DESIGN EXAMPLES—SECTION 3

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3.0 CASE STUDY—WILLOW CREEK

Willow Creek meanders through a natural open space park in Southern Arapahoe County (Figure 1). The low-flow channel carries about 200 cfs, and almost the entire open space is within the 100-year floodplain. The basin tributary to Willow Creek is 8.10 square miles; the lower portion is fully developed and the upper portion is actively being developed. Because of the changes in the basin runoff characteristics, Willow Creek is experiencing higher low-flow volumes. Frequent storms and increased base flows have created a 30-foot-high vertical cliff where the open space borders a residential development. If nothing was done, the house at the top of the cliff was in imminent danger (Photo 1).

Photo 1. Cliff Created by Erosion from Creek

Summary of Flows

Base Flow	> 5 cfs
2-year Storm	1,650 cfs
5-year Storm	3,000 cfs
10-year Storm	4,100 cfs
50-year Storm	5,500 cfs
100-year Storm	6,100 cfs

Because of these safety issues and potential loss of private property, Arapahoe County and South Suburban Parks and Recreational District requested assistance from the Urban Drainage and Flood Control District (District). The sponsors selected Muller Engineering Company, who teamed with Wenk Associates, to design the Willow Creek Channel Improvements. It was agreed at the outset that bioengineering techniques should be explored for this channel improvement project. The client team and the design team both saw this as a great opportunity to try new approaches to channel and bank stabilization.

3.1 Design

Designing a retaining wall to stabilize the cliff was one alternative considered by the client team, but it was rejected because of the cost, safety issues, and “hard” unnatural characteristics. The final design was chosen because it best satisfied the project goals for safety, aesthetics, habitat improvement, and affordability. The design included moving the creek from the south side to the north side of the existing stand of cottonwood trees. The trees’ root systems would provide some stabilization for what would then be the outer bend of the meander. The trees would still receive sufficient water from the relocated stream. With the creek now 60 feet from the toe of the cliff, a safer 2:1 slope could be built to replace it (Figure 2).

Photo 2. Existing "Texas" Low-flow Crossing

Photo 3. New Grouted Boulder Structure & Pedestrian Bridge

Although moving the creek made it feasible to fill in the vertical cliff, it also reduced the amount of area to mitigate to about 0.5 acres of

Photo 4. Biolog & Erosion Mat Installation

wetlands. Wenk designed a wetland backwater area inside the meander to accommodate the additional area needed. The water pools up during a storm event and then slowly drains, creating a good wetland water regime. A temporary wetland drain pipe from the creek was installed to feed the area until the plants were established (Figure 2).

Photo 5. Reconstructed Slope with Wrapped Soil Lifts at Toe

The realignment of the creek shortened the total length of channel and increased its slope. Two grouted boulder grade control structures, with 1-foot drops, were incorporated as permanent "hard" improvements to establish a stable channel slope of 0.5% (for bioengineered channels a milder slope of 0.3 to 0.4% is normally recommended by the District). Adjacent to the grade control structures, box culvert/pedestrian bridges were built to replace the existing slippery "Texas" low-flow crossings, which had been high maintenance for South Suburban as well as being a safety hazard (Photos 2 & 3).

Photo 6. Construction of Brush Layering

Incorporating "hard" grade control structures with the new bridges allowed the rest of the project area to have improvements with a "soft" appearance (Figure 3). Wenk designed a "biolog" or coir-roll stream edge for the outer bank of the low-flow channel. Two biologs, stacked almost on top of each other, laid next to and above a buried rock blanket, line the edge of the new low-flow channel between the bridges. The biologs were partially buried, staked, tied, and overlapped so that they could not be dislodged during a storm event. Willow stakes were also planted through them. Permanent erosion control mat was placed on the bank above the biologs (Photo 4). The inner bank of the meander was covered with a plastic permanent "enkamat" geotextile, designed to trap sediment that is washed around the bend and encourage wetland and riparian plant growth (Figures 4, 6, & 7).

Photo 7. Completed Slope with Brush Layering, Erosion Mat, and Wrapped Soil Lifts

Bioengineering techniques were also used to stabilize and help establish vegetation on the 2:1 fill slope of the 30-foot vertical cliff. Extra stabilization was needed at the toe of the new slope to protect up to the 100-year water surface elevation. Six layers of wrapped soil lifts made of a double layer of coir fabric encasing a 6-inch lift of soil protects the soil from erosion at the toe of the slope while still allowing vegetation to grow (Photo 5 & 9). The upper portion of the


Photo 8. Complete Channel with Plantings

slope is a test area for both brush layering and traditional erosion control matting. For the brush layering, Wenk specified that willow and cottonwood branches be placed horizontally in the slope with about 3 inches of the tips sticking out. These little "fingers" of the mostly dead branches collect leaves and natural debris while breaking up the water that trickles down the slope, preventing rill erosion (Photo 6). The brush layering was used on half of the new fill slope, and the other half received a temporary erosion control blanket. These two methods will be compared over the years to see if one is more successful than the other (Photo 7 and Figure 5).

The channel edges and the wrapped soil lifts were then planted with willow stakes. Cottonwood whips were also planted within the meander and around the check structures (Photo 8). All the willow stakes, the cottonwood whips, and even the brush for the brush layering were harvested from the immediate area.

As an added precaution, the District asked Muller to design modified riprap bank protection, which was buried behind the biologs as a secondary line of defense. Also, to save several existing cottonwood trees, huge boulders were placed as retaining walls to hold back the fill slope from the bases of these trees.

3.2 Criteria

District criteria were followed for the design of this project to the maximum extent possible. As within many District projects that address existing problems, right-of-way limitations often dictate a need to deviate from some of the criteria, knowing full well that had the criteria been followed, the problems that had to be addressed would not have materialized. The new channel slope is 0.5%, and the radius of the new curve is 150 feet. Buried riprap was placed on the downstream side of the box culvert/pedestrian bridge in accordance with the District. The riprap bank protection behind the biologs was slimmed down from the District criteria since it was installed as a precautionary measure. Reference materials obtained from an International Erosion Control Association seminar and from King County, Washington entitled "Guidelines for Bank Stabilization Projects" were used to assist in the design of the bioengineering. However, at the time of the design, there were no established design criteria available for the bioengineering aspects of the project.


Photo 9. Construction of Wrapped Soil Lifts

3.3 Construction

L&M Enterprises was awarded the contract for the construction of this channel project. It was necessary to use small equipment to build the wrapped soil lifts and the brush layering, which made the job go slower than expected. It was also difficult to compact the slope with the brush layering inside of it. The biggest challenge during construction was dealing with higher than anticipated creek flows due to a wet winter and spring. Construction began in October 1998, and in early 1999 there were spring storms that tested the channel before the vegetation took root. Overall, the channel held up well.

In retrospect, it was determined that wider rolls of geotextiles would function better and would be easier to install. The permanent "enkamat" geotextile came in 3-foot-wide rolls, and after the pieces were overlapped, there was little left to cover the ground. Also, there would have been fewer areas of failure if the trees were planted prior to installing the geotextile.

3.4 Success

The Willow Creek Channel Improvement Project continues to be a success story. The new channel has seen numerous storm events, and sediment has deposited on the inside of the bend without eroding the outside. Almost every willow stake has sprouted. Many of the cottonwood whips are growing. The biologs are secure with their double-tied stakes and will soon be permanently anchored by the willows and grasses growing in them. The secondary riprap protection acts as a backup measure for protection during very large flood events. The most surprising success was the cottonwood branches that were placed in the brush layering even without irrigation. The very next season, sprouts were already 3 feet tall. Also, the wetland backwater idea has been incorporated into other projects because of its success.

Willow Creek is once again a meandering creek in this reach with two check structures that mimic splashing waterfalls which are enjoyed by the trail users and the residential neighbors. The looming 30-foot cliff and the slippery channel crossings are gone, and a safe and beautiful Colorado open space was created.

Photo 10. Relocated Channel & New Pedestrian Bridge

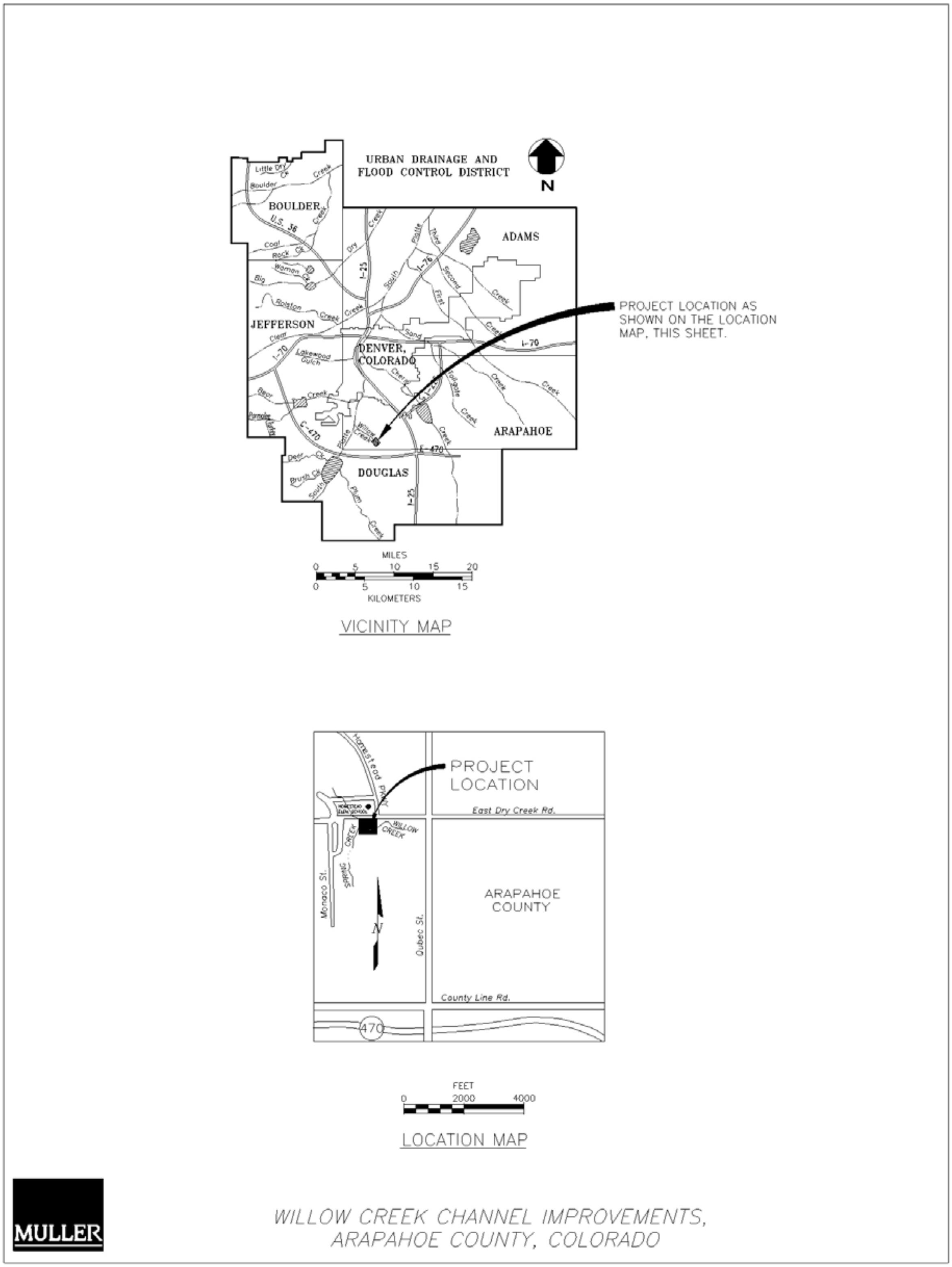

Figure 1—Location Map

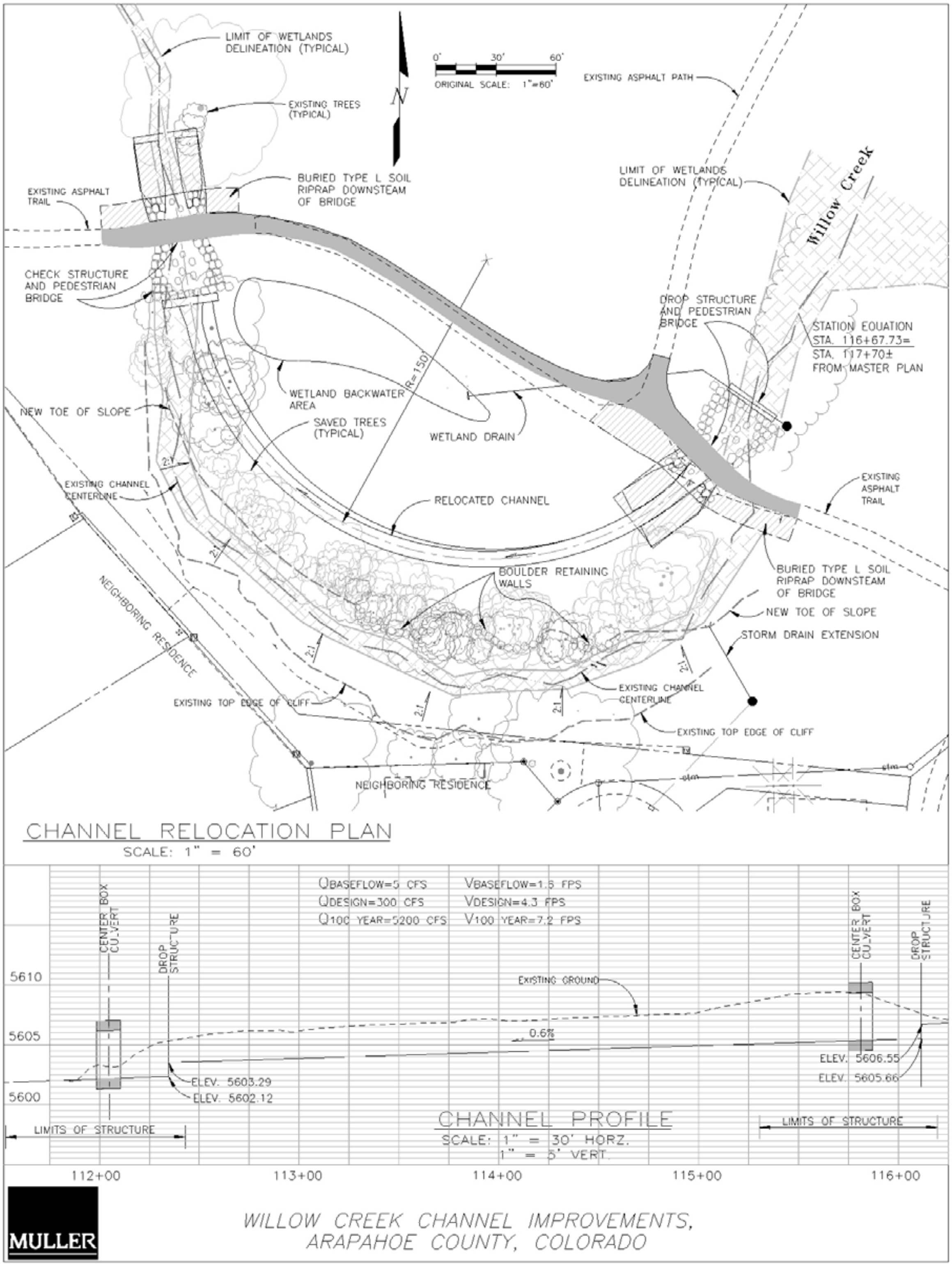

Figure 2—Channel Relocation Plan

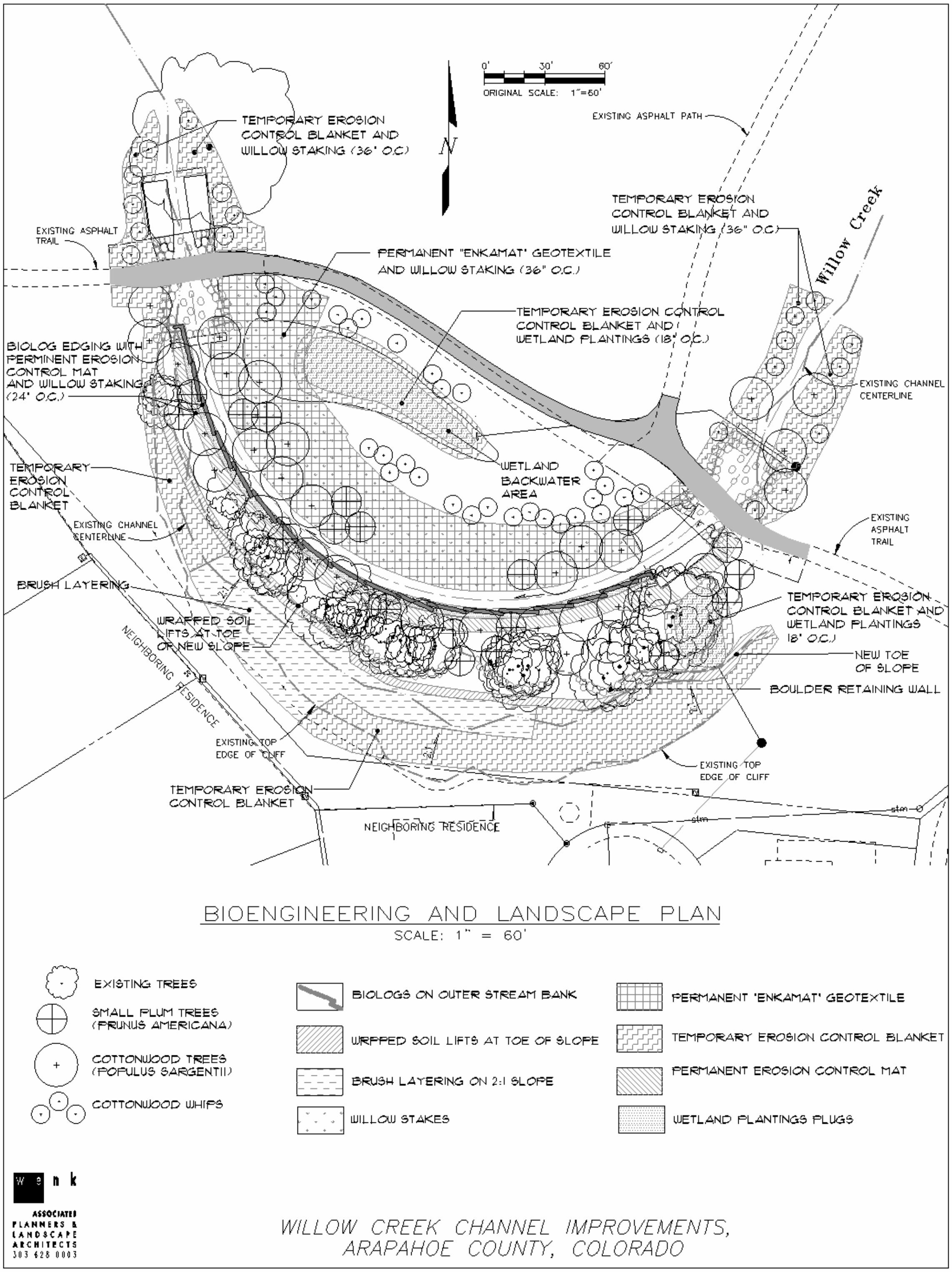

Figure 3—Bioengineering and Landscape Plan

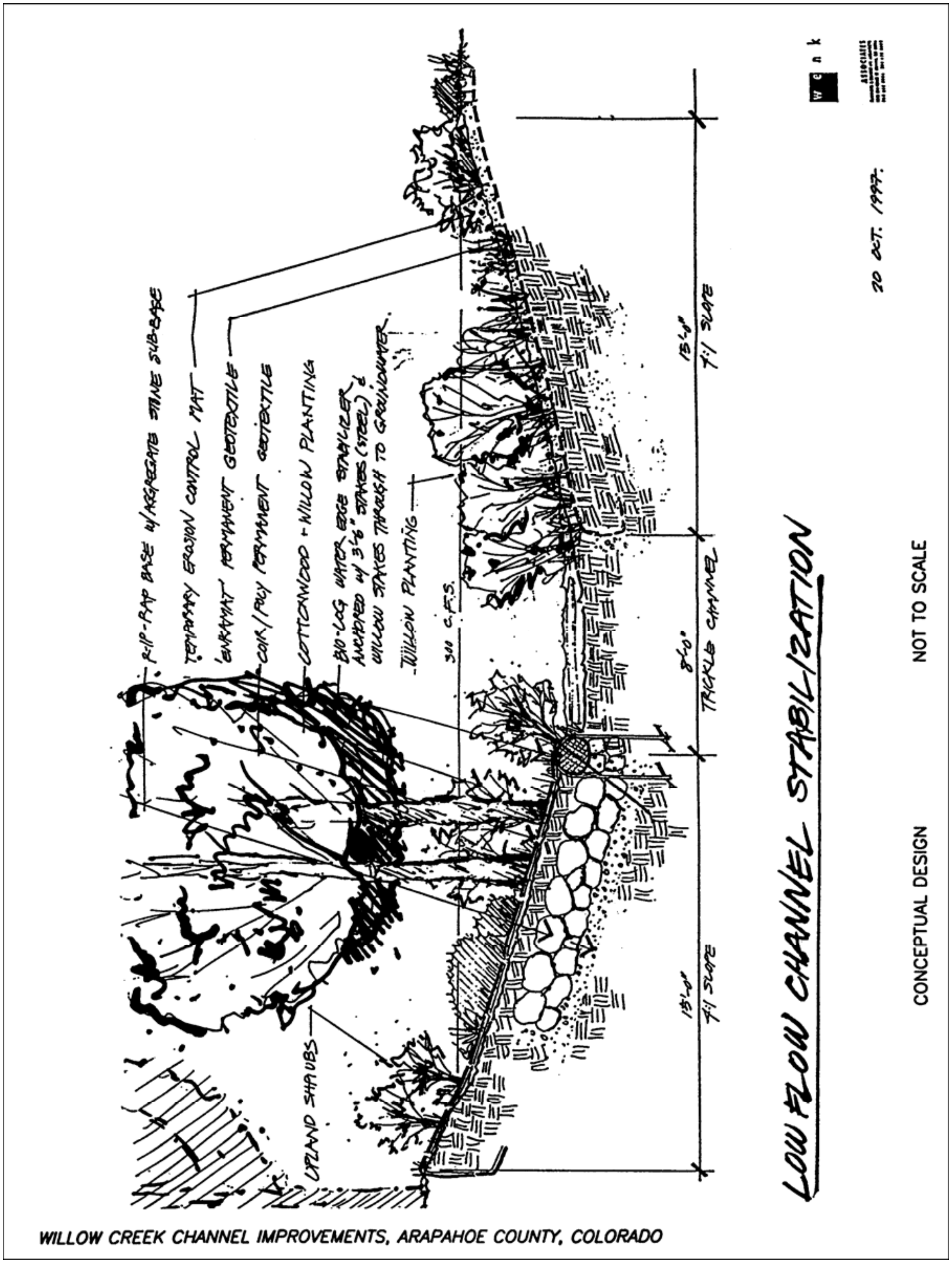

Figure 4—Low-Flow Channel Stabilization

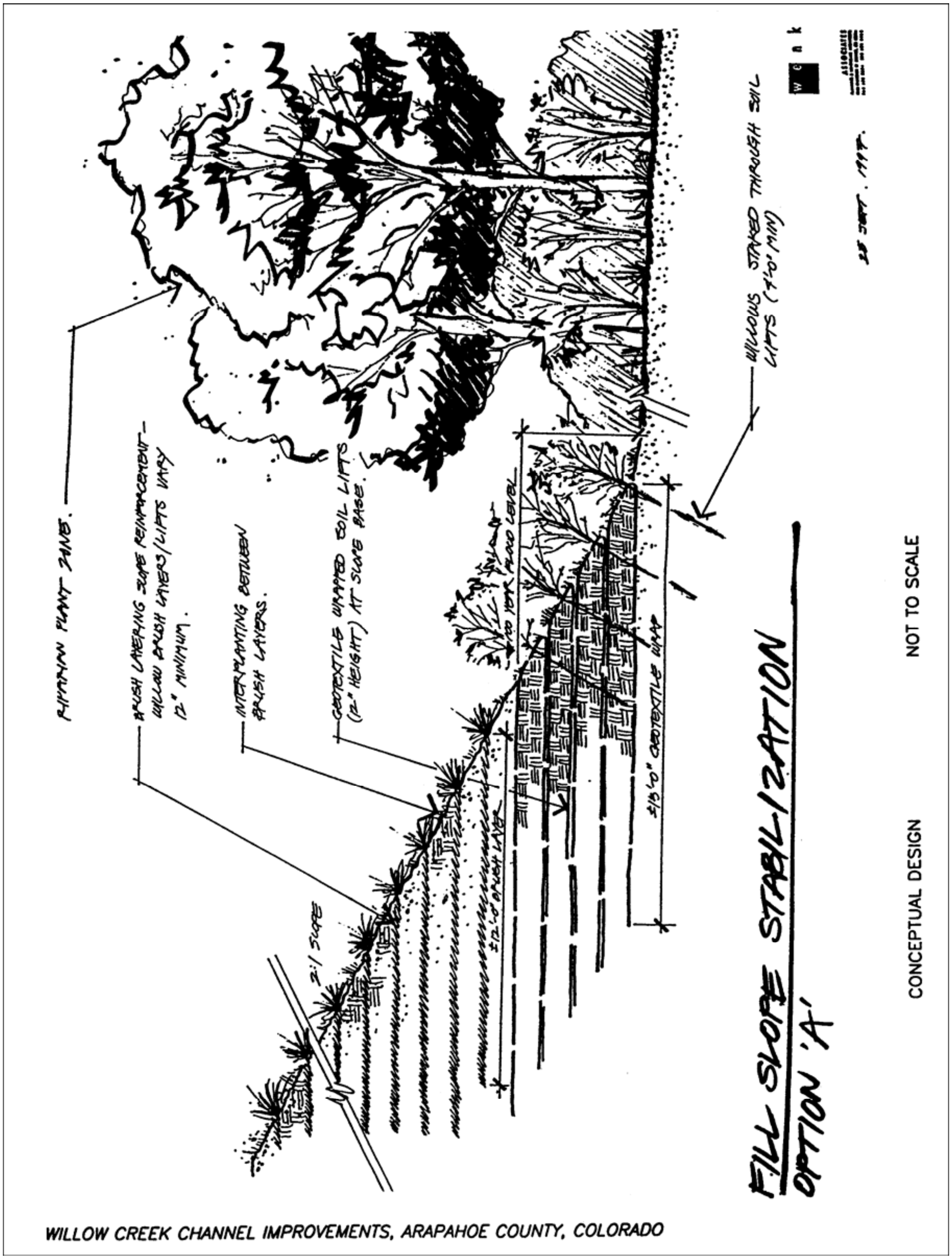

Figure 5—Fill Slope Stabilization Option A

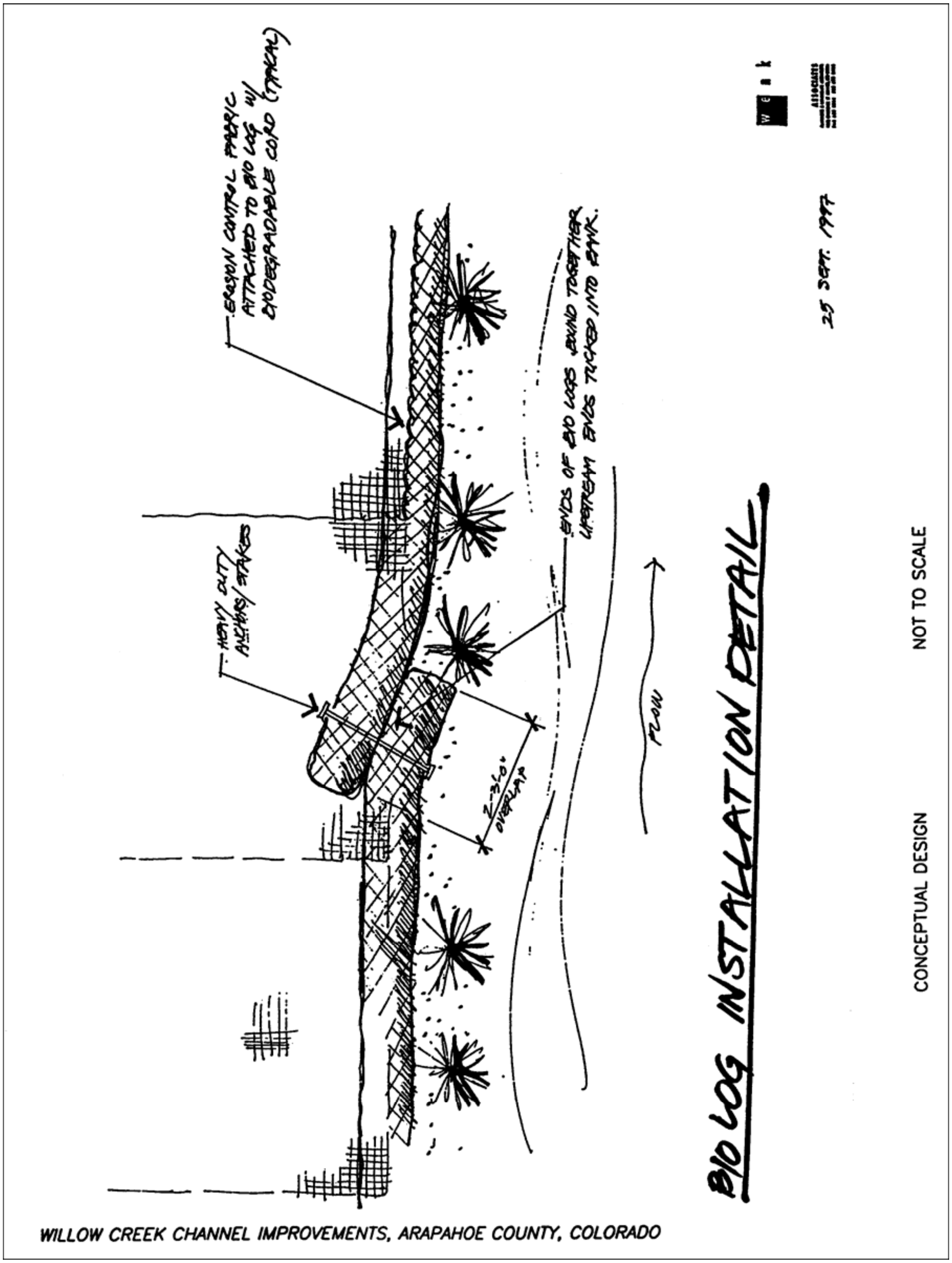

Figure 6—Biolog Installation Detail

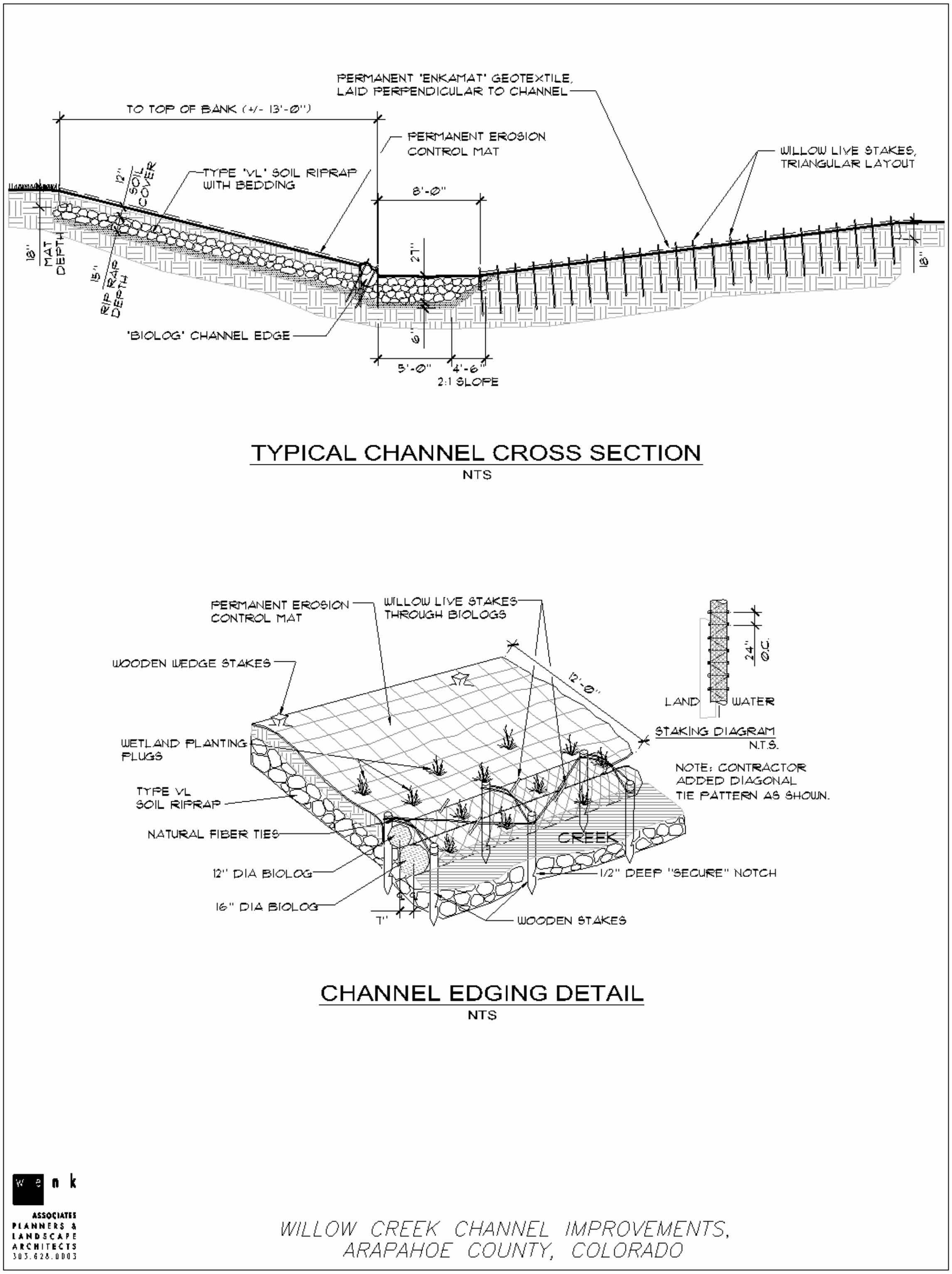

Figure 7—Typical Channel Cross Section and Channel Edging Detail

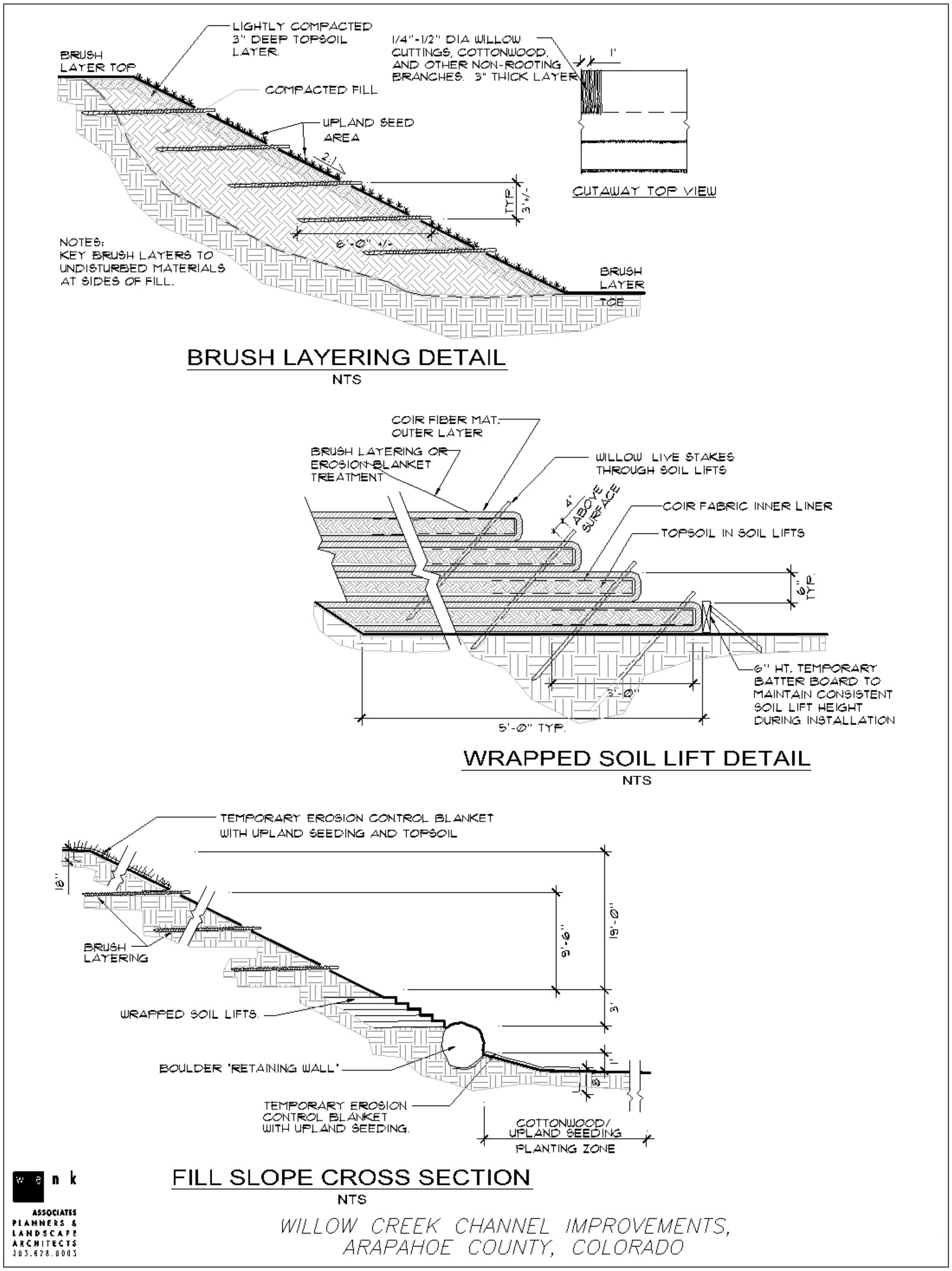

Figure 8—Brush Layering Detail, Wrapped Soil Lift Detail, and Fill Slope Cross Section