GENERAL DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT

HUMBOLDT COUNTY, CALIFORNIA

AND

APPENDICES

U.S. Army Engineer District, San Francisco
Corps of Engineers
San Francisco, California

February 1966

HSU
HUMCO
TC
425
R44
G45

DEPARTMENT OF THE ARMY
SAN FRANCISCO DISTRICT, CORPS OF ENGINEERS
100 McALLISTER STREET
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO
SPNGP

1 February 1966

SUBJECT: General Design Memorandum, Redwood Creek, California

TO: Division Engineer
U.S. Army Engineer Division, South Pacific
San Francisco, California

In accordance with EM 1110-2-1150 and supplemental instructions contained in South Pacific Division Regulation No. 1110-2-3, 14 October 1965, the subject design memorandum which includes basis for cost estimates is transmitted for approval.

1 Incl
as (8 cys)

Robert H Allan
ROBERT H. ALLAN
Lt. Colonel, CE
District Engineer

GENERAL DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT

HUMBOLDT COUNTY, CALIFORNIA

FORWARD

This General Design Memorandum was prepared in accordance with the provisions of EM 1110-2-1150.

The Redwood Creek Flood Control Project was authorized by the Flood Control Act of 1962, Public Law 87-874, Eighty-seventh Congress, Second Session, approved 23 October 1962.

The District Engineer recommends a plan for the construction of local protection works on Redwood Creek near the town of Orick. The principal features of the plan include construction of levees and channel improvement of Redwood Creek from the confluence with Prairie Creek to a point approximately 700 feet upstream of the mouth of Redwood Creek, a distance of 3.4 miles, construction of interior drainage facilities, and relocation of utilities and county roads.

Current total estimated cost of the project is $6,050,000, of which $5,530,000 would be Federal costs and $520,000 non-Federal costs for land and relocations. The benefit to cost ratio is 1.3 to 1. The time required to construct the project is estimated at three years.

GENERAL DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT

HUMBOLDT COUNTY, CALIFORNIA

PERTINENT DATA

HYDROLOGIC DATA:

The drainage area	283 square miles
Standard project flood at Orick	77,000 cubic feet per second
Maximum discharge of record, December 1964	50,500 cubic feet per second
Design flood velocities	11 to 20 feet per second

CHANNEL IMPROVEMENT:

Length, total	17,700 feet
Length, right levee	15,500 feet
Length, left levee	17,600 feet
Bottom width	250 feet
Side slopes, channel	1 on 3
Side slopes, levees	
Channelside	1 on 3
Landside	1 on 2.5
Freeboard	3 feet

PRINCIPAL QUANTITIES:

Excavation, unclassified	1,360,000 cubic yards
Embankment	778,000 cubic yards
Waste	467,000 cubic yards
Excavation, interior drainage ditch	114,000 cubic yards
Riprap	270,000 tons

ESTIMATED COSTS:

Item	First Cost	Average Annual Cost
Federal	$5,530,000	$220,000
Non-Federal	520,000	21,000
Non-Federal Maintenance, Operation and Replacement		19,000
Project, Total	$ 6,050,000	$260,000

ESTIMATED BENEFITS:

Item	Average Annual Benefit
Flood Control	343,000
Land Enhancement	7,000
Total	350,000

BENEFIT TO COST RATIO: 1.3 to 1

GENERAL DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT

HUMBOLDT COUNTY, CALIFORNIA

TABLE OF CONTENTS

Paragraph	Title	Page
	INTRODUCTION	1
1	AUTHORITY	1
	DESCRIPTION OF PROJECT DOCUMENT PLAN	2
2	GENERAL	2
	SPECIFIED LOCAL COOPERATION	2
3	GENERAL	2
	INVESTIGATIONS	2
4	GENERAL	2
	LOCAL COOPERATION	3
5	REQUIRED LOCAL COOPERATION	3
6	ACTION BY LOCAL INTERESTS	3
7	LOCAL OFFICIALS RESPONSIBLE	4
	LOCATION OF PROJECT AND TRIBUTARY AREA	4
8	LOCATION OF THE PROJECT	4
	PROJECT PLAN	4
9	GENERAL	4
	DEPARTURES FROM PROJECT DOCUMENT	5
10	GENERAL	5
	a. Channel and levee extions	5
	b. Control Sill	5
	c. Seepage Control	5
	d. Interior drainage	5
	e. Bridge	5

TABLE OF CONTENTS
(continued)

Paragraph	Title	Page
	HYDROLOGY	5
11	GENERAL	5
12	DESIGN VALUES	6
	a. Channel	6
	b. Interior drainage	6
	c. Friction factors	6
	GEOLOGY	6
13	AREAL GEOLOGY	6
14	SEISMIC ACTIVITY	7
	SOILS	7
15	FOUNDATION CONDITIONS	7
16	LEVEE CONSTRUCTION	7
17	SLOPE PROTECTION	7
	OTHER PLANS INVESTIGATED	8
18	GENERAL	8
	DESCRIPTION OF PROPOSED STRUCTURES AND IMPROVEMENTS	8
19	GENERAL	8
	CHANNEL IMPROVEMENT	8
20	GENERAL	8
	BRIDGE PIER EXTENSION	10
21	GENERAL	10
	INTERIOR DRAINAGE SYSTEM	10
22	GENERAL	10
23	INTERIOR DRAINAGE SYSTEM - RIGHT SIDE	11
24	INTERIOR DRAINAGE SYSTEM - LEFT SIDE	11
25	DESIGN ANALYSIS	13

TABLE OF CONTENTS
(continued)

Paragraph	Title	Page
	ACCESS ROADS	14
26	GENERAL	14
	SOURCES OF CONSTRUCTION MATERIALS	14
27	EMBANKMENT	14
28	RIPRAP	14
29	SAND AND GRAVEL	14
30	CONCRETE AGGREGATE	14
	REAL ESTATE REQUIREMENTS	15
31	GENERAL	15
	RELOCATIONS	15
32	GENERAL	15
33	ROADS	15
	a. Huffords Road - Right Bank	15
	b. Orick River Road - Right Bank	15
	c. Drydens Road - Left Bank	16
34	UTILITIES	16
	a. Station 45+50 and Station 57+10	16
	b. Station 83+70	16
	c. Station 114+25 and Station 123+30	16
	d. Station 127+20	16
	e. Station 127+95	16
	f. Station 127+35	16
	g. Station 149+55	16
	DIVERSION AND CARE OF WATER	16
35	GENERAL	16
	COST ESTIMATE	17
36	ESTIMATES	17
37	SUMMARY OF COST INCREASES	20

TABLE OF CONTENTS
(continued)

PLATES

Plate No.	Title
1	PROJECT AREA AND VICINITY MAPS
2	PLAN AND PROFILE-STATION 15+50 to STATION 42+50
3	PLAN AND PROFILE-STATION 42+50 to STATION 78+56.44
4	PLAN AND PROFILE-STATION 78+56.44 to STATION 113+00
5	PLAN AND PROFILE-STATION 113+00 to STATION 126+00
6	PLAN AND PROFILE-STATION 126+00 to STATION 142+00
7	PLAN AND PROFILE-STATION 142+00 to STATION 160+00
8	PLAN AND PROFILE-STATION 160+00 to STATION 177+25
9	PLAN AND PROFILE-STATION 177+25 to STATION 192+90
10	PROFILE INTERIOR DRAINAGE SYSTEMS
11	CONTROL SILL AND BRIDGE PIER EXTENSION
12	TYPICAL CHANNEL CROSS SECTIONS AND DRAINAGE STRUCTURES
13	DRAINAGE STRUCTURES

TABLE OF CONTENTS
(continued)

PLATES

Plate No.	Title
1	PROJECT AREA AND VICINITY MAPS
2	PLAN AND PROFILE-STATION 15+50 to STATION 42+50
3	PLAN AND PROFILE-STATION 42+50 to STATION 78+56.44
4	PLAN AND PROFILE-STATION 78+56.44 to STATION 113+00
5	PLAN AND PROFILE-STATION 113+00 to STATION 126+00
6	PLAN AND PROFILE-STATION 126+00 to STATION 142+00
7	PLAN AND PROFILE-STATION 142+00 to STATION 160+00
8	PLAN AND PROFILE-STATION 160+00 to STATION 177+25
9	PLAN AND PROFILE-STATION 177+25 to STATION 192+90
10	PROFILE INTERIOR DRAINAGE SYSTEMS
11	CONTROL SILL AND BRIDGE PIER EXTENSION
12	TYPICAL CHANNEL CROSS SECTIONS AND DRAINAGE STRUCTURES
13	DRAINAGE STRUCTURES

GENERAL DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT

HUMBOLDT COUNTY, CALIFORNIA

PROJECT AUTHORIZATION

INTRODUCTION

1. AUTHORITY

The Redwood Creek Flood Control Project, Humboldt County, California, was authorized by the Flood Control Act of 1962, Public Law 87-874, Eighty-seventh Congress, Second Session, approved 23 October 1962, which act reads in part as follows:

> "Section 203. The following works of improvement for the benefits of navigation and the control of destructive flood waters and other purposes are hereby adopted and authorized to be prosecuted under the direction of the Secretary of the Army and the supervision of the Chief of Engineers in accordance with the plans in the respective reports hereinafter designated and subject to the conditions set forth therein."

. . . ."

* * * * * * * *

REDWOOD CREEK BASIN

> "The project for flood protection on Redwood Creek, Humboldt County, California, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers and House Document No. 497, Eighty-seventh Congress, at the estimated cost of $2,580,000."

DESCRIPTION OF PROJECT DOCUMENT PLAN

2. GENERAL

The project document plan found to be most feasible for resolving the flood problem on Redwood Creek provided for channel improvements along the lower 4 miles of the stream. The improvements would consist of channel enlargement, earth levees with service roadways on both sides of the channel, dumped stone revetment along most of the levee and riverbank length and other features pertinent to a channel improvement project. The works would extend from above the mouth of Prairie Creek almost to the ocean.

SPECIFIED LOCAL COOPERATION

3. GENERAL

As specified in the project document, local interests must cooperate in construction of the Redwood Creek Flood Control Project, Humboldt County, California, by giving assurances satisfactory to the Secretary of the Army that they will:

a. Provide all lands, easements, and rights-of-way, including borrow areas and spoil-disposal areas necessary for the construction of the project;

b. Accomplish all relocations and alterations of buildings, utilities, roads and related facilities necessary for the construction and maintenance of the project;

c. Hold and save the United States free from damages due to the construction works;

d. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army; and

e. Prevent any encroachment on the flood channels and ponding areas which would decrease the effectiveness of the flood-control improvements, and if ponding areas and capacities are impaired, promptly provide substitute storage capacity or equivalent pumping capacity.

INVESTIGATIONS

4. GENERAL

Studies and investigations made with survey report (published as House Document No. 497, Eighty-seventh Congress, Second Session) were sufficiently comprehensive to adequately establish the need, justification, and cost of the proposed plan for protection of economic development in Orick and the vicinity against floodflows on Redwood Creek. Topographic, hydrographic and subsurface investigations were made along the lower reaches of the river where local protection works were proposed for control of floodflows. Topographic and preliminary geologic investigations were made of a possible multiple-purpose reservoir site upstream of Prairie Creek in the vicinity of McArthur Creek. Information on damages resulting from floodflows in the basin was obtained from flood-damage surveys and historical accounts of floods contained in newspaper files, combined with hydrologic analysis of probable floodplains for flows exceeding those of record. Stream-flow records were obtained from publications of the United States Geological Survey. As a result of a public hearing held on 1 November 1955 an investigation of multiple-purpose reservoirs and a diversion channel were conducted during the survey report. Neither proposal was found economically feasible. Emergency bank protection were constructed in 1953 and 1956 under authority of Section 14 of the Flood Control Act of 24 July 1946. The works will not be included in the present plan of improvement; however the riprap will be salvaged to the maximum extent practicable.

LOCAL COOPERATION

5. REQUIRED LOCAL COOPERATION

The authorizing legislation provides that local interests shall cooperate in project construction by accomplishment of the items specified in paragraph 3. Local interests have demonstrated that they are in complete accord with the project.

6. ACTION BY LOCAL INTERESTS

By letter dated 24 January 1961, the Board of Supervisors, Humboldt County, stipulated that their agency would accomplish all necessary non-Federal phases of the Redwood Creek Flood Control Project as specified in the project document. Although no additional public hearings took place, local interests have indicated a strong desire for the project and a willingness to give full cooperation. The local views of concurrence with the project were obtained by conferences. On 16 November 1965, the Board of Supervisors met and gave assurances of the County of Humboldt to furnish the required local cooperation. A Certified copy of the proceedings was furnished this District. The estimated cost of required local cooperation will be $520,000 including rights-of-way and relocations. The Public Works Department of Humboldt County is being assisted by the State of California in accomplishing items of local cooperation.

7. LOCAL OFFICIALS RESPONSIBLE

Local officials responsible for cooperation in the authorized flood control project are:

Melvin J. Bareilles, Chairman, Board of Supervisors, Rio Del
Elwyn L. Lindley, Board of Supervisors, Ferndale
Norman R. Robertson, Board of Supervisors, Eureka
Sam S. Mitchell, Board of Supervisors, Eureka
W. F. Landis, Board of Supervisors, Crannell
Guy Charles Kulstad, Director of Public Works, Humboldt County

LOCATION OF PROJECT AND TRIBUTARY AREA

8. LOCATION OF THE PROJECT

The Redwood Creek Flood Control Project is located along the lower reaches of Redwood Creek near Orick, Humboldt County, California. The creek discharges into the Pacific Ocean approximately 50 miles south of the Oregon-California border. The basin is an elongated area of approximately 283 square miles. It extends about 56 miles from the northwest to the southeast and has a maximum width of about 7 miles. The largest tributary to Redwood Creek is Prairie Creek which drains the northern part of the watershed and joins the main stream about 3.5 miles above its mouth. Prairie Creek drains an area of about 40 square miles, extending approximately 12 miles north of the junction of the two streams. The other tributaries are short steep-gradient creeks which extend to the main stream from each side throughout its length. The area protected from floods at the completion of the project will be the lower 3.5 miles of Redwood Creek and the town of Orick.

PROJECT PLAN

9. GENERAL

The proposed plan for control of floods along the lower part of Redwood Creek provides for channel improvement, with levees on both sides for a distance of 3.4 miles in the vicinity of Orick. The project is designed to discharge the standard project flood with a minimum freeboard of 3 feet. The improvements will consist of channel enlargement, earth levees with service roadways on top, riprap slope protection along the levee and sides of the channel and other features pertinent to a channel improvement project. The work will extend from above the mouth of Prairie Creek almost to the ocean. Local geologic and soil conditions and availability of constrution materials are favorable for the type of work proposed herein. Facilities for removal of local runoff from behind the levee system will consist of gated culverts through the levee and gravity systems composed of open channels and closed conduits.

Re-alignment of the channel near the mouth of Redwood Creek will provide for a more direct and effective flow to the Pacific Ocean. The existing sand bar at the mouth will not be removed as part of the construction since it is anticipated that stream velocities will effectively scour this bar out prior to occurrence of peak floodflows, even though it will be filled in each year during low flows. The improved channel will have a bottom width 250 feet throughout the entire length.

DEPARTURES FROM PROJECT DOCUMENT

10. GENERAL

The plan proposed in this design memorandum is substantially the same as the project document plan. Some changes are required as a result of (1) comments from the Office, Chief of Engineers during review of the survey report, (2) detailed hydraulic design, and (3) foundation and soils analyses. The following variations may be noted:

a. Channel and levee extensions. Right bank levee and riprap have been extended upstream, because raising U. S. Highway 101 as called for in the project document would cost more ($160,000) than extending the levee ($60,000). The termination of the downstream end of the project is extended to within 700 feet of the mouth of Redwood Creek to provide for better flushing of silt during low flow.

b. Control Sill. A control sill has been added at the outlet end of the channel to stabilize the end of the levees and to prevent degradation of the channel bottom.

c. Seepage control. A system of relief wells has been placed adjacent to the landward toe of the levee, in critical areas, discharging the anticapted seepage into the collector drains that also serves to collect the interior drainage. This modification in design eliminates the need for the 5 foot toe drain indicated in the project document.

d. Interior drainage. The pumping plant has been deleted and a gravity system substituted. Emergency slide gates have been placed on the river side of all drainage system outlets.

e. Bridge. The project document does not indicate any work required on the U.S. 101 bridge. This design memorandum calls for modification of the bridge piers to provide for more efficient hydraulic conditions.

HYDROLOGY

11. GENERAL

Basic hydrologic data and procedures pertaining to this Design Memorandum are given in Appendix B.

These data include events subsequent to the preparation of the project document. After consideration of the effect of the additional hydrological data, it was found that no departures from the criteria presented in the project document are required.

12. DESIGN VALUES

a. Channel. The project is designed for the standard project flood of 77,000 cubic feet per second.

b. Interior drainage. The hydrologic criteria were based on assumptions of:

(1) Runoff from the 100-year intensity short duration rainfall when the creek is at low stages,

(2) Runoff from rainfall coinciding with the 100-year flood hydrograph in Redwood Creek. A detailed analysis is given in Appendix B.

c. Friction factors. The following coefficients of roughness in the Manning Formula were used in backwater analysis:

(1) Unlined bottom with riprap side slopes - a composite "n" equals 0.032,

(2) Existing natural sections upstream from the excavated channel - "n" equals 0.060.

GEOLOGY

13. AREAL GEOLOGY

The rugged northwest-trending mountains and V-shaped canyons that characterize the Redwood Creek drainage basin are completely covered with evergreen forests. The regional alignment of these topographical features is controlled by the geologic structure of the underlying rocks, which consists of a system of nearly-parallel major folds and faults. Redwood Creek flows northwesterly along one of these faults throughout most of its uppermost water course, then turns abruptly westward, cutting through the mountains and across the regional trend, and flows across a fairly wide flat-floored valley in the last four miles of its journey to the Pacific Ocean. This fault, known as the Grogan Fault, separates the Jurassic-Cretaceous marine sedimentary rocks of the Franciscan Formation on the east from the older metasedimentary rocks of the Kerr Ranch Schist formation on the west. The valley floor in the project area is an alluvial plain that slopes gently seaward. Most of this plain, at least the lower half, represents the exposed upper surface of the delta constructed by Redwood Creek.

The predominate coarseness of the materials indicates that the streams are vigorously down-cutting their canyons and are rapidly washing the erosion products into the valley and delta area. Soft clay was encountered in one boring, which suggests that the fluvial sediments at the lower end of the valley may interfinger with marine deposits. Although the exploratory borings in the valley only extend to a maximum depth of 100 feet, the local geology indicates that the valley fill materials may be over 200 feet thick. Results from laboratory tests on these materials show that they will provide an adequate foundation for the proposed structures.

14. SEISMIC ACTIVITY

No earthquake epicenters have been located in the project area during historic times, and there are no known active faults in the immediate vicinity. However, the area off Cape Mendocino, about 40 to 70 miles southwest of Redwood Creek Valley, is one of the most seismically active areas in California. Numerous strong earthquakes have originated in this region and some of them have generated sufficient energy to radiate into the Orick area and cause slight damage. Records show that this activity is continuing; therefore, an earthquake acceleration factor of 0.1 gravity will be incorporated in the design of the engineering structures.

SOILS

15. FOUNDATION CONDITIONS

Field explorations indicate that the subsurface materials are predominately fine silty sand and sandy silt, with some sandy clays and silt lenses overlying pervious sand and gravel. The materials above the pervious sand and gravel is an impervious blanket and the thickness ranges from 2 to 25 feet on the right bank and from 2 to 19 feet on the left bank of the creek.

16. LEVEE CONSTRUCTION

Embankment materials for levee construction will be obtained from the required channel excavation. The estimates indicate that there will be sufficient amounts of sand and gravel and fine grained materials. The excess material will be wasted in the island areas between the abandoned channel and the project channel near the downstream end of the project.

17. SLOPE PROTECTION

Riprap slope protection will be provided for the levee and the channel slopes in accordance with EM 110-2-3901 "Riprap Channel Protection." The thickness of the riprap layer and filter blanket will be increased by 50 percent when placed under water. A layer of streambed sand and gravel will be required under all riprap placed on fine-grained materials exposed in the channel slopes.

OTHER PLANS INVESTIGATED

18. GENERAL

In the studies and investigations made in connection with this Design Memorandum for developing the most satisfactory solutions for the flood problem on Redwood Creek, two plans were considered. One plan was essentially that indicated in the project document. The second plan, as adopted in this Design Memorandum, calls for the levees to be extended about 2,000 feet downstream from the point of termination in the project document plan. The adopted plan will provide more comprehensive flood control for the valley, and the indicated high velocities will keep the lower reach of the channel clear of the bulk of debris and silt.

DESCRIPTION OF PROPOSED STRUCTURES AND IMPROVEMENTS

19. GENERAL

The proposed plan of improvement consists of 3.4 miles of trapezoidal channel improvements; construction of levees along both banks, averaging 10 feet in height, with side slopes of 1 on 3 on the channel side and 1 on 2-1/2 on the land side, and with 12-foot wide graveled surface service roads on top of the levees; modification of the upstream side of the center bridge piers at Orick by the addition of wing walls that are set in line with the stream flow; construction of an interior drainage system on each side of the channel that is comprised of reinforced concrete pipe and open ditches; and installation of individual culverts extending through the levees at the upstream portion of the project in order to drain isolated areas. The completed channel will have sufficient capacity to contain 77,000 cubic feet per second, the peak flow for the standard project flood, with a minimum freeboard of three feet. Both the design and the construction methods have been coordinated with conservation agencies in order to minimize stream pollution during construction which might adversely affect fish migrating to spawning beds. Details of the improvements are shown on Plates 2 through 13, and are described in the following paragraphs.

CHANNEL IMPROVEMENT

20. GENERAL

The alignment of the improved channel follows the existing alignment of Redwood Creek, with the exception of the first 2,000 feet at the downstream end, where it is realigned to eliminate the last bend and obtain a more direct route to the Pacific Ocean. The channel alignment is shown on Plates 2 through 9.

The cross-section of the improved channel is trapezoidal, with a bottom width of 250 feet and with riprapped side slopes of one vertical on three horizontal. Typical sections are shown on Plate 12. The channel bottom will be graded its full width from Station 15+50, the downstream end of the project, to Station 182+10, a point 800 feet upstream from the confluence of Prairie and Redwood Creeks. No channel excavation occurs upstream of this area. A limited amount of grading will be done at the mouth of Prairie Creek to permit a better entry to the realigned and re-shaped Redwood Creek. A control sill will be constructed at the downstream end of the project to maintain the design invert elevation and to prevent degradation of the channel under flood flows. Stone used in the sill construction will have a maximum weight of 5 tons and will average 2 tons. The slope of the sill at the downstream face is 1 on 3, and at the upstream face is 1 on 2. The downstream face of the sill will terminate at an elevation 15 feet below the design channel invert, and the upstream face will terminate at an elevation varying from 8 to 10 feet below the design channel invert. Sill details are shown on Plate 11. Levees, with an impervious core, will be constructed on each side of the channel, beginning at the downstream end of the project. The levee on the right bank will terminate against the Redwood Highway (U. S. 101) at Station 171+75. No levee will be provided on the right bank of Redwood Creek between the confluence of the Redwood and Prairie Creeks and the upstream end of the project. In this area the existing channel is considerably wider than the proposed channel, and the high hillside will confine the flood waters to the channel. The levee on the left bank will terminate at Station 192+90 where it is tied into a hill. On the land side of the left bank levee, between Station 22+00 and Station 192+90, it will be necessary to fill depressions within the construction right-of-way with excavated material to the level of the surrounding ground to eliminate ponding. Similar work will occur along the right bank between Station 164+00 and Station 171+50. Access ramps, leading to a service road on top of each levee, will be provided at four points along the right bank, and at two points along the left bank; the ramps will terminate at public roads. The service roads and the access ramps will be 12 feet wide; the access ramps will have a maximum grade of 15 percent. The profile of the top of the levees parallels the centerline water surface profile, except at the outside of curves where the levees are raised to accommodate the super-elevation of the water surface. Riprap protection will be provided on the channel side slopes throughout the entire length of each levee. The thickness of the riprap varies from 12 inches to 24 inches, with the toe of the riprap extending from 7 to 10 feet below the channel invert. A discussion of the riprap and the construction of the levees is contained in Appendix A. Existing riprap located on the left bank, between Stations 78+00 and 93+00 and between Stations 123+00 and 139+00, will be salvaged where practicable. Seepage under the levees, occurring at several reaches of the project during the high water stage, will be controlled by the installation of relief wells in a 12-foot wide berm located on the land side of the levees.

Seepage from the relief wells will be conducted to a pipe or to an open ditch that collects local runoff.

BRIDGE PIER EXTENSION

21. GENERAL

Reinforced concrete pier extensions, constructed on piles, will be provided on the upstream side of the two existing center piers of the State Highway bridge at Station 127+50. The axes of the extensions will be orientated to parallel the direction of flow. Details of the pier extensions are shown on Plate 11. The pier extensions will be designed for two conditions: submerged and channel empty conditions. For the submerged condition the lateral loading will be the force of the current acting at an assumed angle of 15 degrees with the centerline of the piers, and flowing with a velocity of 15 feet per second. This assumption results in a design load of 800 pounds per lineal foot or pier. Passive resistance of the soil against the sides of the piers will be ignored, due to possible scouring. Seismic load of 0.1g does not govern. For the channel empty condition only the dead load acting on the supporting piles will be considered. This condition results in a design load of 35 tons per pile. Steel H-piles will be used in order to drive through the streambed gravels. The design unit stresses for reinforced concrete will be in accordance with EM 1110-1-2101, "Working Stresses for Structural Design" and the ACI Building Code 318-63.

Allowable unit stresses for reinforced concrete will be as follows:

<u>Concrete</u>	f'_c	=	3,000 pounds per square inch
	f_c	=	1,050 pounds per square inch
<u>Steel</u>	f_s	=	20,000 pounds per square inch (Intermediate Grade)

INTERIOR DRAINAGE SYSTEM

22. GENERAL

The interior drainage is designed in accordance with EM 1120-1410 to prevent ponding in the vicinity of Orick during the channel high water stage, and to permit the local runoff to flow by gravity to the Pacific Ocean, as shown on Plates 1 through 12 and discussed in detail in Appendix B. Near the upstream end of the project a limited number of culverts will be installed, extending through the levee. These culverts will drain the Redwood Highway and the area adjacent to the levees. Through the town of Orick, the drain will consist of reinforced concrete pipe. Downstream of the town, the pipe empties into an open ditch which carries the local runoff to an existing slough and creek that leads to the ocean.

23. INTERIOR DRAINAGE SYSTEM - RIGHT SIDE

At the upstream end of the project, between Station 192+90 and Prairie Creek, no drainage structures will be provided. Local runoff reaches either Prairie Creek or Redwood Creek through existing ditches and swales. From Prairie Creek (Station 175+00) to Station 159+00, it is necessary to extend three culverts through the levee in order to drain the nearby Redwood Highway and vicinity. The culverts occur at Stations 170+90, 170+00 and 166+75. The extensions under the levee will consist of reinforced concrete pipe. Manholes will be provided at the points where the existing culverts are to be extended so that the extensions may run normal to the levee. The culvert installations will consist of reinforced concrete pipe and reinforced concrete inlet, outlet and gatewell structures. The gatewells will be on the channel side of the levee and will be complete with slide gates. Flapgates will be provided at each outlet. From Station 159+00 to Station 118+50, reinforced concrete pipe will be installed near the interior toe of the levee. Catch basins will be constructed to collect the local runoff, and manholes will be constructed where a change in pipe size occurs and where necessary for proper maintenance. Generally, catch basins or manholes occur at intervals of 200 feet to 400 feet. The pipe will be laid parallel to the channel alignment; a 24-inch diameter pipe is the smallest size to be installed. The relief wells, installed between the pipe and the toe of the levee, will discharge directly into the pipe. A reinforced concrete endwall including the necessary riprap, will be constructed at Station 118+50, the downstream terminus of the pipe. From Station 118+50 to Station 43+00, an open ditch will be provided, parallel to the levee, to transport the local drainage carried by the reinforced concrete pipe and runoff from the adjacent land. The ditch will have a bottom width of seven (7) feet and side slopes of 1 on 3. Relief wells will be installed in the 12-foot berm located between the drainage ditch and the toe of the levee. The relief wells will discharge directly into the drainage ditch. A reinforced concrete box culvert will be provided at Station 57+30 where an access road leading to the top of the levee crosses the drainage ditch. Downstream from Station 43+00, the drainage ditch will branch off to the north to discharge into an existing slough. A reinforced concrete box culvert will be provided near the downstream terminus of the ditch where a private road crosses it.

24. INTERIOR DRAINAGE SYSTEM - LEFT SIDE

Between Station 192+90, the upstream end of the project, and Station 123+00, it is necessary to provide for only one culvert, to be installed through the levee at Station 161+60. The culvert installation consists of 36-inch reinforced concrete pipe, and reinforced concrete inlet, outlet and gatewell structures. The gatewell will be located on the channel side of the levee and will be complete with slide gate. A flap gate will be provided at the outlet. From Station 123+00 to Station 85+00, reinforced concrete pipe will be provided to collect the local runoff.

Manholes and catch basins will be provided in the same manner as described for the right bank. Relief wells are not required between Station 192+90 and Station 85+00. Riprap proteotion and a reinforced concrete endwall will be provided for the outlet of the pipe at Station 85+00. From Station 85+00 to Station 76+00, an open ditch will be constructed for the local runoff, and for the waters collected by the pipe system upstream. The ditch will have a bottom width of 4 feet and side slopes of 1 on 2.5. Relief wells, located on the 12-foot berm provided between the top of the ditch and the toe of the levee, will discharge into the ditch. From Station 65+00 to Station 75+00, a V-ditch with side slopes of 1 on 2.5 will be provided to drain the local runoff back to Station 76+00. Relief wells will also be provided in this reach, located on the berm provided between the ditch and the toe of the levee, and discharging into the ditch. At Station 76+00, the existing drainage channel will be deepened for a distance of 300 feet to conduct the accumulated drainage to Strawberry Creek and thence to the ocean. The concrete drainage structures will conform to EM 1110-2-2502, "Retaining Walls." The following design data will be used:

Concrete:	f'_c	=	3,000 pounds per square inch
	f_c	=	1,050 pounds per square inch
Reinforcing Bars:	f_s	=	20,000 pounds per square inch (Intermediate Grade)

Soils Data:

General:

Weight of Water = 62 pounds per cubic foot
Weight of moist soil = 118 pounds per cubic foot
Weight of saturated soil = 125 pounds per cubic foot
Buoyed weight of soil = 63 pounds per cubic foot
Bearing Value: 1,500 pounds per square foot (dead load only)
2,250 pounds per square foot (dead plus live load)
Angle of internal friction = 31.0 degrees

Cohesion = 0

Storm Drain Headwalls:

Active earth pressure coefficient K_a = 0.77
Slope of backfill i = 18.5 degrees
Point of Application of resultant pressure = 0.38 h
(where h = height of wall)
Inclination angle of resultant pressure = 2/3 ϕ = 19 degrees

Gatewells:

At-rest pressure coefficient K_r = 0.8
Wall Friction angle = 0 degrees

Inlet and Outlet Structures:

At-rest pressure coefficent K_r = 0.99
Slope of backfill (inlet) i = 21 degrees-50'
Slope of backfill (outlet) i = 18 degrees-30'
Wall Friction angle = 0 degrees
Point of application of resultant pressure = 0.38 h
(where h = height of wall)

Deck Slab Loading (Gatewells):

Dead load = 200 pounds per square foot live load + lift thrust load of the gate.

25. DESIGN ANALYSIS

The three components of the drainage structure (inlet, outlet and gatewell works), at Stations 161+60 (L), 166+75 (R), 170+00 (R) and 170+90 (R), will be designed as rigid structures, subject to external at-rest pressure. The gatewell will also be subject to hydrostatic pressure. The governing condition for the gatewell occurs when it is empty and the levee is subjected to hydrostatic head because of high water in the channel. This condition will be used to determine stability and to prevent floatation. Moist earth is assumed above the water level. The base slab will be extended beyond the outer face of the walls to engage the mass of surrounding earth. The inlet and outlet structures will be designed for at-rest moist earth pressures with the channel empty. The at-rest pressure coefficient, K_r will take into account the sloping backfill which varies for these structures. A review of the wall design of the structures will be made to insure that the surcharge pressures due to construction equipment and service road traffic will not overload the structure beyond allowable limits. The construction surcharge will be taken as that caused by normal compaction equipment operating within two (2) feet of the wall to a height two (2) feet below the top and four (4) feet from the wall for the top two (2) feet. The weight of two (2) feet of earth will be used as the equivalent of the road traffic surcharge loading. Concrete headwalls for the storm drain outlets at Stations 118+50 (R) and 85+00 (L), will be designed as L-type cantilever retaining walls using active earth pressures. Weepholes will be provided in the endwalls, and a one-foot layer of gravel extending for the full height of the wall will be provided for drainage of the backfill. Design will be based on moist earth conditions of the backfill with the channel empty. Temporary construction loading will be checked, as previously described. The concrete box culverts will be checked for an alternate loading due to vertical loads from overlying soil plus active earth pressure acting against the sides. The structures will also be designed for surcharge pressures due to construction equipment and maintenance service road traffic. The soils constants and unit design stresses will be the same as previously described.

ACCESS ROADS

26. GENERAL

During construction, existing county roads will be used for access to the project site. These roads will also be available for access and permanent use upon completion of construction. In some cases site access can be gained directly from the turnoffs on Highway U. S. 101. Access from the public roads to the levee will be made by ramps as indicated on Plates 2 through 9. In accordance with Section 207 (a), Public Law 86-645, whenever public roads are utilized for access during construction and require improvement, reconstruction or maintenance, the accomplishment of such work will be carried out as required, as a federal cost of the project.

SOURCES OF CONSTRUCTION MATERIALS

27. EMBANKMENT

Embankment materials for construction of levees will be obtained from the required channel excavation, where ample quantities of suitable material are available.

28. RIPRAP

a. Riprap can be obtained from three sources within 22 miles of the project, all of which have been tested in the laboratory and approved by the District. They are:

(1) Larry Crivelli, Crivelli's Quarry, Klamath, California
(2) Simpson Lumber Co., Klamath Quarry, Klamath, California
(3) Mercer-Frazer Construction Company, Trinidad Quarry, Trinidad, California

b. Additional field reconnaissance may locate other potential rock sources nearer the project.

29. SAND AND GRAVEL

Sand and gravel will be obtained from the required excavation.

30. CONCRETE AGGREGATE

Concrete aggregates are available in areas adjacent to Redwood Creek but not in the immediate vicinity. Sources of concrete aggregates are shown in "Test Data, Concrete Aggregates in Continental United States," Technical Memorandum No. 6-370, compiled by Waterways Experiment

Station, Volume 1, Area 1, Latitude 40° North and Longitude 124° West. All of the sources shown have been approved for use on Corps of Engineers projects.

REAL ESTATE REQUIREMENTS

31. GENERAL

Local interest, as required by authorizing legislation, will acquire project rights-of-way, areas needed for temporary use during construction of the improvements and land required for disposal areas. The Humboldt County Department of Public Works has assumed the responsibility of representing local interest for this project. The Department will acquire an interest in land for the project, as follows: (a) land occupied by the channel and appurtenant structures would be acquired in fee title or by permanent easement; (b) land used for temporary construction would be acquired by permits or leases; and, (c) land used for disposal areas will be acquired by permits, leases or fee title. Local interest will make no rights-of-way conveyance to the United States. However, when local interests have acquired appropriate interest in the necessary rights-of-way, the Government will be formally authorized to enter upon the rights-of-way for prosecution of construction and future project inspection. The Board of Supervisors of Humboldt County has assumed the responsibility of providing all the rights-of-way, land and easements for construction of the project works without cost to the United States.

RELOCATIONS

32. GENERAL

The right-of-way required for the channel improvements will encroach on several existing roads, buildings and utility poles. The roads and poles will be relocated as noted below.

33. ROADS

a. Huffords Road - Right Bank

The portion of this road lying between Stations 45+50 and 57+30 will be relocated to the north side of the interior drainage ditch. Between Stations 114+00 and 124+00, it will be relocated adjacent to the permanent right-of way line.

b. Orick River Road - Right Bank

From Station 144+00 to Station 151+00, a portion of this road will be relocated adjacent to the permanent right-of-way line.

c. Drydens Road - Left Bank

Between Stations 127+00 and 143+00, and between Stations 159+00 and 160+50, this road will be relocated adjacent to the permanent right-of-way line.

34. UTILITIES

a. Between Station 45+50 and Station 57+10 on the right bank of Redwood Creek, Pacific Gas and Electric Company and the West Coast Telephone Company have five joint-use poles which parallel Huffords Road which must be relocated adjacent to the permanent right-of-way.

b. Station 83+70, Pacific Gas and Electric Company has a 60 kilovolt line crossing the channel. Two poles are presently located where the levee will be constructed and will be relocated adjacent to the permanent right-of-way.

c. Between Station 114+25 and Station 123+30 on the right bank, five joint-use poles carrying 12 kilovolts of power, telephone lines and a television cable must be relocated adjacent to the permanent right-of-way.

d. At Station 127+20, joint-use poles carry telephone lines and a television cable across the channel parallel to the Redwood Highway. One pole on the left bank will be relocated since it interferes with the interior drainage pipe. The remaining pole, on the right bank, is on the permanent right-of-way line and can remain in its present location.

e. At Station 127+95 a 12 kilovolt line crosses the channel. Two poles will require relocation to avoid the levees.

f. Between Station 127+35 and Station 133+10 on the left bank joint-use poles carrying 12 kilovolt power and telephone lines must be relocated adjacent to the permanent right-of-way.

g. At Station 149+55 on the right bank one telephone pole will be relocated to avoid the levee.

DIVERSION AND CARE OF WATER

35. GENERAL

Continuing cooperation with the U.S. Fish and Wildlife Service and the State of California, Department of Fish and Game was maintained throughout the preparation of this general design memorandum. Fish mitigation measures agreed upon include the following:

a. Specifications will provide for preservation of the existing low flow channel and resting pools both during construction and at completion of the project.

b. In sectors where the existing streambed lies below channel design grade the channel bottom will not be disturbed.

c. In areas where the streambed requires grading, resting pools about one tenth mile apart will be constructed having a minimum depth of four feet and one vertical on five horizontal side slopes. They will be connected by a low flow channel one foot deep and two to three feet wide.

COST ESTIMATE

36. ESTIMATES

The unit prices shown for construction features in the current project estimates are based on September 1965 price levels. In accordance with South Pacific Division, Design Memorandum Procedures, Regulation 1110-2-3, paragraph 6b., dated 14 October 1965, the bases for the preparation of this Design Memorandum Estimate is as follows:

a. Items No. 1 through 6, 13 and 14a through 14d were developed in accordance with instruction cited in EM 1110-2-1301, Chapter 1, paragraph 1-10 and 1-34. Unit prices for the above items of work are current unit prices bid for similar items of work within the local geographic area.

b. Items No. 7 and 12 are based on an in-place quotation from "Mercer-Fraser Co. Inc.," Eureka, California, with the stone being procured and produced from their "Trinidad Quarry," located approximately twenty-one (21) miles from the project site.

c. The component parts of Items No. 8, 9, 11, 14e and 14f have been developed as described in paragraph 36a above and compiled to arrive at a lump sum or a weighted average lineal-foot unit cost.

d. Item No. 10 was developed based on a quoted material cost plus a preliminary developed plant and labor item.

Item No.	Description	Quantity	Unit	Unit Price	Amount
	a. FEDERAL COSTS-CHANNEL				
1	Diversion and Control of Water	1	Job	L.S.	$ 18,000
2	Clearing and Grubbing	235	Acre	$500.00	117,500
3	Embankment	--	--	--	--
	a. Impervious Core	388,900	c.y.	0.45	175,000
	b. Sand and Gravel	388,600	c.y.	0.40	155,400
4	Excavation, unclassified	1,244,900	c.y.	0.75	933,700
5	Stripping	101,000	c.y.	0.35	35,400
6	Disposal	467,400	c.y.	0.30	140,200
7	Riprap	269,600	Ton	7.00	1,887,200
8	Drainage Structures	--	--	--	--
	a. Station 161+60 (L)	1	Job	L.S.	8,900
	b. Station 166+75 (R)	1	Job	L.S.	6,000
	c. Station 170+00 (R)	1	Job	L.S.	5,500
	d. Station 170+90 (R)	1	Job	L.S.	3,900
9	Pier Extensions	1	Job	L.S.	59,200
10	Steel Piles	1,400	L.F.	7.00	9,800
11	Relief Wells	6,600	L.F.	26.80	176,700
12	Control Sill-Stone	23,200	Ton	9.50	220,400
13	Low Flow Channel and Resting Pools	3,100	c.y.	2.00	6,200
14	INTERIOR DRAINAGE AND SEEPAGE CONTROL				
	a. Excavation, Ditch	114,200	c.y.	0.90	102,800
	b. Inlets, Drainage	18	Ea.	300.00	5,400
	c. Manholes	9	Ea.	400.00	3,600
	d. Reinforced Concrete Pipe	--	--	--	--
	(1) 24 inch	1,100	L.F.	16.00	17,600
	(2) 30 inch	450	L.F.	17.00	7,700
	(3) 36 inch	1,800	L.F.	18.00	32,400
	(4) 42 inch	1,210	L.F.	20.00	24,200
	(5) 48 inch	3,180	L.F.	22.00	70,000

Item No.	Description	Quantity	Unit	Unit Price	Amount
	e. Box Culvert, Concrete	--	--	--	--
	(1) Station 34+84	1	Job	L.S.	9,500
	(2) Station 57+30	1	Job	L.S.	12,300
	f. Drainage Structure				
	(1) Endwall at Station 85+00 (L)	1	Job	L.S.	1,100
	(2) Endwall at Station 118+00 (R)	1	Job	L.S.	1,100
	Subtotal				4,246,700
	Contingencies (15% ±)				653,300
	Subtotal				$4,900,000
	Engineering, Design				300,000
	Supervision and Administration				330,000
	Total Federal Cost				$5,530,000
b.	NON-FEDERAL COST				
	Lands and Damages(including acquisition cost)				365,000
	Utilities Relocation				30,000
	Roads Relocation				109,000
	Engineering and Design				9,000
	Supervision and Administation				7,000
	Total, Non-Federal Cost				$ 520,000
	TOTAL, PROJECT COST				$ 6,050,000

37. SUMMARY OF COST INCREASES

a. A comparison of costs in the project document with the approved PB-3 cost and the current estimate presented in this memorandum follows:

		Estimated Costs (in thousands of dollars)			
No.	Item	July 1960 price levels (project document)	PB-3 approved 1 Jul 65	Current	Difference between approved and current
	FEDERAL COSTS				
9.	Channels	2,130.0	2,560.0	4,900.0	+2,340.0
13.	Pumping plant	50.0	60.0	0	- 60.0
30.	Engineering and Design	190.0	225.0	300.0	+ 75.0
31.	Supervision and Administration	210.0	255.0	330.0	+ 75.0
	Total Federal First Cost	2,580.0	3,100.0	5,530.0	2,430.0
	NON-FEDERAL COSTS				
	Lands and damages	160.0	190.0	365.0	+ 175.0
	Relocations:	110.0	130.0	155.0	+ 25
	Buildings			(0)	
	Utilities			(30.0)	
	Roads			(125.0)	
	Total non-Federal cost	270.0	320.0	520.0	+ 200.0
	Total project costs	2,850.0*	3,420.0 1/	6,050.0	2,630.0

*Excludes $50,000 pre-authorization studies

1/The increase in costs between the project document and the PB-3 are due to price escalation.

b. The increase in the estimated Federal cost for the project is the result of several factors stemming from the more detailed designs, more detailed topography and more extensive subsurface explorations. The principal items making up this increase are: (1) the greater quantity and estimated higher unit costs for riprap slope protection, (2) inclusion of an erosion control sill at the lower end, (3) addition of relief wells and seepage control, (4) extension of the project limits approximately 2,000 feet downstream, (5) extension of the right levee approximately 600 feet upstream and (6) bridge pier extension. The need for the modifications is given under Departures from Project Document, in other sections and in the appendices of this design memorandum. Of the total $2,430,000 cost increase, the item of riprap accounts for approximately $700,000 and the downstream project extension, for approximately $500,000. A summary of the cost increases including the aforementioned six items is given below, with details of their deviation being contained in Attachment I to this design memorandum:

rence
approved
ent

SUMMARY

Item	Cost Increase
1. Original Reach	
a. Riprap	$ 700,000
b. Levees	- 130,000
c. Channels	394,000
d. Drainage and Seepage Control	466,000
e. Bridge Pier Extension	79,000
Sub-Total	$1,509,000
2. Downstream Extension	458,000
3. Upstream Extension	41,000
4. Erosion Control Sill	254,000
Total Increase	$2,262,000

c. Attachment I at the end of this memorandum itemizes major increases in cost between the Project Document and this Design Memorandum. The pumping plant considered in the project document was deleted as being impracticable based on the inclusion of the seepage system and its joint use of the interior gravity drainage disposal system.

d. The increase in Engineering and Design cost is due to increased scope of the project explained in sub-paragraph a, cost of re-survey necessitated by the flood of December 1964 and extensive sub-surface explorations required due to the nature of materials encountered.

e. Supervision and Administration cost is increased based on current overhead rates and increased scope of project.

f. The increase in the cost of lands and damages is due to the increased scope of the project explained in sub-paragraph a.

g. The increase in the cost of relocations is due to refined detailed appraisals.

SCHEDULES FOR DESIGN AND CONSTRUCTION

38. SCHEDULE FOR DESIGN

No additional design memoranda are contemplated; plans and specifications for the channel improvement are scheduled for completion in February 1966.

39. SCHEDULE FOR CONSTRUCTION

Construction of the project will be accomplished in three seasons by a single contract scheduled to start by April 1966. Work will consist of channel clearing, channel excavation, embankment construction and riprap placements. The work for this first construction season will extend from the upper end of the project to the Highway 101 bridge. The second construction season will be from May 1967 to November 1967, and the work will extend about one mile below Highway 101 bridge. The third construction season, from May 1968 to November 1968 will result in completion of construction for the entire project. During the seasonal delays from November 1966 to May 1967 and November 1967 to May 1968, the completed channel will be unobstructed for all floodflows, and the contractor will not be required to work.

40. FUNDS REQUIRED

Prior to construction, funds for Fiscal Years 1964 and 1965 totaled $135,000. It is anticipated that orderly prosecution of construction as discussed above will require funds by Fiscal Years as follows:

Fiscal Year	Federal Funds
1966	400,000
1967	1,340,000
1968	2,500,000
1969	1,155,000

OPERATION AND MAINTENANCE

41. GENERAL

In accordance with the authorizing legislation, local interests will be required to maintain and operate the completed flood control project in accordance with the regulations prescribed by the Secretary of the Army. Total average annual cost of the project operation, ordinary maintenance and major replacements is estimated to be $19,000.

The maintenance cost estimate is based on experience with similar projects in this District and on an office memorandum of the Sacramento District, dated 1 May 1961, subject, "Basis of Cost Estimates for Civil Works," updated to reflect the December 1965 cost index. The criteria used are as follows:

a. Levees - $400 plus $10 per foot of height per mile of levee

b. Channels - $100 per mile

c. Riprap - $30 per foot of height per mile

d. Interior Drainage - 1% of first cost

e. Special allowance for cost of silt removal to keep channel mouth open for low flow

42. OPERATIONS

The Redwood Creek Flood Control Project has been designed to require only moderate operations by local interests. It is estimated that necessary operations, including inspection of flapgates, will average about a $1,000 a year.

43. MAINTENANCE

It is anticipated that yearly maintenance will be required on Redwood Creek. Minor displacement of riprap, minor restoration of levee slopes during early years of the project, small siltation problems in the lower reaches of the project, clearing of flapgates, maintenance and minor repair of access roads, and restoring effectiveness of the relief wells are anticipated. Average annual maintenance will cost an estimated $18,000

DAMAGES

44. GENERAL

The current estimate of damages is based on a review of: (a) consideration of price level increases; (b) consideration of the effects of the December 1964 flood; and, (c) extension of the plan of improvement.

A comparison of the historical damages prepared for the Survey Report (1961) to that determined for this design memorandum follows:

	January 1950	January 1953	December 1955	December 1964
Agricultural	$ 68,000	$106,900	$ 51,600	$ 292,000
Residential	17,000	191,500	68,700	142,000
Commercial	26,000	296,200	215,200	407,000
Industrial	1,000	115,000	45,400	153,000
Public utilities	20,000	231,400	187,100	25,000
Public facilities	-	-	-	20,000
Roads and bridges	-	-	-	-
	$132,000	$941,000	$568,000	$1,110,000

HISTORICAL FLOOD DAMAGE

Historical flood damages as presented in Survey Report under April 1960 price levels and development.

Type	1950	1953	1955	Standard Project Flood
Agricultural	$ 82,000	$ 115,000	$ 56,000	$ 155,000
Residential	24,000	245,000	81,000	344,000
Commercial	41,000	401,000	266,000	568,000
Industrial	1,000	156,000	231,000	206,000
Public facilities	32,000	313,000	56,000	447,000
	$180,000	$1,230,000	$690,000	$1,720,000

45. FLOOD DAMAGES UNDER PRESENT CONDITIONS

In order to present flood damages under 1965 price levels, the historical flood data was brought to 1965 prices by application of standard price indices. Recurrence of recent floods would cause damages within project limits under 1965 prices as shown in the following tabulation. In addition, the estimated damages for a flood of standard project magnitude are tabulated.

HISTORIC FLOOD DAMAGES
(1965 Price Level and Development)

Type	1950	1953	1955	1964	Standard Project Flood
Agricultural	$ 83,000	$ 116,000	$ 57,000	$ 292,000	$ 307,000
Residential	26,000	267,000	88,000	142,000	374,000
Commercial	46,000	450,000	298,000	408,000	484,000
Industrial	1,000	175,000	259,000	153,000	311,000
Public utilities	-	-	-	25,000	58,000
Public facilities	36,000	352,000	63,000	20,000	480,000
Roads and bridges	-	-	-	70,000	216,000
	$192,000	$1,362,000	$765,000	$1,110,000	$2,230,000

46. AVERAGE ANNUAL DAMAGES

Average annual damages were computed by standard damage-frequency analysis. Total average annual damage within the project area for the Survey Report were $188,000 under 1960 prices. For this Design Memorandum, average annual damages under 1965 prices and revision of discharge-damage curve to include the December 1964 flood, average annual damages amount to $246,000.

47. FUTURE AVERAGE ANNUAL DAMAGES

Existing average annual damages must be increased to reflect damage under future development, based on methodology developed in Survey Report. Under 1965 prices and 3-1/8 percent interest rate average annual damages amount $352,000, ($246,000 x 1.43) for 50-year project life.

BENEFITS

48. GENERAL

The current estimate of project benefits is based on a review of: (a) flood plain values contained in the project document giving consideration to price level increase; and (b) local developments occurring subsequent to the project document. A comparison of the estimated average annual benefits prepared for project document to that determined for this design memorandum is as follows:

ESTIMATED PROJECT DOCUMENT BENEFITS - 1962
(Average Annual)

1.	Prevention of flood damage	$222,000
2.	Higher land utilization	6,000
	Total, estimated average annual benefits	$228,000

ESTIMATED DESIGN MEMORANDUM BENEFITS - 1965
(Average Annual)

1.	Prevention of flood damage	$343,000
2.	Higher land utilization	7,000
	Total, estimated average annual benefits	$350,000

49. BENEFITS, FROM FLOOD-DAMAGE REDUCTION

Benefits from flood-damage reduction creditable to the proposed improvements, with protection against the standard-project flood of 77,000 c.f.s. are the difference in damages with and without the project.

Residual damages with the project would accrue to agricultural lands which lie downstream from the improvements or would be affected by backwater around the open-ended levees. Residual damages under these conditions are estimated to be $6,000 annually under 1965 prices. Flood-control benefits are estimated at $240,000 ($246,000 - 6,000) under existing conditions. Under future conditions residual damages for 50-year life would be $9,000. Average annual flood-control benefits creditable to the project are $343,000 ($352,000 - $9,000).

50. LAND ENHANCEMENT

Land enhancement benefits as developed in Survey Report have been re-estimated to reflect a 3-1/8 percent interest rate and are estimated to be $7,000.

ECONOMIC ANALYSIS

51. GENERAL

Based on an economic project life of 50 years and an interest rate of 3-1/8 percent, estimated average annual Federal and non-Federal costs are as follows:

Federal:		
First cost $5,530,000 x 0.03979		$220,000
Non-Federal:		
First cost $520,000 x 0.03979	$21,000	
Maintenance and operation cost	19,000	
Average annual non-Federal cost		40,000
Total, Average Annual Project cost		$ 260,000

A comparison of estimated benefits with estimated average annual cost indicates a benefit-cost ratio of 1.3 to 1.

RECOMMENDATIONS

52. GENERAL

It is recommended this general design memorandum be approved as a basis for preparation of contract plans and specifications and construction of authorized works on Recwood Creek, Humboldt County, California, at a currently estimated Federal cost of $5,530,000. The works to be constructed include channel excavation, levees, minor modifications of channel alignment, interior drainage system, modification of U.S. Highway 101 bridge piers and relocation of roads and utilities within the project area.

ROBERT H. ALLAN
Lt. Colonel, CE
District Engineer

n

ed

ATTACHMENT I

1. The latest cost estimate of the Redwood Creek Flood Control Project is approximately $6,000,000, twice the updated project document cost. The reasons for this cost increase as well as the justification for major design changes are explained in the Design Memorandum and in the appendices which follow. This attachment is furnished in support of the cost estimate to give a detailed comparison and accounting of major cost increases for construction details involved.

2. Items which constitute a major increase in the cost of that shown in the project document, or which were not included originally as part of the project are designated in the following tables:

TABLE 1

MAJOR COST INCREASES OF ITEMS IN ORIGINAL REACH OF PROJECT

Study	Item	Quantity	Unit	Unit Price	Amount	Contin-gencies (PD = 20% DM = 15%)	Subtotal	ENR Update to July 65 (1.20) PD Only
				RIPRAP				
Project Document	Riprap	184,000	Ton	$ 4.50	$ 828,000	$ 165,000	$ 993,000	$1,190,000
Design Memo	Riprap	234,000	Ton	7.00	1,640,000	246,000	1,890,000	1,890,000
	Difference							700,000
				INTERIOR DRAINAGE AND SEEPAGE CONTROL				
Project Document	Drainage:							
	Drainage facil.	1	Job	L.S.	17,000			
	Pumping plant	1	Job	L.S.	50,000			
	Total				67,000	13,000	80,000	96,000
Design Memo	Drainage:							
	Drain. structure	4	Job	L.S.	24,300			
	Relief Wells	6,600	L.F.	26.80	176,700			
	Interior drainage	Composite	Jobs	L.S.	287,700			
	Total				489,000	73,000	562,000	562,000
	Difference							466,000
				LEVEES				
Project Document	Levees:							
	Clearing & grubbing	1	Job	L.S.	26,000			
	Filter gravel	60,000	Ton	2.50	150,000			
	Embankment perv.	390,000	C.Y.	0.25	98,000			
	Embankment imperv.	113,000	C.Y.	0.40	45,000			
	Total				319,000	64,000	383,000	460,000

TABLE 1

MAJOR COST INCREASES OF ITEMS IN ORIGINAL REACH OF PROJECT (continued)

Study	Item	Quantity	Unit	Unit Price	Amount	Contin-gencies (PD = 20% DM = 15%)	Subtotal	ENR Update to July 65 (1.20) PD Only
				LEVEES (continued)				
Design Memo	Levees:							
	Embankment, sand and gravel	337,300	C.Y.	$ 0.40	$ 135,000			
	Embankment, imperv.	337,500	C.Y.	0.45	152,000			
	Total				287,000	43,000	330,000	330,000
	Difference							(-130,000)
				CHANNELS				
Project Document	Channels:							
	Stripping	140,000	C.Y.	0.25	35,000			
	Excavation, perv.	463,000	C.Y.	0.60	278,000			
	Excavation, imperv.	294,000	C.Y.	0.65	191,000			
	Excavation, waste	287,000	C.Y.	0.35	100,000			
	Total				604,000	121,000	725,000	870,000
Design Memo	Channels:							
	Stripping	89,400	C.Y.	0.35	31,300			
	Excavation, unclas.	1,102,000	C.Y.	0.75	827,000			
	Disposal	413,600	C.Y.	0.30	123,800			
	Clearing & grubbing	208	Acre	500.00	104,000			
	Water diversion	1	Job	L.S.	15,900			
	Total				1,102,000	162,000	1,264,000	1,264,000
	Difference							394,000
				BRIDGE PIER EXTENSION				
Design Memo	Bridge:							
	Pier extension	1	Job	L.S.	59,200			
	Steel piles	1,400	L.F.	7.00	9,800			
	Total				69,000	10,000	79,000	79,000
	Total Difference							$1,509,000

Total Difference $1,509,000

TABLE 2

MAJOR INCREASES OF ADDITIONS TO PROJECT

Study	Item	Quantity	Unit	Unit Price	Amount	Contin-gencies (PD = 20% DM = 15%)	Subtotal	ENR Update to July 65 (1.20) PD Only
	DOWNSTREAM EXTENSION OF PROJECT (2,000 feet)							
Design Memo	Riprap	31,000	Ton	$ 7.00	$217,000	$33,000	$250,000	-
	Levees:							
	Embankment, sand and gravel	44,700	C.Y.	0.40	17,900			
	Embankment, imp.	44,800	C.Y.	0.45	20,100			
	Total				38,000	5,700	43,700	-
	Channels:							
	Stripping	11,600	C.Y.	0.35	4,100			
	Excavation, unclas.	143,000	C.Y.	0.75	107,000			
	Disposal	53,800	C.Y.	0.30	16,200			
	Clearing and grubbing	27	Acre	500.00	13,500			
	Water diversion	1	Job	L.S.	2,100			
	Total				142,900	21,400	164,300	
	Reach total						$458,000	

TABLE 2

MAJOR INCREASES OF ADDITIONS TO PROJECT
(continued)

Study	Item	Quantity	Unit	Unit Price	Amount	Contin- gencies (PD = 20% DM - 15%)	Subtotal	ENR Update to July 65 (1.20) PD Only
	UPSTREAM EXTENSION OF RIGHT LEVEE (600 feet)							
Project Document	Riprap	380	Ton	$4.50	$ 1,700			
1/12 Of Design Memo	Levee:							
	Embankment, perv.	550	C.Y.	0.25	100			
	Embankment, imperv.	550	C.Y.	0.45	300			
	Total				2,100	400	2,500	3,000
Project Document	Riprap	4,600	Ton	7.00	32,200	4,800	37,000	
	Levee:							
	Embankment, sand and gravel	6,600	C.Y.	0.40	2,600	400	3,000	
	Embankment, imperv.	6,600	C.Y.	0.45	3,000	500	3,500	
	Total				37,800	5,700	43,500	44,000
	Difference							41,000
	EROSION CONTROL SILL							
Design Memo	Stone	23,200	Ton	9.50	220,400	33,100	253,500	254,000

TABLE 3

SUMMARY

Item	Design Memorandum	Project Document	Difference
Original reach:			
Riprap	$1,890,000	$1,190,000	$ 700,000
Levees	330,000	460,000	-130,000
Channel	1,264,000	870,000	394,000
Drainage and seepage control	562,000	96,000	466,000
Bridge pier extension	79,000	0	79,000
Subtotal	$4,125,000	2,616,000	1,509,000
Downstream extension	458,000		458,000
Upstream extension	41,000		41,000
Sill	254,000		254,000
Total, major items	4,878,000		2,262,000
Miscellaneous	22,000	4,000	18,000
Total, Project	$4,900,000	$2,620,000	$2,280,000

DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT
HUMBOLDT COUNTY, CALIFORNIA

APPENDIX B

HYDROLOGY AND HYDRAULIC ANALYSES

TABLE OF CONTENTS

Paragraph	Title	Page
	GENERAL	
B-1	PURPOSE AND SCOPE	B-1
B-2	PLAN OF IMPROVEMENT	B-1
B-3	BASIN DESCRIPTION	B-1
B-4	CLIMATE	B-2
	HYDROLOGY	
B-5	DEPARTURES FROM THE PROJECT DOCUMENT	B-2
B-6	MAJOR STORMS AND FLOODS SINCE 1961	B-2
B-7	DESIGN FLOOD COASTAL PLAIN CHANNEL IMPROVEMENTS	B-3
B-8	DISCHARGE-FREQUENCY	B-4
B-9	INTERIOR DRAINAGE HYDROLOGY	B-4
	a. Problem area	B-4
	b. Hydrologic criteria	B-5
	c. Rainfall-frequency curves	B-5
	d. General-storm determination	B-6
	HYDRAULIC ANALYSES	
B-10	DEPARTURE FROM PROJECT DOCUMENT	B-7
B-11	DESIGN CRITERIA	B-7

TABLE OF CONTENTS

Paragraph	Title	Page
B-12	HYDRAULIC DESIGN DETAILS	B-8
B-13	SPECIAL STRUCTURES	B-9
	a. Pier extensions	B-9
	b. Control Sill	B-9
B-14	INTERIOR DRAINAGE SUB-AREA DETAILS	B-10
	a. Sub-area "A"	B-10
	b. Sub-area "B"	B-10
	c. Sub-area "C"	B-10
	d. Sub-area "D"	B-10
	e. Sub-area "E"	B-10
B-15	INTERIOR DRAINAGE HYDRAULICS	B-11
	a. Plan	B-11
	b. Design capacities	B-11
	c. Seepage	B-11
	d. Hydraulic design	B-12

LIST OF TABLES

B-1	ANNUAL MAXIMUM DISCHARGE	B-13

LIST OF PLATES

Number	Title
B-1	HYDROLOGIC DATA
B-2	STANDARD PROJECT STORM-FLOOD
B-3	FREQUENCY CURVES
B-4	PLAN OF INTERIOR DRAINAGE

DESIGN MEMORANDUM

REDWOOD CREEK FLOOD CONTROL PROJECT
HUMBOLDT COUNTY, CALIFORNIA

APPENDIX B

HYDROLOGY AND HYDRAULIC ANALYSES

GENERAL

B-1. PURPOSE AND SCOPE

This appendix presents hydrology and hydraulic criteria used as the bases of design of the levee and channel system in the coastal plain of Redwood Creek basin, Humboldt County, California. Included are design flood, discharge-frequency curve and hydraulic design criteria for channel works and interior drainage facilities.

B-2. PLAN OF IMPROVEMENT

The authorized project consists of 3.4 miles of improved channel sections and levees from a point 700 feet inland of the sandbar at the Pacific Ocean to 0.8 mile above the town of Orick on the right bank and 1.3 miles above Orick on the left bank.

B-3. BASIN DESCRIPTION

Redwood Creek drains an area of 283 square miles along the northern California coast. The basin is situated entirely within Humboldt County and flows directly into the Pacific Ocean at a point 50 miles south of the Oregon-California border. Orick, the only town in the basin, is located about three miles upstream from the mouth of Redwood Creek and immediately downstream from Prairie Creek. The basin has an elongated shape, is mountainous and heavily wooded. It extends about 56 miles along a northwest-southeast axis with a minimum width of about seven miles. The elevations of the basin boundary vary from sea level at the mouth to about 5,400 feet above mean sea level at the southeastern extremity of the basin. The most remote part of the basin lies 30 miles inland from the Pacific Ocean and has an average windward barrier height of 2,500 feet and average leeward height of 3,500 feet. Approximately 50 percent of the basin lies above elevation 2,000 feet mean sea level and five percent above 4,000 feet mean sea level. In the lower four-mile reach, the creek has a fairly uniform slope of about eight feet per mile. The main stream has a watercourse length of about 64 miles. The only significant area of level land is located along the lower reaches of Redwood and Prairie Creeks.

B-4. CLIMATE

The lower portion of the basin is characterized by mild, dry summers with frequent local fog, and mild, wet winters. The inland portion of the basin has little summer fog and a greater diurnal temperature range, although the average temperature is about the same as the coastal portion. Ninety percent of the seasonal precipitation generally occurs during the period October through April. Snowfall occurs at the higher elevations but snowmelt is of relatively minor importance in increasing flood peaks since less than five percent of the basin lies above elevation 4,000 feet mean sea level, the elevation above which snowfall is significant. The basin normal annual precipitation is estimated to be about 80 inches, varying from 70 inches at the lower portion of the basin to over 85 inches across the central portion. The high seasonal total compared to coastal basins further south, is due to more frequent precipitation occurrences rather than to rainfall intensity. Precipitation in excess of 0.01-inch can be expected to occur on the average of 120 days each year.

HYDROLOGY

B-5. DEPARTURES FROM THE PROJECT DOCUMENT

Basin hydrologic data and procedures pertaining to the design of the project are given in Appendix A of the District Engineer's Report, "Survey Report for Flood Control and Allied Purposes, Redwood Creek, Humboldt County, California," dated August 1961. The only departure from the hydrologic criteria presented in the project document is the revision of the interior drainage design criteria for the condition of high stage in the creek. In order to obtain a more realistic condition of runoff from interior drainage areas during high stages in the creek, the criteria of 30-year rainfall coincident with the standard project flood in Redwood Creek was revised to 100-year flood in the creek with coincident rainfall over interior drainage areas. It is believed that this criterion represents an actual possible occurrence and furnishes the same design frequency as the criterion of 100-year short duration storm rainfall coincident with low river stages.

B-6. MAJOR STORMS AND FLOODS SINCE 1961

The largest storms which have occurred since submittal of the project document were during January 1964 and December 1964. Rainfall recorded at stations in or near the Redwood Creek basin during these two storms is presented in the following table.

Storm Rainfall Data
(inches)

Date	Eureka	Hoopa	Orick P.C.	Kneeland 10 SSE	Hyampom
17 January 1964	0.68	0.46	1.27	2.38	*
18 January 1964	1.31	2.44	1.17	1.80	2.74
19 January 1964	1.03	1.92	1.95	missing	1.34
20 January 1964	1.29	6.07	4.48	missing	3.01
21 January 1964	0.54	1.12	0.74	missing	0.72
20 December 1964	0.15	0.71	1.66	missing	1.01
21 December 1964	2.15	2.00	2.09	missing	4.35
22 December 1964	0.89	5.77	3.00	missing	8.12
23 December 1964	0.87	8.46	1.01	2.38	1.98
24 December 1964	0.27	1.85	1.29	1.50	0.55

* = accumulated to next day

The January 1964 storm produced a peak discharge of 37,700 c.f.s. at Orick from a drainage area of 278 square miles. The great storm of December 1964, which produced record peaks in many basins in northern California, produced a peak discharge estimated at 50,500 c.f.s. which is slightly larger than the previous maximum of 50,000 c.f.s. recorded in January 1953 and December 1955. The stream gage well was undermined by flood waters during 22 December 1964 and dropped about three feet and was suspended at an angle at the time repairmen were able to reach the site and secure the well to the bridge. Regular stage readings were made by a local observer until the recorder could be placed back in complete working order. Estimates by the U. S. Geological Survey indicate that the runoff during 21-24 December 1964 was 246,000 acre-feet and during the six-day period, 21-26 December 1964, it was about 336,000 acre-feet. This is significantly greater than runoff of 152,000 acre-feet and 192,000 acre-feet which occurred during similar periods in December 1955. A storm isohyetal map and discharge hydrograph estimates are presented in Plate B-1 for the December 1964 storm.

B-7. DESIGN FLOOD COASTAL PLAIN CHANNEL IMPROVEMENTS

The channel project is designed for the standard project flood, the derivation of which is shown in Appendix A of the project document and which was approved by the Office, Chief of Engineers. The hydrology was reviewed to determine the effect of the great storm of December 1964 on the standard project flood. As a result of a study by the U. S. Weather Bureau on an improved index for quantitative precipitation forecasts, this office is modifying the procedure used to transpose standard project storms. The Weather Bureau constructed a map of average rainy day amounts over northern and central California. The tremendous volume of computations required was accomplished by use of a computer at the National Weather Records Center. Formerly, the standard project storm was transposed within a limited range of latitude without correction for north or south movement. By utilizing the ratio of average rainy day amounts over the basin under consideration to the average rain day amount at the storm center, a storm may be transposed anywhere over the San Francisco District except over the upper Klamath River basin which is located in a different hydrologic regime. Transposition of the December 1964 storm over the Redwood Creek basin using the latitude adjustment from its center over the Eel River, resulted in a flood peak discharge of 79,000 c.f.s. Since this peak is practically the same as the standard project flood peak of 77,000 c.f.s. adopted in the project document and since considerable design work had been accomplished prior to the December 1964 flood, the design flood discharge has not been changed. Hydrographs of the design flood are shown on Plate B-2.

B-8. DISCHARGE-FREQUENCY

The discharge-frequency curve for Redwood Creek at Orick shown on Plate B-3 does not differ significantly from the curve adopted in Appendix A of the Survey Report. The curve was redrawn using the additional five years of annual maximum flood peaks for the period 1961 through 1965, thus extending the record to 17 years, 1948 through 1965, minus 1949. Table B-1 lists the recorded annual maxima flood peaks for Redwood Creek at Orick. The curve was computed using the analytical method presented in "Statistical Methods in Hydrology" by Leo R. Beard, dated January 1962. Values from the adopted discharge-frequency curve are presented in the following tabulation:

Discharge-Frequency
Redwood Creek at Orick (278 sq. mi.)

Exceedence Interval (years)	Discharge (c.f.s.)
2	28,300
5	38,500
10	45,000
25	53,000
50	59,000
100	65,500
Standard Project Flood	77,000

B-9. INTERIOR DRAINAGE HYDROLOGY

a. Problem area. The project levees through the Coastal Plain of Redwood Creek will interrupt surface runoff from relatively small areas which presently drain into the creek through natural drainage ways. The only major tributary, Strawberry Creek (drainage area 3.0 square miles), will drain directly into the old Redwood Creek channel and residual flood plain behind the sandbar. This area is frequently flooded under present conditions and consists of sloughs and low grade agricultural land. Maximum elevation of flooding in the area during a standard project flood will be to elevation 12 feet mean sea level. Drainage areas and the extent of residual flood plain are shown on Plate B-4. Culverts through the levee are provided at Stations 166+75, 170+00 and 170+90 on the right bank and 161+60 on the left bank. Drainage ditches and conduits intercept surface runoff and seepage from the creek and carry it along the toe of the levees to the lower end of the project where it is discharged into natural sloughs in the residual flood plain area.

b. Hydrologic criteria. The limited area of flat land available in this part of the State will place a premium on the area protected by the project. Expected development warrants a high degree of protection from flooding due to interior runoff. For this reason, the following criteria were adopted for computed runoff hydrographs:

(1) Runoff from the 100-year intensity short duration rainfall when the creek is at low stages,

(2) Runoff from rainfall coincident with the 100-year flood hydrograph in Redwood Creek.

c. Rainfall-frequency curves. Rainfall depth-duration-frequency curves were derived by procedures outlined in Technical Paper No. 28, "Rainfall Intensities for Local Drainage Design in Western United States," U.S. Department of Commerce, Weather Bureau, Washington, D.C., November 1956. An analysis was made of daily precipitation recorded at Orick Prairie Creek Park for the period 1939-63 to add confidence to the adopted curves. Values taken from the curves presented in Plate B-3 were used in the interior runoff and drainage studies conducted under criterion (1) above, by use of the "Rational Formula" and an infiltration factor. The modified "Rational Formula" is $Q = C\,(I-f)A$, where "Q" is discharge in cubic feet per second, "C" is a coefficient of reduction of outflow over inflow resulting from surface and surcharge storage, "I" is rainfall intensity in inches per hour during the critical time duration, "f" is infiltration rate and "A" is the contributing area in acres. A summary of criterion (1) discharges at left (L) and right (R) bank control points is presented in the table which follows.

Design Discharge at Selected Control Points
100-year Short Duration Storm

Control Point Station	Drainage Area (acres)	Critical Duration (minutes)	Rainfall Intensity (in./hr.)	"C"	"f" (in./hr.)	Discharge (c.f.s.)
161+50 L	63	15	2.20	.5	.10	.66
115+00 L	16	10	2.34	.4	.02	.15
94+00 L	47	15	2.20	.4	.02	.40
76+00 L	60	30	1.96	.4	.02	.47
130+00 R	14	15	2.20	.4	.02	.12
118+00 R	232	15	2.20	.7	.10	340
90+00 R	282	20	2.10	.6	.10	340
62+00 R	332	30	1.96	.6	.10	375
56+00 R	438	60	1.70	.6	.10	425

d. General-storm determination. Rainfall intensities and duration utilized in criterion (2) studies were determined by reducing standard project rainfall intensities over the interior drainage areas by the ratio of the Redwood Creek 100-year flood peak discharge to the standard project flood peak discharges. This resulted in a 72-hour storm depth of 13.8 inches with a maximum hourly value of 0.93 inch. Rainfall depth for durations from one to 24 hours are plotted on Plate B-3 to indicate their approximate frequency of occurrence. Hourly distribution of the storm total was based on the same three recorders used to distribute the rainfall causing the flood hydrograph in Redwood Creek with an arbitrary distribution during 30-minute periods of each hour. Thirty-minute unit hydrographs were derived by synthetic procedures for Station 161+50(L), Station 115+00(L) and Station 118+00(R), and discharge hydrographs derived by applying unit hydrographs to rainfall excess amounts. Hydrographs at the other area points were estimated by discharge area ratio and lag-averages of the three principal index points. The discharge hydrograph for Redwood Creek was determined by multiplying the ordinates of the standard project flood by 0.88 (the ratio of 100-year to standard project flood peak). High river stages will cause controlled seepage through the porous gravels beneath the levees via the drainage wells provided. Seepage estimates were added to surface runoff estimates in proper time relation to derive a maximum discharge to compare with criterion (1) and determine the critical design discharge for the interior drainage system. Some surface runoff upstream of Station 161+50(L) can enter the creek through the outfall drainage structure before the creek rises to a stage which will close the automatic drainage gate; subsequent runoff will pond a negligible amount and then flow through the natural drainage way, behind the levee, to Strawberry Creek. Design discharges are presented with other hydraulic design data in Plate 10 of the main report.

HYDRAULIC ANALYSES

B-10. DEPARTURE FROM PROJECT DOCUMENT

a. Detailed hydraulic studies indicate that the revetted levees should be extended downstream 2,000 feet to a point about 700 feet upstream from the sand spit at the mouth of Redwood Creek. The extended channel provides improved control of flows, a more dependable drainage system and will reduce the area of the residual flood plain. The stream carries a substantial sediment load during floods. The extension would cause the bulk of the sediment to deposit in the ocean where the prevailing littoral currents would progressively move it along the coast. The termination of the levees is sufficiently back from the ocean to be protected from ocean storms and to allow space for entrance of interior drainage between the levees and the sand spit.

b. A control sill is to be placed across the channel invert at the downstream end of the levees to prevent excessive degradation of the bottom during flood flows.

c. The left bank of the existing channel near the upstream end of the project was eroded during the December 1964 flood. This unstable condition requires the replacement of the off-set levee with a levee along the bank and carrying the revetted slopes to below streambed.

d. The pumping station in Orick for interior drainage has been replaced by a ditch along the landward toe of the levee to carry the runoff to the lower end of the project. This change was the result of a more refined and detailed study of runoff and seepage which indicated that drainage ditches would be required for practically the full length of the project. Only nominal increase in size of the ditch results from the elimination of the pumping station.

e. Upstream extensions are provided for the main piers of the highway bridge at Orick in order to increase clearance under the bridge to facilitate passage of floating debris during floods.

B-11. DESIGN CRITERIA

a. The applicable parts of the following references were used for design criteria:

(1) Appropriate Engineer Manuals for Civil Works Construction.

(2) The Distribution of Boundary Shear Stresses in Curved Trapezoidal Channels by A. T. Ippen, et al, Technical Report No. 43, Massachusetts Institute of Technology, October 1960.

(3) Engineering Hydraulics by Hunter Rouse.

b. Plan, profiles and cross-sections are shown on Plates 2 through 9 and Plate 12 of the main report. The channel alignment was selected to closely follow the existing alignment except near the mouth of the creek where the alignment has been changed to cut across a bend. The flow is directed toward the sand spit to accelerate its removal by erosion during rising flood stages. The invert grade closely follows the existing channel thalweg. Adopted channel cross-sections are the most economical which will meet the hydraulic and stability requirements, preserve the existing highway bridge and hold real estate requirements to a practical minimum.

c. The following coefficients of roughness in the Manning Formula were used in backwater analyses:

(1) Unlined bottom with riprap side slopes - a composite "n" = 0.032

(2) Existing natural sections upstream from the excavated channel - "n" = 0.060

d. Acceleration and deceleration energy losses were taken as proportion of the change in velocity head between hydraulic sections as follows:

(1) Uniform channel sections - 0.1 and 0.2

(2) Gradual transitions - 0.2 and 0.3

(3) Abrupt transitions at bridge piers - 0.5 and 0.5

e. Levee grades were established to provide at least three feet of freeboard above the maximum water surface resulting from design flood flow meeting the highest estimated tide level in the Pacific Ocean. Additional height of levees is provided for superelevation of the water surface caused by flows around bends and upstream from the bridge at Orick to allow for higher backwater caused by obstructions due to debris.

B-12. HYDRAULIC DESIGN DETAILS

a. Plates 2 through 9 and Plate 12 of the main report shows pertinent data on channel sections, depths, discharges and velocities. The channel is designed for 77,000 cubic feet per second to the confluence of Prairie Creek and 66,000 cubic feet per second above the confluence.

b. A trapezoidal section has been used throughout the project for the improved channel. The adopted channel section has a 250 foot bottom width with one vertical on three horizontal side slopes from Station 17/00 to Station 171/71, the Prairie Creek confluence. The same section extends from Station 175/50 to Station 182/10. From Station 182/10 to the end of the project at Station 192/90 the existing channel will be undisturbed. Channel velocities range from 11 to 13 feet per second except at the mouth where the flow may pass through critical depth with a velocity of 20 feet per second. All slopes are to be protected with riprap which is to extend seven feet below streambed except on curves and at the downstream end of the levees where the riprap will extend from seven to ten feet below stream bed. These depths of riprap were selected in lieu of the five feet generally adopted due to relatively high design velocities and the type of material in the channel which will probably result in degradation during high flood flows which are greater than normally encountered.

B-13. SPECIAL STRUCTURES

a. Pier extensions. The only bridge crossing the project channel is the two-lane Highway U. S. 101 bridge at Orick with a center span of 220 feet, five approach spans of 30 feet each on the left bank and one 60-foot and five 30-foot approach spans on the right bank. Streamlined pier extensions are to be provided at the upstream side of the two main piers. The extensions will lower the water surface elevation under the bridge, reduce turbulence caused by existing piers and minimize the tendency to collect trash or debris. Details of the pier extensions are shown on Plate 11 of the main report. Bridge clearances during the design discharge would be four feet under the main span and about two and one-half feet under the approach spans. In estimating the maximum water surface upstream from the bridge, one-half of the area of the approach spans was assumed blocked by debris.

b. Control Sill. A rock structure will be placed across the channel at the downstream end of the project to stabilize the channel grade. Studies of various types of structures indicate that a rigid structure would be too costly and that a rock structure, which would withstand the forces from discharges of frequent floods but which might require maintenance after infrequent floods, would be the most economical solution. The structure will consist of a sill in the shape of an inverted trapezoid formed by heavy riprap. The top width is 10 feet, the downstream apron will have a slope of one on three and the approach apron, a slope of one on two. Riprap size is based on a velocity of 20 feet per second, the maximum velocity at critical depth. The apron will extend to an elevation 20 feet below streambed and will be below the anticipated depth of scour. The top of the sill is about minus 4.5 feet mean sea level which is about equal to mean lower low water tidal elevation.

The design water surface will drop from four to 14 feet at the sill to the tidal level dependent upon the tidal stage in the ocean. The daily tidal cycle has two highs and two lows. Flow during the design flood is near peak discharge for about 12 hours. Therefore, it is necessary to design the sill for critical conditions occurring with the design discharge during the entire tidal cycle. Flow leaving the confined channel will spread fanwise, develop a scour hole and breach the sand spit which will form during periods of low flows. The sill will help to protect the downstream ends of the levees and will limit the depth of scour in the reach of the project channel upstream subject to accelerated velocities, thereby preventing undermining of the levees. The height of the levees was established at three feet above the water surface with no credit being taken for the drop through critical depth. The resulting increased freeboard may be required in the event the sand spit does not fully scour.

B-14. INTERIOR DRAINAGE SUB-AREA DETAILS

The boundaries of interior drainage sub-areas and the location of drainage structures are shown on Plate B-4.

a. Sub-area "A" consists of 206 acres of hillside and valley land on the right bank of Redwood Creek. Runoff from the area is concentrated at Station 56+00 in the northwest corner of the area.

b. Sub-area "B" consists of 218 acres on the right bank of the project channel which includes 200 acres of steep hillside lands rising to elevation 800 feet mean sea level. The time of concentration is short and runoff flows in a natural drainage channel which enters the right bank drainage ditch at Station 118+00. Some runoff from the upstream portion of the area will discharge through existing culverts which will be extended through the project levee.

c. Sub-area "C" consists of 14 acres of flat land between Highway U. S. 101 and the right bank project levee in the town of Orick. An interceptor conduit behind the levee, extending from Station 159+00 to Station 118+00, will conduct runoff from this area to the head of the ditch at Station 118+00.

d. Sub-area "D" consists of 60 acres of flat lands between the left bank project levee and Highway U. S. 101. Drainage will flow in a conduit between Stations 123+00 and 85+00 and in an open ditch between Stations 85+00 and 74+00. Flow is then through a slough into Strawberry Creek.

e. Sub-area "E" consists of 33 acres of flat lands and 30 acres of steep, timbered hillside on the left bank of Redwood Creek at the upper end of the project. A natural depression near Station 193+00 will be filled to the adjacent ground surface.

Drainage accumulates at a gated culvert near Station 161/50. Gate closure during high flows in Redwood Creek which will occur infrequently, will result in shallow ponding and diversion of flow down a natural watercourse to the Strawberry Creek channel.

B-15. INTERIOR DRAINAGE HYDRAULICS

a. Plan. The plan, profiles and details of the interior drainage system are shown on Plate B-4 of this appendix and Plate 10 of the main report. The plan consists of interceptor conduits and ditches along the landward toe of the levees to carry surface runoff and seepage to the lower end of the project. The drainage line along the right bank levee is discharged into a slough that extends inland from the mouth of Redwood Creek. The line along the left bank is discharged into a swale that drains into Strawberry Creek which discharges into the by-passed existing section of Redwood Creek and around the downstream end of the levee. The right bank drain consists of 4,100 feet of concrete pipe, two to four feet in diameter, in the upper reach through the built-up area and 7,950 feet of open trapezoidal earth ditch with a bottom width of seven feet and side slopes of one on three. The capacity of the conduits varies from 16 c.f.s. to 80 c.f.s. and the ditch from 340 c.f.s. to 425 c.f.s. The left bank drain consists of 3,800 feet of concrete pipe, two to four feet in diameter for the upper reach through the built-up areas and 2,200 feet of open earth ditch in separate reaches having bottom width of four feet and one foot and side slopes of one on two and one-half. The capacity of the conduits varies from 9 to 42 c.f.s., the main ditch from 42 to 71 c.f.s. and the branch ditch from 1 to 15 c.f.s. On the left side of Redwood Creek at Station 161/50, a three foot drainage culvert with a capacity of 66 c.f.s. with flapgate and an emergency slide gate will pass under the levee. Near the upstream end of the right bank levee, three existing culverts, 18 to 24 inches in diameter, will be extended through the levee and equipped with flapgates and emergency slide gates. Several small depressed areas behind the levees will be earth filled to prevent local ponding.

b. Design capacities. The capacity of the drainage ditches and conduits is designed for the maximum discharge resulting from one of the two criteria discussed in paragraph B-9 b. Seepage is added when Redwood Creek is at high stages.

c. Seepage. On the left side of Redwood Creek, the accumulated maximum peak seepage rates increase almost uniformly from zero at Station 85/00 to 43 c.f.s. at Station 65/00. On the right side of Redwood Creek, the accumulated peak rates increase from zero at Station 158/00 to 192 c.f.s. at Station 75/00. Seepage is added to the general-storm hydrograph in the applicable time sequence to obtain the maximum combination column (3) of the following tabulation:

(1) Control Point Station	(2) 100-year local-storm discharge and no seepage (cubic feet per second)	(3) Seepage plus 100-year general-storm discharge (cubic feet per second)
161+50 L	66	50
115+00 L	15	12
94+00 L	40	35
85+00 L	42	38
76+00 L	47	58
76+00 L	47	71*
130+00 R	12	70
118+00 R	340	156
90+00 R	340	240
62+00 R	375	322
56+00 R	425	372

* Includes contributing seepage from downstream reach.

d. Hydraulic design. The bottom grades and dimensions of the drainage lines were selected to give the most economical plan that would meet the maximum combination of interior runoff and seepage. The design water surface profile is below the adjacent final ground grade. A roughness coefficient in the Manning Formula of 0.012 and 0.035 respectively, was used for determination of the hydraulic capacities of concrete pipe conduits and earth channels.

TABLE B-1

REDWOOD CREEK BASIN
HUMBOLDT COUNTY, CALIFORNIA

ANNUAL MAXIMUM DISCHARGE

Redwood Creek at Orick

Water Year	Date	Stage (ft.)	Discharge (c.f.s.)
1948	1/ 7 January	20.9	30,000
1949			
1950	1/18 January	22.5	36,000
1951	1/17 January	19.5	28,000
1952	1/ 1 February	18.4	24,000
1953	1/18 January	23.9	50,000
1954	24 November	19.2	27,200
1955	31 December	19.5	28,100
1956	22 December	23.9	50,000
1957	12 March	18.5	24,100
1958	13 November	17.9	22,200
1959	12 January	16.5	17,500
1960	8 February	18.7	25,000
1961	25 November	15.6	14,700
1962	19 December	17.8	21,800
1963	2 December	19.0	26,100
1964	20 January	22.0	37,700
1965	22 December	23.3	50,500

STATISTICS:
(1948-65 period, less missing year)
Geometric mean discharge............28,600 c.f.s.
Standard deviation.................. 0.154

NOTE:
1/- From high-water marks and Corps of Engineers' staff observations and rating curve developed after 1953.

DEPARTMENT OF THE ARMY
SAN FRANCISCO DISTRICT, CORPS OF ENGINEERS
100 McALLISTER STREET
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO

SPNGP-WC

8 May 1968

SUBJECT: General Design Memorandum, Redwood Creek Flood Control Project, Humboldt County, California, Supplement No. 1, Proposed Modification of Authorized Project

Division Engineer, South Pacific

1. In accordance with EM 1110-2-1150 and South Pacific Division Regulation 1110-2-3, 15 September 1967, subject supplement is submitted for approval.

2. The basis for cost estimate is the same as in the General Design Memorandum.

3. The erosion problem described in the inclosure is critical. The work proposed should be accomplished prior to the next flood season, if practicable, in order to prevent the potential loss of the road. Early advice of action taken is therefore requested.

1 Incl (14 cys)
As stated

Harry McK Roper Jr
HARRY McK. ROPER, JR.
LTC, CE
Acting District Engineer

Keep Freedom in Your Future With U.S. Savings Bonds

GENERAL DESIGN MEMORANDUM
REDWOOD CREEK FLOOD CONTROL PROJECT
HUMBOLDT COUNTY, CALIFORNIA

SUPPLEMENT NO. 1

PROPOSED MODIFICATION OF EXISTING PROJECT

TABLE OF CONTENTS

Paragraph	Title	Page
	INTRODUCTION	1
1	GENERAL	1
2	BASIS FOR MODIFICATION	1
	PURPOSE OF REPORT	1
3	SCOPE	1
4	PROBLEM	2
5	PREVIOUS DAMAGES	2
	PROPOSED MODIFICATIONS	2
6	BANK PROTECTION	2
7	CHANNEL CLEARING	3
8	COST OF MODIFICATIONS	3
9	EFFECT OF MODIFICATIONS	3
	BENEFITS	4
10	BASIS OF BENEFITS ANALYSIS	4
11	DIRECT DAMAGES AND BENEFITS	4
12	INDIRECT DAMAGES AND BENEFITS	5
13	TOTAL BENEFITS SUMMARIZED	5

TABLE OF CONTENTS (Continued)

Paragraph	Title	Page
	LOCAL COOPERATION	5
14	LOCAL COOPERATION AND CONTRIBUTION	5
	JUSTIFICATION	6
15	ECONOMIC JUSTIFICATION	6
	RECOMMENDATION	6
16	GENERAL	6

PLATES

Number	Title
1	GENERAL MAP OF AREA
2	PLAN AND PROFILE
3	CROSS SECTIONS

GENERAL DESIGN MEMORANDUM
REDWOOD CREEK FLOOD CONTROL PROJECT
HUMBOLDT COUNTY, CALIFORNIA

SUPPLEMENT NO. 1

PROPOSED MODIFICATION OF EXISTING PROJECT

INTRODUCTION

1. GENERAL

The project on Redwood Creek at Orick in Humboldt County authorized in the Flood Control Act of 1962, is nearing completion. The project is described in detail in the General Design Memorandum dated February 1966. The project consists of channel widening, deepening, realignment, levees, riprap protection on both sides of channel and appropriate interior drainage facilities. The general layout of the project is shown on Plate 1.

2. BASIS FOR MODIFICATION

During the winter flows of the past several years it was noted that the channel upstream from the project terminus was meandering and eroding the banks of the creek. The upper end of the left levee, including riprap protection of the slopes, was extended 400 feet in 1967 to prevent the possibility of outflanking the project in the event that the channel course changed so as to direct full force of flow against the left bank upstream from the previous termination point. Continued erosion on the right bank, however, is endangering a road known as the Bald Hill Road on the right side of the valley. The functioning of this project, however, is not affected by this erosion and a consideration of any protective measures has to be based on its own merits and economics.

PURPOSE OF REPORT

3. SCOPE

The purpose of this report is to present, in detail, the problem being caused by channel meandering and resulting erosion, to propose modifications, and to request authorization to modify the existing project so as to include the proposed modifications under the general discretionary authority available to the Chief of Engineers. The scope of this report consists of an analysis of the problem, the economic evaluation of the damages, the description of measures required to prevent damages, the cost of such measures, economic justification and the appropriate recommendation.

4. PROBLEM

The continual severe erosion of the right bank of Redwood Creek upstream of its confluence with Prairie Creek has created a serious problem. The progressive erosion taking place was most apparent in 1965 and 1967. The stream in this reach of Redwood Creek has meandered to such an extent that the flow attacks the right bank at a ninety degree angle, makes a one hundred and eighty degree turn from the north to the south and then makes a ninety degree turn from the south to the west where it enters the improved channel of the authorized project. If no corrective measures are taken, the continual erosion would eventually destroy Bald Hill Road. The importance of Bald Hill Road to Humboldt County, as well as to the town of Orick becomes evident when it is realized that this County road is the only direct link between Orick, the beneficiary of the authorized project, and the areas to the east. A detour by Highway 101 through Arcata to Weitchpec would be at least three times longer than the direct route between these points. Approximately 120,000 vehicles used the road in 1967, of which 24,000 were trucks. The economy of Orick depends upon the operation of its lumber companies which are served to a large extent via Bald Hill Road.

5. PREVIOUS DAMAGES

Bald Hill Road was subjected to severe damages in 1962. The damages as measured by the cost of restoration of the road were about $60,000. The road was out of service to logging trucks for a period of 30 days. Traffic to Weitchpec and to other points east had to contend with one way service for four months.

PROPOSED MODIFICATIONS

6. BANK PROTECTION

The proposed modification needed to prevent the damages would consist of placing riprap along the right bank of Redwood Creek, from Station 185+00 to Station 214+80, and along a portion of the Bald Hill Road embankment as indicated on Plates 2 and 3. The toe of the riprap placement would be approximately 7 feet below the bottom of the natural channel which would be backfilled. The thickness of riprap would be 12 inches and the riprap would extend upstream to the natural tip of the bank, as shown on Plate 3. The design water surface elevations would be higher than the existing ground on the right bank and the overbank velocities in the vicinity of Bald Hill Road would be about 8 feet per second. The proposed modification, therefore, calls for riprap along a portion of Bald Hill Road as shown both on the plan and profile drawings of Plate 2. Other portions of the road do not need riprap because they are not exposed to erosive action from overbank flow. The alternatives to bank protection would be relocation of Bald Hill Road or continual repair of the road after damage takes place. Both alternatives would be more costly than the proposed modification.

7. CHANNEL CLEARING

To improve flow conditions in the creek the proposed modification also includes some channel clearing. The area of the channel to be cleared is indicated on Plate 2. It would be about 250 feet wide and extend for the entire length of the modification, from Station 185+00 to Station 214+80.

8. COST OF MODIFICATIONS

The total cost of modifications is estimated to be $235,000. The unit prices shown for construction features in the current estimates are based on April 1968 price levels. The itemized cost estimate follows:

Item No.	Description	Quantity	Unit	Unit Price	Amount
1	Mobilization & Demobilization	1	Job	L.S.	$ 3,000
2	Channel Clearing	17	Acre	300.00	5,100
3	Clearing & Grubbing	6	Acre	600.00	3,600
4	Random Fill (No Compaction)	82,600	C.Y.	.40	33,100
5	Embankment	6,500	C.Y.	.30	2,000
6	Riprap, 12" (In place)	14,400	Ton	7.60	109,200
	Subtotal				$156,000
	Contingencies				34,000
	Subtotal				$190,000
	Engineering and Design				18,000
	Supervision and Administration				22,000
	Subtotal				$230,000
7	Lands & Damages (including acquisition cost)			L.S.	5,000
	Total Cost				$235,000

The current estimate of total cost for the authorized project is $4,870,000. Including the proposed modification cost of $235,000 would result in a total cost of $5,105,000.

9. EFFECT OF MODIFICATIONS

The proposed modifications will protect Bald Hill Road from further destructive action of Redwood Creek in this vicinity. The riprap would

ies

r

protect the bank of the creek from further erosion and the channel clearing would improve flow conditions so that there will be less tendency for the creek to meander. The proposed modification, therefore, has the purpose of stabilizing the river so as to prevent further erosion of Bald Hill Road. However, it would not reduce flooding nor affect the functioning of the flood control project.

BENEFITS

10. BASIS OF BENEFITS ANALYSIS

In order to establish the benefits resulting from the proposed modifications, assumptions were made as to what would occur in way of damages if the proposed modifications were not constructed, and what would be the amount of the damages that would occur. The damages were divided into two categories; direct damages to road, and indirect damages to the users of the road. The benefits were also divided into these two categories. In the evaluation of both direct and indirect benefits, an interest rate of 3-1/8 percent and a project life of 50 years were used to correspond with the values in the General Design Memorandum.

11. DIRECT DAMAGES AND BENEFITS

In order to evaluate the damages that could occur to Bald Hill Road, it was assumed that the present trend of erosion would continue at approximately the same rate. An analysis of the current rate of erosion indicated that Bald Hill Road would erode linearly at an average rate of about 200 feet per year over a ten-year period for a total of approximately 2,000 feet. Damages in this case would, therefore, be based on the cost of reconstruction of the eroded portion of Bald Hill Road and added riprap protection as a preventive measure against future erosion of the reconstructed road. Although 200 feet of road would be repaired at one time, the following year erosion, in addition to removing 200 feet of natural bank, could easily overlap and take out a portion of the previous year's construction. Experience in observation of erosion patterns on various projects has indicated that incompleted riprap placement (which would be the case in progressive road restoration), is subject to some failure when the area adjacent to the work is eroded. Therefore, more than 200 feet of restoration work each year would be required. To allow for this overlap of erosion it was assumed that 20 percent of the preceding year's road restoration would be damaged and require repair. To evaluate the benefits on an average annual basis, the annual restoration cost was brought back to present worth and then amortized over the 50-year life of the project. The cost of restoration including riprap protection after the first year of erosion was estimated to be $102,000. This erosion would take place at the upstream end of the area under attack by the creek flow, the area subject to most damages because of the contour characteristics. The cost of reconstruction every year therafter for the next nine years would be approximately

$30,000. Based on project life and interest rate previously stated, it was determined that the average annual direct benefits from prevention of damages would be $13,400.

12. INDIRECT DAMAGES AND BENEFITS

In addition to direct benefits from prevention of damages to the road, there are also the indirect benefits realized by avoiding the rerouting of traffic, which would be necessary should this County road be washed out and require restoration. This has been the case in the past as cited previously in this supplement. The distance from Orick to Weitchpec is 25 miles. Rerouting of traffic from Orick south on Highway 101 to the vicinity of Arcata and then to Highway 99 to Willow Creek and thence from Willow Creek to Weitchpec, would be a total distance of 90 miles. This represents a net reroute distance of 65 miles. The average daily traffic count of vehicles from Orick to Weitchpec is 321 as furnished by the California State Department of Motor Vehicles. The reroute cost was based on data of the cost of operating trucks on a per mile basis as obtained from the California Trucking Association, Burlingame, California. Further data were furnished on this cost by the State Division of Highways, State of California. Cost of operating automobiles was assumed to be ten cents per mile. Based on the previous interruptions of service by bank erosion it was assumed that the road would be out of service for a period of 30 days for each year involved in this analysis. The average number of vehicles per day which use the road was adjusted to 1970 conditions and then projected for the auto and truck usage to 1980 based on the projections made by the State of California Department of Motor Vehicles. This analysis resulted in an average annual benefit of $5,900 which represents the equivalent loss incurred by rerouting traffic.

13. TOTAL BENEFITS SUMMARIZED

Adding the direct benefits of damages prevented to Bald Hill Road ($13,400) to the indirect benefits realized by prevention of interruption of service along Bald Hill Road ($5,900) results in a total average annual benefit of $19,300.

LOCAL COOPERATION

14. LOCAL COOPERATION AND CONTRIBUTION

In the event the proposed modifications are adopted as an extension of the authorized project, the only assurance required from local interests other than those outlined in the General Design Memorandum, would be for cost sharing for the proposed modifications and maintaining the additional works. Local interests would be approached for a cost contribution since the proposed modifications include a local slope protection work which is not directly related to the bank of the flood control project. Present policy regarding cost contribution for bank protection works would require a 50 percent participation in the cost of the proposed modifications, now estimated at $115,000 not including cost of lands and damages. The Board of Supervisors of Humboldt County have not been requested to furnish a formal assurance relative to complying with the requirements for local cooperation at this time. Members of the staff of the county have been contacted concerning the project and they have indicated that the county would meet the requirements at the time a formal request is made. It is the opinion of the District Engineer that local interests would be willing to meet the requirements of local cooperation.

JUSTIFICATION

15. ECONOMIC JUSTIFICATION

The estimated average annual Federal and non-Federal costs estimated at 3-1/8 percent interest for 50-year economic project life are as follows:

Federal:		
First cost $115,000 x 0.040		$ 4,600
Non-Federal:		
First cost $115,000 x 0.040	$4,600	
Lands and Damages $5,000 x 0.040	200	
Maintenance & Operation Cost	1,600	
Average annual non-Federal cost		6,400
Total, Average Annual Project Cost		$11,000

A comparison of estimated benefits of $19,300 with estimated average annual costs indicates a benefit-cost-ratio of 1.8 to 1.0, showing economic justification for the proposed modifications.

RECOMMENDATION

16. GENERAL

It is recommended that the proposed modification of the existing project be approved under the discretionary authority available to the Chief of Engineers and that this Supplement No. 1 to the General Design Memorandum be approved as a basis for preparation of contract plans and specifications and construction of the proposed modification of the existing project on Redwood Creek, Humboldt County, California, at a currently estimated Federal cost of $115,000.

Harry McK Roper

HARRY McK. ROPER, JR.
LTC, CE
Acting District Engineer