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State of California
THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 136

NORTH COASTAL AREA INVESTIGATION

Preliminary Edition

SEPTEMBER 1964

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

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FOREWORD

Californians have traditionally demonstrated far-reaching vision in their development of water resources. The State's dynamic and unprecedented growth has been largely fostered by the willingness of its people to construct extensive systems for the conservation and transfer of water. With the completion and full operation of the projects presently under construction and those for which construction will shortly be initiated, the major sources of water supplies in the central and southern portions of the State will be fully utilized. Clearly, if the State's economic growth is to continue, the large quantities of surplus water in the North Coastal area must be tapped.

With this report, the Department of Water Resources concludes a seven-year reconnaissance investigation of the North Coastal area. This investigation has been part of the department's traditional and continuing activities in planning for statewide water development. The objective of the reconnaissance program was to formulate plans by which the water resources of the region can be integrated with the State's expanding economy through orderly, staged development. The planning emphasis has been directed towards major water conservation projects; however, all aspects of water control and utilization have been considered. The planning framework presented herein is thus multiple-purpose in nature; it provides for water conservation for local and export requirements, flood control, power generation, fisheries and wildlife preservation and enhancement, and recreation.

Based on the findings of this investigation, the Upper Eel River Basin has been selected as the location for the initial North Coastal facility of the State Water Project. A development to conserve water in the Eel River Basin and to convey the water in excess of local needs to the Sacramento River Basin has been authorized for construction as an additional conservation facility of the State Water Project. Feasibility-level studies for the facility have begun; final design and construction will follow. Initial water service from this project will be needed in the early 1980's.

The Upper Eel River Development will be only one stage in the long-range plan of development for the North Coastal area. As statewide water demands continue to grow, additional projects will be needed in the Trinity, Mad, Van Duzen, and Lower Eel River Basins, and perhaps the Klamath River Basin. Although the plans shown herein for projects in these basins are primarily illustrative, they indicate the magnitude of the task which lies ahead. The department will continue studies of these possible projects in anticipation of their future need.

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ORGANIZATION OF REPORT

The department's report on the North Coastal Area Investigation consists of this bulletin, three separately bound appendixes to the bulletin, and four separately bound office reports. The appendixes cover the subjects of watershed management, recreation, and fish and wildlife. The office reports cover alternative plans for development, designs and cost estimates, engineering geology, and hydrology. Each of these publications is described briefly below.

Bulletin No. 136

Bulletin No. 136 - North Coastal Area Investigation

This bulletin provides a general description and summary of the investigation. It outlines the objectives, activities, and conclusions of the investigation and describes the plans which have been formulated. This edition of the bulletin, August 1964, is preliminary and subject to a public hearing.

Appendix A - Watershed Management in the Eel River Basin

This appendix is the report of a special study undertaken in response to Senate Concurrent Resolution No. 47 of the 1961 State Legislature. The report summarizes all aspects of watershed management in the Eel River Basin. It includes technical descriptions of the physical characteristics of the Eel River Basin; discussions of watershed management problems including case histories of the Bull Creek and Corbin Creek watersheds; and recommendations regarding watershed management needs.

Appendix B - Recreation

This appendix presents a summary of outdoor recreation in the North Coastal area. It includes the following information: historical background leading to settlement of the area and the development of its recreational resources; the history of private and governmental participation in the development of recreational resources of the area; a summary of present recreational resources of the area and the utilization of these resources; a reconnaissance appraisal of the recreational impact of the water development plans presented in Bulletin No. 136. The studies reported in this appendix were made by personnel of the Department of Parks and Recreation working under contract with the Department of Water Resources.

Appendix C - Fish and Game

The studies reported in this appendix were made by personnel of the Department of Fish and Game working under contract with the Department Water Resources. The appendix includes the following information: a description of existing fish and game resources; estimated streamflows to preserve and, where feasible, enhance anadromous fisheries; reconnaissance evaluations of the effects of the projects presented in Bulletin No. 136 on the fish and game resources; preliminary recommendations for measures which would be required to preserve existing fish and wildlife resources.

Office Reports

The technical record of the investigation, with the exception of the appendix material, is summarized in four office reports. Because the reports are largely technical and are generally of interest only to individuals concerned with the particular activity, they have been printed in limited quantity.

Alternative Plans for Development

Many alternative plans of development were analyzed during the investigation. The plans presented in Bulletin No. 136 were selected as the more favorable of the alternatives. This office report was prepared in the interest of preserving the analyses and conclusions pertaining to all of the plans which were analyzed. It includes a discussion of the general considerations, methods, and procedures used in planning North Coastal projects; a summary of all of the features and plans which have been studied; and tabulations of available topographic mapping.

Designs and Cost Estimates

This report presents a summary of each of the reconnaissance designs and associated cost estimates which was prepared during the investigation. The report discusses the general methods and criteria applicable to this activity as a whole and also the specific assumptions and basic data pertaining to each individual structure. Design layouts and itemized cost estimates are included for selected features.

Engineering Geology

This report covers all of the individual geologic investigations conducted during the North Coastal Area Investigation. The coverage devoted to individual damsites and tunnel alignments varies with the level of work performed and the importance of the feature in the plans for development. The discussions for major damsites include detailed descriptions of the foundation conditions and available construction materials. Discussions of major tunnel alignments include estimates of tunneling conditions and descriptions of anticipated problem areas.

Hydrology

This report contains the hydrologic data developed during and related to the investigation. It includes precipitation data, recorded and estimated streamflow data, correlation equations, estimated flood hydrographs, and flood frequency estimates.

Authorization For Investigation

The Legislature, by the Budget Act of 1956, provided:

"Chapter I, Item 223 -- For conducting investigations in the North Coastal Area and ..., for major water resource developments in California, including preparation of plans and estimates, making reports thereon, and otherwise performing all work necessary for these investigations; ...."

Funds for the investigation were provided by:

Budget Act	Chapter	Item No.	Amount
1956	1	223	$ 10,000 1/
1957	600	263A	165,000
1958	1	257	388,000
1959	1300	262	282,000
1960	11	256	355,000
1961	888	266E	283,000
1962	1	263B	313,000
1963	1050	261B	350,000
		TOTAL	$2,146,000

1/ Activities during fiscal year 1956 were limited to preparation of program schedules and other introductory studies necessary for initiation of investigative activities in fiscal year 1957.

ATE OF CALIFORNIA—RESOURCES AGENCY WILLIAM E. WARNE, *Director*

EPARTMENT OF WATER RESOURCES
O. BOX 388
CRAMENTO

August 5, 1964

Honorable Edmund G. Brown, Governor
and Members of the Legislature
of the State of California

Gentlemen:

I am pleased to transmit herewith the preliminary edition of Bulletin No. 136, "North Coastal Area Investigation," dated August 1964.

This report culminates the department's seven-year reconnaissance investigation of the North Coastal area. The objective of this investigative program was to formulate a comprehensive planning framework for the long-range development of the water resources of the region. The plans presented herein provide for multiple-purpose water conservation projects on the major North Coastal streams, with staged construction to meet statewide water needs as they arise.

In fulfillment of the recommendations from this investigation, the department's planning activities for North Coastal projects are being pursued under two programs: a four-year feasibility-level study for the authorized Upper Eel River Development, and a continuation of the area-wide investigation of the North Coastal area. This latter program is directed towards the further definition of the projects which will follow the Upper Eel River Development.

Sincerely yours,

William E. Warne

Director

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor
HUGO FISHER, Administrator, The Resources Agency
WILLIAM E. WARNE, Director, Department of Water Resources
ALFRED R. GOLZE', Chief Engineer
JOHN R. TEERINK, Assistant Chief Engineer

This bulletin was prepared by the Northern Branch under the

direction of

John M. Haley . . . . Chief, Northern Branch
Stuart T. Pyle . . . . Chief, Planning Section, Northern Branch
Eugene F. Serr . . . . Chief, North Coastal Investigations

by

George R. Baumli . . . . Senior Engineer
David N. Kennedy . . . . Assistant Engineer

The investigation leading to this report was conducted largely under the

direction of

Myer Samuel* . . . . Principal Engineer
John W. Keysor* . . . . Principal Engineer
Robert A. Williams* . . . . Supervising Engineer

---

<u>Planning Staff</u>

George R. Baumli . . . . Senior Engineer
Robert F. Middleton, Jr.* . . . . Senior Engineer
Donald W. Fisher* . . . . Associate Engineer
Theodore G. Roefs* . . . . Associate Engineer
Wendell D. Walling . . . . Associate Engineer
August J. Bill . . . . Engineering Associate
Fred P. DeRose . . . . Engineering Associate
Leo F. Cournoyer* . . . . Assistant Engineer
Richard H. Hawkins* . . . . Assistant Engineer
Kenneth R. Henneman . . . . Assistant Engineer
David N. Kennedy . . . . Assistant Engineer
Gardner E. Trefethen . . . . Engineering Technician II
Stanley W. Cummings . . . . Engineering Technician I
James G. Lopez . . . . Engineering Technician I

Special services were provided by

Design and Cost Estimating

Benson G. Scott* . . . . Senior Engineer
Edward D. Stetson . . . . Senior Engineer
Linton A. Brown . . . . Associate Engineer
Stephen H. Chan . . . . Associate Engineer
Earl Molander* . . . . Associate Engineer
William J. Rothaus* . . . . Associate Engineer
Samuel E. Dickson* . . . . Assistant Engineer
Donald E. Oaks* . . . . Assistant Engineer
Paschal E. Rainwater . . . . Engineering Technician II

Geology

Philip J. Lorens . . . . Senior Engineering Geologist
Ronald P. Bisio* . . . . Associate Engineering Geologist
Billie G. Hicks* . . . . Assistant Engineering Geologist
Vadim Voloshin . . . . Assistant Engineering Geologist

Recreation

George E. Reiner . . . . Recreation Planner III
James McDade . . . . Recreation Planner II

Fish and Wildlife

George W. McCammon . . . . Fishery Biologist IV
Ralph N. Hinton . . . . Fishery Biologist II
Robert D. Mallette . . . . Game Manager III

Economics

Gordon V. Holcomb . . . . Associate Economist
Don K. Cole* . . . . Associate Economist
Glenn B. Sawyer . . . . Associate Land and Water Use Analyst

Power Planning

Edward J. Terhaar . . . . Supervising Electric Utilities Engineer
Fred J. Groat . . . . Supervising Electric Utilities Engineer
R. E. Frey . . . . Associate Electric Utilities Engineer

* Reassigned

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-----0-----

ORVILLE L. ABBOTT
Engineer

WILLIAM M. CARAH
Executive Secretary

4. To evaluate the potential for integration of hydroelectric power, flood control, recreation, and fisheries and wildlife enhancement with the works of the major water conservation facilities.

5. To identify problem areas that will require specific study when the water development plans are investigated at a higher level of intensity.

6. To provide recommendations relative to programs and actions which will be necessary to effect efficient, orderly, and optimum development of the region's water resources.

Scope of Investigation

The major purpose of an area-wide plan of water development in the North Coastal area is to develop presently uncontrolled runoff for meeting requirements in local areas and for export of surplus water to water-deficient areas within the State. Within the framework of a comprehensive water development plan it is possible to consider many associated and interrelated aspects of water control, distribution, and use. In this investigation the following additional purposes were considered for inclusion as multiple-purpose uses of the conservation and conveyance facilities: fisheries enhancement, flood control, recreation, and hydroelectric power.

The areal scope of the investigation included consideration of all streams in the North Coastal area which offer apparent potential for economic development of major water conservation projects. The plan of development as presently conceived would include major projects in the Eel, Trinity, Mad, Van Duzen, Klamath, and Russian River Basins. Minor coastal drainage basins, extending north from the Gualala River to Redwood Creek, were given cursory examination as possible locations for fisheries enhancement projects.

In addition to the above streams, which all drain westward to the coast, portions of the contiguous drainage basins on the west side of the Sacramento Valley, through which the exported water would be conveyed enroute to the Sacramento-San Joaquin Delta, have also been studied. These basins include Putah, Cache, Stony, Thomes, Elder, Cottonwood, and Clear Creeks. The study of these drainage basins was directed primarily to aspects associated with the interbasin transfer of water, such as, possible reregulatory storage sites and hydroelectric power features; however, substantial additional benefits, including conservation of tributary runoff, would be derived from works constructed in these basins.

The North Coastal Area Investigation has embraced many fields of study, including hydrology, geology, surveying and mapping, cost estimates and design, land and water use, watershed management, economics, recreation, fish and wildlife, and hydroelectric power. The intensity or degree of refinement for individual studies ranged from cursory analysis through high-order reconnaissance studies. Summaries of the studies related to each of these fields are in Chapter V. The data and results for each study activity are reported in the appendixes to this bulletin and in the associated office reports.

Conclusions

The conclusions of this investigation are presented in two classes: (1) general conclusions which apply to the overall plan of development for the North Coastal area, and which have a common bearing on all of the proposed plans; (2) specific conclusions regarding planning for the individual major projects which comprise the plan of development.

General Conclusions

1. Approximately 12 million acre-feet of new annual water supply, sufficient to meet California's projected future water needs to beyond the year 2020, could be developed through construction of works similar to those described herein. Of this, 10 million acre-feet would be developed by projects on major streams within the North Coastal area and 2 million acre-feet would be derived from associated works in the Sacramento River Basin.

2. The conservation works associated with development of the major North Coastal streams can be constructed in a series of projects, staged to meet water needs as they arise.

3. Additional increments of water supply to meet demands beyond those presently foreseen could be developed on the numerous minor North Coastal streams; however, the unit cost of developing these supplies would be significantly greater than the range of costs associated with projects on the major North Coastal streams.

4. The timing and sizing of major projects in the North Coastal area will be influenced largely by the rate of demand build-up for new water supplies in other areas of the State.

5. Water requirements within the North Coastal area for irrigation, municipal, industrial, and nonurban domestic uses will grow from a present applied water requirement of 700,000 acre-feet annually to approximately 2,000,000 acre-feet annually by the year 2020.

6. The demands for major increments of new water supply within North Coastal service areas can be met most efficiently and economically through association with large export projects.

7. The major reservoirs constructed for water conservation on North Coastal streams will provide incidental flood control benefits through normal operation. The reservation of reservoir capacity specifically for flood control will in most cases be economically precluded by the high cost of reservoir storage in relation to the value of potential flood control benefits and by the location of the reservoirs high in the watersheds. The conveyance works constructed in adjacent basins tributary to the Sacramento River would offer the potential for substantial reduction of flood damage to local areas along the conveyance routes.

8. The plans for development reported herein include a number of hydroelectric plants; the selection and sizing of these plants were based on power criteria appropriate during the reconnaissance investigation. Projections of future conditions in the electric-power industry indicate a gradual decline in the potential benefits of hydroelectric power, as technological advances reduce the cost of steam electric generation and transmission costs. It is probable therefore that some of the proposed plants will not be economically justified under future analysis.

9. Some of the water diversion plans for the North Coastal area are dependent on large pumping facilities. The projected future lower cost of power production will be reflected in lower costs

of power for pumping, thus partially compensating for the potential loss in hydroelectric power benefits.

10. Recreation will be an important joint-use purpose of the water development projects proposed herein. The relative impact on the economy of the North Coastal area, from recreation use at the conservation reservoirs in that area, will be very significant. However, the greatest intensity of recreation use will be at the reservoirs associated with the conveyance and reregulation of the imported water since they will be located closer to population centers.

11. The construction of major reservoirs on the North Coastal streams would significantly affect fish and wildlife resources. For the earlier staged projects, salmon and steelhead could be preserved and possibly enhanced, with conventional techniques, such as hatcheries, artificial spawning channels, and controlled water releases. Wildlife could be maintained by increasing the productive capacity of adjacent lands.

    Fishery detriments caused by later-staged reservoirs in the lower reaches of the major streams would create much more difficult preservation problems. For these projects, the conventional preservation techniques would have to be supplemented by new and presently untried measures. One possibility would be the relocation of fish runs to the minor coastal streams. It is doubtful, however, whether the entire anadromous fish population of the Klamath River could be preserved if a major dam is constructed on the lower reaches of that stream.

12. The plans described herein embrace areas of water resource development in which local, state, and federal agencies have traditional roles. Only through interagency cooperation in planning and construction will it be possible to efficiently utilize investment capital and technical manpower and ensure that optimum development takes place.

Project Conclusions

The plans for water development described in this report would consist of a number of individual projects. The initial project would fulfill the need for an additional conservation facility of the State Water Project in the North Coastal area. Succeeding projects would meet future statewide water needs arising under the State Water Resources Development System. Possible features of these projects are shown on Plate 1 and are discussed in Chapter IV. The essential conclusions regarding the definition of each project are as follows:

Upper Eel River Development

1. A multiple-purpose water conservation project drawing surplus water from the Upper Eel River is the most favorable initial North Coastal development for providing augmentative water supplies to the State Water Project at the Sacramento-San Joaquin Delta.

2. The physical works of this project would include conservation reservoirs on the Middle Fork of the Eel River in Mendocino County, and associated works to convey the surplus water to the Delta, via either (1) pumped diversion to a reservoir on the upper main Eel River with subsequent gravity diversion via Clear Lake, Soda Creek, Putah Creek, and Lake Berryessa, or (2) gravity diversion to elements of the Glenn Reservoir Complex on Thomes and Stony Creeks on the west side of the Sacramento Valley.

3. The primary purpose of the Upper Eel River Development would be to conserve water supplies for delivery to water deficient areas within the State under the utility operation of the State Water Project. Additional purposes would include flood control, fisheries enhancement, power generation, and recreation.

4. The wide range of physical alternatives within the development preclude selection of an optimum project scale or final identification of specific project features on the basis of reconnaissance studies. These phases of project formulation will be accomplished in the feasibility-level studies which began July 1, 1964.

5. The operational flexibility and comprehensive range of project services associated with this development offer a unique opportunity for joint participation between the state and federal agencies in planning, construction, and operation of the project. Such cooperative effort would be mutually advantageous to all of the agencies.

Paskenta-Newville Project

1. The Paskenta-Newville Project on the west side of the Sacramento Valley, utilizing the two northernmost elements of the Glenn Reservoir Complex, would be one of the more favorable remaining water conservation developments in the Sacramento River Basin.

2. The Paskenta-Newville Project would conserve the surplus flows of Thomes and North Fork Stony Creeks. It would be possible later to integrate the storage facilities of this project with the whole Glenn Reservoir Complex for reregulation of water imported from the North Coastal area.

3. The major portion of water conserved by this project would be released to the Sacramento-San Joaquin Delta for firming unregulated flows. Additional purposes would include local water service, recreation, and fisheries enhancement.

4. The storage facility would consist of two reservoirs with a connecting spillway channel: Paskenta Dam and Reservoir on Thomes Creek and Newville Dam and Reservoir on North Fork Stony Creek. Total gross reservoir storage would be 1,200,000 acre-feet. The estimated capital cost of the project is $30 million.

5. If operated on a schedule for firming unregulated flows in the Delta, the project could develop a new annual yield of 200,000 acre-feet.

6. The scale of this project is limited by the amount of runoff tributary to the site. The potential storage in Newville Reservoir is much greater than is needed to control the runoff. The 1,200,000 acre-feet capacity is based on statistical considerations related to the time required to fill the reservoir.

Trinity River Development

1. When statewide water demands require development of major North Coastal water supplies beyond the capability of the Upper Eel River Development, the next most favorable sources of surplus water will be in the Upper Trinity River and adjacent basins.

2. The water resources in the Upper Trinity River and its adjacent basins could be developed through the staged construction of three physically integrated projects. These projects have been designated the Trinity Diversion Project, the South Fork Trinity Project, and the Mad-Van Duzen Project.

3. The three Trinity River projects are comprised of two groups of physical works: (1) conservation features on the North Coastal streams, and (2) associated conveyance features to and reregulatory features within the Sacramento River Basin.

4. The relationship between physical and economic factors associated with the conservation features of the three projects results in a very narrow latitude in selecting the optimum scale of development. The export yield from each project would be approximately 600,000 acre-feet per year, for a total three-stage annual yield of 1,800,000 acre-feet.

5. There are two alternative routes for exporting water from the Trinity River Basin to the Sacramento River Basin: (1) gravity diversion to Clear Creek, or (2) gravity diversion to Cottonwood Creek. Selection of the route will be made when demands for water service require feasibility-level studies of the projects.

6. The routing via Clear Creek permits generation of substantial quantities of hydroelectric power through construction of reservoirs and powerplants on Clear Creek. However, under projected planning criteria such power generation would be economically marginal. Very little additional new water yield is developed on Clear Creek itself; hence, the scale of accomplishments of a project with routing via Clear Creek would be controlled by the scale of the North Coastal area conservation features.

7. Trinity River yield routed via Cottonwood Creek could be conveyed through the Westside Conveyance System to the Glenn Reservoir Complex. The scale of accomplishments of a Trinity River project with this routing would be considerably greater than with the Clear Creek routing since additional new water yield would be derived from the Westside Conveyance System and the Glenn Reservoir Complex.

Greater Berryessa Project

1. An exceptionally large reservoir with a low unit cost of storage could be formed by construction of a high dam downstream of the existing Monticello Dam.

2. An enlarged Lake Berryessa could economically provide the following services: water conservation, through pumped diversion and storage of Sacramento River flood flows; hydroelectric power utilizing reversible pump-turbine units; reregulation of water conveyed from the Eel River.

3. An enlarged Lake Berryessa, with a storage capacity of 14,000,000 acre-feet, would produce a new annual yield in the Sacramento-San Joaquin Delta of about 1,600,000 acre-feet from drawdown storage and firming of unregulated flows. This would be in addition to releases for the Solano Project and to whatever yield is imported from the Eel River Basin.

4. Staging considerations indicate that this project should be deferred until demand for project services of this large scale develops.

Lower Eel River Development

1. Major water conservation projects on the Eel River below Dos Rios should not be constructed until after the more favorable developments in the Upper Eel River and Trinity River Basins.

2. The primary reason for this later staging is the very high cost of relocating the Northwestern Pacific Railroad out of the Eel River canyon. A major reservoir on the Lower Eel River would

necessitate relocation of about 100 miles of this roadway, at an estimated cost of $130 million.

3. With the works shown in this report, approximately 1,000,000 acre-feet of new annual yield could be developed for export from the Lower Eel River.

4. The Lower Eel River Development is not susceptible to staged construction. The railroad relocation must be accomplished at one time and the high associated cost could not be absorbed with anything less than full-scale development.

5. The water diverted from the Lower Eel River will be pumped upstream through the conservation reservoirs of the earlier-staged Upper Eel River Development. The tunnels and pumping plants of the Upper Eel River Development, however, should not be sized to accommodate Lower Eel River yield, since the incremental capitalized cost of providing the excess capacity during the interim period would exceed the cost of constructing additional facilities at the time of need.

Klamath River Development

1. The water resources of the Klamath River Basin, including the Lower Trinity River, represent the largest potential source of surplus water in the North Coastal area. Projections of state-wide demand indicates that development of this water will not be required for many years.

2. The scale of any project conserving water on the Klamath River and diverting it to the Sacramento Valley would be very great. The scale is indicated by one of the possible plans, which would include construction of Humboldt Dam and Reservoir. This reservoir, with gross capacity of 15,000,000 acre-feet, would develop approximately 6,000,000 acre-feet of firm annual yield. With the associated conveyance system to the valley, the works of the project would represent an investment of over $1.6 billion.

3. Any large dam constructed on the lower reaches of the Klamath River would serve as an impassable barrier to anadromous fish.

The existing runs of salmon and steelhead are so large that conventional methods of preservation would be able to preserve only a small portion of the resource. The potential fisheries loss could possibly be mitigated by the associated improvement of conditions for fish production on the smaller coastal streams.

Knights Valley Project

1. The future construction of Knights Valley Reservoir on Maacama and Franz Creeks, tributaries of the Russian River, would provide a favorable multiple-purpose project. This comprehensive water development would provide water services within the Russian River and adjacent basins.

2. The Knights Valley Project offers potential for staged development, parallel to the growth of demand for water services. An initial stage would be justified on the basis of developing flows in Maacama and Franz Creeks. Later staged development would include raising the two dams and construction of diversion facilities for pumping surplus flows from the Russian River into the enlarged reservoir. Under full development, a reservoir with gross storage of 1.5 million acre-feet could provide a new water yield of 300,000 acre-feet per year.

3. Services provided by this project would include water conservation for agricultural, municipal, and industrial uses, flood control in the Russian River Basin, and outstanding recreation.

4. The plans which have been proposed for this project by the federal agencies are in broad agreement with the objectives of The California Water Plan. The State supports the long-range intention of the federal agencies to construct the project.

Recommendations

The substance of the recommendations from this investigation was presented in the department's Preview Report to this bulletin, published in September 1963. In order to ensure continuity in the transition to the subsequent planning programs, the department has already taken actions to implement the recommendations. These recommendations and the actions taken toward their implementation are as follows:

1. Recommendation: That Upper Eel River Development be officially selected and identified as the initial additional conservation facility of the State Water Project in the North Coastal area.

   Implementation: The Upper Eel River Development was authorized on March 9, 1964. Pertinent aspects of the authorization are discussed in the next section in this chapter.

2. Recommendation: That a planning program conducted to feasibility standards be initiated for the Upper Eel River Development in July 1964, with a target completion date of 1968. The program should include specific study in the following categories: water operations, flood control, hydroelectric power, recreation, fisheries and wildlife, water quality, watershed management, hydrology, geology, and economics.

   Implementation: A four-year feasibility-level planning program for the Upper Eel River Development was initiated in July 1964. The program is discussed in Chapter VII.

3. Recommendation: That formal agreements be negotiated with the concerned federal agencies to provide a cooperative planning program for the Upper Eel River Development.

   Implementation: Preliminary steps towards cooperative planning for the Upper Eel River Development have been initiated through the California State-Federal Interagency Group. Various aspects of federal-state cooperation are discussed in Chapter VI.

4. Recommendation: That the plans described herein be considered a planning framework for the development of the major sources of surplus water in the North Coastal area; and that the local, state, and federal agencies responsible for aspects of economic development which would affect or be affected by the plans, including other natural resources, transportation, and industry, consider future development in the light of these plans.

   Implementation: This report (Bulletin No. 136) is the vehicle through which the recommended consideration will take place.

5. Recommendation: That the plans presented herein for major water projects to follow the Upper Eel River Development be refined and modified on a continuing basis to reflect statewide water demands and technological changes; and that adequate funds be provided to support this planning program.

Implementation: Funds have been provided in the 1964-65 budget for the continuing area-wide North Coastal Area Investigation. This program is discussed in Chapter VII.

Authorization of the Upper Eel River Development

The Director of Water Resources is vested by law with executive authority to add certain units to the State Water Resources Development System. With specific reference to Sections 11290, 12931, and 12938 of the Water Code, the Director signed Project Order No. 7 on March 9, 1964, which authorized the Upper Eel River Development as an additional facility of the State Water Project. By virtue of this action, the project has been officially selected and legally identified as the State's initial additional water conservation facility in the North Coastal area.

Previous reports of the department indicated that a project drawing surplus water from the Middle Fork Eel River would be selected as the initial state facility in the area. These reports included the Progress Report for the North Coastal Area Investigation, published in May 1961, and the Preview Report to this bulletin, published in September 1963.

The primary purpose of the development will be to augment water supplies available for diversion from the Sacramento-San Joaquin Delta, so as to prevent a reduction in the minimum water yield of the State Water Project. The major portion of new water developed by the project will thus be used to guarantee delivery of presently contracted water service. Additional purposes associated with the development will include water service to local areas, flood control, hydroelectric power, recreation, and fisheries and wildlife enhancement.

The works of the Upper Eel River Development are discussed in Chapter IV.

CHAPTER II. THE NORTH COASTAL AREA

For many years the North Coastal area has been synonomous with some of the State's outstanding scenic and recreational attractions: the giant redwood trees along Highway 101, many miles of rugged coastline, and unexcelled salmon and steelhead fishing streams. As statewide planning for water development has focused increasing interest on this area, it has been recognized that the region is relatively unknown to many Californians. Some of the factors which have contributed to this lack of knowledge are its distance from major population centers, limited accessibility, and the fact that many of its products are not readily identifiable with the area.

This chapter provides a general description of the North Coastal area. Some of the items touched upon are covered in much more detail later in the report, principally in Chapter V, Investigative Activities, and in the appendixes. Although the discussion in this chapter is in general terms, it is oriented toward descriptive aspects related to water resources. These aspects are discussed in two broad groups: the physical characteristics which distinguish the area, and the character of the region's economic development.

Physical Description

This section presents a brief physical description of the North Coastal area and is divided into the following subsections: location, topography, climate, and stream system.

Location

For this investigation the North Coastal area has been defined as that portion of northwestern California bounded by the Oregon border on the north, the Pacific Ocean on the west, the southern boundary of the Russian River Basin on the south, and the drainage divide of the coastal mountain ranges on the east. Since it is this latter drainage boundary which gives primary definition to the area, it is appropriate to describe it in more detail.

The northwestern part of the State is interlaced with mountain ranges. The primary drainage divide in these mountains begins north of San Francisco Bay and runs in a northerly direction for over 200 miles. The divide swings to the northeast around the head of the Sacramento Valley, then runs north again to the Oregon border. The land lying to the west is drained directly to the ocean by the Eel, Trinity, and Klamath Rivers and innumerable smaller streams. It is this large group of coastal drainage basins which comprise the North Coastal area.

This region includes almost 20,000 square miles of land, or 13 percent of the total land area in California. It includes all of Del Norte, Humboldt, Trinity, and Mendocino Counties and portions of Siskiyou, Modoc, Shasta, Tehama, Glenn, Lake, and Sonoma Counties. The contiguous drainage areas within the Sacramento River Basin which were also studied in this investigation, including portions of Colusa, Lake, Napa, Yolo, and Solano Counties, are not actually defined as being in the North Coastal area.

Topography

The North Coastal area is mountainous and rugged. In the whole region, only 13 percent of the land is classed as valley or mesa; excluding the Klamath River Basin, less than 6 percent is valley or mesa. There are two distinct mountain groups which give the area its rugged characteristics: the Klamath Mountains and the northern provinces of the California Coast Ranges.

The Klamath Mountains occupy a large part of the northwestern corner of the State. The range includes a number of locally named mountain units, although they all have a common geomorphologic tie. Some of these minor ranges are the Siskiyou, Marble, Salmon, and Scott Mountains, and the Trinity Alps. Much of this country is very remote and inaccessible, an area of magnificent scenery. Peaks and ridges rising boldly above deep, narrow canyons mark the mountains. The higher country includes beautiful rock-basin lakes. Some of the higher peaks include Mt. Eddy (9,025 feet), Thompson Peak (8,936 feet), and China Mountain (8,551 feet).

The northern provinces of the California Coast Ranges lie south and west of the Klamath Mountains. The range is characterized by elongated, northwest-trending ridges and valleys. The mountains are not as high as the

Klamath, the highest range being along the west side of the Sacramento Valley at a general altitude of about 6,000 feet, with a few peaks rising to 8,000 feet. Toward the coastline, the crests of the ranges are progressively lower. The terrain has a more weathered and rounded appearance than the Klamath region. Landslides of both small and large scale are common throughout the Coast Range.

Climate

The climatic aspects of most general interest are temperature and precipitation. The area lying along the coast has moderate temperatures, influenced largely by the ocean. Heavy and recurrent fogs are common throughout much of the year, as are northwest winds. Inland from the coast the temperatures have a wider variation. Summer temperatures are often quite hot and winter temperatures may hover within a small range above freezing for extended periods. Temperatures inland are heavily influenced by elevation and by the topography of the immediate locality.

The precipitation of the North Coastal area has a much more clearly defined regional character than the temperature. Winter storms moving in from the ocean must rise to clear the mountains; the result is heavy precipitation on the western slopes of the mountain ranges. The rainfall in this area is of greater frequency and annual magnitude than anywhere else in the State. The Smith River and lower Klamath River Basins experience a range of 60 to 125 inches per year (on an average seasonal basis), and a range of 40 to 60 inches per year is common in the Eel and Russian River Basins. Precipitation is distinctly seasonal, very little occurring during the months of June through September.

The largest percentage of precipitation is in the form of rainfall. Snow falls in moderate amounts above 2,000 feet, but only at altitudes above 4,000 feet does snow remain on the ground for appreciable periods of time.

Stream System

The mountainous terrain and heavy rainfall in the North Coastal area have resulted in the formation of a complex stream system. There are a great number of individual drainage basins, including five basins with over 1,000,000 acre-feet of annual runoff. The total mean annual natural runoff for the entire area is about 29,000,000 acre-feet.

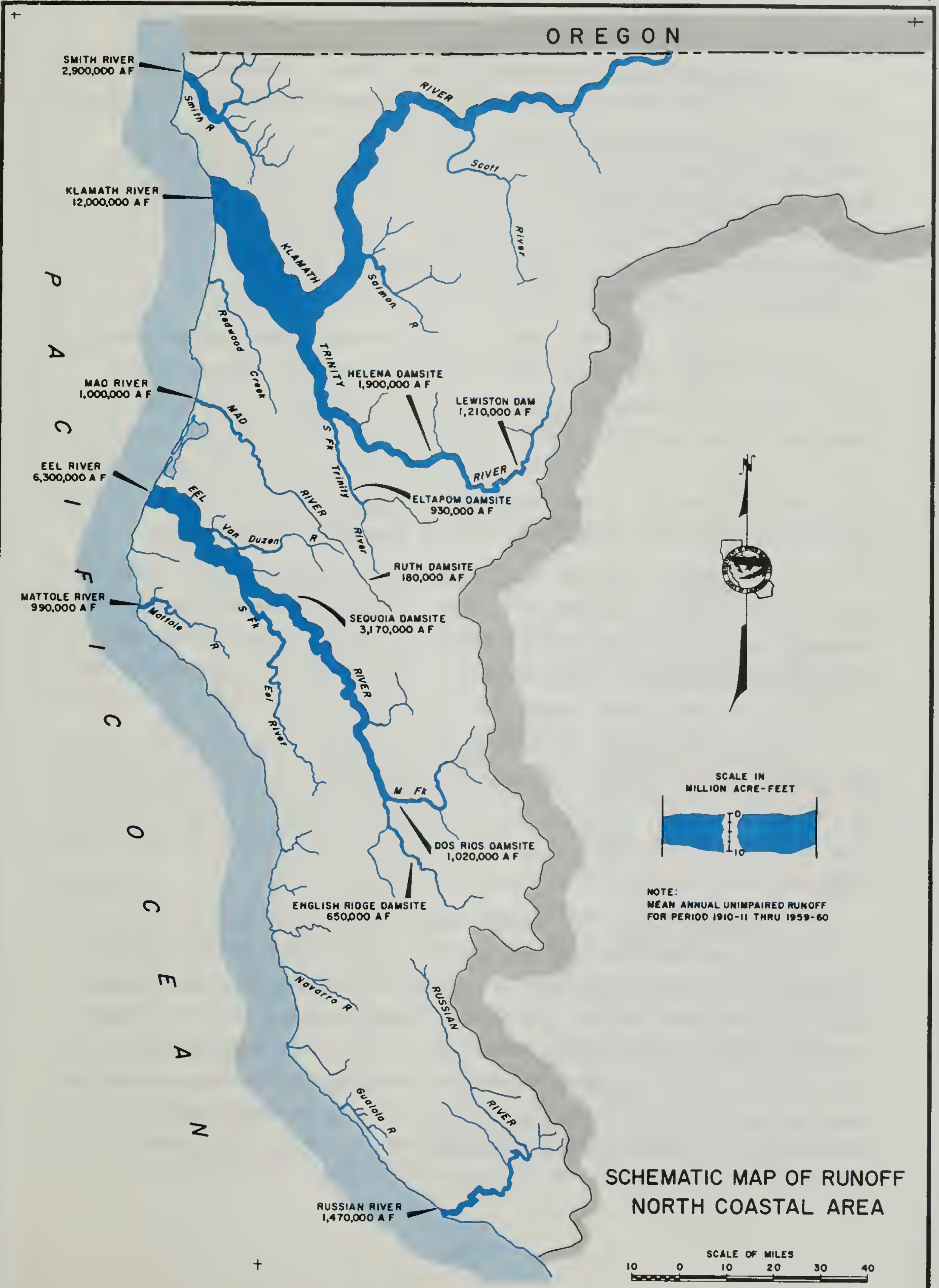
Although the Eel, Trinity, and Klamath Rivers do have some contribution from snowmelt, the stream system is fed primarily by rainfall and consequently the runoff follows a seasonal pattern. In many years runoff from even the major rivers dissipates rapidly during the late spring and summer. Some of the rivers are little more than a series of pools in the late summer.

Figure 1 shows a schematic illustration of the runoff of North Coastal streams. The quantity of annual runoff is indicated by the width of the line representing each stream. The figure readily shows why the Eel, Trinity, and Klamath Rivers are being considered as sources of future water supply. The relatively small amounts of water available for control by the U. S. Bureau of Reclamation's Trinity River Project at Lewiston and by the department's proposed Upper Eel River Development at Dos Rios damsite are apparent in Figure 1.

The following paragraphs are devoted to brief descriptions of each of the major rivers in the North Coastal area.

Smith River. The Smith River Basin occupies the extreme northwestern corner of California. It drains a total of 719 square miles, 87 of which are in Oregon. Although relatively small in area, the basin has the highest average rainfall in the State, and thus produces a large mean annual natural runoff of 2,900,000 acre-feet. The basin offers a potential future water supply; however, it is situated so far from water-deficient areas that no plans have been formulated in this investigation for developing its water resources.

Klamath River. The Klamath River is by far the largest stream in the North Coastal area. Its 12,000,000 acre-feet of average annual natural runoff is about 40 percent of the total runoff of the North Coastal area. Major tributaries include the Trinity, Salmon, Scott, Shasta, Sprague, and Williamson Rivers. The stream system drains a total area of 15,700 square miles, 5,695 of which are in Oregon. In 1957, California and Oregon established an interstate compact commission to insure equitable distribution of Klamath River water between the two states.



SCHEMATIC MAP OF RUNOFF
NORTH COASTAL AREA

DEPARTMENT OF WATER RESOURCES 1964

Trinity River. The Trinity River, a major tributary of the Klamath River, lies in the southern provinces of the Klamath Mountains. It drains a total area of 2,969 square miles. The eastern boundary of the basin coincides with over 100 miles of the divide between the Sacramento River Basin and the North Coastal area. The Bureau of Reclamation's Trinity River Division of the Central Valley Project was completed in 1964. The division's facilities provide for the diversion of about 865,000 acre-feet per year into the Sacramento Valley.

Eel River. The Eel River, with an average annual natural runoff of 6,300,000 acre-feet, is the second largest river in the North Coastal area. The basin lies south of the Trinity River Basin, in the northern provinces of the California Coast Range. Total drainage area in the basin is 3,700 square miles. It is interesting to note, as illustrated on Figure 1, that less than half the total runoff of the Eel River passes Sequoia damsite, the farthest downstream damsite considered during the investigation.

Mad River. The Mad River Basin is a long and very narrow basin lying between the Eel and Trinity Rivers. It has a drainage area of 497 square miles and an average annual natural runoff of 1,000,000 acre-feet. Ruth Dam and Reservoir, which lies high in the watershed, was constructed in 1961 to provide a water supply for the Eureka-Arcata area.

Van Duzen River. The Van Duzen River is a major tributary of the Eel River, joining it about 15 miles from the ocean. It has a drainage area of 430 square miles. Although it is a tributary of the Eel, the studies show it should be developed as a stage of the Trinity River Development, with diversion via the Mad River and South Fork Trinity River.

Russian River. The Russian River Basin is the southernmost basin in the North Coastal area. It has a total drainage area of 1,498 square miles and an average annual natural runoff of 1,470,000 acre-feet. This basin has undergone the greatest economic development of any of the North Coastal basins. The proximity of the San Francisco Bay area population center has promoted extensive recreational development. The major existing water project in the basin is Coyote Dam and Reservoir (Lake Mendocino) on the East Fork of Russian River, constructed by the Corps of Engineers in 1959.

Construction is expected soon on Warm Springs Dam and Reservoir on Dry Creek. This Corps of Engineers project was authorized in 1962.

Coastal Streams. The low mountain ranges along the coast contain a number of small individual drainage basins, usually collectively termed the coastal streams. Most of these lie along the Mendocino coast between the Russian and Eel River Basins. The largest stream in this group is the Mattole River, with an average annual natural runoff of 990,000 acre-feet. Other smaller streams include the Bear, Tenmile, Noyo, Big, Albion, Navarro, Garcia, and Gualala Rivers.

Between the Klamath and Mad Rivers is the Redwood Creek Basin. This stream is also considered one of the coastal streams. It drains an area of 280 square miles.

Economic Development

The economic development of the North Coastal area has been influenced predominantly by its physical characteristics. This is true from two aspects. First, the economic growth that has taken place has been almost entirely related to development of the area's natural resources. Secondly, the factors which have inhibited a greater rate of economic growth are largely of a physical nature.

This section presents a brief summary of various aspects of economic development in the North Coastal area. The following subjects are discussed: population, transportation, industry, land use, existing water use, future water requirements, and water rights.

Population

For the more than 100 years in which there have been settlements in the North Coastal area, the location of population centers and pattern of population growth have run parallel to development of the area's basic natural resources. In most cases the growth of individual towns has been associated with development of a local resource and the collective growth that has taken place in the whole area does not really represent growth of a unified economic region.

The initial influx of people to the area was prompted by the discovery of gold in Trinity and Siskiyou Counties in the 1850's. When the gold mining activity decreased, efforts were turned toward lumbering and limited agricultural developments. These activities developed at a snail's pace for many years because of transportation problems and the scarcity of good land. Except in the Humboldt and Mendocino areas, which were more accessible, the area in the last part of the nineteenth century was practically dormant. For instance, not until 1950 did Trinity County's population again become as great as it was in 1860.

The 1960 population of the seven counties located entirely or largely within the North Coastal area was estimated at 377,500. This was 2.4 percent of the total population in the State. Most of the North Coastal population is centered in the following cities and towns, listed in order of decreasing size: Santa Rosa, Eureka, Ukiah, Arcata, Healdsburg, Yreka, Fort Bragg, Fortuna, and Willits. From a regional standpoint, the population concentrations are in the Russian River Basin and the Humboldt Bay area.

One phase of the Coordinated Statewide Planning Program, described in Chapter V, is to estimate the future population in areas throughout the State. These studies for the North Coastal area indicate that its 1960 population will increase by about four and one-half times, to 1,751,000 people, by the year 2020. The availability of undeveloped land and resources and improved transportation are major reasons for this projected surge in growth.

The following tabulation shows the distribution of the present and projected population among the seven counties of the North Coastal area.

County	Population in 1960	Estimated Population in 2020
Del Norte	17,800	56,000
Siskiyou	32,900	155,000
Humboldt	104,900	390,000
Trinity	9,700	25,000
Mendocino	51,100	224,000
Lake	13,800	101,000
Sonoma	147,300	800,000
Total	377,500	1,751,000

For comparison, the population for the entire State was 15,717,000 in 1960, and is estimated to be 56,000,000 in 2020, an increase of about three and one-half times.

Transportation

Development of a transportation network for the movement of goods and persons is of major importance in the economic development of a region. Such a network includes roads, railroads, shipping, and in modern times, air service.

For many years economic development in the North Coastal area was inhibited by the difficulty of constructing a transportation system in the rugged terrain. Road and railroad alignments included many cuts and fills, often in areas susceptible to sliding, In the last few decades, new construction methods and machinery, together with an increasing demand for products from the North Coastal area, have enabled transportation projects not previously possible. This has in turn permitted greater access to and through the area, with a corresponding boost to the regional economy. In the following paragraphs each of the types of transportation is reviewed briefly.

The principal highway in the area is Highway 101, the Redwood Highway. This highway extends from the Bay area through the Russian River Basin, over the divide into the Eel River Basin, down the canyon of the South Fork and main Eel River to Eureka, and then up the coastline to Oregon. Highway No. 1, the only other north-south highway, extends from the Bay area along the coast to join Highway 101 south of Garverville.

There are three major east-west highways crossing the mountains between U.S. 101 and U.S. 99: State Highway 20 via Clear Lake, U.S. Highway 299 between Eureka and Redding, and U.S. Highway 199 between Crescent City and Grants Pass, Oregon. In addition, State Route 36 is an adequate dry-season route between the Eureka area and Red Bluff.

The principal railroad in the North Coastal area is the Northwestern Pacific, which extends from the San Francisco Bay area northward to Arcata. For over 100 miles this roadway runs through the canyon of the Eel River. Despite an exceptionally high maintenance cost due primarily to landslides, the railroad is commercially successful. Much of the lumber produced in the region is shipped over this railroad.

The principal harbor along the California coast north of San Francisco Bay is at Humboldt Bay. This harbor serves shipping to both coastal and foreign ports. The principal import is petroleum products; the main export is lumber and logs destined for foreign ports. There is also a harbor at Crescent City to handle coastal shipping. Noyo Harbor at Fort Bragg is an important fishing port.

Commercial airline service includes scheduled flights to airports near Arcata and Crescent City. There are also a large number of smaller airports, some excellent, to accommodate private planes.

Industry

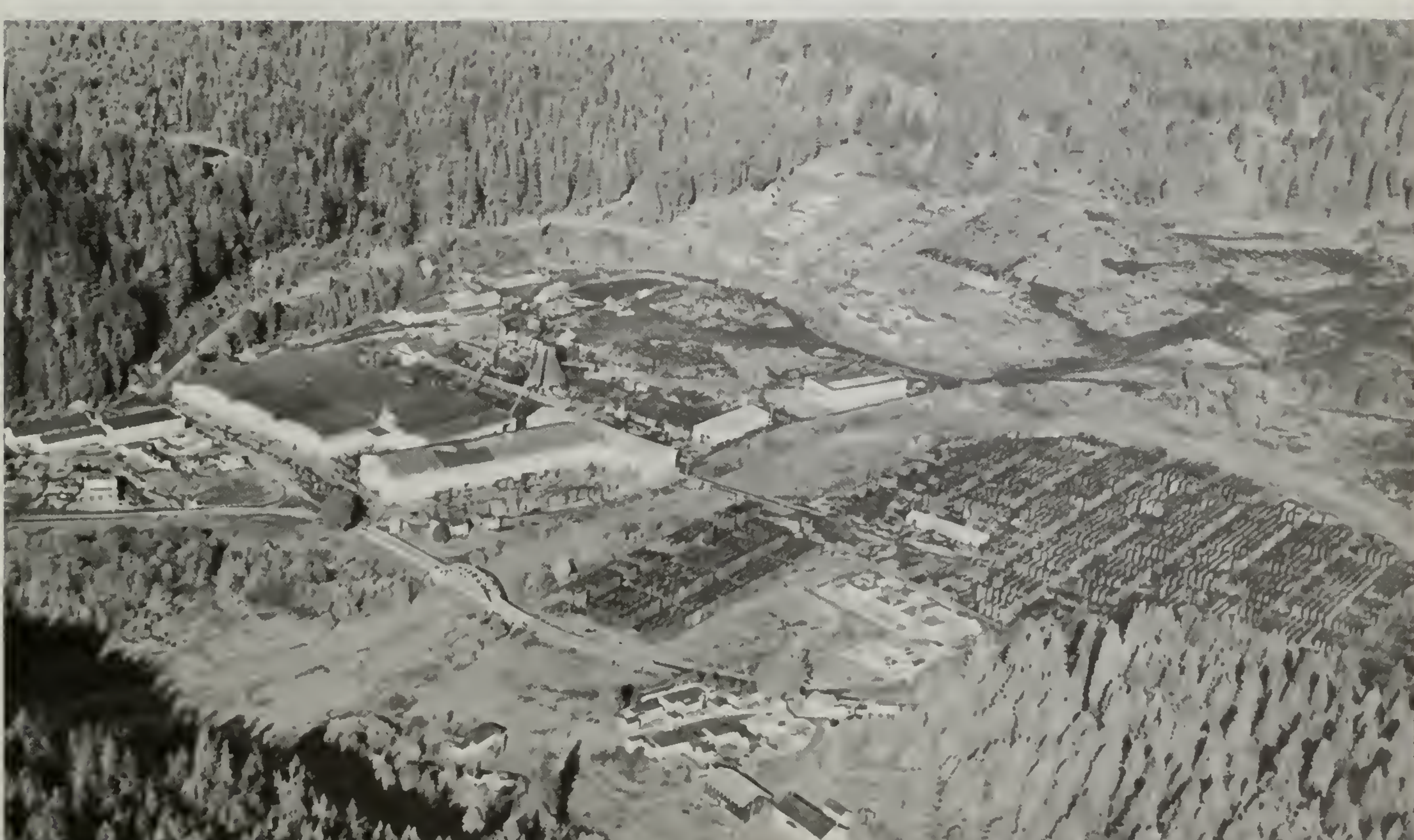
The principal industries of the North Coastal area are lumbering, agriculture, recreation, commercial fishing, and to a very limited extent, mining. Lumbering is by far the most important part of the economic base. It is estimated that the North Coastal forests contain almost 150 billion board-feet of commercial timber, mainly Douglas fir, redwood, and pine. Lumber production has averaged over 5 billion board-feet annually in recent years. Approximately 70 percent of the population in Northwestern California is directly or indirectly dependent on lumbering for a livelihood.

Agriculture was initially developed in this area to meet local needs only. However, during recent decades, with improvements in transportation, agriculture has become increasingly important to the region's economy. Livestock production is the most important agricultural activity. Dairying is highly developed in Sonoma and Mendocino Counties and in the Humboldt Bay area of Humboldt County. Beef production is the mainstay of the remaining North Coastal area. The growing of feed crops has been developed and extended concurrently with the growth of the livestock industry. Fruits, nuts, and grapes are grown commercially in Sonoma and Mendocino Counties, the latter being processed in local wineries.

In recent years the recreation industry has become increasingly important to the economic base of the North Coastal area. Development has come through both public and private investment. The public development includes many state parks located along the coast and in the redwood forest areas near the coast. Private development includes many resorts and the large motels and restaurant facilities required to serve people seeking recreation in the area.

Fishing boats at Eureka

Lumber mill at Korbel on Mad River



The commercial fishing industry is of considerable economic importance in the coastal areas. The centers of the industry are Eureka and Fort Bragg; and sole, crabs, and salmon are the most important products.

Land Use

Forest and range lands represent about 98 percent of the total area. Much of this land lies within national forests, and a considerable amount of the privately owned forest lands are held in large ownerships. The principal economic uses of these lands are associated with lumbering and livestock grazing.

At the present time, approximately 260,000 acres, or less than 2 percent of the lands of the North Coastal area, are irrigated. Of the total, 175,000 acres lie in the Upper Klamath River Basin, above the confluence of the Scott and Klamath Rivers. About 20,000 acres are in the immediate vicinity of Humboldt Bay, 35,000 in the Russian River drainage area, and 20,000 acres are in Lake County. The remaining 10,000 acres are scattered throughout the area.

In the upper Klamath area pasture, hay, grain, and potatoes are the main irrigated crops. In the other areas, pasture accounts for about 70 percent of the irrigated land. Orchards and vineyards are the principal remaining irrigated crops, occurring mostly in the Russian River drainage area.

Dry farm cultivated lands produce hay and grain as well as orchard and vineyard crops, the latter again located mainly in the Russian River drainage area.

Existing Water Use

The applied water use in the North Coastal area is estimated to be about 700,000 acre-feet a year. About 90 percent of this is used in irrigating crops, mainly in the upper Klamath River Basin, along the Russian River, in the Eel River Delta, and in Lake County. Other irrigation developments are small and scattered throughout the area.

The remaining 10 percent of the total applied water use in the area (approximately 70,000 acre-feet a year) is by municipal, industrial, and recreational developments. The forest products industries account for the major portion of the industrial use of water. Plans for expansion of their activities into pulp and paper production will result in future demands for quantities of water considerably greater than can be satisfied by existing local water storage facilities.

Future Water Requirements

Development of the water resources of the North Coastal area for export is predicated upon exporting only water which is surplus to requirements within the area. Thus, before a comprehensive plan of development can be formulated, it is necessary to have available an inventory of projected future water requirements for the areas of origin. These estimates have been prepared under the department's Coordinated Statewide Planning Program.

Preliminary estimates of the future water requirements for counties within the North Coastal area are summarized in Table 1, entitled "Estimated Year 2020 Water Requirements in the North Coastal Area." In order to present a complete picture, the table includes estimated requirements for all of the North Coastal area, including hydrographic units which would not be directly affected by major water development plans.

The estimated year 2020 water requirement data include consideration of agricultural, municipal, industrial, and recreational uses for each of the areas. Within the Humboldt Bay area of Humboldt County and the Mendocino Coast area of Mendocino County, a substantial portion of the total water requirement is attributable to projected uses of the pulp and lumber industry.

Water Rights

The State has water right applications on file with the State Water Rights Board for the proposed major export water developments in the North Coastal area. These applications are held by the California Water Commission, and may not be assigned to any constructing agency, federal, state, or local, if such assignment will, in the judgment of the Commission, deprive the county in which the water covered by the application originates of any such water necessary for the development of the county.

TABLE 1

ESTIMATED YEAR 2020 WATER REQUIREMENTS
IN THE NORTH COASTAL AREA
(In acre-feet)

County/Hydrographic Unit	Irrigation	Other	Total
Modoc			
Lost River-Butte Valley	175,000	---	175,000
Siskiyou			
Lost River-Butte Valley	523,000	2,000	525,000
Shasta-Scott Valleys	245,000	5,000	250,000
Klamath River	24,000	2,000	26,000
County Totals	792,000	9,000	801,000
Del Norte			
Smith River	15,000	5,000	20,000
Klamath River	2,000	1,000	3,000
County Totals	17,000	6,000	23,000
Trinity			
Trinity River	30,000	17,000	47,000
Mad River-Redwood Creek	500	---	500
Eel River	1,500	1,500	3,000
County Totals	32,000	18,500	50,500
Humboldt			
Klamath River	1,000	---	1,000
Trinity River	8,500	3,500	12,000
Mad River-Redwood Creek	15,500	53,000	68,500
Eel River	58,000	187,500	245,500
County Totals	83,000	244,000	327,000
Mendocino			
Eel River	57,500	15,500	73,000
Mendocino Coast	22,500	41,500	64,000
Russian River	48,000	28,500	76,500
County Totals	128,000	85,500	213,500

TABLE 1
(Cont'd)

ESTIMATED YEAR 2020 WATER REQUIREMENTS
IN THE NORTH COASTAL AREA
(In acre-feet)

County/Hydrographic Unit	Irrigation	Other	Total
Sonoma			
Mendocino Coast	500	1,500	2,000
Russian River	112,500	105,000	217,500
County Totals	113,000	106,500	219,500
Marin			
Russian River	5,500	4,000	9,500
Lake	100,000	50,000	150,000
Total North Coastal Area	1,445,500	523,500	1,969,000

Notes to Table 1

Values for Trinity River, Mad River-Redwood Creek, Eel River, Mendocino Coast, and Russian River Hydrographic Units were developed as part of the Coordinated Statewide Planning Investigation and are reported in Department of Water Resources Bulletin No. 142-1.1. All other estimates are preliminary and subject to change upon completion of a more detailed study to be conducted in the near future as part of the Coordinated Statewide Planning Investigation.

Requirements for other than irrigation include municipal, industrial, nonurban domestic, and recreational (excluding water requirements for fish maintenance and enhancement).

CHAPTER III. GENERAL PLANNING CONSIDERATIONS

Formulation of the broad plan for water resources development of the North Coastal region and of the individual projects which comprise the overall plan is controlled and influenced by a number of basic considerations. These include the water supply available for development; the geographic and geologic characteristics of the area; criteria applicable to formulating of the individual projects; and the economic concepts and guidelines which govern staging aspects of the plan. In addition to these factors, which influenced all of the planning of the investigation, there are particular considerations related to the State Water Project which bear on the need for the initial state project in the North Coastal area.

This chapter discusses these general considerations associated with planning major water projects in the North Coastal area.

Water Supply

A general description of the stream system of the North Coastal area was presented in Chapter II. The water supply which may be derived from these large streams is destined to play a major role in sustaining California's continuing growth. This section contains a discussion of the water resources of the North Coastal area as they relate to development of major increments of water supply. The hydrologic studies conducted during the investigation are discussed in Chapter V, Investigative Activities.

Precipitation

Annual rainfall in the North Coastal area is the highest of any region in California and is exceeded in the United States only along the western slopes of the Coast Ranges in Oregon and Washington. Table 2 shows the estimated mean annual precipitation for the period 1906-1955 at selected stations in the North Coastal area. The table also shows the maximum and minimum recorded annual precipitation for the stations. It can be seen from the table that the precipitation varies widely throughout the area, increasing generally from south to north and from east to west. This distribution is due to storm patterns and the orographic affect of the mountains. The table also illustrates that areas in the Upper Klamath River Basin, as represented by the station at Gazelle, lie on the eastern side of the general mountain barrier to Pacific storms, and consequently, receive much less precipitation than other parts of the North Coastal area.

TABLE 2

ANNUAL PRECIPITATION AT SELECTED STATIONS
IN THE NORTH COASTAL AREA

Station	Annual Precipitation, in inches		
	50-year Mean	Maximum	Minimum
Smith River Basin			
Crescent City	80	112	35
Monumental	101	124	90
Shasta River Basin			
Gazelle	11	18	5
Trinity River Basin			
Forest Glen	58	102	37
Hayfork	31	54	14
Hoopa	49	78	33
Weaverville	35	67	18
Eel River Basin			
Branscomb	77	133	46
Covelo	38	66	17
Eureka	37	74	21
Lake Pillsbury	40	63	27
Willits	51	97	19
Mattole River Basin			
Honeydew	107	174	79
Russian River Basin			
Healdsburg	38	73	17
Ukiah	35	60	16

The precipitation follows a distinctly seasonal pattern. Roughly three-fourths of the total precipitation occurs during the five-month period from November through March. The seasonal variation is illustrated in Table 3 which gives the monthly distribution as a percentage of mean annual precipitation (1906-1955) for six representative stations throughout the area. It will be noted that even though the amounts of precipitation vary at the different locations, the patterns of monthly distribution are very similar. This indicates the regional nature of most of the storms which cause precipitation in the area.

While most of the precipitation of the North Coastal area occurs as rain, a few stream basins derive a substantial portion of their runoff from snowmelt. For example, 51 percent of the total runoff of the Trinity River above Lewiston is derived from snowmelt; similarly, the Scott River derives 44 percent, the Salmon River 43 percent, and the Middle Fork Eel River above Covelo, 36 percent.

TABLE 3

MONTHLY DISTRIBUTION OF PRECIPITATION
AT SELECTED STATIONS IN THE NORTH COASTAL AREA

Station	Mean Annual Precipitation (in.)	Percentage of Mean Annual Precipitation											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Crescent City	82	16	15	13	8	5	2	1	1	2	7	14	16
Weaverville	36	18	16	11	7	4	3	t	t	2	6	14	19
Yreka	18	18	15	10	6	5	3	1	1	2	7	15	17
Eureka	37	17	16	13	8	5	2	t	t	2	7	14	16
Ukiah	35	22	18	13	6	3	1	t	t	1	5	11	20
Covelo	38	21	16	12	7	4	2	t	t	1	6	12	19

t - trace

Runoff

While the North Coastal region contains only 12 percent of the State's total area, it accounts for 41 percent of California's average annual surface water runoff. Two aspects of runoff which have a primary influence in the formulation of plans for development of water supplies are its areal distribution and variation with time.

Areal Distribution. The mean annual runoff of the North Coastal area, like the precipitation, increases generally from south to north and from east to west, varying from an average annual runoff of 82 inches in the Smith River Basin to 32 inches in the Eel River Basin.

The total water supply which can be economically developed in this region and conveyed to the Sacramento River Basin is a function of the areal distribution of runoff. As illustrated on Figure 1 (Chapter II), the potential sources of water supply are located at varying distances from the Sacramento River Basin. The basins lying contiguous to the Sacramento River Basin, the Eel and Trinity, both have sufficient runoff in their upper reaches to provide economical export projects. The lower reaches of these two streams, and the lower Klamath River, also offer potential water supplies if they are developed subsequent to the upper basin projects. With large scale projects in the lower basins, and utilizing the earlier staged reservoirs in the upper basins for conveyance, water supplies could be developed at a unit cost of yield comparable to the cost associated with upper basin projects.

The numerous drainage basins lying along the coast, although contributing substantially to the area's runoff, do not offer the potential for economically developing major increments of water supply. The unit cost of yield from projects in these basins would be significantly greater than the cost from projects in the large interior basins of the North Coastal region. This is true for the Smith River Basin also. Even though the Smith has a large runoff, it is so remote from the Sacramento Valley that very extensive and costly conveyance works would be required to accomplish the transbasin diversion.

<u>Annual Variation</u>. The annual variation of runoff for a given stream is a primary factor in determining the quantity of firm water supply which can be developed. The annual variation of runoff from North Coastal streams is illustrated by Figure 2, which depicts the estimated annual runoff of the Eel River at Scotia for the period 1911-1960. The trend of the graph is representative of major North Coastal streams. Several aspects related to developing water supply are apparent from the figure. The driest single year of record was 1924, when runoff was about 25 percent of the long-term mean. The period from 1928-1934 was the driest sustained period during which most of the reservoirs proposed in this report would have been drawn down to minimum storage in order to produce their firm yield. The average runoff during this period was about 60 percent of the long-term mean.

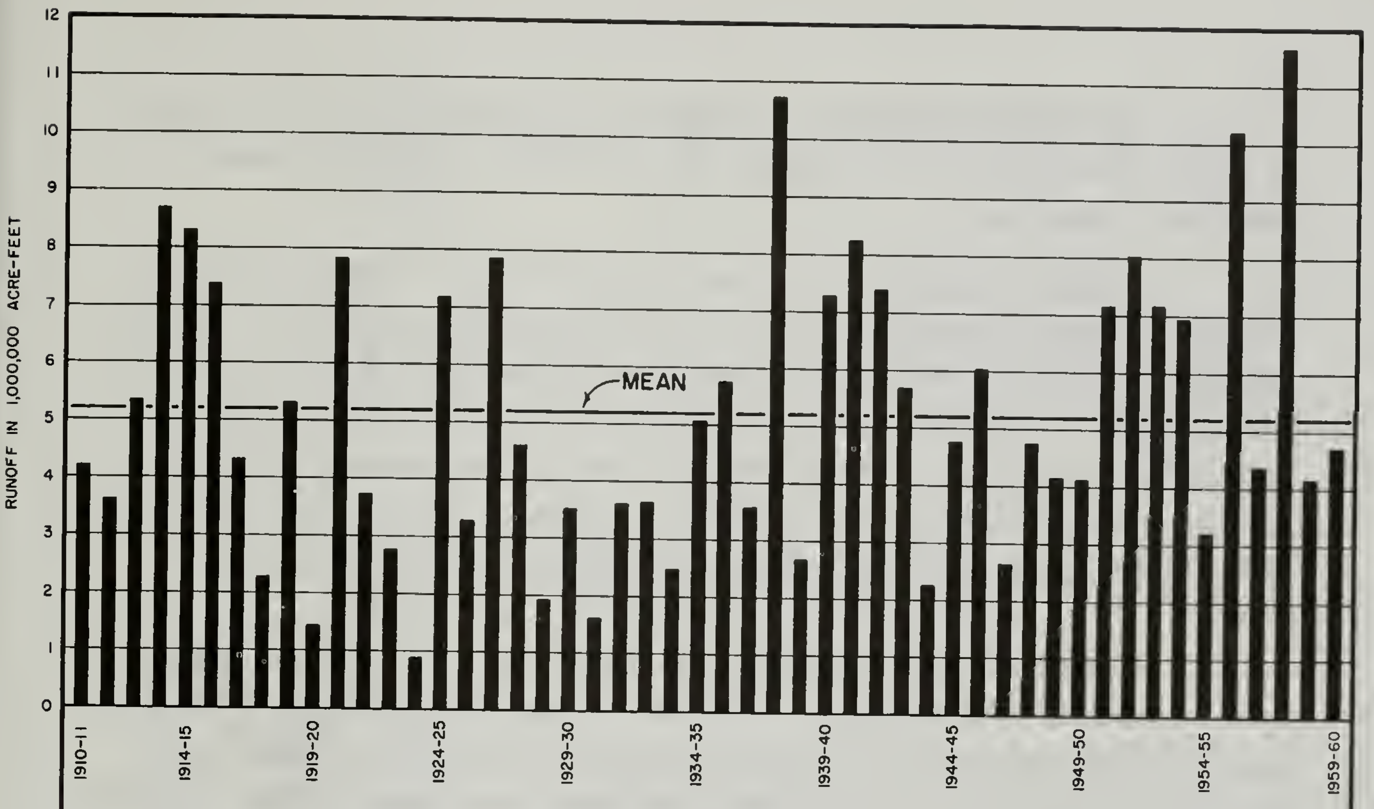


Figure 2. ESTIMATED ANNUAL RUNOFF
EEL RIVER AT SCOTIA

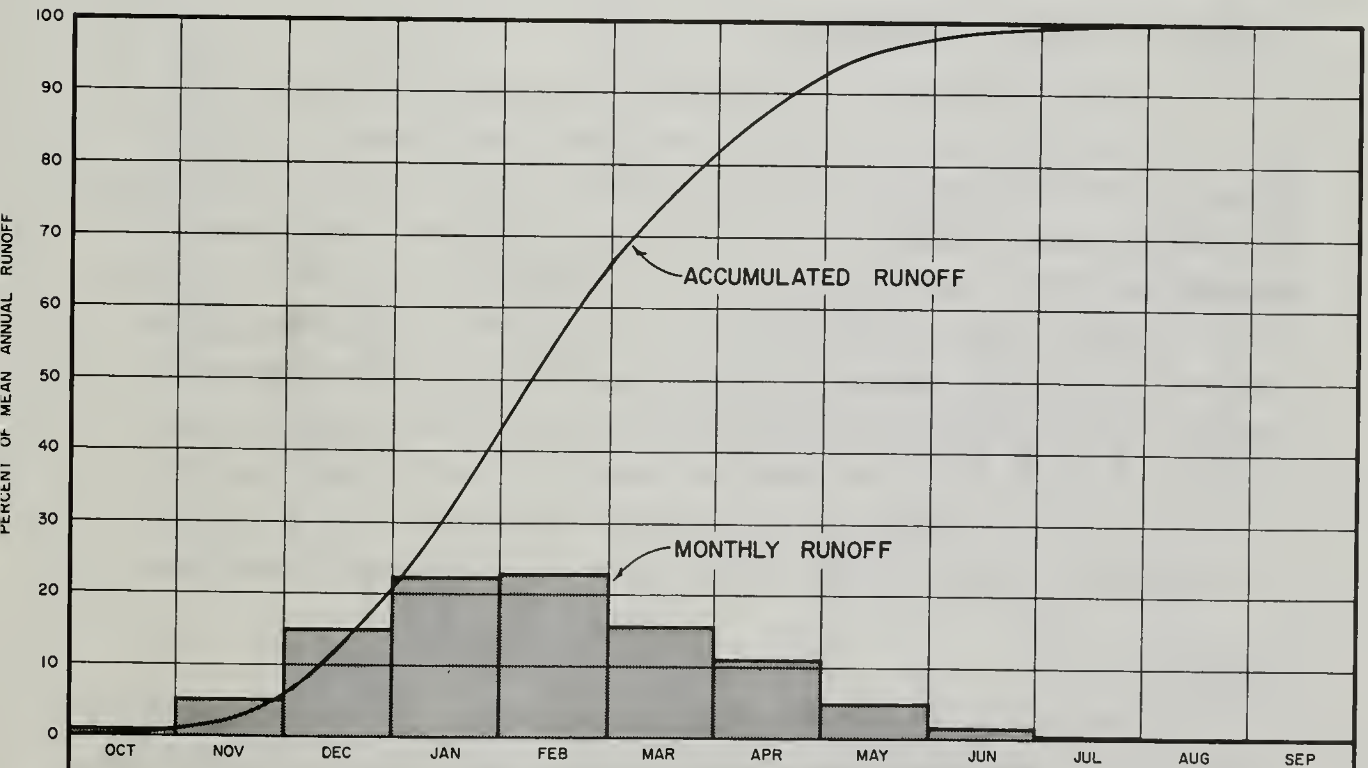


Figure 3. MONTHLY DISTRIBUTION OF MEAN ANNUAL RUNOFF
EEL RIVER AT SCOTIA

DEPARTMENT OF WATER RESOURCES 1964

The annual variation in runoff is also illustrated with the data in Table 4, which show the estimated natural annual runoff at proposed damsites in the area.

Monthly Variation. The monthly variation of runoff from North Coastal streams is generally similar to the precipitation pattern. Figure 3 depicts the monthly runoff for the Eel River at Scotia as a percent of mean annual runoff. The pattern is similar for other streams in the area, particularly those in the Coast Range mountains. The seasonal runoff of streams in the Klamath Mountains would be generally similar, but because of snowmelt and accretions from ground water the peak month would be April or May.

One aspect of water supply for local areas in the North Coastal area is apparent from Figure 3. This is the fact that in spite of the large annual runoff, many of the streams practically dry up in the summer and early fall. Many areas in this water-abundant region have serious shortages of water during this part of the year. The reservoir projects proposed in this report will help alleviate these shortages by providing annual carry-over storage.

Existing Major Water Developments

The only existing water resources development within the North Coastal region which can be classified as a major development is the U. S. Bureau of Reclamation's Trinity River Division of the Central Valley Project, the primary storage feature of which is Trinity Reservoir near Lewiston. Approximately 865,000 acre-feet per year is diverted from the Trinity River to the Sacramento River Basin through this project. Other existing water projects in the North Coastal area are: the Pacific Gas and Electric Company's Potter Valley power development including Lake Pillsbury which diverts an average of 167,000 acre-feet annually from the Upper Eel River to the Russian River Basin, and Ruth Dam and Reservoir on the Mad River which develops 84,000 acre-feet a year for use in the Eureka-Arcata area.

Water Quality

The mineral quality of North Coastal surface waters is generally excellent. The potential water quality problems are of limited areal scope,

TABLE 4

ESTIMATED NATURAL RUNOFF AT PROPOSED DAMSITES
IN THE NORTH COASTAL AREA

Damsite	Stream	Drainage Area Square Miles	50-yr. Mean Annual Natural Runoff (1911-1960) 1,000 A.F.	Max. Annual Runoff 1,000 A.F.	Min. Annual Runoff 1,000 A.F.	Av. Annual Runoff (1928-1934) 1,000 A.F.
Spencer	M.F. Eel River	426	735	1,645	128	445
Dos Rios	M.F. Eel River	745	1,022	2,433	156	547
English Ridge	Eel River	488	654	1,514	66	359
Bell Springs	Eel River	1,578	2,152	5,002	290	1,175
Sequoia	Eel River	2,241	3,166	7,339	473	1,794
Helena	Trinity River	1,299	1,909	4,418	346	1,095
Burnt Ranch	Trinity River	1,453	2,060	4,768	373	1,182
Ironside Mountain	Trinity River	1,705	2,489	5,759	451	1,430
Eltapom	S.F. Trinity River	767	936	2,060	155	550
Beartooth	New River	180	304	704	55	175
Ruth	Mad River	121	180	423	29	106
Anderson Ford	Mad River	211	331	777	52	196
Butler Valley	Mad River	352	740	1,294	208	513
Eaton	Van Duzen River	82	218	420	77	149
Larabee Valley	S.F. Van Duzen River	55	150	276	39	101
Humboldt	Klamath River	12,084	12,000	24,150	3,930	7,986

and are not expected to inhibit major water development in the North Coastal area. Chapter V contains a discussion of the water quality studies conducted during the investigation.

Ground Water

Ground water resources of the North Coastal area are found in widely scattered alluviated valleys and coastal plains. They furnish much of the water supply to certain local areas; however, there is insufficient capacity at any given locality to support long-range requirements in the area. Most areas must ultimately look to surface water development to meet their needs.

Physical Considerations

Geography

The physical shape of the land is one of the most important factors in planning major water developments. The terrain of the North Coastal area is generally rugged, being characterized by irregular mountain formations, steep slopes, and narrow valleys. However, the configuration and direction of flow of the North Coastal streams is an even more adverse geographic condition in the formulation of plans for the transbasin diversion of surplus flows to the Sacramento Valley. With exception of the Russian River, all significant streams flowing to the ocean between San Francisco and the Oregon border flow generally west or northwest. The areas of water deficiency lie to the south and east. Between these two areas lie the mountains of the Coast Range, which separate North Coastal watersheds from the Central Valley. To export North Coastal water into the Sacramento Valley, long tunnels must be constructed through the Coast Range. In addition, all North Coastal water developed for export, except that in the upper reaches of the streams, must be pumped upstream to the export tunnels. In effect, the flow of these rivers must be reversed.

The North Coastal area is sparsely populated, and, aside from the main north-south highway, travel and communications are relatively difficult. Sites for dams, tunnels, power and pumping plants, and related facilities are generally remote and relatively inaccessible and resulting construction costs can be expected to be high. In addition, the typically narrow canyons limit the amount of storage capacity which can be provided at strategic reservoir locations within the area. For example, a dam 390 feet in height at the English Ridge site on the Upper Eel River would provide only 800,000 acre-feet of storage, as compared to a dam of the same height on Stony Creek in the Sacramento Valley which would provide a storage of approximately 3,000,000 acre-feet. The cost per acre-foot of developing reservoir storage would, therefore, generally be much greater in the North Coastal area than in the Sacramento River Basin.

Regional Geology

For purposes of geologic consideration, the area of the North Coastal Investigation has been subdivided into three regions, each having certain common geologic characteristics. These regions are designated the Klamath Mountains, the northern Coast Range, and the Coast Range Foothills.

Klamath Mountains. The Klamath Mountains are the most northwesterly of the major geologic regions in California. The major streams providing drainage for this region are the Trinity, Klamath, and Smith Rivers. Because of early mining activity in the Klamath Mountains, more general geologic information is available here than elsewhere in the North Coastal area. The rock units are some of the hardest and structurally most competent in the North Coastal area.

Northern Coast Range. The northern Coast Range includes the mountains lying south of the Klamath Mountains. The major streams in this region are the Eel, Mad, Van Duzen, and Russian Rivers. Due to a lack of mining activity, poor accessibility, and complex geologic structure, geologic information in this region has been difficult to obtain. The region is underlain almost entirely by the Franciscan group, which is represented by a highly disoriented assemblage of sedimentary and volcanic rock locally intruded with serpentine. The rock units of this group have been extensively folded, faulted, sheared, and brecciated.

Coast Range Foothills. The Coast Range Foothills lie along the west side of the Sacramento Valley. The major streams providing drainage in this region are Clear, Cottonwood, Thomes, Stony, Cache, and Putah Creeks, all of which are tributary to the Sacramento River. The Coast Range Foothills lie within two major geologic units, the Cretaceous bedrock series and the Tertiary Tehama formation. Rock types, in the order of abundance in the bedrock series, are: mudstone, shale, sandstone, and conglomerate. The Tehama formation is composed of an accumulation of continental flood plain sediments which are essentially flat-lying, consisting of poorly sorted and unconsolidated silts, clay-silts, sands, and clayey gravels.

Both preliminary and detailed exploration of each of these regions has disclosed many areas of uncertainty which bear directly on project formulation studies, particularly in the Franciscan formation of the northern Coast Range. Most salient among these areas of uncertainty are the difficult dam foundation and tunneling conditions, the landslide potential, and the scarcity of suitable construction materials for dams.

Foundation Conditions

Of the three major geologic regions, foundation conditions of damsites in the Klamath Mountains have proved to be the most favorable. Many damsites have been examined in this region,and foundations have been found to be satisfactory in most instances for either concrete, rockfill, or earthfill dams.

The foundation conditions at many of the damsites located in the northern Coast Range are among the poorest in the State. Exceptional precautions are required in the planning and design of dams and reservoirs in this region. The underlying Franciscan formation is generally intensely sheared and fractured. Areas of competent hard rock are of limited extent and often surrounded by crushed material.

Foundation conditions of damsites in the Coast Range Foothills are generally favorable for the construction of earthfill dams. The most favorable sites in this region are located on the weather-resistant units of the bedrock series such as sandstones and conglomerates. Other rock units of the series, namely mudstone and shale, are much more susceptible to weathering, and therefore are of lesser quality for dam foundation. The Tehama formation could adequately support relatively low earthfill structures.

Construction Materials

Sufficient quantities of construction materials have been located at or near many of the contemplated damsites on the Trinity River, one of the major streams of the Klamath Mountains. The impervious construction materials consist primarily of deeply weathered rock and sedimentary deposits and appear to be adequate for impervious cores of rockfill dams. Pervious construction materials, located in the river channels, consist of alluvium and dredger tailings from early-day gold mining operations. These gravels would make excellent concrete aggregate. Adequate amounts of high-quality rockfill construction materials can be quarried along the Trinity River.

Selective excavation may be required to obtain suitable impervious materials from the Franciscan formation of the northern Coast Range. Considerable variation in the physical properties of the weathered shales, landslide debris, and shallow terrace materials has been indicated by preliminary tests. Suitable pervious construction materials, such as stream gravels, are in short supply. Competent rockfill material also is limited and scattered throughout the northern Coast Range. Several quarries would be required to provide rockfill material for any major dam in the region. Recourse to the use of sandstones, in some cases mixed with shale, would be necessary at some sites.

Virtually every large damsite in the Coast Range Foothills is within a reasonable distance of the Tehama formation, which contains large deposits of impervious and semipervious materials well suited for earthfill embankment construction. Pervious construction materials are in short supply for most sites, and may need to be supplemented with material from the Sacramento River Channel, except at those sites in the Thomes and Cottonwood Creek Basins where extensive deposits have been located. Rockfill sources consisting of thin beds and lenses of sandstone and conglomerate would provide limited quantities of suitable material.

Tunneling Conditions

For the Klamath Mountains tunneling conditions generally are expected to be quite favorable, with no construction difficulties anticipated in the igneous and metamorphic rock types. Rock conditions encountered in most proposed tunnel construction should vary from massive and moderately fractured, to schistose and moderately blocky and seamy types. Unfavorable tunneling conditions can be expected in relatively narrow fault and serpentine zones, representing only a minor portion of proposed tunnel length. In these zones the rock may vary from extremely blocky and seamy to completely crushed, and heavy steel supports would be required. There probably would be a moderate amount of seepage in the proposed tunnels in this region.

Highly unfavorable tunneling conditions may be encountered in the northern Coast Range. Areas of highly competent rock would be limited and widely separated. Closely spaced steel supports would probably be required throughout the major portion of any tunnels in this region. Although only short lengths of proposed tunnels would be likely to penetrate zones of highly incompetent rock, the cost per unit of length for construction in these zones may be extremely high. Inflow of ground water into tunnels should vary from moderate to high, with highest seepage probably occurring in crushed and brecciated rock zones.

There has as yet been no tunnel exploration in the Coast Range Foothills area.

Seismicity

Seismicity, the tendency or relative probability of an area to experience earthquakes, is considered to be moderately low in the Klamath Mountain region. Several shocks have been recorded within the area, but nearly all were of low intensity. However, major shocks with epicenters outside of the region could trigger damaging rock and landslides within the Klamath Mountains. Such a contingency requires cautious planning, design, and construction of all major dams within the region.

The northern Coast Range, like the Klamath Mountains, is considered to be an area of moderate seismic activity. There are two major and one minor concentrations of epicenters in the region. The first is in the Cape Mendocino area and is an extension of the San Andreas rift zone; the second area of high seismicity is located in the Ukiah-Clear Lake region. Some epicenters of low intensity have been located near Island Mountain on the Eel River.

No epicenters or active faults are known to exist in the Coast Range Foothills. Although the seismicity of this region is moderately low, it is an important consideration in the design of major structures.

Landslide Conditions

Numerous landslides are one of the most noticeable topographic characteristics of the North Coastal area. There are a few massive slides and literally thousands of relatively small ones. The possibility and effect of landslide-triggered waves should be thoroughly investigated for any proposed reservoir in the North Coastal area. The 1963 disaster at Vaiont Dam in Italy emphasized the importance of this consideration.

There are two conditions associated with North Coastal reservoirs which are different than those at Vaiont. First, in the North Coastal area, the volume of a potential slide in relation to the reservoir capacity is relatively small. Thus, the height of wave generated could not approach the one at Vaiont. This factor would tend to be mitigating. On the other hand, most of the proposed dams in the North Coastal area would be of earth or rockfill embankment construction. Thus, they could stand little, if any, overtopping.

Project Formulation

Project formulation is the planning process which takes place between the recognition of need for a project service and the final design and construction of the consequent project. The process is largely one of weighing alternative physical possibilities for satisfying the need. Some of the phases of project formulation are: determination of the project services, selection and sizing of engineering structures, benefit-cost analysis, and financial and repayment analysis. The overall objective of the various phases of formulation is to plan a project, or set of works, such that for the given scale of investment, net economic benefits are at a maximum. The keystone of the formulation analyses is definition of the demand for project services, whether the demand be actual or assumed.

The planning done during this reconnaissance investigation can be considered as the first steps in project formulation. Rather than formulating a single project to meet a specific, identifiable demand, planning has been directed towards a developing a long-range planning framework, comprised of many projects. In addition, with such a large number of alternative possibilities, the evaluation of benefits for purposes of project optimization, even on the basis of assumed demand, would not have been practicable.

The criteria and methods which were used for project formulation in the reconnaissance phase of the North Coastal Area Investigation are discussed in the following sections.

General Approach

The general approach used in formulating the projects described in Chapter IV was dictated by the broad scope and objectives of the investigation. The objectives as they relate to elements of the project formulation process can be categorized as follows: identify the major sources of potential water supplies in the North Coastal area; define the types of works which would be required to develop each source of water supply; identify limiting physical conditions associated with each possible project; determine relationships between water supply, available storage, and potential water yield for each potential site; define alternative conveyance routes for diverting new water yield; select more favorable plans of development for each major source of water.

To fulfill these objectives, a great number of possible plans were analyzed. Many plans would be direct alternatives for developing a certain water supply; others would be more or less independent projects. The primary "yardstick" used to compare alternative plans and assess the merits of individual projects was the unit cost (dollars per acre-foot) of annual water conservation yield. Using the unit cost of yield as a basis for comparison of alternative projects is tantamount to allocating all project costs to conservation yield. Since the primary purpose of major North Coastal projects would be to conserve large quantities of water, this approach was judged to be reasonably reliable for purposes of these studies.

Sizing of Projects

An underlying objective in formulating the plans for development was to maintain planning flexibility by analyzing project units and the overall development and conveyance systems for a range of possible sizes and capacities. For each reservoir studied, cost-capacity relationships and yield-capacity relationships were developed for a range of storage capacities up to the topographic limit of the site. The two relationships were then combined to provide an estimate of firm annual water yield as a function of development cost. For each of the diversion plans presented, individual reservoirs were sized so that the unit cost of water yield was minimized. These reservoir features were then integrated into a plan of development in such a manner that total unit cost of yield from the overall project was minimized.

Other factors considered in determining sizes of individual reservoir units were: requirements to maintain minimum pools for power production, for gravity diversion through tunnels, and for pumping to upstream reservoirs. Maximum capacity of reservoirs in some cases was limited by topography and geology of the site and by the undesirability of inundating an upstream development.

Project Services

In planning for major projects, the department is guided by the multiple-purpose concept, in that consideration is given to all potential beneficial uses of the planned works. These purposes include: water conservation for export and local requirements, fisheries enhancement, recreation, flood control, and hydroelectric power. To some extent, the purposes compete for a limited quantity of water supply or reservoir capacity. Allocation among the purposes is accomplished with the aid of a benefit-cost analysis based on the monetary evaluation of estimated benefits attributable to each purpose.

Since the monetary evaluation of project benefits was not within the scope of these reconnaissance studies, it was necessary to use a different approach in providing for the various project purposes. Inasmuch as water conservation will be the primary purpose of any major project in this region, the approach in these studies was to formulate each project to accomplish that purpose, and then integrate other purposes with the water conservation features.

Water Conservation. At the present time, the specific area of need which will be served by any individual North Coastal project is not identified. It is known, however, that much of the State's future water requirement will be manifested as demands for diversion of water from the Sacramento-San Joaquin Delta. Thus, although the proposed projects would provide water service to local areas in the North Coastal region, the major portion of the conserved water would be exported to augment supplies elsewhere in California. It was therefore deemed reasonable to consider the demands for transbasin diversion of water to be the predominant influence on project formation.

Flood Control. The possibilities for associating flood control with the water development plans in the North Coastal area were considered for the proposed conservation reservoirs on North Coastal streams, and for the conveyance works to and within the Sacramento River Basin.

The reservation of storage capacity specifically for flood control in the conservation reservoirs of the early stage major North Coastal projects probably would not be economically justified. The cost of reservoir storage in these reservoirs would be relatively high, and estimated primary flood control benefits are generally small in comparison. Studies by the U. S. Corps of Engineers have indicated, however, that incidental flood control benefits would accrue through normal operation of these reservoirs for water conservation, in that sufficient storage capacity would often be available to reduce flood peaks.

The works of the conveyance systems would offer possibilities for primary flood control benefits to local areas in the Sacramento River Basin. Both the Clear Lake Diversion Project and the Westside Conveyance System could substantially reduce flood damage to local areas through diversion of flood flows to the large reregulatory reservoirs.

Hydroelectric Power. The plans for North Coastal water development offer the potential to generate substantial quantities of hydroelectric power. Most of the hydroelectric plants would be located in the Sacramento River Basin, in association with the water conveyance works. In formulating the plans, hydroelectric plants were included whenever the power benefit exceeded the cost of the power features. The estimated excess revenue was applied to reduce the unit cost of water conservation yield of the particular project.

The justification for including hydroelectric power as a project purpose is quite sensitive to the future benefit of the power. As explained in Chapter V, some of the plants shown in the plans are economically marginal and may be eliminated on the basis of future analysis.

Recreation. The water development projects in the North Coastal area would offer great opportunity for recreation. Benefits from this purpose would come from both the conservation reservoirs within the North Coastal area and the associated reservoirs in the Sacramento Valley. Analyses of the recreation potential, expressed in annual visitor-days, were made for proposed reservoirs. The recreation studies were made by recreation planners of the State Department of Parks and Recreation who were assigned to the investigation.

Fish and Wildlife. It is state policy, as set forth in the Water Code, that fish and wildlife resources will be preserved and, if feasible, enhanced by state-constructed water developments.

On most North Coastal streams where a proposed reservoir would block existing runs of salmon and steelhead, preservation of those resources would be accomplished with conventional compensatory measures. These include fish hatcheries, artificial spawning channels, controlled water releases from the reservoir to spawning and nursery areas below the dam, improvement of stream channels for spawning, multilevel reservoir outlets for water quality control, and use of interim facilities to protect fish during project construction. Such measures have proven to be effective in connection with existing dams and reservoirs elsewhere. Compensation for losses of wildlife habitat resulting from project development would be achieved by providing substitute habitat on nearby lands.

In regard to construction of major projects in the lower reaches of the Eel and Klamath Rivers, the fishery resources probably could not be preserved with conventional measures. Prior to the construction of the projects in these basins, new approaches to fishery preservation would have to be developed and tested.

Of the preservation measures described above, the one having predominant influence on reconnaissance-level planning is provision for controlled water releases below dams. Accordingly, the plans described in this report include reservation of reservoir storage capacity specifically for conservation of water to make fisheries maintenance releases. The quantity of required releases in each case was estimated by State Department of Fish and Game fisheries biologists assigned to the investigation.

No specific provision has yet been made in the plans for fish or wildlife enhancement. There are a number of streams, however, where fisheries biologists have suggested that fisheries enhancement would be biologically feasible. This possibility, including the economic justification thereof, will be investigated during the course of future study programs.

Staging Considerations

The long-range plan for water development within the North Coastal area is comprised of a number of individual projects which would be constructed at varying time intervals, each project providing an increment of new water service to the State Water Resources Development System, and together, producing a large block of water service for the system. By definition, therefore, the plan is one of staged construction. Some of the considerations in formulating such a plan include determining the proper scales of project development, the physical interdependence between successive stages, the timing of construction, and the sequence of development. The first three of these considerations are discussed in the paragraphs which follow; the considerations with respect to the order of development are discussed in Chapter IV.

Construction of major water projects requires very large capital expenditures. It is essential that a plan of staged development provide for optimum use of investment capital. The effect of inefficient capital investment on a staged construction program would be manifested primarily in three ways: (1) over-investment in a large-scale project which provided unused capacity for many years would tie up capital which could be devoted to other purposes; (2) the apparent low unit cost of water service from a very large-scale project could be offset by the interest charges on the high capital investment during the period of demand build-up, when repayment capability from project revenues would be at a minimum; (3) the need for constructed but unused capacity of a project could be deferred or eliminated by future technological change or a lessening in demand growth rate. The planning objective is to avoid excess commitment of investment resources.

The ideal staging program would be to construct a project each year, of the scale needed to satisfy water demands that year. This policy is practical for two reasons: (1) the remaining undeveloped sources of water generally cannot be economically developed in small increments; and (2) because of hydrologic variables, estimates of yields and demands on the system cannot be refined to such detail.

The concepts associated with scales of development have been translated into certain planning criteria for use in the North Coastal Area Investigation. Basically, each individually staged project should be so formulated that its economic justification and financial feasibility would be independent of possible later stages. The sizing of each project should be such that if it becomes unnecessary to construct a successive stage, the financial and economic integrity of the earlier project would not be impaired.

This independence is significant because of the physical integration of North Coastal projects. One of the factors bearing directly on project formulation and staging is that water from later stages would be conveyed through the physical works of earlier stages. Water developed in the lower reservoirs on the Eel, Trinity, and Klamath Rivers would be pumped up to the earlier stage conservation reservoirs and conveyed through long tunnels to the Sacramento River Basin. The possibility arises of oversizing the transbasin tunnels associated with the earlier stages to accommodate the later staged yield. The general economic guideline used in analyzing this possibility is that any oversizing of initial features should be incremental and should not alter the basic scale of the initial project. Specifically, the oversizing of an initial feature should be such that the capitalized cost of the additional investment, including the costs of interest and operation and maintenance during the build-up period, does not exceed the estimated capital cost of the additional feature if constructed separately at the time of actual need.

The relationship between the scale of staged projects and the growth rate of system water requirements is illustrated by the two extreme scales of projects studied in this investigation. One of the more favorable projects from a unit cost of yield standpoint would include Humboldt Reservoir on the Klamath River. However, the total yield of the project would be so large that there would be no demand for it in the system as a single increment. The project would have to be constructed in internal stages and then only when the system demand requires large increments of new water supply.

The small-scale development is illustrated by the Paskenta-Newville Project on the west side of the Sacramento Valley. As an individual project for developing local flows, it could develop about 200,000 acre-feet of water a year at a comparatively low unit cost of yield. Because of this, it is a favorable project and should be considered for early construction. However, the increment of yield which it would supply to the system on an annual basis is of the same order of magnitude as the hydrologic uncertainties in the system and as the projected annual growth rate of the system water requirement. It is apparent that a single project of this magnitude would have little effect on the long-range system capability.

The timing of the construction of the major North Coastal projects will depend primarily on the growth rate of the water demands at the Delta. These timing projections are not part of the formal objectives of the North Coastal Area Investigation. The projected timing and magnitude of future water requirements are prepared for all investigations in the department under the Statewide Coordinated Planning Program.

State Water Project

The State Water Project is the system of works through which the State of California has entered into the role of a water utility. With the dams, reservoirs, canals, pumping plants, and related structures now under construction, the Department of Water Resources will conserve water and transport it to water agencies throughout the State. It is the projected requirements of the State Water Project, which indicate an additional major increment of water supply will be needed in the 1980's, that have pointed to the need for selecting the State's initial project in the North Coastal area.

The following paragraphs describe those aspects of the State Water Project related to an additional conservation facility in the North Coastal area. A complete discussion of the project is contained in the department's publication, Bulletin No. 132-64, "The State Water Project in 1964."

Project Operation

The department will operate the State Water Project in accordance with the Delta Pooling Concept. Under this concept, the Sacramento-San Joaquin Delta is recognized as the central collection point for all surplus waters from the Sacramento and San Joaquin Valleys. Almost all state project demands in Central and Southern California, as well as a substantial measure of the federal Central Valley Project demands, will be met by diversion of water from the Delta. The water to meet these demands will come from surplus waters now wasting to the ocean during the winter and spring months, augmented by releases from major storage developments in the Central Valley.

The initial conservation features of the project, Oroville and San Luis Reservoirs, in conjunction with surplus flows in the Delta, will develop firm annual yield of about 4,000,000 acre-feet. This has been designated the minimum yield for the project. In the future, as further urban and agricultural development in the area tributary to the Delta depletes the surplus flows in the Delta, the capability of the initial features will fall below the minimum yield. In recognition of this future depletion of Delta water supplies, provision was made in formulation of the State Water Project to construct the additional conservation facilities that are necessary to augment water supplies in the Delta, and thus maintain the minimum yield of the project. The initial North Coastal project would constitute these additional conservation facilities.

Legal and Financial Provisions

The planning concepts for additional conservation facilities were translated into legal provisions in two of the documents which form the legal backbone of the project. These are the California Water Resources Development Bond Act (Burns-Porter Act), which was passed by the Legislature in 1959 and approved by the voters in 1960, and the department's Standard Provisions for Water Supply Contract.

The Burns-Porter Act authorized the sale of $1.75 billion of general obligation bonds as the principal source of funds to construct the State Water Facilities, the initial features of the State Water Project. Although the major portion of the revenue from these bonds will be used to construct the initial features, the act contains a provision whereby proceeds from the bonds shall also be used to construct additional conservation facilities. The "offset bond" provision requires that to the extent money from the California Water Fund (tideland oil revenue) is used for construction of the State Water Facilities, which include such units as Oroville Dam and the California Aqueduct, an equal amount of the $1.75 billion general obligation bonds must be held in reserve to be used only to finance construction of additional conservation facilities. At the publishing of this report, the "offset bond" fund amounted to $140 million, and it is expected to increase by about $11 million a year as further expenditures are made from the California Water Fund. Thus, financing for the State's initial North Coastal conservation facility is virtually assured.

The legal structure for marketing the water from the State Water Project is the department's Standard Provisions for Water Supply Contract.

In contracting for the sale of water, the department has assumed a legal obligation to conserve, transport, and deliver the minimum yield of the project. The repayment structure of the standard provisions provides for increases in future water rates to repay the costs of the additional conservation facilities that are needed to sustain the minimum yield.

The State Water Project is similar in many respects to a large public utility. The advantages of operating the project as a self-supported public utility have been recognized and implemented in important administrative and accounting procedures within the department.

Local Water Service

The additional conservation facilities of the State Water Project will not be limited to sustaining water supplies for diversion from the Sacramento-San Joaquin Delta. The Burns-Porter Act specifies that the facilities may be multiple-purpose, including provisions for flood control, local water service, and other water uses. Article 16(d) of the standard contract provisions, in referring to the construction of additional facilities, provides for the construction of "related, appurtenant facilities necessary and desirable to meet local needs." Although the quantity of water developed by the additional facilities for local service may be nominal compared to the total project yield, it will be quite significant to the local areas affected.

CHAPTER IV. PLANS FOR DEVELOPMENT

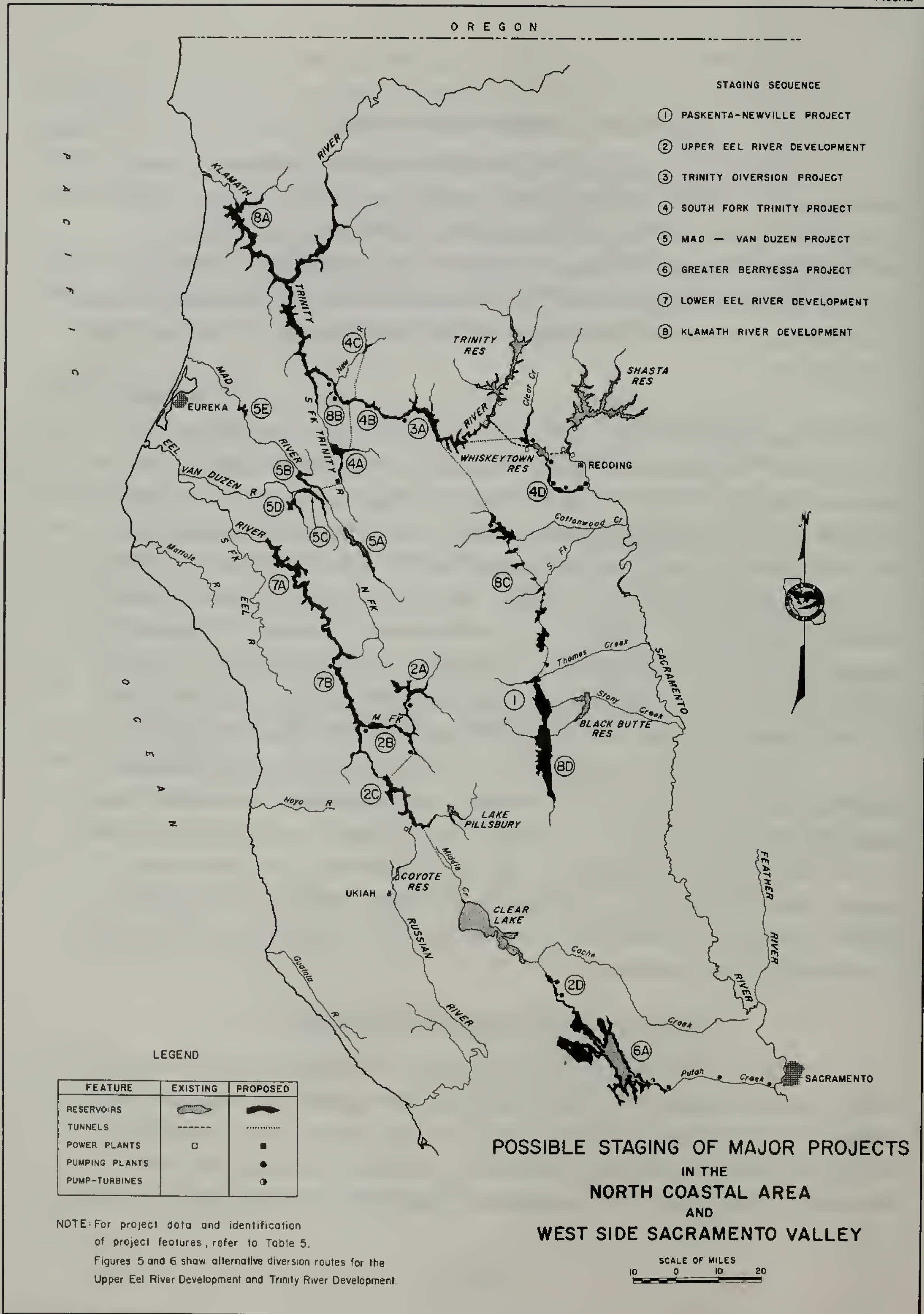
This chapter presents the water development plans which were formulated during this investigation. The projects which comprise the overall plan would provide for essentially full economic development of the major North Coastal streams. Since the major purpose of development would be to divert surplus water to the Sacramento Valley, the plans include, of necessity, associated development of the stream basins on the west side of the valley.

In viewing the plans it is important to recognize the context in which they are presented; both in terms of what they are and of what they are not. As shown, the plans represent a framework outlining the manner in which the region's water resource potential can be integrated into the State's expanding economy through orderly, staged development. The plans show the magnitude, in dollars and in quantity of water, of the development program which lies ahead. Most of the projects will not be needed for many years. However, the framework is provided so that as future demands necessitate development of additional increments of water supply, it will be possible to analyze the required projects in terms of the overall development program, and thus ensure optimum long-range development.

The plans do not represent a recommended program for immediate construction of specific physical works. The engineering structures which comprise the plans shown herein should be considered representative of what will effect optimum development. The identification of the sources of surplus water which can be developed in the North Coastal area and their probable staging of development is more important than the structures shown to accomplish the development.

Staging of Major North Coastal Projects

The staging plan for major project development in the North Coastal area is shown on Figure 4. The sequence of development is indicated by the numbers along side each project. These numbers are repeated in Table 5, which gives the name of each feature and the associated cost and yield. The numbers shown should be considered illustrative of the probable sequence.



POSSIBLE STAGING OF MAJOR PROJECTS IN THE NORTH COASTAL AREA AND WEST SIDE SACRAMENTO VALLEY

NOTE: For project data and identification of project features, refer to Table 5. Figures 5 and 6 show alternative diversion routes for the Upper Eel River Development and Trinity River Development.

TABLE 5

SUMMARY OF POSSIBLE MAJOR EXPORT PROJECTS IN NORTH COASTAL AREA
AND CONTIGUOUS AREAS OF SACRAMENTO VALLEY

Key No.	Project & Principal Features	Project Annual Yield (1,000 A.F.)	Estimated Capital Cost ($1,000,000)
1	Paskenta-Newville Project	200	30
2	Upper Eel River Development (via Clear Lake)		
2A	Spencer Dam & Reservoir	470	55
2B	Dos Rios Dam & Reservoir	110	25
2C	English Ridge Dam & Reservoir	340	80
2D	Putah Creek Power Facilities	---	32
	Conveyance Facilities*	---	106
	Total	920	298
3	Trinity Diversion Project (via Clear Creek)		
3A	Helena Dam & Reservoir	600	84
	Conveyance Facilities*	---	70
	Total	600	154
4	South Fork Trinity Project		
4A	Eltapom Dam & Reservoir	400	55
4B	Burnt Ranch Dam & Reservoir	80	71
4C	Beartooth Dam & Reservoir	120	14
4D	Clear Creek Power Facilities	---	164
	Conveyance Facilities*	---	56
	Total	600	360
5	Mad-Van Duzen Project		
5A	Enlarged Ruth Dam & Reservoir	180	13
5B	Anderson Ford Dam & Reservoir	60	30
5C	Eaton Dam & Reservoir	230	26
5D	Larabee Dam & Reservoir	130	37
5E	Butler Valley Dam & Reservoir	---	13
	Conveyance Facilities*	---	101
	Total	600	220
6	Greater Berryessa Project		
6A	Enlarged Monticello Dam & Reservoir	1,600	131
	Power, Pumping, Conveyance Facilities	---	180
	Total	1,600	311
7	Lower Eel River Development		
7A	Sequoia Dam & Reservoir	600	170
7B	Bell Springs Dam & Reservoir	400	101
	Northwestern Pacific Railroad Relocation	---	130
	Conveyance Facilities*	---	186
	Total	1,000	587
8	Klamath River Development		
8A	Humboldt Dam & Reservoir	6,000	652
8B	Ironside Mtn. Dam & Reservoir	---	11
8C	Westside Conveyance System	---	130
8D	Rancheria Dam & Reservoir	200	90
	Conveyance Facilities*	---	637
	Total	6,200	1,520

* A major part of Conveyance Facilities costs is for tunnels.

As discussed later in this chapter, several of the features, such as the Glenn Reservoir Complex and the Westside Conveyance System, which are shown as later-stage developments, may be constructed earlier as part of an alternative routing plan.

The discussion in this section is directed to the sequence of staging and the reasons therefor. A discussion of the engineering aspects and physical works of each project is presented in succeeding sections of this chapter. The projects described are shown on Plate 1 and Figure 4.

Initial and Earlier-Staged Projects

Paskenta-Newville Project. The Paskenta-Newville Project shown on Figure 4 would conserve and develop the surplus flows of Thomes and North Fork Stony Creeks on the west side Sacramento Valley. It would not be associated initially with North Coastal imports. However, it is probable that at some future date it would be integrated into the Glenn Reservoir Complex as part of the reregulatory storage for Eel, Trinity, and/or Klamath River imports.

The designation of this project as the "initial development" is in relation to early North Coastal projects. A comparison based on unit cost of yield shows that a Paskenta-Newville Project could supply new water to the Delta at less cost than from projects on either the Eel or Trinity Rivers. The project has not yet been directly compared with other projects in the Sacramento Valley. However, all indications are that it is one of the more favorable remaining developments.

Upper Eel River Development. The Upper Eel River Basin has been selected as the location for the initial North Coastal facility of the State Water Project. The characteristics of an Eel River development which establish its priority are in two categories: the development would provide a comprehensive scope of needed water services to local areas at an earlier date than would otherwise be possible; the works of the development offer a high degree of flexibility in operational integration with the State Water Project and the Central Valley reservoir system. These project characteristics will be reflected in the least costly North Coastal development for augmenting water supplies to the State Water Project in the Sacramento-San Joaquin Delta.

The comprehensive nature of the Upper Eel River Development is evident in the variety of services which the project could provide in addition to the primary purpose of augmenting flows in the Sacramento-San Joaquin Delta. The water conservation features within the Eel River Basin could supply water for local requirements, including those in Round Valley and the Eel River Delta area; possibly for fisheries enhancement; and would provide some flood control through normal reservoir operation. The conveyance facilities to and within the Sacramento River Basin offer additional opportunities for flood control, local water service, and fisheries enhancement. All of the reservoirs of the project would provide recreation benefits.

The operational flexibility associated with the Upper Eel River Development is due in large measure to the inclusion in the project conveyance works of a large reregulatory reservoir within the Sacramento River Basin, either the Glenn Reservoir Complex or Lake Berryessa. The operational flexibility provided by either of these storage units is manifest in three ways: (1) the reservoir would provide storage capacity to reregulate the imported water from the incoming diversion schedule to a release schedule compatible with operation of the State Water Project; (2) the storage would provide a safety factor against possible temporary outages in the long transbasin tunnels, a contingency which must be considered, since the tunnels will be constructed through adverse geologic strata; and (3) the reservoir would provide "long-term carryover storage" to the Central Valley reservoir system, in that capacity could be reserved to make extra releases during critically dry periods.

Trinity River Development. As shown in Figure 4 and Table 5, it is presently envisioned that the Upper Eel River Development would be followed in time by the three projects of the Trinity River Development. These three projects are considered as stages of a single development because they would be physically integrated. The second and third projects would be additive to and divert their water yield through the features of the first stage. The projects would develop a total yield of about 1,800,000 acre-feet, in three approximately equal increments.

Westside Conveyance System. The Westside Conveyance System would be comprised of a series of reservoirs and interconnecting channels in the upper reaches of Cottonwood, Red Bank, and Elder Creeks. Its major purpose would be to convey the water imported into the Cottonwood Creek Basin from the North Coastal streams to the Glenn Reservoir Complex for reregulation. This is presently considered to be a possible alternative route for Trinity River water and a probable route for Klamath River imports. In addition to conveying imported water and providing numerous local benefits, the system would also develop about 270,000 acre-feet of new yield from streams tributary to the system. The timing of the system will coincide with either the Trinity or Klamath River imports.

Glenn Reservoir Complex. The Glenn Reservoir Complex would be comprised of three interconnected reservoirs. The Paskenta-Newville portion of the complex has already been described as a favorable early-stage project. The completion of the complex by addition of the large Rancheria Reservoir unit, and the enlargement of the Newville unit would make this storage facility ideal for reregulation of North Coastal imports. The complex is favorably located to provide reregulatory storage for imports from the Eel, Trinity and/or Klamath Rivers. The staging of the complex as a whole will be governed by the staging of the associated import projects.

Greater Berryessa Project. An enlarged Monticello Dam and Lake Berryessa would conserve flood flows pumped from the Sacramento River, reregulate imported water from the Eel River, and generate large quantities of hydroelectric power. The project is located close to the Delta and would have a favorable unit cost of water service. The large block of yield which would be produced, approximately 1,600,000 acre-feet annually, is a larger scale project than will be required in the near future.

Subsequent and Later-Staged Projects

The North Coastal projects that would follow the above-described developments are designated "later-staged" projects. They have been studied in less detail than "earlier-staged" projects. One of the factors which will weigh heavily in future study of those projects will be the value and cost of electric power, inasmuch as large pumping and power generation facilities are associated with them.

Lower Eel River Development. Although the initial major project in the North Coastal area will be located in the Upper Eel River Basin, the Lower Eel River will not be developed until much later in time. The primary reason for this later staging is the very large cost of relocating the Northwestern Pacific Railroad. This railroad parallels the Eel River from Dos Rios to the Eel River Delta and any major reservoir development on the Lower Eel River will necessitate relocation of over 100 miles of this roadway, at an estimated cost of $130 million. When the demands for additional new water supplies become sufficient to justify projects on the Lower Eel River, about 1,000,000 acre-feet of annual yield could be developed by Bell Springs and Sequoia Reservoirs.

Klamath River Development. After development of the projects described above, the remaining major source of undeveloped surface water within the State would be the Klamath River Basin, including the Lower Trinity River. Under full development it would be engineeringly feasible to conserve approximately 6,000,000 acre-feet of firm annual export yield. Projections of future statewide water requirements indicate that this development will not be needed before the end of this century, and it is possible that by that time, technological advances in saline-water conversion will make full development of the basin's water supply unnecessary.

The primary factors which place the Klamath River Development at the end of the staging sequence are the geographical location and the very large scale of the project. The Klamath River is farthest from the Sacramento Valley of any of the North Coastal sources of surplus water. Extensive and costly physical works would be required to conserve the water and convey it to the valley.

* * *

UPPER EEL RIVER DEVELOPMENT

The Upper Eel River Development has been selected as the State's initial project in the North Coastal area. The primary purpose of the development will be to augment water supplies in the Sacramento-San Joaquin Delta so as to prevent a reduction in the minimum yield of the State Water Project. The development will also provide local water service, recreation, hydroelectric power, and flood control.

The works of the development will include conservation reservoirs on the Middle Fork Eel River and associated conveyance facilities to deliver the conserved water to local areas and to the Sacramento River Basin. As illustrated in Figure 5 which shows possible features of the Upper Eel River Development, there are two alternative conveyance routes by which the surplus water could be delivered to the valley: either (1) via pumped diversion from the Middle Fork Eel to English Ridge Reservoir on the upper main Eel River, with subsequent gravity diversion via Clear Lake, Putah Creek, and Lake Berryessa; or (2) via gravity diversion to the elements of the Glenn Reservoir Complex on Thomes and Stony Creeks with subsequent release to the Sacramento River.

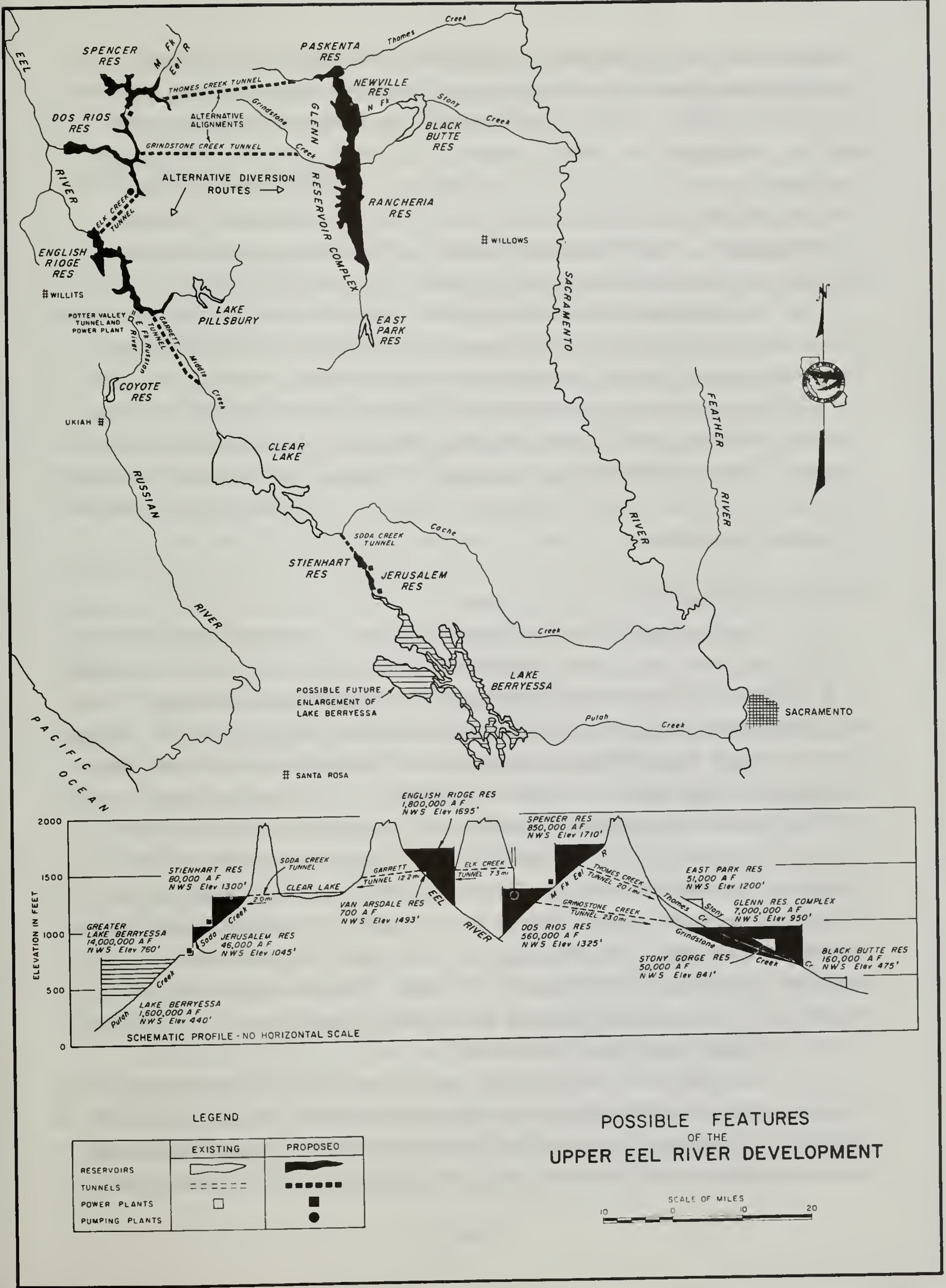
The selection of the diversion route between these two alternatives is a complex problem influenced by many considerations. Reconnaissance comparison of the plans indicates that the Clear Lake route would be more favorable than the Glenn Reservoir route. However, the presently estimated difference in costs and accomplishments of the two plans is not sufficient to enable selection at this time. The decision will be made during the feasibility-level planning for the Upper Eel River Development.

It is apparent that the results of detailed geologic investigation will weigh heavily in selection of the route. Adverse geologic conditions would be reflected in higher construction costs. The geologic investigation to date has been of high-order reconnaissance level, with limited exploratory drilling. The very long tunnels associated with either route, the high dams which are proposed, and the recognized fact that geologic conditions in this area are generally poor, all indicate the necessity of thorough study before a routing decision is made.

This section on the Upper Eel River Development is divided into four parts. The first part describes the essential features of each routing plan and includes an illustrative comparison of the project parameters associated with each plan. The second part describes the alternative conservation features on the Middle Fork Eel River, which would be the key features of the diversion project. The last two parts discuss in more detail the project features associated with the two routing plans.

Plan of Development

At the present time, the department is not recommending construction of specific works for the Upper Eel River Development. Rather, what has been formulated to date is the framework of a diversion project in which the



POSSIBLE FEATURES OF THE UPPER EEL RIVER DEVELOPMENT primary source of surplus water, the Middle Fork Eel River, has been identified and the essential features of two alternative conveyance routes have been outlined. Within this framework there remain many different ways of formulating the overall project. In addition to the question of conveyance routes, the sizes and combinations of the various project features can be so formulated as to provide several alternative scales of development. The different scales are reflected in a wide range of possible new water yield from the Sacramento-San Joaquin Delta.

The following discussion presents the essential features of one set of physical works for each alternative routing plan. The plans presented illustrate what is involved with either routing, and the scales of the projects discussed are representative of the current estimate of the quantity of water service which the selected project will be required to produce. For this discussion, the plans are designated the Glenn Diversion Project and the Clear Lake Diversion Project. The various project features are shown on Figure 5.

Glenn Diversion Project

Surplus runoff from the Middle Fork Eel River would be conserved in a 530,000 acre-foot Spencer Reservoir. This reservoir would be impounded by a 330-foot high dam at the Spencer site on the Middle Fork and a 280-foot high Franciscan Dam on Short Creek at the entrance to Round Valley. Spencer Reservoir would have a water surface area of 5,200 acres at a normal pool elevation of 1,655 feet. From Spencer Reservoir the conserved water would be diverted through a 10-foot diameter, 20.1 mile-long tunnel to Thomes Creek, a tributary of the Sacramento River. There, the water would be reregulated in Paskenta-Newville Reservoir, the first stage elements of the Glenn Reservoir Complex. Under this plan, Paskenta-Newville would have a gross capacity of 3,080,000 acre-feet and a water surface area of 18,000 acres at a normal pool elevation of 970 feet. The reservoir would be formed by a 180-foot high Paskenta Dam on Thomes Creek and a 370-foot high Newville Dam on North Fork Stony Creek.

Over the historical 20-year period from 1916-37, the average annual diversion from the Middle Fork with such a system would have been 470,000 acre-feet. The total firm yield at the Sacramento-San Joaquin Delta would be on the order of 800,000 acre-feet. This yield would be a combination of Eel River water, conserved flows from Thomes and North Fork Stony Creeks, and firming of presently unregulated flows in the Delta. The estimated total capital cost of the project is $184 million.

Clear Lake Diversion Project

Under this plan the conservation features on the Middle Fork Eel River would include two reservoirs. Spencer Reservoir, with a storage capacity of 850,000 acre-feet at a water surface elevation of 1,710 feet, would be formed by construction of two dams: (1) a 385-foot high dam at the Spencer site on the Middle Fork Eel River; and (2) a 335-foot high dam on Short Creek. Dos Rios Reservoir, with a storage capacity of 560,000 acre-feet at a surface water elevation of 1,325 feet, would be formed by construction of a 430-foot high rockfill dam in a narrow canyon of the Middle Fork Eel River, about 2 miles upstream from its confluence with the main Eel River.

From Dos Rios Reservoir, the water would be pumped (mean pumping head, 300 feet) by Elk Creek Pumping Plant to the intake of Elk Creek Tunnel. This tunnel would be about 12 feet in diameter and would extend 7.3 miles to English Ridge Reservoir. Approximately 500,000 acre-feet of water per year would be diverted through these facilities.

English Ridge Reservoir, with a storage capacity of 1,800,000 acre-feet at a water surface elevation of 1,695 feet would be formed by construction of a 535-foot high dam on the upper main Eel River. This reservoir would develop a firm annual conservation yield of about 340,000 acre-feet. It is anticipated that eventually all of this yield would be used within the Eel and Russian River Basins and in areas immediately contiguous to them. However, during the build-up period, the demand probably would be much less than the capability of the reservoir. Under the utility concept of operation, the excess yield, along with that diverted from the Middle Fork Eel River, could be routed via Clear Lake to Lake Berryessa and thence to the Sacramento-San Joaquin Delta for interim use.

The flows diverted from the Middle Fork Eel River, together with excess yield developed by English Ridge Reservoir, would be diverted to the Clear Lake Basin through Garrett Tunnel. Garrett Tunnel would be about 14 feet in diameter and would extend from English Ridge Reservoir, a distance of about 12 miles to Middle Creek, a tributary of Clear Lake.

Clear Lake, with diversions from the Eel River, could be operated in such a manner as to reduce high water levels during the flood season and to maintain a higher, more stable water level during the recreation season. It is anticipated that appreciable recreation and flood control benefits would result.

From Clear Lake, the water would be diverted by a 2-mile tunnel to Soda Creek in the Upper Putah Creek Basin. Approximately 400 feet of head could be developed for power generation by construction of Stienhart and Jerusalem Dams and Powerplants on Soda Creek. Discharges from the power facilities would be released into Lake Berryessa, the storage facility of the federal Solano Project.

Illustrative Comparison of Two Routing Plans

For purposes of illustrative comparison, a summary of project data for the Clear Lake Diversion Project and the Glenn Diversion Project is presented in Table 6. From the table, it is apparent that for the two plans shown the total capital cost and total project yield of the Clear Lake routing plan would be considerably greater than for the alternative Glenn routing. It will be recalled that this comparison is for plans that would put comparable quantities of new yield in the Delta under full project development.

With regard to drawing conclusions from the above comparison, several tempering aspects should be mentioned. While the scale and capital cost of the Clear Lake Diversion Project would be much larger than the Middle Fork Eel diversion project to Thomes Creek, additional benefits in the categories of greater new water yield, flood control, power development, and recreation enhancement may establish this project system as the economically more favorable development. It is believed that allocation of project costs to these purposes and the availability of power revenues from the more comprehensive Clear Lake diversion alternative will result in no greater cost of water supplies to the Delta export user than would be possible under the Thomes Creek alternative and would simultaneously provide new water supplies to future local and adjacent basin users from this system at a lower cost than other possible alternatives, i.e., an independent English Ridge Project.

TABLE 6

UPPER EEL RIVER DEVELOPMENT
SUMMARY OF ALTERNATIVE ROUTING PLANS

Alternative Plan and Project Features	Capital Cost	Gross Storage AF	Water Developed AF/YR
Clear Lake Diversion Project			
Middle Fork Eel River Unit			
Spencer Dam and Reservoir	$ 53,000,000	850,000	---
Dos Rios Dam and Reservoir	25,000,000	560,000	---
Elk Creek Pumping Plant and Tunnel	32,000,000	---	---
Water service to Round Valley	---	---	26,000
Water released for fisheries	---	---	54,000
Water diverted to English Ridge Reservoir	---	---	500,000
English Ridge Dam and Reservoir	$ 80,000,000	1,800,000	---
Water service for local areas	---	---	150,000
Water released for fisheries	---	---	60,000
Water diverted to Delta	---	---	130,000
Garrett Tunnel (12.2 miles long, 14' dia.)	$ 55,000,000	---	---
Soda Creek Tunnel (2.0 miles long, 19' dia.)	$ 15,000,000	---	---
Putah Creek Power Facilities	$ 32,000,000	---	---
Lake Berryessa (existing)	---	1,620,000	247,000
Conveyance facilities to Sacramento River	$ 6,000,000	---	---
Total Delta yield developed by project	---	---	800,000*
Total capital cost of project	$298,000,000	---	---
Glenn Diversion Project			
Spencer Dam and Reservoir	$ 30,000,000	530,000	---
Water service to Round Valley	---	---	26,000
Water released for fisheries	---	---	54,000
Water diverted to Glenn Reservoir	---	---	470,000
Thomes Creek Tunnel (20.1 mi. long, 10' dia.)	$ 75,000,000	---	---
Glenn Reservoir Complex			
Paskenta Dam and Reservoir	$ 10,000,000	80,000	---
Newville Dam and Reservoir	69,000,000	3,000,000	---
Water released for fisheries	---	---	40,000
Water service for local areas	---	---	40,000
Total Delta yield developed by project	---	---	800,000*
Total capital cost of project	$184,000,000	---	---

* Estimated Delta yield based on firming unregulated flows in Delta.

Conversely, the scale of the diversion project via Glenn Reservoir could be greatly increased, if required by increased water demands. As will be described later in this section, and as illustrated in Figure 5, the diversion to Glenn Reservoir could be made from Dos Rios Reservoir. Under such a plan, surplus water would be conserved in Spencer and Dos Rios Reservoirs and diverted through Grindstone Creek Tunnel to the Rancheria compartment of the complex. With an average annual diversion from the Eel River of 660,000 acre-feet, and a gross storage of 6,000,000 acre-feet in Glenn Reservoir, a total new Delta yield of about 1,500,000 acre-feet could be produced. The estimated total capital cost for this plan is $300 million.

Conservation Features on Middle Fork Eel River

The major source of water supply for the Upper Eel River Development is the Middle Fork of the Eel. Capturing and diverting the water will require construction of major conservation storage on the Middle Fork. Although the department has often referred to Spencer and Dos Rios Reservoirs as the proposed conservation works, there are actually several possible ways of providing the required storage. In this section these alternatives are discussed in terms of the conditions which affect formulation of the Middle Fork project and the alternative physical works which could comprise the project.

Conditions Affecting Formulation of a Project

The conditions which affect formulation of a project on the Middle Fork Eel River are: runoff, presence of Round Valley, alternative dam and reservoir sites, in-basin releases, and alternative diversion routes. Each condition is discussed below.

Runoff. A primary condition governing the scale of project which can be considered on the Middle Fork Eel is the quantity of water available for development. The 50-year (1911-60) mean annual runoff of the Middle Fork varies from 735,000 acre-feet per year at Spencer damsite to 1,022,000 acre-feet per year at Dos Rios damsite. The seven-year (1928-34) mean annual runoff for these same sites is 445,000 acre-feet and 547,000 acre-feet, respectively. All of the runoff is uncontrolled at present. Full economic development of the Middle Fork Eel River would correspond to a total new firm yield of between 750,000 and 800,000 acre-feet per year.

Round Valley. Round Valley is so located that its presence is a controlling condition in the formulation of any Middle Fork project. The mean elevation of the valley floor is approximately 1,350 feet. Unless protective works were constructed, the valley would be inundated by major reservoirs on the Middle Fork Eel River. The three general alternative plans for dealing with Round Valley are: (1) limit the maximum water surface elevation in any lower Middle Fork reservoir (low Dos Rios or Jarbow) such that water will not back up Mill Creek into the valley; (2) permit high water surface elevations in the lower Middle Fork reservoir by constructing dikes across Mill Creek (Mill Creek Dam) and Short Creek (Franciscan Dam) and constructing a drainage tunnel from the valley to a point below the dam on the Middle Fork; and (3) utilize the large storage potential of Round Valley as part of the reservoir development. These alternative plans are discussed later in this section.

Alternative Dam and Reservoir Sites. Planning flexibility on the Middle Fork is increased by several potential alternative dam and reservoir sites. To some extent, these sites correspond to different scales of development and to different approaches to handling Round Valley. In upstream to downstream order, the sites have been given major consideration are Spencer, Etsel, Jarbow, and Dos Rios.

In-basin Releases. The primary purpose of a Middle Fork Eel River project would be to develop surplus water for export; however, provision has also been made in each plan for reservoir releases to meet in-basin water requirements for fisheries preservation and Round Valley consumptive needs. The estimated water requirements used in these studies are preliminary and subject to considerable revision. However, they are considered sufficiently accurate for reconnaissance studies, and the availability of more refined data in the future should not significantly alter the plans formulated to date.

The year 2020 consumptive requirement for Round Valley is estimated to be 26,000 acre-feet per year. Reservoir releases of approximately 40,000 acre-feet per year would be made from Franciscan Dam (Spencer Reservoir). The irrigation return flows would pass down Mill Creek and into the lower reservoir on the Middle Fork Eel River. Contract service biologists from the Department of Fish and Game estimated that releases of 54,000 acre-feet per year from Dos Rios Dam, together with downstream channel improvements, would be sufficient to preserve the existing fisheries.

Alternative Diversion Routes. Project formulation on the Middle Fork Eel River is greatly influenced by the diversion route from the basin. As is discussed below, different combinations of dams and reservoirs are required for the diversion to Glenn Reservoir than for the diversion to the upper main Eel River.

Alternative Conservation Features on Middle Fork Eel River

Spencer Dam and Reservoir. Spencer Dam and Reservoir is the farthest upstream site considered for major development on the Middle Fork Eel. It could be either the sole conservation feature for a diversion project to Glenn Reservoir or the upstream reservoir for diversion to Glenn or English Ridge Reservoirs. Spencer Reservoir requires construction of Franciscan Dam on Short Creek at the entrance to Round Valley. This dam prevents the inundation of Round Valley and allows the addition to the reservoir of Williams Valley, which is separated from the Middle Fork by a low saddle.

It is presently considered that Spencer Dam would have a rockfill section. The damsite has been drilled and has had extensive geologic exploration. However, additional investigation is necessary to fully determine the competency of the left abutment, and to determine the availability of suitable rockfill materials for construction. The highest dam considered for this site would be 385 feet and would impound a reservoir of 850,000 acre-feet. The maximum potential storage at the Spencer site is about 900,000 acre-feet.

Etsel Dam and Reservoir. A dam at the Etsel site is a basic alternative to Spencer Dam. Etsel Reservoir would also require construction of Franciscan Dam on Short Creek. Etsel Reservoir would have considerably more storage than Spencer Reservoir because of the addition of Etsel Flats to the reservoir area. However, the relatively higher estimated cost of storage appears to make it a less favorable alternative than Spencer Reservoir for storage capacities up to about 900,000 acre-feet.

Franciscan Dam. Franciscan Dam would be a dike on Short Creek at the entrance to Round Valley. It would be required for Spencer or Etsel Reservoirs or for a high Dos Rios or Jarbow Reservoir to prevent inundation of Round Valley. The site has been drilled, but there are some questions about its competency. The highest dam considered for the site would be about 310 feet high.

Dos Rios Dam and Reservoir. Dos Rios Dam and Reservoir could be a key conservation feature of several alternative plans for development of the Middle Fork Eel River. The damsite is considered to be one of the best in the North Coastal area; and based on surface reconnaissance study, geologists consider that it would accommodate a very high dam. Present reconnaissance designs call for construction of a rockfill embankment at the Dos Rios site.

Jarbow Dam and Reservoir. Jarbow Dam is a direct alternative to Dos Rios Dam. Although it is 145 feet higher in streambed, the canyon is wider than Dos Rios; hence, the cost of storage is higher in the range of dam heights considered. In the first years of this investigation, considerable study was made of plans including Jarbow Dam, before it became apparent that Dos Rios damsite would be more favorable.

Mill Creek Dam. This dam would act as a dike to protect Round Valley from flooding in any of the plans involving a high Dos Rios (or Jarbow) Reservoir. The flow of Mill Creek, which normally drains Round Valley, would be diverted through Mill Creek Drainage Tunnel, which would extend from Round Valley to the Middle Fork Eel River below Dos Rios or Jarbow Dams. Mill Creek Dam would be of earthfill construction and would be approximately 350 feet high.

Spencer Powerplant. In plans which include Spencer Reservoir and a downstream reservoir, either Dos Rios or Jarbow, it would be possible to generate hydroelectric power at Spencer Dam. During the investigation several studies were made to determine the relationships between cost of yield, quantities of yield, and possibly capacity factors of such a powerplant. Generally speaking, it was found that power generation at Spencer Dam would be economically marginal. The decision to include or exclude a powerplant is quite sensitive to the value of power. It is anticipated that with a reduction in the unit value of power revenue, a powerplant at Spencer would not be economical.

One of the more favorable plans studied included a powerplant which would operate on a 50 percent capacity factor in coordination with the Elk Creek Pumping Plant. This would effect a savings in not having to duplicate transmission lines to the load center.

Plans For Diverting Eel River Yield Via Glenn Reservoir

A plan for developing surplus water on the Middle Fork Eel River and delivering it eastward to the Sacramento Valley would include three general types of physical works: (1) conservation reservoirs on the Middle Fork Eel; (2) a long transbasin tunnel through the Coast Range to the valley; and (3) reregulatory storage in all or part of the Glenn Reservoir Complex. The alternative plans presented in this section are discussed under those headings.

Middle Fork Eel River Conservation Features

There are four basic alternative plans by which water could be developed on the Middle Fork Eel River for diversion to the Glenn Reservoir Complex. They are:

(1) Water would be conserved in Spencer Reservoir and diverted through Thomes Creek Tunnel to the Paskenta-Newville compartments of the Glenn Reservoir Complex. Approximately 470,000 acre-feet of average annual yield could be diverted by a Spencer Reservoir with 530,000 acre-feet gross capacity. On the basis of minimum capital expenditures, this plan is the most economical alternative for routing via Glenn. However, the plan represents the smallest practical scale of export development on the Middle Fork and does not develop the full potential of the river.

(2) Water would be conserved in Spencer and Dos Rios Reservoirs and diverted from Dos Rios Reservoir through Grindstone Creek Tunnel. Approximately 660,000 acre-feet could be diverted on an average annual basis from a Spencer Reservoir with 470,000 acre-feet gross capacity and a Dos Rios Reservoir with 560,000 acre-feet gross capacity. Although not providing for full development of the Middle Fork, this plan does develop more of the river's potential than a plan with Spencer Reservoir alone. It also

offers some possibility of internal staging. Round Valley would be protected by limiting the water surface in Dos Rios Reservoir to 1,325 feet.

(3) Water would be conserved in a large Dos Rios Reservoir and diverted through Grindstone Creek Tunnel. Round Valley would be protected from inundation by Mill Creek and Franciscan Dams and would be drained by Mill Creek Tunnel. Approximately 700,000 acre-feet of yield could be diverted annually from a Dos Rios Reservoir of 1,700,000 acre-feet gross capacity. Dos Rios Dam would be about 590 feet high. This plan provides for the greatest development of the Middle Fork without inundating Round Valley. However, the high cost of the increment of yield which this plan provides over a plan with Spencer and a low Dos Rios Reservoir makes this plan a less favorable alternative.

(4) Water would be conserved in a large Dos Rios Reservoir which would inundate Round Valley and would be diverted through Grindstone Creek Tunnel. This plan would combine the very good Dos Rios damsite with the large storage potential of Round Valley and would enable full development of the Middle Fork Eel River. Dos Rios Dam would be about 650 feet high and would impound a reservoir of 5,700,000 acre-feet gross capacity.

Transbasin Diversion Tunnels

From the conservation reservoirs on the Middle Fork Eel, the water would be conveyed to the Sacramento Valley by gravity through a long tunnel. Three principal tunnel alignments are under consideration: Spencer Reservoir to Thomes Creek; Spencer Reservoir to Grindstone Creek; and Dos Rios Reservoir to Grindstone Creek. Thomes Creek drains into the Paskenta storage unit of the Glenn Reservoir Complex and Grindstone Creek drains into the Rancheria storage unit.

Each of these tunnels would be approximately 20 miles long. The geologic conditions of the mountainous terrain through which these tunnels would be constructed could be generally classed as fair to poor. Difficult tunneling conditions would be expected. It is possible that further geologic exploration of these alignments will reveal conditions which could cause substantial changes in the estimated costs of these works.

Glenn Reservoir Complex

The Glenn Reservoir Complex would consist of three adjacent reservoir units located in the foothills on the west side of the Sacramento Valley in Glenn and Tehama Counties. These units are the Paskenta, Newville, and Rancheria Reservoirs. As mentioned in the previous section on staging, the Glenn complex is being considered for possible inclusion under several major water development plans. These include its use as reregulatory storage for imports from the Eel, Trinity, and/or Klamath Rivers and the possible construction of the Paskenta-Newville units as a project for conservation of local tributary flows.

The reservoir area lies between the mountains of the northern Coast Range on the west and a low narrow ridge on the east, called Rocky Ridge. The north fork of Stony Creek cuts through Rocky Ridge at Newville damsite. Stony Creek cuts through low hills of this same formation about 8 miles to the south at Rancheria damsite. Paskenta Reservoir, which would be the northern element of Glenn Reservoir Complex, would be located on Thomes Creek near the town of Paskenta.

Water diverted eastward from the Eel River would be reregulated in one or more units of the Glenn complex. This reregulation is necessary to provide compatibility between the supply-oriented import schedule and the demand-oriented schedule of reservoir releases. The particular combination of storage elements which would be developed initially would depend primarily upon the quantity of water imported from the North Coast.

This storage facility offers a unique opportunity for possible staging. There are innumerable possible physical combinations among dam dizes, saddle dams, and interconnecting channels. Not only could the individual dams be raised in elevation at some future date to increase storage capacities of the respective reservoirs, but each component reservoir could be integrated into the complex by replacing the low saddle dam initially required to separate the reservoirs, with a connecting channel. If constructed to their approximate topographic limits, the three individual reservoirs of the complex would combine to form a single large storage basin having a capacity of 8,600,000 acre-feet. The lake would be 34 miles long and 3 miles wide with a surface area of 55,000 acres.

Although the Glenn Reservoir Complex would be operated primarily to firm up water supplies in the Sacramento-San Joaquin Delta, water would also be provided for domestic use, local irrigation, fisheries enhancement, and recreation. In addition to its favorable location, the unit cost of developing storage at this site would compare favorably with the cost of any other storage development in the Central Valley.

The reservoir area is located in grass-covered rolling hill land. The area is clear except for scattered trees and brush, mainly along the water courses. The community of Elk Creek, with a population of about 150, and scattered farms and rural areas, with a total population of about 175, are located in the proposed reservoir area. The only industrial development in the area is a sawmill located near Elk Creek. Agricultural lands within the proposed reservoir area are relatively unproductive, consisting primarily of open-range grazing lands. A north-south county road traverses the entire length of the reservoir area.

As shown on Plate 1, there are three existing reservoirs on Stony Creek. East Park Reservoir, with a capacity of 51,000 acre-feet, is located on Little Stony Creek near the community of Stonyford. It was constructed in 1910 by the U. S. Bureau of Reclamation as part of the Orland Project. Stony Gorge Reservoir, with a capacity of 50,200 acre-feet, is located on Stony Creek near the community of Elk Creek. It was constructed by the Bureau in 1928 as an addition to the Orland Project. Black Butte Reservoir, with a capacity of 160,000 acre-feet, is located on Stony Creek about 9 miles upstream of the town of Orland, and was completed by the Corps of Engineers in 1963. Although the reservoir will be operated primarily for flood control, it will also provide an annual conservation yield of 54,000 acre-feet.

Plans For Diverting Eel River Yield Via Clear Lake

Under the Clear Lake routing plan, the Upper Eel River Development would include the following project features: (1) conservation storage on the Middle Fork Eel River, (2) diversion facilities for delivering the conserved water from the Middle Fork to the upper main Eel River, (3) a receiving reservoir on the upper main Eel, probably English Ridge Reservoir, (4) a tunnel for delivering the water from English Ridge Reservoir into Middle Creek and the Clear Lake drainage basin, (5) Clear Lake, (6) a tunnel for diverting the water from Cache Creek, which drains Clear Lake, into the Upper Putah Creek Basin, (7) power generation facilities in the Putah Creek Basin, (8) Lake Berryessa, and (9) conveyance facilities from Lake Berryessa to the Sacramento River.

Middle Fork Eel River Conservation Features

There are three basic plans by which water could be developed on the Middle Fork Eel River for subsequent diversion to the upper main Eel. These alternative plans are:

(1) Water would be conserved in Spencer and Dos Rios Reservoirs and diverted by pumping to the upper main Eel. Spencer Reservoir would have a gross capacity of 850,000 acre-feet. Dos Rios Reservoir would have a gross capacity of 560,000 acre-feet. The normal water surface in Dos Rios Reservoir would be limited to 1,325 feet to prevent inundation of Round Valley. This plan represents the smallest practical scale of development for diverting Middle Fork yield via Clear Lake. Approximately 500,000 acre-feet of firm annual export yield could be developed.

(2) Water would be conserved in a large Dos Rios Reservoir and diverted by pumping to the upper main Eel. Round Valley would be protected by construction of Mill Creek and Franciscan Dams and would be drained by Mill Creek Tunnel. This is the largest development for routing via Clear Lake which does not utilize the Round Valley storage potential. Dos Rios Dam would be about 685 feet high and would impound a reservoir with 3,000,000 acre-feet gross capacity. Approximately 690,000 acre-feet of firm annual yield could be developed for export.

(3) Water would be conserved in a large Dos Rios Reservoir which utilized the storage potential of Round Valley. It would provide for full development of the Middle Fork Eel's water potential. Water could be diverted by either pumping or gravity, although the very large inactive storage associated with gravity diversion appears to make this a less favorable alternative. Under the pumping plan, Dos Rios Dam would be about 600 feet high and would impound a reservoir of 4,100,000 acre-feet gross capacity. Between 750,000 and 800,000 acre-feet of firm annual yield could be developed for export.

Elk Creek Diversion Facilities

The diversion facilities for lifting conserved water from the Middle Fork Eel River to the upper main Eel would consist of the following features: (1) a pumping plant on the Elk Creek arm of Dos Rios Reservoir;

(2) discharge lines to the entrance of Elk Creek Tunnel; and (3) Elk Creek Tunnel. Depending on the water surface fluctuation associated with the operation of Dos Rios Reservoir, Elk Creek Pumping Plant might be an underground installation. Elk Creek Tunnel would be about 7.3 miles long and 12 feet in diameter.

It is possible that Elk Creek Pumping Plant could operate in conjunction with a powerplant at Spencer Dam. At a 50 percent capacity factor, the powerplant would have slightly more capacity than required at Elk Creek Pumping Plant. Thus, power from Spencer might be used during peak hours at Elk Creek, and low-cost power purchased commercially for off-peak operation.

Upper Main Eel River Features -- English Ridge Reservoir

A reservoir on the upper main Eel River would be an integral link in the conveyance system for exporting Middle Fork Eel River flows via Clear Lake. Elk Creek Tunnel would terminate in such a reservoir, and the conveyance feature for diverting water to the Clear Lake Basin, probably Garrett Tunnel, would begin there.

In addition to its possible inclusion in the Upper Eel River Development, a reservoir development on the upper main Eel River has also been studied for other purposes. Growing demand for water service in the Russian River Basin and in the area north of San Francisco Bay has pointed to the Eel River as a source of surplus water. It is anticipated that eventually all of the yield developed by a project on the upper Eel River will be used within the Eel and Russian River Basins and in the areas immediately contiguous to them.

Four basic plans for developing reservoir storage on the upper main Eel River were investigated. These included different combinations of English Ridge, Willis Ridge, and Pressley Reservoirs. Of the plans studied, the most favorable appears to be a large English Ridge Reservoir. An English Ridge Dam 535 feet high would impound a reservoir with a gross storage of 1,800,000 acre-feet. This reservoir would develop an annual conservation yield of about 340,000 acre-feet, in addition to the present Eel River diversion into Potter Valley.

The present development of the water resources of the upper main Eel River consists of two reservoirs, a diversion tunnel, and the 9,040 kilowatt Potter Valley Powerplant, all owned by the Pacific Gas and Electric Company. Van Arsdale Dam and Reservoir, with a capacity of 700 acre-feet, was constructed in 1907. Van Arsdale Dam serves to divert water from the Eel River through a 6,000-foot tunnel to the powerhouse penstocks. A 450-foot power drop is made from the tunnel to the powerhouse, which is located at the north end of Potter Valley on the East Fork of the Russian River. Scott Dam, which forms Lake Pillsbury, was constructed in 1921 to provide some regulation of the Eel River runoff. Lake Pillsbury has a gross storage capacity of 93,700 acre-feet.

The annual diversions into Potter Valley have varied from 71,000 acre-feet in 1924 to 205,000 acre-feet in 1952, the average being about 142,000 acre-feet. In April 1950, the Pacific Gas and Electric Company completed the enlargement of a restricted section of the diversion tunnel, thereby increasing the maximum rate of diversion to about 345 cubic feet per second. This would not have increased the amount of water diverted during the extremely dry years, such as 1924, but in an average year the diversion from Van Arsdale Reservoir would have been increased by approximately 25,000 acre-feet. Allowing for this increased diversion capability, the average flow through the tunnel would have been about 167,000 acre-feet annually.

If a major water conservation project is constructed on the upper main Eel River, negotiations with the Pacific Gas and Electric Company will be required to determine the disposition of their existing power facilities. A large reservoir would control that stream to the extent that the water releases into Potter Valley could be made on a firm power schedule. The dependable capacity of the powerplant would be greatly increased as the result of the uniform annual flows and by the increased head provided by the large reservoir on the Eel River. However, the existing plant is not capable of generating at the increased capacity and would probably require expansion or replacement. The water users within the Russian River Basin, who currently utilize this water from the Eel River, would also be benefited by the added regulation provided by the large reservoir.

Scott Dam and Lake Pillsbury

Van Arsdale Dam and Reservoir, Potter Valley in background

Transbasin Conveyance Feature -- Garrett Tunnel

The feature for diverting the Eel River water from that basin to the Sacramento River Basin would be Garrett Tunnel. This tunnel would extend from English Ridge Reservoir to Middle Creek, a tributary of Clear Lake. Numerous combinations of active storages in English Ridge Reservoir and various elevations and alignments of Garrett Tunnel have been analyzed. These studies indicate that the most favorable intake elevation of the tunnel would be 1,500 feet. The corresponding outlet elevation in Middle Creek would be 1,450 feet. The tunnel would be about 14 feet in diameter and 12.2 miles long.

Studies were made of the possibility of hydroelectric development of the head between the upper main Eel River and Clear Lake. One of the more favorable plans included the construction of Pitney Ridge Dam and Powerplant on Middle Creek. However, these studies indicated that the power development probably could not be justified unless annual diversions from the Eel River were in excess of 800,000 acre-feet. In addition, operation of the power facilities would detract from the benefits from coordinated operation of English Ridge Reservoir and Clear Lake. For these reasons, the Middle Creek power development is not proposed as part of the Upper Eel River Development.

Clear Lake

Under operation of the Upper Eel River Development, water diverted from the Eel River would flow from Garrett Tunnel into Middle Creek, which drains into Clear Lake, and thence through Clear Lake. At the outlet of Clear Lake, the water would be diverted through a 2-mile tunnel to Soda Creek, in the Putah Creek drainage basin. In addition to providing a vital link in the conveyance system, Clear Lake would benefit from flood control and recreation enhancement. The present and proposed operation of Clear Lake is described in the following paragraphs.

Clear Lake is a large shallow natural body of water with a gross capacity of about 1,100,000 acre-feet and a surface area of 43,000 acres. The maximum depth is about 50 feet. In 1914, a 32-foot high concrete gravity dam was constructed about 3 miles downstream from the lake on Cache Creek to provide regulation of the stored water. In 1927, this dam and the water rights of the former owners were acquired by the Clear Lake Water Company, which has been operating the system since that time.

The Clear Lake Water Company provides irrigation water service to about 25,000 acres in Yolo County. The diversions from Cache Creek are developed from water released from Clear Lake combined with unregulated runoff. These diversions average about 100,000 acre-feet annually. However, the amount of water available in Cache Creek for diversion is quite variable and the annual diversions have ranged from a low of 13,000 acre-feet in 1931 to 189,000 acre-feet in 1946. The annual diversion during the critically dry period 1928-34 averaged 45,000 acre-feet.

Clear Lake is presently operated as stipulated under terms of the Gopcevic Decree[1/]. Under this decree, the Clear Lake Water Company is permitted to fluctuate the lake between the limits of zero and 7.56 feet on the Rumsey Gage, which is located near the edge of the lake at Lakeport. These gage heights correspond to water surface elevations 1318.59 and 1326.15 feet, respectively. Within these limits, the lake has an active storage capacity of about 314,000 acre-feet.

Water from Clear Lake flows through an extremely narrow and shallow outlet channel before it is released into Cache Creek from the Clear Lake Water Company dam. The outlet channel has a maximum capacity of approximately 2,500 second-feet. This is insufficient to pass the runoff that accumulates in the lake during periods of excessive flood inflow from tributary streams. Consequently, during periods of storm runoff, the lake level rises and extensive flood damage occurs to land and improvements adjacent to the lake. However, under the terms of the Bemmerly Decree[2/], the result of litigation brought by downstream interests, the outlet channel cannot be enlarged to pass waters from the lake at an increased rate of flow. The downstream residents were concerned about flooding of their property should additional water be added to the flow of Cache Creek during its flood stage.

1/ Decree rendered October 7, 1920, by the Superior Court, Mendocino County, in the matter of Gopcevic v. Yolo Water and Power Company.

2/ Judgment rendered December 18, 1940, by the Superior Court, Yolo County, in the matter of Bemmerly v. The County of Lake, Action No. 8812.

Under operation of the Upper Eel River Development, Clear Lake would not be allowed to fluctuate as widely as it does at present. The enlarged outlet channel and the Soda Creek Tunnel would have sufficient capacity to pass the flood waters which normally damage areas adjacent to the lake. The tunnel would have sufficient capacity to convey water needed to satisfy the local demands of Upper Putah Creek and the power demands of the Soda Creek power facilities.

Enlargement of the Clear Lake outlet channel and modification of the operation of Clear Lake would necessitate modification of the Gopcevic and Bemmerly Decrees. However, the desired flood protection and the improved water supply conditions created by the Eel River imports should warrant the required modification of these decrees. Under the modified operation, the Clear Lake Water Company would not be required to increase the releases to Cache Creek during flood periods over what would normally be released under their present operation.

Putah Creek Basin Power Facilities

Soda Creek Tunnel. Soda Creek Tunnel would connect the Clear Lake Basin with the Upper Putah Creek Basin. The tunnel would be sized to convey flows required for generation of peaking power at Stienhart Dam, the uppermost of the Upper Putah Creek Basin power features. The capacity of the tunnel would be sufficient to enable the diversion of essentially all flood flows from the Clear Lake Basin. The tunnel would be about 19 feet in diameter and 2 miles long.

Stienhart Reservoir and Powerplant. Stienhart Dam, Reservoir, and Powerplant would be constructed for power generation on Soda Creek, a tributary of Putah Creek. The earth and rockfill dam would have a height of 275 feet and a crest length of 850 feet. The reservoir site has a natural drainage area of 19 square miles and an estimated mean annual natural runoff of 7,000 acre-feet. The gross capacity of the reservoir would be 80,000 acre-feet, with a water surface area of 850 acres at a normal water surface elevation of 1,300 feet. A powerplant located at the toe of Stienhart Dam would develop about 250 feet of head. With an annual diversion of 500,000 acre-feet, the powerplant would have a capacity of 47,000 kilowatts.

Jerusalem Reservoir and Powerplant. Jerusalem Dam, Reservoir, and Powerplant also would be constructed for the purpose of power generation on Soda Creek. The earth and rockfill dam would have a height of 160 feet and a crest length of 1,400 feet. Jerusalem Reservoir would have a normal water surface elevation of 1,045 feet, a gross capacity of 46,000 acre-feet, and a surface area of 750 acres. The drainage area between Stienhart and Jerusalem damsites is 10 square miles and the estimated mean annual runoff between the two damsites is 4,300 acre-feet. A powerplant located at the toe of Jerusalem Dam, with an excavated tailrace channel, would develop about 240 feet of head. The material from the tailwater excavation would be used as fill material for Jerusalem Dam. With an annual diversion of 500,000 acre-feet, Jerusalem Powerplant would have a capacity of 42,000 kilowatts.

Both Stienhart and Jerusalem Reservoirs would be maintained at their normal pool elevations for power generation. These reservoirs would therefore have no water conservation or flood control benefits, but would provide good areas for recreation.

Lake Berryessa

Lake Berryessa would be the last major link in the conveyance system for bringing Eel River water to the Sacramento Valley via Clear Lake. This reservoir is the storage feature of the federal Solano Project. Under initial development, the existing reservoir would be adequate to provide some reregulation of Eel River imports and also meet Solano Project demands. It is anticipated that at some later date Lake Berryessa would be enlarged. This possibility is discussed later in this chapter.

The existing Lake Berryessa is impounded by Monticello Dam, which was completed in 1957. The reservoir gross storage is 1,600,000 acre-feet. Under full development of the Solano Project, the reservoir's firm annual yield will be 247,000 acre-feet. This yield is based on a reservoir draw-down to 30,000 acre-feet of dead storage during the 20-year historical dry period, 1916-37. By adding Eel River imports, the reservoir's critical period would be reduced to the seven-year period 1928-34, the same as most other major reservoirs in the Central Valley.

Conveyance Facilities to Sacramento River

The facilities for conveying Eel River imports from Lake Berryessa to the Sacramento River would include channelization of Putah Creek, a new channel across the Yolo Bypass, a low-head pumping plant, and a siphon under the ship channel. The total cost of these facilities would be quite minor compared to the cost of the whole project.

* * *

PASKENTA-NEWVILLE PROJECT

In the North Coastal Area Investigation the Glenn Reservoir Complex has been studied primarily with regard to its association with the importing of water from North Coastal streams. It has been recognized, however, that certain elements of the Glenn complex would be justified on the basis of development of local tributary runoff. A project at the Paskenta site has been studied for possible development under the Davis-Grunsky program. In addition, a project utilizing the Paskenta and Newville storage units of the complex for conservation of Thomes and North Fork Stony Creek flows appears to be a favorable early-stage addition to the State Water Resources Development System.

Plan of Development

Under a plan for developing local flows, Paskenta-Newville Reservoir with a gross storage capacity of 1,200,000 acre-feet would provide a total annual yield of about 200,000 acre-feet. This new water supply would be available for consumptive use in west side Sacramento Valley service areas, for fisheries enhancement, and for replenishment of water supplies in the Sacramento-San Joaquin Delta. The estimated capital cost of the project is $30 million.

The Paskenta-Newville Project would consist of two reservoirs with a connecting spillway channel between them. Paskenta Reservoir on Thomes Creek would have a gross storage capacity of 70,000 acre-feet and a water surface area of 1,280 acres at a normal pool elevation of 965 feet. Newville Reservoir on North Fork Stony Creek would have a gross storage capacity of 1,130,000 acre-feet and a water surface area of 11,000 acres at a normal pool elevation of 845 feet.

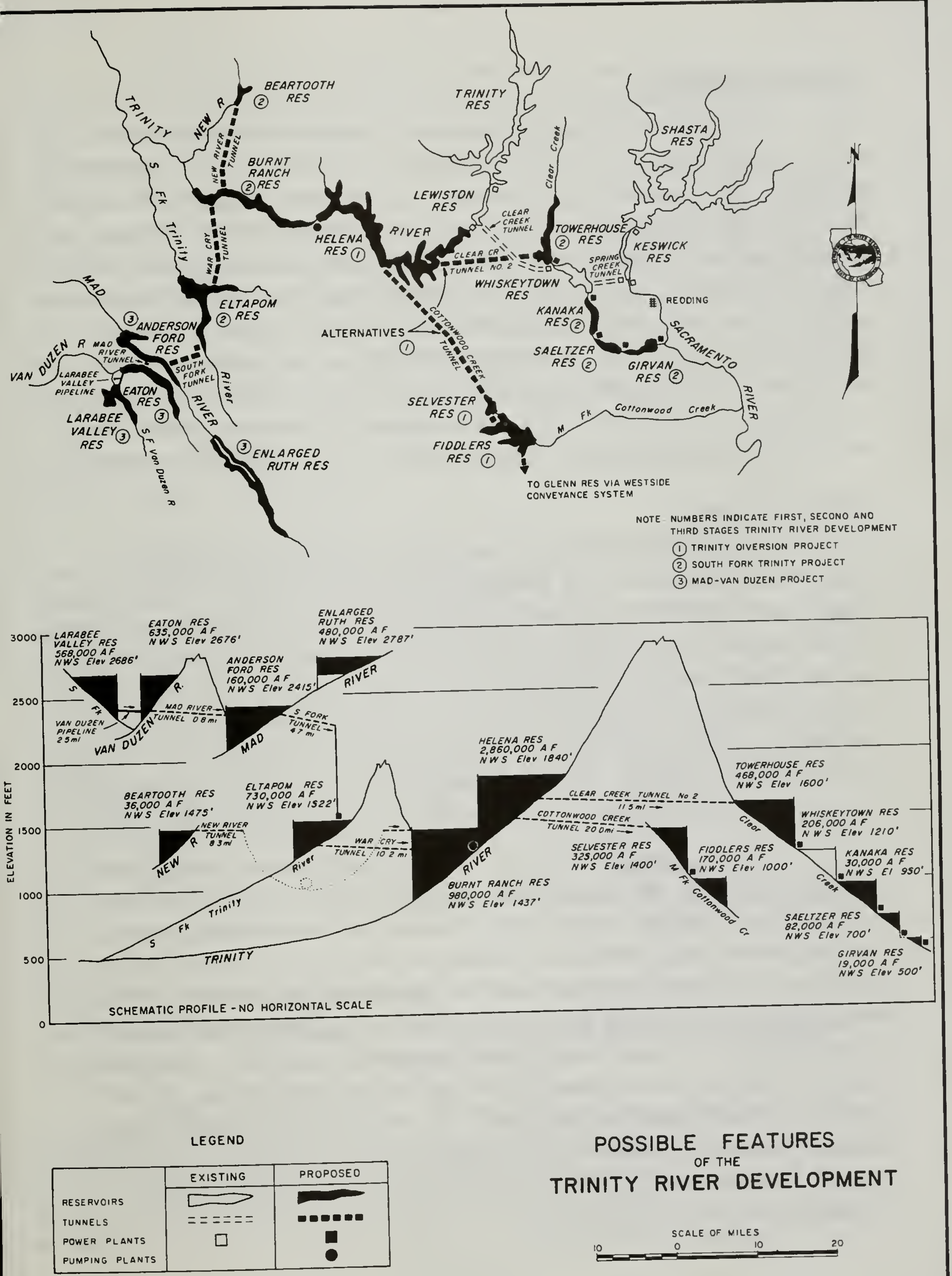
Paskenta Reservoir would be operated to provide for local irrigation and fisheries enhancement releases to Thomes Creek. Spills from the reservoir would be diverted by the channel spillway into Newville Reservoir. The runoff of Thomes Creek is so great in relation to the storage at Paskenta Reservoir, that the reservoir would be at a high operating level most of the time and would thus be conducive to recreation development. Newville Reservoir would be operated on a schedule of firming unregulated flows in the Delta. During average or wet years, there would be only minor releases from the reservoir; during critically dry periods the entire storage of the reservoir could be released.

One important consideration is the time required to fill Newville Reservoir. The high storage-inflow ratio at this site indicates that special attention be given to the maximum reservoir capacity which should be considered. The largest capacity which is being considered at this time is one that would provide for annual releases equal to the long-term mean annual storable inflow minus evaporation losses. Storage-yield data indicate that the reservoir capacity at this point, which might be called the "hydrologic limit," is about 1,200,000 acre-feet. A cursory probability analysis has shown that about 10 years would be required to fill a reservoir of this capacity, assuming local irrigation and fisheries enhancement releases were made during the filling period. The filling time would represent a cost in the economic analysis of the project.

* * *

TRINITY RIVER DEVELOPMENT

The surplus water in the Trinity River and its adjacent basins could be developed by the staged construction of three projects. These three projects would produce a total annual yield of approximately 1,800,000 acre-feet, in three equal increments. The proposed projects have been designated the Trinity Diversion Project, the South Fork Trinity Project, and the Mad-Van Duzen Project. Possible features of the plan are shown on Figure 6, and on Plate No. 1.



POSSIBLE FEATURES OF THE TRINITY RIVER DEVELOPMENT

DEPARTMENT OF WATER RESOURCES 1964

Existing Development

The only major existing diversion of North Coastal water into the Sacramento Valley is through the Trinity River Division of the Bureau of Reclamation's Central Valley Project. The principal features comprising the Trinity River Division are: Trinity Dam and Reservoir and Lewiston Dam and Reservoir on the Trinity River; Clear Creek Tunnel, extending 10.8 miles from Lewiston Reservoir to Clear Creek; Whiskeytown Dam and Reservoir on Clear Creek; and Spring Creek Tunnel and siphon, extending 3.0 miles from Whiskeytown Reservoir to Keswick Reservoir on the Sacramento River. The project includes three major hydroelectric power installations, with a total installed capacity of 384,000 kilowatts. The average annual diversion from the Trinity River to the Sacramento Valley is 850,000 acre-feet.

Plan of Development

There are two practical routes for diverting water from the Trinity River developments to the Sacramento Valley. They are: (1) via Clear Creek, and (2) via Cottonwood Creek and the Westside Conveyance System. Present studies indicate that the Clear Creek routing is the more favorable, but additional studies are necessary for a final selection. As part of the internal staging on the Clear Creek route, it may be possible to utilize the existing Spring Creek power development features for interim generation of hydroelectric energy. For this presentation, the descriptions and costs of the three Trinity River projects correspond to the Clear Creek routing.

Trinity Diversion Project. The Trinity Diversion Project would include a 2,860,000 acre-foot Helena Reservoir, and a gravity flow tunnel to Clear Creek. Helena Reservoir would extend to the downstream toe of Lewiston Dam and would develop an annual new water yield of about 600,000 acre-feet. The developed water would be diverted to the Sacramento River Basin by an 11.5 mile-long Clear Creek Tunnel No. 2, which would extend from Helena Reservoir to Clear Creek, above Whiskeytown Reservoir. This tunnel would be sized to provide capacity for the two succeeding Trinity River projects. From Whiskeytown Reservoir, the water from this stage would be conveyed through the federal Spring Creek Tunnel and Powerplant for generation of secondary energy. The estimated capital cost of the Trinity Diversion Project is $154 million.

South Fork Trinity Project. This project, which would be constructed as the second stage of the Trinity River Development, would include three dams, two tunnels, and a pumping plant. Water would be diverted from Eltapom Reservoir on the South Fork Trinity River through a 10.2 mile-long tunnel to Burnt Ranch Reservoir on the Trinity River. Water would also be diverted to Burnt Ranch Reservoir from Beartooth Dam and Reservoir on the New River. Approximately 600,000 acre-feet of new yield would be pumped from Burnt Ranch Reservoir into Helena Reservoir. The water supply from this second stage, together with the yield from the first stage, would be diverted from Helena Reservoir to Clear Creek through Clear Creek Tunnel No. 2. A series of reservoirs and powerplants would be constructed on Clear Creek to generate hydroelectric power as the water passed down Clear Creek to the Sacramento River. The total estimated capital cost of the second stage is $360 million.

Mad-Van Duzen Project. This project would constitute the third stage of development within the Upper Trinity River and its adjacent basins. Features would include Larabee Valley and Eaton Dams and Reservoirs in the Van Duzen River Basin and Anderson Ford Diversion Dam and an enlargement of Ruth Reservoir on the Mad River. This project would also include construction of a reservoir on the Mad River at the Butler Valley site to sustain and augment the Eureka-Arcata area water supply, presently served from Ruth Reservoir. Surplus flows of the Mad and Van Duzen Rivers developed by these reservoirs would be diverted through a 4.7 mile-long tunnel into Eltapom Reservoir for subsequent diversion to the Sacramento Valley via the previously described conveyance works. The Mad-Van Duzen Project would add another 600,000 acre-feet of new yield to the system at an estimated capital cost of $220 million.

Conservation Features of Proposed Plan

This section presents a more detailed discussion of the conservation features of the three Trinity River projects.

Helena Dam and Reservoir. Helena Reservoir would be formed by the construction of a 585-foot high rockfill dam on the Trinity River, approximately 3 miles downstream of the North Fork confluence with the Trinity River. The reservoir would have a gross capacity of 2,860,000 acre-feet and a water surface area of 19,800 acres at a normal pool elevation of 1,840 feet. The reservoir would develop a conservation yield of about 600,000 acre-feet, would provide the forebay pool for diversion to the Sacramento Valley, and would provide for necessary downstream releases and for reregulation of flows pumped from later staged works. The estimated capital cost of Helena Dam and Reservoir is $84 million.

Eltapom Dam and Reservoir. Previously reported studies indicated that Eltapom Dam should be constructed to a height of 645 feet. The resulting reservoir would enable a gravity diversion to Helena Reservoir. Subsequent geologic exploration has raised questions about the adequacy of the foundation for such a high dam. Consequently, the plan has been revised to include a lower dam at a site half-a-mile downstream, with a diversion to Burnt Ranch Reservoir instead of Helena Reservoir.

As now proposed, Eltapom Reservoir would be formed by the construction of a 350-foot high earthfill dam on the South Fork Trinity River immediately downstream of Eltapom Creek. At a normal pool elevation of 1,522 feet, the reservoir would have a gross capacity of 730,000 acre-feet and a water surface area of 4,650 acres. The reservoir would conserve the surplus flows of the South Fork and reregulate diversions from the Mad-Van Duzen Project. Approximately 400,000 acre-feet of water would be diverted from the reservoir through War Cry Tunnel to Burnt Ranch Reservoir. Releases also would be made for fisheries and downstream needs. The estimated capital cost of Eltapom Dam and Reservoir is $55 million.

War Cry Tunnel. War Cry Tunnel would extend from Eltapom Reservoir to Burnt Ranch Reservoir. The tunnel would be 15 feet in diameter and 10.2 miles long. It would be sized to include capacity for later-staged water from the Mad-Van Duzen Project. The estimated capital cost of War Cry Tunnel is $25 million.

New River Diversion. The diversion of about 120,000 acre-feet of water from the New River to Burnt Ranch Reservoir would be accomplished by Beartooth Reservoir and New River Tunnel. Beartooth Reservoir would be formed by construction of a 285-foot high earthfill dam on the New River about 1 mile upstream of Panther Creek. The reservoir would have a gross capacity of 36,000 acre-feet and a water surface area of 410 acres at a normal pool elevation of 1,475 feet. New River Tunnel would be 12 feet in diameter and 8.3 miles long. The estimated capital cost of the New River Diversion Project is $35 million.

Burnt Ranch Dam and Reservoir. Burnt Ranch Reservoir would be formed by construction of a 600-foot high rockfill dam on the Trinity River about 3 miles upstream of the confluence with the New River. The reservoir would have a gross capacity of 980,000 acre-feet and a water surface area of 5,300 acres at a normal pool elevation of 1,437 feet. The reservoir would develop about 80,000 acre-feet of new yield from the incremental run-off between Helena Dam and Burnt Ranch Dam. It would also reregulate diversions from the South Fork Trinity River and the New River and would serve as a forebay for the Helena Pumping Plant. Provisions are included for downstream releases. The estimated capital cost of Burnt Ranch Dam and Reservoir is $71 million.

Helena Pumping Plant. Helena Pumping Plant, located at the base of Helena Dam, would lift the conserved water from Burnt Ranch Reservoir about 400 feet into Helena Reservoir. The estimated capital cost of Helena Pumping Plant is $17 million.

Larabee Valley Dam and Reservoir. Larabee Valley Reservoir would be formed by the construction of a 452-foot high earthfill dam on the South Fork Van Duzen River about 1.5 miles upstream from its confluence with the Van Duzen River. The reservoir would have a gross capacity of 568,000 acre-feet and a water surface area of 4,050 acres at a normal pool elevation of 2,686 feet. Approximately 130,000 acre-feet per year would be diverted from Larabee Valley Reservoir through a 2.5 mile-long pipeline to Eaton Reservoir. The estimated capital cost of Larabee Valley Dam and Reservoir and the pipeline is $39 million.

Eaton Dam and Reservoir. Eaton Reservoir would be formed by the construction of a 381-foot high earthfill dam on the Van Duzen River approximately 1.5 miles upstream of the confluence with the South Fork Van Duzen. The reservoir would have a gross capacity of 635,000 acre-feet and a water surface area of 4,000 acres at a normal pool elevation of 2,676 feet. Approximately 200,000 acre-feet of new water would be developed by Eaton Reservoir. This water, together with the diversion from Larabee Valley Reservoir, would be diverted via a 0.8 mile-long Mad River Tunnel to Anderson Ford Reservoir on the Mad River. The estimated capital cost of Eaton Dam and Reservoir and the Mad River Tunnel is $29 million.

Enlarged Ruth Reservoir. An enlarged Ruth Reservoir would be formed by the construction of a 277-foot high earthfill dam on the Mad River. The existing dam would be utilized as part of the enlarged embankment. The present capacity of 52,300 acre-feet would be increased to a gross capacity of 480,000 acre-feet. The new reservoir would have a water surface area of 5,420 acres at a normal pool elevation of 2,787 feet. The existing recreation development would be relocated to the edge of the enlarged lake. Approximately 145,000 acre-feet of new yield could be developed by the enlarged lake. Project commitments of the Humboldt Bay Municipal Water District would be met from replacement storage constructed at the Butler Valley site. The estimated capital cost of an enlarged Ruth Reservoir is $13 million.

Anderson Ford Dam and Reservoir. Anderson Ford Reservoir would be formed by the construction of a 372-foot high earthfill dam on the Mad River immediately downstream of Pilot Creek. The reservoir would have a gross capacity of 160,000 acre-feet and a water surface area of 1,400 acres at a normal pool elevation of 2,415 feet. Approximately 125,000 acre-feet of water would be developed by Anderson Ford Reservoir. The 600,000 acre-feet of new yield developed from the Mad and Van Duzen Rivers would be diverted from Anderson Ford Reservoir via South Fork Tunnel to the South Fork Trinity River. The estimated capital cost of Anderson Ford Dam and Reservoir is $30 million.

South Fork Tunnel and Powerplant. Water diverted from Anderson Ford Reservoir would flow through a 4.7 mile-long South Fork Tunnel to the South Fork Powerplant. The estimated capital cost of the 15-foot diameter tunnel is $28 million. The South Fork Powerplant, located on the edge of Eltapom Reservoir, would develop about 700 feet of head. The estimated capital cost of the 156,000 kilowatt powerplant is $18 million.

Butler Valley Dam and Reservoir. Butler Valley Reservoir would be formed by the construction of a 193-foot high earthfill dam on the Mad River about 6 miles upstream of Sweasy Dam. The reservoir would have a gross capacity of 75,000 acre-feet and a water surface area of 1,360 acres at a normal pool elevation of 460 feet. Water developed in the reservoir would be released to provide a supply to the Eureka-Arcata area. Flows would also be provided for fisheries. The estimated capital cost of Butler Valley Dam and Reservoir is $13 million.

Ruth Dam and Reservoir
(Courtesy Swanlund Photo Lab,
Eureka, California)

Conveyance Routes for Trinity River Developments

Two of the more favorable alternative diversion routes from Helena Reservoir to the Sacramento Valley which have been studied during this investigation are: (1) via an 11.5-mile gravity flow tunnel to Clear Creek, thence through a series of reservoirs and power generation features on Clear Creek and into the Sacramento River; or (2) via a 20-mile gravity flow tunnel into Cottonwood Creek, thence through Selvester Reservoir and Powerplant, through the Westside Conveyance System into the Glenn Reservoir Complex and then down Thomes and Stony Creeks into the Sacramento River.

Present studies indicate that the Clear Creek route is more favorable than the Cottonwood Creek route. However, no firm selection of the route can be made at this time. There are two factors which will have considerable bearing on this decision. One is the amount of reregulatory storage required in the Central Valley to make the schedule of diversions from the Trinity River compatible with demands in the Central Valley; the other factor is the future value of hydroelectric power. A discussion of the two routes follows:

Clear Creek Route. The Clear Creek conveyance route would include a tunnel, four dams and reservoirs, and five powerplants. Clear Creek Tunnel No. 2 would be about 20 feet in diameter and 11.5 miles long. The capacity of the tunnel would be sufficient to divert the flows from all three Trinity projects. The estimated capital cost of the tunnel is $70 million.

Four new dams and reservoirs would be constructed on Clear Creek. They are: Towerhouse, Kanaka, Saeltzer, and Girvan. These four dams and reservoirs, together with the existing Whiskeytown Dam and Reservoir, would reregulate diversions from the Trinity River and provide head for the powerplant located at the base of each dam. Approximately 1,150 feet of head would be developed by these hydroelectric facilities on Clear Creek. The estimated total capital cost of the Clear Creek dams, reservoirs, and power facilities is $205 million.

Cottonwood Creek Route. The diversion route via Cottonwood Creek would include Cottonwood Creek Tunnel, Selvester Reservoir and Powerplant, the Westside Conveyance System, the Glenn Reservoir Complex, and possible hydroelectric features between Glenn Reservoir and the Sacramento River.

Cottonwood Creek Tunnel, which would convey the water from Helena Reservoir to the Cottonwood Creek Basin, would be about 18 feet in diameter and 20 miles long. This size tunnel would provide sufficient capacity for diversion of flows from the three Trinity River projects. The estimated capital cost of the tunnel is $78 million.

Selvester Dam and Reservoir on the Middle Fork of Cottonwood Creek would reregulate the diversions from the Trinity River and provide about 375 feet of head for a powerplant located at the base of the dam. Water would be released through the powerplant into Fiddlers Reservoir, the northernmost element of the Westside Conveyance System. The estimated capital cost of Selvester Dam, Reservoir, and Powerplant is $63 million.

The Westside Conveyance System would consist of a series of interconnected reservoirs on the upper reaches of Cottonwood, Red Bank, and Elder Creeks in Shasta and Tehama Counties. It would extend from the Middle Fork of Cottonwood Creek south to Thomes Creek, a distance of 40 miles. The system would require construction of 16 dams, ranging in heights up to 285 feet; and open channel cuts, through the intervening ridges, ranging in depths to 180 feet. Of the alternative alignments which have been studied, the one generally following the 1,000-foot contour was selected as the most favorable.

The primary purpose of the system, as the name implies, is for the conveyance of water to the Glenn Reservoir Complex. There also would be benefits associated with the Westside Conveyance System from flood control, fisheries enhancement, recreation, local irrigation, and hydroelectric power. The estimated capital cost of the Westside Conveyance System is $130 million.

The Glenn Reservoir Complex is discussed under the Upper Eel River Development.

* * *

GREATER BERRYESSA PROJECT

When full, Shasta, Oroville, Trinity, Folsom, and Auburn Reservoirs would store a total of 14 million acre-feet of water. This tremendous volume of water in storage could be matched by the construction of one 590-foot high dam on Putah Creek, forming an enlarged Lake Berryessa. The enlarged

Lake Berryessa would provide for reregulation of imported water from the Eel River and for storage of flood flows pumped from the Sacramento River. Reconnaissance studies indicate that a large pumped storage power generation installation could be included in the Greater Berryessa Project.

The following sections include discussions of the existing Solano Project and of the possible plans for development of a Greater Lake Berryessa.

Solano Project

Lake Berryessa, the key storage feature of the U. S. Bureau of Reclamation's Solano Project, was completed in 1957. At its normal water surface elevation of 440 feet, the lake has a gross storage capacity of 1.6 million acre-feet and a surface area of 19,250 acres. The reservoir can develop an annual irrigation supply of 247,000 acre-feet. The project provides water to Solano County through the Putah South Canal, which extends from the diversion dam on Putah Creek, about 6 miles below Monticello Dam, for a distance of 38 miles southwest to the vicinity of Cordelia.

The recreation development which has taken place around Lake Berryessa has been explosive. There are seven large recreational developments on the west shore of the lake and more are planned. The Bureau of Reclamation has reserved a perimeter strip 300 feet wide around the entire lake. Napa County has been granted a permit to use this land and has in turn subleased to private parties for the development of public resorts and parks. These leases run from 20 to 50 years and contain restrictions as to the construction, operation, and types of facilities permitted. The improvements revert back to the county at the termination of the lease.

Plan of Development

Under the plan of development described herein, Lake Berryessa would be enlarged to a capacity of 14 million acre-feet. The lake would have a water surface area of 65,600 acres at its normal pool elevation of 760 feet. The reservoir would be formed by construction of a 590-foot high earth and rockfill dam on Putah Creek approximately 1 mile downstream of the existing Monticello concrete arch dam. During construction, the existing lake would continue its normal operation.

Extensive conveyance facilities would be required between Lake Berryessa and the Sacramento River. These facilities would enable the diversion of flood flows from the Sacramento River to the lake, the operation of the pumped storage installation, and the conveyance of water from the lake to the Sacramento River. The pumped diversion from the river would require a siphon under the deep water ship channel, two afterbay dams, two low-head pumping plants, and the channelization of Putah Creek. A generating station and additional pumping units would be required at the base of the main dam. In addition to these features, the conveyance from the lake back to the river would require a pumping plant at the intake of the siphon under the deep water ship channel. The diversion point on the Sacramento River would be located approximately 7 miles southwest of Sacramento, upstream of the diversion point of the proposed peripheral canal around the Sacramento-San Joaquin Delta.

With pumped storage operation, water would be lifted from Monticello Afterbay into the enlarged Lake Berryessa during "off-peak" hours by reversible pump-turbine units. During "on-peak" hours water would be released back into the afterbay, and power would be generated by the reversible units. One of the major considerations in the Greater Berryessa Project would be filling the large lake to operating level prior to its initial operation. In order to compare this project with other alternatives, the estimated cost was modified to reflect the interest on the investment and the operating costs incurred during the filling period.

Summary of Plan

An enlarged Lake Berryessa with a gross storage of 14,000,000 acre-feet, with the pumped storage feature and coordinated with the Central Valley reservoir system, could sustain a new firm annual yield in the Sacramento-San Joaquin Delta of 1,600,000 acre-feet. The estimated capital cost of the Greater Berryessa Project is $311 million. This cost includes the conveyance facilities from Lake Berryessa to the Sacramento River, the cost of Greater Berryessa Dam, Reservoir, the reversible pump-generating plant, and the capitalized cost of filling the reservoir to operating level.

* * *

LOWER EEL RIVER DEVELOPMENT

The plan for developing the water resources of the Lower Eel River comprises two large conservation reservoirs on the Lower Eel and conveyance facilities for delivering the new water supply into the Sacramento Valley, either by way of Clear Lake and Lake Berryessa or via the Glenn Reservoir Complex. The construction of a major reservoir on the Lower Eel River would necessitate the relocation of approximately 100 miles of the Northwestern Pacific Railroad. Preliminary estimates indicate that the relocation would cost on the order of $130 million.

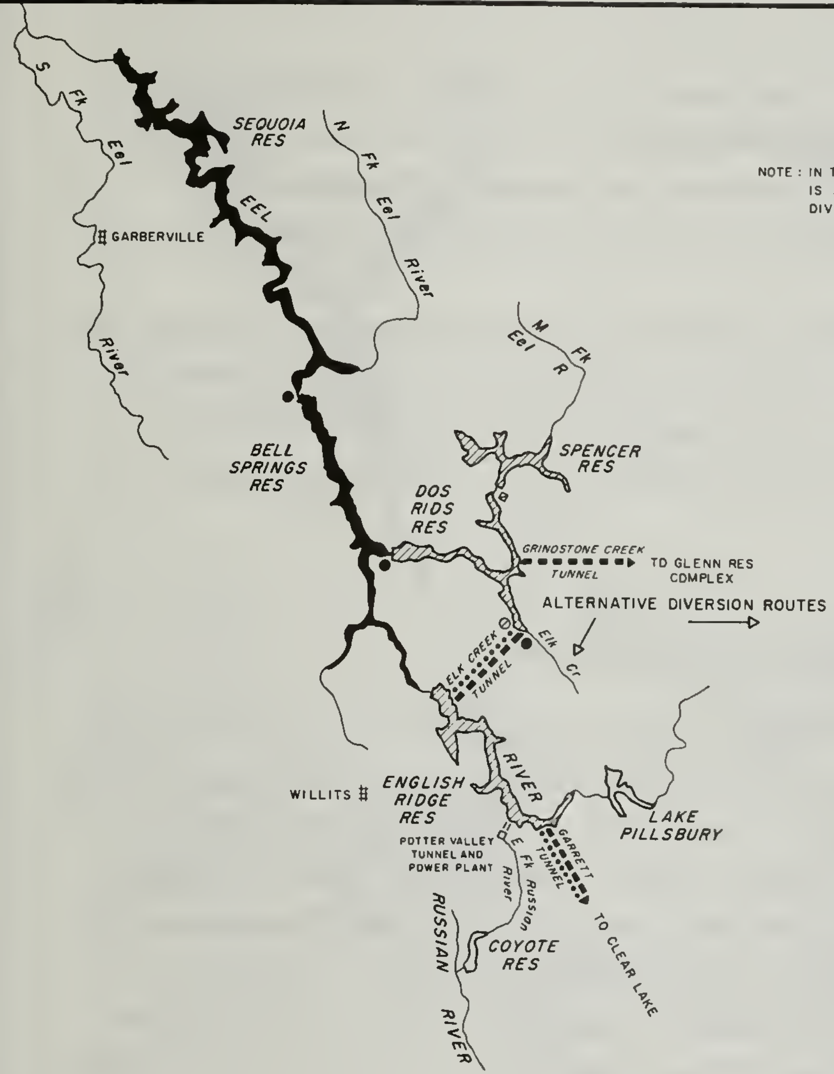
Plan of Development

For purposes of this report, it is assumed that the water from the Lower Eel River Project would be routed to the Sacramento Valley via Clear Lake. The proposed plan of development for the Lower Eel River is as follows: Sequoia Reservoir would be formed by the construction of a 612-foot high dam on the Eel River about 10 miles upstream of the confluence with the South Fork Eel River. The reservoir would have a gross capacity of 5,400,000 acre-feet and a water surface area of 24,000 acres at a normal pool elevation of 740 feet. The inactive storage in the reservoir would be 3,400,000 acre-feet, corresponding to a minimum pool elevation of 650 feet, which would be the same elevation as the Bell Springs Pumping Plant. Releases of over 300,000 acre-feet per year would be made from Sequoia Reservoir for fisheries purposes. Approximately 600,000 acre-feet per year would be pumped into Bell Springs Reservoir for subsequent export. The estimated capital cost of Sequoia Dam and Reservoir is $170 million.

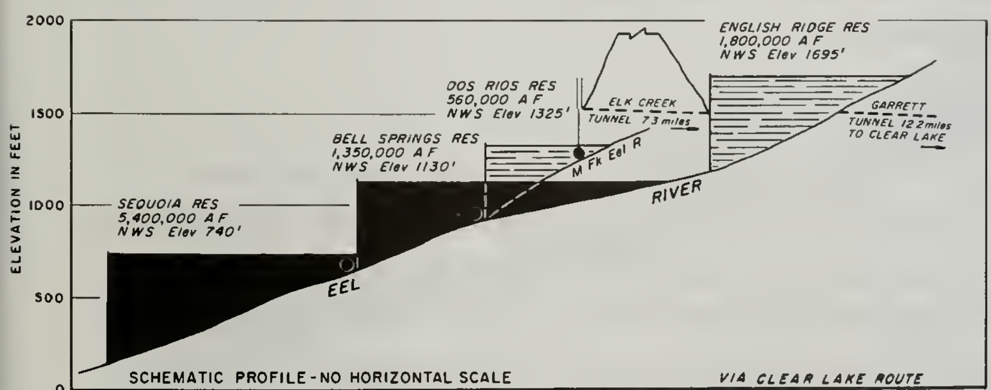
Bell Springs Reservoir would be formed by the construction of a 490-foot high dam on the Eel River about 5 miles upstream from the confluence with the North Fork Eel. The reservoir would have a gross storage capacity of 1,350,000 acre-feet and a water surface area of 8,200 acres at a normal pool elevation of 1,130 feet. The inactive storage in the reservoir would be 300,000 acre-feet, corresponding to a minimum pool elevation of 925 feet, the same elevation as the Dos Rios Pumping Plant. The estimated capital cost of Bell Springs Dam and Reservoir is $101 million.

The 600,000 acre-feet of yield from Sequoia Reservoir, combined with about 400,000 acre-feet of yield developed in Bell Springs Reservoir, would be pumped into Dos Rios Reservoir. From Dos Rios Reservoir the water would be pumped to English Ridge Reservoir through a tunnel parallel to the Elk Creek Tunnel. The water supply would be released from English Ridge Reservoir into Clear Lake through a tunnel parallel to Garrett Tunnel. A

FIGURE 7



NOTE: IN THIS PLAN THE UPPER EEL RIVER DEVELOPMENT IS ASSUMED TO HAVE UTILIZED THE CLEAR LAKE DIVERSION ROUTE



LEGEND

	EXISTING	PROPOSED: UPPER EEL RIVER DEVELOPMENT	PROPOSED: LOWER EEL RIVER DEVELOPMENT
RESERVOIRS	(open outline)	(hatched)	(solid black)
TUNNELS	(dashed line)	(dotted line)	(heavy dashed line)
POWER PLANTS	□	⊠	
PUMPING PLANTS		⊘	●

POSSIBLE FEATURES
OF THE
LOWER EEL RIVER DEVELOPMENT

SCALE OF MILES
10 0 10 20

tunnel parallel to the Soda Creek Tunnel would be used to convey the water from Clear Lake into the Upper Putah Creek Basin. Additional generating units would be constructed at Stienhart and Jerusalem Powerplants. The imported water would be reregulated in Lake Berryessa and released to the Delta.

The estimated capital cost of the facilities needed to convey the 1,000,000 acre-feet of water from Sequoia Reservoir to Lake Berryessa is $186 million. The estimated total capital cost of the Lower Eel River projects, including cost of the railroad relocation, is $587 million.

* * *

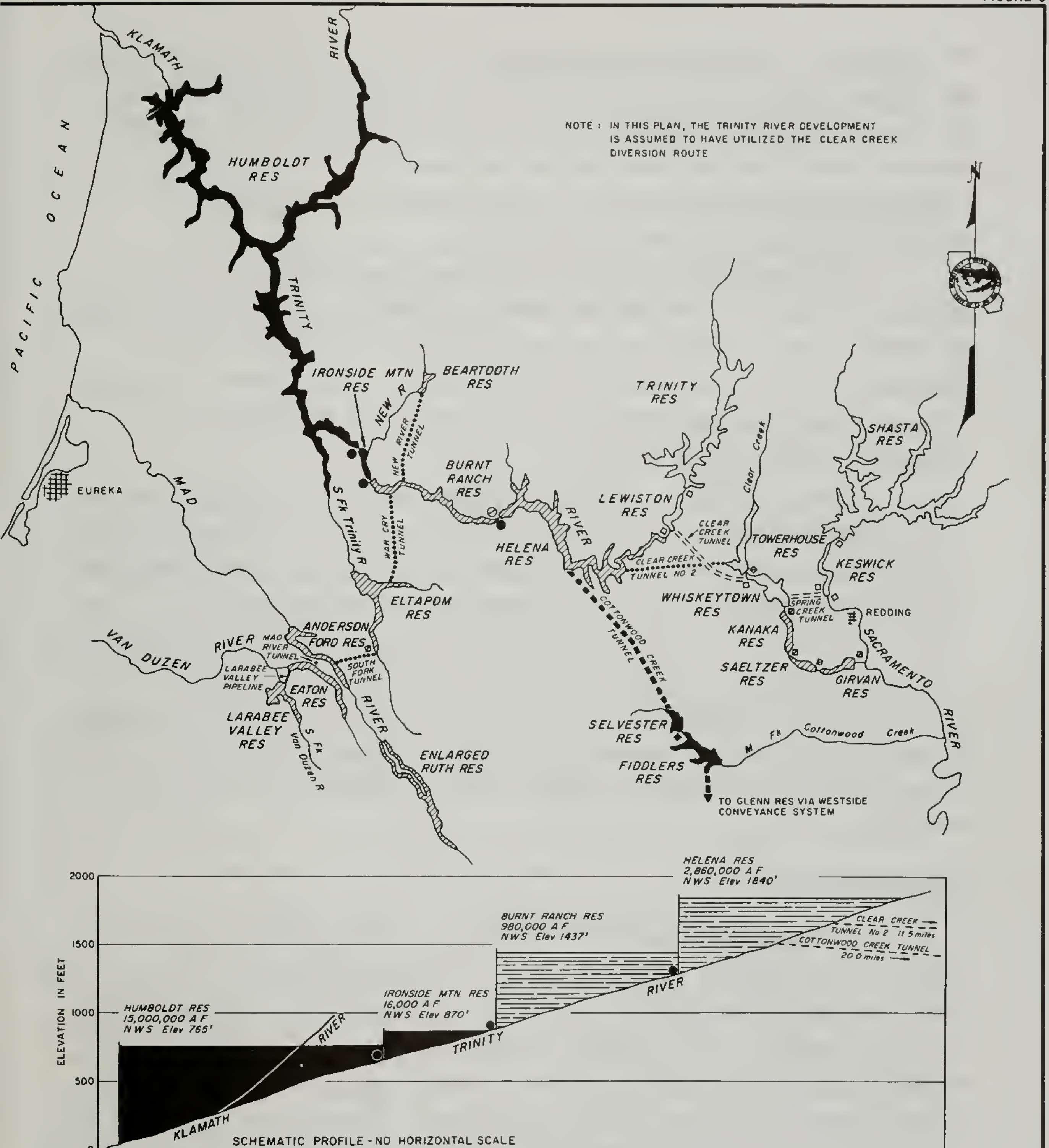
KLAMATH RIVER DEVELOPMENT

After development of the projects described above, the remaining major source of new surface water supplies to meet increasing demands within the State would be the Klamath River Basin, including the Lower Trinity River. As discussed in the previous section on staging, this development will not be needed for many years and could in fact be made unnecessary by future technological advances in saline-water conversion. Studies of alternative plans for the development of the Lower Trinity River and the Klamath River have not been made in as great detail as those for the earlier-staged North Coastal projects.

Possible Plan of Development

Preliminary studies indicate that one of the more favorable engineering plans for Klamath River Development would include construction of a very large reservoir near the mouth of that river. A reservoir and pumping plant on the Lower Trinity River would be required to convey the new water yield into the then existing Burnt Ranch and Helena Reservoirs, constructed as part of the Trinity River Development. Subsequently, this new water supply would be diverted to the Sacramento Valley, possibly to the Glenn Reservoir Complex via Cottonwood Creek and the Westside Conveyance System. Klamath River Development features are shown on Figure 8 and on Plate 1.

Humboldt Reservoir would be formed by the construction of a 740-foot high dam on the Klamath River, about 12.5 miles upstream from the mouth.



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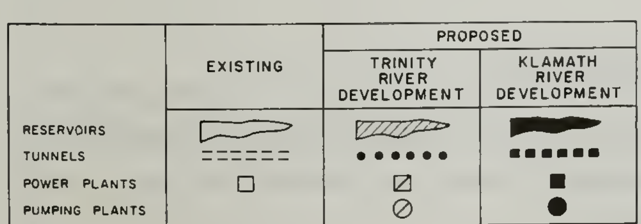
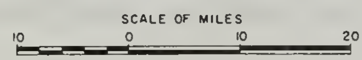


POSSIBLE FEATURES OF THE KLAMATH RIVER DEVELOPMENT



The reservoir would have a gross storage capacity of 15,000,000 acre-feet and a water surface area of 46,200 acres at a normal pool elevation of 765 feet. The reservoir would conserve and make available for upstream diversion some 6,000,000 acre-feet of new annual water supply. This yield would be pumped successively into Ironside Mountain, Burnt Ranch, and Helena Reservoirs, all on the Trinity River.

The transbasin diversion from Helena Reservoir would be via gravity flow tunnel to Cottonwood Creek, a westside tributary of the upper Sacramento River. From there the water would flow via the Westside Conveyance System to the Glenn Reservoir Complex. The estimated capital cost of Humboldt Dam and Reservoir and the diversion facilities to the Sacramento Valley is $1.6 billion.

There would be a number of problems associated with the construction of Humboldt Reservoir. The most serious would be probable elimination of the anadromous fisheries on the Klamath River. The dam would completely block the anadromous fish from their spawning and nursery grounds. It may be possible to maintain a portion of the salmon and steelhead runs with very large artificial propagation facilities; however, the river sport fishery for salmon and steelhead would be virtually eliminated. There are a number of possible compensatory measures which should be explored, but most involve presently untested biological concepts and their degree of success is uncertain.

Alternative Plans

Other possible plans for development of the Klamath River will be studied in the future. One of the more favorable plans would include storage reservoirs in the upper basin which would release water to the lower river during dry periods. Thus, a large sustained flow would be available near the mouth for diversion south through a coastal conduit. There would be no major dams on the lower river in this plan. Although the yield from this plan would be considerably less than that from the Humboldt Reservoir Project, it would have the advantage of creating considerably less fisheries problems.

* * *

KNIGHTS VALLEY PROJECT

Departmental planning efforts in the Russian River Basin have been directed toward a possible water development project at Knights Valley. The purpose of the project would be to conserve the natural flows of Maacama and Franz Creeks and to provide storage for surplus flows diverted from the Russian River. The conserved water would be used in the Napa and Russian River Basins.

Knights Valley Reservoir is a key unit in plans being formulated by both the U. S. Corps of Engineers and the U. S. Bureau of Reclamation. The following is a brief description of the Knights Valley Project and of plans proposed by the federal agencies.

Description

The Knights Valley Reservoir site has a storage potential of about 1,600,000 acre-feet. This large reservoir could be formed by the construction of two dams. One would be located on Maacama Creek and would be about 410 feet high. The other would be a 320-foot high structure on Franz Creek. Only about 240,000 acre-feet of this storage potential would be needed to conserve the natural flows of Maacama and Franz Creeks, which average about 66,000 and 14,000 acre-feet per year, respectively.

A large reservoir constructed at this site would provide storage for surplus flows diverted from the Russian River. There are three practical plans by which this diversion could be accomplished. Each would require a diversion dam on the Russian River, a conveyance canal to the reservoir, and a pumping plant at the reservoir. The department's studies indicate that the most favorable plan would include a diversion dam near Geyserville and a 17 mile-long canal to the forebay and pumping plant.

The Knights Valley Project could be constructed either in stages or to its full potential initially. The department's studies indicate that staged development would be a more favorable utilization of investment capital. The decision as to which type of development to undertake will depend on the rate of demand build-up for project services, primarily for irrigation water. Under ultimate development the large reservoir could provide between 275,000 and 350,000 acre-feet of new annual yield, the actual amount dependent upon the conveyance capacity of the diversion facilities.

The area contiguous to the Knights Valley Project would receive numerous benefits in addition to new water supplies. Considerable flood control and better regulated streamflow would be provided in the Russian

River Basin. The project would have a tremendous recreation potential, including possible enhancement of the proposed Mount St. Helena State Park.

Corps of Engineers Plan

The Corps proposes to construct the Knights Valley Project either in three stages or to ultimate capacity in one stage. If constructed in stages, the first stage would consist of a 233,000 acre-foot reservoir. The yield of 45,000 acre-feet would be available for use in the Napa Valley and the Vallejo area. The second stage would consist of facilities to divert surplus water from the Russian River to the then existing reservoir. This stage would provide 109,000 acre-feet of new water yield. The third stage would consist of raising Maacama and Franz Dams to impound a storage reservoir of 1,500,000 acre-feet and increasing the conveyance capacity of the diversion facilities to 2,000 second-feet. The third stage would provide an additional yield of 196,000 acre-feet. The total project yield would be 350,000 acre-feet per year.

Bureau of Reclamation Plan

Knights Valley Reservoir would be constructed initially to its full capacity of 1,600,000 acre-feet. Diversion facilities would include a dam on the Russian River near Cloverdale, a diversion dam on Big Sulphur Creek, a 38 mile-long canal, and pumping features. The 300,000 acre-feet of new water developed by the project would be delivered by tunnel to the Napa Valley and via canal to service areas in the Russian River.

* * *

COASTAL STREAM PROJECTS

In addition to project formulation studies for major multiple-purpose developments in the interior basins of the North Coastal region, reconnaissance studies have been made of the potential for water resources development in the coastal basins. The studies of the large interior basins such as the Eel, Trinity, and Klamath are oriented toward the development of major multiple-purpose projects to meet both local and out-of-basin demands for project services. Studies of the coastal basins are principally concerned with locally oriented projects for fisheries enhancement and recreation.

Description of Area

The coastal basins under investigation include the secondary drainages north of the Russian River Basin. They are, in a north to south order: Redwood Creek, Little, Bear, Mattole, Tenmile, Noyo, Big, Albion, Navarro, Garcia, and Gualala Rivers. These basins encompass an area of 3,000 square miles and account for 4,500,000 acre-feet of surface water runoff, or about 15 percent of the total of the North Coastal area. The water resources of the basins are presently undeveloped. However, many streams provide excellent fish habitat in their natural state. The excellent fishing in these streams, combined with the serenity of the redwoods and the rugged beauty of the coastline, offers unparalleled recreation opportunity.

Purpose of Study

It is anticipated that development of these streams to supply out-of-basin water demands will not be necessary. Inasmuch as the projected water requirements within these basins are relatively small, the major justification for coastal stream projects may very well be dependent on benefits from fisheries enhancement and, to a lesser extent, recreation. Therefore studies were directed toward the selection of the more favorable fisheries enhancement projects in each basin. In addition to providing fisheries enhancement flows, these reservoirs could provide supplemental water supplies for local agricultural and urban uses.

Some of the more favorable fisheries enhancement projects on the coastal streams may offer economical opportunities for compensating possible fisheries detriments associated with the large multiple-purpose projects on the Eel, Trinity, and Klamath Rivers. The association of the coastal basin projects with major developments located within the internal basins could provide a method for financing these smaller projects which may otherwise not be possible.

Scope of Studies

The intensity of the study conformed to rough reconnaissance standards. The designs and cost estimates were based on limited surface geology, and in many cases topographic mapping was limited to U.S.G.S. quadrangle maps, scale 1:62,500. There are few stream gaging stations on the coastal streams; consequently, water supply estimates were based on area-precipitation relationships. Estimates of releases required for fisheries enhancement were made by the Department of Fish and Game. The estimates are very preliminary, but indicative of the requisite magnitude, and provide a basis for comparison of alternative projects on the same stream.

Three general guidelines were used in selecting the location of possible fisheries enhancement projects on the coastal streams. The reservoirs should be located: (1) in the headwaters of the stream so as to enhance the greatest possible length of stream; (2) where the stream runoff is sufficient to develop the enhancement releases; and (3) such that reservoir inundation of spawning areas is kept to a minimum.

Results of Studies

Data corresponding to each of the selected projects is presented in Table 7. Considerable additional study is required to determine the associated costs and benefits. Additional studies of possible developments on the coastal streams will be undertaken as part of the department's continuing planning program in the North Coastal area.

A discussion of the fisheries aspects of the coastal streams is included in the appendix on Fish and Wildlife Resources.

TABLE 7

COASTAL STREAMS
POSSIBLE PROJECTS FOR FISHERIES ENHANCEMENT

Stream	Dam and Reservoir	Damsite Location	Reservoir Gross Storage 1000 AF	Reservoir Water Surface Elevation Feet	Reservoir Annual Release 1000 AF	Length of Stream Enhanced Miles
Redwood Creek	Lupton	SE$\frac{1}{4}$, Sec. 10, T6N, R3E	20	982	43	43
Little River	Tiptop	NE$\frac{1}{4}$, Sec. 2, T7N, R1E	4	284	6	7
Bear River	Brushy	Sec. 8 & 17, T1S, R1E	10	1,370	15	22
Mattole River Bear Creek	Thorn and Jewett	N$\frac{1}{2}$, Sec. 22, T5S, R2E N$\frac{1}{2}$, Sec. 12, T4S, R1E	24 32	1,126 860	20 31	61
Tenmile River	Churchman	SW$\frac{1}{4}$, Sec. 20, T19N, R16W	50	322	26	10
Noyo River	Northspur	SE$\frac{1}{2}$, Sec. 8, T18N, R15W	6	386	7	23
Big River	Dunlap	SE$\frac{1}{4}$, Sec. 17, T17N, R15W	20	387	14	36
Albion River	Comptche	S$\frac{1}{2}$, Sec. 2, T16N, R16W	8	300	2	14
Navarro River	Rector	NE$\frac{1}{4}$, Sec. 25, T13N, R13W	18	742	16	46
Garcia River	Garcia	SE$\frac{1}{4}$, Sec. 12, T12N, R13W	4	1,002	6	35
Gualala River	Neese Ridge	NE$\frac{1}{4}$, Sec. 31, T10N, R12W	10	458	15	31

CHAPTER V. INVESTIGATIVE ACTIVITIES

This chapter presents discussions of the work that has been accomplished during this investigation in the fields of hydrology, engineering geology, topographic mapping, design and cost estimating, power, fish and wildlife resources, recreation, watershed management, and economics and land use. Emphasis in this chapter is placed on general approaches and brief summaries of results. Detailed data are included in the appendixes and office reports for the various study activities.

Portions of the study activities relating to basic data in the fields of water requirements and land and water use were conducted under the department's Coordinated Statewide Planning Program. A brief description of the program is presented at the end of this chapter.

Hydrology Studies

This section discusses studies of precipitation, runoff, floods, reservoir operations, and ground water. Detailed summaries of each study activity and extensive compilations of basic hydrologic data are presented in an office report to this bulletin, entitled "Project Hydrology," and in Bulletin No. 142-1.1.

A large portion of the basic data used in the hydrology studies was provided by the U. S. Geological Survey. That organization has recently released a report (June 1964), entitled "Surface-Water Hydrology of Coastal Basins of California," which contains an analysis of the surface water hydrology of the Eel, Klamath, and Smith River Basins and several minor coastal basins.

Precipitation Analysis

There are over 200 precipitation stations in the region covered by the North Coastal Investigation. The longest continuous record, which dates from 1878, is for the station at Eureka. With few exceptions, all the stations are or were operated by the U. S. Weather Bureau.

For purposes of this investigation the recorded precipitation figures were extended by correlation procedures to cover the 50-year base period, 1906-1955. These 50-year mean annual precipitation values were used as a basis for plotting isohyetal maps, which show a generalized picture of the areal distribution of precipitation. The isohyetal maps were then used for estimating water supply and flood flows at proposed damsites where stream gaging records were not available.

The Project Hydrology office report contains discussions of precipitation, an isohyetal map, and tabulations of precipitation stations, showing location, elevation, periods of record, mean, maximum, and minimum precipitation amounts.

Runoff Analysis

There are 251 stream gaging stations in the area covered by this investigation. Of these, 74 have records of 10 years or more. Three, Trinity River at Lewiston, Eel River at Van Arsdale, and Scotia, have records extending back for over 50 years. The station with the longest record (55 years) in the North Coastal area is the Eel River at Van Arsdale. In the course of this investigation, 97 new stations were installed. Most of these were installed and are maintained by the U. S. Geological Survey in cooperation with the department.

The records covering short periods of time were extended by statistical correlation procedures to cover the 50-year period of analysis (1911-60). The three gaging stations with records covering the base period were used as base stations to extend the shorter records. The station at Sacramento River near Red Bluff, with the longest continuous record in the State (74 years), was also used as a base station.

The monthly distribution of estimated annual runoff at the gaging stations with short periods of record was determined by statistical comparisons with long-term stations on streams with similar characteristics. Precipitation patterns were also considered in estimating monthly flow distribution.

After annual and monthly estimates of stream runoff for the base period were completed for the major stream gaging stations, estimates were made of runoff at possible damsites. The damsite runoff estimates generally were made by application of an area-precipitation relationship to runoff estimates at the nearest reliable stream gage.

The Project Hydrology office report contains descriptions of runoff characteristics for stream basins in the area, tabulations of stream gaging stations, and estimates of natural flow at gaging stations. The report also contains detailed discussion of the methods used to estimate runoff at damsites; tabulations showing estimated natural monthly runoff for the period 1911-60 for proposed damsites; an iso-runoff map; and discussion and results of flow-duration studies for the major streams.

Flood-Flow Analysis

Studies of flood volumes, peaks, and frequencies were made to determine spillway requirements at proposed dams.

Two severities of flood hydrographs were used as the basis for spillway design: "standard project" and "probable maximum." The standard project flood hydrograph represents simulated flood runoff from a very large storm over the basin. This storm is one which would result if all of the historically observed individual meteorologic conditions most likely to produce a flood were present at the same time. The spillways for dams were designed to pass the standard project flood without any damage or encroachment upon the safety limits of the project. These spillways could pass the probable maximum flood, without safety encroachment, but there may be damage to appurtenant structures. The probable maximum flood is the largest flood reasonably possible at a site, considerably larger than any flood ever observed.

The flood studies also were made to determine the capacity of works required for diversion of the streams during construction. In most cases, the flood which occurred in December 1955 was used as a basis for designing the stream diversion facilities.

The Project Hydrology office report contains descriptions of the methods used to determine standard project and probable maximum flood hydrographs for proposed damsites. The report also contains discussion of flood frequency studies and regional flood frequency analyses. The flood frequency studies will provide a basis for the evaluation of flood control benefits to be made in the higher intensity planning studies.

Estimates of Reservoir Yield

The amount of conservation yield a reservoir can develop is determined from studies in which operation of the proposed reservoir is simulated using water supply conditions as they occurred at the site during historical dry periods. As discussed in Chapter III, one such dry period occurred from 1917 through 1937. Within this period, there was an even dryer period, 1928 through 1934. Operation studies for yield determinations in these studies covered these two dry periods.

In the operation studies, the proposed reservoir was assumed to be full at the beginning of the critically dry period. At the end of the critical period, having utilized the available inflow and storage, the reservoir would be drawn down to its minimum allowable level. The average annual amount of water which could be released from the reservoir on a sustained dependable basis during this critical period is designated "firm annual yield."

Numerous monthly reservoir operation studies were made for purposes of estimating reservoir yield and hydroelectric power production. Electronic computers were utilized in many of these studies. For each reservoir site considered, estimates of reservoir yield were made for a wide range of possible reservoir sizes, generally from a very nominal storage up to the topographic limit of the site.

The results of the reservoir operation studies are summarized with graphs of reservoir capacity vs. firm yield on a series of plates included in the "Alternative Plans for Development" office report.

Reservoir Release Schedules. Since projects in the North Coastal area would be operated as multiple-purpose developments, water would be released from the reservoirs on a number of different schedules. Reservoir releases for local irrigation uses would be made to conform to the normal growing season. Releases for fisheries purposes would be made on a schedule primarily designed to accommodate anadromous fish. In developments including hydroelectric powerplants, reservoir releases would be made on a schedule favorable to the generation of peaking power. For the associated reservoirs in the Sacramento Valley, reservoir releases would be made primarily on a schedule compatible with diversion requirements from the Sacramento-San Joaquin Delta.

Reservoir Evaporation. In the reservoir operation studies made for yield determinations, allowances were made for evaporation from the reservoirs surfaces. The rate of evaporation in the North Coastal area tends to increase with the distance inland.

The amount of water lost to evaporation is appreciable in very large lakes and reservoirs. Clear Lake, for instance, with a gross storage capacity of 1,100,000 acre-feet and a water surface area of about 43,000 acres, loses about 150,000 acre-feet of water per year through evaporation.

Ground Water Studies

Studies of available ground water supply in the North Coastal area were conducted under the Coordinated Statewide Planning Program and are presented in Bulletin No. 142-1.1. These studies, as well as investigations by other agencies, have shown that most of the usable supplies of ground water in the predominantly mountainous North Coastal area are found in widely scattered alluviated valleys and coastal plains. Ground water resources of northwestern California are not developed as extensively as they are elsewhere in the State.

Engineering Geology

Engineering geology plays a paramount role in the development of water resources projects. Most engineering decisions on the suitability of damsites, the availability of construction materials, and on tunneling conditions, depend heavily on the accumulation and interpretation of geologic data. Quite frequently a potential project is considered either a favorable or unfavorable alternative on factors relating directly to geologic conditions, since such conditions are directly reflected in the cost of the projects.

Also of fundamental importance are the safety aspects of proposed projects, which depend heavily on proper interpretation of geologic data. The complex geologic structure of foundation conditions in the North Coastal area, together with its seismic activity, landslides, and scarcity of construction materials lay a tremendous responsibility on the engineering geologist.

Geological work accomplished by the department prior to this investigation was limited to reconnaissance surveys in relation to the studies for Bulletin No. 3, The California Water Plan. The surveys consisted primarily of preliminary geological mapping of dam and reservoir sites and brief memorandum reports.

Since initiation of the North Coastal Area Investigation in 1957, an intensive geological program has been conducted. This program has included geologic mapping of damsites and tunnel alignments, exploration for construction materials, subsurface exploration of dam foundations and tunnel alignments, and the preparation of office reports. The intensity of the geologic studies has ranged from rough reconnaissance to detailed subsurface exploration.

The geologic studies are summarized in an office report to this bulletin entitled, "Engineering Geology." The report includes approximately 20 detailed damsite reports covering the foundation conditions and the availability of construction materials, in addition to discussion of special geologic problems. Tunneling conditions for approximately 12 important alternative tunnel routes are also discussed in detail, including the estimated properties of the rock at depth, the description of anticipated areas of poor rock, and the tunneling difficulties which may be encountered. In addition to the detailed studies, the geologic report contains, partially in tabular form, a complete summary describing briefly the geologic conditions of all the alternative features of the investigation. The report contains about 48 plates depicting geologic information.

The discussion in this section covers the extent and intensity of the engineering geology studies of damsites and tunnel alignments which have been made during this investigation. A more detailed summary is presented in the office report. Also included in this section are discussions of landslide studies in the Eel River Basin and of special studies made in regard to the Glenn Reservoir Complex.

Damsite Studies

Damsite investigations conducted under the North Coastal Area Investigation can be subdivided into four general categories: (1) surficial reconnaissance; (2) detailed reconnaissance including geologic mapping -- no subsurface exploration; (3) geologic study including preliminary subsurface exploration of the foundation and/or construction materials; and (4) pre-feasibility level geologic study which includes subsurface exploration of the foundation, borrow areas, and appurtenant structures. The four categories are interrelated levels of study intensity. All studies began with category one and proceeded through as many of the four levels as was warranted by the importance of the structure involved.

The first category, a surficial geologic reconnaissance, consisted of a cursory field study of the foundation conditions of the site and appurtenant structures, evaluation of available construction materials and a rough evaluation of apparent geologic problems which might affect the suitability of the proposed site. A sketch map was sometimes prepared showing the overall foundation geology and approximate location of construction material borrow areas. Potential problem areas such as faults, shear zones, permeable horizons, and landslides were also shown. The data were presented in outline form with added geologic maps, diagrams and short descriptions where required. This level of geological study was made for all structures considered in the planning investigation.

The second category, a detailed reconnaissance study, involved five to ten days of geologic field work on the basis of which a brief memorandum report containing a geologic map and sections was prepared. Geologic work performed at this level consisted of a general evaluation of the regional geologic setting, damsite geologic mapping, evaluation of foundation conditions, estimate of slope stability, location and description of potential borrow areas,and a general discussion of any other special geologic problems which could influence project feasibility.

In this category, special emphasis was placed on geologic mapping of the proposed foundations of the dam and appurtenant structures in order to establish the character and condition of the underlying rock and to estimate the necessary foundation preparation and treatment. In the course of geologic mapping, such features as faults, shears, joints, folds, permeable horizons, weak strata, landslides, terraces, etc., were recorded on a topographic map, and their significance to the construction of the dam was described in the text of the geologic report on that project. Further foundation,borrow,or reservoir exploration programs were outlined as recommendations in the order of importance to project formulation. This level of study was made for all possible projects which could not be eliminated from consideration by topographic, geographic, and hydrologic conditions.

The third category of geologic investigation consisted of a continuation of the detailed reconnaissance stage and included limited subsurface exploration of the foundation and/or borrow areas. The subsurface study was generally directed toward solution of specific foundation problems such as a fault zone, buried stream channels, or an incompetent rock structure which would have a major bearing on the overall project feasibility. A minimum amount of exploration was accomplished by any one or a combination of the following: trenching, excavation of pits, diamond drilling, auger drilling, and/or geophysical exploration.

A limited construction materials sampling and testing study was also initiated at this level if the outlined borrow areas were considered of questionable suitability. Soil samples were obtained and tested to determine the grain size distribution and compaction characteristics.

The results of the geologic exploration were covered in an office report which included a thorough description of the foundation conditions, expected foundation preparation, quality and location of the borrow areas, and a more general discussion of regional geologic setting as related to the proposed project. Studies in this category provided sufficient geologic information for reconnaissance designs and cost estimates.

The fourth category of damsite geologic studies during the reconnaissance stage of the investigation includes all the work performed during the first three phases and, in addition, an exploration and testing program which provided preliminary design criteria for the entire dam foundation, related structures, and construction materials.

Both deep and shallow methods of subsurface exploration were included in these studies. Trenches in the foundation or borrow areas provided information on the depth and condition of overburden and weathered bedrock. The overall character of stratified material was determined from representative samples obtained from trenches. This method of exploration proved to be very economical in determining the near surface conditions of a dam foundation and was used extensively throughout the investigational area.

Diamond core drilling was the most commonly used exploration technique for determining the foundation conditions at depth. This method provides a continuous small diameter sample which affords a close examination of the rock as it occurs at depth. Diamond drill holes to great depths have been used most advantageously in exploration of river channels where long, inclined holes are necessary to probe under the alluvium. All drill holes within dam foundations were water tested -- that is, water was introduced into the holes at various pressures, depending on the height of the proposed structure, and the water losses were recorded for each interval tested. This procedure provided information on the overall permeability of the rock with varying depth and was used in estimating the cutoff and grout curtain requirements.

The testing of drill cores and soils samples provided valuable information to the designer. The tests revealed such important physical characteristics of the material as: mineralogical content, compressive and tensile strength, unit weight, modulus of elasticity, chemical reactivity with concrete, and degree of expansion or slaking when exposed to air or water.

At the conclusion of the exploration and testing program, a comprehensive geologic report was prepared which described the foundation conditions, exploration results and other factors which had a bearing on the engineering feasibility of the damsite. This report included a geologic map and cross section, summary logs of exploration, tables summarizing the water testing, and laboratory rock and soil test results. Altogether, 11 damsites in the North Coastal area were investigated at this fourth level.

A summary of damsite geological investigations conducted during the North Coastal Area Investigation is presented in Table 8.

Tunnel Alignment Studies

Tunnel studies during this investigation consisted primarily of surficial geologic mapping. Only one tunnel alignment, Middle Eel-Glenn, was investigated by diamond drilling. The drilling on this alignment was quite limited and provided some information on actual conditions at the depth of the tunnel beneath the surface. The complexity of the problem of determining tunneling conditions can be appreciated from the fact that the tunnel alignment would be over 20 miles long and have as much as 4,500 feet of cover over it.

The general procedure used to determine information on tunneling conditions was as follows. A regional geologic reconnaissance covering a large scale area was conducted, and gross geologic features were traced on a regional geologic map. The most promising alignments were selected on this basis. The less favorable alignments, such as those following faults or shear zones, were similarly eliminated. On the basis of geologic mapping, tunneling conditions zones were differentiated, and rock load

TABLE 8

SUMMARY OF DAMSITE GEOLOGICAL INVESTIGATIONS
CONDUCTED DURING NORTH COASTAL AREA INVESTIGATION

Damsite Location	Stream	Status
Humboldt	Klamath River	II
Red Cap	Klamath River	I
Mettah Creek	Klamath River	I
Burnt Ranch	Trinity River	IV
Helena	Trinity River	IV
Lowden	Trinity River	I
Ironside	Trinity River	I
Big Bar	Trinity River	III
Horse Linto	Trinity River	I
Hoopa	Trinity River	I
Eltapom, Upper	South Fork Trinity River	III
Eltapóm, Middle	South Fork Trinity River	IV
Eltapom, Lower	South Fork Trinity River	II
Buck Mountain	Van Duzen River	I
Dinsmores	Van Duzen River	I
Camp	Van Duzen River	I
Eaton	Van Duzen River	III
Forks	Van Duzen River	I
Larabee Valley	South Fork Van Duzen River	II
Ruth	Mad River	I
Ranger Station	Mad River	III
County Line	Mad River	I
Eight Mile	Mad River	I
Anderson Ford	Mad River	II
Butler Valley	Mad River	IV
Blue Lake	Mad River	I
Essex	Mad River	I
Sequoia	Eel River	IV
Island Mountain	Eel River	I
Bell Springs	Eel River	IV
Woodman	Eel River	II
Willis Ridge	Upper Eel River	IV
English Ridge	Upper Eel River	II
Garcey Ranch	Upper Eel River	II
Marshall	Upper Eel River	I
Pressley Ranch	Upper Eel River	I
Benmore	Upper Eel River	I

TABLE 8 (Cont'd)

SUMMARY OF DAMSITE GEOLOGICAL INVESTIGATIONS
CONDUCTED DURING NORTH COASTAL AREA INVESTIGATION

Damsite Location	Stream	Status
Upper Mina	North Fork Eel River	I
Mina	North Fork Eel River	II
Spencer	Middle Fork Eel River	IV
Upper Etsel	Middle Fork Eel River	II
Etsel	Middle Fork Eel River	IV
Jarbow	Middle Fork Eel River	I
Dos Rios	Middle Fork Eel River	II
Mill Creek	Mill Creek - tributary to Middle Fork Eel River	I
Franciscan	Short Creek - tributary to Middle Fork Eel River	IV
Newville	North Fork Stony Creek	III
Paskenta	Thomes Creek	III
Rancheria	Stony Creek	III
Millsite	Stony Creek	III
Chrome Dike	No stream	III
Westside Conveyance System (17 damsites)	Tributaries of Cottonwood, Red Bank, Elder Creeks	II
Selvester	Middle Fork Cottonwood Creek	I
Fiddlers	Middle Fork Cottonwood Creek	IV
Towerhouse	Clear Creek	I
Kanaka	Clear Creek	II
Saeltzer	Clear Creek	II
Girvan	Clear Creek	II

Status

I Surficial reconnaissance level; no geological mapping; outline office report.

II Detailed reconnaissance level; geological mapping included; memorandum report.

III Preliminary exploration level; detailed geological mapping; brief office report.

IV Pre-feasibility level; includes subsurface exploration; comprehensive office report.

factors were assigned to various rock units. The second stage involved detailed geologic mapping along the selected alternative alignments and consisted primarily of refinement of the first stage. Tunnel cost data obtained from surficial geologic observations and interpretation of the conditions at depth were used for preliminary cost estimates. The final stage of tunnel investigation involved estimating quantitative data on the characteristics of rock types at tunnel invert elevations. These estimates included determination of the degree of fracturing and shearing at depth, ground water conditions, geothermal gradient, and a quantitative study of the rock load which can be anticipated in various rock types. This information is best obtained by exploration adits and diamond drill holes.

A summary of tunnel geological investigations conducted during the North Coastal Area Investigation is presented in Table 9.

Landslide Studies

One of the more important special geological studies made during the investigation was in relation to landslides in the Eel River Basin. The purpose of this study was to determine the effects landslides might have on proposed reservoirs. The approach to this reconnaissance study was to estimate the quantity of unstable material that might move into the proposed reservoirs.

From a study of aerial photographs of the Eel River system, approximately 200 landslides were plotted on a one-half mile to the inch strip map. Over 100 of these slides were field checked to more accurately define the limits of moving ground. The volumes of the slides were approximated by determining the surface area of the slides above the proposed reservoirs and applying a depth factor. These volume estimates, although very preliminary, did provide a rough idea as to the amount of storage capacity which might be lost if these slides moved into the reservoirs.

Some information was compiled regarding the movement of the landslides, but very little is presently known about this aspect. Indications are that the rate of movement is closely related to amount of precipitation falling on the slide. The effects of fluctuating reservoirs on slides cannot be determined with the available data. However, it is assumed that sliding due to the reservoirs would take place during the early

TABLE 9

SUMMARY OF TUNNEL GEOLOGICAL INVESTIGATIONS
CONDUCTED DURING NORTH COASTAL AREA INVESTIGATION

Tunnel	Location	Status
Clear Creek Tunnel No. 2	Trinity River to Clear Creek	II
Cottonwood Creek Tunnel	Trinity River to Cottonwood Creek	II
War Cry Tunnel	South Fork Trinity to Trinity	II
Larabee Valley Tunnel	South Fork Van Duzen to Van Duzen	II
Anderson Ford Tunnel	Mad River to South Fork Trinity	I
Eaton Tunnel	Van Duzen to Mad River	II
Eel-Glenn Tunnels	Middle Fork Eel River to Glenn Reservoir	III
Sequoia Tunnel	Eel River to Larabee Creek	II
Garrett Tunnel	Eel River to Clear Lake	II
Mina Tunnel	North Fork Eel to Middle Fork Eel	I
Elk Creek Tunnel	Middle Fork Eel to Eel River	I
Mill Creek-Jarbow Tunnel	Drainage for Round Valley	I
Mill Creek-Dos Rios Tunnel	Drainage for Round Valley	I
Soda Creek Tunnel	Cache Creek to Putah Creek	III

Status

I Reconnaissance geologic mapping of the tunnel area.

II Detailed geologic mapping along a specific alignment.

III Alignment study included subsurface drilling.

years of operation. Another aspect of the landslides, which needs intensive study and which is perhaps the most critical, is the effect of landslide triggered waves in reservoirs.

Landslides and their possible effects on water development projects will be thoroughly analyzed during the advance planning program for the Upper Eel River Development.

Special Studies

Another special geological study was in regard to the Newville portion of the Glenn Reservoir Complex. Part of the east rim of Newville Reservoir, called Rocky Ridge, is a hogback ridge formed by differential erosion of sedimentary rocks. The ridge is quite narrow and would in effect be a very long natural dam for Newville Reservoir. Studies were made to determine the stability of Rocky Ridge, possible leakage through it, and the feasibility of constructing dams in the low saddles.

A board of outside consultants was retained to provide expert counsel to the department's engineering geologists in this determination. The studies were specifically directed toward definition of the various rock units forming the ridge, the determination of the physical properties of the rocks, and the location of faults. The investigation consisted of geologic mapping, diamond drilling, water pressure tests, and rock testing.

Topographic Mapping

Adequate maps are fundamental tools to the planner, whether he is laying out a subdivision, a highway, or a major water development system. By means of a map the planner not only can locate his plan geographically but can also determine how it will best fit the land. More often than not, the land surface must be sculptured to accommodate the proposed works. Through use of maps, the amount of sculpturing can be determined and translated into cost. The accuracy of the cost estimate is a function of the quality of the maps used.

The importance of high quality mapping in the North Coastal Area Investigation was recognized, and an extensive mapping program was accomplished. Large scale maps were prepared by modern photogrammetric methods for important dam and reservoir sites. These maps are generally to scales of 1" = 200' and 1" = 400', with a contour interval of 20 feet. Numerous other topographic maps of damsites and reservoir areas have been compiled by federal, state, and local agencies. These maps, together with those prepared for this study, were used during reconnaissance-level studies.

A complete mapping index is included in the office report on Alternative Plans for Development. The index lists available maps for over 200 dam and reservoir sites in the North Coastal area. The scale, contour interval, date of mapping, and other pertinent information is included.

Designs and Cost Estimates

The preparation of realistic designs and adequate cost estimates plays an important role in the economic evaluation of any water development project. Because of the North Coastal area's rugged topography, and geographic location with respect to the place of use of the developed waters, the envisioned projects are large, involving works that in some cases are more extensive than anything yet constructed.

In the formulation of a plan, many structures and combinations of structures are compared. An essential element of the comparison is the estimated capital cost of each structure. Generally, the level of accuracy required for the cost estimates increases as the alternatives are narrowed down. Cost estimates that have been prepared as a part of the North Coastal Area Investigation have ranged in accuracy from the level attainable from a curve drawn through a plot of experienced costs for similar structures, to a level approaching that required for a feasibility report.

Cost Estimating Procedures

Cost estimating procedures used in this investigation have varied, depending upon the significant cost factors for a particular site and structure, and upon the amount of time and money available for basic data collection. Because of the relatively large cost and the variation in cost with site conditions associated with dams and tunnels, these structures were given somewhat detailed treatment; while powerplants and pumping plants were estimated in less detail. Allowances were made in all cost estimates for costs of engineering, administration, contingencies, and interest during construction. The following is a generalized description of the procedure followed in preparing cost estimates for each of these types of structures.

Dams and Spillways. After selection of possible damsites, available data pertaining to topography, geology, flood hydrology, and cultural development were reviewed, and where necessary, additional data was collected. For each of the selected sites, cost estimates were prepared for three possible reservoir sizes to define the relationships between cost and reservoir capacity. An appropriate type of dam and spillway was selected for each site. This frequently involved fairly detailed functional design and cost analysis of alternative dam types. In some instances complete estimates were produced for more than one type of dam at a given site.

Embankment designs for dams were usually based on a conservative modification of an existing design. This approach was used where the available construction material at the proposed site appeared to have similar characteristics to that at a site for which a detailed design was available. In some cases, when an adequate precedent design was not available, designs were based on preliminary stability studies. Layouts of proposed dams were made on the best available topographic maps; for important structures the scale was usually 1" = 400' with a contour interval of 20 feet. Embankment quantities were measured by planimeter; conduit and tunnel lengths were scaled.

Most cost estimates for dams were based on unit costs derived from analyses of recent bids. In some cases unit costs for excavation and embankment placement were calculated by assuming a typical construction plant to produce the required work. Relocation costs were based on map layouts, and the application of typical unit costs per mile for roads, transmission lines, etc. Construction schedules were based on requirements for streamflow diversion during construction, volumes of embankment involved, and site conditions.

Tunnels. Geologic studies of proposed tunnel alignments have not been intensive enough to provide more than approximations of tunneling conditions that may be encountered in construction. Consequently, the tunnel cost estimates are subject to considerable modification as additional geologic data are collected.

Developing cost estimates for tunnels involved three steps. Step one involved geologic study of the proposed alignment, as described in the section on Geology; from this study a prediction was made of the rock and water conditions that would be encountered during tunnel construction.

Step two involved analysis of past bid prices for tunnels with similar rock and water conditions and preparation of generalized cost curves. Step three simply consisted of utilizing the cost curves developed in step two to estimate costs.

Power and Pumping Plants. The cost estimates of proposed power and pumping plants have been derived from construction costs of existing plants of similar capacity and head. Due to the large number of preliminary estimates required, it was neither practical nor within the scope of the studies to prepare a detailed design of each plant. The cost estimate for a plant with a given capacity and head was determined from lump sum estimates of each of the following components:

1. Basic plant consisting of:
    a. Structure and improvements
    b. Turbines and generators, pumps and motors
    c. Accessory electrical equipment
    d. Miscellaneous equipment

The capital costs of transmission lines were not included with the cost of the proposed projects; however, the annual cost of transmission, which includes repayment of the capital investment, is reflected in the unit value of electrical power.

Relocations. Relocation costs for projects in the North Coastal area will be a major item. Projects built on the Lower Eel River will require the relocation of about 100 miles of the Northwestern Pacific Railroad, through what may be the most unstable terrain in the North Coastal area. U. S. Highway No. 299, which follows the main stem of the Trinity River, will also require relocation as development of that stream progresses. Estimates of relocation costs were made by laying out a new alignment on a map and applying to it a unit cost-per-mile based on experienced costs in similar construction conditions.

Office Report on Designs and Cost Estimates

The designs and cost estimates for the alternative projects described herein are discussed in detail in an office report to Bulletin No. 136, entitled "Designs and Cost Estimates." The report includes a detailed description of the methods used, the basic data available at the time of preparation of the cost estimate, a description of the generalized design forming the basis for the cost estimate, typical design layouts, and a summary of the cost estimate (by principal items) for each structure receiving serious consideration in the North Coastal Area Investigation.

Hydroelectric Power

Hydroelectric power has been an inseparable partner in the development of California's water resources. It is a major factor affecting the price of water from the federal Central Valley Project, the State Water Project, and numerous local projects. With the North Coastal area producing over 40 percent of the State's runoff, one would expect it to have a proportionately high hydroelectric potential. There are a number of factors, however, which have held hydroelectric development in the area to a minimum; thus, although the plans developed during this investigation include a number of hydroelectric facilities, most of these are actually located in the Sacramento River Basin, in association with the conveyance of water.

This section is devoted to a discussion of existing hydroelectric development in the North Coastal area, the factors affecting hydroelectric development in the area and the studies which have been made during this investigation regarding hydroelectric plants and pumping plants. Chapter VI contains a discussion of technological changes in electric power generation and their impact on plans for water development in the North Coastal area.

Existing Hydroelectric Development in the North Coastal Area

Compared to the Sierra Nevada area, where single-purpose hydroelectric projects abound, the North Coastal area is practically devoid of such development. During the past 50 years, numerous studies of the power potential of the North Coastal area have been made by federal, state, and local agencies, and by private concerns. However, very few developments have materialized.

The outstanding hydroelectric development in the North Coastal area is the U. S. Bureau of Reclamation's Trinity River Division of the Central Valley Project. The primary purpose of this multiple-purpose project is the conservation of Trinity River water for diversion to the Sacramento Valley; however, considerable hydroelectric power is generated as the water is conveyed from the Trinity River to the Sacramento River.

The only other hydroelectric development of consequence in the area is that of the Pacific Power and Light Company on the Upper Klamath River, south of the Oregon border. This is part of the company's power development of the steep section of the river on both sides of the state border. The development benefits from storage provided by multiple-purpose Klamath Lake and an associated pumped storage installation.

Table 10 presents a summary of existing hydroelectric installations in the North Coastal area.

TABLE 10

EXISTING HYDROELECTRIC DEVELOPMENTS
NORTH COASTAL AREA

Name of Plant	Owner	Date Built	Water Source	Head Feet	Capacity Kilowatts
Fall Creek	PP&L	1909	Fall Creek	730	2,000
Copco No. 1	PP&L	1922	Klamath River	125	20,000
Copco No. 2	PP&L	1925	Klamath River	157	27,000
Iron Gate	PP&L	1962	Klamath River	158	18,000
Junction City	PG&E	1905	Canyon Creek	602	3,000
Lewiston	USBR	1963	Trinity River	60	350
Trinity	USBR	1963	Trinity River	375	100,000
Clear Creek	USBR	1963	Trinity River	561	134,000
Spring Creek	USBR	1963	Trinity River	569	150,000
Potter Valley	PG&E	1907	Eel River	450	9,000

Physical Factors Affecting Hydroelectric Development in the North Coastal Area

There are certain physical factors which have been and will continue to be adverse to hydroelectric development in the North Coastal area. The most significant are: lack of good hydroelectric sites, configuration and direction of flow of the streams, anadromous fisheries problems, and location of the area with respect to major power load centers. The following is a discussion of these factors.

Hydroelectric Sites. Existing developments have preempted the more favorable hydroelectric sites on steep sections of the Klamath and Trinity Rivers; most of the remaining sections of these major streams are relatively flat. Several opportunities exist for development of sizeable heads elsewhere in the North Coastal area, but small flows and other factors preclude economic development of hydroelectric power in most instances.

Stream Configuration. The major streams of the North Coastal area, with the exception of the Russian River, flow to the west and northwest. The areas of water deficiency lie to the south and east. To deliver water from these streams to the deficient areas, it is necessary to construct long tunnels through the mountains, and pump water upstream to the tunnels. The cost of constructing long tunnels to convey the flows even on a somewhat uniform schedule is extremely high. Increasing the size of the tunnels to accommodate the higher flows required for the operation of hydroelectric plants at the end of the tunnels is generally prohibitive. The fact that most of the water must be pumped upstream precludes the installation of hydroelectric plants at the base of the conservation dams in the North Coastal area.

Fisheries. Peaking flows associated with hydroelectric plants are detrimental to anadromous fishes and must be smoothed out by constructing costly reregulating afterbays. In addition, costly fish hatcheries, or other artificial spawning facilities, must be constructed and operated to compensate for the loss of upstream spawning and nursery habitat.

Location. The remote location of the North Coastal area with respect to the major power load center in the San Francisco Bay Area also detracts from its hydroelectric power potential. The location is significant because peaking generation produces the greatest benefit, and a large power load is required to absorb large increments of peaking power. Moreover, North Coastal area plants would be in competition with the peaking plants at other localities in Northern California. The value of power from a hydroelectric plant located in the interior of the North Coastal area would be less than that from a plant located nearer the power load center because of the greater cost of transmission facilities and the greater loss of power in transmission.

Hydroelectric Planning

Numerous hydroelectric studies were made during the North Coastal Area Investigation. The planning considerations and the results of these studies are presented in this section.

Planning Criteria. The general guideline followed in these studies was to make each hydroelectric opportunity yield the maximum feasible output in terms of dependable capacity and energy, consistent with the other demands for the water resources concerned. Major planning considerations include in each case: determination of the most economic combination of reservoir size, active storage, power head, and water releases for power, in balance with releases for other purposes; provision for generation of peaking power, where economically justified, with adequate afterbay and forebay storage as needed; and utilization of power head potential along major conveyance routes where feasible and justified.

Department criteria regarding the sale of hydroelectric power provide that power will be sold at market value and net revenues will be used to reduce the charges for water. Thus, during this investigation, hydroelectric power was included as a project purpose when the projected revenue exceeded the associated costs. The capacities of the hydroelectric installations were based on that combination of plants and conservation works which resulted in a minimum unit cost of water.

The unit values of hydroelectric power used in the studies were based on the estimated cost of producing equivalent power in the privately financed steam-electric plant which would be constructed if the hydroelectric plant were not constructed. The unit cost of power for pumping was based on the same steam-electric plant production cost as was used in determining unit values for generation. The unit values of power and unit costs of power for pumping were adjusted to reflect the costs and power losses associated with transmission. The procedures used in estimating costs of pumping facilities and hydroelectric facilities are discussed in this chapter under "Design and Cost Estimates."

For purposes of these reconnaissance studies, it was assumed that hydroelectric plants would generate peaking power. Peaking plants operate during periods when power demand is high and either remain idle or operate as spinning reserve when the power demand is low. Generally speaking, the shorter the period of time of peak operation, the higher the power capability, and hence the higher the revenue producing capability. The amount of time a particular plant operates is governed by requirements of the power system into which the power is absorbed. On the average, peaking plants in the North Coastal area would operate about 30 percent of the time;

roughly speaking, from 8 to 14 hours a day, five days a week. The plants would not normally operate on weekends.

Results of Studies. The hydroelectric installations included in plans for development of the North Coastal area, as shown on Plate 1, are representative of selection and analysis of power sites based on conventional power planning criteria. As described in Chapter VI. it is probable that some of the hydroelectric facilities will not be economically justified under future analysis. Table No. 11 presents a summary of the possible hydroelectric and pumping plant installations shown on Plate 1.

Fish and Wildlife Resources

Northwestern California possesses a wealth of economically and aesthetically valuable fish and wildlife resources. These resources are mainstays of the area's recreation service industry, which is second only to lumbering in economic value. Some of the fish resources contribute substantially to the commercial fishing industry of the North Coastal area. The annual income from commercial fishing is about equal to that derived from agriculture and is exceeded only by lumbering and recreation.

The construction and operation of dams, reservoirs, and conveyance facilities for the export of surplus water from the North Coastal area would have profound impact on the fish and wildlife resources of the area, particularly anadromous fishes. It is State policy that these resources will be preserved and, if feasible, enhanced by state-constructed water developments. To this end, Department of Fish and Game biologists, working under contract with the Department of Water Resources, have made reconnaissance evaluations of the effects of proposed water projects and have prepared tentative recommendations for the preservation and enhancement of these resources. This section contains general discussions of the fish and wildlife resources and of the studies which have been made regarding them.

Fishery Resources

The fisheries of North Coastal area streams are largely anadromous species such as king salmon, silver salmon, and steelhead trout. The Russian, Eel, Klamath, Trinity, and Smith River systems are widely recognized for the salmon and steelhead angling they provide. The fish produced in

TABLE 11

POSSIBLE HYDROELECTRIC AND PUMPING PLANT INSTALLATIONS
NORTH COASTAL AREA AND WEST SIDE SACRAMENTO VALLEY

Reservoir	Stream	Reservoir Gross Storage 1,000 A.F.	Gross Head, Ft.	Power Plant: Plant Capacity, Mw.	Power Plant: Energy, 1,000 Mwh.	Pumping Plant: Gross Head, Ft.	Pumping Plant: Plant Capacity, Mw.	Pumping Plant: Energy, 1,000 Mwh.
Bell Springs	Eel River	1,310	--	--	--	450	62	268
Dos Rios	Eel River	560	--	--	--	390	90	392
Spencer	Eel River	850	363	48	126	--	--	--
Elk Creek	Elk Creek	--	--	--	--	400	82	707
Stienhart	Soda Creek	80	250	125	327	--	--	--
Jerusalem	Soda Creek	46	240	120	314	--	--	---
Monticello	Putah Creek	14,000	552	240	1,110	567	450	1,875
Monticello Afterbay	Putah Creek	60	--	--	--	120	48	185
Davis	Putah Creek	--	--	--	--	90	36	140
Sacramento River	Putah Creek	--	--	--	--	15	10	35
Ironside Mountain	Trinity River	16	--	--	--	270	448	1,962
Burnt Ranch	Trinity River	980	--	--	--	567	940	4,117
South Fork	S.F. Trinity R.	--	700	156	410	--	--	--
Helena	Trinity River	2,860	--	--	--	412	816	3,574
Towerhouse	Clear Creek	468	403	1,061	2,790	--	--	--
Whiskeytown	Clear Creek	206	260	638	1,677	--	--	--
Kanaka	Clear Creek	30	250	646	1,699	--	--	--
Saeltzer	Clear Creek	82	200	517	1,360	--	--	--
Girvan	Clear Creek	19	115	259	681	--	--	--
TOTALS				3,810	10,494		2,982	13,255

Mw. = Megawatt = 1,000 kilowatts; capacities shown correspond to full project development
Mwh. = Megawatt hour = 1,000 kilowatt hours

these, and other North Coastal streams, also contribute substantially to sport and commercial salmon fisheries in the ocean.

The life cycles of anadromous fish are of major significance in relation to the proposed water developments in the North Coastal area. The stages of the life cycle spent in fresh water are exacting in their requirements. Anadromous fish must be able to migrate upstream from the ocean to suitable spawning areas, where adequate gravels and streamflow of proper temperature and quality must prevail during the spawning and egg incubation periods. Although most young king salmon migrate downstream to the ocean soon after hatching, juvenile silver salmon and steelhead may remain in fresh water for one or more years before migrating to the ocean. These latter species require a suitable habitat throughout the year.

Sport Fishery. Both king and silver salmon sustain an important sport fishery in ocean waters. This sport fishery extends along the entire Northern California coast, but is concentrated near San Francisco, Fort Bragg, Humboldt Bay, and Trinidad Head. The U. S. Fish and Wildlife Service (1960) estimated that total sport catch of king salmon in northwestern California during 1956 at over 44,000 fish. Of this total, about 30,000 were caught in streams and about 14,000 in ocean water. The estimated sport catch of silver salmon was 18,000 fish, of which about 16,000 were caught in the ocean and 2,000 in fresh water. Recent fishery census data indicate that substantially larger angling catches of salmon have been made in the ocean and streams since 1956. For example, in 1963 sport fishermen caught approximately 30,000 king salmon at the mouth of the Klamath River alone.

During the king salmon runs, anglers concentrate in the estuary and lower riffle areas of the Klamath, Smith, and Eel Rivers. Anglers follow the runs upstream as the fish move to the spawning beds. Although sizeable runs of silver salmon ascend the streams, relatively few are caught by anglers due to the short duration of the run and high, turbid streamflows.

A run of immature steelhead accompanies the fall run of king salmon. As these "half-pounders" enter the rivers in late summer and early fall, fishermen congregate at accessible points along the main streams.

Commercial Fishery. Commercial fishing is a basic industry of the North Coastal area. Along with lumbering and agriculture, it plays a

Roosevelt elk at Prairie Creek State Park

Steelhead fishing on Trinity River

major role in the economy. The fishing ports which receive most of the fish landings north of San Francisco Bay are: Eureka, Fort Bragg, Fields Landing, and Crescent City.

The relative contribution of streams of the North Coastal area to the ocean salmon fishery has not been clearly determined. The results of several tagging studies suggest that, while North Coastal area streams contribute to the commercial salmon catch in Oregon and Washington, their major contribution is to California waters. Most of the California catch of king salmon is produced in the Sacramento River, although fish produced in the streams of the North Coastal area provide an important part of the catch in the Eureka region. Coastal streams of Oregon apparently produce most of the silver salmon landed along the northern coast of California.

Wildlife Resources

The North Coastal area supports a wide variety of wildlife species. Deer abound in much of the area, and where access is available, provide excellent public hunting. Humboldt and Mendocino Counties consistently lead the State in the number of deer harvested each year. Quail, bandtail pigeons, and waterfowl are locally abundant, and are important from an economic as well as aesthetic standpoint.

The black-tailed deer is by far the most abundant and important big game species found in the North Coastal area. In general, resident deer herds are found at lower elevations, below the influence of deep snow. Migratory deer inhabit areas at higher elevations during the summer and move to lower elevations during the winter. Generally, the winter ranges are just far enough below the snow line to obtain suitable browse. Resident and migratory deer ranges often overlap during the winter period. For the most part, the deer winter ranges are limited to the streamside areas. Any reduction of these narrow winter ranges by proposed water development projects will present a serious problem for migratory deer.

The North Coastal area also contains a wide variety of upland game, including quail, doves, pigeons, grouse, pheasants, rabbits, and squirrels. California quail are the most numerous of all game birds in the area and also the most hunted. Their range covers the entire North Coastal area. Mountain quail are much less numerous and inhabit higher elevations and the rougher terrain. Mourning doves inhabit most of the area in moderate number during the summer, but migration reduces the number in the winter. Hunting pressure on doves in this area is not as high as in other parts of the State. Although band-tailed pigeons are numerous, the most hunted county, Sonoma, is rated only ninth in the State. The other species of upland game are of relatively minor importance.

Fish and Wildlife Preservation

The construction of major water projects in the North Coastal area would pose many formidable problems in connection with the preservation of the area's fish and wildlife resources. Salmon and steelhead problems associated with potential water projects are the most serious. A general discussion of the problems presented by fish and wildlife preservation is presented in subsequent paragraphs of this section. Detailed discussions of specific problems are presented in Appendix C, Fish and Wildlife Resources.

The initial phase of study in formulating plans to provide for fisheries preservation is the acquisition of adequate basic data regarding the existing fisheries resource. Since salmon and steelhead are migratory and require a relatively narrow range of environmental conditions, they are exceptionally sensitive to alterations in their freshwater habitat. Effective planning for the maintenance of anadromous fish runs must be based on reasonably accurate estimates of fish populations; the timing of the upstream migration of adult fish and the downstream migration of juvenile fish; the location of spawning areas; the time of actual spawning; the location of nursery areas; and the physical and chemical characteristics of the stream during the freshwater life history phases of each species.

As would be expected in a relatively undeveloped region, there is only limited basic data of this type presently available for the North Coastal area. However, the comprehensive fish and wildlife studies programmed for the Upper Eel River Development include adequate funds to collect the necessary basic data related to that project; and the continuing area-wide investigation includes funds to initiate the acquisition of basic data for subsequent major projects.

Based on the basic data which are available, it is possible to make general statements about preserving the fishery resources. The construction of major dams and the consequent impoundment of large reservoirs will probably preclude the preservation of the fishery resources in their natural state. The dam structures will serve as impassable barriers to fish migrating upstream; and even if in some cases it were possible to pass the fish over the dams with conventional fish ladders, the fish face additional problems in the reservoir. The reservoirs would inundate substantial portions of existing spawning habitat. In addition, no feasible means has yet been devised of passing the young salmon and steelhead back down through the reservoir.

In light of the preceding considerations, it is probable that existing salmon and steelhead resources would have to be maintained in the stream sections below North Coast water conservation projects. The conventional measures that would be employed to preserve the fish runs include: (1) construction and operation of fish hatcheries and artificial spawning channels to compensate for lost or inaccessible spawning habitat; (2) improvement of conditions for natural spawning in the stream channels below the dams; (3) controlled releases of water below the dams; (4) provision of multilevel outlet works to regulate the temperature of controlled releases; and (5) provision of interim facilities to protect fish during the construction period. It is believed that through such measures the present population levels of salmon and steelhead could be maintained at most projects.

These preservation measures would not apply to projects proposed for the lower reaches of the Eel and Klamath Rivers. New approaches to fishery protection would be required in connection with these projects to supplement conventional measures. It is probable that no biologically feasible means of fully compensating for potential Klamath River fish losses could be formulated in connection with Humboldt Dam.

The effects of North Coastal water developments on wildlife would be similar at each project. The major influence would be the elimination of habitat through inundation, spoil deposition, "borrowing" for fill materials, road construction, and recreation area development. The wildlife that would be displaced would be forced onto adjacent lands. Since nearby lands would probably already be carrying all the wildlife they are capable of supporting, the net result, if no compensatory measures were taken, would be the loss of displaced wildlife. These wildlife detriments could be compensated for by acquiring and developing adjacent lands for increased wildlife production.

Contents of Fish and Wildlife Appendix

The Fish and Wildlife Appendix to Bulletin No. 136 contains information and data from studies conducted under both the North Coastal Area Investigation and the Coordinated Statewide Planning Program. The appendix describes the fish and wildlife resources in the North Coastal area, evaluates the effects of proposed water projects, and suggests measures for preservation and enhancement of the fish and wildlife resources.

The appendix includes a description of the hydrographic units and subunits of the North Coastal area. The fish and wildlife resources of these areas are described and estimates are made of the average population of anadromous fishes. The fish and wildlife resources of associated areas in the Putah-Cache Creek Basins and the west side Sacramento Valley are also described. Streamflows required to maintain fish and wildlife population at present levels are presented for each hydrographic subunit boundary. Enhancement flows are also estimated for streams having potential for increased fish production.

Preliminary evaluations are made of the effects of the proposed North Coastal area developments on both fish and wildlife. Measures required to preserve fish and wildlife in connection with the construction of these projects are described; and where losses would be unavoidable, measures required for compensation are listed. These measures include fish hatcheries, improved streamflow releases below dams, spawning channels, and development of new wildlife habitat. Preliminary estimates for fish and wildlife enhancement in connection with specific projects are also presented.

Recreation

To a large portion of the population of California, the North Coastal area is synonymous with recreation. The diversified topography includes 400 miles of picturesque ocean frontage and a forested belt immediately inland that includes a large portion of the redwood forests of California. Further inland, a mountainous area covered by a mixed coniferous forest contains some of the foremost wilderness country in California. This rugged natural beauty, coupled with some of the finest fishing streams on the continent, lures thousands of vacationers to the area each year. In addition to the natural attractions, a few small reservoir developments receive considerable recreation use.

Recreation plays a major role in the economy of the North Coastal area, ranking second only to lumbering. The majestic redwoods and the steelhead and salmon fishing are the major recreation attractions. During August and September, the lower Klamath River is literally teeming with fishing enthusiasts. During 1963, there were $5\frac{1}{2}$ million visitor-days of use in the 39 state parks in the North Coastal area, of which about $3\frac{1}{2}$ million were in the redwood parks. As important as recreation is, the potential is just beginning to be developed.

The construction of major water developments will have a great impact on recreation in the North Coastal area. With the construction of these developments and prior to their use for recreation, extensive facilities will be constructed. These will include access roads, boat ramps, camp and picnic grounds, and sanitary facilities. A perimeter strip extending a minimum of 300 feet back from the high water line of each reservoir will be acquired for recreational purposes. Additional land for recreation would be acquired if necessary.

Recreation Studies

The purpose of the recreation studies made during the reconnaissance phase of this investigation was to establish a foundation of information upon which the recreation aspects of proposed water development projects can be determined. The recreation studies were made in three phases: (1) compilation of the history of outdoor recreation in the North Coastal area; (2) compilation of information on present recreation development; and (3) determination of future recreation conditions, with emphasis toward effects and potentials of proposed water developments. The recreation studies were largely compilation and analysis of available data; very little field work was done. The three phases of the work, which are covered in detail in the recreation appendix to this bulletin, are briefly described below.

Historical Development

The first portion of the recreation appendix traces the development of the North Coastal area, beginning in 1776 with the Spanish settlements in the San Francisco Bay Area. A discussion of early state and federal legislation affecting recreation development of the area is included. Historic events, such as the famed weekend excursion known as the "Triangle Trip" from the Bay Area to the Russian River country, are described. The effect of the railroads and highways on recreation development in the North Coastal area are woven into the story, which extends to the present.

Present Development

Information on present recreation development in the North Coastal area was compiled and is presented in the appendix by hydrographic units. These units, which roughly correspond to the major stream basins, are: Marin-Sonoma, Russian River, Mendocino Coast, Eel River, Mad-Redwood Creek, Klamath River, Trinity River, Shasta-Scott Rivers, and Smith River.

This portion of the appendix describes the recreation developments in each of the units, and presents data on visitor-day use. Information and data on state parks, historical monuments, reservoir projects, and other scenic attractions are included.

Future Development

The last section of the recreation appendix is devoted to a discussion of procedures used to estimate future recreation use of proposed water projects in the North Coastal area. The variables which influence recreation use at proposed reservoirs are discussed in detail. Some of these variables are: population, attractiveness of facilities, travel time, travel effort, travel expense, competition from other attractions, and per-capita use.

The physical factors affecting the recreation potential of proposed reservoirs are discussed and preliminary estimates of expected recreation use are presented for each. The appendix includes information and data for the following proposed reservoirs: Knights Valley, Dos Rios, Spencer, English Ridge, Glenn Reservoir Complex, Clear Lake, Greater Lake Berryessa, Bell Springs, Sequoia, Helena, Burnt Ranch, Eltapom, Ruth, Eaton, Butler Valley, Humboldt, and the Westside Conveyance System.

The following discussion and use estimates for Knights Valley Reservoir are presented as an illustration of the coverage in the appendix.

The Knights Valley Reservoir would be impounded by the construction of dams on Franz and Maacama Creeks, tributaries to the Russian River. The reservoir site is located close to the growing suburban population centers of the North Bay area. Santa Rosa is about 20 miles away and Healdsburg and Calistoga are about 10 and 6 miles, respectively, from the shore of the proposed reservoir. The construction of the reservoir should promote accelerated residential development of nearby lands. The terrain adjacent to the reservoir site is unusually well suited for park and recreation use. The reservoir would extend into land that is currently being proposed for acquisition for state park purposes.

Considering the terrain and planned reservoir operation, Knights Valley Reservoir possesses an excellent recreation potential. The following table summarizes the attendance which could be expected and for which recreation facilities would be needed if the project were completed by about 1975. These estimates are for a reservoir with a gross storage capacity of 280,000 acre-feet and a water surface area of 4,300 acres, at a normal pool elevation of 445 feet.

KNIGHTS VALLEY RESERVOIR
EXPECTED RECREATION USE

Year	Expected Average Annual Attendance (Million visitor-days)
1980	2.2
1990	3.2
2000	4.4
2010	5.9
2020	7.5

Present recreation use of Knights Valley is relatively low. Unless the proposed Mt. St. Helena State Park becomes a reality, it is probable that recreation use will remain at a low level in future years. If the state park were developed, the reservoir and associated recreation developments should supplement the park rather than eliminate or compete with the established facility. Therefore, the attendance figures are considered to be approximately net attendance and to measure the recreation enhancement that would result from construction of the reservoir.

Numerous additional studies are necessary to thoroughly evaluate the recreation potential of proposed projects in the North Coastal area. After detailed data on visitor-day use is compiled, land use plans for each reservoir must be prepared and the cost of recreation facilities determined. The studies made thus far provide a solid foundation for the future studies.

Economics, Land and Water Use

Economists and land and water use specialists have played an important role in the North Coastal Area Investigation. In water resources planning their contribution is usually associated with benefit-cost analyses, selection of service areas, and allocation of project services. As mentioned in Chapter III, these phases of project formulation were approached somewhat differently during this investigation. Consequently, the contribution of these specialists was of a somewhat different nature.

The services of economists and land and water use specialists during this investigation were in two general areas: (1) studies connected with developing and analyzing data for the water requirements phase of the Coordinated Statewide Planning Program, and (2) special studies required to properly analyze certain aspects of alternative plans for development. The studies in both of these areas are discussed briefly in this section.

Future Water Requirements

The responsibility for providing estimates of future water requirements throughout the State is vested in the department's Coordinated Statewide Planning Program. Economists and land and water use specialists associated with the North Coastal Investigation participated in the water requirements program by developing and analyzing data related to service areas in the North Coastal area. In addition to its use as basic data for statewide planning, this information was used in this investigation to ensure that in project plans adequate water was allocated for future water services within the North Coastal area.

Estimates of future water requirements were based on forecasts of the nature and extent of cultural practices as they affect the use of water. Future water requirements were estimated for municipal and industrial uses, irrigated agriculture, recreational purposes, and maintenance of natural fish and wildlife population.

Municipal and industrial water requirements in the North Coastal area were based on projections of future populations and the potential for industrial development, with special emphasis on the processing of forest products.

Future requirements for irrigation water were based on estimates of the type and amount of agricultural activity which may reasonably be expected within the area by the year 2020. Future crop patterns were based on present land use practices, climate, soil conditions, and market potential. Estimates of the amount of agricultural produce expected to be marketed from the North Coastal area were based on comparative analyses of competition from other producing areas. Preliminary estimates of payment capacities and projections of future economic demand for water were made as part of these studies.

Future water requirements for recreation were based on projections of outdoor activity to the year 2020. These activities include camping, picnicking, fishing, hunting, and water sports. Water requirements for fish and wildlife were based on streamflow requirements for preservation and maintenance of average fish and wildlife populations. These water requirements are included as beneficial uses of water in the determination of water surplus and deficiency.

Special Studies

Several special economic studies of specific problems were made during this investigation. Four of these were presented in the form of separate memorandum reports. These involved the Northwestern Pacific Railroad, the economic impact of the Glenn Reservoir Complex, the projected right-of-way costs for Greater Berryessa Reservoir, and the economy of Round Valley.

Economic Study of the Northwestern Pacific Railroad. The high cost of relocation of the Northwestern Pacific Railroad poses a special problem in the consideration of storage facilities on the Lower Eel River. Any major reservoir development on the Eel below the confluence of Outlet Creek would necessitate the relocation of over 100 miles of the main line railroad at a cost estimated to exceed $130,000,000. Several factors indicated that purchase of the railroad and discontinuance of rail service should be considered as a possible alternative. Among these factors were the high cost of maintenance of the railroad because of slides, the increasing use of truck lines by the lumber industry, and the limited passenger service involved. An economic study of the operation of the railroad was made to consider this alternative.

The investigation included study of the history of the railroad, meetings with company officials, and study of published statistical reports relative to the recent operation of the company. The extension of the line to Eureka from the Bay Area was completed in 1914, while it was under joint ownership of the Santa Fe and Southern Pacific Companies. Southern Pacific bought out Santa Fe's interest in 1929, and the Northwestern Pacific Railroad Company is today one of some 26 subsidiaries of Southern Pacific. The Northwestern Pacific Railroad runs between San Rafael and Eureka, operates over 328 miles of main track, and utilizes 137 additional miles of sidings and yard trackage.

When the first of the 41 railroads ultimately to form the Northwestern Pacific Railroad came into existence about 1852, passenger service was paramount. Today, lumber is king, and passenger service is of minor importance. Redwood, pine, and fir logs are hauled to the mills; and milled lumber, pilings, and redwood ties are transported to the San Francisco Bay Area for use there or for further shipping. It is estimated that 80 percent of the finished wood products from the Humboldt Bay area are shipped by rail. The other significant payloads, such as Russian River gravel to the Bay Area and poultry feed to Petaluma, are not carried north into the Eel River Basin.

Operating costs and returns indicate that the railroad has operated on a fairly stable and constant basis in recent years. The investment in operating property, which includes the roadways and rolling stock, has remained about constant. Operating revenues have varied and were somewhat lower for the last two years of available data, 1960 and 1961, than for the preceding four years. Operating expenses have declined steadily, probably reflecting recent improvements in the system.

It was concluded from this study that a discontinuance of this railroad would have a serious economic impact upon the area served, particularly Mendocino and Humboldt Counties. Truck and water transportation could not economically, and perhaps not physically, provide the necessary transportation to support the area served. The principal items shipped being timber, lumber, and lumber products, any appreciable increase in transportation cost would leave the area in a poor competitive position in a highly competitive industry. Future industrial development of the area would be severely impeded.

It was therefore concluded that, from an economic viewpoint, railway service between the Humboldt and San Francisco Bay areas must not be discontinued. Water development projects that would require relocation of the Northwestern Pacific Railroad must be considered on the basis of the cost of such relocation.

Economic Impact of the Glenn Reservoir Complex. An analysis was made of the probable economic impact of the proposed Glenn Reservoir Complex in Glenn County. A detailed land classification survey of the affected area was made with the aid of aerial photographs and field inspection. The classification considered soil types, depths, texture, chemical compositions, drainage, topography, and other physical characteristics.

Projections of future crop patterns in the reservoir area were made, with consideration of land use and land classification data, climate, general economy of the area, availability and cost of water, and economic return. Based on these projections and analysis of assessed evaluations, possible tax losses to Glenn County resulting from the proposed reservoirs were estimated. No loss in tax base as a result of relocation of the sawmill at Elk Creek was estimated.

Detailed estimates were made of the economic impact during and following construction of the proposed development. The principal source of direct employment and economic activity created by the project after completion of construction was found to be associated with recreation.

It was concluded from this study that the increase in tax revenues to Glenn County brought about by project construction would exceed the increase in local governmental costs during the period of construction. At the end of the first ten-year period following completion of project construction, property tax gains would begin to exceed tax losses, and at the end of the next 12-year period accumulated gains would exceed losses accumulated from the beginning of construction. At that time, annual property tax revenues, under project conditions, would be increasing with recreational developments. Under nonproject conditions, revenues would be considerably less and increasing much less rapidly.

The loss in gross value of agricultural production under project conditions would represent about 1 percent of the county total over the period of analysis. The estimated gross annual recreation expenditure under project conditions in the county by the year 2000 is over ten times the estimated gross loss of agricultural production.

Projected Right-of-Way Costs for Greater Berryessa Reservoir. A very preliminary property acquisition estimate was prepared in May 1963, of the costs of acquiring the property for the proposed enlargement of Lake Berryessa. A cursory economic study was subsequently made to project the present values to the year 2000. This study involved the collaboration of an economist, a land and water use analyst, and a recreation planner. The projections of values were based largely on the development required of lessees under the terms of their leases, the rate and extent of development that followed the creation of Lake Berryessa upon the completion of Monticello Dam in 1957 to date, and the expected future demand for recreation facilities in and around the area.

The economic development of the Lake Berryessa area is dependent almost entirely upon the demand for recreational usage of the lake and immediate environs. The rapid rate of development, indicated by recent increases in tax values and an expansion program currently under way, is expected to continue for some time in the future. The sublease or concession agreements between Napa County and the various concessioners not only set forth construction standards, but also provide for specific improvements and the addition of new facilities in accordance with a previously prepared public use plan.

Increased recreation use will prompt further development of the seven existing resort areas and the establishment of new areas. Privately owned areas suited for subdivision and commercial enterprise, located outside the public-owned perimeter zone, will also be developed concurrently with recreational usage demands.

The study indicated that development around Lake Berryessa would continue to grow and that the cost of property acquisition in the year 2000 would be over three times what it was in 1963.

Present and Potential Economy of Round Valley. An analysis of the present and potential economy of Round Valley was made to assist in the evaluation of proposed projects on the Middle Fork Eel River. Much of the data used in the study were from secondary sources prepared by various local, state, and federal agencies. Land classification and land use data were from the survey made by the department. Population, crop patterns, and property values were projected to the year 2020. The study indicated that by the year 2020, the population of the valley would have grown from 1,540 (1960 census) to 16,000, and the economic value would have increased four times.

Coordinated Statewide Planning Program

Basic data relating to land and water use in the State are being accumulated and compiled under the department's Coordinated Statewide Planning Program. For purposes of these studies, the State has been divided into major hydrographic areas. These areas, in turn, have been subdivided into hydrographic units generally comprising watersheds of individual streams. This activity has initially been concentrated in the northwestern part of the State, since it is anticipated that large amounts of surplus water will be exported from this area. It is of fundamental importance to have information concerning the amount of water which can be made available for export without depriving the area of water necessary for its own economic development.

Results of these studies are being presented in two types of reports, covering (1) present land and water use, and land classification with respect to possible future use, and (2) water resources and water requirements. The present land and water use reports, designated the Bulletin No. 94 series, have been completed and published for the following hydrographic units in the North Coastal area: Trinity River, Eel River, Russian River, Mad River-Redwood Creek, Mendocino Coast, Klamath River, Shasta-Scott River, and Smith River.

The reports on water resources and water requirements are designated the Bulletin No. 142 series. The first of these, No. 142-1.1, covers the hydrographic units of the southern portion of the North Coastal area. The southern portion includes the Trinity River, Eel River, Russian River, Mad River-Redwood Creek, and the Mendocino Coast. Bulletin No. 142-1.2 will cover the remaining portion of the North Coastal area. These bulletins will contain data and discussions about each of the hydrographic units relative to water supply, estimated future water requirements, and surplus water available for export.

CHAPTER VI. SPECIAL CONSIDERATIONS

In a long-range planning program, such as the North Coastal Area Investigation, two special considerations must receive careful and continuing attention. These are: technological changes which may affect plans for development made on the basis of current and conventional methodology; and, the relationship of this planning program with those of other concerned agencies.

This chapter presents discussions of certain technological advances which could have an appreciable effect on the plans for water development in the North Coastal area. These are in the fields of saline water conversion and electric power generation. The chapter also contains a discussion of federal-state cooperation and of regional water planning as related to the North Coastal area.

Saline Water Conversion

At the present time, converted sea water cannot compete economically with the conventional development of natural fresh water sources within the State. However, indications are that converted water will play an important role in the future. Although it is anticipated that staging of the initial project in the North Coastal area will not be affected by the impact of saline water conversion, it is probable that it will affect the staging of additional projects.

The transition to economically competitive desalted water will probably occur gradually. Initially, the primary use of desalted water will be in the metropolitan areas located in semiarid regions where high transportation costs are associated with the delivery of natural fresh water. In addition, desalted water may be of value to areas where a usable supply of water can be obtained by admixing the very high quality converted water with locally derived surface and ground water supplies of lower quality.

The operation of large-scale water desalting plants in conjunction with nuclear-electric plant generation offers one of the more promising means of reducing the cost of desalting water. These dual-purpose plants would produce large quantities of desalted water and electric power. With the ever-growing demand for water and the associated demand for electric power to pump the water, the dual-purpose desalting and nuclear-electric powerplants are destined to eventually play a major role in water development in California.

The department's present interest in the field of saline water conversion is oriented toward the application of conversion processes for development of water resources that are unsuitable in their natural state. Such waters include sea and brackish water and treated waste waters. In furtherance of this objective, the department monitors research and development activities of the federal government and others in the field of saline water conversion. One of the activities of the department was its cooperation with the Department of Interior in the design and construction of the Point Loma sea water conversion demonstration plant. The State contributed 50 percent of the cost of construction and the department participated during the design and construction phase of the plant by providing engineering inspection at the site, as well as in the review of construction drawings. The information developed from operation of the plant is of considerable interest to this department in its continuing evaluation of the economic potential of sea water conversion.

Currently (1964), the department is participating in discussions with federal agencies towards obtaining a larger conversion plant for integration into the State Water Project. Only through continued study and analysis of alternative water development possibilities, including saline water conversion, can it be assured that the most economical means for meeting our future water needs will be selected.

Technological Changes in Electric Power Generation

The following discussion is quoted from Bulletin No. 3, "The California Water Plan," published in 1957:

> "Full satisfaction of California's water demands will require mass movement of large volumes of water through long conveyance systems and over high mountain ranges. Considerably more electrical

energy will be needed for pumping than is presently developed in the State. Moreover, it is estimated that by the year 2020, California's total energy demand will exceed by 10 to 12 times the present power capability; the pumping load will be only a small part of that total demand. Hydroelectric power now finds its greatest value as 'peaking' energy, and efficiently and economically complements steam power generated from fossil fuels. Likewise, it will combine equally well with atomic power generation in the years ahead. It seems reasonably certain that the power market will absorb hydroelectric power output as rapidly as it can be made available."

The statement remains a good description of the present hydroelectric power picture in California. However, technological changes in steam-electric generation in the past two years have dictated a reorientation of water resources planning regarding the future role of the hydroelectric power and power for pumping.

The following is a discussion of these technological changes and their impact on plans for water resources development in the North Coastal area. The discussion is divided into three sections: value of hydroelectric power, impact of nuclear power, and cost of power for pumping.

Value of Hydroelectric Power

Department policy states in effect that the value of hydroelectric power used for planning purposes should be based on the cost of equivalent power from the most likely alternative source which would be constructed in absence of the hydroelectric plant. This alternative is presently considered to be a privately financed steam-electric generating plant.

The power value is first calculated at the "load center" of the power system. The value is then referenced to the location of the proposed hydroelectric plant by subtracting the costs associated with transmission of power from the plant to the load center.

The power value consists of a constant component and a variable component. The constant component, which reflects the fixed charges on construction cost of the steam-electric plant, is commonly referred to as the capacity component. The variable component, which is largely determined by the cost of fuel and the generating efficiency of the plant, is referred to as the energy component. The annual values of the capacity and energy components used in analyses of power potential in the North Coastal Area Investigation were on the order of $22.00 per kilowatt and $0.003 (3 mills) per kilowatt hour.

The capacity component of steam-electric power cost in fossil fuel plants has decreased about 25 percent during the past 10 years, the major portion of the decrease during the last two years. The principal reason for this reduction is the economies which have resulted from the significant increases in the size of steam-electric generating units. In Northern California for example, the size of units has increased from 165 megawatts to 750 megawatts in the past 10 years. It is anticipated that units of 1,000 megawatts, or larger, will be in operation by 1975, resulting in further decline in the capacity component of power cost.

The energy component of steam-electric power cost has been essentially constant the past 10 years. The cost of fossil fuel has increased; however, increases in the efficiency of generation have been compensating. It now appears that for the next two decades any nominal increase in the cost of fossil fuel will be compensated by further increases in efficiency, so that the energy component of fossil fuel-electric power costs will remain essentially constant.

The net effect of these trends in the capacity and energy cost components of fossil fuel-electric power generating plants will be a corresponding decrease in the future value of hydroelectric generation. This decrease in the value of hydroelectric power, measured as the cost of alternative generation from thermo-electric sources, will tend to reduce the possibility of associating hydroelectric powerplants with water development projects in the North Coastal area. Where hydroelectric generation remains justifiable, the margin of excess revenues over costs will be substantially reduced. This will have a substantial effect upon the ability of hydroelectric power to assist financially in future water projects.

Impact of Nuclear Power

The discussion to this point has focused on the roles of hydroelectric plants and conventional fossil fuel-steam-electric plants in water resources development. It assumed no appreciable expansion of the nuclear-electric industry. There are clear indications, however, that the nuclear-electric industry is on the verge of rapid expansion. The impact of nuclear-electric generation on water resources development is discussed herein in terms of the capacity and energy components of power cost and value.

In the early years of the nuclear-electric industry, the capacity component of cost will be higher than for fossil-fuel electric plants, since the unit cost of nuclear-electric plant construction will be greater. Thus, initially, the value of hydroelectric power will not be appreciably affected by the installation of nuclear plants. Eventually, however, the unit cost of nuclear-electric plant construction will become less and will result in a reduction in the value of the capacity component which may be assigned to future hydroelectric powerplants. The great economic advantage of the nuclear plant lies in its potentially low fuel cost, which would result in a low energy component of cost.

In the long run, this continuing reduction in both the capacity and energy components of cost due to an increased usage of nuclear-electric plants will tend to preempt the use of fossil fuel for generation purposes and will cause an even further reduction in the value of hydroelectric power.

Cost of Power for Pumping

It is the policy of the department to base the cost of power for project pumping on the alternative cost of steam-electric generation. Hence, the technological changes which will be responsible for the reduction in the value of hydroelectric power would also be reflected in a reduction in the cost of power for pumping. Inclusion of nuclear-electric plants in the system will have a major influence in this regard.

The impact of low cost pumping power could be appreciable in the North Coastal area, where many of the plans for water development include large pumping installations. The impact would be particularly significant in those transmountain crossings where pumping to higher elevation would shorten tunnel length. This could result in a net reduction in the total required capital investment.

Federal-State Cooperation

The State of California and the federal government through the Bureau of Reclamation, and Corps of Engineers are looking toward development of the North Coastal waters to fulfill their respective commitments and responsibilities in the various fields of water resources development. This section presents discussions of various cooperative activities to date and of possible future cooperation to embrace a regional planning program for the Pacific Southwest.

Cooperative Activities

To facilitate coordination and cooperation among water agencies, the California State-Federal Interagency Group was established in 1958. This group consists of the Director of Water Resources, the Director of Region II of the Bureau of Reclamation, the Pacific Southwest Division Engineer of the Corps of Engineers, and the State Conservationist of the Soil Conservation Service. Although the geographic scope of committee activities is intended to be statewide, primary effort has been directed initially toward cooperation in planning for future major water conservation developments in Northern California. Through the workings of this committee and its subcommittees, consisting of staff members of the four agencies, frequent discussions and exchanges of information have taken place relative to water resources development policies, project formulation criteria and procedures, basic data, and the physical plans under study.

The three public agencies primarily concerned with major water resources developments have reached general agreement on an overall project plan for the Upper Eel River and adjacent basins. Authorization of the Upper Eel River Development by the State has opened the way for joint state-federal cooperation in the feasibility-level planning, construction, and operation of these facilities.

To work out the details of cooperative agreements on the joint planning program for the Upper Eel River Development, a special work group under the California State-Federal Interagency Group was created in January 1964. It has been agreed among the agencies that the Department of Water Resources will coordinate the joint program.

There are at the present time two possible means for implementing a joint agency construction development program for water projects within the North Coastal area. These are: (1) the provisions of the Federal Water Supply Act of 1958; and (2) consummation of a direct federal-state partnership agreement similar to the San Luis Agreement.

The Federal Water Supply Act of 1958 (Public Law 85-500, Title III; 72 Stat. 297, 319, 43 U.S.C. Sec. 390B; 1958 ed.) authorizes the Corps of Engineers and the Bureau of Reclamation to provide municipal and industrial water supply storage in their projects when reasonable evidence exists that there will be a future demand for this water. These federal agencies may provide such storage through modification of existing projects or by inclusion in projects which are now being planned. In order for the Bureau of Reclamation or the Corps of Engineers to provide water supply storage for future municipal or industrial demands under the provision of this act, the State or local interests must give reasonable assurance that project costs allocated to water supply can be paid in full during the life of the project.

The provisions of this act open up the possibility that the State may not need to construct all of the projects required to supply future municipal water demands in state project service areas. Instead, state and local agencies may be able to participate in federal multiple-purpose projects, paying only the annual charges for the costs allocated to this use. The provisions of the act pertaining to the 10-year deferred repayment of costs for municipal and industrial water supplies could also be of immense significance. Application of the act would lessen the need for state borrowing and the possible problems of financing those later stages of the State Water Resources Development System to be constructed by the department.

The San Luis Unit of the Central Valley Project is a precedent in federal-state cooperation in the development of water resources. It is believed that this relationship can be extended to development of water resources in the North Coastal area to the benefit of all concerned. These possibilities for cooperative and partnership development in the North Coastal area will be explored and implemented further through meetings of the California State-Federal Interagency Group.

Regional Water Planning

The United States Supreme Court opinion in Arizona v. California, rendered June 3, 1963, initiated a renewed interest in regional planning for development of water resources. This planning has recently been directed toward the Pacific Southwest, but may in the near future be expanded to embrace other areas of the Western United States as well.

The court's opinion presented a potentially serious water supply situation for California. In recognition of this and the fact that water supplies from the Colorado River without supplementation from sources outside of that basin could not in any event meet the future needs of the region, the Secretary of the Interior launched an expedited planning program to develop a regional approach to solution of the water problems of the Pacific Southwest. The proposed regional plan of development was released in August 1963, for comment and recommendations by the concerned state and federal agencies. A final report was published in February 1964, which incorporated most of the recommendations of the State of California.

The Department of the Interior's Pacific Southwest Water Plan report recommended, among other things, initiation of feasibility-level investigations leading toward federal authorization for the Trinity Diversion and South Fork Trinity Projects, previously described herein. The report recognized that the State Water Project and the federal Central Valley Project both envision future expansions to include water service and development within the North Coastal region of California. It observed that opportunities exist for joint development within the North Coastal area under these two projects, including possible conservation features of a regional program for the Southwest, at considerable cost savings to each of the projects and to the proposed regional plan.

Evaluations made during the course of this investigation relative to the cost savings possible through increases in project scale and scope support this observation. The potential economies available to these federal and state projects and to the proposed Pacific Southwest program through joint participation in development of North Coastal projects and through a pooling of supplies to be developed within the North Coastal region warrant further investigation.

Thus, while the Pacific Southwest Water Plan report included the two Trinity projects for financial analysis purposes and tentatively recommended federal authorization subject to the findings of feasibility investigations, the report also recognized that opportunities exist for early joint development within the Eel River system, including the possibility of an enlarged Lake Berryessa.

Because of the great potential of regional and interstate water resources planning programs to complement (and under certain conditions conflict with) the water development programs within California, the Department of Water Resources will continue to follow closely these studies of the Department of the Interior and others which may be initiated in the near future.

CHAPTER VII. FUTURE PLANNING PROGRAM

Departmental planning for major water projects in the North Coastal area is being carried forward in two programs: (1) an advance planning program for the Upper Eel River Development, (2) continuation of the area-wide investigation of the North Coastal region. A description of these two programs follows.

Advance Planning - Upper Eel River Development

This program is an outgrowth of the authorization of the Upper Eel River Development as an additional conservation facility of the State Water Project. It will be a comprehensive planning program to provide final formulation and definition of the development. Funds for the program will come from the California Water Resources Development Bond Fund, through the "offset provisions" of the Burns-Porter Act.

The Upper Eel River Development, as described previously in this report, will consist of conservation reservoirs on the Middle Fork Eel River and associated conveyance features to deliver the conserved water supplies to local areas and to the Sacramento River Basin either, (1) via pumped diversion to the upper main Eel River with subsequent gravity diversion via Clear Lake, Soda Creek, Putah Creek, and Lake Berryessa to the Sacramento River, or (2) via gravity diversion to Thomes or Stony Creeks in west side Sacramento Valley with the inclusion of elements of the Glenn Reservoir Complex.

The objectives of this program are: (1) select the conveyance route for delivering the conserved surplus water from the Middle Fork Eel River to the Sacramento River Basin; (2) identify the specific project features which will comprise the Upper Eel River Development; (3) define the capacities, sizes, costs, and other appropriate parameters of the specific project features; (4) identify local needs which could be served from the development and define the necessary appurtenant works to supply these needs; (5) determine the relationship between projected benefits and costs for the different project purposes, in order to provide a cost allocation and a project services allocation among the various purposes;

(6) provide comprehensive and specific recommendations for the subsequent programs and actions which will be necessary to design, construct, and operate this facility.

The program will be conducted in direct cooperation with the U. S. Bureau of Reclamation, the U. S. Corps of Engineers, and the Soil Conservation Service, as discussed in Chapter VI. Close liaison will also be maintained with other federal, state, and local agencies.

North Coastal Area Investigation - Second Phase

This is the second phase of the department's continuing planning investigation covering the entire North Coastal area. The program will be funded from the state General Fund.

Activities will be directed toward further definition of possible multiple-purpose developments in the Trinity, Mad, Van Duzen, Lower Eel, Klamath, and Coastal Stream Basins.

The objectives of the investigation are: (1) recommend general sequence of major, multiple-purpose projects in the North Coastal area to follow the Upper Eel River Development; (2) define specific features of the first project in this sequence in sufficient detail to enable future initiation of feasibility-level studies; (3) compare alternative projects in later-staged works; (4) identify local projects which might be constructed for purposes of local water supply, flood control, recreation, and fisheries enhancement.

APPENDIX D

RELATED REPORTS

This appendix contains a listing of reports related to the North Coastal Area Investigation. More detailed bibliographies related to specific activities of the investigation are contained in the separately bound appendixes and office reports.

<u>Department of Water Resources</u>

Bulletin No. 1, "Water Resources of California," 1951, presents an inventory of the water resources of the State. It includes available basic data on precipitation, runoff, flood frequencies, and quality of surface and ground waters throughout California.

Bulletin No. 2, "Water Utilization and Requirements of California," June 1955, presents results of a comprehensive analysis of present and probable ultimate use of water in California for irrigated agriculture, domestic, industrial, and other beneficial purposes.

Bulletin No. 3, "The California Water Plan," May 1957, presents a master plan to guide and coordinate the activities of all agencies in the planning, construction, and operation of works required for the control, development, protection, conservation, distribution, and utilization of California's water resources.

Bulletin No. 83, "Klamath River Basin Investigation," May 1960, contains an inventory of the water resources of the basin, estimates of present and probable ultimate water requirements, and a master plan for development of the basin.

Bulletin No. 58, "Northeastern Counties Investigation," June 1960, presents the results of a comprehensive analysis of present and probable ultimate water needs of 15 counties: Butte, Colusa, Glenn, Lake, Lassen, Modoc, Plumas, Shasta, Sierra, Siskiyou, Sutter, Tehama, Trinity, Yolo, and Yuba.

Bulletin No. 14, "Lake County Investigation," July 1957, contains an inventory of the water resources, estimates of water requirements, and preliminary plans for development in Big Valley, Scott Valley, and the Upper Lake area.

Bulletin No. 90, "Clear Lake-Cache Creek Basin Investigation," March 1961, presents the proposed Wilson Valley Project as a comprehensive plan for the development of the basin.

Bulletin No. 92, "Branscomb Project Report," June 1962, presents data and information on the proposed Branscomb Reservoir on the South Fork Eel River.

Bulletin No. 99, "Reconnaissance Report on Upper Putah Creek Basin Investigation," March 1962, presents data and information on water problems in the basin and preliminary plans for development.

Bulletin No. 94, series, "Land and Water Use"

No.	Hydrographic Unit	Date
94-2	Trinity River	October 1962
94-4	Smith River	December 1962
94-5	Shasta-Scott Valleys	June 1963
94-6	Klamath River	May 1963
94-7	Mad River-Redwood Creek	October 1963
94-8	Eel River	October 1963
94-9	Lost River-Butte Valley	Incomplete
94-10	Mendocino Coast	March 1964
94-11	Russian River	Incomplete
94-13	Putah-Cache Creeks	April 1964

These bulletins report the present status of land and water use and classification of lands within hydrographic units as to suitability for irrigation and recreation development.

Bulletin No. 142-1.1, "Water Resources and Water Requirements," 1964, presents a quantitative comparison of the water resources and water requirements within the Trinity River, Mad River-Redwood Creek, Eel River, Russian River, and Mendocino Coast hydrographic units, to determine the present and future water surpluses and deficiencies.

Bulletin No. 87, "Shasta Valley Investigation," July 1961, contains an inventory of the water resources in the Shasta River Basin, estimates of present and future land use and water requirements, and plans to supply additional water to the basin. Also included are appendixes covering geology and fish and wildlife.

U. S. Department of the Interior

Bureau of Reclamation, "Trinity River Division, Central Valley Project, California," February 1957.

Bureau of Reclamation, "Eel River Division, North Coast Project, California," June 1963.

Pacific Southwest Field Committee, "Natural Resources of Northwestern California, Preliminary Report," 1956. Appendixes to this report have been prepared on the following subjects:

Plans for Water Development
Water Requirements
Water Quality
Geology
Recreation Resources
Fish and Wildlife
Timber Resources
General Economy

Geological Survey, "Surface Water Hydrology of Coastal Basins of Northern California," 1964.

U. S. Army Corps of Engineers

"Review of Reports, Eel River, California, for Flood Control with Reference to Sandy Prairie Area, Fortuna, California," September 25, 1956.

"Review Preliminary Examination Report on Mad River and Tributaries, California, for Flood Control and Allied Purposes," July 1957.

"Report for Water Resources Development, Eel River, California, and Appendix," January 1964.

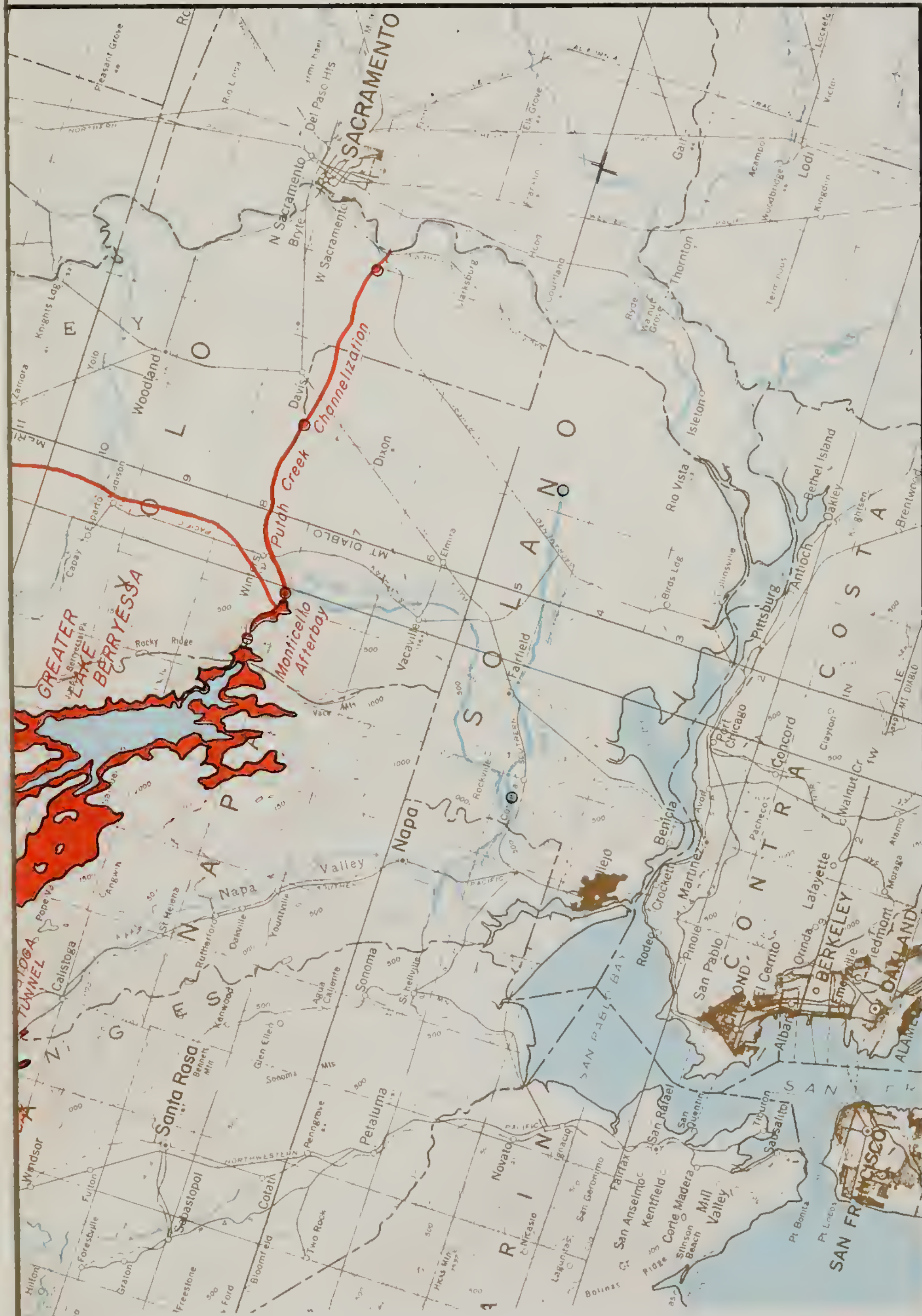
"Review Report for Flood Control and Allied Purposes, Russian River, California," February 1964.

Others

"Report to Humboldt County Board of Supervisors on Mad River Water Supply Study," October 1955. Bechtel Corporation.

"Report to Board of Directors, Humboldt Bay Municipal Water District on Mad River Water Supply Study, Part 2: Pipeline," May 1956. Bechtel Corporation.

"Report on Eel River Investigation," prepared for The Metropolitan Water District of Southern California, December 1959. Bechtel Corporation.



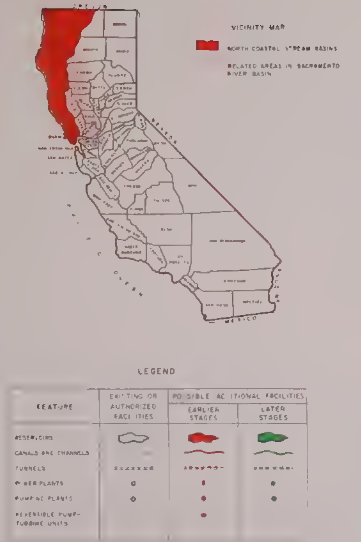
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
NORTH COASTAL AREA INVESTIGATION

POSSIBLE ADDITIONAL FACILITIES
TO THE
STATE WATER RESOURCES DEVELOPMENT SYSTEM
IN THE
NORTH COASTAL AREA
AND
WEST SIDE SACRAMENTO VALLEY

1964

SCALE OF MILES

8 0 8 16


VICINITY MAP
NORTH COASTAL STREAM BASINS
RELATED AREAS IN SACRAMENTO RIVER BASIN
LEGEND
FEATURE
EXISTING OR AUTHORIZED FACILITIES
POSSIBLE ADDITIONAL FACILITIES
EARLIER STAGES
LATER STAGES
RESERVOIRS
CANALS AND CHANNELS
TUNNELS
POWER PLANTS
PUMPING PLANTS
REVERSIBLE PUMP-TURBINE UNITS


OREGON
SISKIYOU
DEL NORTE
HUMBOLDT
TRINITY
SHASTA
TEHAMA
GLENN
COLUSA
MENDOCINO
LAKE
SONOMA
NAPA
SUTTER
YOLO
SOLANO
CONTRA COSTA
Crescent City
Red Bluff
SACRAMENTO
WEST SIDE CONVEYANCE
GLENN RESERVOIR COMPLEX
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
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SCALE OF MILES