TETRA TECH

MEMORANDUM

TNC – Fisher Slough Final Design and Permitting
Subject: Large Wood Debris Design

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Date: Sept. 10, 2009

Introduction

This hydraulic design technical memorandum is the engineering analyses performed for the large wood debris design for the Fisher Slough Tidal Marsh Restoration Project. There are approximately 20 to 30 large cottonwood trees, approximately 3-4ft in diameter and more than 100ft long that will be salvaged as part of the project for optional installation during construction. The actual installation is contingent upon approval of the design and installation by The Nature Conservancy and Dike District #3, and will be decided at an unknown date in the future. This technical memorandum includes the large wood debris installation analysis and design requirements if carried forward.

Hydraulic Analysis of LWD Installation

Placement of LWD in the tidal marsh area will be subjected to frequent inundation, with extremely low channel velocities (less than 1fps on the marsh plain) and hydraulic forces. Therefore, it is assumed that the design shall protect against buoyancy and floatation of LWD, which could then be transported downstream towards other floodgate, levee, bridge infrastructure.

Buoyancy design involves developing some sort of anchorage for the wood system. Three types of anchorage/ballast are typically used, including:

- Soil ballast covering a significant portion of the LWD member
- Rock anchors attached to the LWD via bolts, cables and/or chains
- Pile anchors attached to the LWD via bolts, cables and/or chains

Recent placement of LWD in tidal marsh areas with soil ballast has had poor results and this type of anchorage is not considered appropriate for this project. Rock anchors are also not considered appropriate, as rock is not typically found in the Skagit Delta area naturally. Therefore, the remaining anchorage type deemed most appropriate is the use of a pile anchoring system.

A pile resistance analysis was performed to provide supporting documentation of the adequacy of the proposed LWD anchorage design.

The first step in the pile analysis involves estimating the wood buoyancy forces. The buoyancy force is determined using the following **Equation 1**. The buoyancy force is described as the equivalent to the weight of the displaced fluid acting upward on the LWD member. **Equation 2** is the estimate of volume of wood, that is displacing the water, including the tree rootball and bole.

Equation 1. $$F_B = \gamma_w V_{wood}$$

Equation 2. $$V_{wood} = L_{RB} A_{RB*} + L_B A_B$$

Where,

F_B = Bouyancy force on wood
γ_w = Unit weight of water
V_{wood} = Volume of LWD wood member
L_{RB} = Length of rootball
A_{RB} = Average area of rootball
L_B = Length of LWD bole
A_B = Area of LWD bole based on DBH

The buoyancy force for a fully submerged, 50ft long cottonwood with a 4ft DBH is estimated at 51,214lbs of force.

The buoyancy forces for anchored wood structures require the use of pile anchors. The following Equations 3 – 6 were evaluated to determine the anchor pile configuration for the proposed features. **Table 1** is a summary of the analysis results. The overall result is that using 2, 1ft diameter timber piles located at either end of the structure indicate that the piles shall be driven a minimum depth of 30ft to prevent pull-out. Other options would be to install extra piles or use larger diameter piles to increase surface area resistance.

Equation 3. $$P_s = f_s SA_p$$

Equation 4. $$SA_p = \pi DL$$

Equation 5. $$f_s = \frac{1}{2} K_t \gamma_s' Y_p \tan\phi$$

Where:
Kt = 0.5 to 0.7 (USACE, 1991) selected 0.6

Factor of safety to determine pile sizing is as follows:

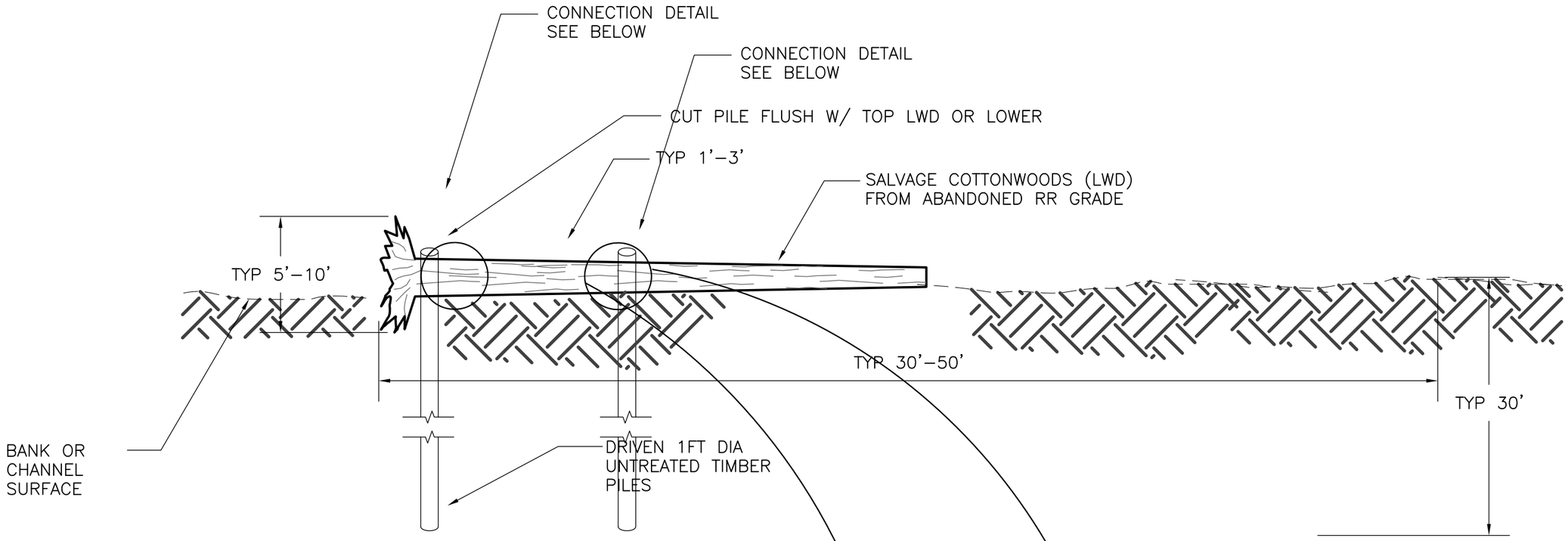
Equation 6. $FS = \frac{F_b}{P_s} \geq 2.0$

Table 1. Design Analysis Summary

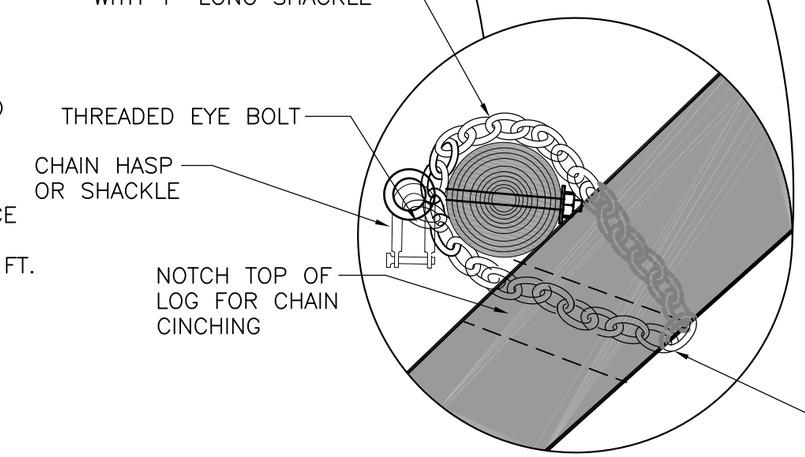
Wood Parameters	
Volume LWD	
LWD Length - L_b (ft)	50.0
LWD Diameter - DBH (ft)	4.0
LWD Rootball Length - L_{rb} (ft)	5.0
LWD Rootball Diameter - D_{rb} (ft)	10.0
Volume LWD V_{wd} (ft^3)	**820.7**
Buoyancy Force F_B (lbs)	**51,214.2**
Surface Area of Pile	
Number of Piles	2.0
Diameter of Pile	1.0
Buried Length of Pile	30.0
Surface Area of Pile (sf)	**188.5**
Pile Skin Resistance (fs)	
Passive soil pressure coefficient (Kt)	0.5
Buoyant Soil Unit weight (γs')	103.0
Assumed pile length below bed (ft)	20.0
Soil friction (failure) angle (φ)°	34.0
Soil friction angle adjustment (δ)	0.9
Adjusted soil friction (failure) angle (φ')°	30.6
Pile Skin Resistance (fs) (lbs/sf)	547.2
Pile Anchor Resistance Force (lbs)	**103,150.8**
Factor of Safety	**2.0**

A final design check was performed on the chain connection. It was determined that chains with 25,000lb working loads shall be wrapped a one time to meet the load requirements of the buoyancy forces. Connections shall also use through bolts, and not anchor screws, to prevent pull out failures. Wood with different sizes can use different load ratings, depending upon the buoyant characteristics. Minimum pile installation shall be as specified, 30ft deep, 1ft diameter pile, with two pile anchors. The following **Attachment A** has a conceptual design plan for single, large wood debris installation configurations.

Attachment A – Large Wood Debris Installation Design Plan



LARGE WOOD DEBRIS
N.T.S



CONNECTION DETAIL
N.T.S

NOTES
1. LARGE WOOD DEBRIS INSTALLATION IS CONNECTED TO DRIVEN PILES USING CHAIN CONNECTIONS.
2. CHAIN AND SHACKLE WORKING LOAD IS MINIMUM 25,000LBS (SPEC – $\frac{5}{8}$IN 100 ALLOY).
3. SINGLE CHAIN & SHACKLE REQUIRED FOR EACH PIECE OF WOOD USING MINIMUM WORKING LOAD.
4. DRIVE PILES TO MINIMUM EMBEDMENT DEPTH OF 30 FT.
5. LOWER GRADE CHAIN CAN HAVE MULTIPLE WRAPS. NUMBER OF WRAPS SHALL MEET MINIMUM WORKING LOAD OF 25,000LBS.
6. LOWER GRADE SHACKLES ARE NOT ACCEPTED.
7. CHAIN & SHACKLES TO BE PAIRED FOR COUPLING.
8. SHACKLES SHALL HAVE THREADED OR COTTER TYPE PINS.
9. EYEBOLT SHALL MEET 50,000LB WORKING LOAD AND ALLOW CONNECTION OF TWO CHAIN LINKS.

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LARGE WOOD DEBRIS CONNECTION DETAILS

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File Name

Drawing No.
C68

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