QUALITATIVE SLOPE STABILITY EVALUATION AND CONCEPTUAL BANK STABILIZATION DESIGN

Lopez Creek
Smith River, California

Prepared for:
Smith River Rancheria
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April 23, 2010
LACO Project No. 7270.00

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PROJECT DESCRIPTION

Members of the Smith River Rancheria have identified an unstable area adjacent to Lopez Creek that is reportedly contributing excess sediment to the creek, and negatively effecting downstream water quality. The intake structure for the Rancherias drinking water treatment facility is located less than 100-feet downstream of the identified unstable area. Excess turbidity of the intake water is resulting in increased water treatment needs.

The unstable area is located on the right bank of Lopez Creek in the northeast quarter of Section 17, T. 18, R. 13W, Humboldt Baseline and Meridian (Figure 1). Latitude and Longitude of this area is 41.9583° and -124.1985°, respectively. For the purpose of this report, this unstable area is referred to as the "site."

SCOPE OF WORK

LACO Associates (LACO) was retained by the Smith River Rancheria to conduct a reconnaissance of the site and provide a qualitative stability evaluation of the site instability, an analysis of hydrologic and hydraulic conditions, and conceptual design details to reduce the potential for further instability of the stream bank with resultant sediment load to the creek.

Our Scope of Work for this project, as outlined in our proposal to the Rancheria dated February 11, 2010, is composed of four parts:

1. Provide a qualitative evaluation of the identified slope instability to characterize the type of instability, activity level, aerial extent, potential for future sediment delivery, and potential factors influencing the stability of the surrounding slopes.
2. Prepare a survey controlled topographic map of the unstable area, surrounding slopes affecting the unstable area, and the creek below the unstable area.
3. Conduct a hydrologic analysis of the creek at the location of the instability to quantify peak flows and support an open channel hydraulic analysis.
4. Prepare conceptual plans of a proposed bank stabilization design to support project planning and an opinion of probable construction costs.

Our Scope of Work for this project did not include a subsurface investigation, laboratory testing, quantitative stability analysis, or preparation of construction plans.

Site Conditions

Geologic and Geomorphic Setting

Based on field observations and published geologic mapping by Davenport (1983), the Lopez Creek drainage basin is primarily underlain by Cretaceous-Jurassic Franciscan Broken Formation bedrock (map symbol KJfbf, Figure 1) consisting of massive, fractured sandstone and interbedded, sheared argillite.

In the vicinity of the site, the bedrock is mantled with relatively young river terrace deposits and slope colluvium (map symbols Qrt and Qac, respectively). The terrace deposits are primarily composed of rounded sands and gravels adjacent to the drainage while the slope colluvium is composed of silty/clayey soils with variable amounts of angular to subangular gravels.

These geologic materials can be highly susceptible to failure by mass wasting, especially where subject to prolonged saturated conditions. Published geomorphic mapping of the Lopez Creek drainage basin identifies several types of mass wasting features of various activity levels which attest the inherent instability characteristics of the geologic materials (Figure 1).

Seismic Setting

This project area is located within a seismically active region which is subject to frequent moderate to large earthquakes. The regional tectonic framework in northwestern California is primarily controlled by compressional tectonics associated with the collision of the onshore North American plate and offshore Juan de Fuca/Gorda plates. Crustal deformation associated with the collision of the plates is expressed as a 90-kilometer (km) wide fold and thrust belt that comprises the western edge of the North American plate margin (Carver, 1987).

The proximity of multiple active seismic sources to the site results in frequent strong ground motions which commonly trigger landsliding in the coastal mountains. We are unaware of any information to support an interpretation that the instability at the site is the direct result of seismic shaking. However, we can not preclude the possibility that periodic seismic shaking has in some way contributed to the instability of the site or other sites within the Lopez Creek drainage basin.

Observations

The configuration of the native slopes in the vicinity of the site has been modified by historic grading and logging activities. An old dirt road crosses the middle of the site and continues up gradient in an easterly direction. A separate road splays off of the main road easterly of the site and leads upslope to a broad low gradient bench at the north end of the site. The roads and bench appear to have been constructed with cut/fill construction techniques. Cutbank and fill slopes appear relatively low and are estimated to be less than 4 vertical feet high in the vicinity. The roads were reportedly constructed over 50-years ago and do not appear to be in active use. The road and bench surfaces are currently covered with grass and small vegetation.

A narrow bench is present on the right bank of the creek at the location of the unstable area and continues easterly adjacent to the creek for several hundred feet. The bench is approximately 10 feet wide and follows the edge of the creek. The slopes on the north side of the bench ascend steeply to the surrounding slopes. The western edge of the bench ends abruptly at the unstable area while the eastern end gradually narrows before finally disappearing near a bend in the creek.

The unstable area is clearly defined at the crown (upslope limits) and toe (downslope limits) by abrupt breaks in slope (LS-1 and LS-2 of Figure 2). Near the center of the unstable area, the changes in topography are less abrupt but easily identified by a depression in the old road. The property owner reports that the depression in the road has gradually deepened throughout the years. With the exception of isolated areas adjacent to the creek, the unstable area is generally covered with dense vegetation and scattered small trees. The southwesterly edge of the unstable area intersects the creek and is actively eroding in isolated areas. The southeasterly edge of the unstable area is contained on the narrow bench that parallels the creek and is not experiencing active erosion by the creek.

A second unstable area is present upstream of the primary unstable area (LS-3 of Figure 2). The second area is also defined by abrupt breaks in slope. The crown of LS-3 is an arcuate concave depression in the slope that is situated immediately above a convex mound. Two small springs originate from the base of the concave slope. The convex mound of material is contained on the narrow bench that parallels the creek. The creek is not actively eroding LS-3.

Geologic Interpretations

Landslide Characterization and Estimated Depth

Based on the morphology of LS-1 and observations by the landowner of gradual slope movement across the road through time, the slide is a slump/earthflow (earthflow) type of failure. An earthflow is a landslide that moves downslope in a semi-viscous highly plastic state at various rates through time. Soils susceptible to earthflow style failure are typically fine grain silts and clays. The rate of movement is often directly related to soil moisture conditions and slope gradient. Based on schematic cross sections through the site (sections A through D, Figures 2 and 3), the slide plane of LS-1 is estimated to be approximately 20 feet below the existing ground surface.

The secondary failure present near the base of the earthflow (LS-2) is a rotational/translational slide (RTS). An RTS is characterized by a concave arcuate slope immediately above a convex slope. The convex slope represents material that was evacuated from the concave area above. Soils transported by a RTS typically are a somewhat coherent mass of material that fails along an arcuate failure plane. The slide plane for the RTS is estimated to be approximately 7 feet below the ground surface (bgs) (sections A and B, Figures 2 and 3). Soils involved in RTS are typically cohesive materials.

The smaller slope failure upstream of the main unstable area (LS-3) is also a RTS with a slide plane estimated to be less than 7-feet below the ground surface (section C, Figures 2 and 3).

Landslide Activity Assessment

The following activity assessment is based on the methodology and procedures of Keaton and DeGraff (1996).

Based on the displacement of the road and bench and observation by the landowner of gradual road deformation through time, both LS-1 and LS-2 are classified as active slides. Given the similar morphology of LS-3, LS-3 is also classified as active.

Volume Estimates

Table 1 presents estimated volumes of material incorporated in the identified landslides. The volume estimates are based on assumed depths. The crown scarp areas of both LS-2 and LS-3 are not included in the "length" measurements.

Table 1. Estimated slide volumes.

Landslide	Average Width (feet)	Average Length (feet)	Estimated Depth (feet)	Volume (cubic feet)	Volume (cubic yards)
LS-1	45	85	20	76500	2833
LS-2	55	35	7	13475	499
LS-3	30	15	7	3150	117

Potential for Future Failure and Sediment Delivery

Given that all three landslides are considered active, the risk of future failure for all three slides is high.

Future failures of both LS-1 and LS-2 are anticipated to be relatively slow, on the order of millimeters to inches per year. However, the rate of failure is anticipated to be strongly related to soil moisture conditions. High soil moisture conditions due to heavy precipitation or misdirected runoff from above may result in higher rates of movement (upwards of multiple feet per year). Anticipated continued movement of LS-1 and LS-2 will likely result in periodic small failures into the creek and exposure of soil to active erosion by the creek. Due to the type of failure and assumed bedrock materials, the risk is low that LS-1 and LS-2 will fail catastrophically, and completely block the creek.

Future failures of LS-3 are anticipated to be relatively small failures in the vicinity of the crown scarp area. Debris from crown scarp failure are anticipated to remain on the slope or bench adjacent to the creek. Future sediment delivery to Lopez Creek from LS-3 is anticipated to be limited to materials delivered by other surface waters through erosion of bare ground. Failures of the crown scarp area will result in gradual movement of the slide upslope toward the existing dirt road. The risk is low that LS-3 will fail catastrophically and block the creek.

Factors Influencing Local Slope Instability

In the absence of a qualitative stability evaluation, the factors influencing the stability of the local slopes are speculative. However, basic slope stability physics dictates that there are two basic forces that influence the stability of a slope - driving forces and resisting forces. Slopes fail when the driving forces exceed the resisting forces.

The main driving force on slopes is gravity, whereas the main resisting force is the strength of the soil. Grading and water have a significant effect on changes to the stability of a slope. Both grading and the addition of water to a slope have the potential to decrease resisting forces and/or increase driving forces, depending on how they are applied.

At this site, resisting forces appear to have been removed from the toe of the slope by either grading (if the narrow bench represents an old road) or streamside erosion. Springs within both LS-2 and LS-3 indicate that the soils near the base of the slope are saturated and subject to excess pore water pressures. Additionally, the absence of drainage control structures along the midslope road provide a mechanism by which excess surface runoff can collect and drain toward both the LS-1 and LS-2.

Hydrologic and Hydraulic Analysis

Hydrology

Hydrologic flows for the Lopez Creek watershed were calculated using United State Geologic Survey (USGS) regression equations and parameters for specific design storm events. The USGS regression equations were developed by the USGS to estimate flows on ungauged waterways with an area less than 2,000 square miles at specific recurrence intervals. The USGS equations were developed by means of a regression analysis that utilizes basin characteristics and flow data associated with gauged stations. Although Lopez Creek was gauged for 11 years, the flow data is insufficient to complete an analysis using the gauge data.

The hydrologic calculations, parameters, and a graph illustrating the modeled flows for specific return periods are included as Attachment 1. Results of the hydrologic calculations are summarized below in Table 2.

Table 2. Hydrologic peak flows.

Event	Peak Flow Q (cubic feet per second)
2-year	**191**
5-year	**286**
10-year	**374**
25-year	**464**
50-year	**551**
100-year	**602**

Hydraulics

Design storm flows were modeled using hydraulic modeling software HEC-RAS River Analysis System Version 4.0 created by the U.S. Army Corp of Engineers (USACE). HEC-RAS software is used to perform "one-dimensional steady and unsteady flow river hydraulics" calculations.

Results of the hydraulic modeling suggest the flow velocities vary for the design storm events. Average velocities in the channel range from 6.5 ft/s for the 2-year, 191 cfs design flow to 7.4 ft/s for the 100-year, 602 cfs design flow. Slope erosion increases with increased flow velocity. HEC-RAS results with design water surface elevations are included as Attachment 2.

Based on the hydraulic modeling and HEC-11 (Brown *et al*, 1989), rock slope protection incorporated into the design mitigation for the unstable area must have a minimum average rock size (D_{50}) of 18-inches to resist scour. Shear forces on rock slope protection (RSP) range from 1.8 to 6.3 pounds per square foot for the design storm events.

Conceptual Design Options

Effective mitigation measures for this site must either:

- Decrease the driving forces
- Increase the resisting forces
- Or provide a combination of both

For this project, we provide five design options. Additional site specific analysis and design is necessary to quantify the effectiveness of each option and produce final design documents. It is not our intention for the Rancheria to implement all options presented. Rather, each option should be evaluated through quantitative slope stability modeling to determine which option or combination of options provide a level of stability acceptable to the Rancheria. For instance, stability modeling may indicate that rock slope protection adjacent to the creek, combined with excavation at the head of the slide provides adequate protection against future instability. Therefore, vertical drains and soil nails are not necessary.

Reduction in Driving Forces

Driving forces on the slope can be reduced by removing mass from the head of the unstable area through grading. Detail E of Figure 4 provides schematic design details to support re-grading of the site. Select advantages and disadvantages of site grading are detailed below in Table 3.

Table 3. Design options to support a reduction in driving forces.

Detail	Description	Advantages	Disadvantages
E	Removal of soil from the head of LS-1	Work is performed outside of the channel	Excavated soil must be transported to a stable location for disposal
		Creates additional usable property	Grading permit may be required

Increase Resisting Forces

Resisting forces on the slope can be increased by installing retaining structures. Two types of retaining structures appropriate for this site are soil nails near the center of the unstable area and/or a rock buttress at the base of the slope. Design details of both options are included as details F and G on Figure 5. Table 4 provides a comparison of each option.

Table 4. Design options to support an increase in resisting forces.

Detail	Description	Advantages	Disadvantages
F	Installation of soil nails within LS-1	Work is performed outside of the channel	Requires specialized equipment for installation
		Minimal disturbance to existing vegetation and slope	
		Can be designed for minimal visual impact	
		Soil nails also provide conduits to drain excess pore water	
G	Construction of a rock buttress at the base of the slope	Rock buttress will provide protection from creek erosion	Work is performed in the channel
		Rock buttress is permeable and will allow groundwater to drain	Buttress can change hydraulics and create additional hazards to other locations
			Construction will result in significant disturbance to existing vegetation and slope

Water Control

Control of water on a slope can provide both an increase in resisting forces and a decrease in driving forces. Near the top of an unstable slope, excess water increases the driving forces by adding weight through saturation of the soil. Near the base of an unstable slope, excess water decreases the resisting forces by increasing porewater pressures within the soil. Increased porewater pressures result in a reduction in shear strength and a reduction in resisting forces.

Details H, I, and J of Figure 6 provide design options for controlling excess water at the site. Detail H illustrates a schematic water bar placed on the existing dirt road to reduce the volume of surface water entering the site. Details I and J illustrate a vertical subsurface drain installed at the toe of the unstable area to control excess porewater pressure in the soil. Horizontal drain(s) are an alternative to the vertical drain. However, the proposed vertical can be constructed with conventional excavation equipment, whereas the horizontal drains require specialized drilling equipment. Given the relatively small size of this project, the specialized drilling equipment may not be a cost effective solution. A comparison of each option is provided in Table 5.

Table 5. Design options to control ground and surface water.

Detail	Description	Advantages	Disadvantages
H	Installation of water bars	Work is performed outside of the channel	Minimal control of groundwater
		Minimal disturbance to existing vegetation and slope	Concentrated flow from water bars can lead to hazards below outlets
		Work can be performed by Rancheria staff at minimal cost	May impair vehicle traffic on the road
			May require periodic maintenance
I and J	Installation of vertical drains within LS-1 and LS-2	Limited construction activities are necessary adjacent to the creek	Construction will result in disturbance to existing vegetation and slope
		Construction can be completed with standard excavation equipment	Low area of influence in fine grain soils

Budgetary Construction Costs

Table 6 provides probable construction costs for the various design options presented. The cost estimates are based on the subjective assessments and assumptions stated within this report and are subject to change upon completion of detailed design documents. The cost estimates assume that all work will be completed by licensed contractors and professionals using standard rates and materials. With the exception of the water bars, the estimates assume that all materials will be imported onto the site from local suppliers, and that all excess materials from excavations will be disposed of offsite.

The cost estimates do not include fees associated with necessary additional investigations, design, and/or permitting.

Table 6. Budgetary construction costs.

Description		Unit	Quantity	Unit Price	Subtotal	Total
Removal of soil from the head of LS-1	Excavation and disposal	CY	200	$45	$9,000	
	Erosion Control	LS	1	$5,000	$5,000	$14,000
Installation of soil nails within LS-1	Soil Nails	LF	50	$1,500	$75,000	
	Erosion Control	LS	1	$500	$500	$75,500
Construction of a rock buttress at the base of the slope	Excavation and disposal	CY	80	$45	$3,600	
	Imported rock rip-rap	TON	400	$100	$40,000	
	Erosion Control	LS	1	$5,000	$5,000	$48,600
Installation of water bars	Excavation	LS	1	$2,000	$2,000	
	Erosion Control	LS	1	$500	$500	$2,500
Installation of two vertical drains within LS-1 and LS-2	Excavation and disposal	CY	20	$45	$900	
	Imported drain rock	TON	300	$60	$18,000	
	Erosion Control	LS	1	$5,000	$5,000	$23,900

CY = Cubic Yard TON = Ton
LS = Lump Sum LF = Linear Feet (Width of slide)
EA = Each

Recommended Future Work

Geotechnical Investigation

The interpretations and conceptual design options presented in this report are based on a qualitative evaluation of the site. The effectiveness of the proposed mitigation measures must be assessed through quantitative slope stability analysis. Additional geotechnical analysis necessary to support a quantitative slope stability analysis includes:

- Geotechnical drilling to characterize the subsoil conditions and collect soil samples for laboratory analysis.
- Laboratory analysis of soil samples to quantify strength characteristics.

Water Quality Investigation

During our field reconnaissance, we noted several additional areas of instability and active creek erosion within a mile upstream of the site. Other areas likely exist further upstream. Water quality investigations at several locations along Lopez Creek can identify specific areas that are contributing significant turbity to the creek. The results of the investigation can be used to prioritize potential mitigation sites.

Water System Design Review and Upgrade

The water treatment facility was designed and constructed approximately seven years ago. Water treatment technology is continuously improving and recent advances may provide opportunities to upgrade the system to address excess turbidity concerns. Upgrades to the existing water treatment facility may provide a cost effective means for addressing excess turbity.

LACO Associates has a full staff of geologist, engineers, surveyors, and planners that are available to support the Rancheria with any of these future work recommendations.

Recommended Minimum Mitigation

We understand that the Rancheria may not necessarily implement any or all of the design options presented in this report prior to next winter. However, construction of drainage control structures on the existing road network is a relatively inexpensive mitigation measure that will reduce the volume of surface water entering the unstable area. We recommend that the Rancheria install drainage control structures (waterbars) on the road network prior to next winter to reduce the potential for surface water to continue to collect and drain toward the unstable area. The drainage control structures should be installed in a manor to support continued use of the road by property owners.

LIMITATIONS

This report and accompanying design sheets have been prepared for the exclusive use of the Smith River Rancheria. LACO has endeavored to comply with generally accepted engineering geologic practices common to the local area. LACO makes no other warranty, expressed, or implied.

The purpose of our investigation and this report was to characterize the unstable area identified by members of the Rancheria and provide conceptual design options to reduce the potential for additional slope instability at the site. LACO can not accept responsibility for damages to parties that choose to accept the potential hazards and risks of the site.

Other unstable areas may be present in the vicinity that has the potential to effect turbity in Lopez Creek. Our investigation and conceptual design options are not intended as final design and/or construction documents. Additional site specific geotechnical and engineering design is necessary to support preparation of design documents. Furthermore, our geologic interpretations are limited to qualitative means. The effectiveness of our design options may be modified by results of a quantitative slope stability analysis.

The interpretation included in this report are based on assumptions about subsurface conditions that may only be verified by drill data and/or monitoring systems.

Note that LACO is not responsible for any claims, damages, or liability associated with any other party's interpretation of the subsurface data or reuse of this letter for other projects or at other locations without our express written authorization.

REFERENCES

Brown, Scott A., and Clyde, Eric S., 1989, Design of Riprap Revetment: U.S. Department of Transportation, Federal Highway Department, March 1989, 182 p.

Carver, G. A., (1987), Late Cenozoic tectonics of the Eel River basin region, coastal northern California. In H. Schymiczek and R, Suchland, eds., Tectonics, sedimentation, and evolution of the Eel River and other coastal basins of northern California: San Joaquin Geological Society Misc. Publication 37, p. 61-72.

Davenport, C. W, (1983), Geology and geomorphic features related to landsliding, Smith River 7.5' quadrangle, Del Norte County, CA. CDMG OFR 83-19 SF. 1:24,000 scale.

Keaton, J. R. and J. V. DeGraff, (1996), Surface Observation and Geologic Mapping. In: Turner, A. K. and R. L. Schuster (editors), Landslides Investigation and Mitigation, Special Report 247: Transportation Research Board, National Research Council.

LIST OF FIGURES AND APPENDICES

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ATTACHMENT 1

Hydrologic Calculations

EVENT	C	A	a	P	b	H	c
2-year	3.52	0.92	0.90	80	0.89	0.7	-0.47
5-year	5.04	0.92	0.89	80	0.91	0.7	-0.35
10-year	6.21	0.92	0.88	80	0.93	0.7	-0.27
25-year	7.64	0.92	0.87	80	0.94	0.7	-0.17
50-year	8.57	0.92	0.87	80	0.96	0.7	-0.08
100-year	9.23	0.92	0.87	80	0.97	0.7	0

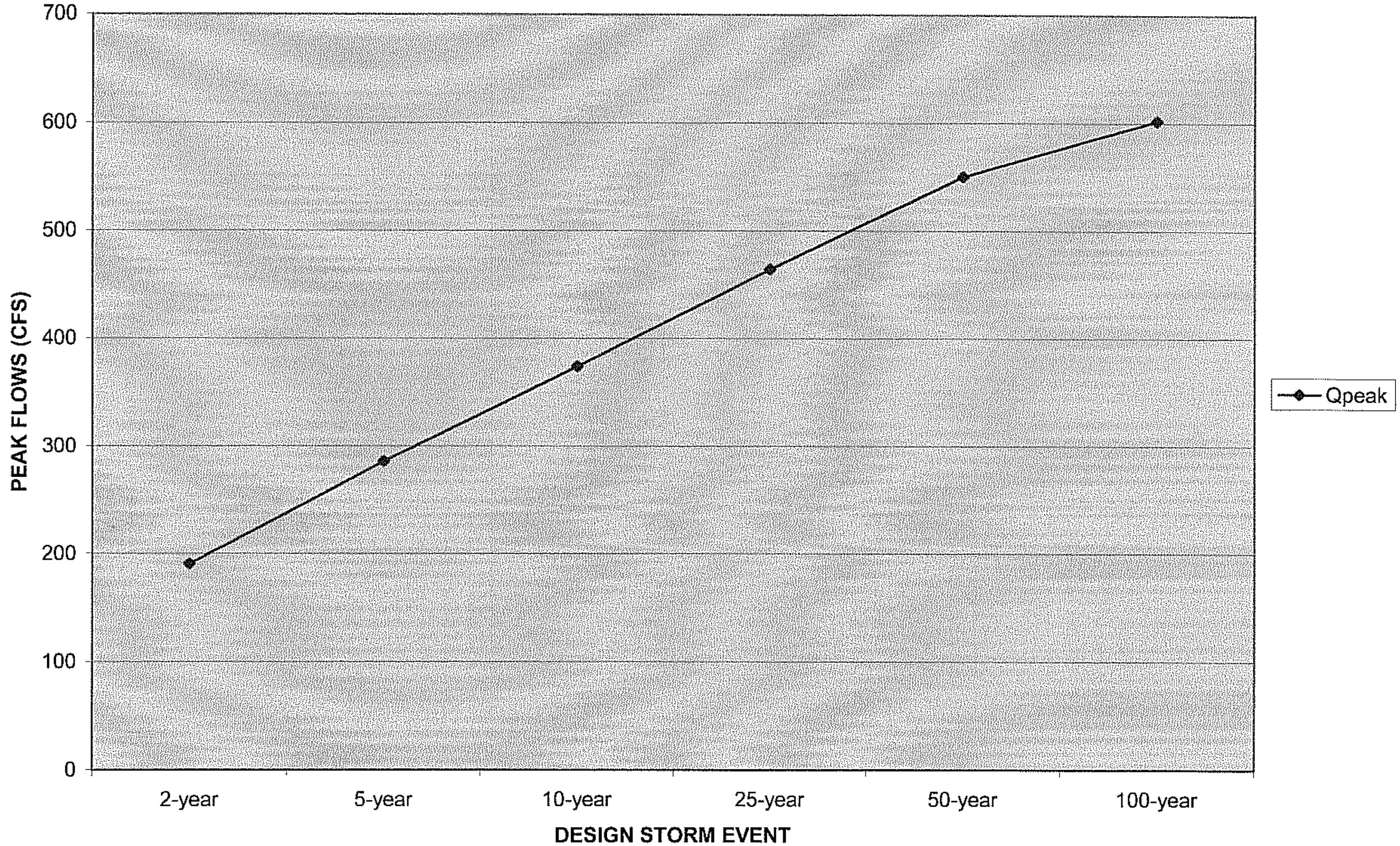
$Qpeak = C x A^a x P^b x H^c$

Where:

Qpeak is the peak flow at specified recurrence interval (ft^3/s)
C is a regression constant based upon return period and region
A is watershed area above point of interest (square miles)
P is mean annual precipitation (inches)
H is altitude index (mean of altitude taken at points 10 percent and 85 percent distance between point of interest and basin divide; (1000 ft), and
a, b, c are regression exponents based upon return period and region

EVENT	C	A^a	P^b	H^c	Qpeak
2-year	3.52	0.928	49.4	1.18	**191**
5-year	5.04	0.928	53.9	1.13	**286**
10-year	6.21	0.929	58.9	1.10	**374**
25-year	7.64	0.930	61.5	1.06	**464**
50-year	8.57	0.930	67.1	1.03	**551**
100-year	9.23	0.930	70.1	1.00	**602**

LOPEZ CREEK #11533000 USGS REGRESSION EQUATION PEAK FLOWS



ATTACHMENT 2

HEC-RAS Results

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 2-YEAR

E.G. Elev (ft)	91.29	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.21	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	91.08	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)	90.19	Flow Area (sq ft)	0.03	51.83	0.01
E.G. Slope (ft/ft)	0.016569	Area (sq ft)	0.03	51.83	0.01
Q Total (cfs)	191.00	Flow (cfs)	0.01	190.99	0.00
Top Width (ft)	29.80	Top Width (ft)	0.64	29.00	0.16
Vel Total (ft/s)	3.68	Avg. Vel. (ft/s)	0.22	3.69	0.21
Max Chl Dpth (ft)	3.08	Hydr. Depth (ft)	0.04	1.79	0.04
Conv. Total (cfs)	1483.9	Conv. (cfs)	0.0	1483.8	0.0
Length Wtd. (ft)	90.00	Wetted Per. (ft)	0.65	29.84	0.18
Min Ch El (ft)	88.00	Shear (lb/sq ft)	0.04	1.80	0.04
Alpha	1.00	Stream Power (lb/ft s)	0.01	6.62	0.01
Frctn Loss (ft)	2.83	Cum Volume (acre-ft)	0.00	0.08	0.00
C & E Loss (ft)	0.04	Cum SA (acres)	0.00	0.05	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 5-YEAR

E.G. Elev (ft)	91.62	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.41	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	91.21	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)		Flow Area (sq ft)	0.17	55.48	0.04
E.G. Slope (ft/ft)	0.029588	Area (sq ft)	0.17	55.48	0.04
Q Total (cfs)	286.00	Flow (cfs)	0.10	285.88	0.02
Top Width (ft)	31.06	Top Width (ft)	1.65	29.00	0.41
Vel Total (ft/s)	5.14	Avg. Vel. (ft/s)	0.56	5.15	0.52
Max Chl Dpth (ft)	3.21	Hydr. Depth (ft)	0.10	1.91	0.10
Conv. Total (cfs)	1662.7	Conv. (cfs)	0.6	1662.0	0.1
Length Wtd. (ft)	90.00	Wetted Per. (ft)	1.66	29.84	0.46
Min Ch El (ft)	88.00	Shear (lb/sq ft)	0.19	3.43	0.17
Alpha	1.01	Stream Power (lb/ft s)	0.11	17.70	0.09
Frctn Loss (ft)	2.85	Cum Volume (acre-ft)	0.04	0.10	0.00
C & E Loss (ft)	0.02	Cum SA (acres)	0.12	0.06	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 10-YEAR

E.G. Elev (ft)	92.02	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.53	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	91.49	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)		Flow Area (sq ft)	0.97	63.76	0.24
E.G. Slope (ft/ft)	0.031635	Area (sq ft)	0.97	63.76	0.24
Q Total (cfs)	374.00	Flow (cfs)	1.00	372.77	0.23
Top Width (ft)	33.92	Top Width (ft)	3.93	29.00	0.98
Vel Total (ft/s)	5.76	Avg. Vel. (ft/s)	1.03	5.85	0.96
Max Chl Dpth (ft)	3.49	Hydr. Depth (ft)	0.25	2.20	0.25
Conv. Total (cfs)	2102.8	Conv. (cfs)	5.6	2095.8	1.3
Length Wtd. (ft)	90.00	Wetted Per. (ft)	3.96	29.84	1.10
Min Ch El (ft)	88.00	Shear (lb/sq ft)	0.48	4.22	0.43
Alpha	1.03	Stream Power (lb/ft s)	0.50	24.67	0.42
Frctn Loss (ft)	3.03	Cum Volume (acre-ft)	0.06	0.12	0.00
C & E Loss (ft)	0.04	Cum SA (acres)	0.14	0.06	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 25-YEAR

E.G. Elev (ft)	92.38	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.67	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	91.71	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)		Flow Area (sq ft)	2.01	70.06	0.50
E.G. Slope (ft/ft)	0.035270	Area (sq ft)	2.01	70.06	0.50
Q Total (cfs)	464.00	Flow (cfs)	2.80	460.55	0.65
Top Width (ft)	36.09	Top Width (ft)	5.67	29.00	1.42
Vel Total (ft/s)	6.39	Avg. Vel. (ft/s)	1.39	6.57	1.30
Max Chl Dpth (ft)	3.71	Hydr. Depth (ft)	0.35	2.42	0.35
Conv. Total (cfs)	2470.7	Conv. (cfs)	14.9	2452.3	3.5
Length Wtd. (ft)	90.00	Wetted Per. (ft)	5.72	29.84	1.59
Min Ch El (ft)	88.00	Shear (lb/sq ft)	0.77	5.17	0.70
Alpha	1.05	Stream Power (lb/ft s)	1.08	33.99	0.91
Frctn Loss (ft)	3.19	Cum Volume (acre-ft)	0.09	0.13	0.00
C & E Loss (ft)	0.08	Cum SA (acres)	0.16	0.06	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 50-YEAR

E.G. Elev (ft)	92.70	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.79	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	91.91	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)		Flow Area (sq ft)	3.31	75.87	0.83
E.G. Slope (ft/ft)	0.037747	Area (sq ft)	3.31	75.87	0.83
Q Total (cfs)	551.00	Flow (cfs)	5.62	544.07	1.31
Top Width (ft)	38.09	Top Width (ft)	7.27	29.00	1.82
Vel Total (ft/s)	6.89	Avg. Vel. (ft/s)	1.70	7.17	1.58
Max Chl Dpth (ft)	3.91	Hydr. Depth (ft)	0.45	2.62	0.45
Conv. Total (cfs)	2836.0	Conv. (cfs)	28.9	2800.4	6.7
Length Wtd. (ft)	90.00	Wetted Per. (ft)	7.33	29.84	2.03
Min Ch El (ft)	88.00	Shear (lb/sq ft)	1.06	5.99	0.96
Alpha	1.07	Stream Power (lb/ft s)	1.81	42.97	1.52
Frctn Loss (ft)	3.34	Cum Volume (acre-ft)	0.11	0.14	0.00
C & E Loss (ft)	0.12	Cum SA (acres)	0.17	0.06	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 190 Profile: 100-YEAR

E.G. Elev (ft)	92.89	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.84	Wt. n-Val.	0.100	0.075	0.100
W.S. Elev (ft)	92.04	Reach Len. (ft)	90.00	90.00	90.00
Crit W.S. (ft)		Flow Area (sq ft)	4.34	79.71	1.08
E.G. Slope (ft/ft)	0.037916	Area (sq ft)	4.34	79.71	1.08
Q Total (cfs)	602.00	Flow (cfs)	8.04	592.06	1.90
Top Width (ft)	39.46	Top Width (ft)	8.42	29.00	2.04
Vel Total (ft/s)	7.07	Avg. Vel. (ft/s)	1.85	7.43	1.76
Max Chl Dpth (ft)	4.04	Hydr. Depth (ft)	0.52	2.75	0.53
Conv. Total (cfs)	3091.6	Conv. (cfs)	41.3	3040.6	9.8
Length Wtd. (ft)	90.00	Wetted Per. (ft)	8.48	29.84	2.30
Min Ch El (ft)	88.00	Shear (lb/sq ft)	1.21	6.32	1.12
Alpha	1.09	Stream Power (lb/ft s)	2.24	46.97	1.96
Frctn Loss (ft)	3.45	Cum Volume (acre-ft)	0.12	0.14	0.00
C & E Loss (ft)	0.13	Cum SA (acres)	0.18	0.06	0.00

Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 2-YEAR

E.G. Elev (ft)	88.41	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.66	Wt. n-Val.		0.075	
W.S. Elev (ft)	87.76	Reach Len. (ft)			
Crit W.S. (ft)	87.76	Flow Area (sq ft)		29.38	
E.G. Slope (ft/ft)	0.081578	Area (sq ft)		29.38	
Q Total (cfs)	191.00	Flow (cfs)		191.00	
Top Width (ft)	22.69	Top Width (ft)		22.69	
Vel Total (ft/s)	6.50	Avg. Vel. (ft/s)		6.50	
Max Chl Dpth (ft)	1.76	Hydr. Depth (ft)		1.29	
Conv. Total (cfs)	668.7	Conv. (cfs)		668.7	
Length Wtd. (ft)		Wetted Per. (ft)		23.85	
Min Ch El (ft)	86.00	Shear (lb/sq ft)		6.27	
Alpha	1.00	Stream Power (lb/ft s)		40.78	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 5-YEAR

E.G. Elev (ft)	88.76	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.36	Wt. n-Val.	0.100	0.075	
W.S. Elev (ft)	88.40	Reach Len. (ft)			
Crit W.S. (ft)	88.40	Flow Area (sq ft)	38.86	44.81	
E.G. Slope (ft/ft)	0.033909	Area (sq ft)	38.86	44.81	
Q Total (cfs)	286.00	Flow (cfs)	50.99	235.01	
Top Width (ft)	141.33	Top Width (ft)	117.05	24.28	
Vel Total (ft/s)	3.42	Avg. Vel. (ft/s)	1.31	5.24	
Max Chl Dpth (ft)	2.40	Hydr. Depth (ft)	0.33	1.85	
Conv. Total (cfs)	1553.1	Conv. (cfs)	276.9	1276.3	
Length Wtd. (ft)		Wetted Per. (ft)	117.06	26.00	
Min Ch El (ft)	86.00	Shear (lb/sq ft)	0.70	3.65	
Alpha	1.96	Stream Power (lb/ft s)	0.92	19.14	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 10-YEAR

E.G. Elev (ft)	88.95	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.38	Wt. n-Val.	0.100	0.075	
W.S. Elev (ft)	88.56	Reach Len. (ft)			
Crit W.S. (ft)	88.56	Flow Area (sq ft)	59.28	48.77	
E.G. Slope (ft/ft)	0.035803	Area (sq ft)	59.28	48.77	
Q Total (cfs)	374.00	Flow (cfs)	97.07	276.93	
Top Width (ft)	157.67	Top Width (ft)	133.36	24.31	
Vel Total (ft/s)	3.46	Avg. Vel. (ft/s)	1.64	5.68	
Max Chl Dpth (ft)	2.56	Hydr. Depth (ft)	0.44	2.01	
Conv. Total (cfs)	1976.6	Conv. (cfs)	513.0	1463.6	
Length Wtd. (ft)		Wetted Per. (ft)	133.36	26.16	
Min Ch El (ft)	86.00	Shear (lb/sq ft)	0.99	4.17	
Alpha	2.05	Stream Power (lb/ft s)	1.63	23.66	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 25-YEAR

E.G. Elev (ft)	89.10	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.38	Wt. n-Val.	0.100	0.075	
W.S. Elev (ft)	88.72	Reach Len. (ft)			
Crit W.S. (ft)	88.72	Flow Area (sq ft)	81.39	52.58	
E.G. Slope (ft/ft)	0.035569	Area (sq ft)	81.39	52.58	
Q Total (cfs)	464.00	Flow (cfs)	152.38	311.62	
Top Width (ft)	173.36	Top Width (ft)	149.02	24.34	
Vel Total (ft/s)	3.46	Avg. Vel. (ft/s)	1.87	5.93	
Max Chl Dpth (ft)	2.72	Hydr. Depth (ft)	0.55	2.16	
Conv. Total (cfs)	2460.3	Conv. (cfs)	808.0	1652.3	
Length Wtd. (ft)		Wetted Per. (ft)	149.02	26.32	
Min Ch El (ft)	86.00	Shear (lb/sq ft)	1.21	4.44	
Alpha	2.06	Stream Power (lb/ft s)	2.27	26.29	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

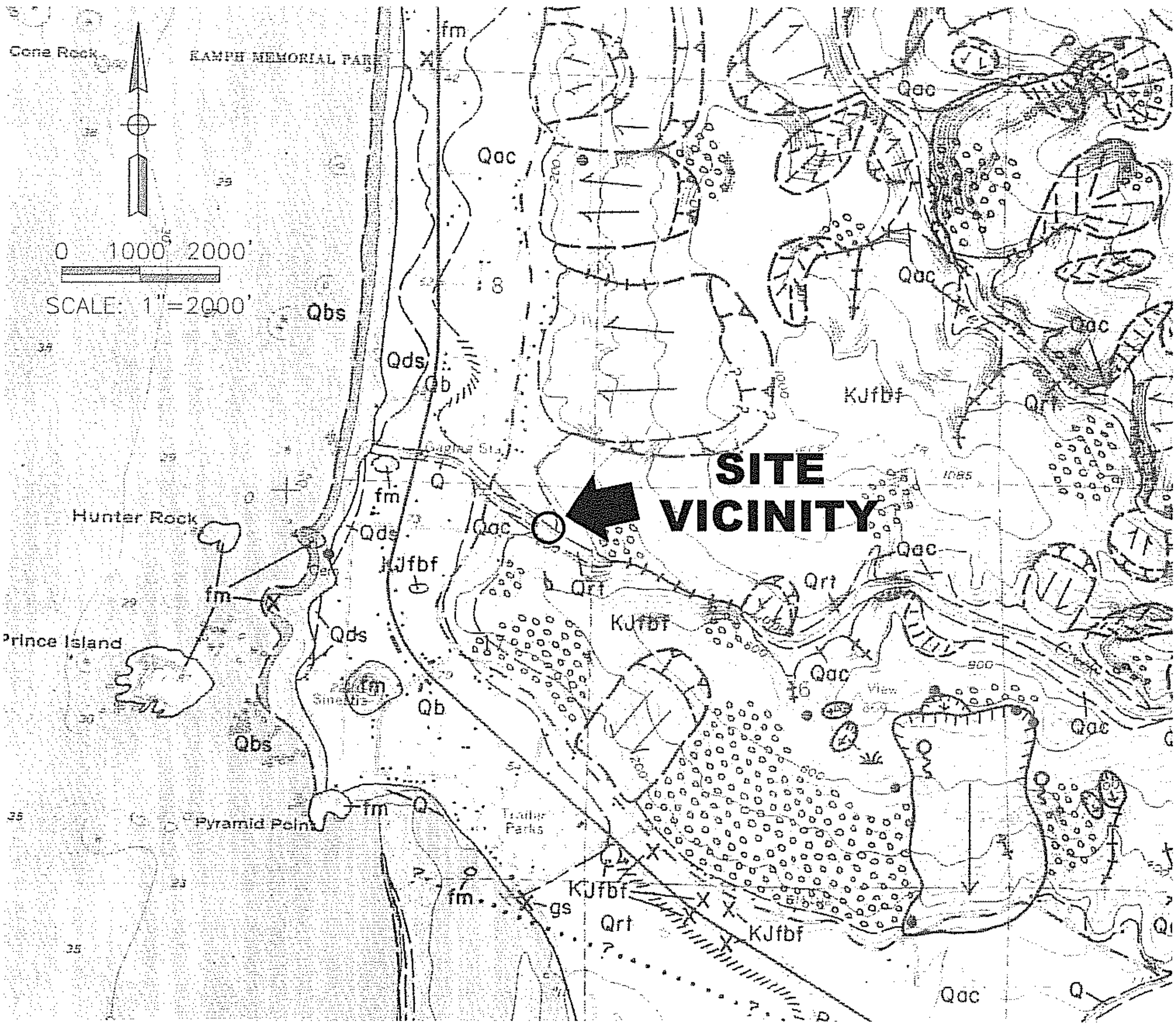
Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 50-YEAR

E.G. Elev (ft)	89.24	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.40	Wt. n-Val.	0.100	0.075	
W.S. Elev (ft)	88.84	Reach Len. (ft)			
Crit W.S. (ft)	88.84	Flow Area (sq ft)	100.06	55.51	
E.G. Slope (ft/ft)	0.036462	Area (sq ft)	100.06	55.51	
Q Total (cfs)	551.00	Flow (cfs)	206.69	344.31	
Top Width (ft)	185.43	Top Width (ft)	161.06	24.37	
Vel Total (ft/s)	3.54	Avg. Vel. (ft/s)	2.07	6.20	
Max Chl Dpth (ft)	2.84	Hydr. Depth (ft)	0.62	2.28	
Conv. Total (cfs)	2885.6	Conv. (cfs)	1082.4	1803.1	
Length Wtd. (ft)		Wetted Per. (ft)	161.06	26.45	
Min Ch El (ft)	86.00	Shear (lb/sq ft)	1.41	4.78	
Alpha	2.04	Stream Power (lb/ft s)	2.92	29.64	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

Plan: Plan 01 LOPEZ LOPEZ RS: 100 Profile: 100-YEAR

E.G. Elev (ft)	89.31	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.42	Wt. n-Val.	0.100	0.075	
W.S. Elev (ft)	88.89	Reach Len. (ft)			
Crit W.S. (ft)	88.89	Flow Area (sq ft)	107.48	56.62	
E.G. Slope (ft/ft)	0.038740	Area (sq ft)	107.48	56.62	
Q Total (cfs)	602.00	Flow (cfs)	235.64	366.36	
Top Width (ft)	189.98	Top Width (ft)	165.61	24.38	
Vel Total (ft/s)	3.67	Avg. Vel. (ft/s)	2.19	6.47	
Max Chl Dpth (ft)	2.89	Hydr. Depth (ft)	0.65	2.32	
Conv. Total (cfs)	3058.6	Conv. (cfs)	1197.2	1861.4	
Length Wtd. (ft)		Wetted Per. (ft)	165.61	26.49	
Min Ch El (ft)	86.00	Shear (lb/sq ft)	1.57	5.17	
Alpha	2.03	Stream Power (lb/ft s)	3.44	33.45	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

LACO ASSOCIATES CONSULTING ENGINEERS 21 W 4TH ST. EUREKA, CA 95501 (707)443-5054	PROJECT LOPEZ CREEK LANDSLIDE	BY JB	FIGURE 1
	CLIENT SMITH RIVER RANCHERIA	DATE 4/19/10	
	LOCATION 140 ROWDY CREEK RD., SMITH RIVER, CA., 95567	CHECK BED	JOB NO. 7270.00
	GEOLOGIC & GEOMORPHIC MAP	SCALE 1"=2000'	



(DAVENPORT, 1983)

LEGEND

TRANSLATIONAL/ROTATIONAL SLIDE: indicates scarp, indicates direction of movement; solid where active, dashed where dormant, queried where uncertain.

EARTHFLOW: indicates scarp, ⟵ indicates direction of movement; solid where active, dashed where dormant.

DEBRIS SLIDE: includes scarp and slide deposits; solid where active, dashed where dormant.

DEBRIS FLOW/TORRENT TRACK

DEBRIS SLIDE AMPHITHEATER/SLOPE

INNER GORGE: ⟷ where too narrow to delineate at this scale.

ACTIVE SLIDE: too small to delineate at this scale.

DISRUPTED GROUND: irregular ground surface caused by complex landsliding processes resulting in features that are indistinguishable or too small to map individually at this scale; also may include areas affected by downslope creep, expansive soils, and/or erosion; boundaries usually are indistinct.

Q ALLUVIUM (Holocene): stream channel deposits of sand and gravel; area of active stream channel erosion.

Qbs BEACH DEPOSITS (Holocene): sands and gravels along the coast line.

Qds DUNE SAND (Holocene): includes vegetated and unvegetated deposits of fine, gray aeolian sand near the coast; in places, contains gravel.

Qac ALLUVIAL FAN/COLLUVIUM (Holocene-Pleistocene): alluvial fan deposits and/or colluvial slope deposits adjacent to mountains; angular sandstone, shale, and schist fragments supported in a silty-clay matrix.

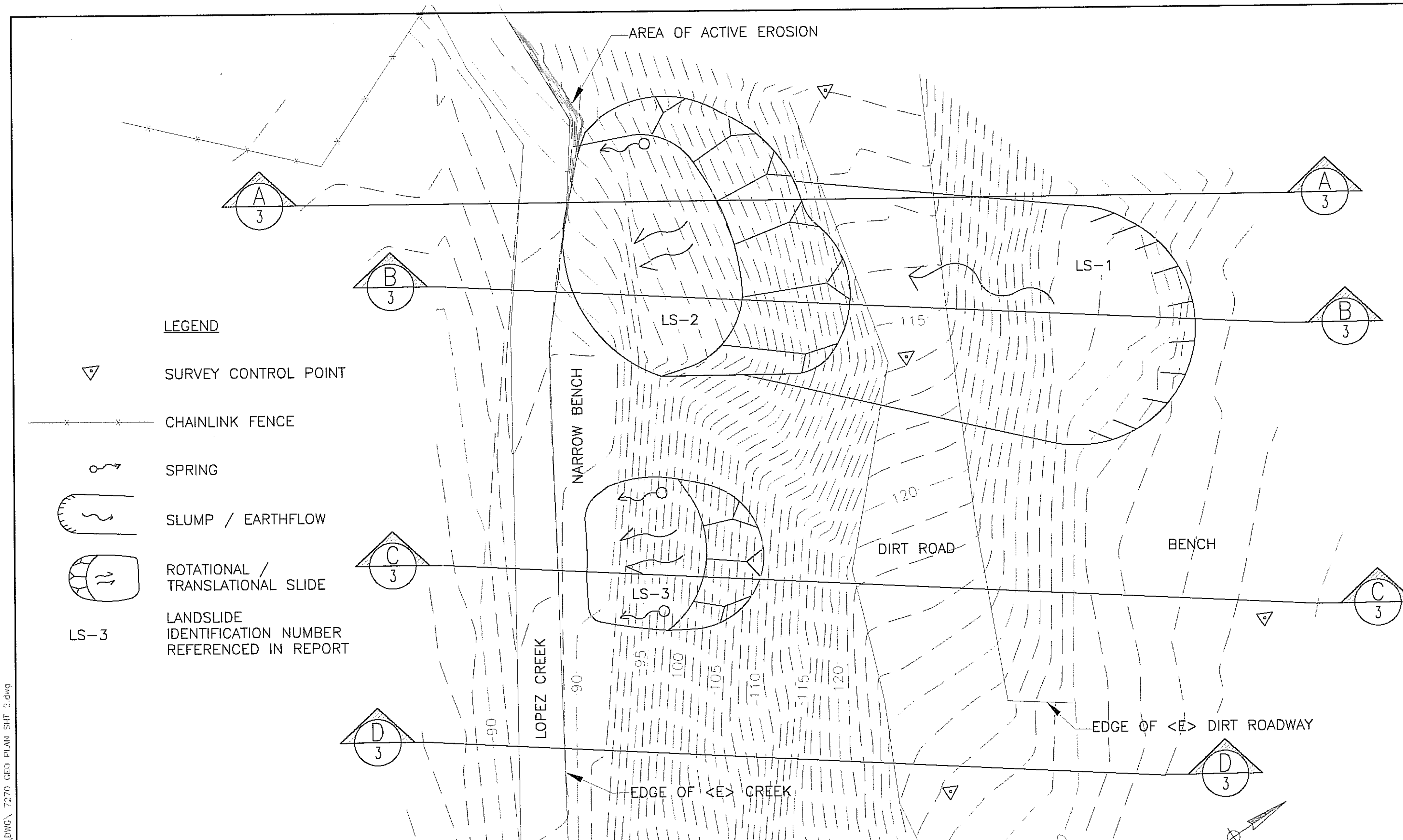
Qrt ALLUVIAL TERRACES (Holocene-Pleistocene): older river gravels located above present stream channels; includes former or present flood plain deposits that are covered with vegetation and contain a strong organic-rich or silty-clay soil profile; area of deposition.

Qb BATTERY FORMATION (Pleistocene): marine terrace and sand dune deposits overlying abrasion platform; consists of tan to reddish-brown unconsolidated medium-grained quartz sands alternating with silty clay and imbricated gravels.

Qt UNDIFFERENTIATED MARINE OR RIVER TERRACE DEPOSITS (Pleistocene): topographic bench paralleling the ocean; exposures consist of brown to tan, sandy to silty clay overlying gravels.

bm BAY MUD (Pliocene-Pleistocene): blue-gray, very sticky clay; exposed near base of the coastal hills; may underlie most Quaternary units; may be part of Pliocene St. George Formation which crops out near Crescent City.

NOT FOR CONSTRUCTION



NOTE:

BASIS OF BEARINGS: LINE "L10" AS DESIGNATED AND SHOWN ON THAT CERTAIN MAP ENTITLED "RECORD OF SURVEY FOR THE STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION, NEAR THE SMITH RIVER RANCHERIA IN THE COUNTY OF DEL NORTE" AND ON FILE IN THE OFFICE OF THE DEL NORTE COUNTY SURVEYOR, IS TAKEN AS SOUTH 0-02'-08" EAST 2719.94 FEET BETWEEN FOUND MONUMENTS NO.'S 114 AND 504 (C.C.S. ZONE 1, N.A.D. 1983, EPOCH 1991.35)

BENCH MARK: NATIONAL GEODETIC SURVEY MONUMENT B-1399 (PID LV0544) ELEVATION 43.61' (NAVD '88)

SITE MAP
SCALE: 1"=20'

NOT FOR CONSTRUCTION

LACO ASSOCIATES
CONSULTING ENGINEERS
21 W 4TH ST. EUREKA, CA 95501 (707)443-5054

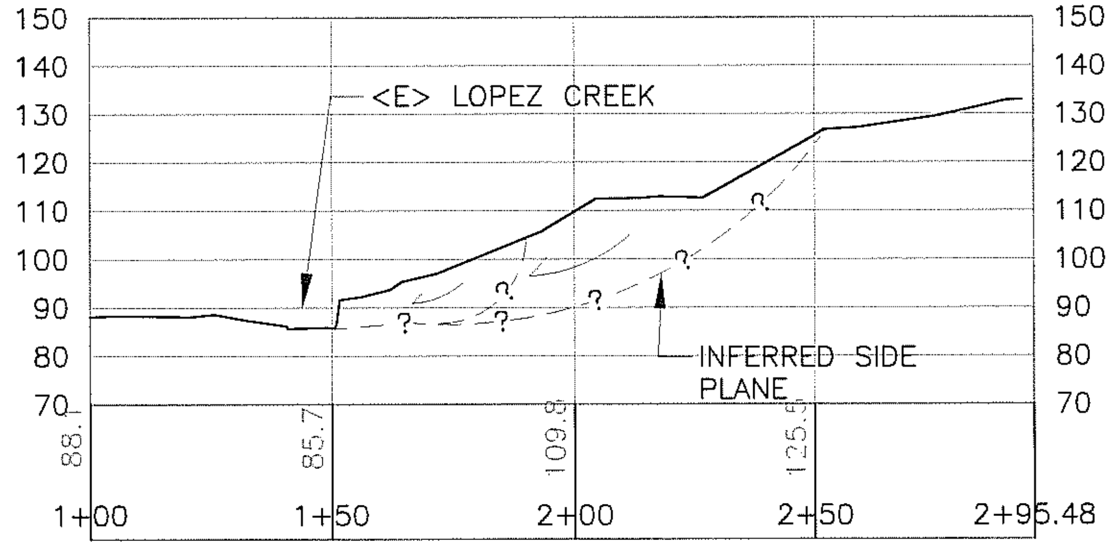
NO.	REVISION	BY	CHK	DATE

LOPEZ CREEK
SITE MAP

SMITH RIVER RANCHERIA
140 ROWDY CREEK RD., SMITH RIVER, CA., 95567

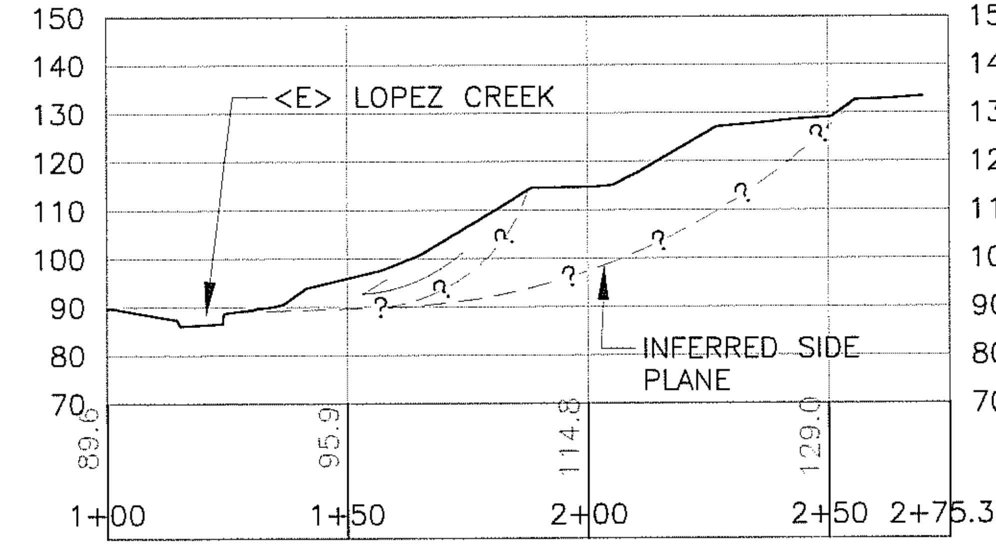
SCALE	AS SHOWN
DRAWN	JB
CHECK	AWP
APPVD	BED
DATE	4/19/10
JOB NO.	7270.00
FIGURE 2	OF 6

Apr 19,2010-3:31pm
T:\Cadfiles\7200\7270 LOPEZ CREEK\DWG\ 7270 GEO PLAN SHT 2.dwg



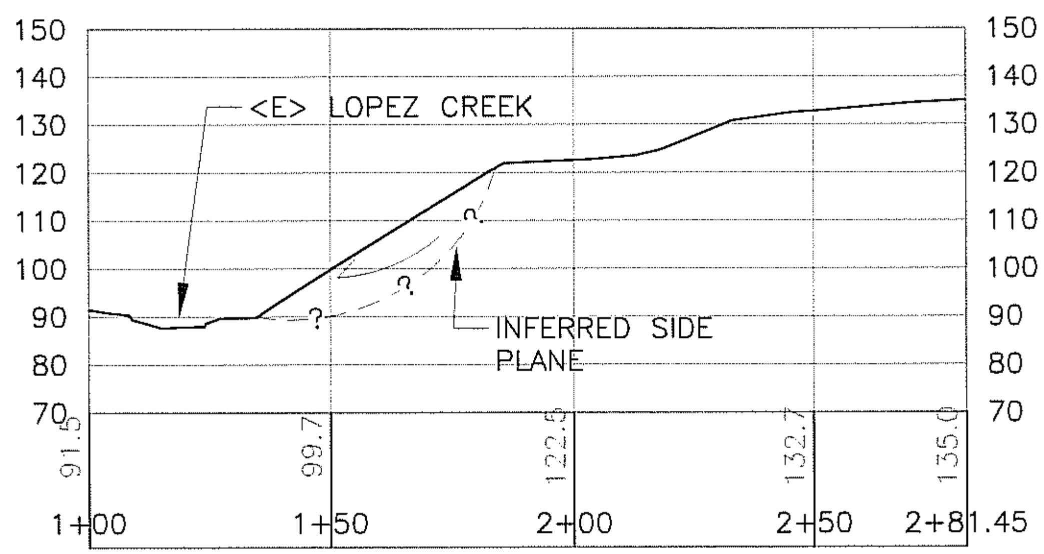
A/2 **SECTION**

1"=40'



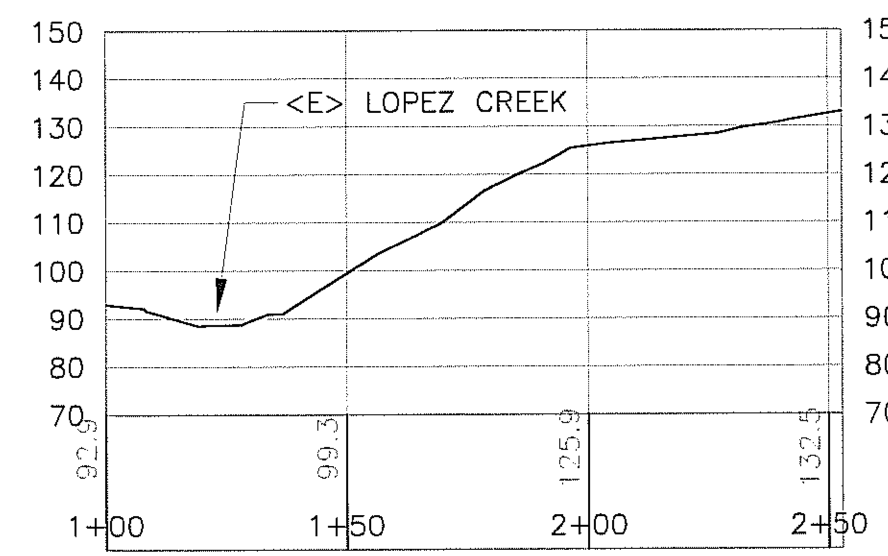
B/2 **SECTION**

1"=40'



C/2 **SECTION**

1"=40'



D/2 **SECTION**

1"=40'

NOT FOR CONSTRUCTION

LACO ASSOCIATES
CONSULTING ENGINEERS
21 W 4TH ST. EUREKA, CA 95501 (707)443-5054

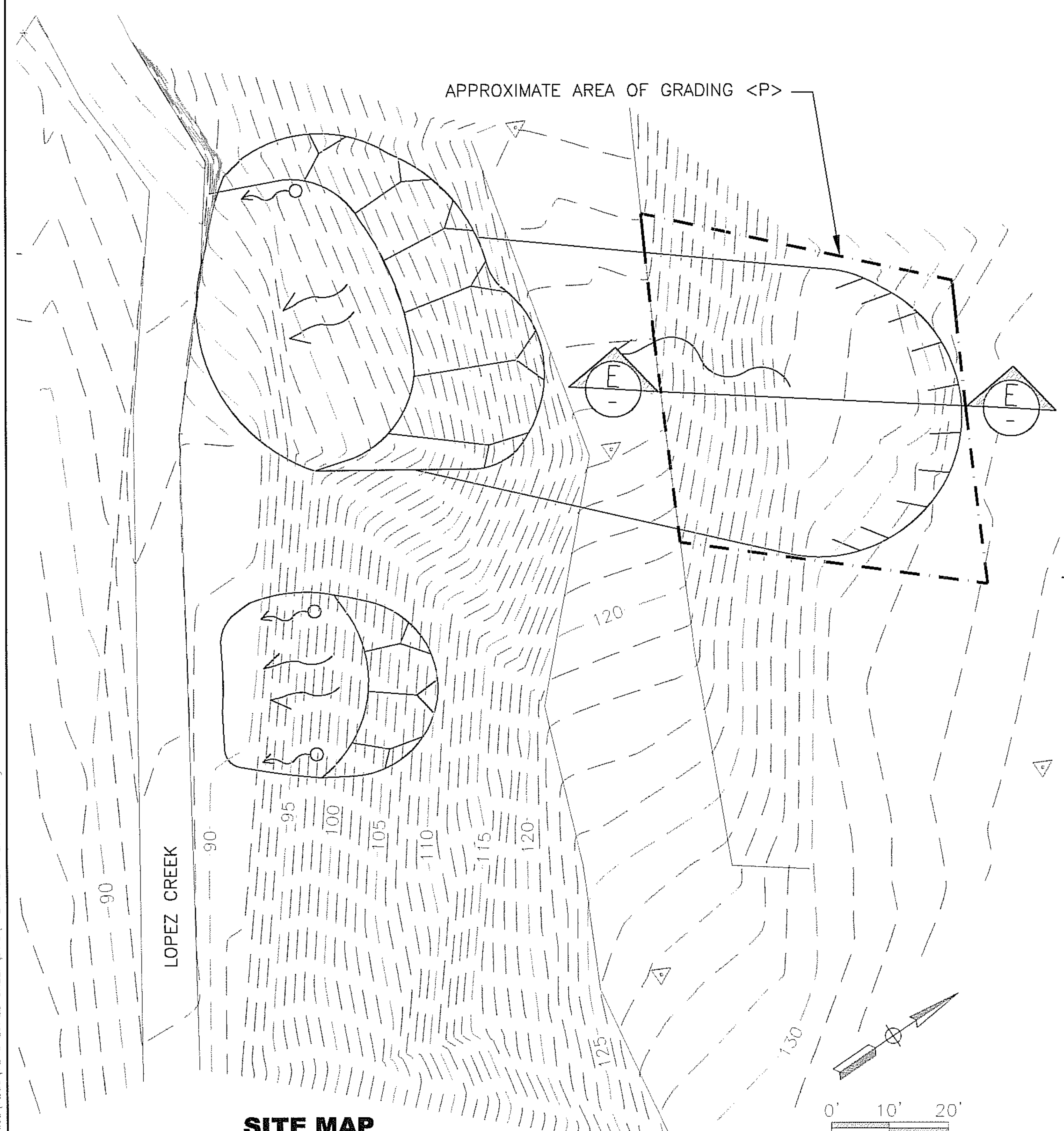
NO.	REVISION	BY	CHK	DATE

LOPEZ CREEK
SECTIONS

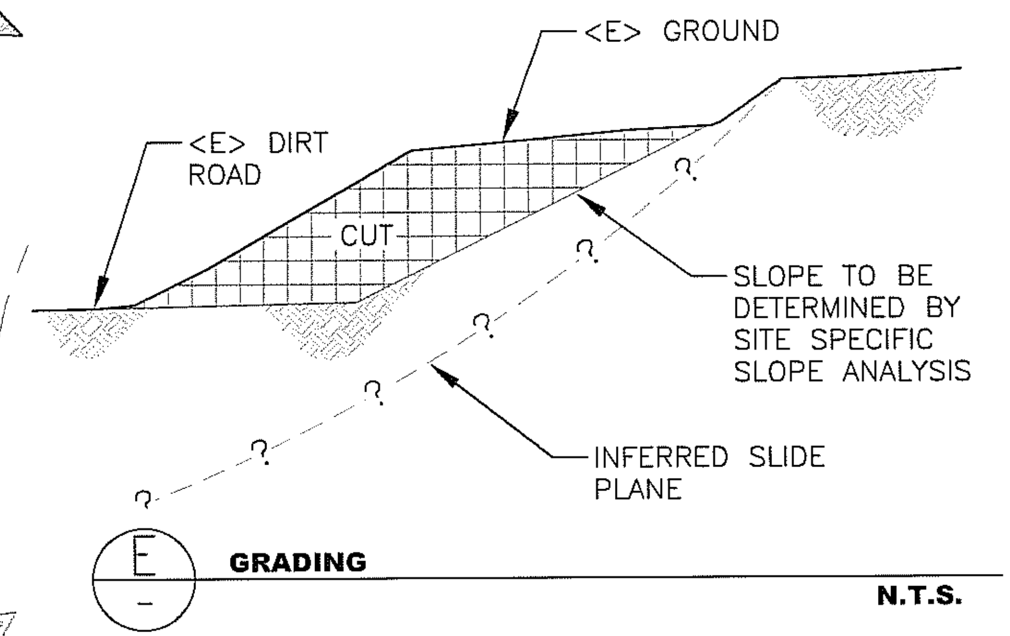
SMITH RIVER RANCHERIA
140 ROWDY CREEK RD., SMITH RIVER, CA., 95567

SCALE	AS SHOWN
DRAWN	JB
CHECK	AWP
APPVD	BED
DATE	4/19/10
JOB NO.	7270.00
FIGURE 3	OF 6

Apr 19,2010-3:37pm
T:\Cadfiles\7200\7270 LOPEZ CREEK\DWG\ 7270 GEO PLAN SHT 3.dwg



SITE MAP
SCALE: 1"=20'



E **GRADING**
N.T.S.

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LACO ASSOCIATES
CONSULTING ENGINEERS
21 W 4TH ST. EUREKA, CA 95501 (707)443-5054

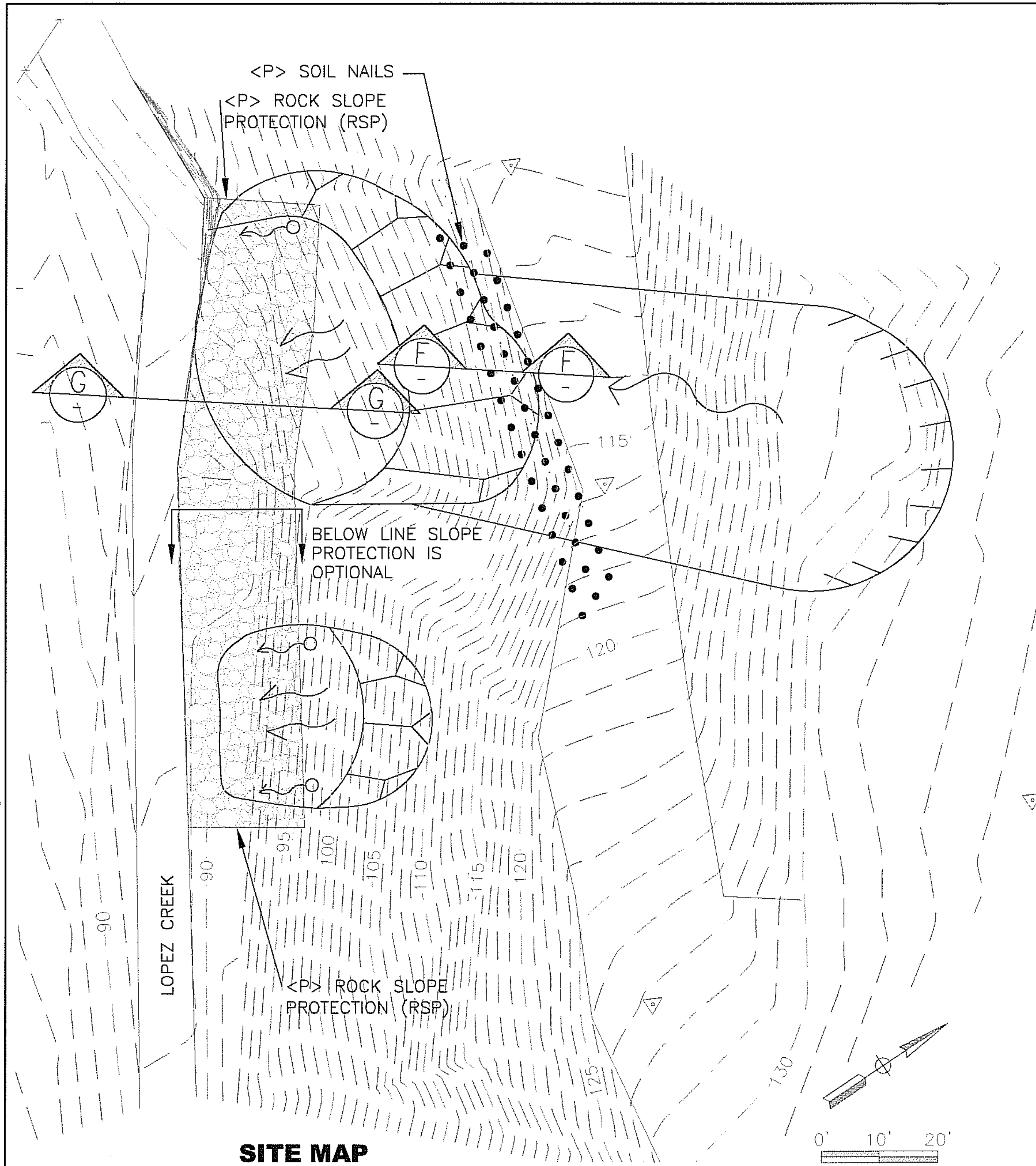
NO.	REVISION	BY	CHK	DATE

LOPEZ CREEK LANDSLIDE
DESIGN OPTION: REDUCTION IN DRIVING FORCES

SMITH RIVER RANCHERIA
140 ROWDY CREEK RD., SMITH RIVER, CA., 95567

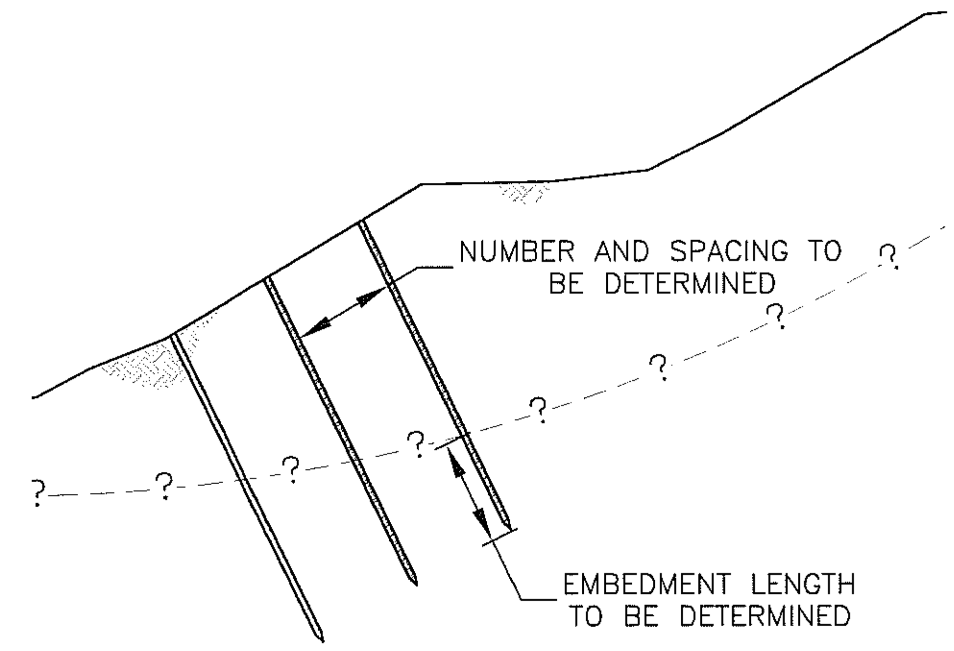
SCALE	AS SHOWN
DRAWN	JB
CHECK	AWP
APPVD	BeO
DATE	4/19/10
JOB NO.	7270.00
FIGURE 4	OF 6

Apr 19,2010-3:40pm
T:\Cadfiles\7200\7270 LOPEZ CREEK\DWG\ 7270 GEO PLAN SHT 4.dwg

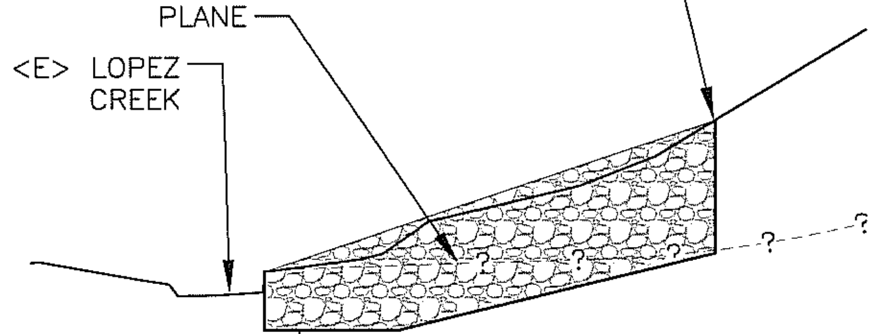


SITE MAP

SCALE: 1"=20'



F
SOIL NAILS **N.T.S.**



G
ROCK SLOPE PROTECTION **N.T.S.**

NOT FOR CONSTRUCTION

LACO ASSOCIATES
CONSULTING ENGINEERS
21 W 4TH ST. EUREKA, CA 95501 (707)443-5054

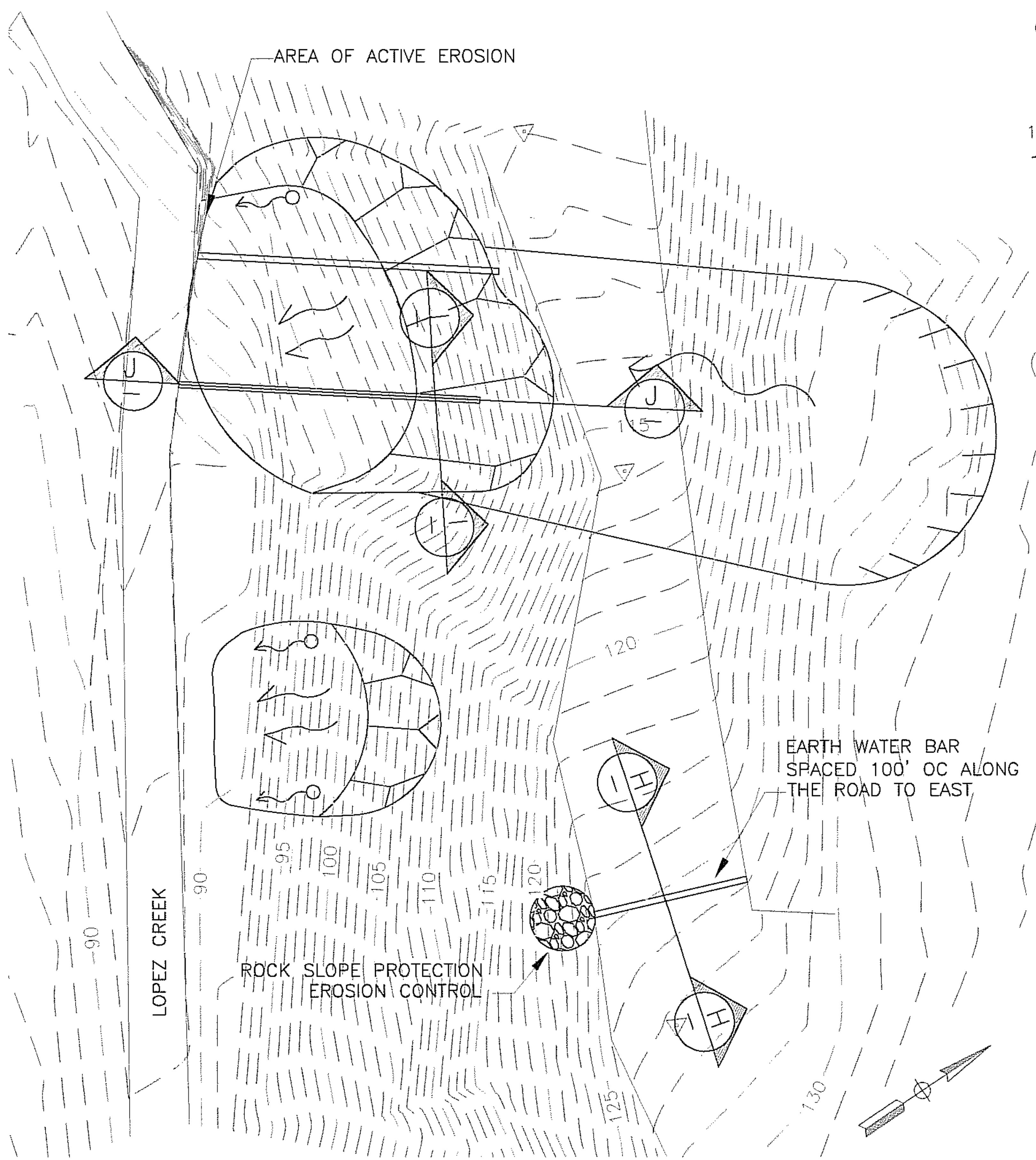
NO.	REVISION	BY	CHK	DATE

LOPEZ CREEK LANDSLIDE
DESIGN OPTION: INCREASE IN RESISTING FORCES

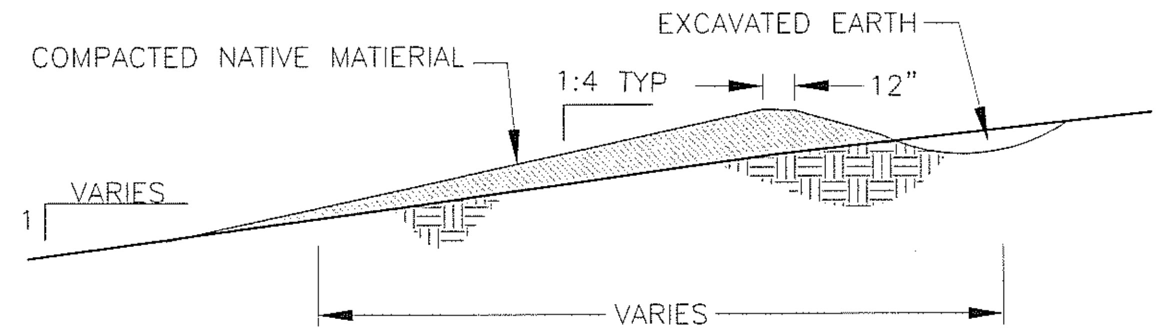
SMITH RIVER RANCHERIA
140 ROWDY CREEK RD., SMITH RIVER, CA., 95567

SCALE	AS SHOWN
DRAWN	JB
CHECK	AWP
APPVD	BEB
DATE	4/19/10
JOB NO.	7270.00
FIGURE 5	OF 6

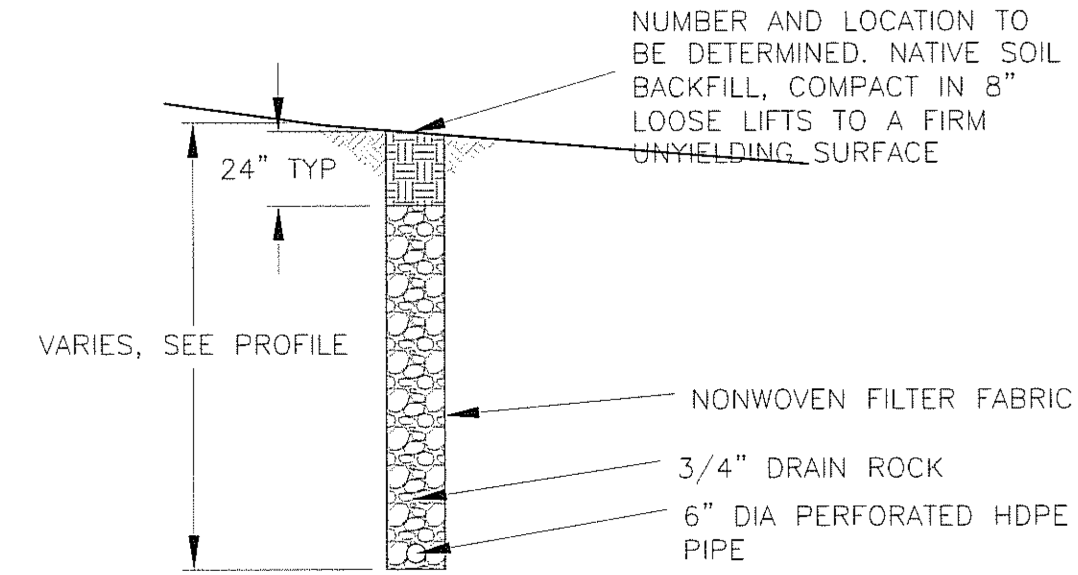
Apr 19,2010-3:44pm
T:\Cadfiles\7200\7270 LOPEZ CREEK\DWG\ 7270 GEO PLAN SHT 5.dwg



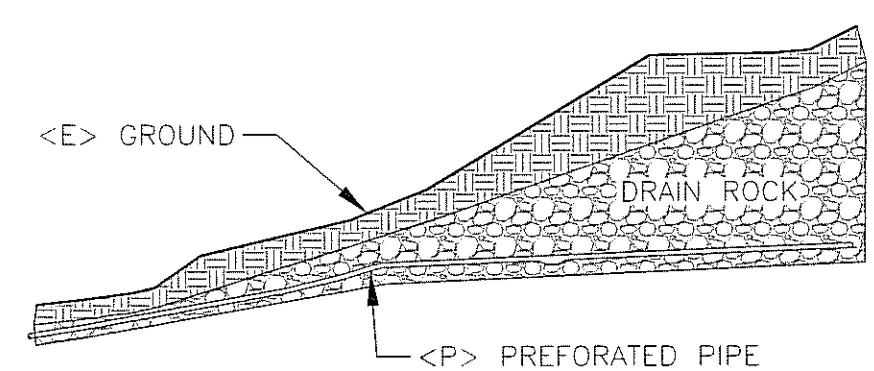
SITE MAP
SCALE: 1"=20'



H – EARTH WATER BAR N.T.S.



I – TYPICAL SUBSURFACE DRAIN SECTION N.T.S.



J – SUBSURFACE DRAIN PROFILE N.T.S.

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LACO ASSOCIATES
CONSULTING ENGINEERS
21 W. 4TH ST. EUREKA, CA 95501 (707)443-5054

NO.	REVISION	BY	CHK	DATE

LOPEZ CREEK LANDSLIDE
DESIGN OPTION: WATER CONTROL

SMITH RIVER RANCHERIA
140 ROWDY CREEK RD., SMITH RIVER, CA., 95567

SCALE	AS SHOWN
DRAWN	JB
CHECK	AWP
APPVD	BED
DATE	4/19/10
JOB NO.	7270.00
FIGURE 6	OF 6

Apr 19,2010–3:46pm
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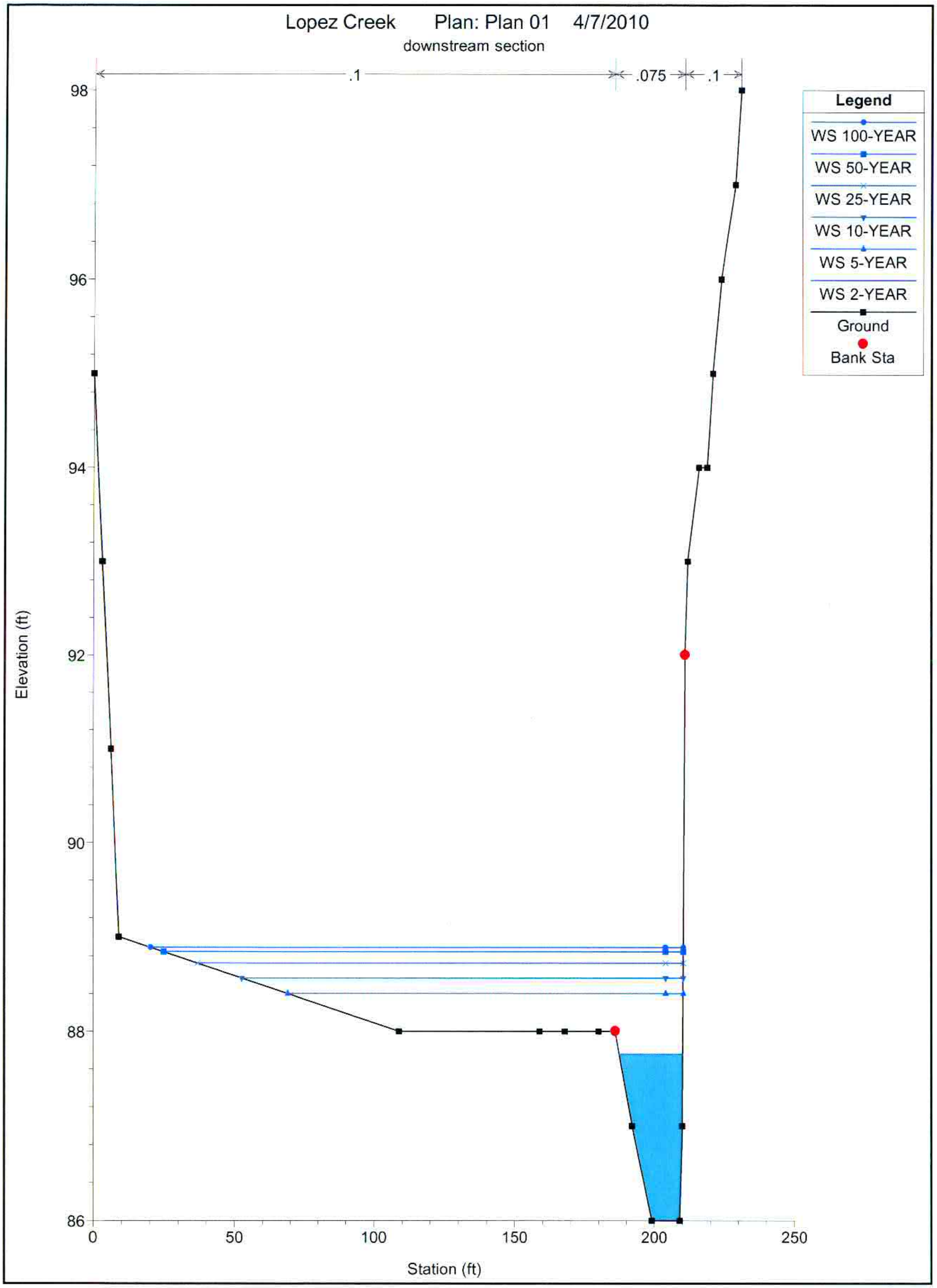
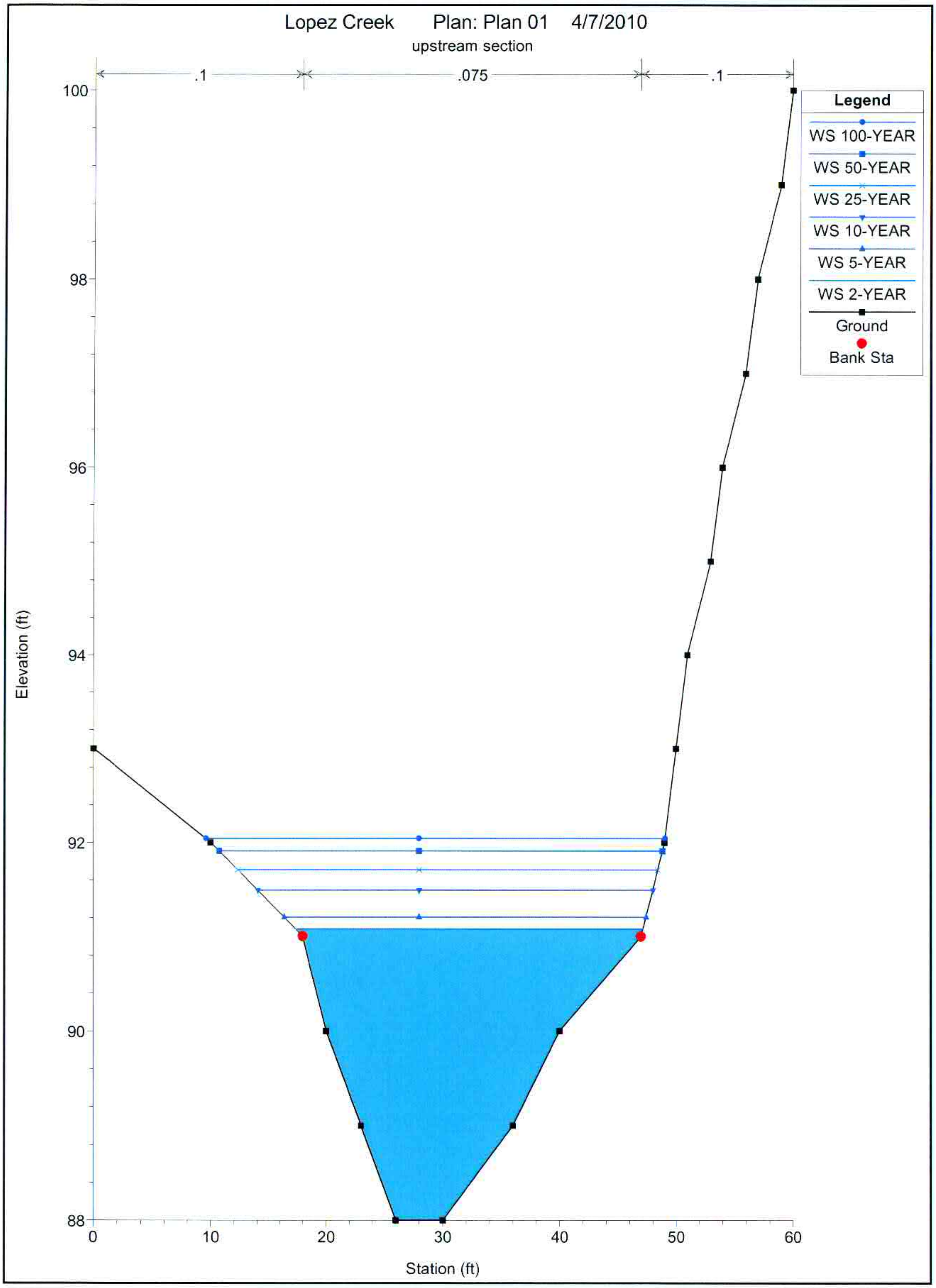


Lopez Creek Plan: Plan 01 4/7/2010
downstream section
.1
.075
.1
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 5-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
98
96
94
92
90
88
86
0
50
100
150
200
250
Station (ft)


Lopez Creek Plan: Plan 01 4/7/2010
upstream section
.1
.075
.1
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 5-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
Station (ft)
100
98
96
94
92
90
88
0
10
20
30
40
50
60