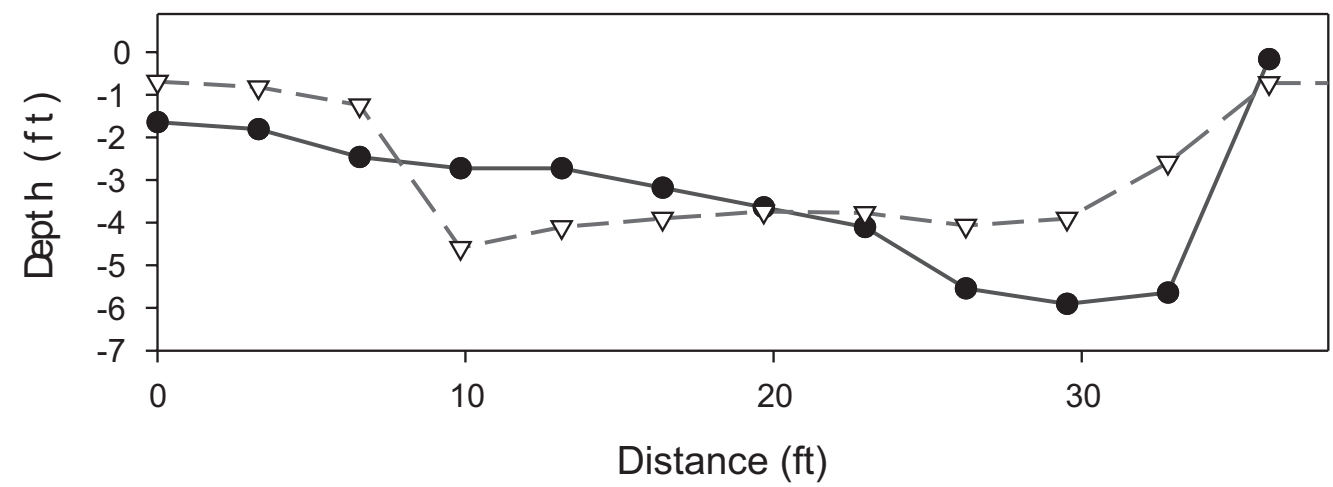


FAN LAKE RESTORATION
DESIGN CHANNEL CONFIGURATION
FEBRUARY 14, 2006



FAN LAKE RESTORATION
DESIGN CHANNEL CROSS SECTIONS
FEBRUARY 15, 2006

REFERENCE CROSS-SECTIONS¹



¹Source: Anthony 1989

VOLUME ESTIMATES¹:

TOTAL CUT: 9591 yd³
TOTAL FILL: 9194 yd³
NET: 397 yd³

¹ Grid method, values unadjusted for expansion or contraction

