CHAPTER C5

TABLE OF CONTENTS

C5.00 Introduction

Section 1 Unpaved Shoulders

C5.01 General
C5.02 Policy

Section 2 Fences

C5.03 General
C5.04 Policy
C5.05 Types of Fences
C5.06 Maintenance of Fences
C5.07 Repairing Chain Link Fence

Section 3 Drainage and Miscellaneous Facilities

C5.08 General
C5.09 Applicable Law
C5.10 Inspections
C5.10.1 Inspections by District Maintenance Supervisors
C5.10.2 Inspections by District Culvert Inspection Program

C5.11 Culverts
C5.11.1 Record of Culvert Performance
C5.11.2 Culvert Installation

C5.12 Ditches and Gutters
C5.13 Drainage Channels and Shorelines
C5.14 Under Drains, Horizontal Drains and Down Drains
C5.15 Edge Drains
C5.16 Structure Drainage Systems
C5.17 Minimum Thickness of Cover
C5.18 Jacking and Boring Pipe

C5.19 Private Irrigation Facilities
C5.20 Entry upon Private Property
C5.21 Maintenance of Over Side Drains and Slope Ditches
C5.22 Under Drains
C5.23 Horizontal Drains
C5.24 Dry Fords
C5.25 Bank and Slope Protection
C5.25.1 Bank Protection
C5.25.2 Training Systems
C5.25.3 Tetrahedrons
C5.25.4 Jackstraws
C5.25.5 Fence Type Protection
C5.25.6 Control of Ditch Erosion

Section 4 Other Roadside Appurtenances

C5.26 General
C5.27 Benches
C5.28 Curbs and Curbed Islands
C5.29 Sidewalks
C5.30 Curb and Sidewalk Repair
C5.31 Debris Barriers
C5.32 Retaining Walls and Cribs
C5.33 Graffiti Removal
C5.34 Disposal of Waste Material
C5.35 Non-Motorized Facilities

C5.00 Introduction

This chapter is divided into four sections:

Section 1: Unpaved Shoulders
Section 2: Fences
Section 3: Drainage and Miscellaneous Facilities
Section 4: Other Roadside Appurtenances

Some of the topics included in this chapter are discussed elsewhere in this manual. For example, Section I builds on the information included in Chapters A and B. Where appropriate, there will be references to other chapters.

Section 1: Unpaved Shoulders

C5.01 General

Unpaved shoulders are that portion of the right of way bordering the traveled way, and may be constructed either of native or imported material. Unpaved shoulders may be adjacent to inside or outside lanes, and provide the same function as paved shoulders. Unpaved shoulders may either be part of the original design of the highway, or may have come into existence through usage.

Shoulders should slope away from the pavement at a 5 percent gradient, except on the outside of super-elevated curves or other special sections. Replace native material with imported material where maintaining lateral support of pavement edges is a recurring problem.

Where native material is unsatisfactory and is being replaced, refer to the Standard Specification Plans (SSP) 19-7.02 for shoulder backing material.

C5.02 Policy

(A) Type and Frequency of Maintenance

The maintenance measures to be taken and the frequency of their use should largely be determined by the amount of traffic, general pavement condition, time of year, and the structural materials. Diked sections of shoulders require less frequent unpaved shoulder maintenance.

(B) Lateral Support

Lateral support of the pavement edge is an important maintenance consideration for protection of pavement integrity. When the support has diminished to approximately one-half the pavement thickness it should be scheduled for repair. Loss of lateral support is more critical for narrow paved shoulders than for wider shoulders due to distribution of loads relative to the edge of the pavement.

(C) Unsurfaced Areas

The above requirements for lateral support also apply to unsurfaced areas abutting the traveled way or paved shoulders. In addition, these unsurfaced areas should be relatively free of ruts and properly sloped. This ensures adequate drainage and provides room for disabled vehicles.

Shoulder blading is not a satisfactory method of vegetation control. Excessive blading can cause undesirable air and water quality problems.

(D) Safety Considerations

Shoulder operations should be conducted only on one side of the highway at a time. Refer to the appropriate Maintenance Codes of Safe Operating Practices.

Loss of lateral support greater than two inches may adversely affect an errant vehicle's ability to return safely to the travelway.

(E) Need for Drainage

Drainage should be maintained to eliminate ponding near the edge of shoulder.

Section 2: Fences

C5.03 General

Fences are divided into three categories:

(A) Freeway Fences and Right of Way Fences

Freeway fences and right of way fences are State owned and act as physical barriers to ensure integrity of access lines or right of way lines. As a secondary function, these fences may acts as a property fence. All freeway and right of way fences are placed either on the access line, or immediately adjacent to the right of way line.

(B) Property Fences

These are privately owned fences outside the right of way that serve the abutting property owners' needs. Although they are the property of the abutting owner, such fences may serve access control purposes. The State provides property fences only as a right of way consideration and does not maintain them unless the condition of the fence poses a hazard.

(C) Median Fences

Median fences prevent indiscriminate crossings of the median by vehicles or pedestrians.

C5.04 Policy

State owned fences are provided to delineate right of way, control access, and prevent indiscriminate crossing of medians or ramps by vehicles or pedestrians.

State owned fences should be maintained in condition to serve their intended purposes.

State owned fences should be repaired when they are damaged to the extent that the physical barrier effect is lost or severely reduced. Owners of private property fences should be promptly notified when their fences are in need of repair in order to protect the highway user.

In case of damage that destroys the barrier effect of private fences or walls controlling State-owned access, take action to restore the barrier effect. The property owner should be notified promptly of the damage and encouraged to make permanent repairs.

C5.05 Types of Fence

The following are the standard fences used by Caltrans Maintenance:

(A) Type BW: Five strands of barbed wire on either wood or metal posts.

(B) Type WM: Wire Mesh with three strands of barbed wire at the top, on wood or metal posts.

(C) Type CL4: Chain Link fencing 48 inches high on metal posts.

(D) Type CL6: Chain Link fencing 72 inches high on metal posts.

Type BW or WM fencing are normally used in rural areas. However, either BW or WM fencing may be placed in urban areas where natural barriers or other conditions are such that this fencing will afford the same access protection as chain link fencing.

Chain Link Fences (Type CL) are generally used in urban or developed areas. Chain link fences along the right of way line and in the outer separation shall be six (6) feet high.

Exceptions to the 6-foot height will be allowed along the right of way where isolated improvements exist, and a lower fence will be in keeping with the height of adjacent property fences. At these locations, the four (4) foot chain link fence may be installed.

When required, a 4-foot high chain link fence, raised 6 inches off the ground may be used in a median.

C5.06 Maintenance of Fences

State owned highway fences shall be maintained by the Department. Property fences are maintained by the adjoining owner. It may be necessary to check the Superintendent's copy of "As Built" plans, right of way agreements, or actually measure on the ground to establish the location and ownership of fences. The Caltrans Permits office may also be a source in determining the location of property fence lines.

C5.07 Repairing Chain Link Fence

The standard for chain link mesh can be found in Standard Specification section 80-4.01B. However, mesh design varies by manufacturer, and the Standard Specification for chain link mesh allows for variance. For example, a 72-inch height chain link fence from one manufacturer will have 21 and 1/2 vertical meshes; other manufacturers will have 22 and 1/2 meshes. Manufacturers also use different types of weaving. Some prefer a right-hand weave, while other companies use a left-hand weave.

Chain link fencing carried in the warehouse will vary in the number of meshes and right and left hand weave, depending upon which manufacturer is awarded the purchase order. Fence material ordered from stock may not always match the existing fencing.

New fencing material may be joined or spliced with an existing fence by inserting a seven-gauge tension wire of sufficient length through the alternate meshes vertically. This method may be used in joining fencing having either right to left, right to right, or left to left mesh, or of a different number of meshes to the height.

When joining fencing having an unequal number of meshes per height, it will be necessary to cut the wire in one diamond at a point where the wires will not mesh.

Section 3: Drainage and Miscellaneous Facilities

C5.08 General

This chapter covers the repair, replacement and cleaning of ditches, culverts, under drains, down drains, horizontal drains, headwalls, debris racks, bank and shore protection and miscellaneous drainage features. Also included are sections on drift removal, bench cleaning, slide removal, fill slope replacement, repairs or replacement of retaining walls, sidewalks and curbs, bins, cattle guards and other minor structures.

C5.09 Applicable Law

The following code sections apply to drainage:

(A) Damage to Highway by Water 588 Penal Code: 725 Streets and Highway Code.

(B) Drainage or Impounding of Water, 725 - 729 Streets and Highway Code.

(C) Water, 725 - 727 Streets and Highway Code.

C5.10 Inspections

Inspections and monitoring required by the Facilities Pollution Prevention Plan (FPPP), the Maintenance Activities Pollution Prevention Plan (MAPPP), and corresponding corrective actions taken as a result of the implementation of these plans are covered in Chapter "F" of this manual. Also, see the Caltrans Storm Water Quality Handbook – Maintenance Staff Guide.

C5.10.1 Inspections by District Maintenance Supervisors

Visual, surface level inspections of drainage facilities shall be made by District Maintenance Supervisors to identify obvious defects, hazards or potential problems, and also to monitor known problems. These inspections should be made annually and during and after each major storm. The purpose of these inspections is to supplement the more detailed, but less frequent, inspections by the District Culvert Inspection Program (for those districts that have this program).

When major defects or hazards are found, they shall be immediately reported to the District Culvert Inspection Program or Maintenance Engineer. If an emergency condition exists, appropriate action shall be taken as soon as possible to ensure the safety of the traveling public and to prevent further damage from occurring, including restricting traffic on the roadway or closing it completely, installing temporary drainage or support systems, making temporary repairs, etc.

C5.10.2 Inspections by District Culvert Inspection Program

Every district has a Culvert Inspection Program, coordinated by Headquarters. The District Culvert Inspection Program accomplishes the following:

- Identifies and establishes a statewide inventory of all drainage facilities, including site location, design information, and deficiencies, which is used to establish the statewide inventory.

- Thoroughly evaluates condition and identifies deficiencies at early stages where corrective maintenance strategies will be effective, or prevent failure from occurring, which has worker and public safety impacts.

- The strategy and frequency for inspections will rely on a priority system based on route classification, Average Daily Traffic, culvert age and size, material type, and site conditions.

- Initiates a process for commencing corrective maintenance projects and regular programming of rehabilitation and replacement culvert projects to avoid future catastrophic culvert failure. This process is similar to the inspection, repair, and rehabilitation process for the highway system bridges, whereby the inspection process is the precursor of all bridgework, effectively preventing bridge failure.

- Improves the understanding of the mechanisms leading to culvert failure, and will potentially lead to changes in design specifications, construction methods, and/or materials for improved culvert performance.

- Improves workforce expertise and ability for quick response to emergency situations involving culverts.

Inspections may be performed by visual, "walk-through" inspections for larger culverts, or by the use of remote video inspection equipment for smaller culverts or culverts with limited accessibility. Ideal inspection teams consist of at least one engineer and one field Maintenance worker qualified to operate and maintain the remote video inspection equipment. Additional team members may be required for confined space or other safety requirements. See Appendix B of the Code of Safe Operating Practices for confined space entry procedures.

C5.11 Culverts

Culverts are defined as closed conduits that allow water to pass and are generally reinforced concrete boxes, individual pipes, or groups of pipes with openings measured along the centerline of roadway of 20 feet and less. The criterion which that distinguishes a culvert from a bridge is found in section H.05 of this manual. Culverts should be kept open and in a state of good repair.

Damage that impairs the structural integrity of the culvert should be repaired immediately.

Culverts should be cleaned of sediments when they are no longer able to function properly. See Chapter "F" of this manual for additional storm water cleaning requirements.

Channels should have sufficient depth and grade to ensure drainage to and from culverts, from the roadway, and from other roadside areas. Scoured areas that potentially compromise the structural integrity of the culvert or pavement should be corrected. Drainage grates should be maintained free of debris.

C5.11.1 Culvert Inspections by District Maintenance Supervisors

The following duties should be performed by District Maintenance Supervisors. Performance data in regard to the more important culverts should be recorded after major storms and while evidence of flood stage elevations are clearly observable. The height of drift above invert near the outlet and inlet of the culvert should be noted after the storm. The condition of the culvert should be checked as soon after the storm as possible noting abrasion, pitting, rust, rivets, spalling, exposed reinforcing, cracks, joint openings, drift and detritus in barrel. Scour and erosion should be noted at both inlets and outlets. Erosion of channel banks downstream should be observed. Erosion and undercutting of slope protection near a culvert should be noted.

In addition, each District Culvert Inspection Program should update and maintain a database that includes inventory, condition, and recommended repair strategies for any deficiencies. This database shall be maintained in close coordination with Headquarters.

C5.11.2 Culvert Installation

Culverts shall be installed as set forth in the appropriate sections of the Standard Specifications and Standard Plans. A geotechnical investigation is warranted when significant perforations exist, if there is loss of soil around the pipe, or if there are slope failures or depressions apparent above the pipe,

Where traffic or other conditions warrant, half width construction may be permitted. If conditions do not permit open trench construction, it may be necessary to jack pipe through the embankment.

If the inverts of metal pipe installations are worn to the extent requiring repair or replacement, consider the following courses of action (It is recommended to consult with the Maintenance Engineer or district hydraulic section prior to altering any culvert material type or size):

(A) If the remainder of the barrel is in good condition the pipe may be relined with mesh reinforced concrete.

(B) Insert and seal a smaller diameter pipe inside the original pipe if hydraulic requirements permit.

(C) If the existing culvert appears to be inadequate, replacement with large pipe should be referred to district hydraulic section (Maintenance Engineer may assist). There are numerous issues that could involve right-of-way, increased flows, erosion, or other aspects, which should be studied before a culvert is increased in size.

C5.12 Ditches and Gutters

Ditches and gutters should be inspected periodically and maintained to permit free flow. Lined ditches and gutters should be sealed or repaired to maintain structural integrity.

C5.13 Drainage Channels and Shorelines

Highway facilities are susceptible to damage from heavy flows of water, and protective devices are provided for many facilities such as riprap, slope paving, gabions, walls, vegetation or other devices. It is essential that these devices be maintained to ensure proper function. Refer to the Bank and Shore Protection section of the Highway Design Manual for further information.

Protective devices near water channels and shorelines should be checked periodically to detect conditions that may cause scour, undermining, washout, or other damage to the highway or

facilities by water or wave action. Deficiencies that endanger highway facilities should be repaired promptly. Temporary repairs often are necessary until permanent repairs can be scheduled. Consult the District Hydraulics Unit for assistance with repairs that require significant effort.

Repair or correction of deficiencies not having an immediate effect on the structural integrity of highway facilities should be coordinated with routine maintenance operations. Work in channels should be coordinated with the local offices of State and federal regulatory agencies.

C5.14 Under Drains, Horizontal Drains and Down Drains

Under drains (including underground groundwater relief systems, horizontal drains-cut slope groundwater drains, and down drains), surface drainage conduits, and accompanying collector systems should be inspected once a year and cleaned or repaired as necessary to ensure free flow.

Surface water should not be permitted to discharge into an under drain.

C5.15 Edge Drains

Properly installed and maintained pavement edge drains can help ensure long pavement life.

Edge drains should be inspected early in the winter season to assure that they are functioning.

Inspect during or shortly after a rainstorm to observe the flow. If a drain appears to be clogged, it may be checked with a "snake" and cleaned by water jet equipment if necessary. Clean outs have been installed for this purpose. See Chapter ”F” of this manual for any storm water related restrictions to cleaning.

Inspections make sure the wire mesh cover at the end of clean outs and outlets are not damaged. Damaged mesh might allow access to rodents who can build nests in these drains and block flow of sub-surface water.

C5.16 Structure Drainage Systems

Bridge drainage systems should be inspected annually prior to the rainy season, and cleaned where necessary. These systems should be observed during storms to ensure proper functioning.

C5.17 Minimum Thickness of Cover

The table below provides the minimum thickness of cover measured at the edge of travel way required for design purposes over pipes and pipe arches. For construction purposes, a minimum cover of six (6) inches greater than the thickness of the structural cross section is desirable for all types of pipes.

Where cover heights above culverts are less than the values shown in the table below, stress reducing slab details available from Headquarters Design drainage detail library using the following web address may be used: http://onramp.dot.ca.gov/hq/design/drainage/library.php

Where cover heights are less than the values shown in the stress reducing slab details, contact the Office of State Highway Drainage Design or the Underground Structures Branch of DES – Structure Design.

Class 4 concrete backfill may be used for culverts where it is necessary to have less than two (2) feet of cover below the top of a flexible pavement. A minimum of six (6) inches of concrete backfill should be used on each side of culverts up to 42 inches in diameter; and, a minimum of one (1) foot of concrete backfill should be used on each side of culverts over 42 inches in diameter.

	Minimum Thickness of Cover				
Surface Type	**Corrugated metal pipes and pipe-arches**	**Structural plate pipes and pipe-arches**	**Reinforced concrete pipes**	**Plastic Pipes**	**Cast-in-Place concrete pipes**
Flexible pavements or unpaved	Diameter or span/5 Or 2 ft. minimum	Diameter or span/8 Or 2 ft. minimum	2 ft. minimum	2 ft. minimum	Structural Section plus 2 ft.
Rigid Pavements	Diameter or span/5 Or 1.2 ft. minimum	Diameter or span/8 Or 1.2 ft. minimum	1 ft. minimum	1 ft. minimum	Structural Section plus 2 ft.

Figure C5-1: Minimum Thickness of Cover for Culverts

C5.18 Jacking and Boring Pipe

Reinforced concrete pipe (RCP) and welded steel pipe may be installed by jacking or boring through the embankment / fill. There are also specialty pipe types that are useful for jacking, and approval for use of specialty pipes can be obtained from the Headquarters Hydraulic Engineer.

Usually, pipe that is 30 to 60 inches in diameter is the size for installation by jacking. As the jacking operation progresses, material is hand excavated, or sluiced from inside the pipe.

Pipe smaller than 36 inches in diameter may be installed in a similar manner by boring. In this case, material is excavated from inside the pipe with a mechanical earth auger.

Obstructions in the fill such as boulders, rocks or utility lines may make this method impractical.

C5.19 Private Irrigation Facilities

Where cross pipes or siphons are installed for the purpose of conveying irrigation water, maintenance of the installation may be the responsibility of the abutting property owners or others. Check right of way contracts and encroachment permits for conditions regarding such culvert installations to determine Maintenance responsibility. Note any instances of illicit connections or illegal discharges as outlined in Chapter ”F” of this manual.

C5.20 Entry Upon Private Property

Conditions may require that employees enter upon private property to maintain and repair drainage culverts or other structures or appurtenances within the State highway right of way.

A legal opinion on this subject states that except in cases of emergency, "Before entering upon private property to maintain or repair culverts, or other structures, or appurtenances, employees should obtain the property owner's consent whenever practical, and in no event should employees ever enter private property after an owner thereof has expressed opposition to such entry."
If entry is denied but is necessary, contact the Deputy District Director, Maintenance. He or she may determine that legal assistance is necessary.

Consent to enter upon private land may be obtained by a simple document such as the following:

> Date --------
> I hereby grant permission to the State of California and its authorized employees to enter upon only so much of my property as may be necessary to maintain and repair drainage culverts, or other structures or appurtenances, located within the highway right-of-way.
> This permission shall continue in effect until revoked by me or my successors.
>
> _____
> (Signature)

Figure C5-2: Right of Entry Request

C5.21 Maintenance of Over Side Drains and Slope Ditches

Pipe or flume down drains, paved spillways, and slope ditches are provided to convey water from the embankment or slope.

Structures of this type should be maintained intact, and in the case of metal assemblies, maintained in tight contact with shoulder surfacing, side ditch lining, and dike paving. If embankment settlement occurs, restore to grade, and re-establish down drains or spillway, side ditch and dike.

Fill and seal cracks around inlets of down drains and seal paved spillways to prevent seepage of water into embankment areas.

If RSP is provided at the end of down drains or paved spillways, they should also be inspected and repaired if needed.

C5.22 Under Drains

Under drains serve to intercept ground water before it reaches the sub-grade. Perforated pipes that may be steel, aluminum, plastic, galvanized corrugated metal or tile are used for this purpose.

Local conditions will determine whether the installation should be along the shoulder line or toe of slope or a herringbone system under the traveled way.

The minimum diameter of pipe to be used is six (6) inches. Place perforated metal pipe with perforations down. Invert grade of pipe should be at least three (3) feet below surface. A grade of at least 0.5 percent should be used if possible; however, if this slope is unobtainable grades of 0.20 percent for laterals, and 0.25 percent for mains may be established.

Refer to Standard Specifications and Standard Plan D102 for methods of placing pipe, filter material and grading of filter material. Stabilize soft or mucky trench bottoms by tamping in straw or add sufficient granular material to stiffen the muck.

Surface drainage should not be permitted to discharge into an under drain. Clean outlets of under drains to maintain flow of water.

C5.23 Horizontal Drains

Subsurface water is frequently a primary cause of landslides or slip outs that may close or impair the use of the road. Landslides can sometimes be prevented or controlled through installation of horizontal drains, by themselves or in combination with other treatment.

Horizontal drains consist of perforated metal pipes or PVC pipes (see Standard Specifications, Section 68-2) installed in holes drilled on a slight gradient into fill, cut or natural slopes. Perforated two (2) inch iron pipe is normally used for casing. It is usually necessary to provide a suitable collection system to remove the intercepted water from the area.

Horizontal drains will lose their effectiveness unless properly maintained. The drains require periodic cleaning, and the collection system must be kept in repair. The Caltrans Transportation Laboratory (Translab) can recondition horizontal drains. Translab will also perform condition surveys on request.

C5.24 Dry Fords

Stream fords may be provided on minor highways at watercourses subject to flash floods.

Culverts carry the normal flow and paved dips with cutoff walls or slope paving on either side carry the overflow. Keep culverts clean and dip surfacing intact and sealed. Repair and support undercut walls or slope paving.

C5.25 Bank and Slope Protection

Protective measures may be required where a stream flow or wave action endangers highway embankments or structures and even private property. Erosion may be controlled through a variety of methods, as provided in this section. The SM&I ABME should be notified anytime erosion affecting a bridge is found.

The type of protection should be chosen so as to maintain the location and natural roughness of the bank, making optimum use of local material. The velocity of flow and direction of currents are very critical factors in selecting the material. Consult with district hydraulic section for assistance in selecting the appropriate type and location and depth of placement for the bank or slope protection.

During emergencies, rock may be deposited along the bank for erosion control. Sandbags and weighted canvas or plastic sheets may also be used. Dumping tree trunks or stumps along a bank to control erosion is not advised, since this material may float out on subsequent storms and endanger downstream bridges or structures. Planting willows along an overflow bank may aid in controlling erosion by reducing the velocity of flow, but the possibility of the willows being scoured out and becoming damaging drift should be considered.

Dikes may be constructed to direct water away from a fill or bridge abutment, but may cause erosion of private property. Dikes or other obstructions that cause abrupt change in current should be avoided.

If bank or slope protection or stream control devices extend beyond the right of way, right of entry should be obtained before making repairs. See Section C5.20: Entry Upon Private Property.

Bank and slope protection devices are generally broken down into two categories: armor protection and training systems.

C5.25.1 Bank Protection

Armor protection, which includes rock slope protection, PCC grouted rock slope protection, concrete slope paving, sacked concrete slope protection, fabric formed slope protection, and gabions is the artificial surfacing of bend, banks, shore or embankment to resist erosion or scour. These devices may be flexible or rigid. A discussion of some of the common types of armor protection follows; see Highway Design Manual, Section 873.3 for specific details.

(A) Rock Slope Protection (RSP) or Riprap

Rock slope protection is flexible, easily repaired and has the ability to resist heavy impact from drift and debris. The toe should be below depth of scour. The size of rock should be based on the velocity of flow and depth of scour. Refer to Standard Specifications for size and quality and to the report "California Bank and Shore Rock Slope Protection Design – Practitioner's Guide and Field Evaluations of Riprap Methods" for design and method of placement. The report can be found at the following website: www.dot.ca.gov/hq/oppd/hydrology/hydroidx.htm. Filter fabric may be required for the RSP to function properly.

Slope protection damaged or displaced should be replaced after each storm, as conditions warrant. In an emergency with damage continuing, repairs may be made with heavier unclassified rocky material. Additional information on emergency repair procedures using RSP is available from the Headquarters Hydraulic Engineer.
Rock that is dumped into place (Method B Placement) must be larger than rock placed by Method A, which required a three point bearing placement.

(B) PCC Grouted Rock Slope Protection

This type of protection consists of rock slope protection having voids filled with portland concrete cement (PCC) grout to form a solid armor. It has application in areas where rock of sufficient size for ordinary rock slope protection is not economically available. Grouting not only protects the rock system from the full force of high velocity water, but also integrates a greater mass to resist its pressure. Grouting will usually increase the cost per unit volume of rock.

This type of protection is rigid without high strength and requires support by embankment. Prevention of undermining is important. Grout penetration should be 18 inches for 1/2 ton rock varying to six (6) inches for cobbles.

It should not be used on slopes steeper than 1 1/2:1. The grout should be placed in voids that do not have fine material that will hinder the penetration of the grout. The depth of grout penetration is shown in "California Bank and Shore Rock Slope Protection Design – Practitioner's Guide and Field Evaluations of Riprap Methods" which can be found at the following website: www.dot.ca.gov/hq/oppd/hydrology/hydroidx.htm.

PCC grouted RSP needs to include weep tubes to allow for passage of water than can build up in the soil on the bank of the revetment. Extra precaution should be observed to construct the toe of grouted slope protection on solid rock or below the depth of scour. A gravity cut-off wall at the toe of the slope protection may be required. The rougher the surface the better the protection serves. Ends should be protected by tying into solid rock or forming smooth transitions with embankment subjected to lower velocities. If the embankment material is exposed at the top, freeboard is warranted to prevent overtopping.

(C) Concrete Slope Paving

This rigid type of slope protection composed of concrete reinforced with wire mesh is used only where flow is controlled and will not over-top the protection. It may be damaged by undermining hydrostatic pressure and material being washed through cracks. If degrading of stream or scour exposes the toe, the toe should be protected with heavy rock, grouted rock, or concrete cut-off wall. The cost of concrete slope paving is high on a cubic meter basis but generally less, on the basis of area, than for sacked concrete slope protection.

Weep holes should be placed in the slope paving if there is a possibility of water seeping behind the paving. They may be placed by drilling a hole in the slope paving, placing rock behind the paving, and grouting a section of pipe in place. If cracks develop of sufficient size to permit the backing material to wash out, they should be sealed with concrete grout.

(D) Sacked Concrete Slope Protection

The Sacked Concrete Slope Protection (SCSP) method is no longer a Caltrans standard design, and should only be used for replacement in kind, where repairs of existing slopes that already have SCSP are needed. To facilitate such repair work, please refer to the developed plan at http://pd/design/drainage.asp.

This method of protection consists of facing the embankment with sacks filled with concrete. The toe should be below anticipated scour. The strength depends on the

embankment that should be well compacted. Placing of the sacks usually leaves sufficient voids so hydrostatic pressure is not built up behind the sacks. Sacks should be placed high enough to avoid overtopping.

A lot of hand labor is required, but it is simple to construct and adaptable to almost any embankment contour. The installation must depend upon the stability of the embankment for support, and should not be placed on slopes steeper than the angle of repose. 1 1/2:1 slopes are preferred, but 1:1 have been used safely.
The cost is usually more than the cost of rock for equal protection against velocity of flow, and is used primarily where stream gravel is available, and satisfactory rock is not economical.

Almost all failures of sacked concrete are a result of stream water eroding the embankment material from the bottom, the top, or the ends. If the ends are not tied into rock or other non-erosive material, cutoff returns are to be provided, and if the protection is long, cutoff stubs are used at intervals and at ends in order to prevent or retard a progressive failure.

Dry pack placement can be applied by spraying the surface with the water. Dowels have been driven into the wet sacks in place to add extra strength.

(E) Fabric Formed Protection

Fabric formed protection uses sectionalized fabric mattresses filled with a fine aggregate concrete.

The protection is formed by using a double-layered envelope of nylon or other suitable synthetic fabric that is laid on the area to be protected, and then filled by pumping a fine aggregate concrete into the mat. It is relatively easy to place, and may be installed in the dry or under water. It is a relatively cost effective alternative to conventional slope paving methods.

Hydrostatic uplift pressure is relieved through filter points or plastic weep tubes inserted through the mat. A filter fabric is used under the mat when relief of hydrostatic pressure is necessary.

(F) Gabions

Gabions consist of baskets fabricated from rectangular wire mesh filled with rock or cobbles (size and grade designated by District Lab or hydraulic sections). Multiple baskets are connected together as a unit and well anchored.
Gabions are useful where the only rock economically available is too small to be used as RSP. They are subject to damage by salt air and streams carrying gravel and stones which would erode the wire mesh. Like RSP, gabions may require filter fabric.

Flexible rock and gabions, properly anchored, may be used to protect against severe scour, especially at the base of concrete slope paving or sacked concrete slope paving. If undercut, the toe of the mat tends to adjust itself to the scoured section and retards further undermining.

Economy of use is governed by availability of selected rock filling and likelihood of corrosion of the galvanized wire mesh.

C5.25.2 Training Systems

Training systems are structures, usually within a channel, that act as countermeasures to control the direction, velocity, or depth of flowing water. They are broken down into three categories: retards, jetties, and baffles. Permeability is the most important property of a training system. An impermeable system may deflect the stream flow entirely, whereas a permeable structure may serve mainly to reduce the strength of water velocity or current. A discussion of some of the common types of training systems follows; see Highway Design Manual, Section 873.4 for specific details.

(A) Retards and Permeable Jetties

Retards and permeable jetties are extensive or multiple unit structures composed of similar open forms like piling, fencing and unit frames. They are dissimilar in function and alignment, with retards being parallel and jetties being oblique to the embankment. Retards are milder remedies than jetties.

Retards lessen the velocity along the embankment, preventing erosion or scour to its toe. They may be used in conjunction with other slope protection methods, or to encourage deposition of waterborne material between the retard and the bank or induce vegetation growth along the bank. They may be used to slow the flow on one side of the channel or discourage a stream from meandering.

Permeable jetties are elongated, artificial obstructions projecting into a stream from the bank to control shoaling and scour by deflection or redirection of currents. The permeability allows for some flow through the structure to minimize the formation of eddies immediately downstream.

Maintenance of such structures is confined primarily to the replacement of stone fill, if used.

(B) Groin

A groin is a solid or permeable and relatively slender barrier opposing the natural flow of water to control the movement of bed material. It may be built of stone, concrete, steel piling or timber piling.

(C) Baffle

A baffle is a pier, fence, wall, or mound built on the bed of a stream to control, deflect, check or disturb the flow. Baffles may vary in magnitude from a check dam on a small stream to a system of training dikes or permeable jetties for deflecting or directing flow. A potential drawback to installing a baffle is the possibility of erosion to previously unexposed areas, threat to adjacent property, eddy currents, and possibility of scour.

Drop structures or check dams are effective for gradient control, and are most suited to locations where bed materials are relatively impervious; otherwise, underflow must be prevented by cutoff walls.

C5.25.3 Tetrahedrons

Tetrahedrons constructed of steel rails are limited to use in broad stream channels where the slight restriction effected by the tetrahedrons will not appreciably increase stream velocity, or across embayment's which have developed in recent floods. This permeable type of protection tends to reduce stream velocity adjacent to the embankment and promotes deposition of material.

C5.25.4 Jackstraws

Jackstraws, usually constructed of railroad rails, are not recommended for general use, but may be resorted to in emergency as a control measure, at critical locations.

C5.25.5 Fence Type Protection

Wire mesh fences, constructed either with steel rail or pipe, and may be used to confine streams of moderate flow within definite channels or to protect embankment slopes, which are subject to erosion by high water. This type of protection consists of a single or double line of posts and wire mesh, between which is formed a wire mesh basket filled with brush and rocks. Fences should be well anchored to prevent overturning.

As the wire basket settles due to scouring action or compaction of filler material, additional brush and rock may be added to maintain the effectiveness of the structure.

See Section 2 of this Chapter: Fences, for details of rail and wire fence construction.

C5.25.6 Control of Ditch Erosion

Excessive erosion in drainage ditches may be controlled by applying asphalt concrete or premix material, loose cobbles or grouting rock, and by constructing check dams. Sausage rolls of chicken wire filled with small rock are effective.

Where water ponds on shoulder areas, provide additional drainage by cutting dikes and installing over side drains. Prevent slope erosion by paving outlet ditches on flat slopes or by using pipes or flumes on steep slopes.

Consult with the District Hydraulic Engineer for assistance with the design when using these measures.

Section 4: Other Roadside Appurtenances

C5.26 General

This section discusses appurtenances located throughout roadsides. It does not include electrical roadside appurtenances, nor those associated with pedestrians.

C5.27 Benches

Bench areas in slope areas should be physically inspected as needed. Accessible benches should be cleaned when drainage is operationally impaired.

C5.28 Curbs and Curbed Islands

These facilities provide one or more of the following functions: Control drainage, separate vehicles from pedestrians, channelize traffic, or provide pedestrian refuge.

When curbs fail to perform their function due to settlement, heave, or damage, they should be repaired or replaced.

C5.29 Sidewalks

Periodic inspections should be made of sidewalks, both in unincorporated area, and in cities to ensure that they are safe for users. Breaks, holes, or other damage should be repaired promptly.

Significant variation in height between adjoining slabs in a sidewalk should be corrected. Sidewalk repairs within cities should be handled by city forces where a maintenance agreement exists. Where unsafe conditions are found to exist, cities should be requested to have repairs made promptly.

Curbs that are attached to sidewalks should be maintained approximately to the level of the sidewalks.

C5.30 Curb and Sidewalk Repair

The responsibility for repairing curbs and sidewalks within the right of way will, in general, be assumed by the State.

The exceptions to this are the placement of a sidewalk under encroachment permit, where the permittee will maintain the sidewalk; and where local agencies have requested nonstandard items, in which case, they should be responsible for maintenance costs.

In the event the permittee, upon proper notification, refuses to repair a hazardous sidewalk condition, the duty falls upon the State to repair such condition.

Where a substantial expenditure is required to repair a dangerous or defective condition in a sidewalk, a claim shall be made against the permittee who is obligated to make repairs.

In incorporated cities, the responsibility for maintenance of curbs and sidewalks may be delegated to the city. In such cases, the city should exercise reasonable diligence in the performance.

C5.31 Debris Barriers

Debris barriers such as fencing, walls, cribs, and dikes are installed to reduce the possibility of falling rocks and other material from reaching the traveled way.

Surveillance of debris barriers should be made as needed to ensure functional integrity.

Material accumulated behind debris barriers should be removed before the effectiveness of the barrier is impaired.

C5.32 Retaining Walls and Cribs

Retaining walls may be plain or reinforced concrete, metal, concrete or timber cribs, or sacked concrete.
Check and repair as necessary all rubble or masonry walls. Concrete or mortar shall conform to Standard Specifications. Keep weep holes in walls open. Prevent erosion at base of walls.

Peel bark from logs, except redwood or cedar, used as cribbing.

Keep timbers free of weeds and fire hazards. Small trees growing between concrete crib members should be removed.

Concrete in sacks stacked one upon another has proven satisfactory for low retaining walls and for paving slopes.

A periodic check should be made on all timber cribs, and bulkheads, for signs of failure. Make such repairs as conditions warrant.

Very large retaining walls may be assigned a bridge number and inspected by Area Bridge Maintenance Engineers. See Section H.05 for details.

C5.33 Graffiti Removal

Offensive or discriminatory graffiti should be removed as soon as possible after discovery.

Removal of other graffiti should be scheduled on a regular basis as are other maintenance activities. In scheduling removal of inoffensive graffiti that is within our right of way and visible, the highway facility should be given top priority over that visible from cross streets, adjacent property, frontage roads, etc.

Maintenance management should be alert for efficient and cost effective ways of handling this problem. Graffiti removal may be scheduled during peak hour traffic when work on the traveled way is not possible. It is also a good activity for the use of those involved in the law violator program. Response to complaints concerning graffiti should be made on a timely basis taking other work priorities into consideration. District and Headquarters personnel making field reviews should be alert for problem areas, and report them as part of their review reports.

Refer to Chapter "D1" of this manual: Litter, Debris and Graffiti.

C5.34 Disposal of Waste Material

In some cases, it may be appropriate to use suitable waste materials to reinforce pavement edges or widen shoulders and parking areas.

To the extent practicable, waste materials shall be hauled to disposal sites that have been approved for that purpose through accepted procedures. In areas where haul distances to disposal sites are unreasonable, earthen waste material may be disposed of along the right of way at locations.

In all cases, these disposal locations must be agreed upon by concerned agencies such as Fish and Game, U.S. Forest Service, Regional Water Quality Control Board, District Stormwater/NPDES Coordinator, and the local enforcement agency responsible for controlling disposal of solid waste. The District Environmental Branch Chief should be consulted for liaison with these agencies. In identifying and using such locations, the prime considerations should be that the material to be disposed of is essentially inert. The following are primary considerations in selecting right of way disposal sites:

(A) Petroleum-based material such as asphalt pavement shall not be placed in streambeds;

(B) The sites should not objectionable from the esthetic standpoint; and

(C) The waste material shall not go directly into streams or stream channels.

Before using any disposal areas, be certain the water quality control boards are made aware of the locations and concur in their use. The instructions found in Chapter 1 of this manual, Section 1.23: Protection of Sensitive Environmental Resources, apply to disposal of waste material.

When it is not practicable to stockpile or haul material during an emergency, it may be disposed of over the side of the roadbed at the nearest convenient location. Examples of such emergencies are slides that have caused road closures, or when materials on the roadbed are creating traffic hazards.

The disposal location must not create further hazards, or cause problems greater than the existing situation. Only the minimum quantities necessary to open the road and make it safe may be disposed of in this manner.

In the case of large slides (many thousands of cubic yards/ cubic meters), Caltrans may push over the side only the amount of material required to use trucks or hauling equipment to pioneer the slide. Only the minimum quantities necessary to open the road and make it safe may be disposed of in this manner. Remaining material should be stockpiled at a nearby location for temporary storage if necessary, and then later hauled to an approved disposal site, preferably before disposal.

Any emergency disposal of materials into a water body must be reported to the California Department of Fish and Game within fourteen days.

C5.35 Non-Motorized Facilities

Areas where non-motorized travel is permitted, separated bicycle paths, shoulder areas, and sidewalks shall be maintained at a level that provides for safety. Maintenance activities shall include, but not be limited to, sweeping, patching, striping and other functions necessary to achieve the desired level of maintenance. Facilities for non-motorized travel shall be maintained in conjunction with the traveled way.

Non-motorized paths (separated from motor vehicle traveled ways) should be repaired and maintained in the same manner as flexible roadbed. They should be inspected for loose material and swept accordingly.

In addition to using separated bicycle paths, bicyclists are permitted to travel on State highways except certain prohibited sections of freeway. Maintenance procedures and highway improvements on freeways open to bicyclists should ensure safe and convenient bicycling. See Chapter A of this Manual, Section A.22: Non-Motorized Travelers on State Highways for more detailed information.

Section 885-894.2 of the Streets and Highways Code pertains to bicycles.

Figure C5.-3: Half-ton RSP, 2-Sha-5, Postmile 50.1. Courtesy, Kathy Coots, Maintenance Supervisor, 2-98.

Figure C5-4: Half-ton RSP with Weep Pipe, District 10, East Fork Carson River Courtesy, Jim Racin, ESC, Office of State Highway Drainage Design, 1-97.

Figure C5-5: Grouted RSP, District 10, East Fork Carson River. Courtesy, Jim Racin, Office of State Highway Drainage Design, 1-97.

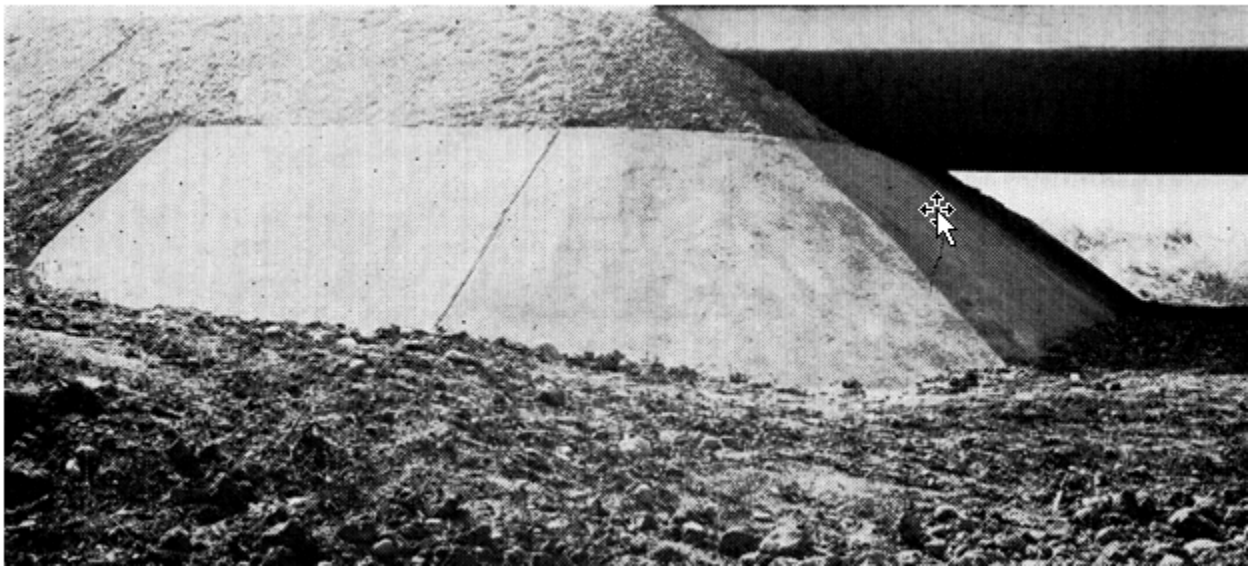

Figure C5-6: Paved Slope Protection Courtesy, Steve Ng, Maintenance and Investigation Office, 4-98.

Figure C5-7: Sacked Concrete Slope Protection, District 2, Trinity County,. Courtesy, Steve Ng, Maintenance and Investigation Office, 4-98.

Figure C5-8: Rock filled double pipe and wire fence, Dry Creek, Lake County. Courtesy, Steve Hg, Maintenance and Investigation Office, 4-98.

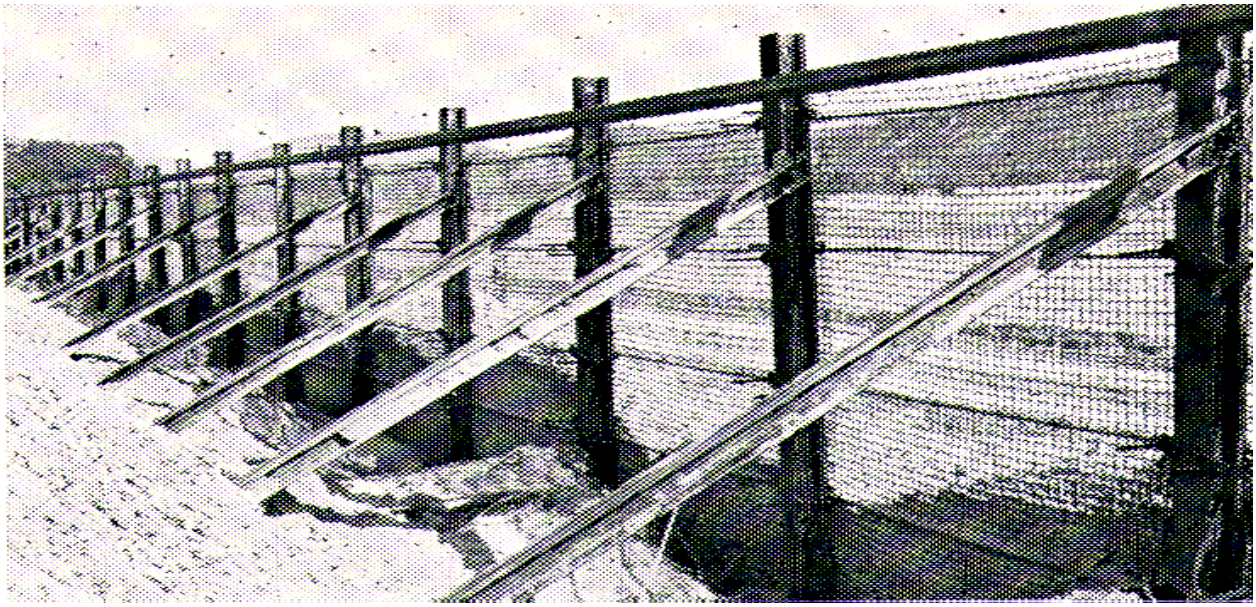

Figure C5-9: Single Row Rail Pile Retard, District 7, Ventura County. Courtesy Steve Ng, Maintenance and Investigations Office, 4-98.

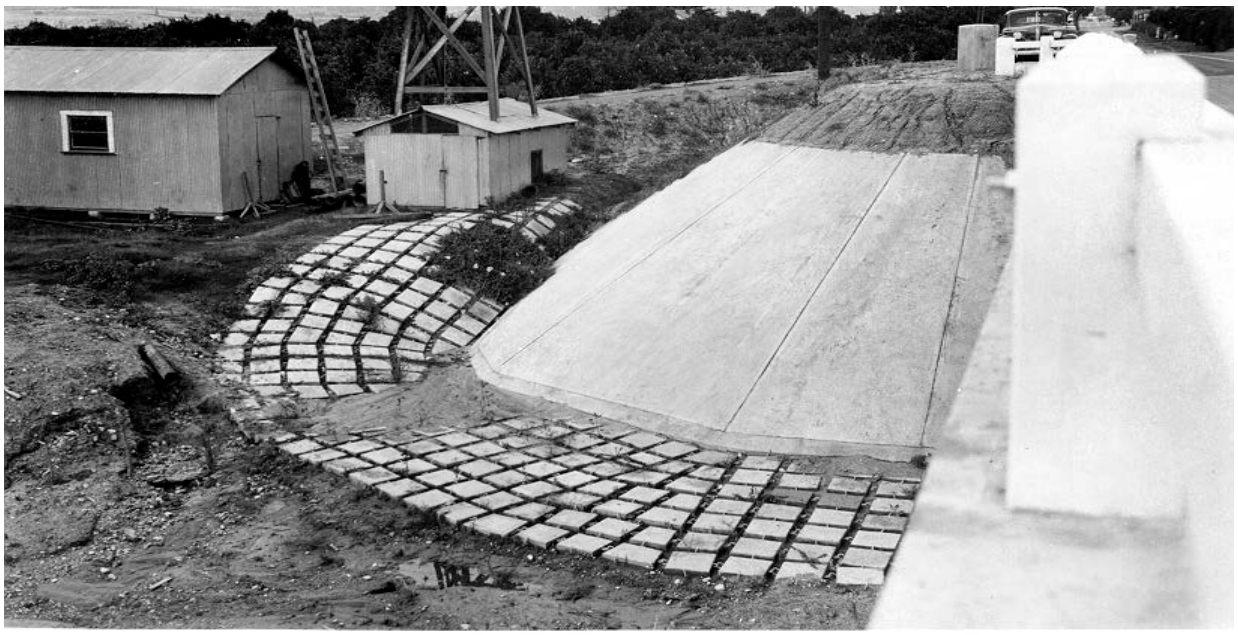

Figure C5-10: PCC Mattress and Concrete Paved Slope Protection Courtesy Steve Ng, Maintenance and Investigations Office, 4-98.

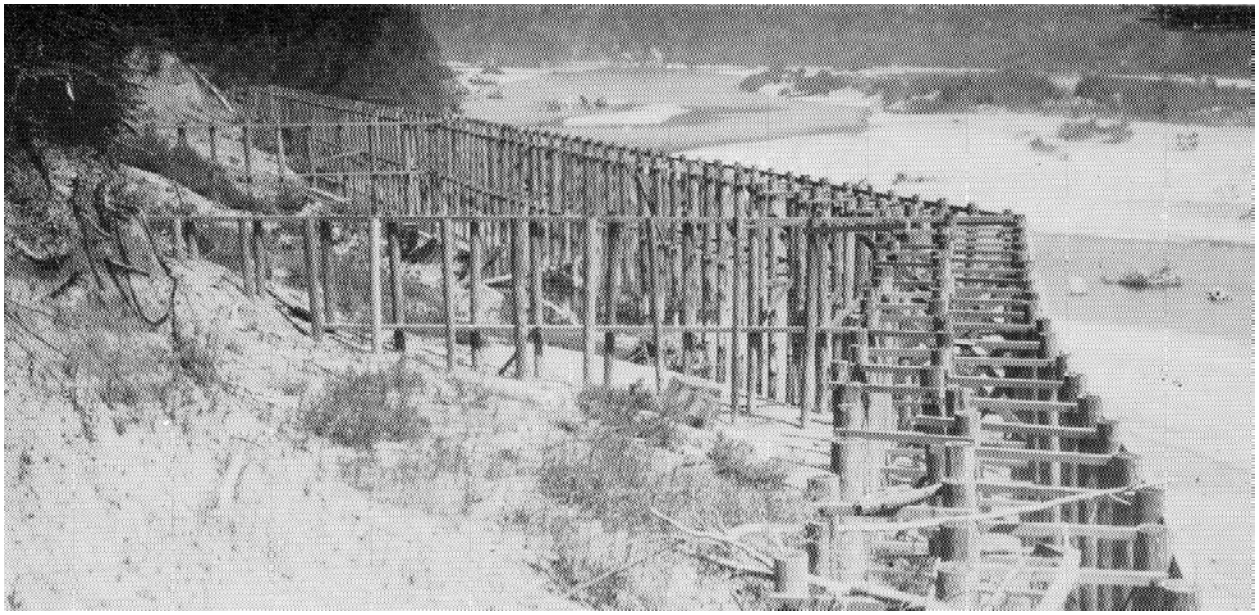

Figure C5-11: Permeable Pile Retard, Humboldt County, Eel River Courtesy, Steve Ng, Maintenance and Investigations Office, Circa 1924.

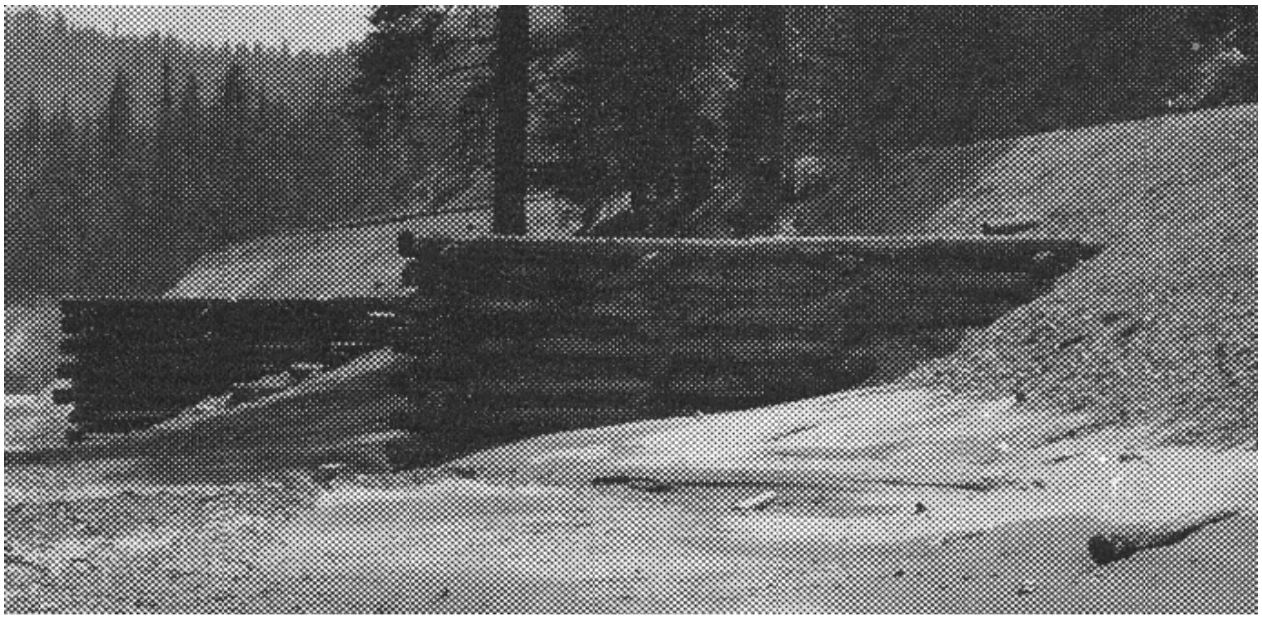

Figure C5-12: Log Crib Impermeable Jetty, Triangular, Humboldt County, Eel River Courtesy, Steve Ng, Maintenance and Investigations Office, 4-98.

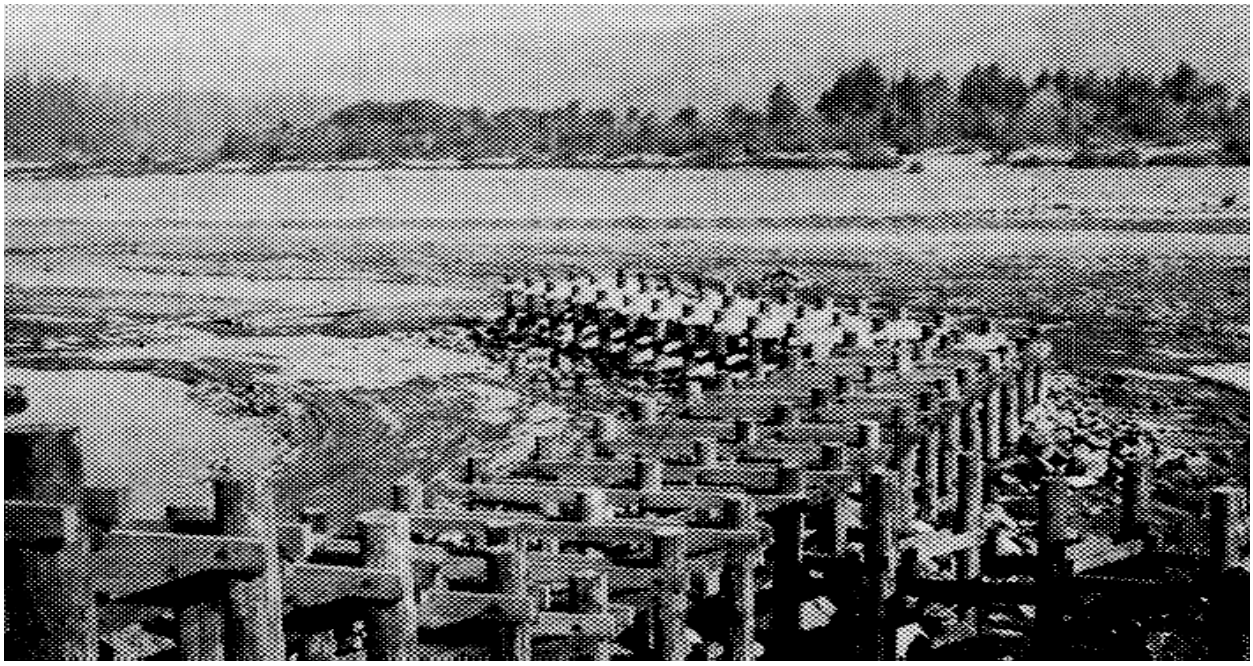

Figure C5-13: Timber Pile Jetty, Permeable, Humboldt County, Eel River. Courtesy, Steve Ng, ESC, Maintenance and Investigations Office, 4-98.

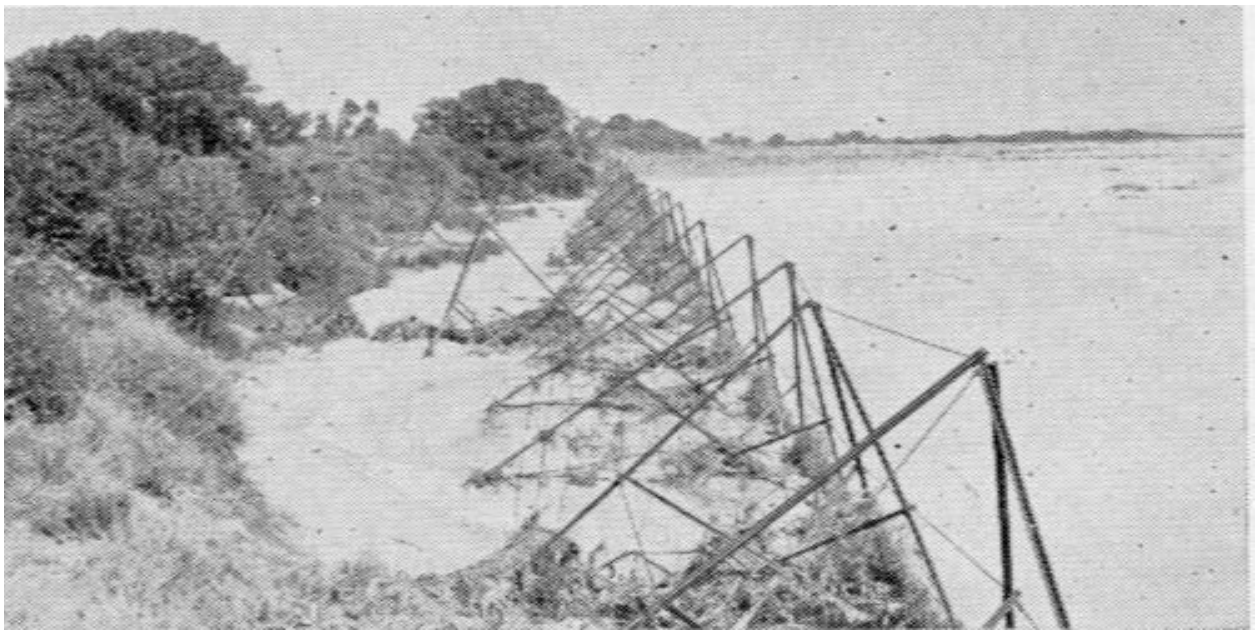

Figure C5-14: Steel Rail Tetrahedon Retard, District 5, Salinas River Courtesy, Steve Ng, Maintenance and Investigations Office, 4-98.

Figure C5-15: Double Row of Fence, rock Filled, District 5, San Benito River Courtesy, Steve Ng, Maintenance and Investigations Office, 4-98.