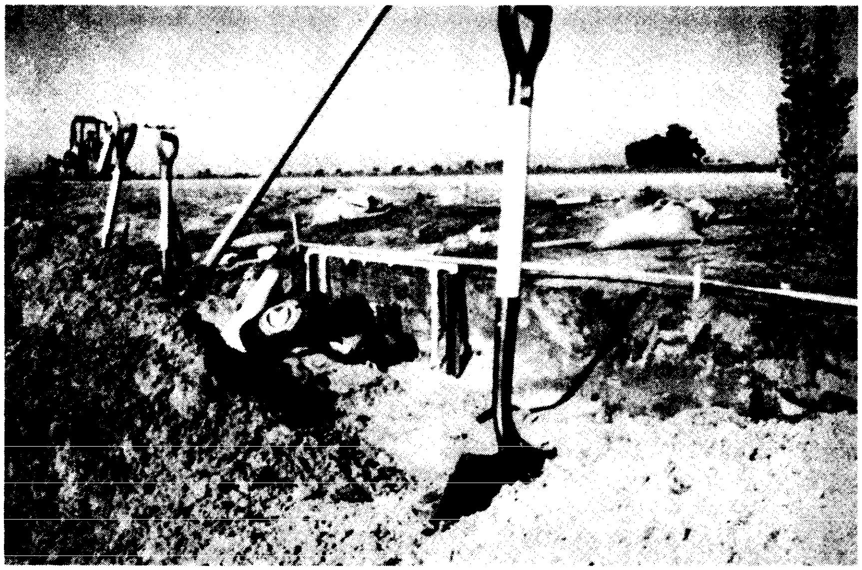
REMR TECHNICAL NOTE EI-M-1.3

VEGETATION AND THE STRUCTURAL INTEGRITY OF LEVEES: RESULTS OF FIELD INVESTIGATIONS



Mapping root distribution in levee on Sacramento River using the profile wall method.

PURPOSE: To present the preliminary results of a field study of effects of vegetation on a Sacramento River levee.

BACKGROUND: Current CE guidelines for levee maintenance and operation limit vegetation on levee embankments to sod-forming grasses, 2 to 12 in. high, to provide for structural integrity, inspectability, and unhindered flood-fight access. These standards allow just enough vegetation on levees to provide soil-holding capacity. Such standards are justified by the absence of data which clearly establish the relationship between the properties of vegetation on levees (size of individual plants, plant density and rooting structure, or the ecology of locally common species assemblages), and the structural impairment of levees. Exceptions to the standards allow taller or woody vegetation on overbuilt levee sections only. In many areas of the country, however, these standards cause a significant loss of riparian habitat and may be impractical for local climatic conditions. Before revising the standards, however, additional knowledge must be developed regarding vegetal components of the geotechnical system.

TEST METHODS: To address the question of the amount and distribution of root material in levees, six 1-m-deep, L-shaped trenches were excavated on a levee along the Sacramento River between the confluences of the Feather and American Rivers. Each trench was located in an area dominated by a different species or type of representative vegetation: herbaceous weeds and low shrubs, live and dead valley oaks (Quercus lobata), willow (Salix hindsiana), elderberry (Sambucus mexicana) and black locust (Robinia pseudoacacia). Trenches were located at or within the crown of monospecific clumps of the dominant plant species at site. Root locations and sizes were mapped on two trench faces, one parallel and one perpendicular to the levee crown, adapting the profile wall method of Bohm (Ref a). Trench sides were cleaned with masonry trowels to obtain a smooth face, and root positions, diameter classes, and species (where identifiable) were mapped on acetate overlays. Mapped depths were restricted to 1 m because of the loose nature of levee soils and limitations imposed by safety regulations.

Coincident with root mapping, the levee material was sampled for gradation, density, and in-situ strength. The levee consists of primarily coarse to fine sand, with a density range of 12.6-15.7 kN/m^3 (80-100 pcf), an average angle of internal friction of 31.6 degrees, and an average cohesion of 8.0 kPa/m^2 (1.16 psi). Soil permeability values ranged from 0.03 to 0.7 cm/sec as determined with a gas permeameter. These geotechnical properties reflect the construction of the levees from material dredged (hydraulically and with a clamshell) from the Sacramento River in ca. 1914-1916.

TEST RESULTS: Data obtained from these excavations generally confirm rooting patterns noted in the horticultural and plant physiology literature: the majority of roots for shrubby species are confined to the top meter of the soil, although isolated roots may be found somewhat lower. Table 1 shows the distribution of values of root-area ratio [RAR] (cross-sectional area of roots/total cross-sectional area of interest) for each of the trench sites. Table 2 shows the total cover by major species for each site in percent of the levee surface covered.

Additional excavation around an oak stump (dead oak site) showed a taproot of 0.5-m diam at 1.4 m below the levee surface, with lateral roots of ≤ 0.1 m still intact after more than 20 years of decay. At other sites, numerous root casts were observed where the woody material was replaced with sand while the bark remained intact, suggesting that voids from roots do not generally persist in these sandy levees.

Root-area ratios from the elderberry trench represent the extreme shrub or tree root density observed in the trenches. When the trench intersected the main plant stem, the maximum RAR, 1.1 percent, was observed at 30-cm depth and decreased to ~0.1 percent below 70-cm depth; when the trench was located at the riverward dripline of the shrub, the RAR was <0.2 percent.

The data on root distributions and material types were used to examine both slope stability and seepage through the levee under conditions of actual duration of inundation. Because roots are similar to other fiber reinforcement, RAR's can be used to calculate an increased apparent soil cohesion (Ref b) which can be used in stability analyses; the observed increase in cohesion was approximately 22 kPa/m^2 (3.2 psi) per percent RAR averaged over multiple species. Stability analyses showed that roots stabilize shallow, critical failure surfaces. Increased overburden stabilizes deeper failure surfaces below the rooting zones. Transient seepage analysis, following the method of Huang (Ref c), showed that steady-state seepage could be reached in these levees on average in 12 to 15 hours for the design stage (approximately a 70- to 80-year recurrence interval flood). Steady-state seepage analyses showed that if the levee skin is less permeable than the core, enlargement of the discharge area (seepage zone) and greater exit gradients at the downstream face resulted. Although it might be intuitively argued that the levee surface

Table 1

Root Area Ratios (%) vs. Depth, Sacramento Levee Sites

Depth (inches)	Control		Dead Oak		Live Oak		Willow		Elderberry		Black Locust	
	Par.	Perp.	Par.	Perp.	Par.	Perp.	Par.	Perp.	Par.	Perp.	Par.	Perp.
0-4	2.02	0.10	0.04	0.001	0.32	0.01	0.03	0.20	0.16	0.50	0.03	0.85
4-8	0.02	0.62	0.02	0.01	0.23	0.04	0.10	0.18	0.11	0.55	0.12	0.07
8-12	0.01	0.18	0.40	0.01	0.28	0.01	0.36	0.26	0.08	1.11	0.07	0.62
12-16	0.10	0.12	0.11	0.003	0.25	0.01	0.01	0.20	0.05	0.78	0.02	1.02
16-20	0.19	0.01	0.04	0.01	0.15	0.02	0.01	0.10	0.06	0.42	0.02	0.87
20-24	ND	0.06	0.03	0.01	0.06	0.12	0.01	0.05	0.17	0.33	0.002	0.01
24-28	ND	0.39	1.06	0.001	0.09	0.02	0.01	0.03	0.05	0.18	0.001	0.02
28-32	ND	0.06	0.004	0.03	0.09	0.04	0.01	0.004	0.11	0.07	0.001	0.13
32-36	ND	0.10	0.09	0.24	0.13	0.02	0.001	0.06	0.03	0.12	0.001	0.01
36-40	ND	0.15	0.001	0.16	0.08	0.13	0.004	0.34	0.01	0.07	0.001	0.001

Depth below levee surface, inches (4 inches = 0.102 meters)

ND: No data
Par: Parallel
Perp: Perpendicular

Table 2

Plant Cover At Trench Sites

Species	Absolute Cover (percent)					
	Control	Dead Oak	Live Oak	Willow	Elderberry	Black Locust
Grasses (various)	16.8	Burned	-	Burned	Burned	ND
Sedges (various)	6.7	-	<0.1	Burned	-	-
Rosa Californica	31.6	-	5.9	forbs	3.7	2.1
Heterotheca grandiflora	1.5	-	-	-	-	-
Lotus Purshianus	0.2	-	-	-	-	-
Glycyrrhiza lepidota	-	-	13.3	-	-	-
Sisymbrium officinale	-	-	4.7	-	-	0.4
Convolulus spp.	-	-	<0.1	-	-	-
Salix Hindsiana	-	-	-	~10	-	-
Sambucus mexicana	-	-	-	-	72.0	-
Ribes spp.	-	-	-	-	1.7	-
Robinia pseudoacacia	-	-	-	-	-	72.4

permeability is directly proportional to RAR, the actual effect of vegetation on the permeability of these levees is not known.

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c. Huang, Y. H. (1986). "Unsteady State Phreatic Surface in Earth Dams." Journal of Geotechnical Engineering, ASCE, 112(3), 3353-353.