Bullock, Bennett & Associates, LLC ∗ 165 N. Lampasas Street ∗ Bertram, Texas 78605
Telephone: 512.355.9198 ∗ Fax: 512.355.9197

January 15, 2016
BBA Project No. 15-214.1

Mr. Robert Stevens, P.E.
Plant Manager
Coleto Creek Power, LP
P.O. Box 8
Fannin, TX 77960

RE: Coleto Creek Power – September 2015 Primary and Secondary Ash Ponds Dike Inspection

Dear Mr. Stevens:

Bullock, Bennett, and Associates, LLC (BBA) performed a visual inspection of the Coleto Creek Primary and Secondary Ash Ponds dike systems on September 16, 2015. The Primary Ash Pond is approximately 190 acres and the Secondary Ash Pond is approximately 10 acres (the Primary and Secondary Ash Ponds are hereafter referred to collectively as the Ash Ponds). The Ash Ponds were constructed in the late 1970s and include a perimeter dike system approximately 2.5 miles in total length. The crest width of the Ash Ponds is approximately 15 feet, and side slopes (interior and exterior) of the Primary Ash Pond were reportedly constructed to 2.5(H):1(V) and the Secondary Ash Pond to 3(H):1(V). The Ash Ponds were reportedly constructed in accordance with Texas Department of Water Resources technical guidelines. Ash material is sluiced to the Primary Ash Pond where most settlement takes place, and water is decanted from the Primary Ash Pond through a weir located within the shared dike between the Ash Ponds to the Secondary Ash Pond. Water can be pumped (although pumps are not currently operational) from the Secondary Ash Pond back to the plant for reuse, or is discharged in accordance with the site TPDES permit.

As part of this inspection, BBA reviewed the "Geotechnical Stability and Hydraulic Analysis of the Coleto Creek Energy Facility Primary and Secondary Ash Ponds" report completed by AECOM in 2012, and provided to BBA prior to the site inspection. The report findings indicate the Ash Ponds had adequate factor of safety against structural failure under the steady-state, flood, rapid drawdown, and seismic conditions modeled, and have adequate factor of safety against liquefaction. Based on the AECOM report, the dikes of the Ash Ponds range in height from approximately 4 to 43 feet, and have an estimated design storage capacity of 7,500 ac-ft, thus making the Ash Ponds intermediate in size. Based on field instrument and LIDAR surveys conducted by AECOM, it was determined that the Ash Ponds dikes, weir structure, and staff gauge had settled uniformly approximately 0.75 feet since original construction in 1977. The report also evaluated the hazard level of the dike system and determined it to be Low Hazard. The report summarizes a hydraulic analysis conducted on the Ash Ponds based on surveyed waste volumes in place and use of a design storm event of 26.25 percent of the probable maximum precipitation (PMP), and determined based on the evaluation that the Ash Ponds have sufficient freeboard to meet the hydraulic requirements to prevent overtopping of the dikes.

Since 2012, very little ash has reportedly been placed in the Ash Ponds, as Boral Materials Technologies (Boral) has been recycling almost all fly ash generated with the exception of small quantities of off-spec ash which is sluiced to the Primary Ash Pond. Bottom ash is excavated from the Primary Ash Pond by Boral and hauled off site for beneficial reuse, thus creating additional storage capacity in the Primary Ash Pond. Based on recycling of fly ash and excavation of bottom ash for beneficial reuse, the Primary Ash Pond likely has approximately the same amount of remaining storage capacity (approximately 300 ac-ft) as determined during the 2012 AECOM study.

No changes in geometry of the Ash Ponds dike system have occurred since their construction. Records of water level minimum and maximum elevations were not available; however, the water level is reportedly typically maintained below elevation 135 feet on the staff plate.

Mr. Dan Bullock, P.E. and Mr. Chris Winkler of BBA performed the site inspection. Rain had passed through the area the night prior to and morning of the inspection, but site conditions allowed access to the entire dike system. Inspection began near Sta No. 10+00 and proceeded in a counterclockwise direction (Figure 1). The completed inspection forms are included in Attachment A. Inspection photographs (photos) and the site figure with stationing are included in Attachment B. Technical Note Series No. 705 (regarding recommended procedures for tree removal) is included in Attachment C.

PRIMARY ASH POND

Figures 2 through 4 include September 2015 inspection photographs of the Primary Ash Pond dikes.

<u>Interior (upstream) Dike Inspection</u>
Along the perimeter of the Primary Ash Pond from approximately Sta 38+00 to Sta 98+00 (traveling clockwise), ash material was observed to an elevation that appeared generally to be about 3-5 feet below top of dike crest elevation (based on visual observation, not surveyed), and the remaining perimeter of the Primary Ash Pond impounds water. Based on staff plate readings, it appeared the water surface was approximately 6 feet below the top of perimeter dike, thus most of the interior dike was covered by ash or under water and was not visible for inspection. The portions of interior dike in areas filled with ash were vegetated and appeared in generally good condition. The interior dike sections in areas impounding water are armored with rock riprap material and also appeared in generally good condition. As noted on the inspection forms, there were some areas along the interior dikes that contained sporadic, small trees. Trees and shrubs can cause piping (preferential pathways for water flow within the dike that can remove internal dike soils) via root systems, localized removal of grass and soil (when trees fall due to wind, thus displacing grass and soil with the root ball), obstruct visual inspection of levee surface, and prevent healthy growth of grass cover (due to reduced available sun light, rainwater, and nutrients), and should be removed.

Photos 7429, 7545, and 7564 show inside slope rock armor in areas impounded with water. Photo 7408 shows the inside of the ash pond with a drainage channel cut within the ash to convey sluice material. Photos 7564 and 7571 show small trees on the interior slope.

<u>Dike Crest Inspection</u>
The dike crest appeared in generally good condition with only minor tire rutting observed in localized areas. The crest included a perimeter access road comprised of a coarse aggregate base material with grassed shoulders and grass intruding through the aggregate in the center of the access road (between tire paths).

<u>Exterior (downstream) Dike Inspection</u>
Wet areas were identified near the toe of slope in a few locations between approximately Sta 85+00 and Sta 90+00. These have been identified in previous inspection reports (from the late 1980s and

early 1990s) provided to BBA for review during the site visit. More recent inspection reports were not obtained by BBA for review however, these areas have reportedly continued to persist since observations discussed in the old inspection reports. The wet areas (including some locations of puddled water) and associated erosional features are shown in photos 7455, 7470, 7473, 7478, and 7486 (covering an area approximately 500 feet long). Some of the puddled water observed was cloudy with suspended sediments (photo 7470). The cloudy water is likely a result of accumulation of surface water runoff from rainfall impacting the localized areas of disturbed vegetation given no seepage flow was detected, and some of the wet areas observed within better stands of grass were clear, not cloudy. Similar wet areas along this reach of levee have historically been observed with reportedly no suspended sediments. There was no discernible subsidence observed along the interior dike slope, dike crest, or upgradient portions of the external dike slope in these areas. These areas should be routinely monitored with careful attention paid to the wet areas for observation of possible seepage flow. If seepage flow is observed to include suspended solids (such as clay or silt particles), this could be an indication of internal dike erosion that may lead to unstable dike conditions. These wet areas should be further investigated and addressed based on investigation findings. Given the localized toe erosion and wet soil conditions in the area, this section of dike could worsen to cause unstable dike conditions if not addressed.

The existing seepage collection system located near the pump house in the vicinity east of Sta 70+00 was not inspected.

Other than the wet areas discussed above, the exterior slope of the dike appeared in good condition. A few small trees were observed as shown in photos 7383 and 7594, and grass, although in good condition and with good coverage, was tall and restricted visibility of the levee surface.

An approximate 6-inch diameter pipe was observed on the west dike near Sta 35+00 as shown in photo 7585.

<u>Outlet Works</u>

The outlet works from the Primary Ash Pond includes a weir as shown in photos 7547, 7548, and 7549. Stoplogs were not in place at the time of inspection. The staff plate reading as shown in photo 7548 indicated a water surface elevation of approximately 134.0 ft (approximately 6 feet below top of dike elevation).

SECONDARY ASH POND

Secondary Ash Pond dike inspection photographs from September 2015 are provided in Figure 5.

<u>Interior (upstream) Dike Inspection</u>

As indicated in the attached photos, the Secondary Ash Pond interior side slopes appeared to exhibit minor to moderate and generally uniform bank cut likely due to wave action. This erosion feature appears to have occurred a long time ago given the slope is currently heavily vegetated. At the time of inspection, the water level was low enough to enable access to the interior slope as indicated in the photos. The cut does not appear to be problematic from a dike stability standpoint and no immediate action is required. Maintaining the water level as low as observed during the inspection will prevent future progression of erosion. Alternatively, armoring the slope to reduce future bank cut may be considered as a means to reduce potential future erosion. Other than the bank cut observed, the interior slopes appear well vegetated and in generally good condition. Bank cut erosion is shown in photos 7530 and 7532.

<u>Exterior (downstream) Dike Inspection</u>

The exterior slope of the Secondary Ash Pond appeared in generally good condition. A section of the exterior slope from approximately Sta 114+00 to Sta 125+00 was enclosed within barbed wire fencing, and was not mowed or maintained to the same degree of the remaining portions of dikes. All exterior slopes were well vegetated with tall grass, limiting visual inspection. Numerous small trees and shrubs were observed predominantly within the fenced sections of the dike.

<u>Outlet Works</u>

The pump station used to pump water from the Secondary Ash Pond back to the plant was not inspected.

<u>Action Items</u>

The following is a list of action items BBA recommends. Additional detail for some of these items is included in the attached inspection report.

- Continue to monitor the observed Primary Ash Pond wet areas between Sta 85+00 and 90+00. Investigate the observed wet areas and address as appropriate based on investigation findings. During this investigation, also perform a detailed inspection of the existing seepage collection system in the vicinity of the pump house, east of Sta 70+00.
- Remove small trees and shrubs observed from all side slopes.
- Mow the exterior dikes on a regular basis to improve ability to visually inspect the dike, encourage good vegetation, and maintain removal of trees and shrubs.
- Evidence of animal rooting/grubbing on the dike was minimal during this inspection. However, if evidence of increased activity is observed, implement rodent control as needed. Evidence of fire ants was minimal; however, continue to inspect for fire ants especially in summer months and implement fire ant control as needed (fire ant colonies can be intrusive into the dike interior potentially resulting in piping or initiation of erosion areas).

BBA appreciates the opportunity to assist Coleto Creek Power with this project. If you have any questions regarding this inspection report, or if we can be of further assistance, please call us at (512) 355-9198.

Sincerely,

STATE OF TEXAS
DANIEL B. BULLOCK
82596
REGISTERED
PROFESSIONAL ENGINEER

Bullock, Bennett & Associates, LLC

1/15/16

Dan Bullock, P.E.

Texas PE No. 82596

Attachments

ATTACHMENT A

Inspection Reports

NAME OF DAM: Coleto Creek Dike System INSPECTION DATE: September 16, 2015

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVEST-IGATE	REPAIR
		EMBANKMENT 1 OF 2		CHECK (X) ACTION NEEDED		
CREST	1	SURFACE CRACKING	Surface generally appears in good condition.	X		
	2	CAVE IN, ANIMAL BURROW	No cave-ins or substantial animal burrows observed.	X		
	3	LOW AREA(S)	None observed.	X		
	4	HORIZONTAL ALIGNMENT	Good.	X		
	5	RUTS AND/OR PUDDLES	Minor ruts observed in some locations.	X		
	6	PRESENCE/COND. OF VEGETATION	Perimeter access road on crest has road base material, with vegetation on shoulders of crest and in center of road between track paths. Shoulder vegetation in good condition.	X		
	7					
INTERIOR SLOPE	8	SLIDE, SLOUGH, SCARP	No substantial slides, sloughs, or scarp observed.	X		
	9	SLOPE PROTECTION	Armored with rock riprap. Generally appears in good condition.	X		
	10	CAVE-IN, ANIMAL BURROW	No cave-ins observed. Evidence of minor animal rooting/grubbing observed in sporatic locations.	X		
	11	EMB.-ABUT. CONTACT	Embankment intersections of Primary/Secondary Ash Ponds appear in good condition.	X		
	12	EROSION	No substantial erosion observed on Primary Ash Pond. Minor to moderate and generally uniform bank cut of Secondary Ash Pond observed as shown on photos; however, due to cross sectional width of embankment and crest this erosion does not appear problematic with regard to levee stability (should continue to be monitored). Placement of slope armor may be considered as means to reduce future progression of bank cut and therefore reduce long term erosion repair costs.	X		
	13	PRESENCE/COND. OF VEGETATION	Wave protection armor (rock riprap) covers most of slopes impacted by standing water (see photos). Areas without standing water are generally covered with vegetation.	X		
	14					

Dike crest and interior slope appear generally well maintained and in good condition. Vegetation control on levee slopes appears generally effective; however, some small trees/shrubs were observed. Trees and shrubs can cause piping (preferential pathways for water flow) via root systems, removal of soil (when trees fall due to wind, thus displacing soil with root ball), obstruct visual inspection of levee surface, and prevent healthy growth of grass cover (due to reduced available sun light, rainwater, and nutrients), and should be removed. The trees/shrubs observed were generally small. Tree removal and killing of stump is recommended (see attached Soil Conservation Service Technical Note 705 for guidance related to tree removal). Riprap slope protection material generally appears in good condition.

NAME OF DAM: Coleto Creek Dike System INSPECTION DATE: September 16, 2015

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	MONITOR	INVEST-IGATE	REPAIR
		EMBANKMENT 2 OF 2		CHECK (X) ACTION NEEDED		
EXTERIOR SLOPE	15	WET AREA(S)	Wet areas observed at toe of slope in approximate area of Sta 85+00 to 90+00. Appears to be a combination of possible seep water and ponding from recent rainfall events.	X		
	16	SEEPAGE	Wet areas observed between Sta 85+00 to 90+00. No flow observed, but surficial erosion was observed. Some of the wet areas included puddled water, partially from accumulation of recent rainfall (it rained the night prior and morning of the inspection) and possibly due to seepage water - should be further investigated.	X	X	
	17	SLIDE, SLOUGH, SCARP	None observed.	X		
	18	EMB.-ABUT. CONTACT	Embankment intersections of Primary/Secondary Ash Ponds appear in good condition.	X		
	19	CAVE IN, ANIMAL BURROW	No cave-ins observed. Evidence of minor animal rooting/grubbing observed in sporatic locations.	X		
	20	EROSION	Erosion in wet areas observed in proximity of Sta 85+00 to 90+00 as shown in photos. No other substantial erosion areas observed.	X		
	21	UNUSUAL MOVEMENT	No indication of unusual movement observed.	X		
	22	PRESENCE/COND. OF VEGETATION	Grass generally in good condition, but tall at time of inspection - should be mowed to enhance ability to visually inspect. Sporadic stands of small trees observed – should be removed (see tree removal discussion on page 1 of 2).	X		
	23					
INSTRUMENTATION	24	PIEZOMETERS/OBSERV. WELLS	Not inspected. Piezos and wells observed and inspected during routine groundwater monitoring.	X		
	25	STAFF GAUGE AND RECORDER	Staff plate appeared in good condition. Water surface elevation observed at approximately 134.0 ft (approximately 6.0 feet below top of dike)	X		
	26	SURVEY MONUMENTS	Not observed.	X		
	27	DRAINS	No internal chimney drains within levee system. Seepage collection system located east of levee (near the bank of Coleto Creek Cooling Pond) in vicinity of Sta 70+00 was not inspected, however, no embankment seepage was observed in the area.	X		
	28	FREQUENCY OF READINGS	NA.			
	29	LOCATION OF RECORDS	NA.			
	30					

Exterior slope generally appears in good condition; however, a wet area in the proximity of Stat 85+00 to 90+00 was observed. Seepage flow was not detected, however ponding water was observed – possibly a combination of recent rainfall and seepage. This area should be investigated and addressed appropriately based on investigation findings. This wet area has been observed in historic inspections performed by others. Future observations of fines (such as clay or silt particles) in the water may indicate internal erosion of the dike which could lead to unstable conditions.

Tall grass should be mowed and small trees removed from side slopes (see discussion of tree removal included on page 1 of 2). Some evidence of minor animal rooting/grubbing observed – control of rodents should be implemented as needed.

NAME OF DAM: Coleto Creek Dike System INSPECTION DATE: September 16, 2015

AREA INSPECTED	ITEM NO.	DOWNSTREAM AREA AND MISC. 1 OF 1 CONDITION	OBSERVATIONS	CHECK (X) ACTION NEEDED MONITOR	INVEST-IGATE	REPAIR
MISCELLANEOUS	31	ACCESS ROADS	The dike access road is in good condition and includes a granular wearing surface	X		
	32	SECURITY DEVICES	Site includes manned guard gate and combination of perimeter site fence and natural barriers.	-		

AREA INSPECTED	ITEM NO.	SPILLWAYS 1 OF 1 CONDITION	OBSERVATIONS	CHECK (X) ACTION NEEDED MONITOR	INVEST-IGATE	REPAIR
INLET	33	Weir	Weir structure was submerged and therefore could not be inspected.	X		
	34	Trashrack (if applicable)	Not observed.	X		
	35					

ATTACHMENT B

Inspection Photographs and Site Plan

N

APPROXIMATE SCALE: 1" = 400'

0 200 400 800

7586 PHOTO # AND DIRECTION OF PHOTO

STATE OF TEXAS
DANIEL B. BULLOCK
82596
REGISTERED
PROFESSIONAL ENGINEER

Daniel B. Bullock
1-8-2016

SOURCE: AERIAL PHOTO PROVIDED BY IMAGEPATCH.COM EARTHSTAR GEOGRAPHICS, DATE: MAY-OCT 2011.

Coleto Creek Power, LP

Figure 1

DIKE INSPECTION
(September 2015)

PROJECT: 15-202	BY: K2P-RR	DATE: JAN 2016	CHECKED: DBB

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

Plot Date: 01/08/16 - 4:28pm, Plotted by: roodrj
Drawing Path: K:\ACAD\clients\BBA\Coleto Ck\, Drawing Name: C-ST-PL104.dwg

7383 - Exterior

7408 - Top of Levee

7422 - Exterior

7455 - Exterior Toe (Wet Area)

7387 - Exterior

7413 - Exterior

7423 - Top of Levee

7470 - Exterior Toe (Wet/Erosion Area)

7397 - Exterior

7415 - Exterior Toe (Rodent Grubbing)

7429- Interior Slope Protection

7473 - Exterior Toe (Wet Area)

NOMENCLATURE

"Interior" means interior side slope of primary ash pond dike.

STATE OF TEXAS
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PROFESSIONAL ENGINEER

Daniel B. Bullock
1-8-2016

Coleto Creek Power, LP

FIGURE 2
DIKE INSPECTION
PRIMARY ASH POND
(September 2015)

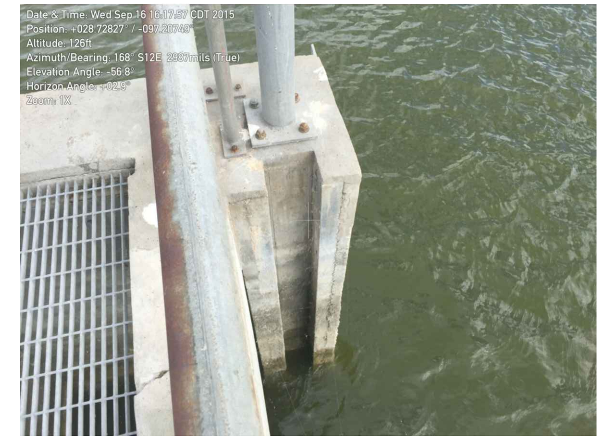
PROJECT: 15-202	BY: K2P	DATE: JAN 2016	CHECKED: DBB

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

Plot Date: 01/10/16 - 8:11am, Plotted by: roodrj
Drawing Path: K:\ACAD\clients\BBA\Coleto Ck\, Drawing Name: C-ST-Photos1-2016.dwg


7478 - Exterior Toe (Wet Area)


7545 - Interior Slope Protection

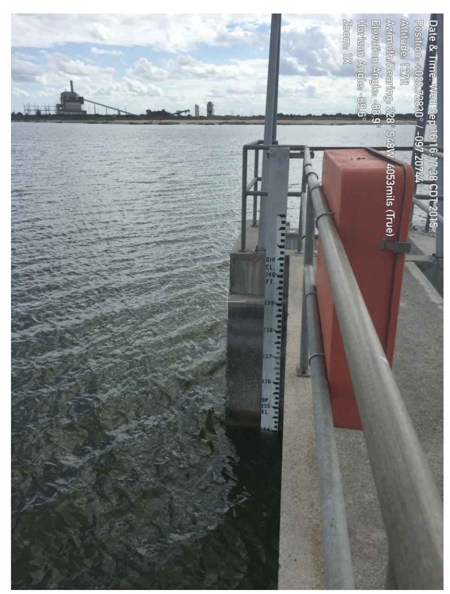

7549 - Stoplog Slots


7486 - Exterior Toe (Wet Area)


7547 - Outlet Works


7553 - Water Surface and Interior


7498 - Top of Levee


7548 - Staff Plate


7562 - Exterior

NOMENCLATURE

"Interior" means interior side slope of primary ash pond dike.

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PROFESSIONAL ENGINEER

Daniel B. Bullock
1-8-2016

Coleto Creek Power, LP

FIGURE 3
DIKE INSPECTION
PRIMARY ASH POND
(September 2015)

PROJECT: 15-202	BY: K2P	DATE: JAN 2016	CHECKED: DBB

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

Plot Date: 01/10/16 - 10:18am, Plotted by: roodrj
Drawing Path: K:\ACAD\clients\BBA\Coleto Ck\, Drawing Name: C-ST-Photos1-2016.dwg

7564 - Interior

7586 - Exterior

7596 - Interior

7571 - Top of Levee

7594 - Exterior

7585 - 6" Pipe, Exterior

7595 - Top of Levee

NOMENCLATURE

"Interior" means interior side slope of primary ash pond dike.

STATE OF TEXAS
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Daniel B. Bullock
1-8-2016

Coleto Creek Power, LP

FIGURE 4
DIKE INSPECTION
PRIMARY ASH POND
(September 2015)

PROJECT: 15-202	BY: K2P	DATE: JAN 2016	CHECKED: DBB

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

Plot Date: 01/08/16 - 4:30pm, Plotted by: roodrj
Drawing Path: K:\ACAD\clients\BBA\Coleto Ck\, Drawing Name: C-ST-Photos1-2016.dwg

7524 - Interior

7534 - Exterior

7530 - Interior

7544 - Exterior

7532 - Bank Erosion, Interior

7560 - Interior

NOMENCLATURE

"Interior" means interior side slope of secondary ash pond dike.

STATE OF TEXAS
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PROFESSIONAL ENGINEER

Daniel B. Bullock
1-8-2016

Coleto Creek Power, LP

FIGURE 5
DIKE INSPECTION
SECONDARY ASH POND
(September 2015)

PROJECT: 15-202	BY: K2P	DATE: JAN 2016	CHECKED: DBB

Bullock, Bennett & Associates, LLC
Engineering and Geoscience
Texas Registrations: Engineering F-8542, Geoscience 50127

Plot Date: 01/08/16 - 4:34pm, Plotted by: roodrj
Drawing Path: K:\ACAD\clients\BBA\Coleto Ck\, Drawing Name: C-ST-Photos1-2016.dwg

ATTACHMENT C

Soil Conservation Service Technical Note Series No. 705 – Operations and Maintenance Alternatives for Removing Trees from Dams

SOUTH
TECHNICAL
SERVICE
CENTER

TECHNICAL NOTE

Subject: **ENGINEERING**

Series No.: **705**

Reference: **Operations and Maintenance Alternatives for Removing Trees from Dams**

Date: **April 1, 1981**

4-36888 9-78
USDA—SCS—FORT WORTH, TEXAS 1981

SOIL CONSERVATION SERVICE
U. S. DEPARTMENT OF AGRICULTURE

STSC TECHNICAL NOTE 705

Re: Operations and Maintenance Alternatives
for Removing Trees From Dams

TABLE OF CONTENTS

I. General Operations and Maintenance Considerations

A. Purpose

The purpose of this technical note is to outline and discuss the alternatives for maintenance of dam embankments containing trees and heavy brush. This Technical Note contains general recommendations and provides guidance on evaluating the interrelationships between tree types, tree locations, soil types, and depth of normal pool. It is recognized that the responsible engineer may weigh additional factors in arriving at a final plan for tree removal or treatment. In some cases the final plan may require total removal of all tree roots.

The guidelines presented here assume that the dam in question has been properly designed and constructed prior to tree invasion. It is anticipated that this document will serve as a working tool and help promote consistency (1) when evaluating several damsites simultaneously, (2) when two or more individuals are involved in maintenance inspections and recommendations, and (3) over extended periods of time and changes in personnel.

B. Problem Discussion

SCS O&M Handbooks and project agreements have always required that dams and emergency spillways be kept free of trees and brush by regular mowing or treatment. It is also recognized that maintenance has not always been performed when needed. If yearly O&M inspections indicate the existence of trees and brush, our O&M recommendations require that trees and brush be removed from the dam embankments immediately.

1. Roots

a. Piping - Where trees have been allowed to grow to some size, cutting the trees may create a problem. The decay and deterioration of larger roots after the tree has been cut and killed can eventually result in open channels in the fill, creating possible seepage paths. This condition could be extremely serious in soils with a high potential for piping. The greatest concern usually involves trees on the downstream side of the earthfill dam where seepage exits occur.

b. Drain infiltration - Tree roots commonly plug drain lines used for subsurface land drainage, and they can and do plug drain outlets for dams.

2. Scour

Scour damage can be induced by trees located in the exit of emergency spillways and on the slopes of dams. The scour damage occurs during overtopping of the dam or when the emergency spillway flows. The damage is caused by water turbulence around an obstruction to the flow. Trees providing obstructions along the top of the dam, on the downstream slopes or in the exit channel of the earth spillway can induce serious damage by progressive scour eorsion. This kind of failure has been observed and documented in numerous cases.

During high water levels scour damages can occur on the upstream slope of the dam. The scour damage is caused when waves are wind driven up the slope and the sheet of water recedes at a faster rate causing scour below the tree obstruction.

3. Vegetation

Trees reduce the available moisture in the soil due to interception and transpiration. They also reduce light available to desirable grass and legume cover and compete for space. It is clear that the establishment and maintenance of good grass and legume vegetative covers require the control of trees and other woody growth on dams.

C. Considerations for Tree Removal

1. The best alternative is to prevent the growth of trees by regular mowing of the dam. If a low maintenance cover is established, then cutting new trees every 2-3 years would be necessary.

2. Once trees have been allowed to establish, the recommendation is to remove them in all cases. Remaining stumps should be chemically treated to prevent sprouting.

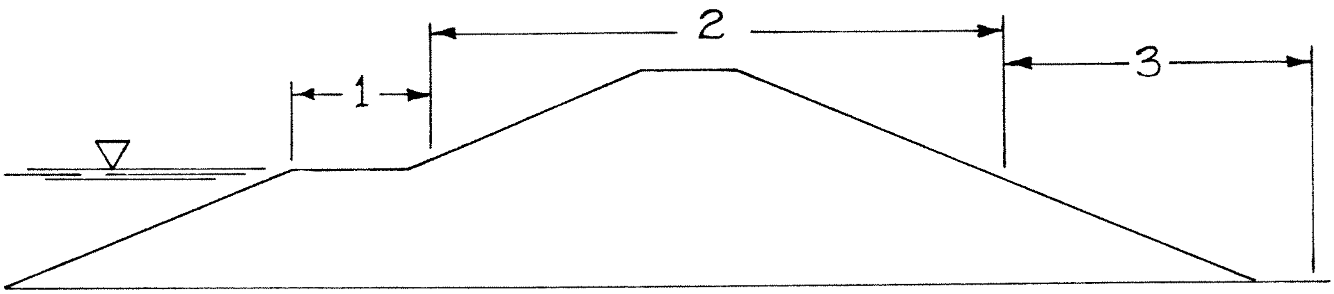
3. The removal of stumps and root mass will be required where the potential for problems from seepage, slope stability or drain clogging exists.

4. Where scouring potential exists from flowing water, the remaining stumps should be cut at least 6" below ground and filled over with compacted earth.

II. Factors Affecting Recommendations for Stump and Root Mass Removal

A. Tree Location Zones

These zones are general areas of an earthfill dam that can have significant differences with regard to alternatives for tree removal. Zone limits are variable with each individual structure. Recommendations in Table A are keyed to these zones.



1. Waterline - Potential problems include slope damage from tree blowdown, visual masking of the structure that may hinder clear observation of a potential problem, tree root interception of spillway conduits, treetop interference with hydraulic performance of principal spillways and wave action scour due to obstructions.

2. Frontslope, Crown and Backslope - Potential problems include seepage in root zone through the narrow top section at high water periods, damage from uprooting during blowdown, visual masking of covered areas, scour potential during overtopping due to obstructions, and seepage paths along roots that intercept the phreatic line from the backslope.

3. Toe of Dam - Potential problems include the development of a seepage path along roots that intercept drainage outlets or phreatic surfaces, root clogging of drainage systems, visual masking of the toe area where seepage is most likely, loss of the protective blanket if trees are uprooted by a storm event and scour from obstructions during overtopping. (This zone needs to extend at least 20 feet beyond the toe of slope.)

B. Types of Impoundments and Embankments

1. Impoundment

As the depth of permanently impounded water becomes a greater percent of dam height, the potential problems associated with existing trees may increase. This may require more careful and extensive removal and repair. Although this factor is not recognized in Table A, it must be a consideration in determining the extent of the problem and potential hazard in each case.

2. Embankment

The nature of the materials and their distribution in the embankment are the factors considered.

a. Dispersed clay shells or dispersed materials in dams with thin protective shell.

b. Embankment with chimney drain or pervious downstream shell.

c. Homogeneous or zoned embankment with outside shell soils of low PI, with moderate to high piping potential.

d. Homogeneous or zoned embankment with soils of moderate-high PI, low permeability, low piping potential.

C. Types, Sizes, and Distribution of Trees

1. Types of Trees (Root Systems)

A distinction is made between trees that have a deep taproot as opposed to the more common spreading root system. Special notes are used in the tables to address the root growth of water-loving trees such as willow.

a. Long taproot - Generally, pines and other coniferous trees.

b. Spreading root systems - Deciduous trees such as willows, cottonwood, sycamore, sweetgum, red maple, silver maple, water oak, willow oak, pin oak, Nuttall's oak, Southern red oak, elm, yellow poplar, hickory, etc.

2. Sizes of Trees

Eight inches diameter at breast height is used as the tree size where root system may start to be significant.

a. DBH $< 8''$ = Average diameter at breast height is less than 8".

b. DBH $\geq 8''$ = Average diameter at breast height is 8" or greater.

3. Distribution of Trees

Tree distribution will determine whether the root system can be considered isolated and independent or continuous and joined with other systems over a significant area.

a. Isolated or scattered trees = light cover. Light cover is defined as three trees per 400 square feet with a DBH $<$ 8" or two trees per 400 square feet with a DBH $\geq$ 8" or more.

b. Clumps or continuous tree growth = heavy cover. Heavy cover is defined as more than three trees per 400 square feet with a DBH $<$ 8" or more than two trees per 400 square feet with a DBH $\geq$ 8" or more.

III. Criteria and Recommendations for Stump and Root Mass Removal

A. Definition of Treatment Methods

Consideration of the factors previously listed was used to develop the appropriate treatment methods for stump and root mass removal on embankments. General recommendations are summarized in Table A.

Definitions of each of the treatment methods listed in this table is as follows:

1. Cut and Kill Stump

Trees should be cut approximately six inches below the ground surface to eliminate the hazard of any surface obstruction.

An approved silvicide should be applied to the stump surface, as recommended by the manufacturer, prior to backfilling and reseeding.

2. Cut and Grub Stumps and Root Mass to Specified Depth Uniformly

In the area specified, a uniform cut will be made with appropriate equipment. The underlying root mass that remains will be disturbed as little as possible by using sharp cutting tools. Exposed tap roots will be treated with an appropriate silvicide to prevent reemergence.

3. Cut and Grub Stumps and Root Mass to Depth and Diameter of Removal Dictated by Type and Size of Tree (See Tables)

   For taprooted trees, the removal of this mass should create a roughly parabolic shaped hole with a depth and diameter at the surface as specified in the tables. For spreading root trees, the depth of removal shown in the tables should be uniform over the diameter area specified in the tables.

4. Complete Removal of Stump and Root System

   It is anticipated that this treatment will be unusual and must be judged on an individual basis. Generally this would be an impractical solution and may, in some cases, be detrimental to the structure. Some of the complications are as follows: (1) area of disturbance, (2) depth and slopes of excavation, (3) procedures for effective backfilling of the excavation, (4) timing and duration of the removal operation.

5. Partial Removal of Stumps and Root Systems and the Addition of a Filter (See backfill method 3, page 6.)

   This treatment may be the most positive solution when there is concern for piping but treatment number 4 (complete removal) is not feasible.

B. Types of Backfill and Methods of Backfilling After Removal of Stumps and Root Mass

1. Selection of Soil Materials for Backfill

   The selection of soil for the backfilling of treated areas should be based primarily on the permeability characteristics of the backfill with respect to the surrounding embankment.

   Generally backfill materials in Zones 1 and 2 of the embankment should be of similar permeability to the adjacent embankment. In embankments of known dispersive clays care must be taken to find nondispersed clay borrow material or treat dispersed borrow material with hydrated lime.

   For backfill in Zones 3 and 4, if the materials in the embankment are permeable shell type materials, it is important that borrow material be at least as permeable and preferably more permeable than the adjacent fill material. At the same time, in critical locations, the borrow soils should satisfy filter design criteria to prevent any possible piping.

2. <u>Method of Placement and Backfill</u>

   Where stump and root mass removal is to a uniform depth over an accessible area, backfill should be placed in lifts no thicker than 6" and compacted at about optimum moisture by at least two passes of the tracks of the earth moving equipment.

   Where stump and root mass removal is in confined areas, backfill should be compacted with hand directed power tampers. Backfill should be placed at a minimum of 90 percent maximum dry density (ASTM D-698A) and approximately optimum moisture. Lift thickness should be 4-6".

3. <u>Special Treatment</u>

   Where extensive root mass removal is necessary and seepage is either evident or probable, the use of a filter may be appropriate. Filter material gradations must be selected to prevent piping or movement of embankment materials but allow seepage and safe exit of water. The filter may be added in conjunction with partial removal of extensive root systems.

C. <u>General Recommendations for Tree Removal</u>

Table A on page 8 contains general recommendations for tree removal.

TABLE A

GENERAL RECOMMENDATIONS FOR TREE REMOVAL 1/

2-1-81

TREE LOCATION ZONE	TREE TYPE A (TAP ROOT)				TREE TYPE B (SPREADING ROOTS)			
	DBH < 8"		DBH ≥ 8"		DBH < 8"		DBH ≥ 8"	
	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER
1 1/	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.
2 4/	Cut and kill stumps. 2/	Cut and grub stumps and root mass to 18" depth uniformly.	Cut and grub stumps and root mass to 24" depth in 1/2 crown width diameter area.	Cut and grub stumps and root mass to 24" depth uniformly.	Cut and kill stumps 2/	Cut and grub stumps and root mass to 12" depth uniformly.	Cut and grub stumps and root mass to 18" depth in crown width diameter area.	Cut and grub stump and root mass to 18" depth uniformly.
3 7/	Cut and kill stumps.	Cut and grub stumps and root mass to 18" depth uniformly.	Cut and grub stumps and root mass to 24" depth in 1/2 crown width diameter area. 3/	Cut and grub stumps and root mass uniformly to 18" depth.	Cut and kill stumps. 5/	Cut and grub stumps and root mass to 12" depth uniformly. 5/	Cut and grub stumps and root mass to 18" depth in crown width diameter area. 3/ 5/	Cut and grub stumps and root mass uniformly to 12" depth. 6/

1/ Tree growth smaller than 2" DBH will be removed by spraying, injection or cutting and stump killing. Trees and shrubs planted for shoreline protection in Zone 1 shall be maintained at heights < 4 feet.
2/ In embankment type (a) dispersed soil--cut stumps 12 inches below surface and backfill with compacted soil.
3/ In embankment type (d) earthfill with low piping potential--cut and kill stumps.
4/ In riprapped or heavy rockfill sections grubbing is not required.
5/ For water-loving trees such as willows, remove stump and root mass in twice the crown width area.
6/ For water-loving trees such as willows, remove stumps and root mass to 18" depth uniformly.
7/ Individual large trees in this zone may need the special treatment as described in Section 3.