Task #11

Final Project Report

Little Colorado River and Nutrioso Creek Riparian Enhancement Project

Springerville, AZ

AWPF Grant 07-143WPF

March 2013

Natural Channel Design, Inc.

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We have been honored to have participated
in this project from its inception.

It has been a satisfying and enlightening experience.

NCD staff and associates:
Allen Haden, Stephanie Yard,
and Mark Wirtanen
In memory of Tom Moody; the man with the vision.

We would like to express sincere thanks to

Rick Benoit, Troy Burk, and the Arizona Game and Fish Department

Without their willingness and support, this project would not have been such a success.

And thanks to the staff and Commission members of the Arizona Water Protection Fund.
Special appreciation to Rodney Held and Stephen Tighe,
whose encouragement and oversight were crucial to success.

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The views or findings presented are the Grantee's and do not necessarily represent those of the Commission, the State, or the Arizona Department of Water Resources.

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EXECUTIVE SUMMARY

The final report of the Little Colorado River and Nutrioso Creek Riparian Enhancement Project summarizes each step of the project from its commencement to completion. The report is organized into an Introduction, Inventory and Assessment, Design, Construction and Implementation, Monitoring, and Public Outreach. At the end of the report, a Lessons Learned section summarizes stumbling blocks, modifications, or great successes that occurred while working six years to complete this worthwhile restoration project.

The project site lies at 7,000 feet elevation along the Little Colorado River near the eastern Arizona community of Springerville. The project lies within properties owned by Rick Benoit and Troy Burk. The goal of the restoration project is to enhance the aquatic, biological, and physical resources of the riparian corridor. The enhancement of these resources will directly benefit fish and wildlife resources dependent on the river and the associated riparian ecosystem. During the initial assessment, the channel profile was determined to be stable, however over 75 percent of the outside meander banks within the project area were actively eroding. This contributed to high sediment loads entering the channel on a regular basis, which in turn caused decreasing aquatic ecosystem health. Additionally, because of the active erosion, riparian vegetation within the toe, bank, and transition zones of the banks was sparse. The restoration prescription included sloping the eroding banks to a 2:1 gradient, planting and seeding with native, and when possible, locally harvested vegetation, and using various bioengineering techniques to stabilize the banks. Structural practices such as toe rock were utilized only when absolutely necessary to stabilize a bank.

Project tasks included in the AWPF grant were:

- Task 1: Permits, Clearances and Personnel
- Task 2: Site Assessment Plan
- Task 3: Design Plan
- Task 4: Fencing/Monitoring/Outreach Plan
- Task 5: Construct Exclosure Fencing
- Task 6: Primary Construction
- Task 7: Final Construction
- Task 8: Monitoring
- Task 9: Public Outreach
- Task 10: Post Final Construction
- Task 11: Final Report

The contract was awarded in 2007 and the project completed in 2012. The initial design included an off –channel wetland and fish habitat structures that were not ultimately built. Concerns with water rights that were not resolved resulted in the off –channel wetland being dropped from the design. The fish habitat structures were removed as a condition in the Army Corps 404 permit in response to U.S. Fish and Wildlife concerns. The structures could increase habitat for non-native fish that would prey upon the native Little Colorado spinedace that are present in the project area. The spinedace is a federally listed species.

The initial implementation of the restoration design plan took place for a week in October/November 2008. A second construction phase to improve any problematic areas or to modify previous treatments took place in October 2010. A final seeding and planting occurred in August 2012.

The project was monitored for four years post-construction starting during the fall of 2009 with the final monitoring taking place October 2012. Monitoring methods included cross-section surveys, bank erodibility hazard index assessments, and repeat photo monitoring. Structural

elements and vegetation were visually inspected each year to evaluate structural soundness and growth, respectively.

Public outreach for the project took place in 2008 in conjunction with a workshop held by Natural Channel Design, Inc. In November 2011, a workshop was held on site to showcase the project to the general public. A sign outlining the project and identifying other Arizona Water Protection Fund funded projects located in the Springerville area was installed at that time as well.

The project site has responded well to the applied restoration practices. The eroding banks have become vegetated and plantings are becoming established. Bank erodibility hazard index assessments show improved bank stability.

BACKGROUND

SITE DESCRIPTION

The project area includes two adjacent properties belonging to Mr. Rick Benoit and Mr. Troy Burk located north of the town of Springerville in Eastern Arizona at approximately 7,000 feet in elevation. The project area lies in the greater Round Valley area along the Little Colorado River near two similar enhancement projects also funded by the AWPF in T9N, R29E, Section 29 (Figure 1).

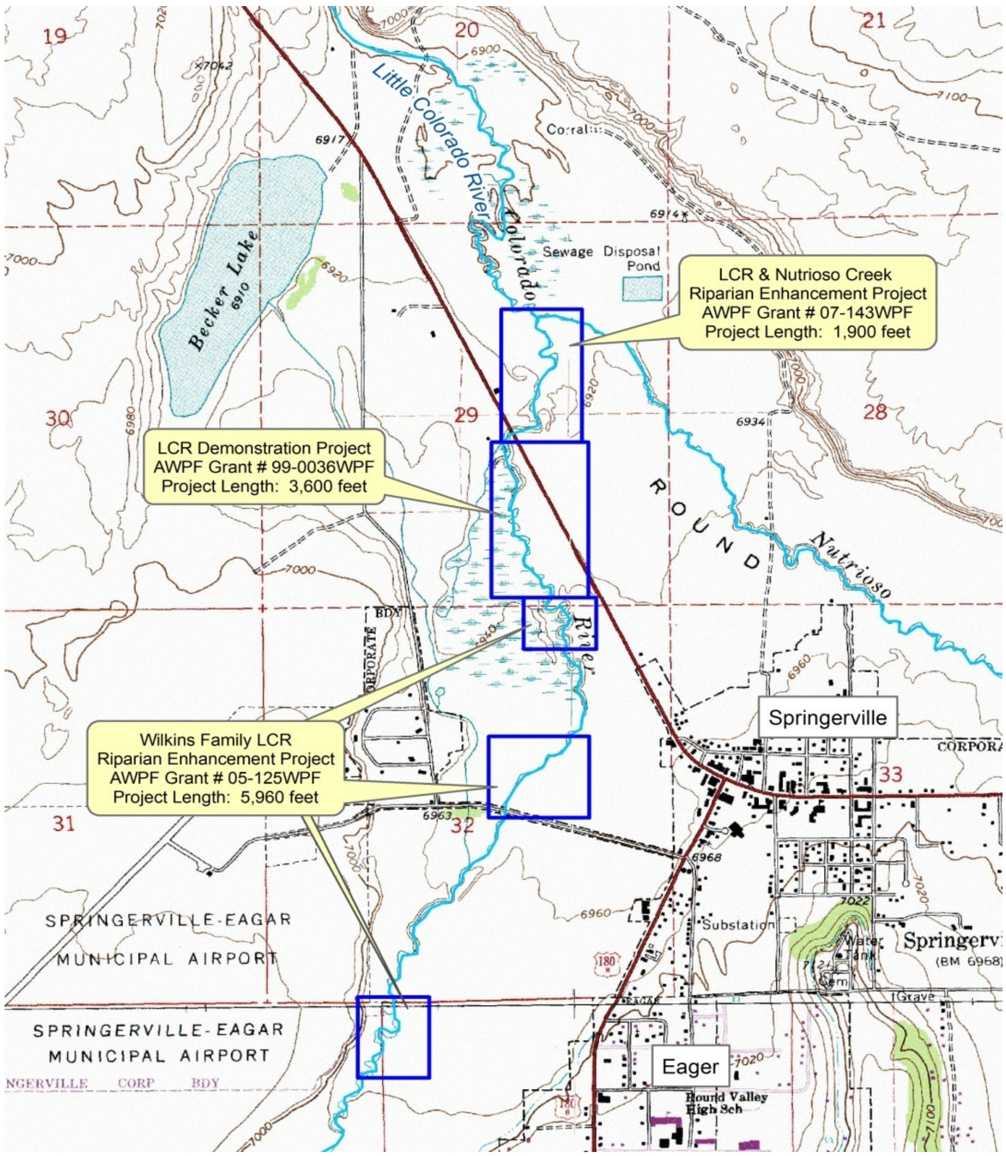

Figure 1. Project location.

The project is located in Springerville, AZ downstream of project #99-092WPF on the Little Colorado River.

The project includes 2,007 feet of perennial stream channel–1,832 feet of the Little Colorado River (LCR) and 175 feet of Nutrioso Creek. The associated riparian corridor extends approximately 50 feet on either side of the LCR and 30 feet on either side of Nutrioso Creek. The size of the project area is approximately 4.5 acres (Figure 2). The LCR is a low-gradient gravel bed stream with broad, well-vegetated floodplains. Where functional, the LCR supports a robust native riparian plant community. Both stream channels have experienced intensive grazing in the past that has degraded the native riparian habitat, resulting in extensive bank erosion and reduced floodplain function.

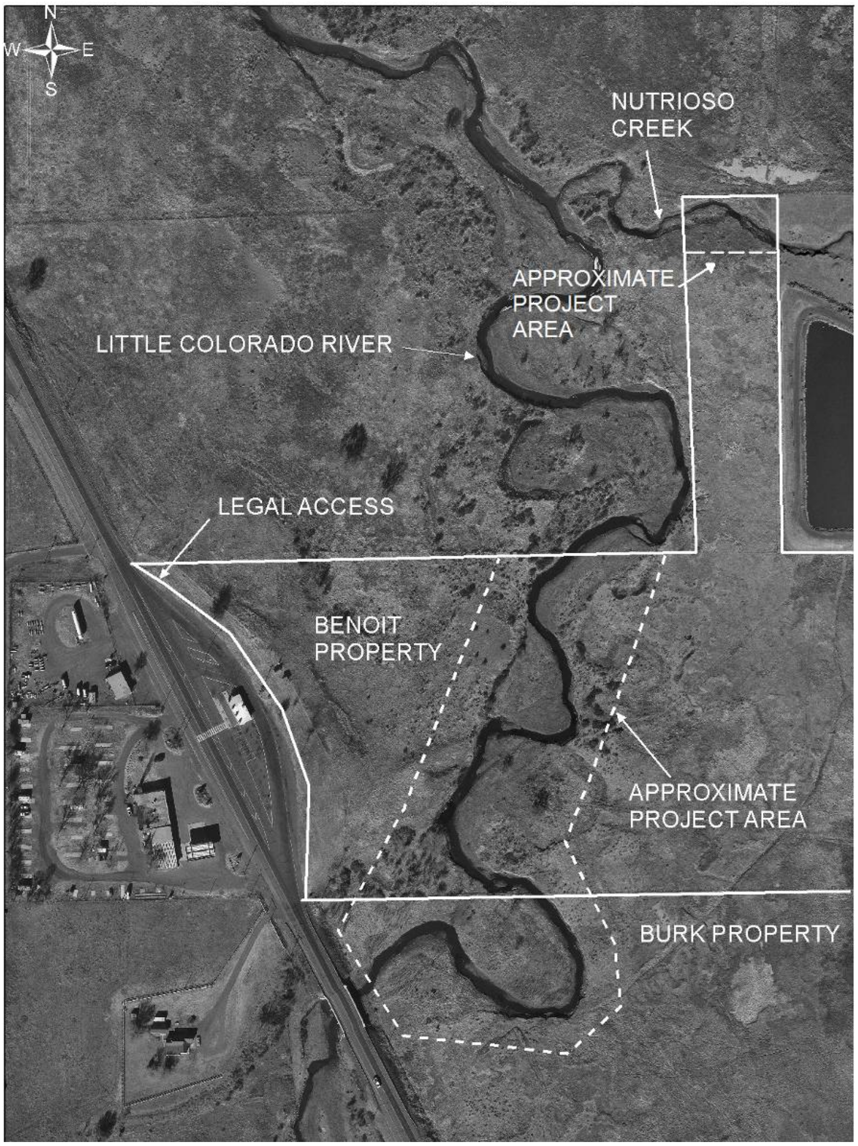

Figure 2. Approximate project area on Benoit and Burk properties.

PROJECT DESCRIPTION

The Little Colorado River provides unique habitats for avian, terrestrial, and aquatic species within the arid southwest. In the Round Valley, intense agricultural and grazing practices have depleted river resources resulting in decreased vegetative cover and channel stability, as well as increased sediment input and water temperature. As land uses continue to change and sustainable land management practices are incorporated, landowners seek to restore the river to greater functionality.

Having witnessed the success of the nearby LCR demonstration project and the Wilkins Family LCR enhancement project, Mr. Benoit and Mr. Burk wished to restore the portion of the river flowing through their properties. They submitted this project for grant funds in 2006 to further the goals and mission of the Upper Little Colorado Partnership.

GOALS AND OBJECTIVES

The landowners shared the common goal to restore this stretch of the river to healthier conditions by enhancing the depleted aquatic and riparian resources. The specific objectives of this project included:

- Increasing the stability of the stream channel while maintaining natural dynamic fluvial processes including proper hydrologic function, stream geomorphology, and channel/floodplain function.
- Reducing the quantity of fine sediments supplied to the stream from eroding stream banks benefiting aquatic habitats for native fish species including the Little Colorado River spinedace, a federally listed species.
- Enhancing the native riparian vegetation along the project reaches to increase the quantity and quality of native riparian wildlife habitat.
- Providing a positive example of riparian restoration and wildlife habitat enhancement on private properties in the Little Colorado River watershed.

PROJECT TIMELINE

Table 1. Project timeline.

A one year no-cost contract extension was approved in April 2012 to allow for additional seeding and monitoring of the project.

Year	Month	Task
2006	August	AWPF Application
2007	April	AWPF Grant Awarded
2008	April	Initial Design, permitting complete
2008	October	Initial Construction
2008	December	Baseline Monitoring
2009,2010	November	2nd & 3rd Years Monitoring
2010	December	Final Construction
2011	November	Public Outreach Site Visit
2011	August	Final Seeding/Planting
2012	November	Final Monitoring
2013	March	Final Report

PROJECT BUDGET

Table 2. Little Colorado River and Nutrioso Creek Riparian Enhancement Project budget.

Task	Original Budget	% of Project Funds
Task 1: Permits, Clearances and Personnel	$12,180.00	6%
Task 2: Site Assessment Plan	$4,515.00	2%
Task 3. Design Plan	$13,860.00	7%
Task 4. Fencing/Monitoring/Outreach Plan	$5,828.00	3%
Task 5: Construct Exclosure Fencing	$17,850.00	9%
Task 6: Primary Construction	$67,620.00	34%
Task 7: Final Construction	$22,281.00	7%
Task 8: Monitoring	$38,063.00	19%
Task 9: Public Outreach	$7,875.00	4%
Task 10: Post Final Construction	$8,195.00	4%
Task 11: Final Report	$8,925.00	4%
	$198,997.00	100%

Task 10 – Post final construction was included in 2011 to address additional erosion that had occurred the previous year and to provide a final seeding effort on banks that had lower success of grass establishment. Funding for this task came from remaining funds in Task 6 that were not initially used.

PROJECT APPROACH

A stream adjusts its size, slope, and sinuosity to accommodate typical stream flows and to move sediment through the system. Generally speaking, a stream is constantly dissipating energy as it moves downstream. In a low gradient channel, bars, meanders and a broad floodplain are important features for dissipating excess energy. If unable to expend this energy the channel is inherently unstable and prone to lateral and/or vertical erosion, especially during large flow events.

Stream channels are created and maintained by moderate, frequent flood events (Leopold, 1994) with return intervals in the range of one to two years (Moody et al., 2003). In many gravel bed streams, this flow has been shown to carry the greatest amount of sediment over time (Andrews, 1980) and is considered the stream forming flow, channel maintenance flow or bankfull flow. The stability of any natural channel is dependent on an appropriate dimension, pattern, and profile of the bankfull channel and associated floodplain (Leopold et al., 1964). A natural channel approach to design seeks to identify the stable geomorphic dimensions of a channel and incorporate those into designs to meet specific objectives. In this project self-maintaining bedforms and associated aquatic habitats will be carefully characterized and evaluated to meet project enhancement objectives. Closely matching the central tendencies of the natural channel results in a design that works with the existing channel rather than against it. The approach achieves greater success with least maintenance cost. The geomorphic design approach involves four distinct steps: 1) characterization of existing physical and biological parameters, 2) identification and characterization of reference conditions that represent the full potential of the system, 3) evaluation of existing conditions against reference to determine enhancement needs and 4) develop specific design prescriptions to move the system toward the "reference" condition.

The goal of the project was the enhancement of the physical, biological, and aquatic resources of the riparian corridor within the project area. Within the framework of the natural channel morphology, a thorough assessment of existing conditions of the physical and biological components within the project reaches was undertaken. The existing channel/floodplain and associated riparian vegetation community were evaluated against a morphologic "reference" condition developed from assessment surveys. The reference condition represents the full potential of the system consistent with project objectives.

PART I: ASSESSMENT & INVENTORY

INVENTORY & ASSESSMENT

A comprehensive guide to the enhancement of physical and biological resources of the upper Little Colorado River was prepared in 2001 (Moody et al, 2001). The Concept Plan assessed several miles of the upper LCR and described the physical and biological potential for individual reaches. This document was used to validate the identification of reference conditions and assessment conclusions for the project reaches.

The entire project is 1,875 feet or 0.35 miles in length. Topographic surveys were conducted of the entire stream corridor within the project area to provide detailed ground analysis for design. Aerial photos were also obtained for the area and used to help display the project site. These photos and maps served as the foundation for inventory, assessment, and design.

During the site assessment, the project area was evaluated and individual banks requiring enhancement were identified and labeled alphabetically starting at the upstream end (Figure 3). These banks received individualized treatments depending on the erosion taking place and the stream geometry. The overall stream channel through the project site was determined to be a "C" type channel according to the Rosgen Classification system which is a low-gradient, meandering alluvial channel with broad, well-defined floodplains (Rosgen, 1996). The slope and sinuosity of the channel are shown in Table 3.

Table 3. Project Stream Information

Property	STA	Length	Slope	Sinuosity
Benoit/Burk	0+00 to 20+00	1,875 ft	0.003	1.5

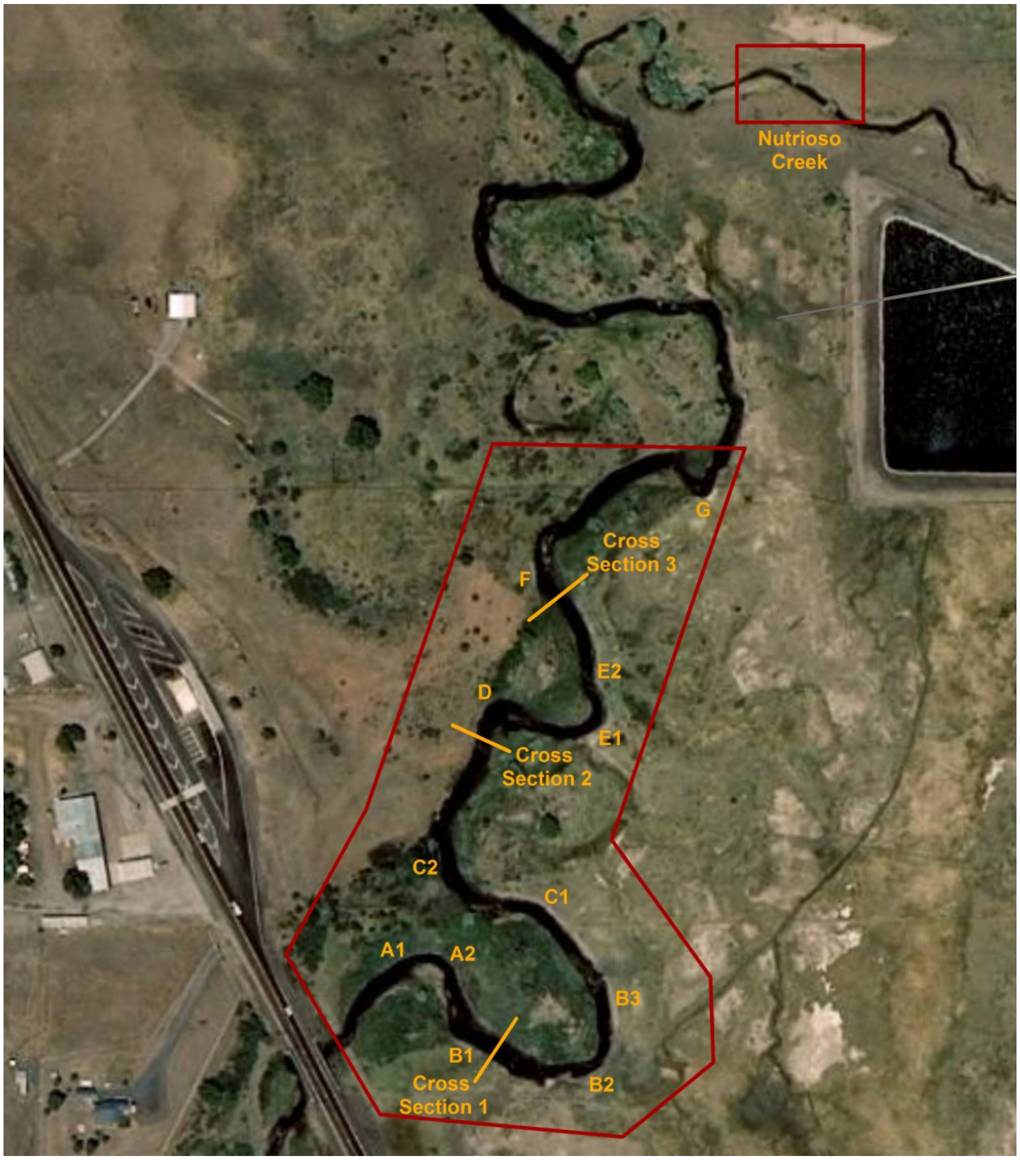

Figure 3. Aerial image showing bank locations in uppercase letters

Stream Channel Morphology

The Little Colorado River is a low gradient, gravel bed, meandering stream with a well-vegetated floodplain through the project reach. The valley is wide and channel slopes are relatively consistent through all reaches (Table 4). There is evidence of historic incision with the formation of the current floodplain approximately four feet below the valley floor. The channel is very sinuous but the outside meander banks were commonly unstable and eroding. The following sections describe the characterization of the channel dimension, pattern, and profile.

Table 4 . Channel delineative values

XS	W-D Ratio[1]	Ent. Ratio[2]	Slope (ft/ft)	D50	Sinuosity[3]	Stream Type
1	37.6	3.3	0.003	Sand	1.5	C5
2	21.2	4.7	0.003	Sand	1.5	C5
3	41.6	3.3	0.003	Sand	1.5	C5
Design	21 - 41	> 2.2	0.003	Sand	1.5	C5

[1] Width-Depth Ratio is defined as bankfull channel width divided by mean bankfull depth and describes the bankfull channel shape.
[2] Entrenchment Ratio is defined as floodprone width divided by bankfull channel width and describes the floodplain area available for spreading moderate flow events.
[3] Sinuosity is defined as stream length divided by valley length and describes the relative meander of the stream.

CHANNEL DIMENSION

In addition to the topographic survey, a series of representative cross-sections were surveyed to characterize channel dimension. Bankfull elevation was determined by identifying consistent physical features representing floodplain elevation along the longitudinal profile (Dunne & Leopold, 1978). The bankfull elevation was transferred to cross-sections to develop channel dimension (Table 5). Dimensionless ratios from the surveyed cross-sections used to describe channel morphology and used in the Natural Channel Classification System (Rosgen, 1996) are given in Table 4 .

Table 5. Channel dimension values

XS	XS Area (sq ft)	Bkf Width (ft)	Mean Depth (ft)	Max Depth (ft)	Floodprone Width[1] (ft)	Depth Ratio[2] ______
1	53.8	45	1.2	2.1	150+	0.6
2	48.4	32	1.5	2.3	150+	0.65
3	48.7	45	1.1	2.1	150+	0.5
Average	50.3	40	1.3	2.2	150+	0.58

[1] Floodprone width is defined as the width of the floodplain at an elevation twice maximum depth of the bankfull channel and describes the area available for spreading moderate flood flows.
[2] Depth Ratio is defined as mean bankfull depth divided by maximum bankfull depth in a riffle section. The ratio describes the general channel shape.

Natural fluvial processes have shaped and maintained the channel for the past decades and it is assumed that channel and floodplain dimensions represent natural conditions. To validate this hypothesis bankfull morphology was compared with regional data. Project morphological data was compared with regional curves (the correlation of bankfull channel cross-sectional area as a function of watershed area) and found to be consistent (Figure 4). As a result, existing channel dimension at the representative cross-sections for all reaches appear to represent natural, stable conditions and the values used for design purposes

The consistent values and lack of erosion in the riffle sections suggests the channels represent the range of reference conditions. With this information it was determined that the restoration design would focus on stabilizing meander bends and no mechanical change in channel dimension was recommended.

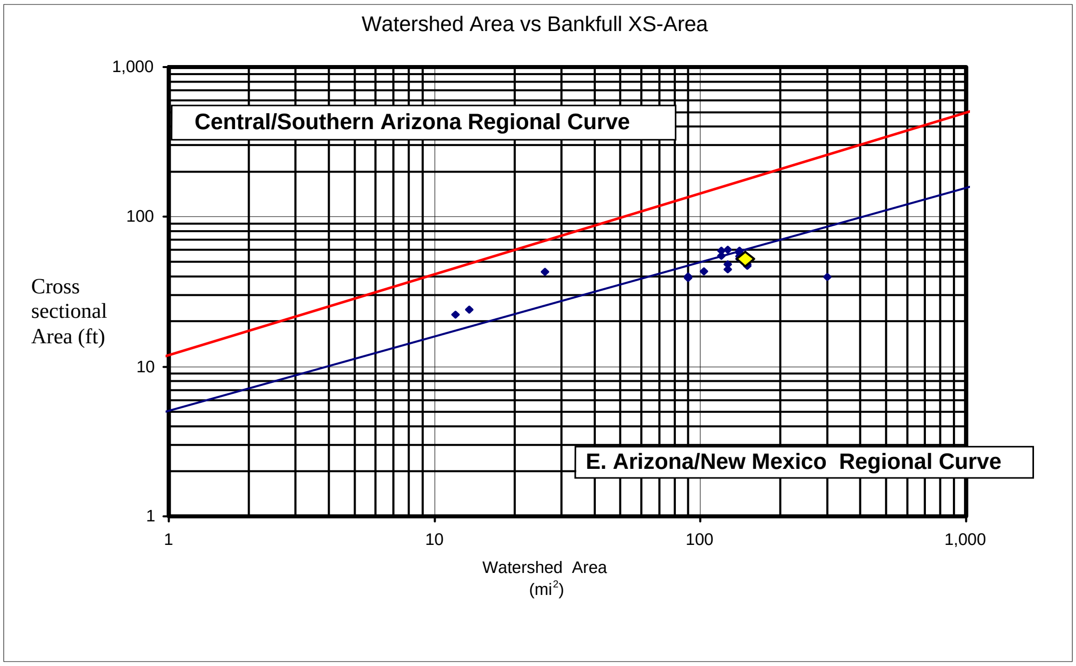

Figure 4. LCR local calibration curve.

Project cross-sectional areas (diamond data point) are consistent with local and regional data.

CHANNEL SUBSTRATE

Channel substrate was sampled using the Wolman Pebble Count protocols (Wolman, 1954). One hundred particles were collected within the gravel streambed through the project reach in a consistent, random method. The median axis of each particle was measured, recorded and graphed as a cumulative distribution (Figure 5) and as a percentage of total substrate (Figure 6). Figure 6 displays a bimodal distribution of substrate particles with a large amount of fine sediment present and a more normal distribution of gravel sized substrate. The fine sediments are a concern as they can reduce the quality of the aquatic habitats. The source of these fine sediments is assumed to be the highly eroding banks that are present in the project.

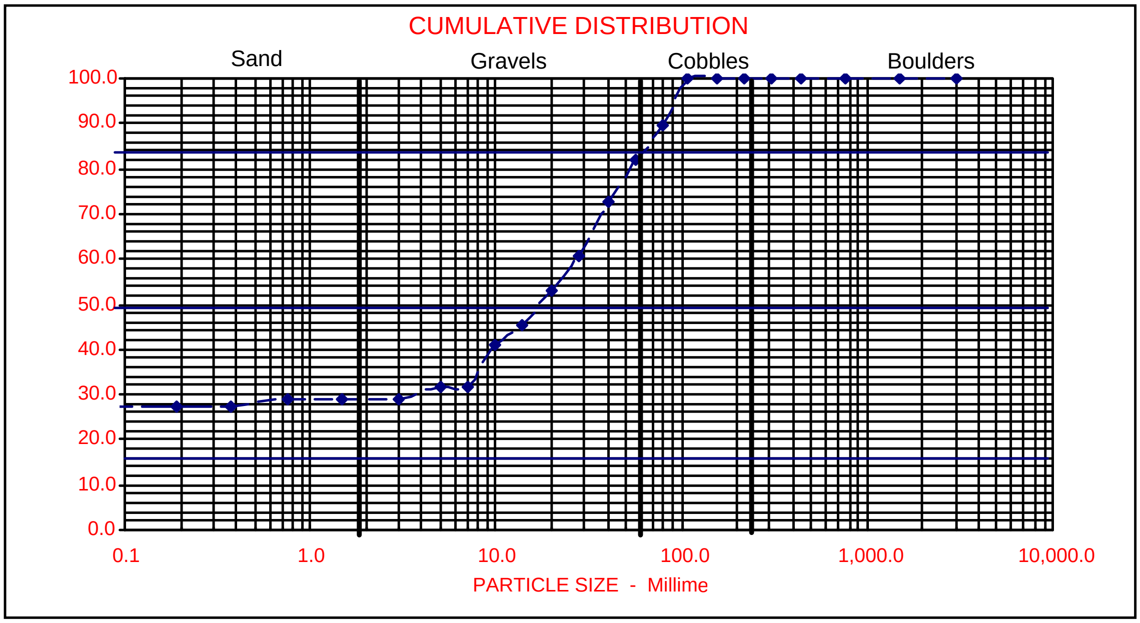

Figure 5. Cumulative distribution of channel bed substrate.

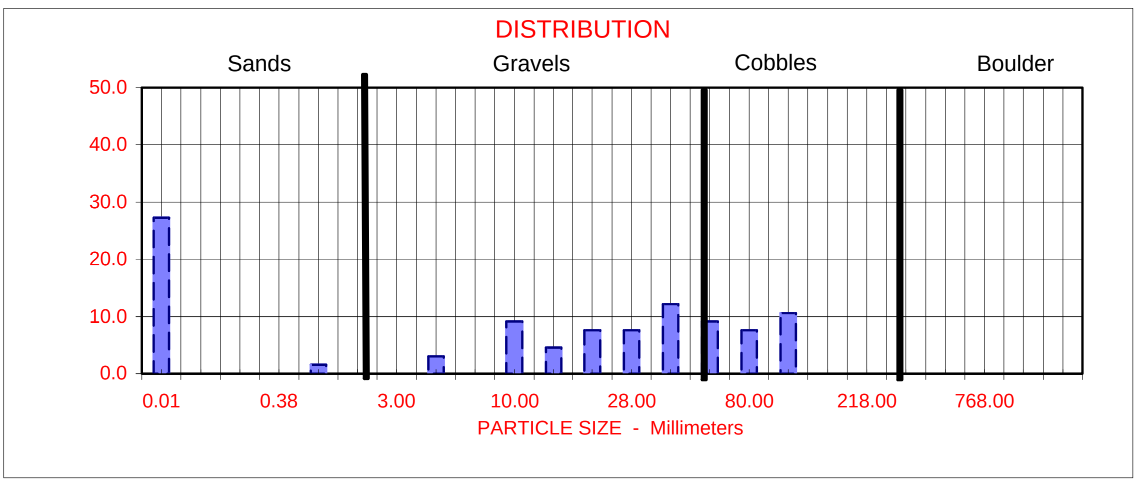

Figure 6. Channel bed substrate; percent of total.

CHANNEL PATTERN

The Little Colorado River within the project is very sinuous. Radius of curvature values were measured at each unstable meander and divided by bankfull width (40 ft) to create a dimensionless ratio (Table 4). Two stable banks within the project area located at STA 9+00 to STA 10+50 and STA 17+50 to STA 18+80 (Bank F) were measured for comparison. A summary of information is included in Table 4, which includes observations about each bank that is also used to determine the most appropriate treatment. The stable bank at STA 9+00 – STA 10+50 has a ratio of 2.3 and Bank F follows with a ratio of 1.9. Both of these banks represent stable or very nearly stable banks in the project area. The rest of the banks, which were experiencing erosion, have values less than 1.9. An evaluation of bank condition suggests that meanders with radius of curvature ratios of 1.5 and less have more severe erosion.

Table 4. Meander Pattern Values.

STA	BANK	Rc (ft)	Rc Ratio	Observations
STA 2+40 to 3+00 (left)	A	60	1.5	Floodplain side, veg stable
STA 3+80 to 5+40 (left)	B1	--	--	Broad healing toe
STA 5+40 to 6+15 (right)	B2	61	1.5	Raw vertical bank
STA 6+15 to 8+25 (right)	B3	--	--	Broad healing toe
STA 8+25 to 9+40 (right)	C	71	1.7	Healing toe downstream
STA 9+00 to 10+50 (left)	--	95	2.3	Stable, well vegetated
STA 12+45 to 13+30 (left)	D	45	1.1	Healing toe upstream
STA 14+50 to 15+20 (right)	E1	45	1.1	Raw vertical bank
STA 15+20 to 15+55 (right)	E2	--	--	Raw vertical bank
STA 17+50 to 18+80 (left)	F	75	1.9	Healing, active beaver
STA 20+75 to 21+15 (right)	G	24	0.6	Raw vertical bank
	Average	59.5	1.5	
	Minimum	24	0.6	
	Maximum	95	2.3	

Experience in the LCR Demo project immediately upstream suggests that toe rock was necessary to stabilize the most severe of these turns. As a result, toe rock was used to stabilize tight meanders in the project and brush revetment and other methods were used on larger radius turns. One exception to this prescription is Bank A. This bank is on the floodplain side of the meander and is very well vegetated. Coir log was installed to protect the toe even further and allow vegetation to grow thick. Coir log and brush revetment was used on Bank G instead of toe rock because of its location (only the first half of the meander was within project area) and proximity to the neighbor's property downstream.

CHANNEL PROFILE

The project channel is composed of riffle-pool and riffle-run bedforms common in low gradient meandering gravel bed streams. Table 5 displays the length and maximum depth of each pool in the project area. Sixty percent of the stream length through the project area is composed of pools; however those pools are rather long and shallow with an average length of 112 feet and average maximum depth of one foot. Riffle and run sections make up approximately 40% of the project stream length. No change in pool geometry or spacing was recommended.

Table 5. Length and depth of pools present in the project area.

LABEL		LENGTH (ft)	MAX DEPTH (ft)
A		96.83	1.30
B		86.66	0.94
C		48.1	0.92
D		81.87	0.59
E		87.86	0.66
F		72.13	0.78
G		298.67	2.10
H		56.09	1.38
I		145.9	0.91
J		141.4	1.06
	Average	111.50	1.06
	Min	48.10	0.59
	Max	298.67	2.10

BANK STABILITY

Bank instability and the associated fine sediments delivered to the streambed are a substantial concern within the project area. Bank erosion is common on nearly all meander bends. The length of eroding banks (1,155 feet) is approximately 31 percent of the entire site and 70 percent of all meander banks. Bank Erosion Potential (BEP) is a measure of the banks tendency to erode based on quantifying the physical structure. Assessment criteria include bank height ratio (bank height/bankfull depth), bank slope, surface cover, root density, and root depth (Figure 7). All eroding banks were assessed using the Bank Erosion Potential (BEP) and the results are shown in Table 6.

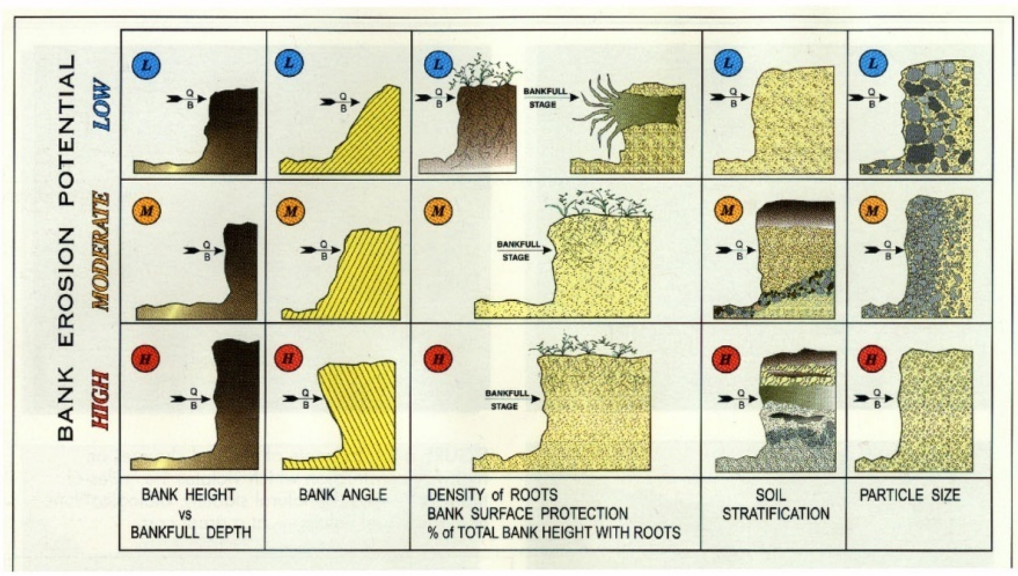

Figure 7. Bank Erosion Potential criteria.

Table 6. Bank erodibility potential (BEP) values at the site

STA	Bank	Height (ft)	Bank Length (ft)	Bank score	BEP rating	R_C Ratio
STA 2+40 to 3+00 (left)	A	2.0	62	High	32.1	1.5
STA 5+40 to 6+15 (right)	B2	5.5	75	Very High	42	1.5
STA 8+25 to 9+40 (right)	C	5.0	116	Moderate	28.6	1.7
STA 9+00 to 10+50 (left)	Ref			Low	17.7	2.3
STA 12+45 to 13+30 (left)	D	3.5	81	Moderate	20.5	1.1
STA 14+50 to 15+20 (right)	E1	5.5	70	High	38.8	1.1
STA 17+50 to 18+80 (left)	F	4.5	130	Moderate	24.5	1.9
STA 20+75 to 21+15 (right)	G	6.0	70	Very High	42.3	0.6

Bank instability is generally limited to the outside of meander banks. The point bars on the inside of each meander are depositional and stable as are the riffle or transition sections. The eroding meander banks represent seventy percent of all meander banks. Of these eroding banks, over half had High or Very High BEP ratings. The mean BEP value for eroding banks was 32.6 contrasted with a reference bank value (stable, well-vegetated sloped bank) of 17.7. Structural and bioengineering efforts will be required to stabilize these banks. The radius of curvature ratio values are placed next to the BEP ratings in Table 8 for ease of comparison. Indeed, the reference bank has a much higher ratio (2.3) than the other actively eroding banks in the project area. The ratio indicates that the curve is larger at the reference bank than at other banks, which reduces the stress on the bank as water passes by. Since the radius of curvature ratios at the other banks indicate higher stress levels and the BEP ratings indicate that their erodibility is high, the plan to repair the banks by sloping and then re-vegetating them will reduce the BEP ratings and increase the ability of the banks to withstand the forces of the water passing through these sharper curves.

HYDROLOGY

The Little Colorado River within the project area has a total watershed area of approximately 150 square miles with an unregulated watershed area downstream of Greer Lakes of approximately 125 square miles (Figure 8). The stream originates along the north side of Mt. Baldy at 10,000 feet in elevation. The upper watershed is dominated by evergreen forests of pine, spruce, and fir. The East Fork and West Fork join at an elevation of 8,500 feet at the head of Greer Valley. The Little Colorado River is perennial within the project reach. Greer Lakes, a series of reservoirs located below Greer Valley and upstream of the project, store water to be utilized for agricultural uses downstream. Below the reservoirs, a number of smaller tributaries join the river above the project site. These reservoirs are not large but their operation complicates the base and flood flows at the project site.

The Greer Lakes stores water during the winter season (September 15 to April 15) that is subsequently released during the growing season (April 15 to September 15). As a result, base flows are often reduced, especially during the fall when the reservoir is filling. During the spring and summer months, flows are increased as irrigation demands increase. However, the project area lies downstream of most irrigation diversions and therefore often experiences very low flows during the growing season. The reservoirs alter the flood magnitudes, though the impacts are difficult to quantify. This large, high elevation watershed is capable of producing substantial annual water volumes. The relatively small volume of the reservoirs suggests that they fill annually except during drought periods. High flood events are generally produced during wet winters and by large storm systems. It is assumed that under these conditions the reservoirs would be full and not reduce flow magnitudes. Likewise, the watershed areas below the reservoirs contribute small, unregulated flood flows. It is likely that medium flow events experience the greatest impact from the reservoirs.

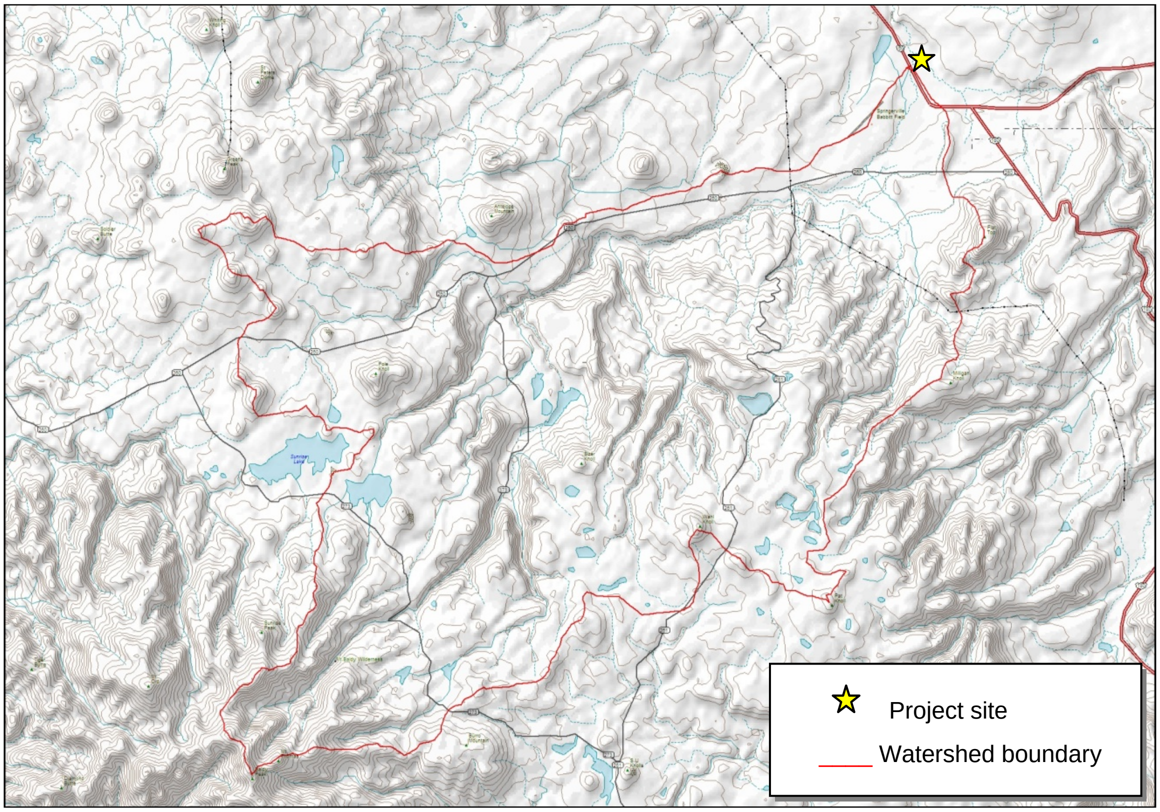

Figure 8. The map displays entire watershed from headwaters to start of the project site.

The Little Colorado River watershed from headwaters in the White Mountains to the beginning of the project site is about 150 square miles. Greer reservoirs impede the natural flow of the water above that point, but below the reservoirs, flow is unregulated to the project site.

Only one stream gage (Little Colorado River at Greer, AZ) was initially located on the Little Colorado River near the project and it had been discontinued. (Two new gages have since been installed on the river near the project area.) In order to make estimates of flood flows at the project site a regional analysis method was used (USDA SCS, 1983). The method uses stream gage data from surrounding sites to develop an empirical relationship between flow magnitudes and watershed area for various flood frequencies. Estimated discharges through the project for various recurrence intervals are listed in Table 7.

Table 7. Estimated flow values for various recurrence intervals.

	WS Area (sq miles)	Q1.5 (cfs)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)
Project Site	150	270	420	1,030	1,700	3,100

HYDRAULICS

Hydraulics can be assessed by a variety of methods. One common practice is to estimate these values using a cross-section analyzer, a computer program utilizing cross-sectional survey information, slope, and a composite roughness factor. Utilizing the computer model along with field observations and other stream morphology analyses helps determine the velocities to expect and the volume that can be tolerated by the system. Table 8 reports the estimated velocities for various return intervals from the computer model.

Table 8. Velocities associated with various size flows for the project area.

Q (cfs)	Return Interval	Stage (ft)	Velocity (ft/s)	Alluvial Feature
285	1.5	2.8	3.65	Bankfull stage
443	2	3.3	3.73	Floodplain
1026	5	4.2	4.07	Floodplain
1739	10	4.8	4.88	Floodplain
3118	25	5.6	6.28	Floodprone

The average velocity at bankfull stage was estimated in order to link and validate hydrology and channel morphology assessments. Regional data collected at gaged stream channel sites throughout the southwest suggest that values for average velocity at bankfull stage are commonly found in the range of 3 to 7 feet per second (Moody et al., 2003). Based on an average cross-sectional area of 50.3 square feet (see Section I: Stream Channel Morphology) and an estimated bankfull discharge of 270 cubic feet per second (see Section I: Hydrology), the estimated average velocity is 3.6 feet per second and consistent with expectations.

In summary, the assessment of stream channel morphology found no evidence of down-cutting or incision. The size and shape of stream channel and floodplains are adequate and appropriate. Floodplains were extensive, well-vegetated, and without evidence of extreme scour or deposition from high flow events. Channel bed substrate contains larger amounts of fine material than expected which, while it doesn't appear to impact stream function, could seriously impair aquatic habitats. Streambank erosion is common along the outside of channel meanders but the presence of a few well-vegetated and stable banks suggests that the problem may be lack of bank strength (lack of vegetation, steep slope) rather than excessive hydraulic forces.

ANNUAL PRECIPITATION

The Little Colorado River through the project site is situated in a broad, well-watered alluvial valley. There were two weather stations near the project, one at Springerville and the other near Greer (Table 9). Average annual precipitation was estimated between the values recorded at these stations and is approximately 20 inches with mean monthly values ranging from 0.7 to over 4.0 inches. These values indicated that supplemental irrigation would not be a necessary component to achieve planting success.

Table 9. Precipitation values at Springerville and Greer, Arizona from 1911 to 2000.

Precipitation values at Springerville, AZ

Period of Record : 4/1/1911 to 4/30/2000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Total Precipitation (in.)	0.53	0.47	0.53	0.36	0.41	0.52	2.70	3.06	1.56	0.89	0.46	0.52	12.02
Average Total Snow Fall (in.)	4.9	3.7	3.3	1.1	0.4	0.0	0.0	0.0	0.0	0.7	2.5	4.1	20.6

Precipitation values at Greer, AZ

Period of Record : 4/1/1911 to 4/30/2000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Total Precipitation (in.)	1.69	1.47	1.69	0.82	0.72	0.92	4.21	4.34	2.32	1.92	1.35	1.95	23.39
Average Total Snow Fall (in.)	21.6	19.0	18.0	6.4	1.0	0.1	0.0	0.0	0.0	0.7	2.5	4.1	20.6

SOIL TYPE

In addition to precipitation, soil composition is an important factor in determining the success of plantings within a given project area. Four general soil types (Figure 9) exist at the site. The floodplains and terraces within the project area are dominated by 3 types of Nutrioso Loam with small depressional areas filled with Shay Clay. The Nutrioso Loam soil type is well-drained with high available water capacity and a deep effective root depth. Thus, the soil type was determined to be adequate for planting needs. The Shay Clay is hard packed and drains poorly. Plantings in the hard Shay Clay were determined to be less likely to succeed; therefore areas dominated by Shay Clay were avoided and plantings were focused on the Nutrioso Loam soils.

Soil Salinity was not considered a concern based on soils data provided by local USDA NRCS office. Observations of the species composition at the project site confirmed that assessment. At the time of project inception, exotic species were uncommon on the site and did not appear to be aggressively expanding.

Source: Soil Conservation Service.

Nutrioso Loam – (NT) (South Fork, Schoolbus Rd., Round Valley)

This soil is on floodplains and alluvial fans that are as much as one-half mile across. They are well-drained soils that formed in alluvium derived from volcanic tuff and basalt. Slopes generally are 0 to 3 percent but range as much as 5 percent. Average annual precipitation is 13 to 16 inches, average annual temperature is 43 to 47 degrees F. Frost-free season is 90 to 120 days. Permeability is moderately slow, and available water capacity is high. The effective root depth is more than 5 feet. Runoff is slow and the hazard of erosion is slight. The hazard of flooding is slight (once in every 10 to 100 years) along the main drainageway.

Nutrioso Loam, 1 to 3 percent – (NuB) (South Fork, Schoolbus Rd., Round Valley, Highway 60)

Similar to NT. This soil is found on floodplains and alluvial fans along the Little Colorado River through these reaches. Southeast of Eagar are large areas of a soil that is on a fan and is loam throughout. On the floodplains west of Eagar, there is a small included area where the soil is gravelly below a depth of 3 feet. Runoff is medium and the hazard of erosion is moderate.

Nutrioso loam, - 0 to 1 percent (NuA) (Schoolbus Rd., Round Valley, Highway 60)

Similar to NT. This soil is on floodplains along the Little Colorado River through these reaches. Included in the mapping of this unit are somewhat poorly drained areas where the water table fluctuates between 2 and 5 feet from the surface. Also included, west of Eagar, are small areas where the soil is gravelly below a depth of 3 feet. Runoff is slow and the hazard of erosion is slight along the main drainageways.

Shay Clay - (Sh) (Schoolbus Rd., Round Valley, Highway 60, Wenima)

This is a poorly drained soil that formed in alluvium derived mainly from volcanic ash and basalt. This soil is found in flat or depressional areas on the floodplains of the Little Colorado River. Slopes are smooth, flat or slightly concave, and 0 to 1 percent. Average annual precipitation is 11 to 12 inches, average annual temperature is 47 to 49 degrees F. Frost-free season is about 120 to 130 days. The soil is calcareous and moderately alkaline throughout. Permeability is slow, and the available water capacity is high. Runoff is ponded or very slow, and the hazard of erosion is slight. The effective root depth is more than 5 feet. For about 2 months of the year, usually July and August, these soils are wet to the surface. The rest of the year, the water table is about 2 feet below the surface.

Figure 9. Soil types within the project area.

RIPARIAN VEGETATION

Although a well-established native riparian plant community is associated with the Little Colorado River within the project area, much of the community has been impacted by past management practices. The woody plant community is dominated by small, flexible species such as strapleaf willow (*Salix ligulifolia*), coyote willow (*Salix exigua*), and Arizona rose. Tree species are generally found as single individuals of a mixture of native and non-native species including Siberian elm, narrowleaf cottonwood, New Mexico locust, buckthorn, and box-elder. The herbaceous community is comprised of a variety of sedge/rush and grass species. Tamarisk was and still is present, but is at the upper limits of its range and uncommon. It does not appear to be a threat to the native community. There are numerous Russian olive trees of various size classes, these plants are invasive and will continue to outcompete native species.

The dominant plant communities were identified with a set of riparian planting zones (Figure 10, Hoag et al., 2001). These zones represent differing levels of disturbance and soil moisture, the two dominant influences on the composition and distribution of riparian plant species. Understanding the composition by zone assisted in assessment and, ultimately, in the enhancement design.

Toe and Bank Zones (streambanks to floodplain elevation): Herbaceous wetland/grass species

Overbank Zone (low and high floodplains): Herbaceous wetland/grass with some willows

Transition Zone (wet meadows): Rose, assorted native/non-native tree species, grasses, willow/wetland species where moisture is sufficient (generally irrigated)

Upland Zone (above meadow) not included in project area.

The plant communities and zones were represented at all project areas.

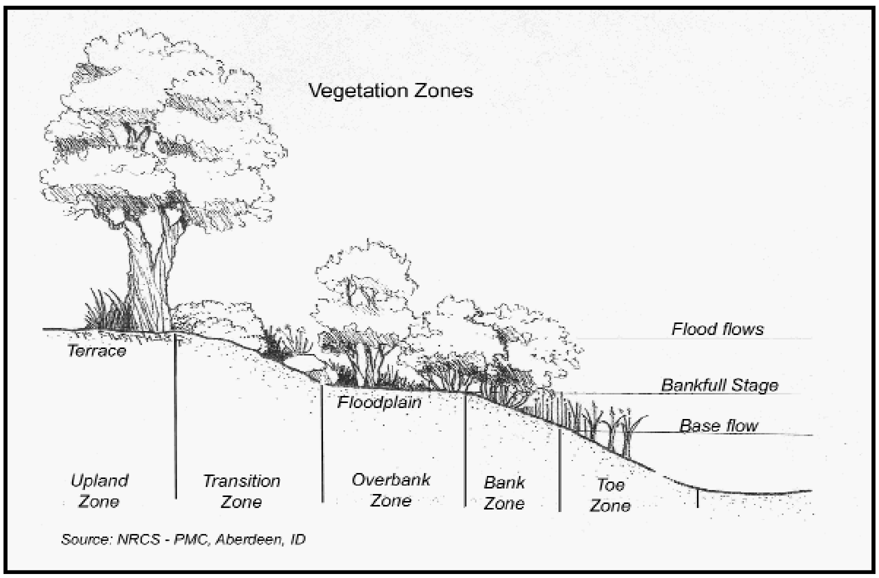

Figure 10. Riparian vegetation zones.

The existing riparian vegetation was inventoried by creating polygons that described different plant communities along the project reach. The delineated polygons can be viewed in the Design Report associated with Task 3 of this project. The polygons were then divided into six habitat types depending on the dominant species (Table 10). The categories represent varying heights of overstory (>15 feet in height), intermediate class (2-15 feet in height) and herbaceous species (< 2 feet).

Present and past management differs in the project area. Mr. Burk manages livestock on his property during winter months at the upstream end of the project. Thus, willows are present because they are not browsed during the summer, however woody structure could improve and the grass community could benefit from more diversity. Mr. Benoit recently acquired the land that encompasses the rest of the project area which also appears to have been heavily grazed in the past and has been utilized by neighboring horses recently. Larger woody species are present on Mr. Benoit's property, but plant structure diversity could be improved as well as grass species diversity. Community Type II is absent from the project area. Community Type I, comprised of overstory more than 15 feet tall, is present in small quantities.

Table 10. Riparian habitat types by structure.

Community Type	Description	Reach 1
I	Overstory more than 15 feet tall; Intermediate class is 2-25 feet tall;	5%
II	Overstory more than 15 feet tall; no intermediate class 2-15 feet tall	0%
III	No overstory >15 feet; native intermediate class 2-15 feet tall	50%
IV	Native grasses/wetland species; no overstory or intermediate class	35%
V	No overstory >15 feet; mixed exotic/native or impaired native intermediate class 2-feet tall	2%
VI	Mixed exotic/native or impaired native grasses/wetland species; no overstory or intermediate class	8%

Native species represent the riparian zones throughout the project area. Toe, bank, and overbank zones are dominated by a mixture of native herbaceous wetland and grass species that provide a functional and appropriate riparian plant community. Woody species, such as willows, are starting to establish in these zones on Mr. Benoit's property where grazing has been discontinued in recent years.

Tall trees provide overstory within a riparian corridor. However, large tree species are uncommon anywhere along the Little Colorado River in the Round Valley area. The reason for this is not known. Within the project area, there is one protected spot where a large Siberian elm and other deciduous trees are growing. Bird activity is high and scat from many animals has been observed. This area was not be disturbed during restoration activities.

A combination of management changes along with active revegetation were used to enhance the existing healthy riparian plant community. The goal was to create a complex mosaic of native woody and herbaceous plants and to increase the willow population in the project area, especially along meander banks. The final riparian mosaic should still allow carefully managed uses of the riparian corridor for recreation and livestock.

AQUATIC HABITAT

Aquatic habitat was generally poor throughout this section of the Little Colorado River. The lack of overhead vegetation, absence of cover in water, and the shallow uniformity of runs throughout the Round Valley result in inadequate aquatic habitat for many fish. Sedimentation caused by eroding banks embedded many of the gravels, degrading spawning and juvenile fish habitat. Macro-invertebrates have also been affected by sedimentation and lack of aquatic habitat structure. Lack of cover, both overhead and in-stream, increases water temperature during the summer months, rendering the existing habitat undesirable.

In the project reach, pools are located at meander bends. The deepest pool is located upstream of Bank D and at base flow is approximately three feet deep. The runs leading to riffle sections are typically wide and shallow with virtually no cover available for fish. As discussed in the channel profile section, most pools are relatively shallow and do not provide much habitat for fish.

The woody community that provides intermediate structure was almost completely missing in Reach 1 and much of Reach 3. The lack of intermediate structure in these reaches decreased the quality of habitat and caused greater bank instability.

SPECIAL STATUS SPECIES

The Arizona Game and Fish Department, On-Line Environmental Review Tool and the Fish and Wildlife Service's Web site were used to obtain a list of Endangered Species Act (ESA) special status species that may occur in Apache County, Arizona. The list identified four threatened or endangered species that may occur in the project area (Table 11). There were several species identified as "Species of Concern" under the ESA that are also known to occur in Apache County.

Table 11.List of special status species evaluated

Common Name	***Scientific Name***	**Status [1]**
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	E
Apache Trout	*Oncorhynchus apache*	T
Little Colorado Spinedace	*Lepidomede vittata*	T
Chiricauhua Leopard Frog	*Rana chiricahuensis*	T

[1]Status Definitions
T = Federal Threatened E = Federal Endangered

Of the four species listed, only the Little Colorado Spinedace was known to occur in the project area. The design was altered to accommodate US Fish and Wildlife concerns regarding this species.

CRITICAL HABITAT IN ACTIVITY AREA

The project area *is not in designated* critical habitat for any of the species considered. Critical habitat has been designated for the federally listed Little Colorado River spinedace in the Little Colorado River and Nutrioso Creek, but *does not include* the section within the project area.

PART II: DESIGN

Based on the assessment, it was determined that the dimension, pattern, and profile of the river in the project area was relatively intact, supporting a well-developed and functional channel, floodplain, and terrace features. However, bank instability was extreme and widespread and appeared to contribute substantial amounts of fine sediments to the stream channel (Figure 11). Streambank erosion was generally located along the outside of meander bends. There were over 1,155 feet of eroding banks within the project, 70 percent of all meander banks. Extensive stabilization of these stream banks was recommended to meet project objectives.

Figure 11 . Eroding vertical banks were common throughout project.

BANK STABILIZATION PLAN

The series of practices described in this section were applied throughout the project and served dual purposes. The first is to provide long-term stabilization for stream banks; the other function is to develop and enhance riparian habitats. All bioengineering plantings utilized native species harvested locally. See Table 16 and Figure 3 for a list and location of treated banks.

Bank re-sloping

A significant element in project enhancement was the stabilization of eroding streambanks. If banks are too steep (< 1:1) vegetation simply struggles to become established and erosion persists. Bank sections were reshaped to a 3:1 slope to provide a stable surface for streamside vegetation. This slope angle, when combined with herbaceous or woody native vegetation, has been identified at stable bank sites in this region. Banks were re-sloped using a track excavator. Excavated materials were carefully pulled up the bank and away from the stream. This material was smoothed on higher terraces away from the channel. These banks were then treated with the structural or bioengineering practice described below to provide further stabilization. All disturbed areas were reseeded and protected with erosion control fabric.

Toe Rock

This structural bank stabilization practice consists of graded angular rock placed along the base of an eroding stream bank and is designed to protect the vulnerable bank toe. Rock was graded from a minimum diameter of 3 inches to a maximum of 12 inches. Minimum thickness of toe rock is

18 inches placed on a maximum slope of 1.5:1. Rock extends upward only to the elevation of the floodplain to minimize the structural component and encourage revegetation. Bioengineering practices were integrated with this toe protection.

Base Rock with Vegetated Geogrid

This structure uses a combination of toe rock and strong, durable fabric to stabilize a severely eroding bank. The toe rock is placed in a trench at the bottom of the channel and stops at the low water line. The Turf Re-enforced Mat (TRM) fabric is laid over the toe rock, fill added and the fabric wrapped over the fill. Above bankfull elevation, the remaining bank is sloped.

Water Gap/Cattle Crossing

Water gaps, which were also cattle crossings if pasture needed to be accessed on the opposite side of the river, are placed in riffle sections of the river and banks sloped if needed. Geotextile fabric is laid and ends are folded into the soil. Gravel is laid on top of the fabric to reduce the amount of fine sediment that may enter the stream because of livestock use.

Brush Revetment

This practice consists of a series of evergreen or other brushy trees placed tied end to end and placed along the toe of the stream bank. The trees are secured to T-posts or bank anchors. The revetment provides temporary structural protection to the bank as vegetation becomes established. Over time, fine sediments accumulate, partially burying the degrading material. An added benefit is the aquatic habitat structure the mass of tree limbs provide. Once bank vegetation is established, T-posts or other anchors are removed.

Coir Log

Coir logs are long rolls of coconut fiber tightly woven together and installed at the toe of the bank to provide temporary structural protection. The logs are secured in place with rope and long stakes driven into the toe. After sediment builds up, often the logs become vegetated and biodegrade.

Pole Cluster Plantings

This practice consists of planting a group of 3-4 bare pole willows or other woody species in stream banks. The poles are inserted in holes in the moist bank. Holes were drilled utilizing an auger mounted on a mini-excavator. The willows were native species and harvested locally.

Vertical bundles

This practice consists of the planting of a series of willow bundles vertically along the stream bank. The bundles have their bases in the permanent water table and extend up the bank. The stems are buried and sprout all along their length providing willow roots well above the groundwater table.

Wetland Plugs

Wetland plugs consisting of native sedges and rushes were harvested from nearby and planted into the installed coir log and TRM mat, as well as other appropriate toe zones in the project area. Wetland plugs were harvested from on site sources. Four plugs per foot were planted in the coir log installed in the project area. Other plugs were planted randomly in the appropriate planting zone.

Container Shrubs/Trees

Shrubs and trees were purchased in containers and have established roots. These plant species generally do not establish from wood cuttings or grow best with established root balls. The addition of container shrubs and trees aids habitat greatly by increasing species diversity, plant community structure and composition, and forage available for wildlife.

Post Plantings

This practice involves planting larger limbs (4 to 6 inches diameter) of cottonwood species in clusters of three in appropriate overbank areas. Cottonwood posts were placed in holes excavated to groundwater elevation and backfilled with amended soil to increase drainage and encourage root growth.

Erosion cloth over reseeding

All disturbed areas are reseeded using native grass and riparian seed. Seed is dispersed evenly by hand. To reduce surface erosion, maximize water retention, and reduce the amount of seed lost to wind and animals, erosion fabric or other jute netting is installed and secured in place with wooden stakes. Metal staples are added in between stakes for extra protection against strong winds.

ADDITIONAL ENHANCEMENT TASKS NOT IMPLEMENTED

Several other enhancement practices were initially recommended in the Design Plan, but were not implemented during this project. The first was Aquatic Habitat Structures. These were structures intended to provide cover habitat for the native fish populations. These structures would have included boulder clusters and bank overhang structures. These structures were eliminated from the design after review from the US Fish and Wildlife Service. As a condition of the 404 permit, these structures could not be included since they could provide habitat for non-native fish that prey on the native Little Colorado River Spinedace, which occupy the project site.

The second practice eliminated from the design was the formation of an off channel ephemeral wetland adjacent to Bank E2. This wetland would have been formed in an abandoned ox bow channel forming a connecting channel from the river to the wetland. The wetland would have been submerged during high water flows, but would drain as the river returned to base flows. The bed of the wetland would have been excavated to just above the rivers' low water stage so emergent plants would be closer to the groundwater table. Due to water rights concerns, this practice was eliminated from the design.

RIPARIAN VEGETATION PLAN

The primary objectives of this project are to increase the natural stability of the stream channel and to enhance the native riparian vegetation within the project site along the Little Colorado River. The native community consists of a well-established herbaceous mat along banks and across floodplains. Terraces contain hardy wetland species and a variety of warm and cool season grasses. An intermediate tier of coyote and strapleaf willow cover the floodplains and low terraces. Rose and other native shrubs are intermixed. Mature tree species including Siberian elm, box-elder, and buckthorn are present as individuals and comprise the overstory.

The herbaceous community is well established throughout the project site; however the woody species and willow community were limited in several areas. Floodplain areas were considered healthy and stable throughout the site (Figure 12). In general, the most unstable part of the stream was the outside of the meanders. Native wetland/grass communities are considered the most important vegetation component for these commonly flooded areas. No changes to the herbaceous floodplain vegetation were necessary.

Figure 12. Herbaceous wetland plant and willow plant communities on floodplain

Where soil moisture is sufficient, supple woody willows colonize low and high terrace areas adjacent to the stream channel .These willow communities help to stabilize banks and provide more complex riparian habitats. After the comparison between the existing and reference reach conditions, creating a mosaic of native woody and herbaceous plant communities that would increase habitat and support hydrologic and morphologic processes became the focus for the revegetation design. In addition, after an assessment of the soil types and average rainfall for the project area, it was concluded that it would be unnecessary to include plans for supplemental water or irrigation systems. In an effort to create more diversity, a variety of riparian shrubs were added to the upper banks to increase plant structure and diversity. Additional plantings of willows were needed to meet the project goal of creating a mosaic of native woody and herbaceous plant communities to increase habitat and support hydrologic and morphologic processes.

Re-vegetation efforts focused on the establishment of vegetation at eroding banks after the banks were resloped (Figure 13). Also targeted for re-vegetation were areas without sufficient woody species for habitat and restoration of areas disturbed by machinery during construction. The re-vegetation design included installing plantings along the toe of the active channel, on the floodplain, and on the terrace zones. These zones are primarily differentiated by distance from perennial flow, and as a result, soil moisture conditions. The active channel and floodplain zones represent moist soil conditions and support riparian wetland communities such as sedge/rush species. Most bioengineering practices take place within these zones. The terrace zone generally has lower soil moisture and supports grass and woody species.

Figure 13. Raw banks after re-sloping

Primary project practices include bioengineering and revegetation using the dominant species from each vegetative community. All planting mimicked existing vegetation distributions. For example, willows and other woody species were planted along the floodplain to a depth of groundwater. In most cases we consider that to be the elevation of minimum stream base flows. Woody species were planted in trenches dug to ground water level or in holes drilled by an auger.

SOURCES AND TYPES OF PLANT MATERIALS

Herbaceous emergent species

Herbaceous emergent species were harvested on site in plugs and added to the toe zone of the bank in the soil or in holes created in the coir log. The plugs contained *Carex spp*. and *Juncus spp.*, as well as other moisture tolerant species dormant in the soil seed bank of the plug.

Grass species

Floodplain and terrace areas were seeded with a mixture of grass and forb native seeds. The area covered with grass seed was approximately 2.0 acres with a seeding rate of 19.2 lbs per acre. The area where forb seed was applied is 0.35 acre @ ~18.8 lbs per acre. The species planted are listed in Table 14. All herbaceous plantings and seed used were native species, purchased from Granite Seed, Lehi, UT.

Woody species

All woody plant materials consisted of native species and were harvested from local sources. Harvesting took place during the dormant season to reduce stress to the plant. During the collection of bare poles, a maximum of one third of any single plant was harvested. Poles had a minimum diameter of 0.5-inches. After cutting, the poles were bundled and submerged in water for 3 to 7 days prior to planting to maximize water retention. Plant materials were never allowed to dry out during harvesting, transportation, or storage. No plants were propagated for this project.

Willow and cottonwood planting included the following species:

- Coyote willow (*Salix exigua*) used for pole planting along the floodplain elevation. While this willow is present on the site it is near the upper limits of its range and does not grow robustly.
- Strapleaf willow (*Salix ligulifolia*) is occasionally found at the site and was planted along upper banks and terrace areas intermixed with the coyote willow.
- Narrowleaf cottonwood (*Populus angustifolia*) was planted on the terrace along the channel.

Table 12. Grass and forb species planted

Species	Scientific Name	% of Mix	lb PLS/ac for Pure Stand*	lb PLS/ac for Desired Comp	lb PLS for 5.5 acres
Western Wheatgrass	(*Pascopyrum smithii*)	28%	18	5.04	27.72
Bottlebrush Squirreltail	(*Elymus elymoides*)	22%	12	2.64	14.52
Blue Grama	(*Boutelua gracilis*)	12.5%	3	0.38	2.06
Sideoats Grama	(*Bouteloua curtipendula*)	10%	15	1.50	8.25
Little Bluestem	(*Schizachyrium scoparium*)	10%	9	0.90	4.95
Sand Dropseed	(*Sporobolus cryptandrus*)	5%	0.5	0.03	0.14
Upright Prairie Coneflower	*(Ratibida columnifera)*	4.5%	2	0.09	0.50
Common Sunflower	*(Helianthus annuus)*	4%	20	0.80	4.40
Globemallow	*(Sphaeralcea sp.)*	1%	6	0.06	0.33
Aspen Daisy	*(Erigeron speciosus)*	1%	2	0.02	0.11
Rocky Mountain penstemon	*(Penstemon strictus)*	1.0%	6	0.06	0.33
Plains Aster	*(Aster bigelovii)*	1%	2	0.02	0.11
TOTAL		100.00%		11.5	63.4
				lb PLS/ac	lb PLS

* Planting to be done by hand broadcasting, values have been increase by a factor of 2.

Container woody species

Selected native species were purchased from a local supplier in Flagstaff, AZ and brought to the site for planting. Table 13 lists the species that were planted at the project site.

Container plants were installed by digging a hole as deep as the root ball and twice the root ball width. The plants were staked for support against the windy conditions in Springerville. After planting, mulch was applied around the base of the plant.

HERBIVORY

Herbivory by elk, beaver, and domestic livestock can impact revegetation efforts. These threats were addressed in the following manner:

Livestock: The riparian area on Mr. Burk's property was fenced to exclude all domestic livestock for a minimum period of 5 years. Fences that crossed the stream channel were designed to swing upward during high flow events. Fencing was monitored regularly by the livestock manager. There was no livestock on Mr. Benoit's property.

Beaver: Beaver are common in the Little Colorado River near the project site. However, previous experience in the LCR Demonstration Project in Springerville suggests that beaver herbivory will not negatively impact willow plantings as browsing results in multiple branching. Bush willow and tree plantings may be impacted. Beaver activity was monitored during the subsequent growing season. Should beaver activity appear to permanently threaten the success of the revegetation effort, vegetation will be protected with wire.

Table 13. Containerized plantings

TYPE	Scientific Name	Common Name	Number
Tree			
	(Populus angustifolia)	Cottonwood	12 plantings
	(Salix matsudana)	Navajo or Globe Willow	3 ea
	(Acer negundo)	Box Elder	5
	(Acer glabrum)	Rocky Mountain Maple	1
	(Alnus tenuifolia)	Thinleaf Alder	7
	(Betula occidentalis)	Water Birch	7
	(Juglans major)	Arizona Walnut	2
Shrub			
	(Cornus sericea)	Redosier Dogwood	10
	(Robinia neomexicana)	New Mexican Locust	10
	(Sambucus melanocarpa)	Blackbead Elder	8
	(Symphoricarpos oreophilus)	Mountain snowberry	4
	(Amelanchier utahensis)	Utah Serviceberry	6
	(Prunus virginiana vars. demissa & melanocarpa)	Common Chokecherry	6
	(Shepherdia rotundifolia)	Roundleaf Buffaloberry	8
	(Rhus trilobata)	Sumac	10
	(Lonicera arizonica)	Arizona Honeysuckle	4
	(Rhamnus californica)	Coffee Berry	4

NOXIOUS WEED REMOVAL

At the project site, no extensive invasion of any species of noxious weeds has been apparent. There are a couple of Siberian elm and Russian olive trees which provide valuable canopy and high structure and were not removed. There are non-native thistles present in very small quantity and crews hand-pulled them when present.

Enhancement Tasks by Bank

Complete record drawings and specifications for the project are located on construction sheets attached to this report (Appendix B).

Streambank stabilization using a variety of bioengineering and structural practices was the primary enhancement activity in this reach. The eroding banks were extensive (43% of all banks). Bank treatments include structural toe rock where necessary combined with revegetation using native plant species to provide long-term stability to streambanks and improve riparian habitats (Table 14). A total of 1,275 feet of river bank at 11 locations was treated. The project area was fenced and livestock excluded for a period of 5 years on Mr. Burk's property. Livestock was excluded indefinitely on Mr. Benoit's property.

Table 14. Treatments prescribed at each bank within the project area. Bank 13 is Nutrioso Creek.

Bank No.	STATION	Prescription
A	STA 2+40 to 3+00 (left)	Slope bank, coir log with wetland plugs, seed & fabric
B1	STA 3+80 to 5+40 (right)	Slope bank from toe, vertical bundles, willow clusters, seed& fabric
B2	STA 5+40 to 6+15 (right)	Slope from water level, toe rock, willow trench, seed & fabric
B3	STA 6+15 to STA 9+40 (right)	Slope bank from toe, vertical bundles, willow clusters, seed & fabric
C1	STA 8+25 to STA 9+40 (right)	Slope bank from toe, vertical bundles, willow clusters, seed & fabric
All	STA 11+00 to 12+00	Boulder clusters (REMOVED FROM PROJECT)
D	STA 12+45 to 13+30 (left)	Slope upstream bank from toe, vertical bundles, willow clusters, seed & fabric
E1	STA 14+50 to 15+55 (right)	Re-align channel, toe rock trench, matrix fabric with wetland plugs, willow cluster trenches, seed & fabric,
E2	STA 15+55 to 17+00 (right)	Slope bank from toe, vertical bundles, willow clusters, seed & fabric
E2	STA 50+00 to 51+50 (right)	Excavate backwater, contour, willow clusters, seed & fabric (REMOVED FROM 08 CONSTRUCTION)
F	STA 17+50 to 18+80 (left)	Willow clusters, seed
G	STA 20+75 to 21+15 (right)	Slope from water level, coir log with wetland plugs, brush revetment, VB's and clusters, seed & fabric
Nutrioso	STA 0+00 to 1+50 (left/right)	Willow clusters, seed

PART III: CONSTRUCTION & IMPLEMENTATION 2008 - 2012

INITIAL CONSTRUCTION EFFORT

The initial construction effort took place during the week of October 29 – November 5, 2008. Three Natural Channel Design personnel and an eleven-person American Conservation Experience (ACE) crew worked directly on the project. Two Arizona Game and Fish personnel with three laborers collected willows and junipers for the project. Equipment utilized during this initial phase of construction included an ATV with trailer, large flatbed trailer, one large excavator and one mini-excavator with stinger attachment, large back-hoe and a 10-wheeled dump truck.

The following list summarizes the work accomplished during the first phase of construction:

Willow Clusters Planted	567 Clusters (avg. 1700 willow stems)
Erosion Fabric (Double net straw/coconut)	7 ft x 827 ft (12 rolls)
Erosion Fabric (Single net straw)	7 ft x 1,105 ft (16 rolls)
Turf Reinforcement Mat (TRM) Installed	6.5 ft x 115 ft (2 rolls)
Non-Woven Geotextile	15 ft x 85 ft
Re-sloped banks	980 linear ft
Cottonwood Post Plantings	12 plantings (2-3 cottonwoods, 1-3 willows/planting)
12 inch coir logs installed	80 linear ft
Brush Revetments Installed	50 linear ft.
Toe Rock installed	85 ft (70 CY rock)
Base Rock installed	115 ft (60 CY rock)
Potted Trees/shrubs	95 planted

CATTLE CROSSING

Above Bank A in the Burk property, a ramp 20 feet long by 15 feet wide on either side of the river was prepared by excavating and sloping the banks. Geotextile fabric was then placed with the lower end buried in a trench at the river's edge and all sides staked. The fabric was then covered with medium-sized gravel and small cobbles to a minimum of 6-inches deep (Figure 14).

Figure 14. Cattle crossing installation

Banks A through G were all re-sloped to a 3H:1V slope to eliminate the vertical cutbank that was initially located there. The sloped banks were then planted with willow clusters, seeded and covered with erosion control fabric (Figure 15 and Figure 16).

Figure 15. Example of vertical banks located throughout the project area.

Figure 16 Example of completed bank treatment

In addition to the sloping and planting of the banks, Banks B and E received additional stabilization practices. Bank B was a tall bank with a tighter radius of curvature. In an effort to stabilize this bank, toe rock was added to help harden the bank and prevent future erosion (Figure 17).

Figure 17. Bank B pre and post construction

Bank E was in a similar condition to Bank B. At this location however, a less intensive rock application called base rock, was applied. Rock was only placed up to the low water elevation. The upper bank was covered with turf reinforcement mat. This application protected the toe of the bank while allowing vegetation to take hold lower down to the water. This application was more aesthetically pleasing than a rock lined bank (Figure 18).

Figure 18. Time series of Bank E

Planting of the willow clusters along the banks was accomplished with a mini-excavator mounted auger. Clusters of three bare willow pole stems were then installed into each hole. The holes were then watered and backfilled (Figure 19 and 20).

Figure 19. Installing willow clusters

Figure 20. Planted willow clusters on Bank B3.

COTTONWOOD POST PLANTINGS

Twelve cottonwood post plantings were installed throughout the project area in 2008. Cottonwoods were wild harvested from AZGF property near Becker Lake. Each planting location received three cottonwood posts and between 1-3 willows, depending on the size of the willow planting. Holes were excavated on the terrace for the plantings and were typically six to eight feet deep in order to reach the water table. None of these plantings were successful though, with only the willow stems remaining after the first season.

BRUSH REVETMENTS

Fifty feet of brush revetments were installed along Bank G during this initial construction effort. Junipers were harvested from AZGF property and installed from downstream to upstream at each prescribed location. As each upstream tree was placed on top of each downstream tree they were anchored to the toe of the bank with a T-post. The brush revetments were installed to protect the newly disturbed toe of treated banks (Figure 21).

Figure 21. Bank G with brush revetment.

COIR LOGS

Similarly, eighty feet of coir logs was installed at Banks A and G to protect the toe of the bank and help prevent soil erosion. Coir logs were placed at the toe of the bank down to the gravel of the riverbed. The upstream end of each coir log was embedded into the bank so that the log would not be compromised by water flowing behind it. Each log was tied and staked on both sides every five feet (Figure 22).

Figure 22. Installing coir logs.

POTTED TREES/SHRUBS

A total of 95 potted trees and shrubs were planted on the Burk and Benoit properties. They consisted of a variety of species as shown in Table 13. The large and medium sized plants received a protective wire fence around the planting to protect them from browsing animals (deer and beavers). The protective wire fence will not hinder the growth of the plantings and will eventually be removed when the trees and shrubs have become established (Figure 23).

Figure 23. Containerized Plantings

2010 Construction and Re-vegetation

Construction and re-vegetation activities took place during the week of October 25 – 27, 2010. The work crew consisted of four Natural Channel Design personnel. Equipment utilized during this phase of construction included one mini-excavator with bucket and auger attachment. Work consisted of repairing minor erosion that occurred during the spring and summer of 2010 that was identified during the Fall 2010 monitoring.

The following list summarizes the work accomplished during this phase of construction:

Willow Clusters Planted	120 Clusters (360 willow stems)
Erosion Fabric (Double net straw/coconut)	7 ft x 130 ft
Erosion Fabric (Single net straw)	7 ft x 150 ft
Jute Netting	9 ft x 40 ft
Re-sloped banks	190 linear ft
12 inch coir logs installed	190 linear ft
Native Seed on disturbed areas	11 lbs.

Practices Implemented in 2010

Monsoon storms of the previous summer resulted in flows which caused minor erosion at the project site. Banks B1, B3, D and G had sections that were resloped to eliminate eroded areas. These banks then received willow plantings, were re-seeded and covered with erosion control fabric. Twelve-inch coir logs were installed along the toe of these banks as well. Grass species included in the seed mix is shown in Table 15.

Table 15. 2010 Seed Mix

Common Name	Species	Seeding Rate lb/ac PLS	Seed Mix Applied (1 acre) lb PLS
Blue Grama	*Bouteloua gracillis*	1.3	1.3
Sideoats Grama	*Bouteloua curtipendula*	2.3	2.3
Alkali Sacatoon	*Sporobolus airoides*	1.0	1.0
Bottlebrush Squirreltail	*Elymus elymoides*	3.8	3.8
Sand Dropseed	*Sporobolus cryptandrus*	0.9	0.9
Little Bluestem	*Schizachyrim scoparium*	1.7	1.7
		11.0 lb/ac	11 lbs

Bank D in particular required additional bank and channel work. At this location, the channel has a split flow caused by a small vegetated bar in the center of the channel (Figure 24). The channel on the left side of the bar was deepened to allow flow around this bar and reduce the back-eddy during high flows. The left bank was resloped and covered with a jute netting (Figure 25). This bank has now become vegetated with willows, sedges and grass and is stable (Figure 26).

Figure 24. Split flow at Bank D

Erosion in 2010 was occurring along the left bank where the flow is split by the mid-channel bar

Figure 25. Bank D Construction 2010.

Figure 26. Bank D in October 2012.

2012 RE-VEGETATION

The grant was extended for an additional year to allow for an additional monitoring period following a final seeding of several banks that were lacking adequate grass coverage. Revegetation crews included a Natural Channel Design supervisor along with an eight-person American Conservation Experience crew. Crews worked from August 7th through 9th, 2012.

Activities undertaken during this effort included mulching with 180 cubic feet of composted mulch; seeding with native grass seed mix as shown in Table 15, saltbush seed and native rose seed; and placement of 1,800 square feet of single net erosion control fabric. In addition, there were 41 plantings of coyote willow bundles (3 willow stems tied into a bundle) along the treated banks and 20 container grown trees were planted on the Benoit portion of the project area.

Areas targeted for this final seeding effort included banks that had sparse grasses growing on the upper portions of the banks. This included Banks B1, B2, B3, C1, E and G (Figure 27).

Figure 27. Example of seeding and fabric on upper portion of Bank C

Composted mulch was spread over and mixed into the top 3 inches of soil along all banks seeded. It is anticipated that this addition will improve moisture retention and help loosen the soil enough for the grasses to become established. Existing grasses were avoided during the mulching process (Figure 28) and areas with extensive grasses were spot treated.

A shrub component to the seed mix was added during this effort. These species included four wing saltbush and native rose. Both species occur within the project area and this seeding will help to establish these plants on banks where other vegetation is having difficulties growing due to soil conditions.

Figure 28. Compost spread over bare areas on Bank E1.

CONTAINERIZED PLANTINGS

Containerized tree plantings provided by the landowner were installed along the overbank zone adjacent to the Little Colorado River channel on the Benoit property of the Project Area. Exact placement was indicated by the landowner. Approximate two foot diameter holes were hand dug approximately 1.5 feet deep. Mulch was added to amend the back filled soil. Twenty trees were planted during this effort. The tree species were a mix of native cottonwood, aspen, box elder and Arizona black walnut. These trees are supplementing the original tree plantings that occurred in 2008.

ARCHAEOLOGICAL EXCLUSION AREA AT BANK B

During the permitting process, an archaeological survey was conducted at the project site. A small scattering of historical and pre-historical artifacts was located on the Burk property near Bank B1 (Figure 3). This forty foot section of bank was avoided during construction. During the first season after construction, a beaver dam was built at this site. The resulting high water and overtopping of the dam has caused continual erosion at this bank. In December of 2011, a forty foot brush revetment was installed along the toe of this bank downstream from the dam (Figure 29). In addition, twenty one coyote willow poles were planted along the toe. The intention of the revetment was to help stabilize the toe of the bank, preventing a lateral migration of the channel.

To date, the revetment has accomplished the intended goal. Though the upper bank continues to slough off, the toe has stabilized and is becoming vegetated. The beaver dam will continue to divert flows towards this bank during high water events. But with a stable, vegetated toe, the extent of disturbance will be lessened.

Figure 29. Installing brush revetment along Bank B1, 2011

Figure 30. Brush revetment and beaver dam at Bank B1, 2012

PART IV: MONITORING

Monitoring of the project began in the fall of 2007 prior to initial construction. Monitoring continued on an annual basis, ending with the final monitoring in October 2012. Monitoring components were designed to assess project objectives and included: 1) stream channel monitoring; 2) photo point monitoring; and 3) bioengineering monitoring. All components were monitored annually in the fall after monsoon activity had diminished.

Stream channel monitoring included annual surveys of three permanent cross-sections located throughout the project area (Figure 3). This survey is used to detect changes in channel dimensions over time that could indicate channel stability problems. These cross-sections were resurveyed to evaluate changes in channel width and bed elevation. For all cross-sections, it was expected that: 1) channel width would not increase over time (lateral instability) and 2) that channel bed elevations would not excessively increase or decrease at cross-sections located in riffles (an indicator of vertical instability). A reduction in channel width would suggest increased lateral stability from improving riparian vegetation.

Riffle sections were chosen for these cross-sections because they represent the most stable, or least dynamic, areas of a river. They are appropriate areas to monitor for change resulting from stream modifications. Rivers are not static and some change is to be expected. Also, human error during data collection cannot be completely eliminated. For this project, it was determined that a positive percent change (channel widening) of greater than five percent for channel width would indicate unsatisfactory lateral stability. Changes in width of less than five percent should be visually evaluated, but may be attributed to field error, such as tape placement, how level the rod is, or difficulty locating the true edge of the channel because of thick vegetation. It was also determined that a positive or negative percent (aggradation/degradation) change greater than 25 percent for median depth values (bed elevation) would indicate unsatisfactory vertical instability. Changes in depth of less than 25 percent should be visually evaluated, but may simply be within the limits of natural variation.

The channel profiles measured during a monitoring period were overlaid with the previous year's profiles in order to determine any change to channel dimensions. As of 2012, all three cross-sections remain stable, with only minor changes in dimensions (Table 16). These changes are relatively small and are attributed to natural sediment movement over time. See Appendix A for the profile and photos of each cross section from 2007 to 2012.

Table 16. Stream cross-section bankfull width and depth values for 2007 through 2012.

XS #	YEAR	BANKFULL WIDTH (ft)	PERCENT CHANGE	MEDIAN DEPTH (ft)	PERCENT CHANGE
1	2007	44		1.2	
	2009	40	9.1% decrease	1.5	25% increase
	2010	39	2.5% decrease	1.4	6.7% decrease
	2011	40.5	3.8% increase	1.3	7.1% decrease
	2012	40.5	0%	1.0	Decrease caused by beaver dam
2	2007	33		1.6	
	2009	33	0.0%	1.8	12.5% increase
	2010	33	0.0%	1.9	5.6% increase
	2011	33	0.0%	1.9	0%
	2012	33	0.0%	1.8	5.6% increase
3	2007	40		1.2	
	2009	40	0.0%	1.3	8.3% increase
	2010	33	21% decrease	1.3	0.0%
	2011	33	0.0%	1.4	7.7% increase
	2012	33	0.0%	1.4	0.0%

*See the explanation below for unexpected values under stream channel stability.

The larger change in width measured at cross-section 3 was due to sediment deposition after a large flow event and increasing vegetation on the flood plain at this location. This cross section remains unchanged since that event.

BANK STABILITY (BEP)

In addition to the channel cross-section monitoring, six of the banks that received enhancement activities and one bank that was not treated were evaluated for bank stability utilizing the Bank Erodibility Potential (BEP) portion of the Bank Erodibility Hazard Index (BEHI) developed by Dave Rosgen (Rosgen, 1996).

The BEP consists of a set of physical characteristics of the stream bank that indicate erodibility, including bank height, bank slope, root depth, root density, cover, bank material, and stratification. BEP scores relate to an erodibility value between Extreme and Low. It is expected that individual BEP scores will decrease over time as banks heal and stabilize toward an optimum value.

After the first year after construction, BEP scores did not change significantly. The high pre-treatment scores were a result of vertical cutbanks and lack of vegetation. After treatment, the bank scores lowered significantly. The rest of the score changes over time are a result of increasing vegetation, root mass and bank surface protection. The BEP scores for the monitoring period are shown in Table 17.

Table 17. BEP Scores at BEHI Survey Sites.

BEHI	Pre-treatment		2009		2010		2011		2012	
Bank	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index
A	32.1	high	9.6	low	9.6	low	9.6	low	8.5	v. low
B	42	very high	25.9	moderate	24	low	24	low	21	low
C	28.6	moderate	28.1	moderate	27.1	moderate	27.1	moderate	25.1	moderate
C2	17.7	low	17.5	low	17.5	low	16	low	14.5	low
D	29.9	high	27.8	moderate	25.8	moderate	24.9	mod	23.9	mod
E	38.8	high	22.5	low	20.3	low	19.9	low	19	low
F	24.5	moderate	23.7	moderate	22.3	moderate	19.8	low	18.3	low

Bank C2 is the control bank that did not receive any enhancement activities.

Stability of Structural Components

The structures installed in the project site include toe rock along bank B2 and the base rock and TRM fabric at Bank E1. Both of these structures are functioning as designed with no erosion taking place. Vegetation is continuing to fill in between the rock installed at B2 (Figure 31). See Figures 17 and 18 for additional photos of these two banks.

Figure 31. Bank B2 toe rock in 2012.

BIOENGINEERING PRACTICES

Any evaluation of change in condition in a riparian area is dependent on the climatic conditions since the last monitoring effort. Drought periods can reduce the growth and vigor of vegetation, while wet periods are a benefit. Morphologic changes must be balanced against the magnitude and duration of stream flows. For each monitoring effort, annual stream flow and precipitation data was gathered and analyzed to determine the duration and force of water that the banks would have experienced that year. This information can be found in the Annual Monitoring Reports associated with Task 8 of this project.

All bioengineering treatments were evaluated to determine establishment success. Successful establishment was quantified by an estimate of planted stems that survived. As monitoring continued, the presence of actively growing willow stems was used to evaluate treatment success.

Five growing seasons have passed since initial construction activities in the fall of 2008. A deficiency in precipitation over the past years resulted in less vegetative cover on the resloped banks than was hoped for at this point in the recovery phase. Large patches along banks where grass and forb seed was planted on the banks during the initial construction activities either failed to germinate or dried out soon after it started growing. Though there are grasses growing and filling in, the majority of the banks are covered in annual forbs which provide little root mass to help bind the soil. In August of 2012, additional grass and shrub seed was distributed along banks and slopes where there was sparse or no growth.

Willow cluster plantings have fared better than the other plantings. Most of the willow clusters are growing vigorously, though many have been browsed by wildlife and beavers have continually cut the larger stems. Additional sprouts have been seen coming up around the original plantings.

Surviving rooted plants installed in 2008 have declined in number each year. Of the original 95 planted, 32 were alive during the 2010 monitoring period. In 2011, there were 27 plants surviving, and in 2012, thirty-three plants were located, though some of these were planted earlier in this season. The shortage of natural precipitation and lack of supplemental irrigation resulted in inadequate soil moisture for plants to develop vigorous root systems during the establishment period. Rick Benoit has indicated an interest in continuing to replant trees on his property.

A list of the surviving plants, their locations along with a map can be found in the final Annual Monitoring Report dated December 2012.

PHOTO MONITORING

A series of photo points were established prior to construction to capture changes over time in stream channel morphology and riparian conditions. Each photo point was marked with a rebar, yellow cap, and label. Photo points are spread throughout the reaches looking at a segment of river where treatments took place or directly associated with channel monitoring sites. Each of the different types of photo documentation was taken annually during the monitoring. A summary of the all photos taken are displayed in the final Annual Monitoring Report dated December 2012. The various types of photo documentation that were conducted are described below

Cross-Section Photos

At the cross-section survey sites, photos were taken from slightly upstream of the cross-section location viewing downstream through the middle of the cross-section or from one side of the bank. Cross-section survey photos were taken during each monitoring period.

Bank Stability Photos

At the BEHI survey sites, photos were taken from the point bar opposite the bank to be treated, viewing the bank at a downstream 45-degree angle or directly across from the bank on the floodplain. BEHI survey photos were taken during annually since construction.

General Site Photos

Photos were taken of the project area to document general site characteristics. All photo points are marked with permanent pins with caps and their locations were recorded for future monitoring (Table 20). An example of the photo monitoring included in the Annual Monitoring Report is show in Figure 32.

Table 18. Photo point locations

PP#	Latitude	Longitude
1	N34 08.809	W109 17.684
2	N34 08.839	W109.17.600
3	N34 08.867	W109 17.653
4	N34 08.897	W109 17.634
5	N34 08.926	W109 17.603
6	N34 09.063	W109 17.545

(Datum:NAD83, State Plane AZ Central FIPS)

The general trend observed from comparing these photo points is that vegetation along the stream corridor is maturing and becoming denser. No change in the stream channel location or stability has been observed.

Photo Point 5

January 2008

October 2009

September 2010

October 2011

October 2012

Figure 32. Example of General Site Photo time progression

PART V: PUBLIC OUTREACH

The first public outreach for the project occurred in the Spring of 2007 in conjunction with a workshop hosted by Natural Channel Design, Inc. At that time, the project was in the design phase and the participants conducted an assessment of the current conditions at the project site. The role of the Water Protection Fund was explained and then the participants were taken on a tour of the past Water Protection Fund funded projects that had occurred or that were still in progress in the Springerville area.

The next workshop occurred during the fall of 2008, just prior to the start of initial construction activities. Again, participants of the workshop were informed of the projects funding by the Water Protection Fund and had field tours of past WPF funded projects in the Springerville area. Surveys and assessments were made at the project site and the current conditions were recorded.

Additional workshops had been planned to occur at the project site to include monitoring and assessment of the implemented project, but were put on hold indefinitely due to the passing of Natural Channel Design's founder and workshop instructor.

Natural Channel Design, Inc. (NCD) and the grantee, Rick Benoit conducted a final public outreach workshop for this project on Saturday, November 26, 2011. The objective of the workshop was to provide outreach to Springerville/Eager citizens and local landowners with an interest in riparian areas and demonstrate techniques to protect, restore or enhance stream banks, aquatic habitats and riparian areas. Efforts to contact potential participants included a flyer invitation which was circulated around town, an announcement in the local paper and through personal contacts.

LESSONS LEARNED

In any project it is important to assess successes and shortcomings to help refine future projects. For this project, the following lessons learned are discussed below.

- During the final design, any time containerized plantings are recommended there needs to be careful analysis on the need for supplemental watering for the first two years after planting. Relying on natural precipitation to provide adequate soil moisture for containerized plantings on higher areas in the floodplain resulted in higher than anticipated mortality of plants.
- A design change (elimination of an ephemeral wetland due to lack of water rights) resulted in many of the recommended containerized plantings being installed higher in elevation and further away from the water table.
- If species of concern are located at a project site, earlier consultation with the U.S. Fish and Wildlife service on proposed project activities could help to eliminate or design features that are not compatible with such species, thereby reducing the need for re-design later in the permitting phase. Initial design features meant to enhance habitat for spinedace were eliminated at the request of USFWS reviewers because they could provide enhanced habitat for nonnative competitors (rainbow trout).
- The need for water rights approval should be sought earlier in the design phase as well. Even though the proposed off channel wetland feature was a naturally occurring feature along the Little Colorado River it was considered off channel storage of water and required a water right which could not be obtained in time for construction.
- An area of problematic soils was encountered that was not identified during the assessment. This limited area had high clay content with alkaline chemistry and the prescribed planting treatments did not have as much success. Future site assessments should attempt to identify microsites with difficult of differing conditions.

Alternative Practices

In the last several years, alternative methods to stabilizing banks have been investigated. One practice that could perform well at this site would be the installation of toe-wood with bankfull benches. This is a practice that is used along the outside banks along meanders in lieu of rock. This practice utilizes tree trunks and associated root balls placed along the toe of the bank as a scaffold to hold soil. A narrow bench is then constructed on top of the wood which allows flood waters to spread out of the channel and thereby reducing the stress against a bank. In addition, submerged aquatic habitat can be developed with this type of structure. This practice could replace the toe rock along the two banks, thereby eliminating the need for importing large rock into a system that does not have naturally occurring large rock.

Another practice that could help the aquatic habitat as well as reduce the stress against meander banks would be the development of the pools in the system. Naturally, pools occur in meanders and are formed and maintained by the stream. During analysis, measurements of the pools in the project area indicated that they were long and shallow. This is probably due to the sediment load in the system resulting in pools being filled. Without adequate pool depth, high water events can result in excessive shear stress against meander banks, resulting in erosion.

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APPENDIX A: CROSS-SECTION PROFILES AND PHOTOS

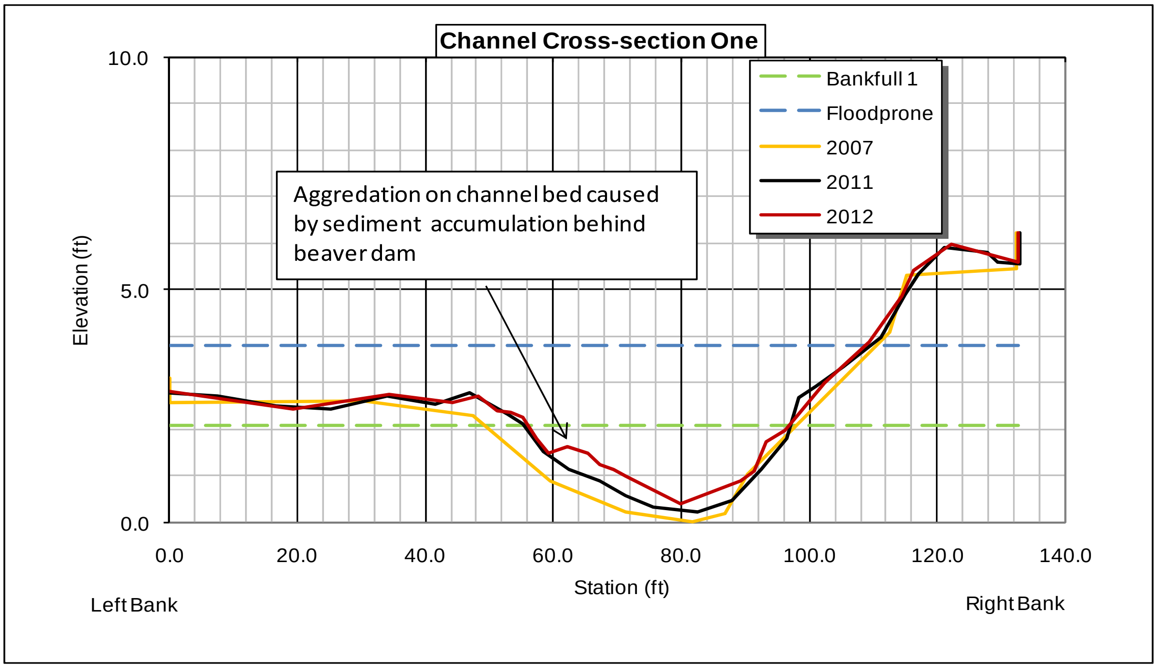

Figure 33. Channel Cross-section One Profile

There has been no change in channel geometry at this cross section other than the sediment accumulation behind the beaver dam. As shown on the graph, there was some buildup in 2011, and sediment continued to accumulate in 2012. This location has been affected by a beaver dam since initial construction (Figures 50 and 51). Even with the beaver dam, the cross-section is stable.

Figure 34. Cross section 1, June 2007

Pre-construction view is looking downstream from left bank.

September 2010-View is looking downstream from right bank.

October 2011-View of right bank from left bank.

November 2012-View is looking downstream from right bank.

Figure 35. Channel Cross-section One.

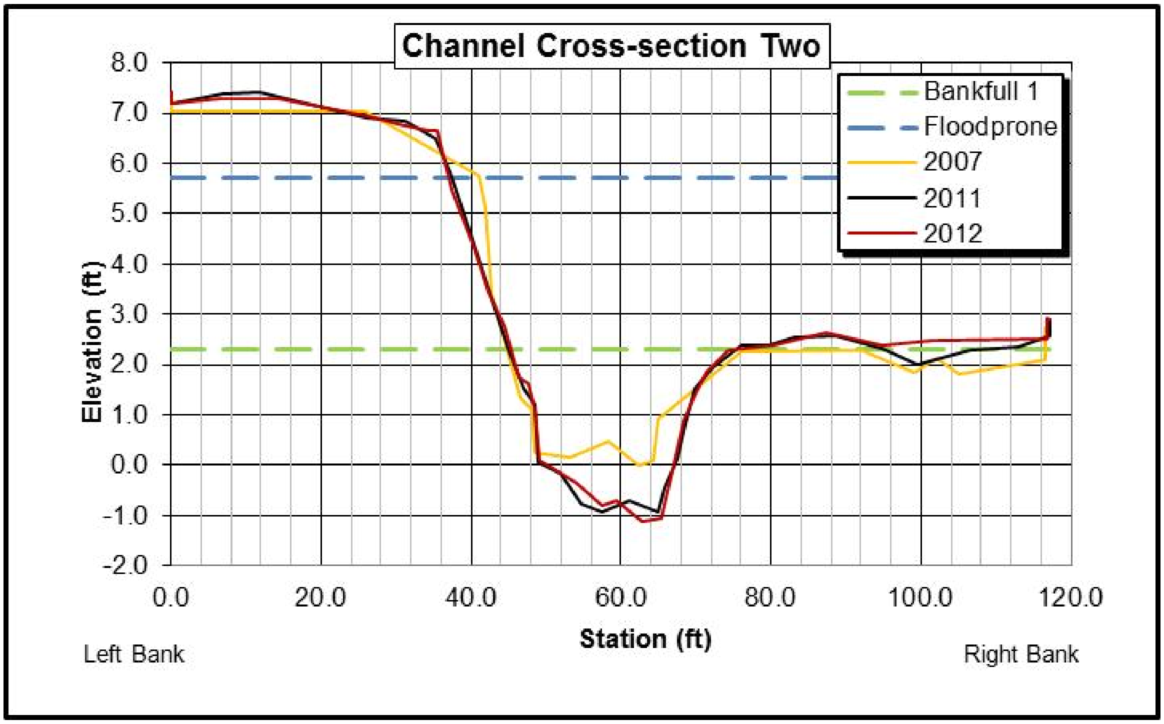

Figure 36. Channel Cross-section Two Profile

A large beaver dam was constructed approximately six feet upstream of this cross section soon after the initial survey. The change in bed elevations seen in the cross section graph was caused by water flowing around and over the dam (Figure 52). The dam washed out on 2010 and was not rebuilt. This channel has remained laterally stable throughout the past five years of monitoring. There was some scouring of the bottom of the bed as a result of the elimination of the dam, but the bed has remained stable since 2011(Figures 53 - 55).

June 2007-Pre-construction. View is downstream from left bank.

Figure 37. Pre-construction view of Cross-section two.

September 2010-View is downstream from mid channel. Note the beaver dam is nearly gone.

October 2011-View is downstream from right bank. Beaver dam is gone.

Figure 38. Cross-section two in 2010 and 2011.

November 2012- Beaver dam has not been reconstructed at this location.

Figure 39. Cross-section two in 2012.

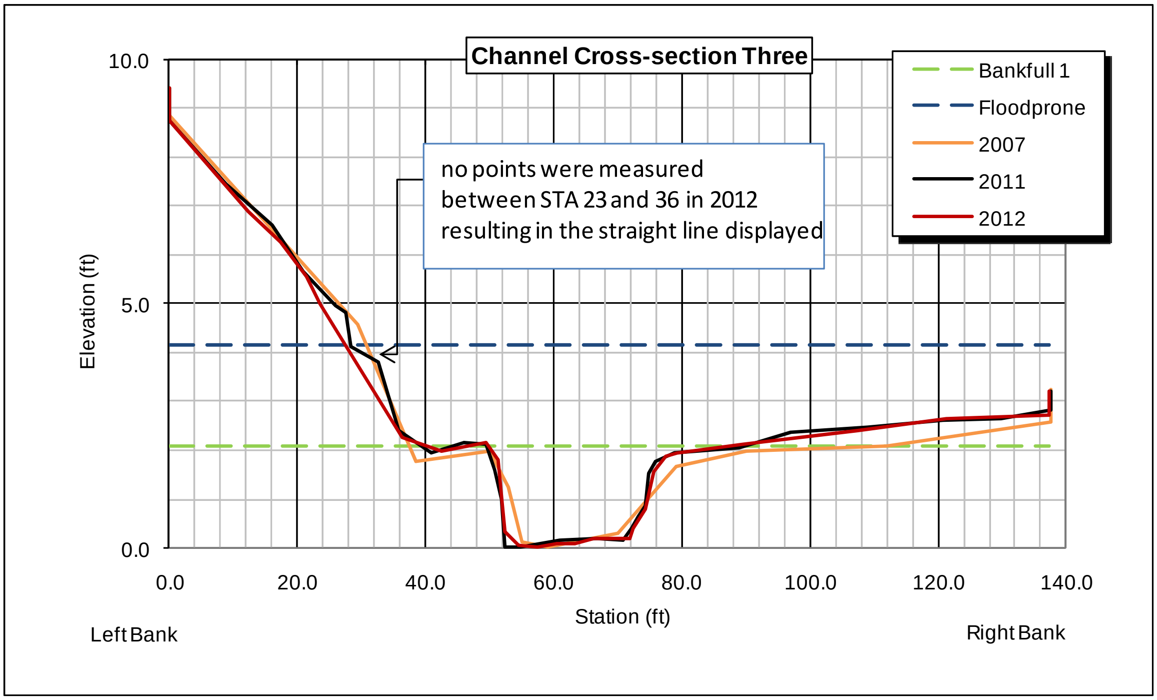

Figure 40. Channel Cross-section Three Profile

There have been no significant changes to this cross section over the past five years. High flows in early 2010 caused some sediment to be deposited on the point bar on the right, a normal occurrence for this type of channel. Vegetation along both banks remains robust and healthy (Figures 57-59).

Figure 41. Pre construction photo of cross section three.

June 2007-Pre-construction. View is downstream from left bank.

September 2010-View is from midstream looking downstream

October 2011-View is from midstream looking downstream

Figure 42. Cross section three in 2010 and 2011.

November 2012-View is from the left bank

Figure 43. Cross section three in 2012.

APPENDIX B: AS-BUILT CONSTRUCTION DRAWINGS & SPECIFICATIONS

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SHEET 2: CONSTRUCTION NOTES AND SPECIFICATIONS
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SHEET 5: PLAN VIEW: Aerial Photo and Control Points
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SHEET 9: PROFILES & CROSS SECTIONS
SHEET 10: PLAN, PROFILE, CROSS-SECTIONS: Backwater
SHEET 11: DETAIL: Toe Rock
SHEET 12: DETAILS: Vegetated Geogrid with Base Rock and Channel Realignment
SHEET 13: DETAILS: Bank Sloping, Erosion Control Fabric, Coir Log
SHEET 14: DETAILS: Pole Clusters and Vertical Bundles
SHEET 15: DETAIL: Containerized Plants and Post Plantings
SHEET 16: DETAIL: Brush Revetment
SHEET 17: DETAILS: Fish Structure and Livestock Crossing
SHEET 18: Fish Habitat DETAIL: Boulder Clusters
SHEET 19: PLAN VIEW: Planting Layout for Shrubs & Trees
SHEET 20: DETAIL: Water Barrier for Dewatering
SHEET 21: PLAN VIEW: Delineation of Jurisdictional Area
SHEET 22: PLAN VIEW: Planting Layout for Shrubs & Trees

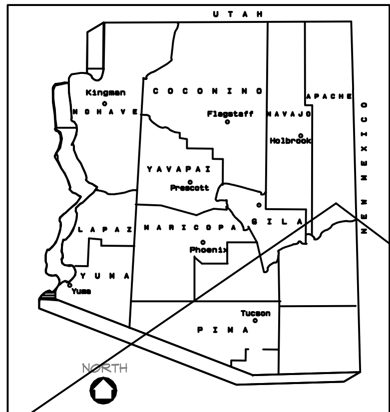
RECORD DRAWINGS

Construction Period:
October 2008 to August 2012
Earthwork Contractor:
Rob Overaker
Revegetation Labor:
American Conservation Experience

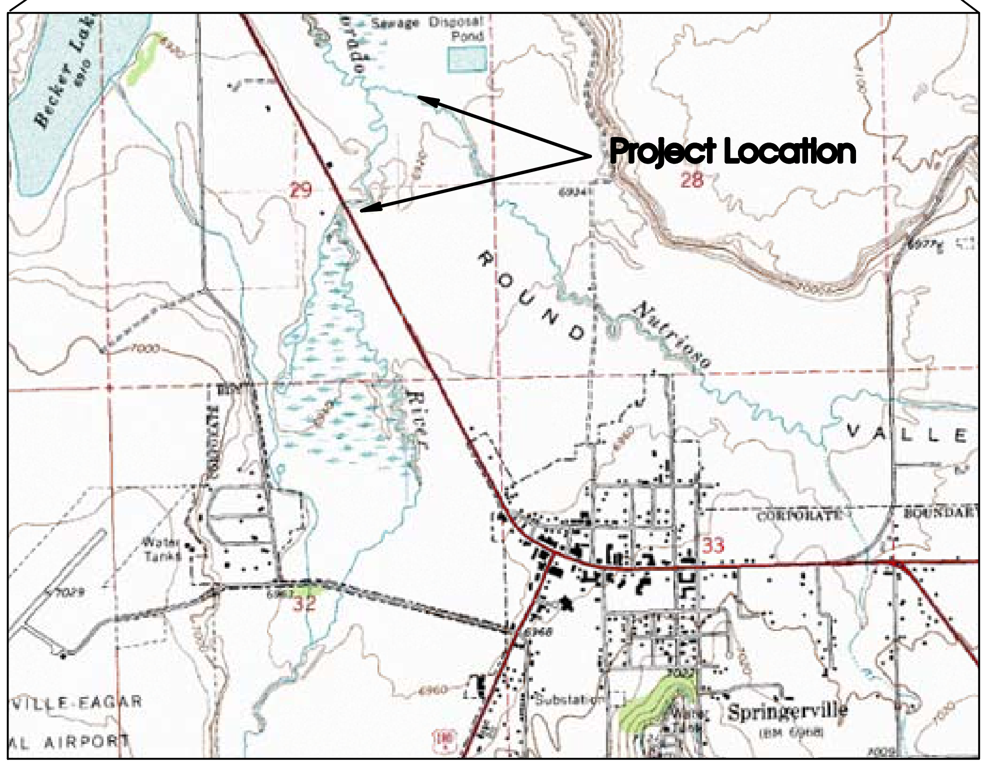
Little Colorado River Nutrioso Creek Riparian Enhancement Project

Springerville, AZ

Arizona Water Protection Fund Project #: 07-143 WPF



LOCATION MAP



Section 29, T9N, R29E
Springerville, Apache County, Arizona

Little Colorado River
Total Watershed Area = 150 square miles
Unregulated Watershed Area = 120 square miles

Stream Project Length: LCR: 1835 feet
Nutrioso: 150 feet

CALL TWO WORKING DAYS BEFORE YOU DIG
263-1100
1-800-STAKE-IT
(OUTSIDE MARICOPA COUNTY)

INDEX OF DRAWINGS

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MATERIAL LIST

EARTHWORK	
Backwater Excavation	400 cy
Bank Sloping	1066 cy
Geogrid Fill	67 cy
DIVERSION STRUCTURE	
1.5ft Water Barrier	25 ft
3 ft Water Barrier	150 ft
5 ft Water Barrier	30 ft
TOE PROTECTION	
Toe Rock/Base Rock	135 cy
Coir Logs	130 ft
Brush Revetment	80 ft
Livestock Crossing Rock	15 cy
~~FISH HABITAT STRUCTURES~~	
~~Boulder Clusters~~	~~6 ea (4.8 cy)~~
~~Fish Structure~~	~~2 ea~~
VEGETATION	
Willow Cuttings	3510 ea
Cottonwoods	33 ea
Container Trees	34 ea
Container Shrubs	70 ea
Seeding	2 ac
Sedge Plugs	520 ea
Deer Grass	1000 ea
FABRIC	
Non-Woven Geotextile	175 sq yd
Turf Reinforcement Mat (TRM)	260 sq yd
Erosion Control	2400 sq yd
Double Net (8'x67.5')	13 rolls
Single Net (8'x67.5')	25 rolls

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DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	4-14-08	MW	TOC, Materials
2	3-14-13	CS	RECORD DRAWINGS

COVER SHEET: Location, Index, Materials

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

Electronic copy of final document; Sealed original document is with Tom O. Moody, P.E. #4977296

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 1 of ~~21~~ 22

PROJECT DESCRIPTION

The project design includes enhancing and restoring native riparian vegetation, aquatic, biological, and physical resources of the riparian corridor of the Little Colorado River, as well as a small segment of Nutrioso Creek, in the project area. Historic and current grazing at the site has resulted in eroding banks, impacting the terrestrial and aquatic habitat for many species. The enhancement of these resources is expected to directly benefit fish and wildlife dependent on river, stream, and riparian resources. Treatments include stabilizing banks (bank sloping and toe protection measures where appropriate), reestablishment of native plant communities along the river corridor, and installation of fish habitat structures.

GENERAL NOTES

1. Site survey data was collected by NCD in June of 2007 and January 2008.
2. All stationing refers to base line of construction and is measured horizontal distance.
3. Project survey data provides the most accurate representation of site topographic conditions. All existing conditions are to be verified in the field prior to construction.
4. No representation is made as to the existence or nonexistence of any utilities, public or private. Absence of utilities on these drawings IS NOT assurance that no utilities are present. The existence, location and depth of any utility must be determined by the contractor prior to any excavation.
5. Construction activities will be conducted in a manner consistent with all safety regulations and requirements of Section 404 of the Clean Water Act (ACOE).
6. Installation shall be constructed to the lines and grades as shown on the drawings or as staked in the field by the ENGINEER, recognizing there is variation in nature.

CONSTRUCTION MANAGEMENT

Construction is timed to allow for the lowest base flows, the lowest chance of flood flows, and to provide the least disturbance to wildlife. To minimize disturbance caused by the actual construction, the project will commence in the fall/winter thereby avoiding spawning and nesting activities of native fish and bird species of concern. Reconstruction and revegetation activities will be completed in as quick a time frame as possible, reducing the time of disturbance and maximizing the healing of banks and establishment of the vegetation prior to spring runoff.

Pollution Control/Resource Protection

Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution are minimized and held within legal limits. The measures and works shall include, but are not limited to, the following:

1. Diversions: Standard best management practices will be used to temporarily divert water away from work areas within the active channel. Such diversions shall be temporary and shall be removed and the area restored to its near original condition immediately upon completion of work within the active channel or when permanent measures are installed (i.e. toe rock). Temporary diversions will be located at STA 5+12, STA 12+40 and STA 13+25. See SHEETS 6&7 for locations, SHEET 20 for details.
2. Equipment Access and Staging Areas: Transportation routes for materials, personnel, and equipment to, from, and within the project area shall be limited to access areas located on the drawings or determined in the field.
3. Revegetation: Impacts to existing vegetation and habitats shall be minimized. All disturbed areas shall be replanted with native vegetation.
4. Equipment: All equipment shall be in good operating condition. Equipment shall be cleaned and weed free prior to arrival on the job site.
5. Equipment Use in Streams: When stream channel work is necessary, every effort will be made to enter and exit the channel in locations without important vegetation and where impacts do not result in stream bank instability. The use of heavy equipment in the stream will be kept to an absolute minimum.
6. Stream Crossings: Stream crossing points shall be minimized and shall be removed and the area restored to its near original condition when crossings are no longer required. Temporary stream crossings will be located at STA 3+75 and STA 14+20.

Construction Supervision

Supervision shall be provided for the earthwork, structural and revegetation tasks. Supervisory personnel shall have an understanding of the natural channel design as applied to stream restoration.

Earthmoving Equipment

The following earthmoving equipment are expected to be utilized during the construction:

- Backhoe/Trackhoe/Excavator with thumb: Bank sloping, backwater excavation and rock installation
- Backhoe/Front End Loader: Moving structure rock and various fill
- Dump Truck: Miscellaneous hauling

Construction Sequence

Construction will proceed from the upstream end towards downstream of the project. Revegetation efforts will proceed downstream as the bank sloping is completed.
The following is a recommended construction sequence:

1. Slope banks (3:1 min)
2. Install Water Barriers to dewater specific banks
3. Install toe rock and base rock and fish habitat structures (boulder clusters, lunkers)
4. Excavate backwater
5. Install vegetative practices and bioengineering
6. Install livestock access and fencing

Remove and dispose non-native exotic species as designated in the field.
Remove and dispose appropriately any abandoned fencing, car bodies and other non-natural materials from site.

Equipment Use in River

To the maximum extent possible, mechanized equipment utilized to accomplish project activities shall be operated outside of the active channel.

Permitting Requirements

No construction shall begin until all necessary permits are obtained. All contractors and construction representatives shall read the Corps 404 authorization and acknowledge they understand its contents and their responsibility to ensure compliance with all general and special conditions.

EARTHWORK

The earthwork shall consist of bank sloping and excavating backwater habitat. See SHEETS 6 through 10, for location of earthwork activities and SHEETS 11, 12 and 13 for Details.

Excavation

Excavation shall be limited to bank shaping and backwater creation as shown on the drawings or as staked in the field. All finished surfaces shall be generally smooth and pleasing in appearance.

Soil excavated from the bank will be spread out over designated areas. These areas will be reseeded with native grass seed mix. Disturbance of existing vegetation shall be minimized to the greatest extent possible during excavation.

Earthfill

Materials: All fill materials shall be obtained from the required excavations and approved borrow sources. Fill materials shall not contain sod, brush, roots perishable materials, or frozen materials.

Placement: The placement of fill materials shall follow these guidelines:

- Any vertical banks shall be sloped before placement of fill material.
- The placing and spreading of fill material shall be started at the lowest point and the fill brought up and compacted to obtain a density similar to the surrounding bank material.
- Material when placed shall contain sufficient moisture so that a sample taken in the hand and squeezed shall remain intact when released.
- All finished surfaces shall be generally smooth and pleasing in appearance and blend into surrounding terrain.

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REV	DATE	BY	REVISION
1	4-14-08	mw	Diversion Water Barrier
2	3-14-13	CS	RECORD DRAWINGS

CONSTRUCTION SPECIFICATIONS (General Notes & Earthwork)

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

Electronic copy of final document; Sealed original document is with Tom O. Moody, P.E. #4977296

RECORD DRAWINGS

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 2 of ~~21~~ 22

STRUCTURES PLAN

Structures plan shall consist of installing toe protection (rock, brush revetments, erosion control logs) and fish habitat structures (boulder clusters, lunkers).

Toe Protection

Toe Rock & Base Rock with Willow Cluster Trench: This structural bank stabilization practice consists of graded angular rock placed along the base of an eroding stream bank and is designed to protect the vulnerable bank toe. Rock extends slightly above the elevation of the floodplain to minimize the structural component and encourage revegetation. A willow cluster trench shall be integrated with this toe protection. See SHEETS 11 & 12 for Toe & Base Rock Detail and SHEET 14 for Willow Cluster Trench Detail.

. The work shall consist of excavation, delivery of rock, and installation of rock for rock riprap as shown on the drawings or staked in the field by the authorized representative.
. The rock shall be well graded from a minimum of six inches to a maximum size of 12 inches with greater than 50% by weight being larger than 8 inches.
. The rock shall be angular, dense, sound and free from cracks, seams, or other defects conducive to accelerated weathering. The least dimension of an individual rock shall not be less than one-half the greatest dimension.
. The rock source shall be approved by the ENGINEER or authorized representative and have a bulk specific gravity of not less than 2.5 per ASTM C127.
. Non-woven geotextile shall be placed behind the toe rock. Fabric shall have a minimum grab tensile strength of 90 lb, greater than 50% elongation at failure, a minimum of 40 lb puncture strength, and UV resistance of 70% strength retained. The geotextile shall be joined by overlapping a minimum of 6 inches and secured against the underlying foundation material.

Brush Revetment: Revetment is constructed from whole trees that are wired together and anchored by earth anchors or fence posts. Brush or trees are secured to the streambanks to protect the toe of the bank by slowing velocities and diverting the current away from the bank edges. The revetment also traps sediment from the stream. The revetment material generally does not sprout. Always plant live willows or other quickly sprouting species behind the revetment. Trees for tree revetments shall be freshly harvested Juniper or Pinyon, unless otherwise specified. The limbs shall be "green" and pliable at the time of placement to prevent breakage. The trees shall retain limbs, needles, or leaves immediately before placement to form a single tree canopy of not less than 75 percent of the unharvested tree. Brush revetment shall be installed along the toe of the bank. See SHEET 16 for Detail.

Erosion Control Logs: These flexible logs are made of Coir, Straw, Aspen Excelsior, or other natural materials and installed to protect the streambank by stabilizing the toe of the slope and by trapping sediment. Cuttings and herbaceous riparian plants can be planted into the log and behind it. Secure the logs with 24 to 36 inch long wedge-shaped stakes at 5 foot intervals. Stakes can be driven through center of log or both sides of log and tied with twine. See SHEET 13 for Detail.

~~Fish Habitat Structures~~

~~Boulder Clusters: Clusters consist of one or more boulders of varying sizes and arrangements installed in the center of the bankfull channel. The tallest boulders are installed at an elevation that affects flow vectors and velocities at bankfull stage. The structures can be installed singly or in sets to provide deep quiet areas used by juvenile fish and/or upstream migrating spawners as resting areas as well as varying flow vectors and velocities to enhance feeding and sort spawning gravel. They can also increase variation in channel width, protect eroding banks by deflecting flow, and improve gradation of substrate materials. See SHEET 18 for Detail.~~

~~Fish Structure: These structures provide overhead cover for fish by mimicking an overhanging bank condition. The pre-fabricated structure is embedded into the bank and forms a roof, supporting the bank while providing a hollow niche along the base of the bank where fish can seek cover. Rocks can be placed along the outside edge to break up flow velocities. Structures will be place in Bank D. See SHEET 17 for Details.~~

Livestock Crossing

Livestock Crossing: The purpose of the livestock crossing is to restrict livestock access to the river at a single point and to allow access to a pasture on the opposite side. The crossing is 20 ft wide and banks should be resloped to no more than a 3H:1V slope. A 6 inch layer of large gravel is then placed on the slope and compacted to form a hardened surface that is resistant to erosion and minimizes sediment input to the stream. See SHEET 6 for location, SHEET 17 for details.

REVEGETATION PLAN

Revegetation Plan includes native grass seeding (with mulch & fabric), willow and cottonwood plantings, and contanerized shrubs & tree plantings, wetland plugs and deer grass containers.

All woody species shall be native and collected from designated local sources or obtained from local nurserys. Willows and cottonwood will be planted appropriately throughout project:

PLANT MATERIAL PROCUREMENT and HANDLING

Woody Plant Materials:

All woody species shall be native and collected from designated local sources.

Dormant unrooted hardwood cuttings can be taken after leaf fall and before bud burst in the spring. Never remove more than 1/3 of any single donor plant during harvesting. The best rooting success is from cuttings that are disease-free, green plants that are 2-10 years old. The best diameters for pole planting, vertical bundles, and trenches are 1/2 to 1 inch and 2 to 3 inches for post plantings. Cutting length varies depending on the application. It shall be long enough to reach 6 to 8 inches into the lowest water level of the year and high enough to expose at least two to three buds.

Cuts shall be made with clean, sharp tools. The bottom end of the stem cutting shall be cut to a 45-degree angle and the top end shall be cut square across or horizontal to the stem. Trim off all side branches and the terminal bud (bud at the growing tip) so energy will be rerouted to the lateral buds for more efficient root and stem sprouting. Do not trim terminal bud from cuttings for vertical bundles and willow trench until after planted. Trimmed tip ends shall be sealed by dipping in light-colored latex, water-based paint.

Submerge cuttings in water for 3 to 7 days prior to planting to maximize water retention. Do not allow the roots to emerge from the bark.

CONTAINERIZED PLANTINGS: Trees & Shrubs

Containerized plantings are procured from a local nursery or grown from locally derived stock. One to five gallon plants will be procured for planting.

CONTAINERIZED PLANTINGS: Deer Grass

Deer grass (Muhlenbergia rigens) will be propagated from seed collected from sources of similar elevation by reputable nursery in either transplant cones or 1-gallon containers. These plants are placed along the toe of the bank, above the low water line. Container plants shall be healthy and well rooted with roots showing no evidence of damage, restriction or deformed growth. Containerized plantings should be stored in an approved area and watered enough to maintain adequate soil moisture.

WETLAND PLUGS

Wetland plants are readily transplanted because of their well developed root systems. Dig no more than 1 sq ft of plant material from a 4 sq ft area. It is not necessary to go deeper that 5 to 6 inches. Enough root mass will be harvested to ensure good establishment at the project site. It will also retain enough of the transplants' root system below the harvest point to allow the plants to grow back quickly.

Transplants can be taken at almost any time of the year. Cut the top growth to about 4 to 5 inches above the potential standing water height or 10 inches whichever is higher. One sq ft of plant material provides 6 to 9 individual plant plugs.

Leaving the soil on the plug increases the establishment rate by about 30%. Beneficial organisms that are typically found on the roots of the wetland plants are important in the nitrogen and phosphorous cycles. These organisms may not be present at the new site. Leaving soil on the plug, however, will increase the volume of material that needs to be transported. There is a chance that weed seeds could be transported in the soil if collected from a weed-infested area. Washed plugs reduce weed seed transport and can be inoculated with mycorrhizae purchased from dealers.

Make sure the length of the plug is related to the saturation zone at the planting site. The bottom of the plug needs to be in contact with the saturation zone. Match the amount of water with the wetland plant species. (Hoag et al 2003). Where possible, plugs and sod shall be grown and harvested locally.

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REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

CONSTRUCTION SPECIFICATIONS (Structures & Revegetation Plan)

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

RECORD DRAWINGS

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07-143-AZ

REVEGETATION PLAN (cont')

INSTALLATION OF PLANT MATERIALS

Installation of vegetation shall start when the general excavation operations are being completed.

Coyote willow (Salix exigua) and Strapleaf willow (Salix ligulifolia) shall be planted in the upper Bank and lower Overbank Zones. Fremont cottonwood (Populus fremontii) shall be planted in the upper Overbank and Transition Zones in groups of three. Containerized tree and shrub species will be planted according to container planting specifications. See figure on SHEET 5 for riparian planting zones, SHEET 19 for Planting Layout

POLE PLANTINGS and POLE CLUSTERS:

Pole cuttings are placed in the ground deep enough to reach the lowest water table of the year and high enough to expose at least two to three buds. Root primordia will develop when good soil-to-stem contact is made and exposed sections of the cutting will sprout stems and leaves.
Dormant cuttings can be planted with a digging bar, auger, water-jet, or if the soil is saturated, they may be pushed into the soil. Pole Plantings are planted in the Bank and Overbank Zone and shall be spaced 2-4 feet apart in the row. In multiple row plantings, spacing between rows shall be staggered with respect to those in adjacent rows.

Pole Clusters require four to six inch holes augered into the bank, down to the water table with the use of a hydraulic auger attached to an excavator or tractor. Four willow poles are placed into the hole, backfilled and watered in. A Willow Trench uses pole clusters at 1 foot spacings behind the toe rock that creates a "fence" to filter runoff before it enters the stream and provide dense vegetation to stabilize the eroding bank. See SHEET 14 for Details.

VERTICAL BUNDLES

Vertical bundles are placed in shallow trenches vertically up the slope. It will protect the Toe, Bank and Overbank Zones. Vertical bundle diameters should be from 3 to 6 inches (typically 3 to 6 stems). Bundle heights should be tall enough to extend from about 8 inches into the water table to about 1 foot above the top of the bank. Vertical bundles can be installed on 4 foot centers between waters edge and top of bank. Cuttings are stripped of side branches, tied into bundles, and soaked. See SHEET 14 for Details.

POST PLANTINGS

This practice involves planting of larger limbs (2 to 3 inches diameter) in clusters of three in designated areas. Cottonwood posts will be placed in holes in the Overbank Zone. Cottonwood posts shall be placed down to approximately four to six inches above the water table (never into saturated soils). Willows can be added and should extend into the water table. Backfill posts, ensuring posts and poles remain upright and spaced apart. For fine grained clayey soils, it may be necessary to add coarse grained material (up to 50% small gravels and sand) to amend and loosen the soil.
See SHEET 15 for Details.

CONTAINERIZED PLANTINGS: Trees, Shrubs, Deer Grass

Plants are removed from their container and circling roots are cut prior to placing into hole. Backfill soil should be mixed with 3 parts soil to 1 part sand, cinders or mulch. Fill hole 3/4 full with soil. Fill remainder of hole with water to eliminate air pockets. After all water has drained, finish filling hole with soil. Mound soil around edges of hole. Add 4 inches of mulch to trees and shrubs. See SHEET 15 for Detail.

TRANSPLANT PLUGS: Plant plugs by flooding the planting site. Saturated soil is much easier to plant in than dry soil. The soil should be super saturated so that a hole can be easily dug with a bare hand. Hand planting is more successful with fine soils than with coarse soils. Take the plug trays and place them in a Styrofoam cooler. Cover the roots with water while in transit. At the planting site, drain off most of the water so the cooler will float. Use the cooler to move the plugs around the area as you plant. Plant plugs in the Toe Zone. The plugs can either be chopped with a shovel very rapidly or the plugs can be cut with a small saw so they will easily fit into a predrilled, set diameter hole. To get the right length of plug, lay the large plug on its side on a sheet of plywood and use a saw to cut the bottom off level and to the desired length. After this, stand the plug up and slice smaller plugs off like a cake.

SEEDING & FABRIC

Disturbed area within the project site including terraces and bank sloping sections will be seeded with native grasses. Specific areas will be mulched and/or overlayed by fabric/netting as determined in the field. Prepare seedbed where needed. Seed shall be incorporated into the soil, but not more than 1-inch deep. Reseeding may be required for successful plant establishment.

SEEDING

Seed shall be purchased from a reliable supplier. The grass seed mix includes species with spring, summer, and fall growth periods. Plan to seed immediately prior to the highest expected precipitation (early spring and/or late summer). The seeding rates below are for broadcast planting. Native grass seed will be applied at a rate of 18.75 pounds to the acre PLS (Pure Live Seed). Forbs (wildflowers) can be added to seed mix to increase diversity and improve aesthetics. Forbs (wildflowers) that have low maintenance, high survival rate, cold hardy, beautiful colors, and ecologically appropriate (non-invasive) are listed. Estimated area of disturbance is 2 acres.

The grass seed mix will consist of the following species as available:

Native Grass Species:		Seeding Rate lb/ac PLS	Seed MIX (2.0 ac) lb PLS
Blue grama	*(Bouteloua gracilis)*	1.35	2.70
Sideoats grama	*(Bouteloua curtipendula)*	2.70	5.40
Alkali sacaton	*(Sporobolus airoides)*	0.90	1.80
Bottlebrush squirreltail	*(Elymus elymoides)*	5.40	10.80
Sand dropseed	*(Sporobolus cryptandrus)*	0.90	1.80
Little Bluestem	*(Schizachyrim scoparium)*	2.10	4.20
Sheep Fescue	*(Festuca ovina)*	2.04	4.08
Bluebunch Wheatgrass	*(Pseudoroegneria spicata spp.spicata)*	3.36	6.72
		18.75 lb/ac	26.70 lbs

Native Forb Species:		Seeding Rate lb/ac PLS	Seed MIX (0.35 ac) lb PLS
Sulfur Flower	*(Eriogonum umbellatum)*	4.20	1.47
Western Yarrow	*(Achillea millefolium)*	0.60	0.21
Rocky Mountain Penstemon	*(Penstemon strictus)*	1.80	0.63
Rocky Mountain Iris	*(Iris missouriensis)*	12.0	4.20
Yellow Prairie Coneflower	*(Ratibida columnifera)*	0.60	0.21
		19.2 lb/ac	6.7 lbs

FABRIC

Erosion Control Fabric

Fabric made of Jute, Coir, Sraw, Coconut or other natural material is laid and anchored over seeding to reduce soil erosion and provide a good environment for vegetation regrowth. For stream applications and along the bank toe, a tightly woven coconut fiber blanket is the ost durable option.

Fabric shall be installed for slope protection and seed germination enhancement. Woody cuttings and herbaceous plants can be planted into the fabric and seed can be placed underneath the fabric.
See SHEET 13 for Fabric Installation.

VEGETATED GEOGRIDS

Vegetated geogrids are useful for rebuilding very steep eroded streambanks or configuring new banks in stream realignment. Reinforced lifts are composed of select fill compacted and wrapped in a high strength geotextile or geogrid and planted. Thickness of encapsulated lifts should not exceed 12-inches. Once the live plantings become established, their root systems penetrate the grids and the entire system becomes a cohesive mass.

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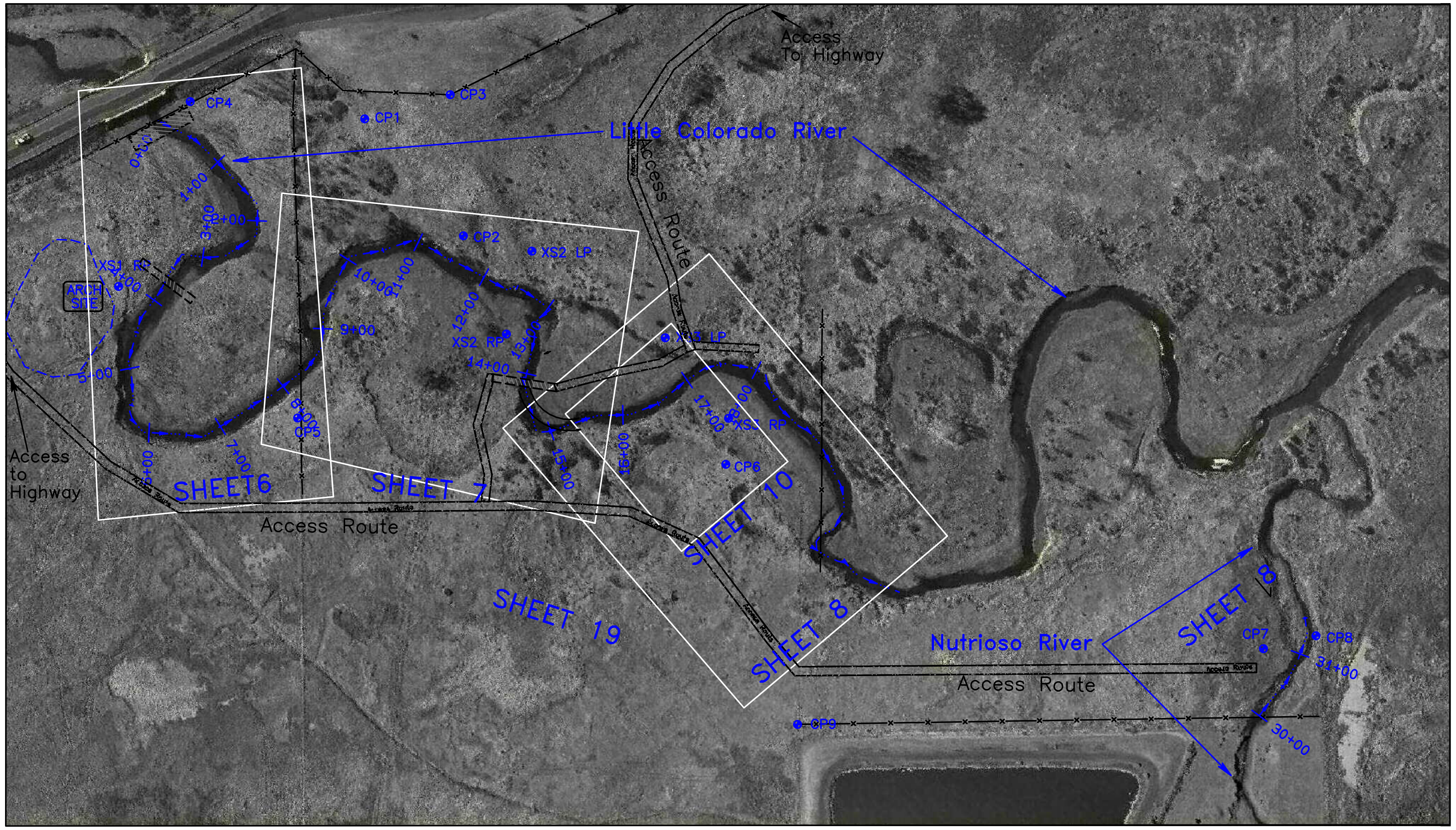
REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

CONSTRUCTION SPECIFICATIONS (Revegetation Plan)

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

RECORD DRAWINGS

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07-143-AZ



GENERAL NOTES

- Re-seed all disturbed terraces and banks with native grass seed mix.
- Plant additional riparian vegetation where prescribed.
- Remove and dispose non-native exotic species as designated in the field.
- Remove and dispose appropriately any abandoned fencing, car bodies and other non-natural materials from site.

- See the following sheets for planned treatment measures:

SHEET 6 – PLAN VIEW: Burk Property, STA 0+00 to 8+25

SHEET 7 – PLAN VIEW: Benoit Property, STA 8+25 to 15+20

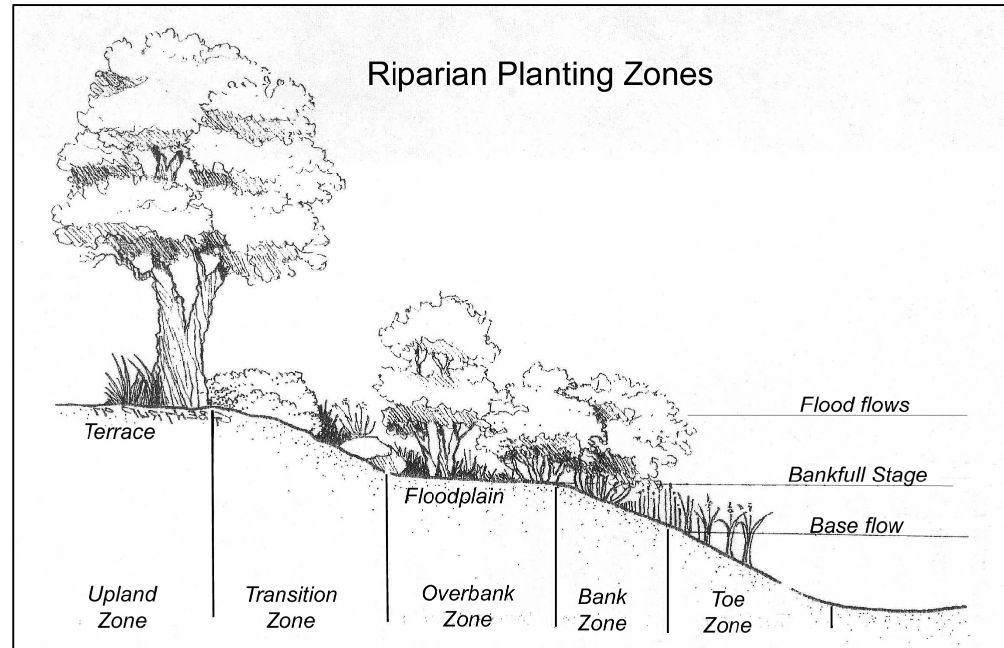
SHEET 8 – PLAN VIEW: Benoit Property, STA 15+20 to 21+15
Nutrioso Creek STA 30+00 to 31+50

SHEET 9 – PROFILES and CROSS-SECTIONS

SHEET 10 – PLAN, PROFILE, CROSS-SECTIONS: Backwater

SHEETS 11–18,20 – DETAILS

SHEET 19 – PLAN VIEW: Planting Layout for Shrubs and Trees



Source: Hoag, et al., 2001. Riparian Planting Zones in the Intermountain West. Information Series #16. NRCS - Plant Material Center, Aberdeen, ID.

CONTROL POINTS

Point	Northing	Easting	Elevation	Description
CP1	5000.00	5000.00	1000.00	1/2" Rebar, NCD Yellow Cap
CP2	5205.04	5000.00	996.62	1/2" Rebar, NCD Yellow Cap
CP3	5049.19	4891.53	1000.84	1/2" Top of concrete fence anchor
CP4	4831.44	5163.72	993.85	1/2" Top of fence corner brace
CP5	5248.18	5327.17	989.66	1/2" Rebar, NCD Yellow Cap
CP6	5665.79	4928.82	985.87	1/2" Rebar, NCD Yellow Cap
CP7	6319.28	4537.71	983.55	1/2" Rebar, NCD Yellow Cap
CP8	6351.45	4472.77	980.75	1/2" Rebar, NCD Yellow Cap
CP9	5994.05	5080.14	984.96	Prop Marker, Orange Cap
XS1 RP	4958.76	5396.82	991.21	1/2" Rebar, NCD Yellow Cap
XS2 RP	5342.74	5040.89	984.83	1/2" Rebar, NCD Yellow Cap
XS2 LP	5279.92	4943.14	989.49	1/2" Rebar, NCD Yellow Cap
XS3 RP	5621.04	4886.20	983.91	1/2" Rebar, NCD Yellow Cap
XS3 LP	5483.89	4881.49	990.01	1/2" Rebar, NCD Yellow Cap

RECORD DRAWINGS

Natural Channel Design, Inc
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(928) 774-2336

DRAWN BY: M.Wirtanen, J.Sutton, R.Lyman

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW: Aerial Photo and Control Points

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1 in = 200 ft
200 0 200

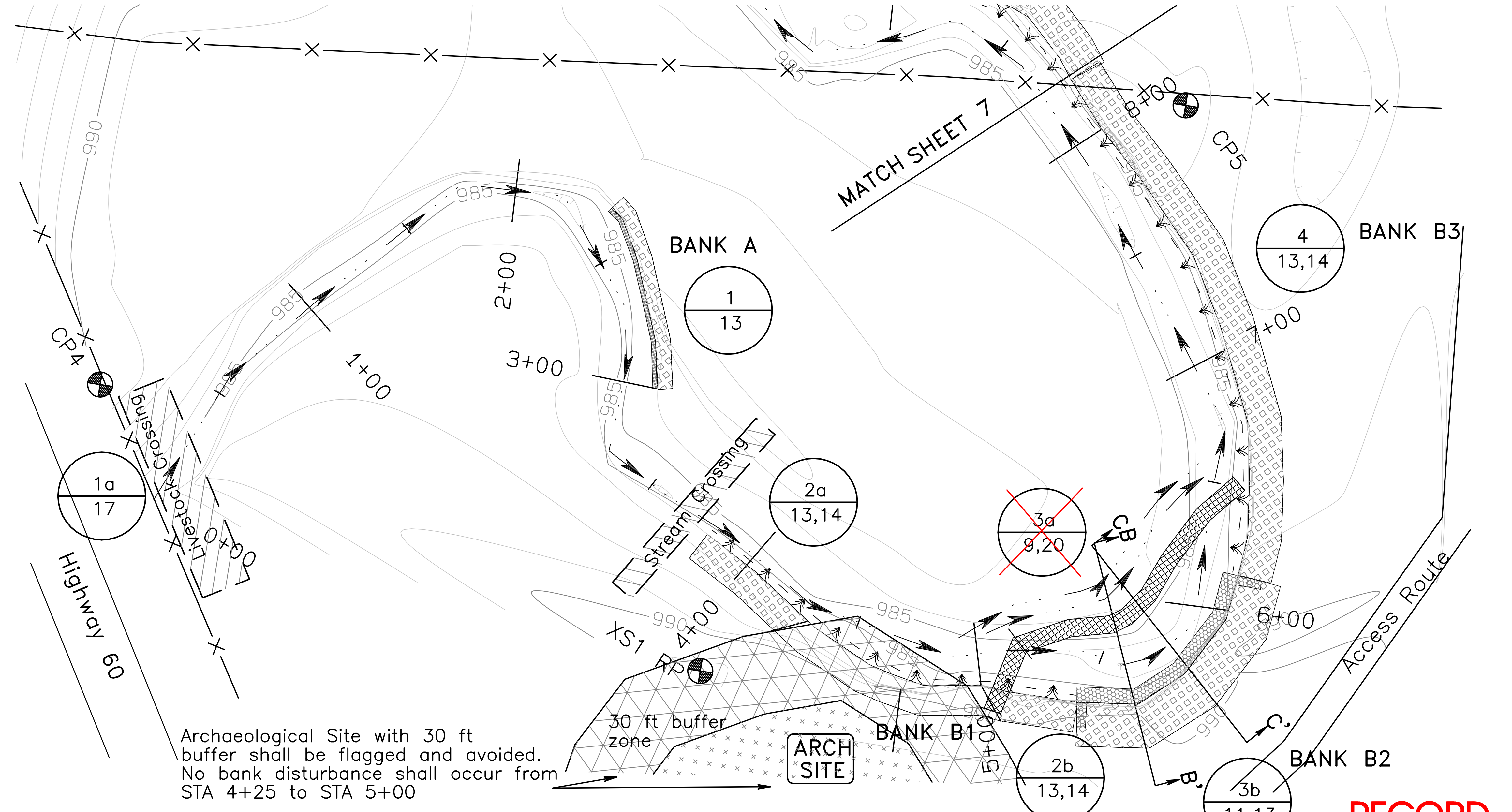
W S N E

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 5 of ~~21~~ 22



See SHEET 9 for Cross–Sections and SHEET 19 for Planting Layout.

MATERIAL QUANTITIES

EARTHWORK	
Bank Sloping	452 cy
DIVERSION STRUCTURE	
3 ft Aqua Dam	150 ft
5 ft Aqua Dam	30 ft
STRUCTURES	
Toe Rock	70 cy
Coir Logs	60 ft
Livestock Crossing Rock	15 cy
VEGETATION	
Willow Cuttings	840 ea
Cottonwoods	9 ea
Container Trees	6 ea
Container Shrubs	12 ea
Seeding	0.6 ac
FABRIC	
Non–Woven Geotextile	160 sq yd
Erosion Control Fabric	780 sq yd
Double Net (8'x67.5')	5.3 rolls
Single Net (8'x67.5')	5.5 rolls

LEGEND

- Reslope Banks, Seed, Fabric
- Toe Rock, Willow trench
- Coir Log
- ~~Water Barrier~~
- Brush Revetment
- Vertical Willow Bundles and Clusters
- ~~Boulder Clusters~~
- ~~Lunker Structures~~

Stationing	Planned Treatment Measures	Length	DETAIL Sheets
(1) 2+40 to 3+00 (L)	Reslope left bank, coir log with wetland plugs, seed and fabric	60 ft	13
(1a) 0+00 to 0+20	Livestock Crossing	20 x 40 ft	17
(2a) 3+80 to 4+25 (R)	Reslope right bank, vertical bundles & clusters, seed and fabric	45 ft	13,14
(2b) 5+00 to 5+40 (R)	Reslope right bank, vertical bundles & clusters, seed and fabric	40 ft	13,14
~~(3a) 5+12~~	~~Install Water Barrier to divert water~~	~~150 ft~~	~~9,20~~
(3b) 5+40 to 6+15 (R)	Reslope right bank, toe rock, willow cluster trench, seed and fabric	75 ft	11,13,14
(4) 6+15 to 8+25 (R)	Reslope right bank, vertical bundles & clusters, seed and fabric	210 ft	13,14

RECORD DRAWINGS

SHEET Notes

(#) Note No.
(#, #) Ref SHEET

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DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	4-11-08	MW	Archy Buffer Zone, Water Barrier
2	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW: Burk Property
STA 0+00 to STA 8+25

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1" = 50'

50 0 50

Contour Interval = 1 ft

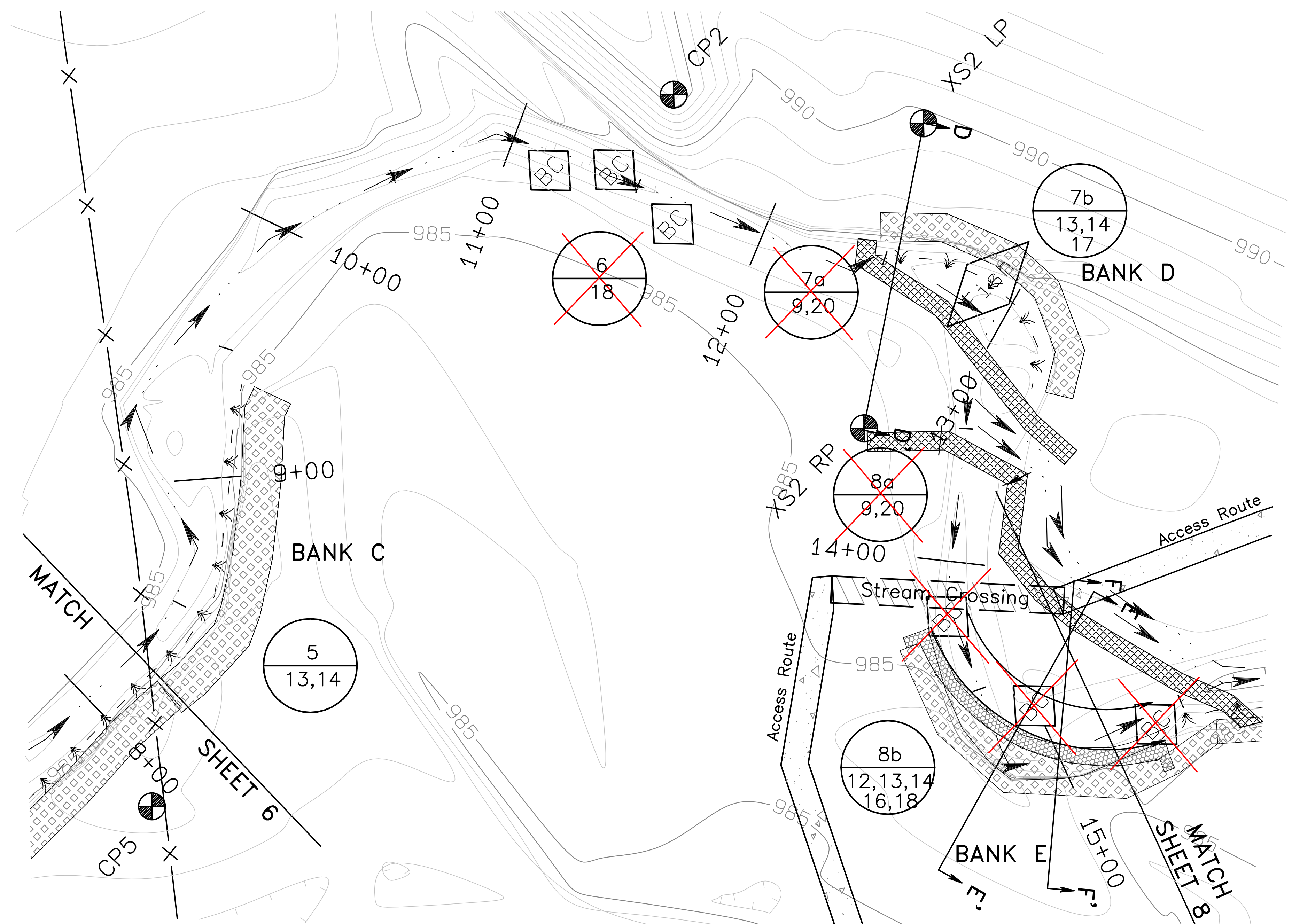
N W E S

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 6 of ~~21~~ 22



See SHEET 9 for Cross-Sections.
SHEET 19 for Planting Layout

MATERIAL QUANTITIES

EARTHWORK	
Bank Sloping	402 cy
DIVERSION STRUCTURE	
1.5ft Aqua Dam	25 ft
3 ft Aqua Dam	150 ft
5 ft Aqua Dam	30 ft
TOE PROTECTION	
Toe Rock	57 cy
~~**FISH HABITAT STRUCTURES**~~	
~~Boulder Clusters~~	~~6 ea~~
~~Fish Structure~~	~~2 ea~~
VEGETATION	
Willow Cuttings	1002 ea
Cottonwoods	15 ea
Container Trees	9 ea
Container Shrubs	32 ea
Seeding	0.4 ac
FABRIC	
TRM Fabric	260 sq yd
Erosion Control Fabric	606 sq yd
–Double Net (8'x67.5')	4.8 rolls
–Single Net (8'x67.5')	5.3 rolls

LEGEND

- Reslope Banks, Seed, Fabric
- Toe Rock, Willow trench
- Coir Log
- ~~Water Barrier~~
- Brush Revetment
- Vertical Willow Bundles and Clusters
- ~~BC Boulder Clusters~~
- ~~Fish Lunker Structures~~

SHEET Notes

#	Note No.
#, #	Ref SHEET

	Stationing	Planned Treatment Practices	Length	DETAIL Sheets
5	8+25 to 9+40	Reslope right bank, vertical bundles & clusters, seed and fabric	115 ft	13,14
~~6~~	~~11+00 to 12+00~~	~~Boulder clusters~~	~~100 ft~~	~~18~~
~~7a~~	~~12+40~~	~~Install Water Barrier~~	~~110 ft~~	~~9,20~~
7b	12+45 to 13+30	Reslope left bank from toe, ~~fish structure,~~ seed and fabric, willow clusters and vertical bundles	85 ft	13,14,~~17,20~~
~~8a~~	~~13+25~~	~~Install Water Barrier.~~	~~200 ft~~	~~9,20~~
8b	14+25 to 15+55	Realign channel, base rock, TRM fabric wrap with wetland plugs, willow cluster trench, willow clusters, seed, fabric, ~~boulder clusters,~~ brush revetment	110 ft	12,13,14,16,~~18~~

RECORD DRAWINGS

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DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	4-11-08	MW	Water Barrier
2	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW: Benoit Property
STA 8+25 to STA 15+20

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

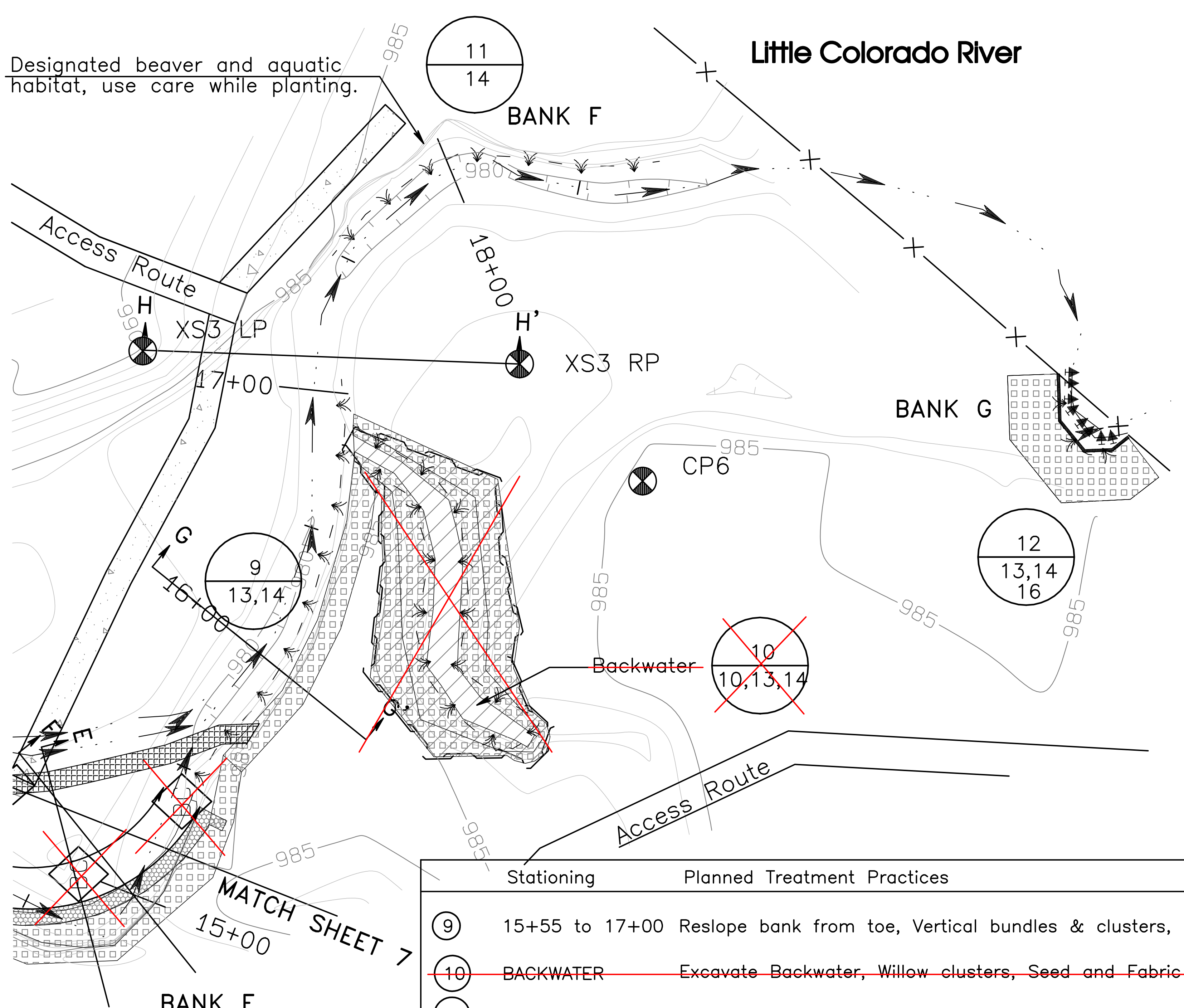
HORIZ SCALE: 1" = 50'
50 0 50
Contour Interval = 1 ft

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 7 of ~~21~~ 22

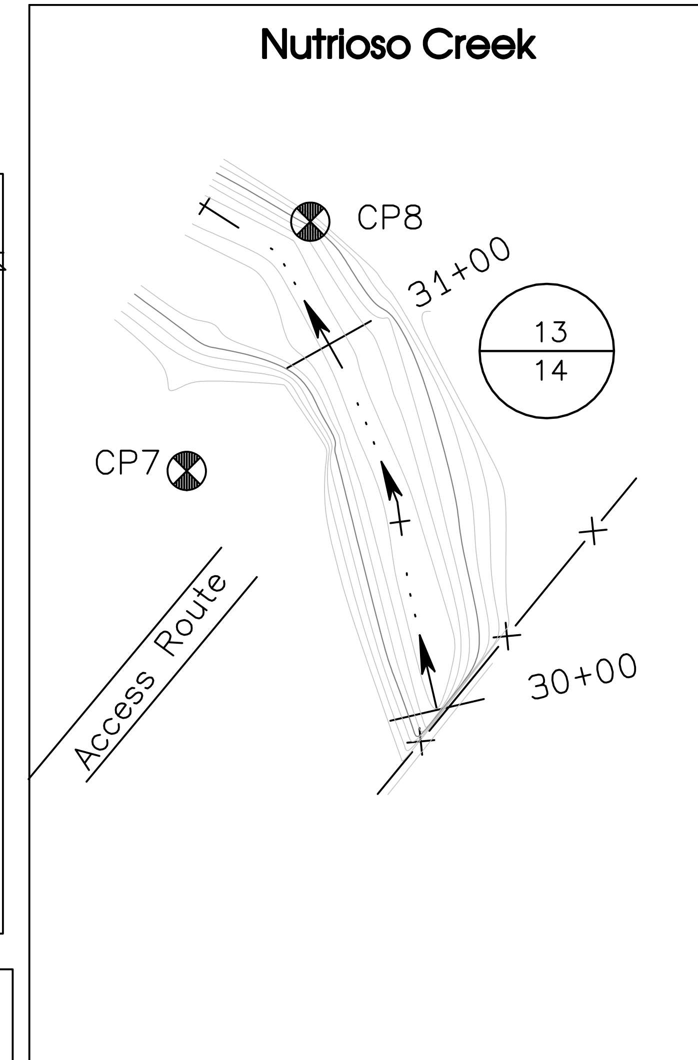


See SHEET 9 for Cross-Sections.
SHEET 19 for Planting Layout

MATERIAL QUANTITIES

EARTHWORK	
Bank Sloping	212 cy
TOE PROTECTION	
Brush Revetment	80 ft
Coir Logs	70 ft
VEGETATION	
Willow Cuttings	1380 ea
Cottonwoods	9 ea
Container Trees	19 ea
Container Shrubs	26 ea
Seeding	0.6 ac
FABRIC	
Erosion Control Fabric	474 sq yd
Double Net (8'x67.5')	3.4 rolls
Single Net (8'x67.5')	4.5 rolls

Nutrioso Creek



SHEET Notes
— Note No.
#, # — Ref SHEET

LEGEND

- Reslope Banks, Seed, Fabric
- Toe Rock, Willow trench
- Coir Log
- ~~Water Barrier~~
- Brush Revetment
- Vertical Willow Bundles and Clusters
- ~~Boulder Clusters~~
- ~~Lunker Structures~~

	Stationing	Planned Treatment Practices	Length	DETAIL Sheets
9	15+55 to 17+00	Reslope bank from toe, Vertical bundles & clusters, seed and fabric	120 ft	13,14
~~10~~	~~BACKWATER~~	~~Excavate Backwater, Willow clusters, Seed and Fabric~~	~~150 ft~~	~~10,13,14~~
11	17+50 to 18+80	Willow clusters, Seed	130 ft	14
12	20+75 to 21+15	Reslope bank from water level, coir log, brush revetment, vertical bundles & clusters, seed and fabric	70 ft	13,14,16
13	Nutrioso Creek 30+00 to 31+50	Willow clusters, Seed	150 ft	14

RECORD DRAWINGS

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DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

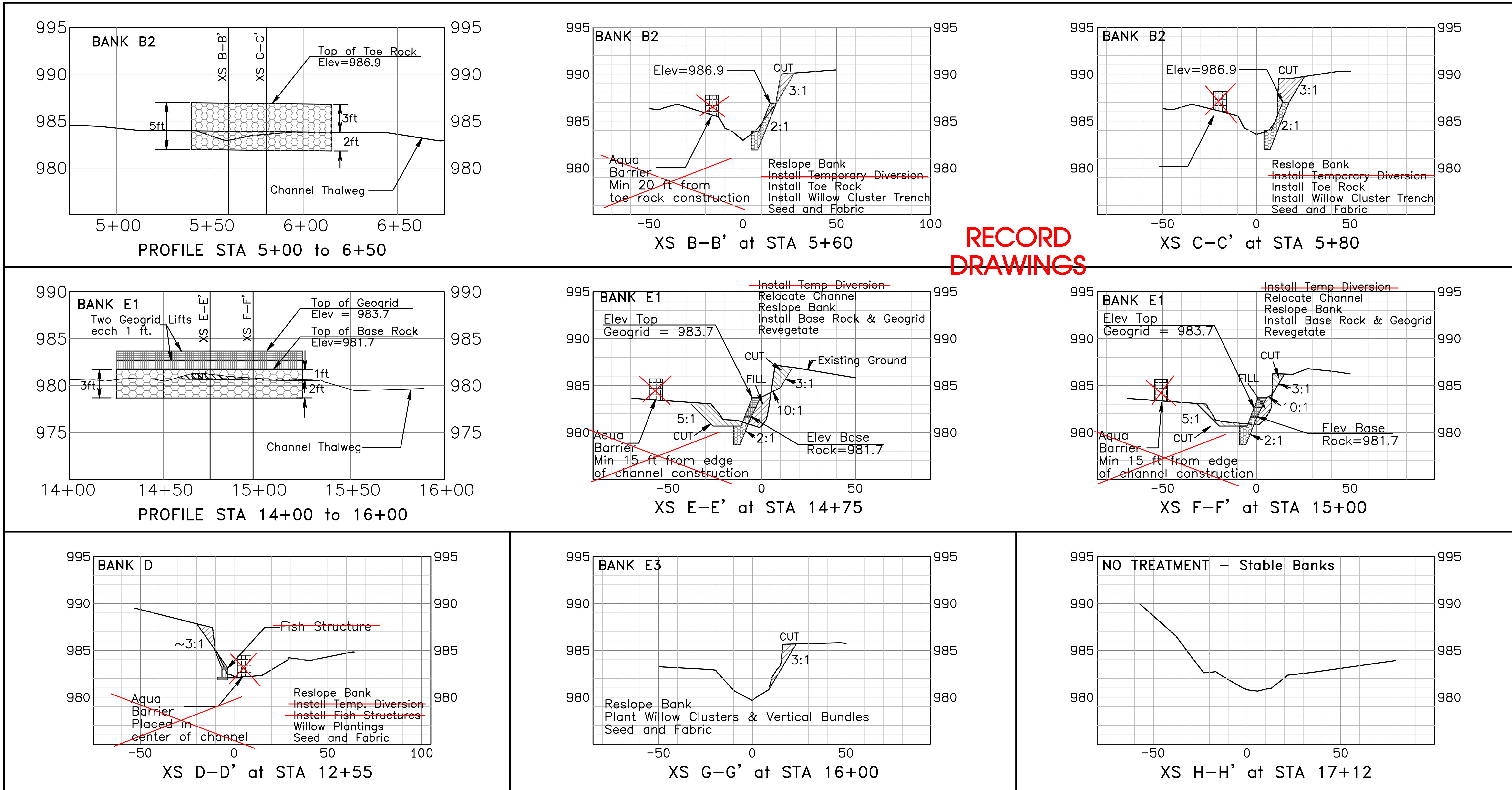
REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW:
Benoit Property STA 15+20 to 21+15
Nutrioso Creek STA 30+00 to 31+50

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1" = 50'
50 0 50
Contour Interval = 1 ft

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07-143-AZ
SHEET: 8 of ~~21~~ 22



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REV	DATE	BY	REVISION
1	4-11-08	MW	Water Barrier
2	3-14-13	CS	RECORD DRAWINGS

PROFILES & CROSS SECTIONS

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

VERT SCALE: 1" = 10'
HORIZ SCALE: 1" = 50'
50 0 50

FILE NAME: LCR Benoit.pro

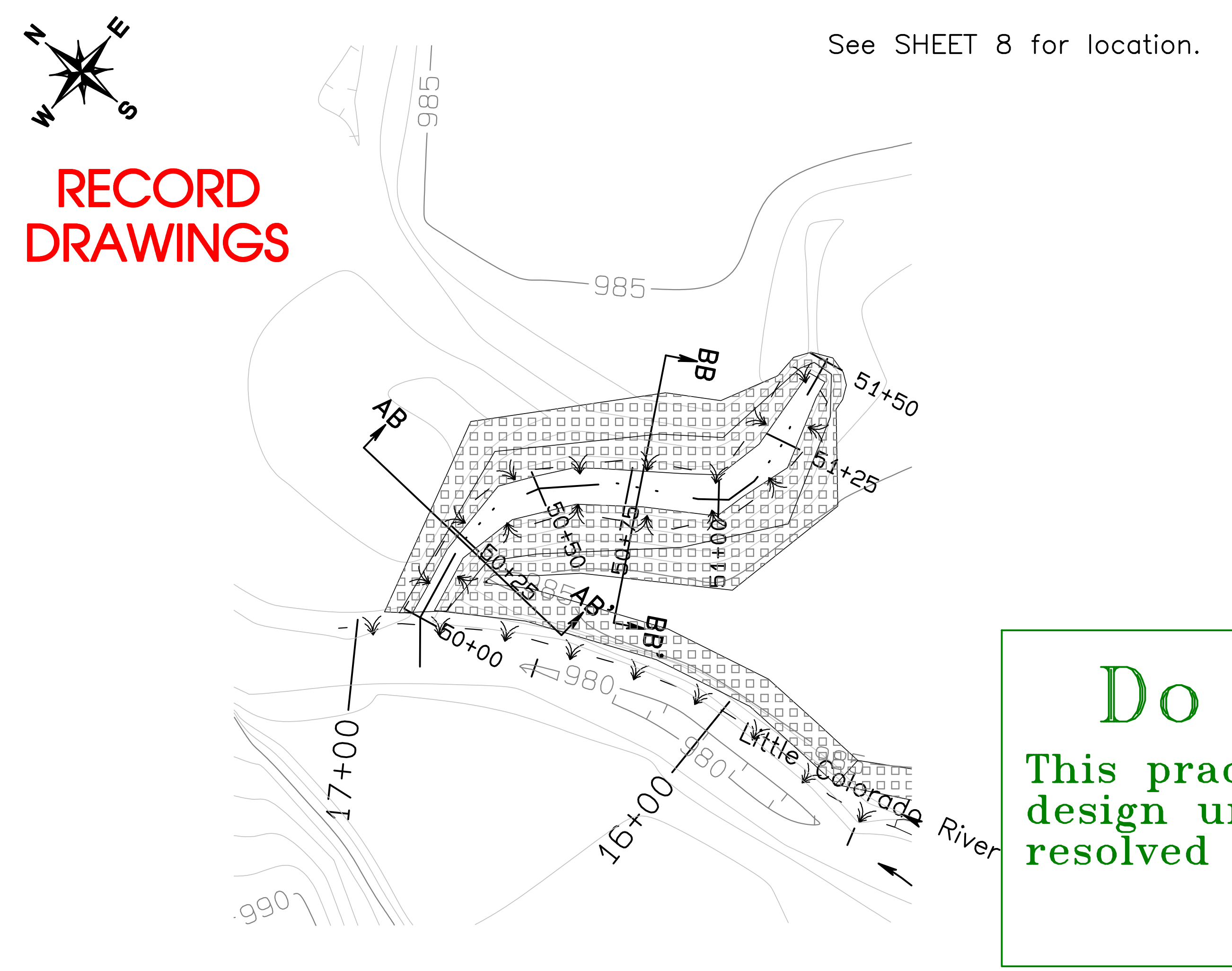
DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 9 of ~~21~~ 22

RECORD DRAWINGS

See SHEET 8 for location.



PLAN VIEW: Backwater

Contour Interval = 1 ft

NOTES
All disturbed areas to be seeded. Resloped banks to be covered with mulch fabric.

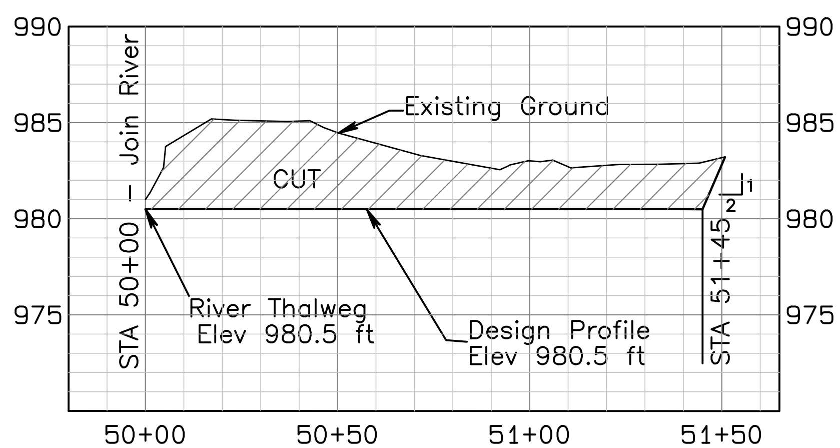
Station (going east from river)	Bottom Width	Bottom Elevation	North Bank Slope	South Bank Slope
50+00 to 50+25	5 feet	980.5 ft	2H:1V slope	2H:1V slope
50+25 to 50+50	transition from 5 feet to 10 feet	980.5 ft	transition from 2H:1V to 4H:1V slope	transition from 2H:1V to 3H:1V slope
50+50 to 51+15	10 feet	980.5 ft	4H:1V slope	3H:1V slope
51+15 to 51+45	transition from 10 feet to 5 feet	transition from 980.5 ft to match existing ground at 2H:1V slope	transition from 4H:1V to 2H:1V slope	transition from 3H:1V to 2H:1V slope

Note:
Plant one row of willow clusters (288 linear feet) along toe at four foot spacings

MATERIAL QUANTITIES	
EARTHWORK	
Backwater Excavation	400 cy
VEGETATION	
Willow Cuttings	288 ea
Seeding	0.40 ac
FABRIC	
Erosion Control Fabric	560 sq yd
Single Net (8'x67.5')	9.2 rolls

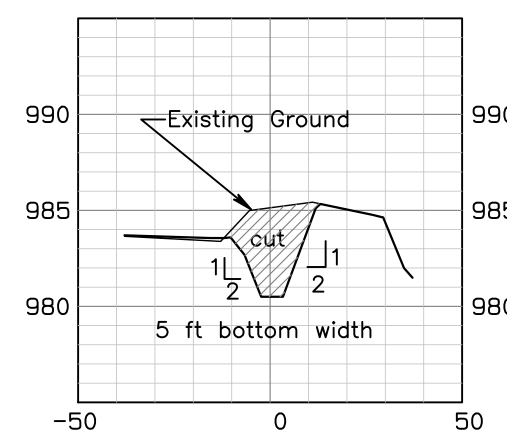
Do Not Construct

This practice has been deleted from the design until water rights issues have been resolved and upon approval by ADWR staff.

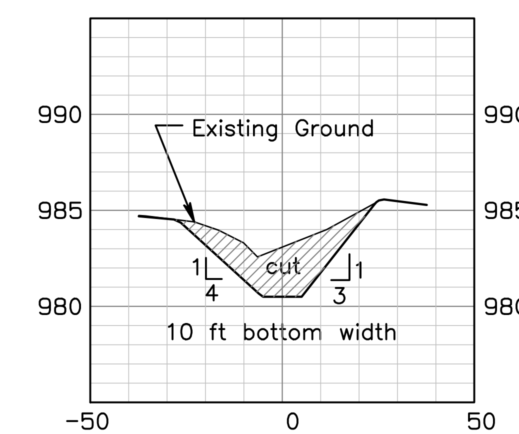


PROFILE: Backwater

CROSS–SECTIONS: Backwater



XS AB–AB' at STA 50+24



XS AB–AB' at STA 50+78

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REV	DATE	BY	REVISION
1	7–08	MW	deleted from design
2	3–14–13	CS	RECORD DRAWINGS

PLAN, PROFILE, CROSS-SECTIONS: Backwater

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

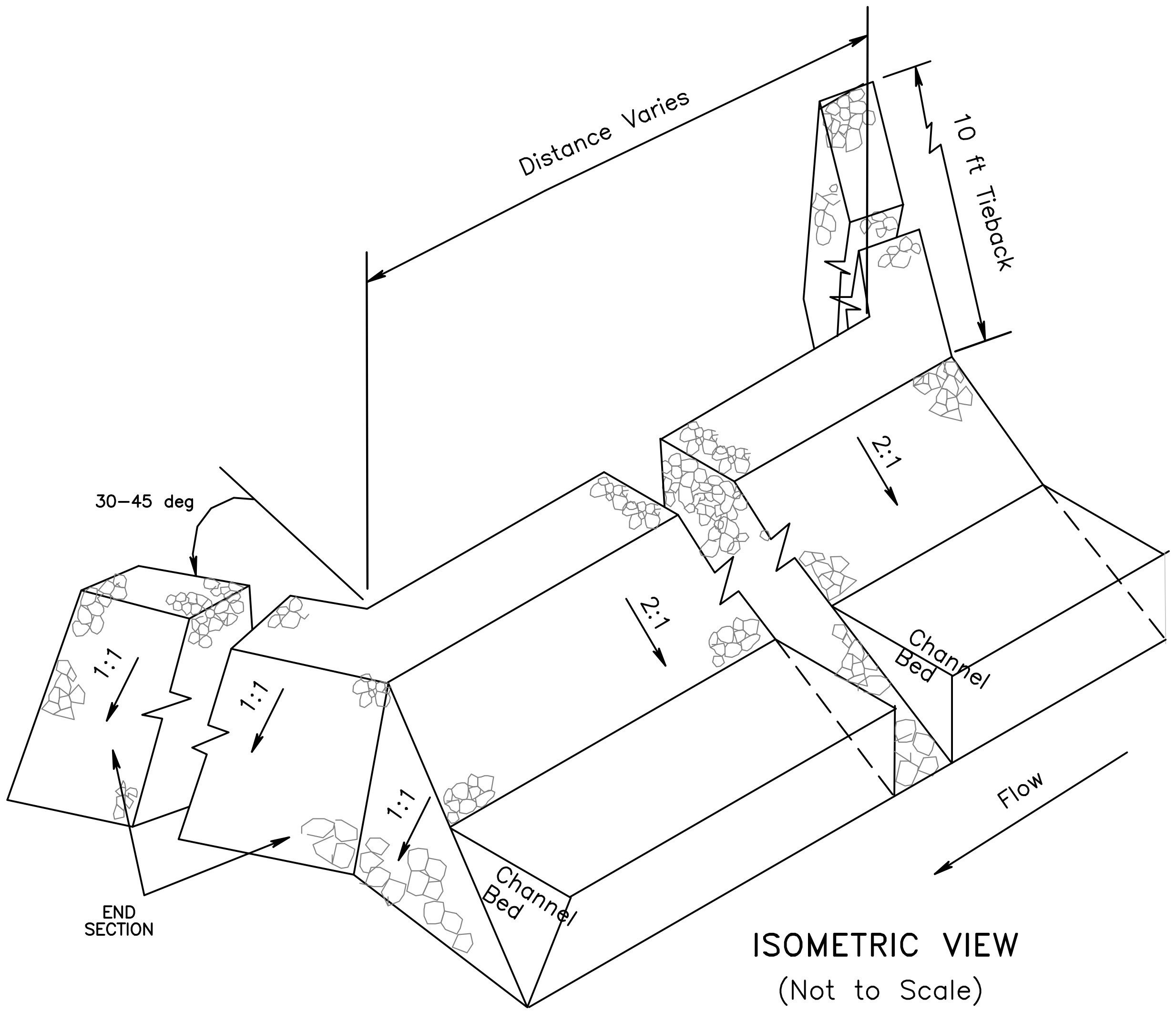
HORIZ SCALE: 1" = 50'
VERT SCALE: 1" = 10'
50 0 50

FILE NAME: LCR Benoit.pro

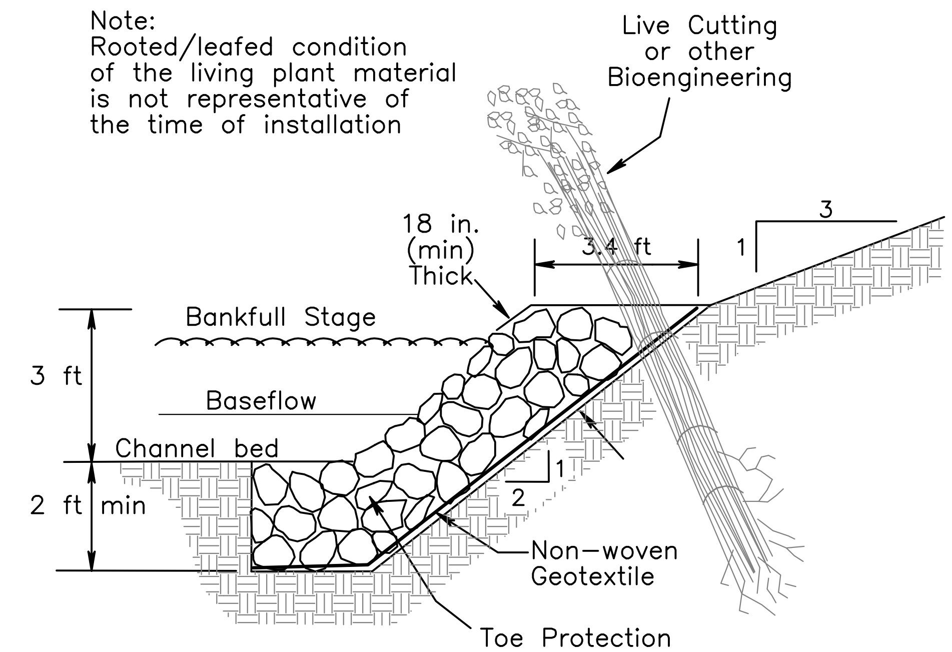
DATE: Mar 11, 2008

PROJECT NO: 07–143–AZ

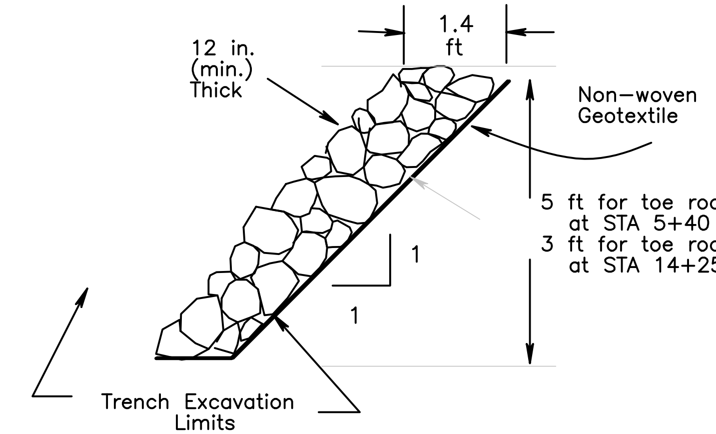
SHEET: 10 of ~~21~~ 22



ISOMETRIC VIEW
(Not to Scale)



TYPICAL TOE ROCK SECTION
(Not to Scale)



TYPICAL TIEBACK SECTION
(Not to Scale)

TOE ROCK VOLUME

0.85 cubic yards per linear foot
Total Distance = 75 ft

TOTAL VOLUME = 64 CY

TIE BACK VOLUME

0.26 cubic yards per linear foot
Total Distance = 20 ft
TOTAL VOLUME = 6 CY

GEOTEXTILE

15 ft wide rolls
Total Distance = 75 ft

TOTAL FABRIC = 175 SY

NOTES

Vegetative plantings: Plant a row of willow clusters above Toe Rock at 1 ft centers. See SHEET 14.

TOE ROCK LOCATIONS

STA	ACTUAL LENGTH
5+40 to 6+15 (right)	75 FT

GEOTEXTILE SPECIFICATIONS

Geotextile shall be a non–woven fabric with a minimum tensile strength of 90 lb, greater than 50% elongation at failure, a minimum of 40 lb puncture strength, and UV resistance of 70%.

Geotextile shall be joined by overlapping a minimum of 6 inches.

Geotextile shall be anchored in a trench with rock along the top edge of bank.

Geotextile shall be secured against the underlying foundation material. Securing pins shall be installed as necessary to prevent undue slippage or movement of the geotextile.

ROCK SPECIFICATIONS

Use well–graded, angular rock with bulk specific gravity greater than 2.5

Gradation: Dmin = 6 in
D50 = 8 in
Dmax = 12 in

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REV	DATE	BY	REVISION
1	3–14–13	CS	RECORD DRAWINGS

DETAIL: Toe Rock

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

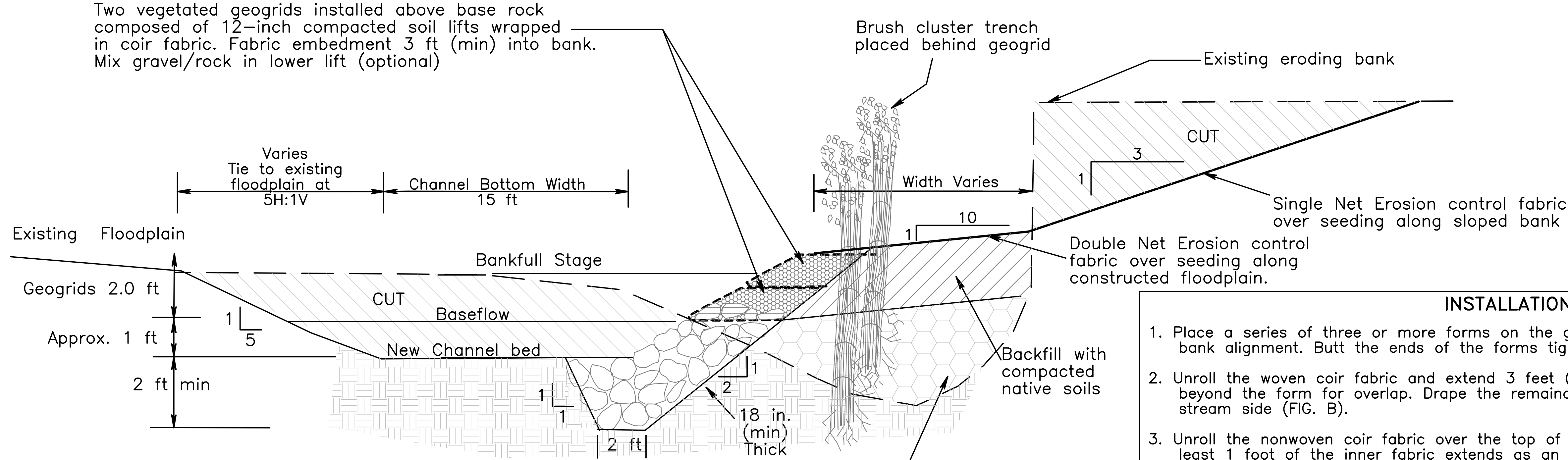
RECORD DRAWINGS

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07–143–AZ

SHEET: 11 of ~~21~~ 22



TYPICAL CROSS-SECTION

(Not to Scale)

BASE ROCK SPECIFICATIONS

Use well-graded, angular rock with bulk specific gravity greater than 2.5

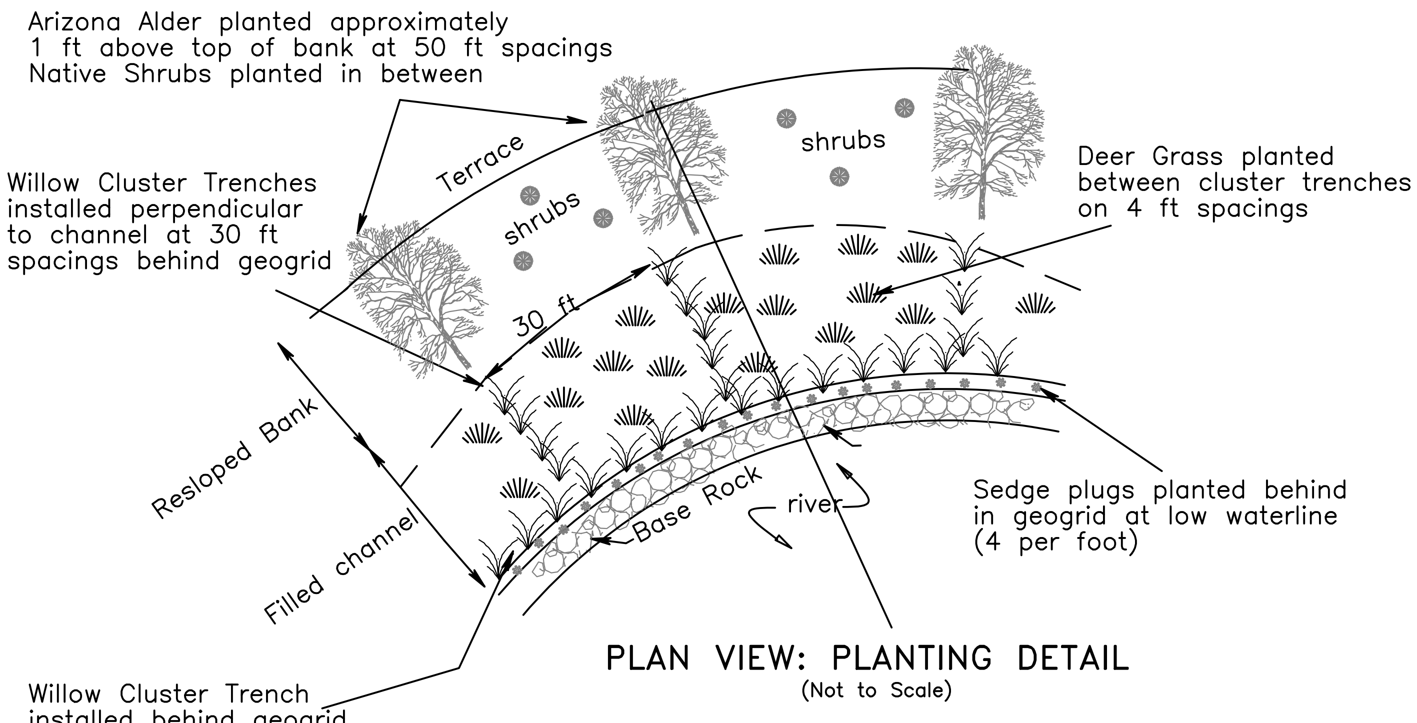
Gradation: Dmin = 6 in
D50 = 8 in
Dmax = 12 in

GEOGRID MATERIALS

Fill: Compacted topsoil or stone
Fabric: Nonwoven coir (inner) and woven coir (outer)
(Coconut erosion control banket shall be able to withstand 10 fps water velocities and 4.5 psf shear stress.)

INSTALLATION NOTES

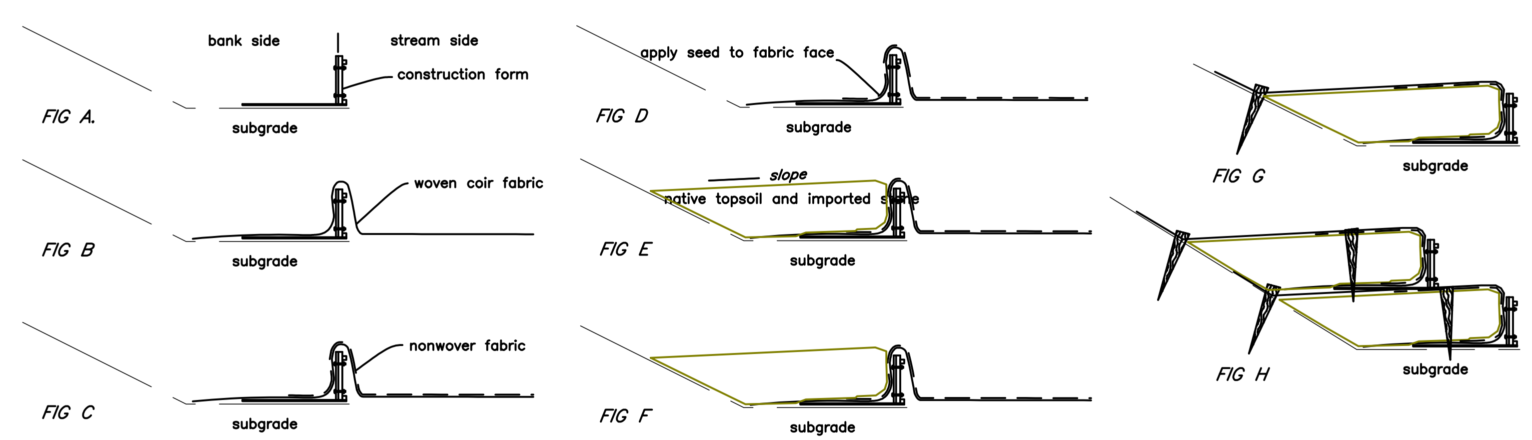
1. Place a series of three or more forms on the ground so that the forms follow the proposed stream bank alignment. Butt the ends of the forms tightly together.
2. Unroll the woven coir fabric and extend 3 feet (min) into bank (FIG. B), and 3 feet (min) extends beyond the form for overlap. Drape the remainder of the fabric over the top of the forms on the stream side (FIG. B).
3. Unroll the nonwoven coir fabric over the top of the woven coir fabric (FIG. B) and position so that at least 1 foot of the inner fabric extends as an embedment length on the bank side of the forms (FIG. C). Drape the remainder of the fabric over the top of the forms on the stream side and align the long edges of the coir fabrics. Stretch and pull the fabric layers to remove wrinkles.
4. Apply native seed mix to nonwoven coir fabric along vertical edge of lift (FIG. D). Place specified fill over the fabric on the bank side of the forms. Slope the fill downward to the bank and compact to 85–90 percent standard proctor density (FIG. E).
5. Apply native seed mix to top of fill from the front of the lift to 3 ft back from front of the lift (FIG. F).
6. Fold the loose ends of the two coir fabric layers back over the compacted fill material and stretch tightly to remove wrinkles (FIG. G). Secure with wooden stakes 1 per 3 L.F. Along the back edge and into undisturbed soil.
7. Remove the forms from the front of the completed lifts.
8. Proceed with a new series of lifts by extending a new row of forms.



PLAN VIEW: PLANTING DETAIL

(Not to Scale)

See SHEETS 14 and 15 for planting Details



DETAILS: Constructing Reinforced Earth Lifts

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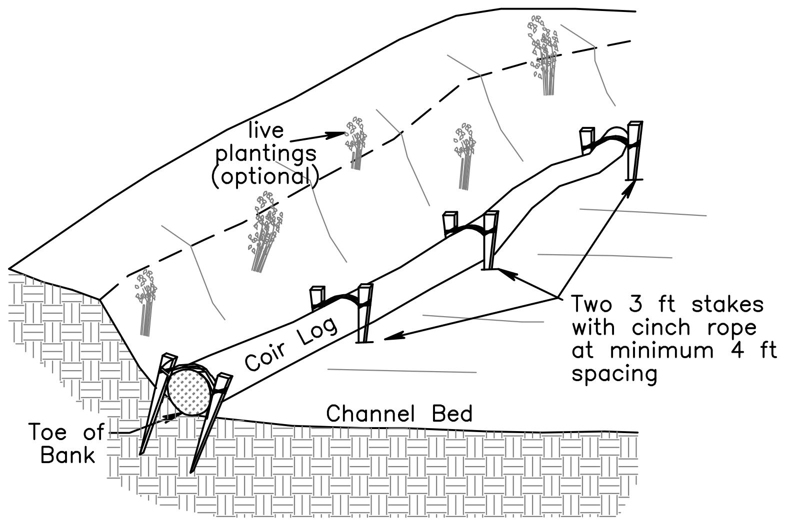
REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

DETAILS: Vegetated Geogrid with Base Rock & Channel Realignment (STA 14+25 to 15+40)

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

RECORD DRAWINGS

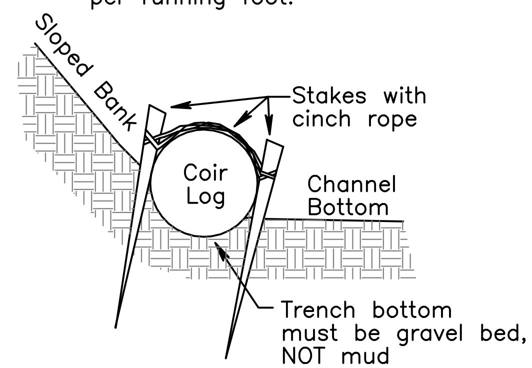
FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07-143-AZ
SHEET: 12 of ~~21~~ 22



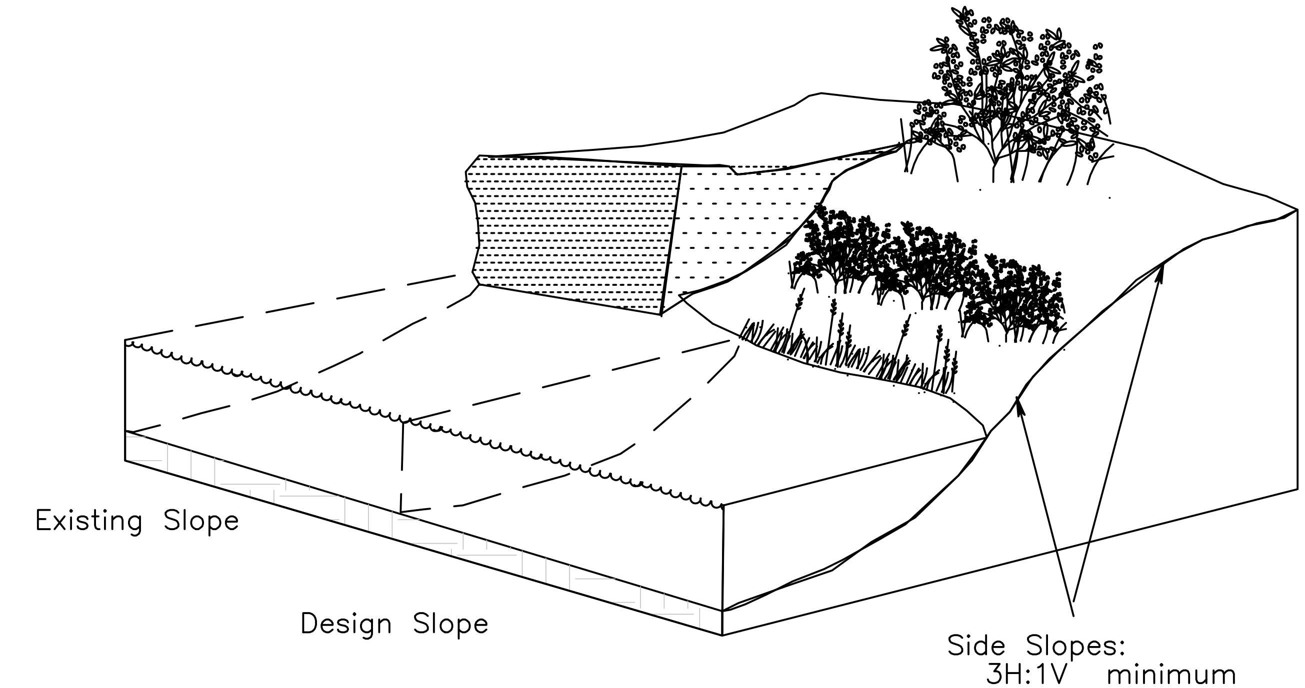
ISOMETRIC VIEW
(not to scale)

COIR LOG INSTALLATION

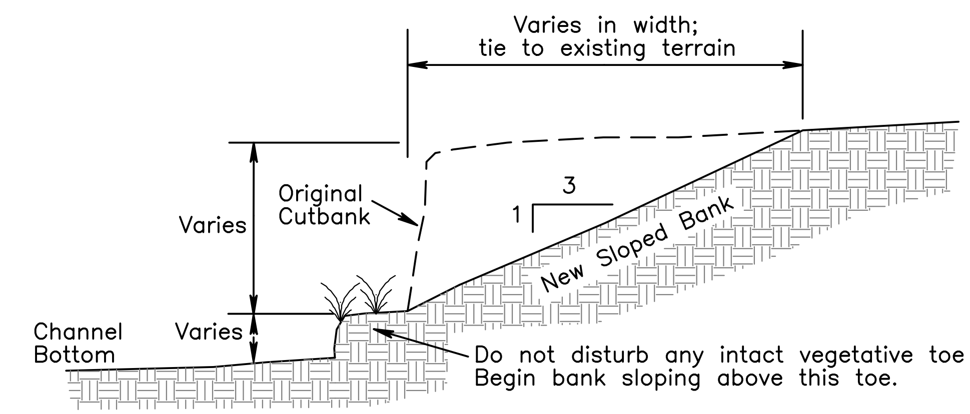
NOTES
1. Excavate shallow trench at toe of bank. Trench must be cleared of mud so log sits on gravel bed. Bury coir log no more than 1/2 log diameter.
2. Stitch ends of coir log segments together to make one long segment.
3. Place coir log into trench at toe of slope.
4. Stake coir log at 4 foot intervals utilizing two stakes with cinch rope.
5. Plant sedge plugs into coir log at 4 plugs per running foot.



SECTION VIEW
(not to scale)

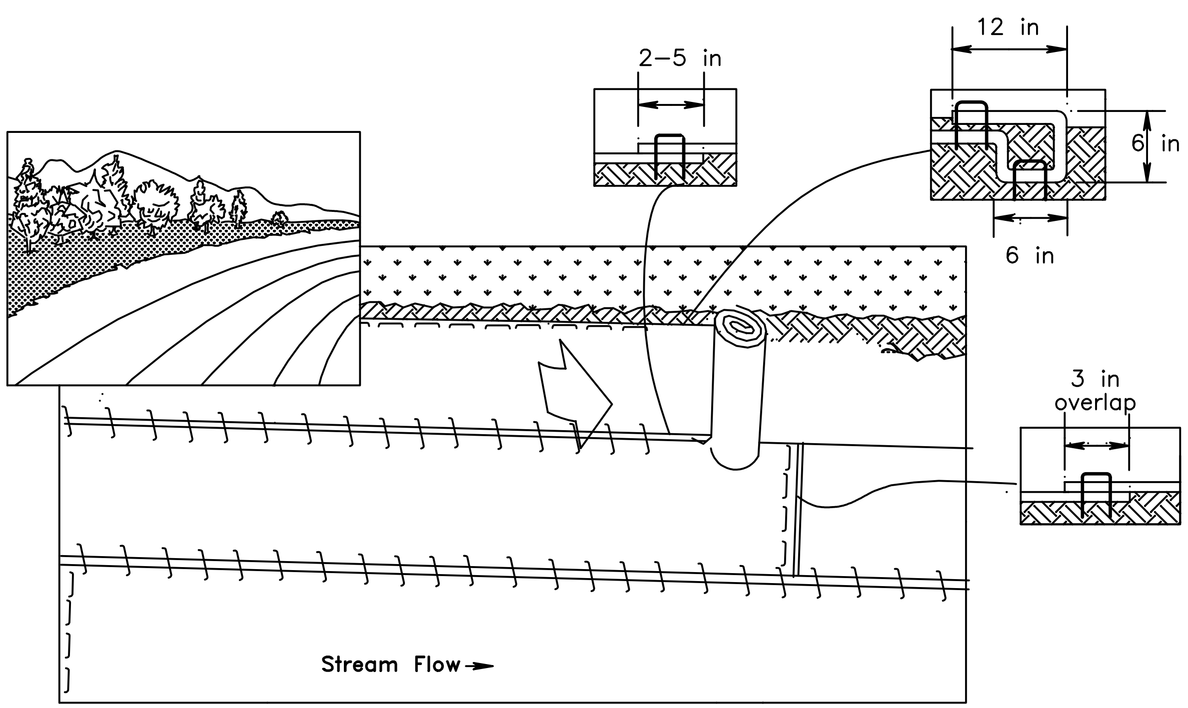


ISOMETRIC VIEW
(Not to Scale)



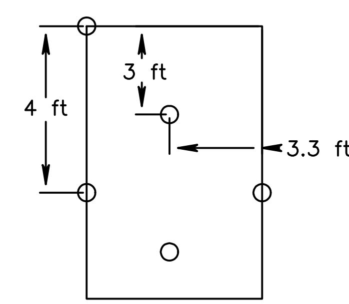
SECTION VIEW OF TOE
(Not to Scale)

BANK SLOPING



EROSION CONTROL FABRIC: SLOPE INSTALLATION

NOT TO SCALE



0.7 Staples per sq. yd.

STAPLE PATTERN

Natural Channel Design, Inc
206 S. Elden St.
Flagstaff, Arizona 86001
(928) 774-2336

DRAWN BY: M.Wirtanen, J.Sutton,R.Lyman

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

DETAILS: Bank Sloping, Erosion Control Fabric, Coir Log

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

RECORD DRAWINGS

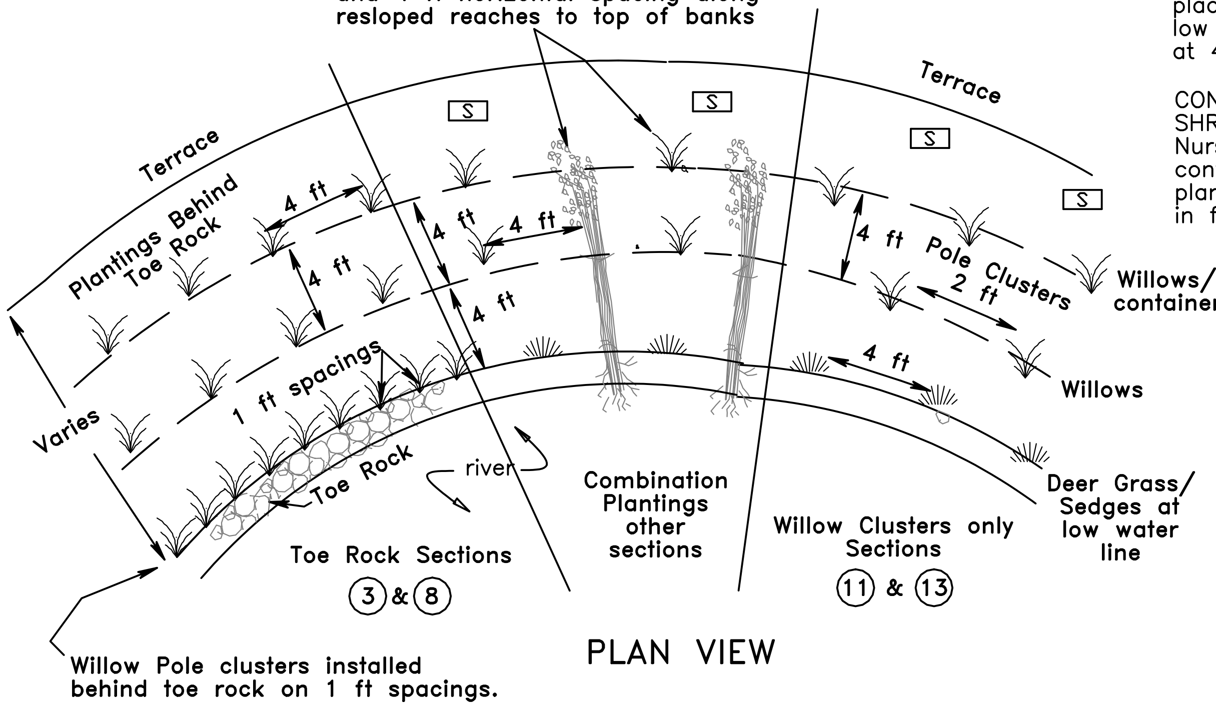
FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 13 of ~~21~~ 22

NOTES:
DRAWING NOT TO SCALE



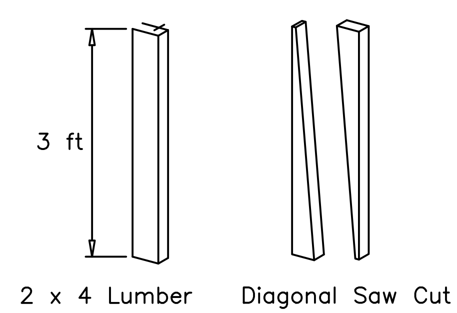
PLAN VIEW

DEER GRASS OR SEDGES
Containerized plants placed along bank at low water elevation at 4 ft spacings

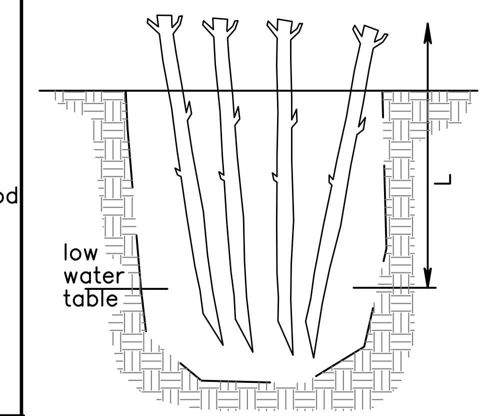
CONTAINERIZED SHRUBS
Nursery derived containerized stock planted as indicated in field

POLE CLUSTERS
Dormant native poles placed in augered cluster holes at 2 ft alternate spacings. (Cluster rows @ 1 ft spacings.)

Species Willows, Dogwood
Dia 1/2 to 2 in.
Length 6 to 8 ft.



DEAD STOUT STAKES



POLE CLUSTERS

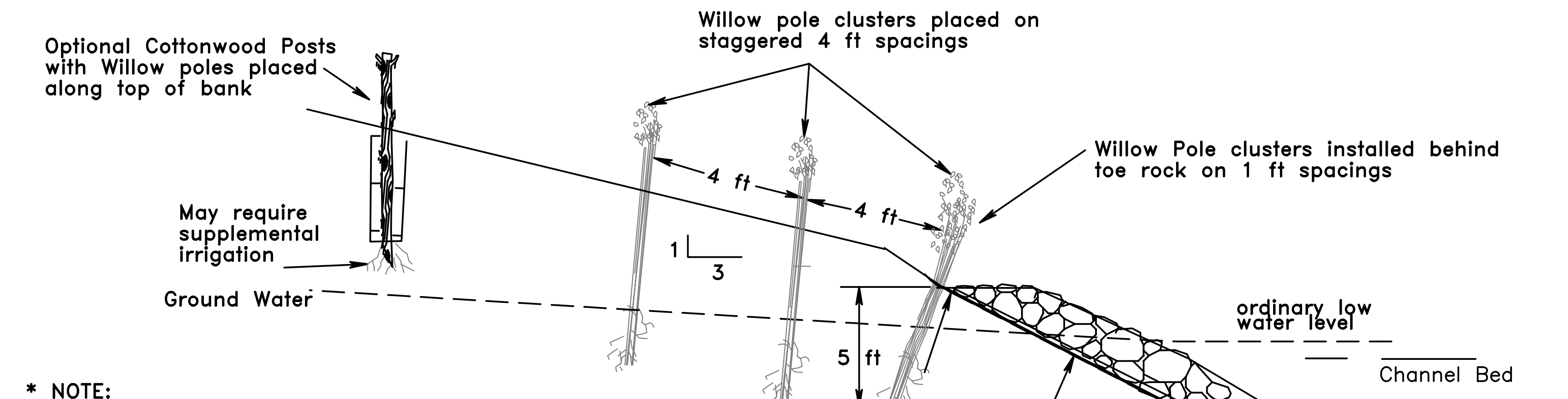
NOTES
Use 1/2–2 in. cuttings.
In holes excavated with an auger, place approximately 4 cuttings in hole to maximize sprouting success.
Holes are backfilled with excavated material and watered.

NOTES

1. Cuttings shall be dormant, stripped of side branches, and soaked 3 to 7 days.
2. Cuttings shall be 3/4 to 2 inches in diameter and typically 3–6 stems per bundle or cluster.

VERTICAL BUNDLES

1. Bundles shall be tied with untreated twine about every 2 feet.
2. Excavate a vertical trench with a slope of 3:1 or more in the streambank.
3. Make sure the bottom of the trench will still be under water during low flows.
4. The trenches should be excavated on 4 foot centers alternating with willow clusters to ensure adequate protection and to encourage rapid growth to fill in the bank.
5. Place bundle in the trench with the cut ends in the water.
6. Secure bundles to back of trench with wooden stakes at about 3 foot spacings.
7. "Muddy" in bundles with water and soil (covering the bundles 1 to 2 inches deep)
8. Leave approximately 30 percent of upper branches exposed.
9. Tops of cuttings are cut off after placement.



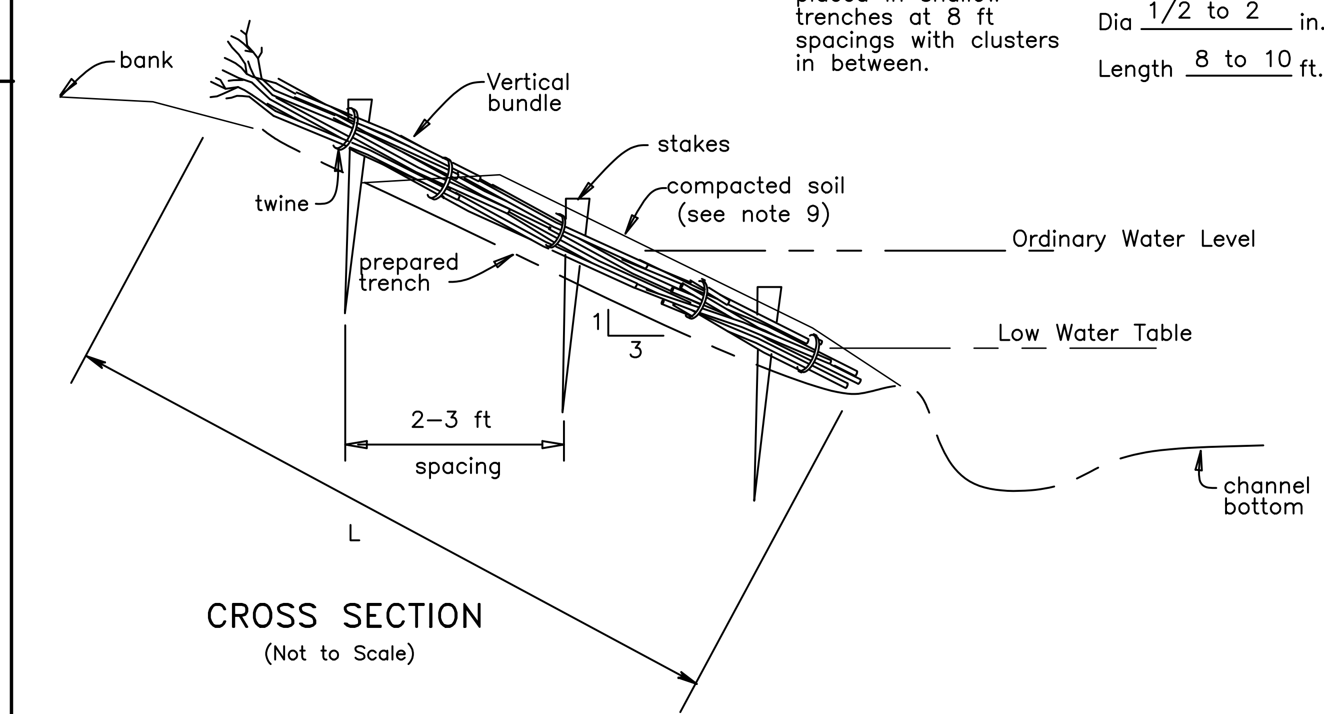
* NOTE:
All plantings must be installed to groundwater or provided with supplemental irrigation.

PLANTING SECTION VIEW
(Not to Scale)

VERTICAL BUNDLES

Dormant native poles placed in shallow trenches at 8 ft spacings with clusters in between.

Species Willows
Dia 1/2 to 2 in.
Length 8 to 10 ft.



CROSS SECTION
(Not to Scale)

REFERENCES:
Practical Streambank Bioengineering Guide (1998–NRCS ID PMC)
Streambank and Shoreline Protection, EFH–16 (1996–NRCS)
USDA NRCS Oregon Standard Drawing No. OR–A–533A1
USDA NRCS Oregon Standard Drawing No. OR–A–520A
USDA NRCS Washington Standard Drawing No. WA–BIO–0030

Spacing of Plantings

VERTICAL BUNDLES

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Flagstaff, Arizona 86001
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DRAWN BY: M.Wirtanen, J.Sutton, R.Lyman
DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

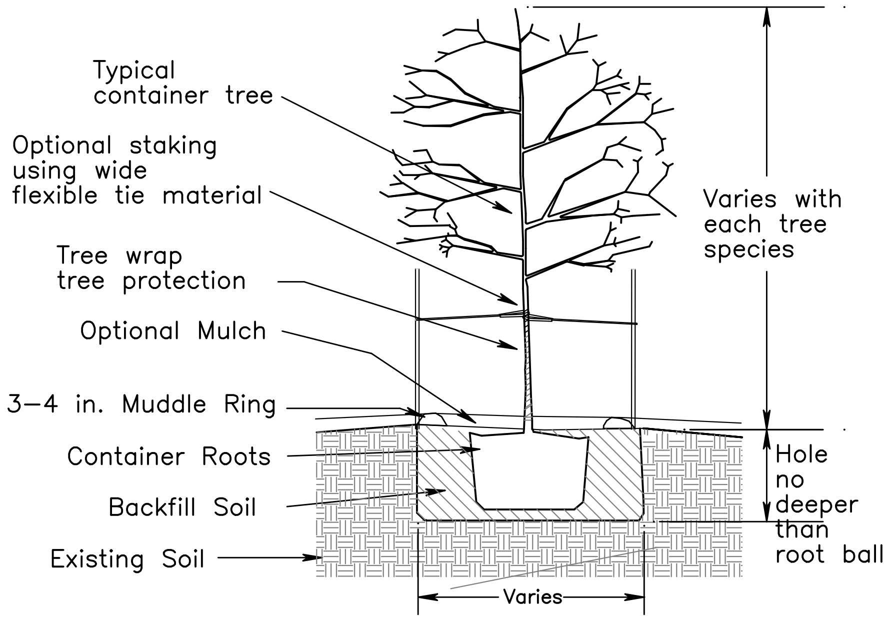
REV	DATE	BY	REVISION
1	3–14–13	CS	RECORD DRAWINGS

DETAILS: Pole Clusters and Vertical Bundles

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

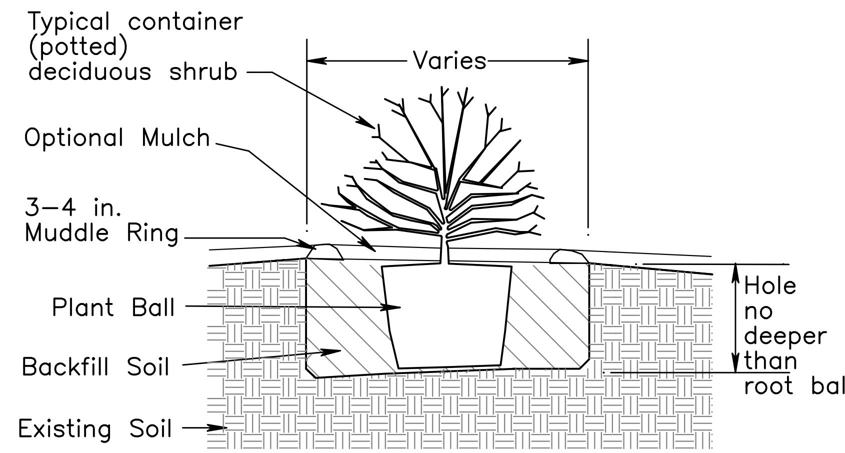
RECORD DRAWINGS

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07–143–AZ
SHEET: 14 of ~~21~~ 22



CONTAINER/POTTED DECIDUOUS TREE DETAIL

NOTE: Prune shrub as recommended by grower only after the plant has been watered in to the planting soil



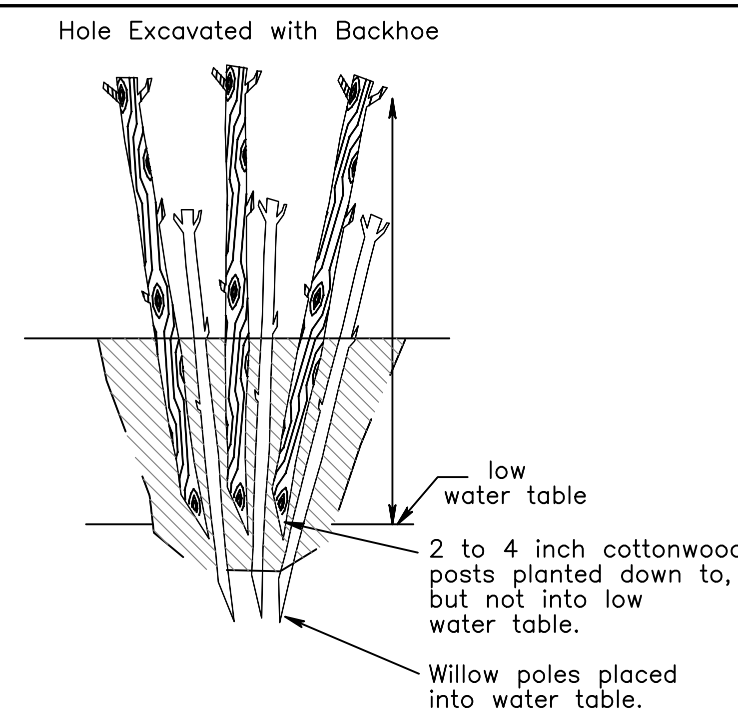
CONTAINER SHRUB PLANTING DETAIL

CONTAINER PLANTING NOTES

1. Excavate hole a minimim of 2 times root ball diameter and only as deep as the root ball height. If planted too deeply, roots will have difficulty developing due to lack of oxygen. It is better to plant the tree a little high (2-3 inches above the base of the trunk flare) than to plant it at or below the original growing level.
2. Remove container and inspect root ball for circling roots and cut or remove them. Place plant into hole. To avoid damage when setting the tree or shrub in the hole, always lift tree by the root ball, never by the trunk.
3. Fill the hole around root ball about 1/3 full and gently but firmly pack the soil around base of root ball. If necessary, remove any fabric, wire or string wrapping from around the root ball.
4. Fill remainder of the hole, taking care to firmly pack soil to eliminate air pockets what may cause roots to dry out. If necessary, add a few inches of soil and settle with water. Continue until hole is filled and tree is firmly planted.
5. Stake trees if necessary for support if windy conditions are a concern. Two opposing stakes are used in conjunction with a wide, flexible tie material on the lower half of the tree. This holds the tree upright and provides flexibility while minimizing injury to the trunk. Remove stakes after the first year of growth.
6. Place mulch around base of tree. Mulch is organic matter applied around the base of the plant. It acts as a blanket to hold moisture, moderates soil temperature and reduces competition from grasses or forbs. Mulch can be leaf litter, pine straw, shredded bark or composted wood chips. (Do not use fresh, uncomposted wood chips since this can attract termites, harbor fungus and can rob nutrients from the soil as they decompose). A 2 to 4 inch layer is ideal, since more than 4 inches can cause problems with oxygen and moisture levels. Be sure that the actual trunk of the plant is not covered since it can cause decay of the bark at the base of the tree.

POST PLANTING NOTES

1. Holes for post plantings should be a minimum of 2 ft x 4 ft. and dug down to the water table.
2. Cottonwood posts should be 2 to 4 inch diameter and long enough to extend from the water table to a minimum of 1 foot above top of back filled hole. A minimum of 3 cottonwood posts to be placed in each hole.
3. A minimum of 9 willow poles, 1/2 to 2 inch dia. should also be placed into each hole. These should be a shrub type willow, not a tree species.
4. Cottonwood posts should be placed down to approximately four to six inches above the water table (never into saturated soils). Willows should extend into the water table.
5. Backfill posts, ensuring posts and poles remain upright and spaced apart. For fine grained clayey soils, it may be necessary to add up to 50% small gravels (d50 50mm) and sand to amend and loosen the soil.
6. Thoroughly water the plantings.



POST PLANTING DETAIL

Containerized Plantings

The following list contains potential plant species which may be planted. See SHEET 19 for Planting Layout

TREE
Cottonwood – *(Populus angustifolia)*
Arizona Sycamore – *(Platanus wrightii)*
Weeping Willow – *(Salix x sepulcuia)*
Navajo or Globe Willow – *(Salix matsudana)*
Arizona Alder – *(Alnus oblongifolia)*
Box Elder – *(Acer negundo)*
Rocky Mountain Maple – *(Acer glabrum)*
Thinleaf Alder – *(Alnus tenuifolia)*
Water Birch – *(Betula occidentalis)*

SHRUB
Coyote Willow – *(Salix exigua)*
Strapleaf Willow – *(Salix ligulifolia)*
Redosier Dogwood – *(Cornus sericea)*
New Mexican Locust – *(Robinia neomexicana)*
Blackbead Elder – *(Sambucus melanocarpa)*
Fendler Ceanothus, Fendler Buckbrush – *(Ceanothus fendleri)*
Mountain Snowberry – *(Symphoricarpos oreophilus)*
Utah Serviceberry – *(Amelanchier utahensis)*
Common Chokecherry – *(Prunus virginiana vars. demissa & melanocarpa)*
Roundleaf Buffaloberry – *(Shepherdia Rotundifolia)*
Arizona Honeysuckle – *(Lonicera arizonica)*
Three-leaf Sumac – *(Rhus trilobata)*

RECORD DRAWINGS

Natural Channel Design, Inc
206 S. Elden St.
Flagstaff, Arizona 86001
(928) 774-2336

DRAWN BY: M.Wirtanen, J.Sutton, R.Lyman

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

DETAILS: Containerized Plants & Post Plantings

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

REFERENCE:
Practical Streambank Bioengineering Guide (1998-NRCS C.Hoag, ID PMC)
International Society of Arboriculture

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
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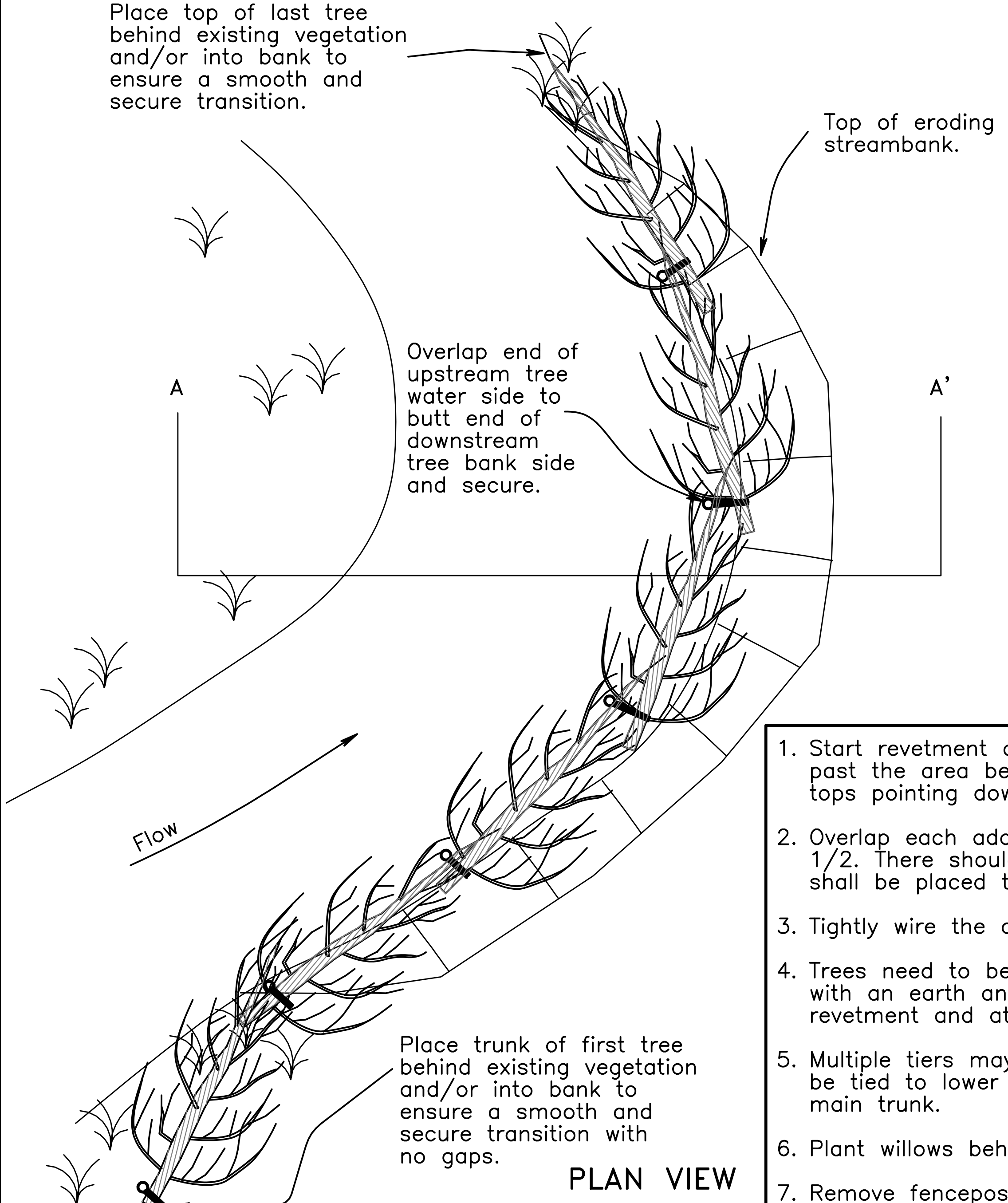
SHEET: 15 of ~~21~~ 22

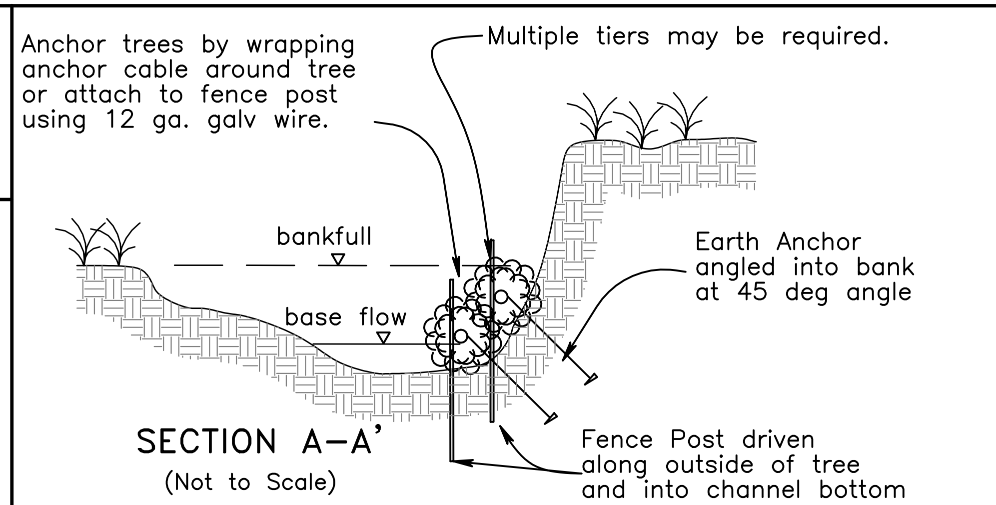
BRUSH REVETMENT

Provides temporary physical protection to toe of bank by moving current away from bank. This practice also traps sediment and provides overhead cover for fish habitat.



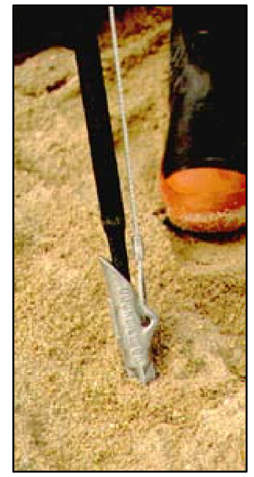
PLAN VIEW

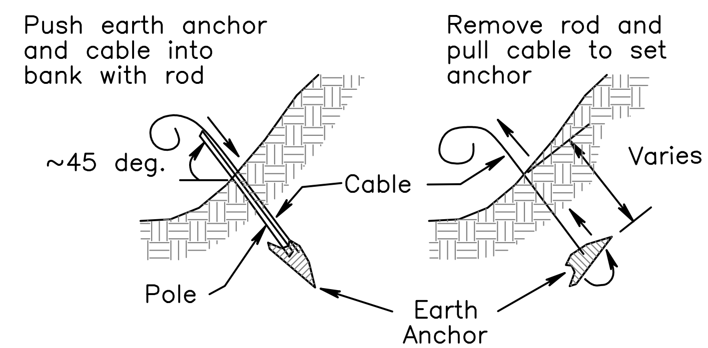
(Not to Scale)



SECTION A–A'

(Not to Scale)





EARTH ANCHOR INSTALLATION

(Not to Scale)

Installation of Brush Revetment anchoring with fence posts

Brush Revetment close–up

NOTES

1. Start revetment at the downstream end of the treatment area, a minimum of one tree length past the area being treated and tie into the bank. Place tree stump pointing upstream and tops pointing downstream.
2. Overlap each additional tree trunk into the main branches of the preceeding tree by 1/3 to 1/2. There should be no gaps or holes in the coverage of the bank. Each upstream tree trunk shall be placed to the river side of the preceeding tree in a shingle fashion.
3. Tightly wire the overlap sections with 12 gauge galvinized wire.
4. Trees need to be well anchored to withstand the force of the river. Each tree shall be anchored with an earth anchor, fence post, or rock bolster. Anchor points include each end of the revetment and at each overlap section at a minimum. Earth anchors shall be angled into bank.
5. Multiple tiers may be required to protect against higher flows. Upper tiers shall be tied to lower tiers. Fill in any spaces with additional branches and secure to main trunk.
6. Plant willows behind revetment to provide permanent cover and roots.
7. Remove fencepost in 2–3 years once toe is stable.

MATERIALS & EQUIPMENT

- dead/live brush or trees with dense branching (e.g. junipers) min. 6 to 8 ft length or longer
- 12 gauge galvinized wire
- 6ft fence t–posts
- earth anchors & installation rod
- wire cutters
- post pounder
- chainsaw

RECORD DRAWINGS

Natural Channel Design, Inc

206 S. Elden
Flagstaff, Arizona 86001
(928) 774-2336

DRAWN BY: R.Lyman, S.Yard

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3–14–13	CS	RECORD DRAWINGS

DETAIL: Brush Revetment

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

REFERENCES:
Practical Streambank Bioengineering Guide (1998–NRCS C.Hoag, ID PMC)
USDA NRCS Utah Standard Drawing ConiferRev.dwg

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

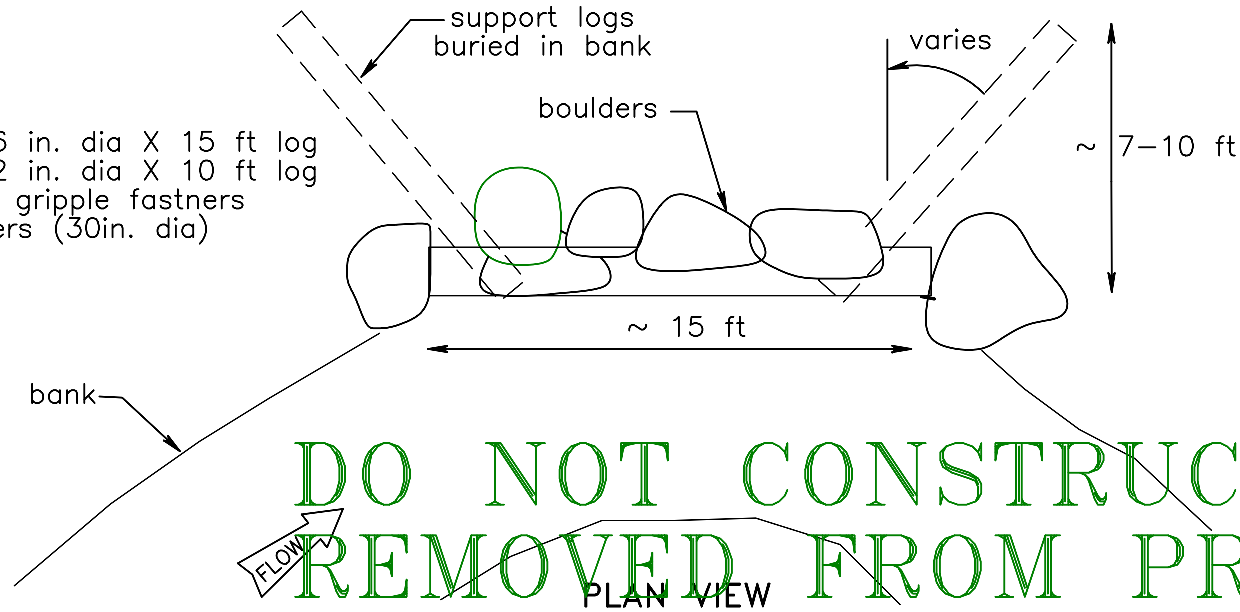
PROJECT NO:

SHEET: 16 of ~~21~~ 22

LOG OVERHANG STRUCTURE

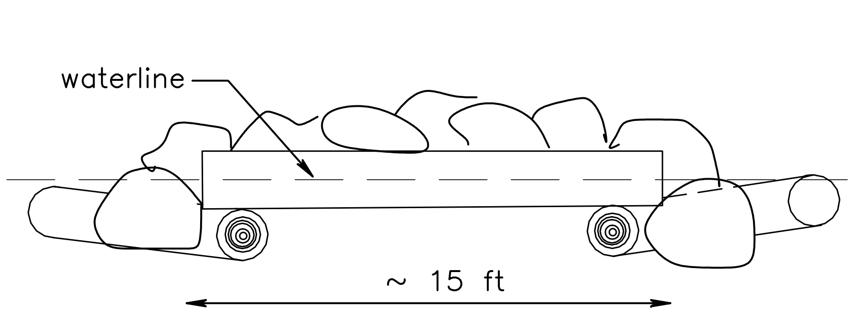
MATERIALS

1 ea	12–16 in. dia X 15 ft log
2 ea	10–12 in. dia X 10 ft log
6 ea	No. 2 gripple fastners
12 ea	Boulders (30in. dia)

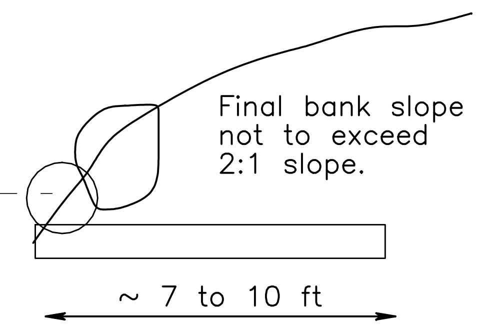


PLAN VIEW
(Not to scale)

DO NOT CONSTRUCT FISH STRUCTURES
REMOVED FROM PROJECT



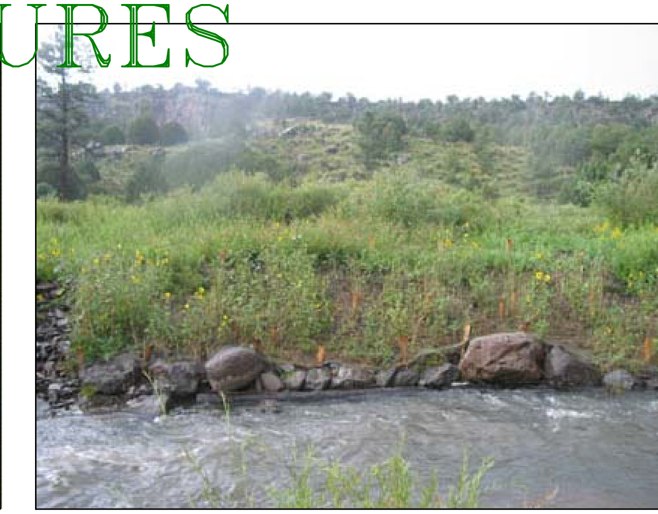
FRONT VIEW
(Not to scale)

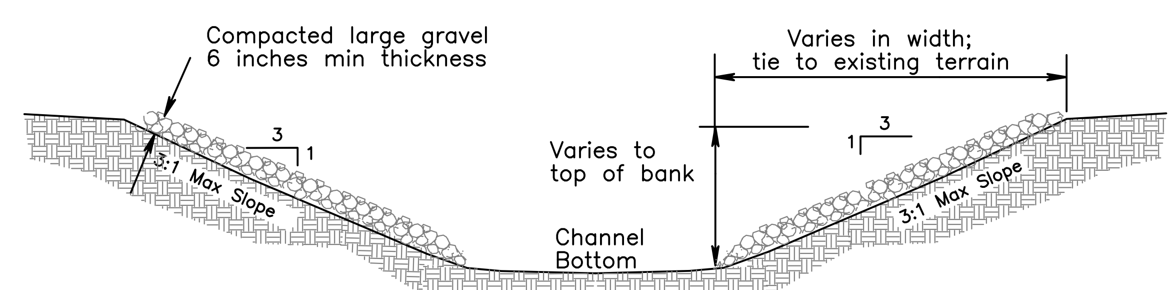


SIDE VIEW
(Not to scale)

INSTALLATION:

Install along the outside of bend with higher banks.
Excavate trenches for footer logs down to stream bottom elevation without disturbing bank at center of structure.
Set footer logs so they extend the width of top log into the stream.
Notch top of footer logs with chainsaw to accommodate top log.
Set top log and snchor to stream bank with gripple fastners.
Fill footer trenches and place ballast rock between top log and bank, as well as at ends of structure.
Regrade and replant bank with native vegetation.
Boulder clusters can be placed in stream in front of structure to break up current.





SECTION VIEW
(Not to Scale)

LIVESTOCK CROSSING

RECORD DRAWINGS

Natural Channel Design, Inc
206 S. Elden
Flagstaff, Arizona 86001
(928) 774-2336

DRAWN BY: A.Haden, R.Lyman

DESIGNED BY: A.Haden, S.Yard

REV	DATE	BY	REVISION
1	Aug 08	MW	Removed from Project
2	3-14-13	CS	RECORD DRAWINGS

DETAIL: Fish Structure & Livestock Crossing

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ

SHEET: 17 of ~~21~~ 22

BOULDER CLUSTERS

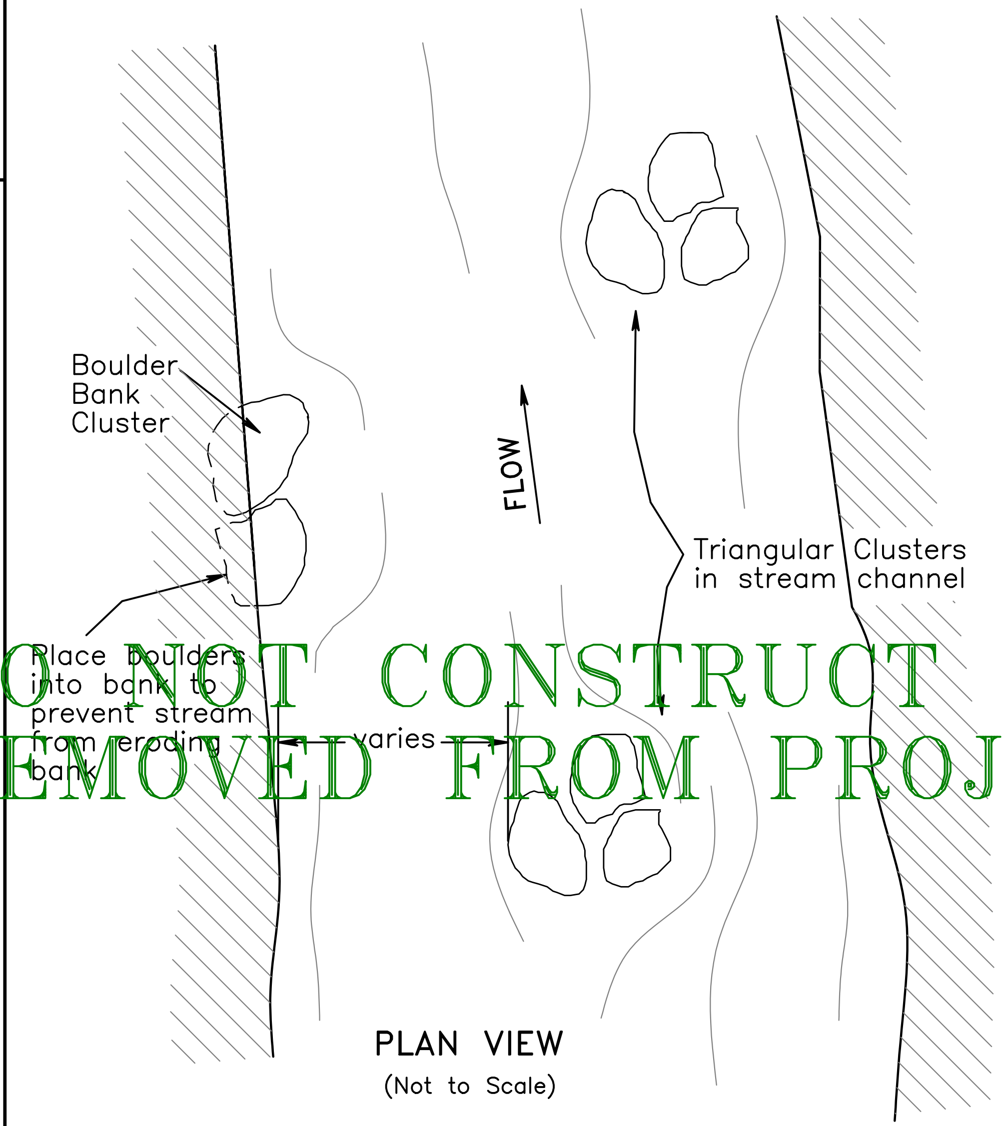
Provides overhead cover and creates scour pockets around boulders, builds quiet water resting areas, and sorts spawning gravel.

INSTALLATION NOTES

1. Minimize disturbance to the stream and adjoining areas by scheduling the work when it will interrupt aquatic plants and animals the least.
2. Select stable stream reaches which are not likely to degrade and undermine rock placements.
3. Boulders cluseters can be placed along the channel edge and in the middle half of the channel (where deposition is not expected to occur).
4. Boulders can be placed in riffles, runs, flats, glides, and open pools.
5. A suggested spacing of clusters within the same stream segment is one–third of the stream width apart, placed in a manner to break up high velocity flows.
6. Avoid locations where placement could divert the steam channel's thalweg or threaten impingement on potentially unstable stream banks.
7. Boulders shall be large 1 to 3 ft, irregularly shaped; angular rock locks together better and provides the most hiding spaces.
8. Embed the boulders a short distance into the stream bed in a triangular pattern with spaces between the boulders ranging from 6 in. to 1 ft. This spacing provides cover and other habitat niche needs, and ensures the creation of scour pockets. Top of boulders should be below bankfull elevation.
9. Boulder clusters provide overhead cover and create deep areas which are used by juvenile fish as resting areas.
10. They can restore meanders in channelized reaches, protect eroded banks by deflecting flow, and improve gradation of substrate materials.

RECORD DRAWINGS

DO NOT CONSTRUCT
REMOVED FROM PROJECT



PLAN VIEW
(Not to Scale)

Generally, a group of boulders are placed either randomly or selectively, in clusters and/or individually (depending on the pattern of natural boulders in the reach), at strategic points along a channel bed and along the channel fringe. Clusters are located in straight, stable, moderately to well–confined low–gradient riffles (0.5 to 1 slope) for spawning gravel enhancement; they are also placed in higher gradient riffles (1 to 4 percent) to improve rearing habitat and provide cover. At least 1 to 3 foot diameter boulders are recommended, except in very small streams.

Boulder clusters at various locations in stream.

Closeup of Rock Cluster

MATERIALS & EQUIPMENT

1 ea – Three foot boulder
2 ea – Two foot boulders
3 ea – One foot boulders

Excavator with thumb attachment

Natural Channel Design, Inc
206 S. Elden
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(928) 774-2336

DRAWN BY: A.Haden, R.Lyman

DESIGNED BY: A.Haden, S.Yard

REV	DATE	BY	REVISION
1	Aug 08	MW	Removed from Project
2	3-14-13	CS	RECORD DRAWINGS

Fish Habitat DETAIL: Boulder Clusters

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

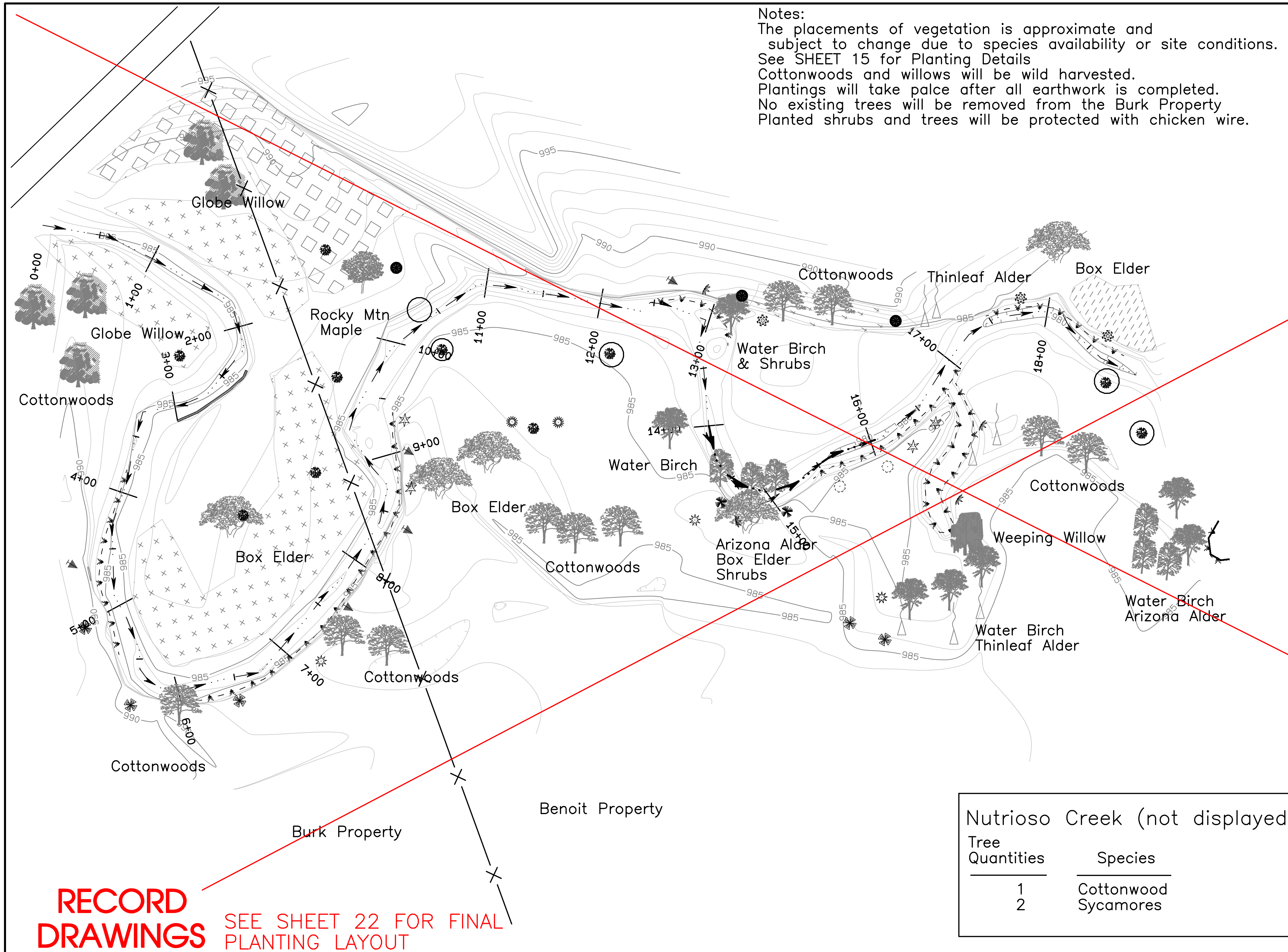
SOURCE:
Stream Corridor Restoration Handbook, USDA, 1998.
USDA NRCS California Drawing No. CA–NSTR1

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07–143–AZ

Notes:
The placements of vegetation is approximate and subject to change due to species availability or site conditions.
See SHEET 15 for Planting Details
Cottonwoods and willows will be wild harvested.
Plantings will take palce after all earthwork is completed.
No existing trees will be removed from the Burk Property
Planted shrubs and trees will be protected with chicken wire.



PLANT LEGEND

EXISTING TREES

- Siberian Elm
- Russian Olive

- Mixed Deciduous Trees/Shrubs
- Dense Coyote Willow
- Mixed native roses/deciduous shrubs
- low density native shrubs

TREES – 1 container plant per symbol unless noted

	Benoit Property	Burk Property
Cottonwood (3 posts/planting)	24 ea	9 ea
Arizona Sycamore	2 ea	0 ea
Weeping Willow	1 ea	0 ea
Navajo or Globe Willow	0 ea	5 ea
Arizona Alder	6 ea	0 ea
Box Elder	4 ea	1 ea
Rocky Mountain Maple	1 ea	0 ea
Thinleaf Alder	7 ea	0 ea
Water Birch	7 ea	0 ea
Total No. Containers	28	6

SHRUBS – 2 container plants per symbol (except for willows)

Coyote/Strapleaf Willow (4 poles/planting)	2460 ea	1040 ea
Redosier Dogwood	10 ea	0 ea
New Mexican Locust	6 ea	4 ea
Blackbead Elder	8 ea	0 ea
Fendler Ceanothus	4 ea	0 ea
Mountain Snowberry	4 ea	0 ea
Utah Serviceberry	6 ea	0 ea
Common Chokecherry	4 ea	2 ea
Roundleaf Buffaloberry	8 ea	0 ea
Arizona Honeysuckle	4 ea	0 ea
Three Leaf Sumac	4 ea	6 ea
Total No. Containers	58	12

Nutrioso Creek (not displayed)

Tree Quantities	Species
1	Cottonwood
2	Sycamores

RECORD DRAWINGS

SEE SHEET 22 FOR FINAL PLANTING LAYOUT

Natural Channel Design, Inc
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(928) 774-2336

DRAWN BY: M.Wirtanen, J.Sutton,R.Lyman

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	4-14-08	MW	Tree quantities
2	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW: Planting Layout for Shrubs & Trees

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1 in = 100 ft

100 0 100

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

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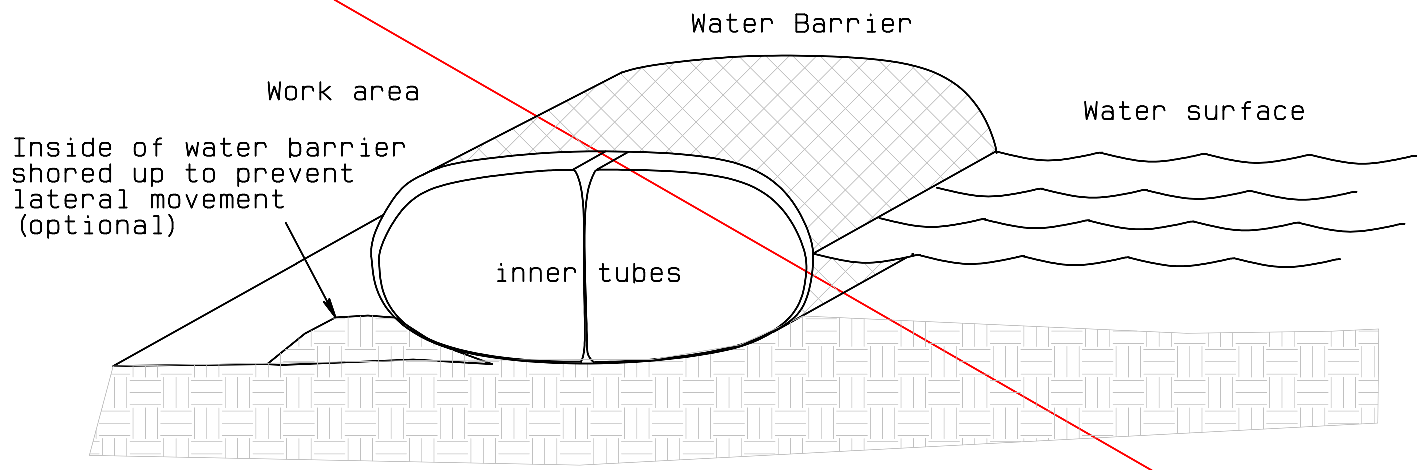
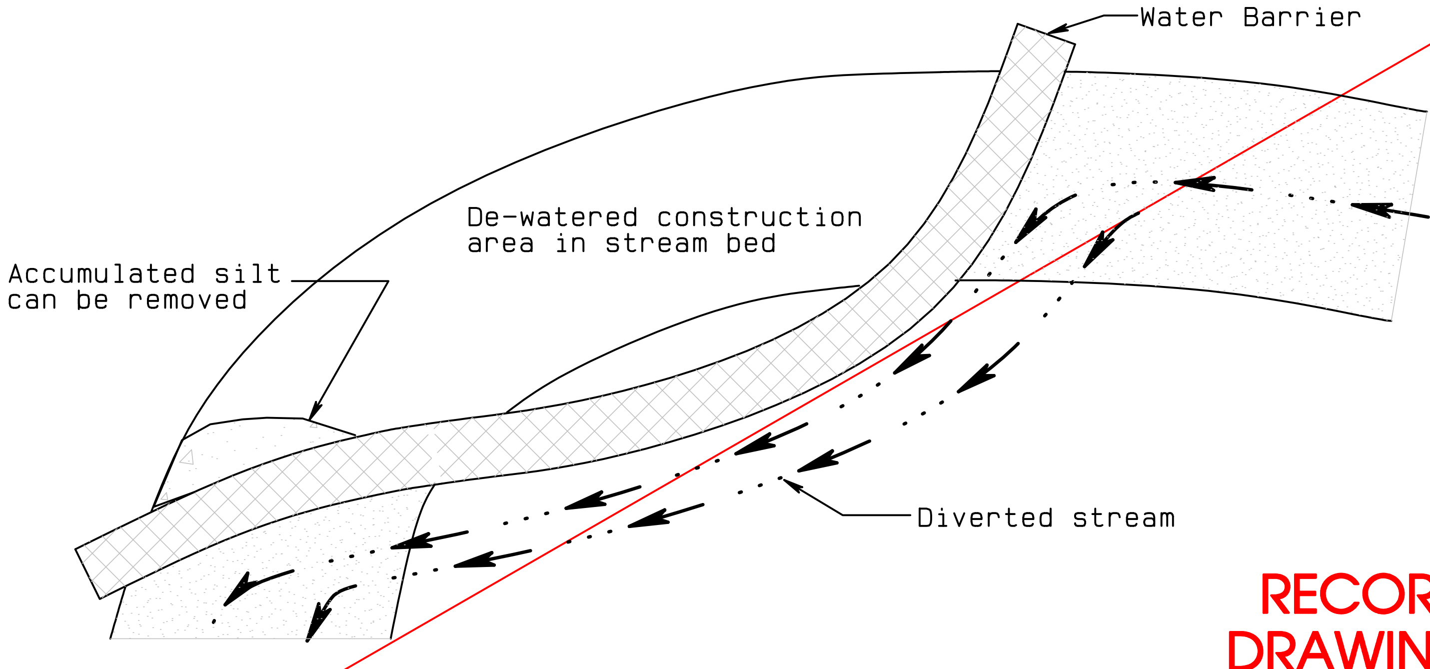
Typical Cross-Section
(not to scale)



DID NOT USE WATER BARRIER DURING CONSTRUCTION

Typical Plan View
(not to scale)



RECORD DRAWINGS

Dewatering is the removal of water from the project area to minimize impacts during excavation or other activities. Water shall be temporarily removed using a water filled barrier diversion combined with supplemental pumping.

Water Barrier Installation Sequence

1. Clear water barrier installation path of all debris, large angular rocks, sharp objects and tree branches to ensure a good seal. Observe the installation path for holes, obstructions or washed out areas which could cause problems.

2. Position the end of the water barrier master tube on the bank at least a foot above the final height of the full water barrier (unless manufactured with a closed end). The opposite end of the water barrier will also have to be higher than the water level inside the barrier after inflation. A small amount of fill material can be placed to create a berm if the existing bank height is insufficient.

3. Secure the corners at the end of the water barrier to a rock or tree to prevent the barrier from slipping down the bank slope.

4. The discharge hoses from two portable gas powered pumps should be inserted into the inner fill tubes of the water barrier (a single gas powered pump can also be alternated between fill tubes) and duct taped or tied with rope so that the discharge hoses don't slip out. The river can be used as a water source for the pumps.

5. Laborers should stand behind the rolled water barrier at the toe of the bank or waters edge. Water should be pumped into both fill tubes at the same rate. This will cause the water barrier to push against the laborers as it trys to unroll. The rolled water barrier should be held in place as the water level inside the tube rises and builds pressure. Once the water barrier inflates to the proper height, the labors should step back in unison allowing the barrier to unroll further, then hold it in place while it again inflates to the proper height. This process continues until the water barrier is completely inflated.

6. Continue to check the area in front of the unrolling barrier for hidden debris or other sharp objects in the stream.

7. Subsurface water in the toe trench shall be removed by pumping. Sediment–laden water which needs to be dewatered shall be pumped through a geotextile material before it is discharged to the watercourse.

General Installation Notes

Two to four laborers are typically required to install a water barrier with, an additional laborer operating the pumps.

Water levels inside the water barrier should be higher than the depth of the stream at the upstream side of the barrier. As the water barrier unrolls, it will constrict the stream causing the stream depth to increase. The pressure of the water mass inside the water barrier must be greater than the pressure of the stream on the upstream side of the barrier to prevent it from moving downstream.

For a water barrier that is four or more feet in height, restraining ropes are typically used to prevent the barrier from unrolling as it is inflated. The ropes should be twice the length of the water barrier plus 50 feet. Prior to pumping water into the barrier, one end of the ropes should be secured to trees or metal posts at the starting place. Each rope is run under the rolled barrier then back over the top of the roll to the starting point.

Let out ropes 2–3 feet at a time to allow the pressure inside the water barrier to continue building as it unrolls across the stream. The ropes can be wrapped around the trees or metal posts to gain mechanical advantage. Typically, the ropes move to the outside of the rolled barrier and must be adjusted by the laborers back to the center of the roll. One rope can hold the roll in place while the other is adjusted.

Safety Considerations

Each laborer should carry a utility knife for safety reasons. If a laborer becomes trapped under the aqua barrier as it is unrolled, a single long, lateral slice should be made in the upstream side of the barrier to drain it and allow it to move off of the trapped worker.

Natural Channel Design, Inc
206 S. Elden St.
Flagstaff, Arizona 86001
(928) 774-2336

DRAWN BY: J. Sutton

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

DETAILS: Dewatering

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

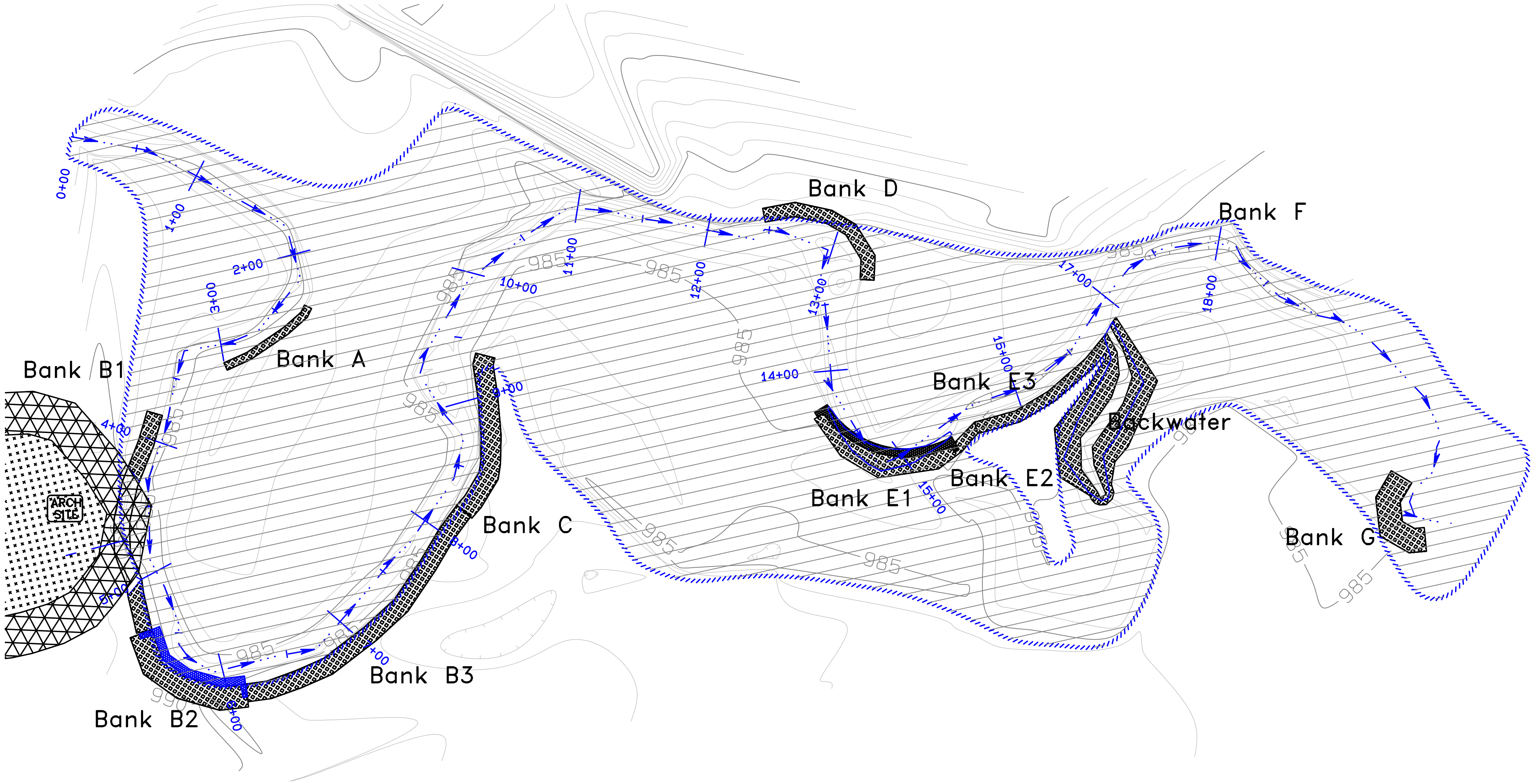
FILE NAME: LCR Benoit.pro

PROJECT NO: 07-143-AZ

DATE: Mar 11, 2008

SHEET: 20 of ~~21~~ 22

RECORD DRAWINGS



Note:
Contour Intervals: 1 ft
Ordinary High Water Mark determined at 2x max bankfull depth (approximate 5 year flow)
Area within Ordinary High Water Mark = 6.2 acres
Area of disturbance due to project activities = 0.6 acre

LEGEND

	Reslope Banks, Seed, Fabric
	Toe Rock, Willow trench
/////////////	Ordinary High Water Mark

Natural Channel Design, Inc
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DRAWN BY: R.Lyman, S.Yard

DESIGNED BY: E.J.Ruther, M.Wirtanen, T.Moody, S.Yard

REV	DATE	BY	REVISION
1	3-14-13	CS	RECORD DRAWINGS

PLANVIEW: Delineation of Jurisdictional Area

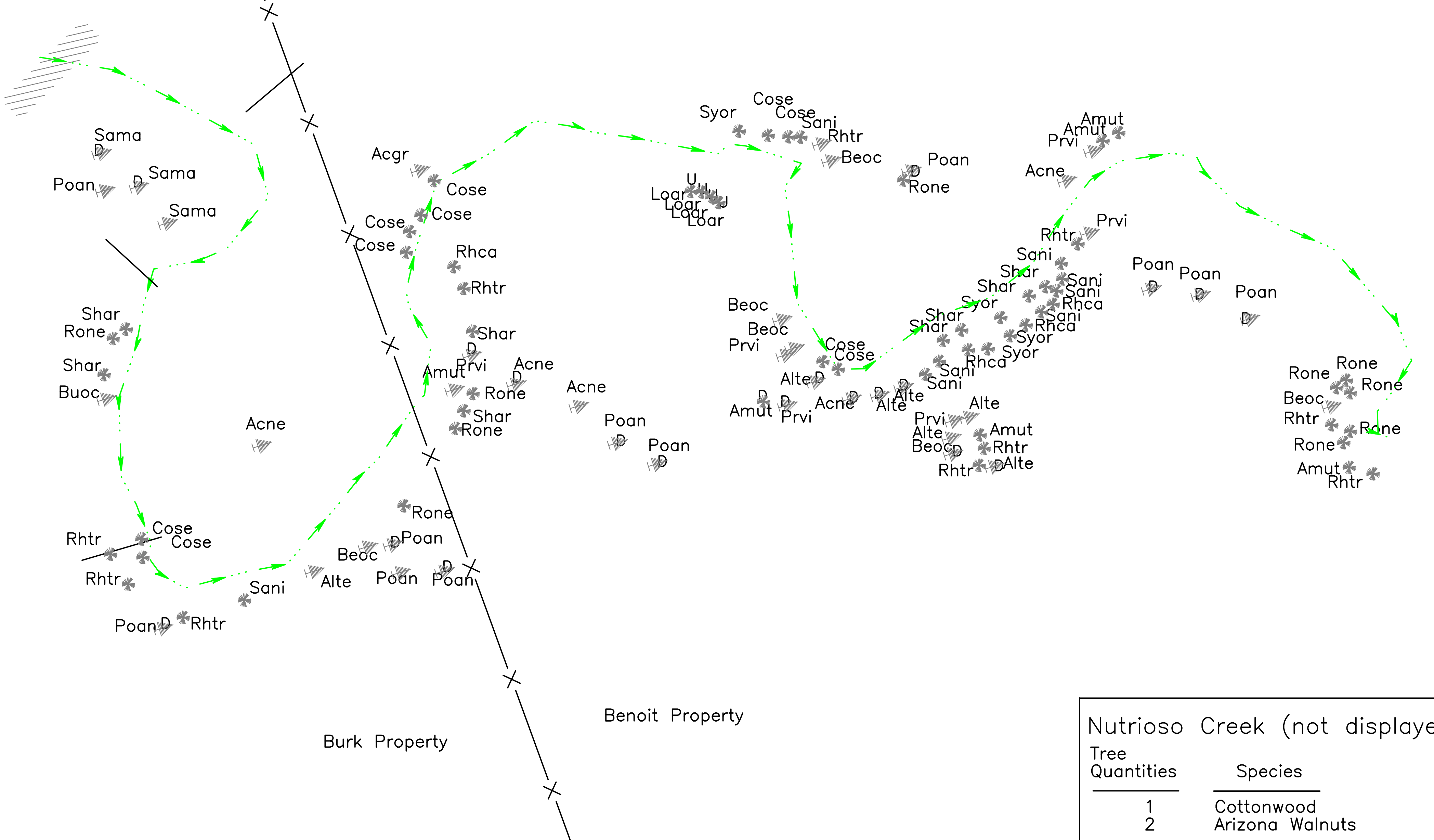
LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1 in = 100 ft
100 0 100

FILE NAME: LCR Benoit.pro
DATE: Mar 11, 2008
PROJECT NO: 07-143-AZ
SHEET: 21 of ~~21~~ 22

RECORD DRAWINGS

Notes:
Approximate location of all trees and shrubs planted during the 2008 construction period.



Nutrioso Creek (not displayed)	
Tree Quantities	Species
1	Cottonwood
2	Arizona Walnuts

PLANT LEGEND

TREES — 1 container plant per symbol unless noted

Cottonwoods (Poan)	12 ea — Non Containerized
Globe Willow (Sama)	3 ea
Box Elder (Acne)	5 ea
Rocky Mtn Maple (Acgl)	1 ea
Thinleaf Alder (Alte)	7 ea
Water Birch (Beoc)	7 ea
Arizona Walnut (Juma)	2 ea
Total No. Containers	25

SHRUBS — 1 container plant per symbol

Redosier Dogwood (Cose)	10 ea
New Mexican Locust (Rone)	10 ea
Blackbead Elder (Same)	8 ea
Mountain snowberry (Syor)	4 ea
Utah Serviceberry (Amut)	6 ea
Common Chokecherry (Prvi)	6 ea
Roundleaf Buffaloberry (Shro)	8 ea
Sumac (Rhtr)	10 ea
Arizona Honeysuckle (Loar)	4 ea
Coffee Berry (Rhca)	4 ea
Total No. Containers	70

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DRAWN BY: M.Wirtanen,

DESIGNED BY: M.Wirtanen,

REV	DATE	BY	REVISION
1	4-14-08	MW	Tree quantities
2	3-14-13	CS	RECORD DRAWINGS

PLAN VIEW: Planting Layout for Shrubs & Trees

LCR-Nutrioso Creek Riparian Enhancement Project
AWPF Grant 07-143 WPF

HORIZ SCALE: 1 in = 100 ft

100 0 100

FILE NAME: LCR Benoit.pro

DATE: Mar 11, 2008

PROJECT NO: 07-143-AZ21

SHEET: 22 of 22