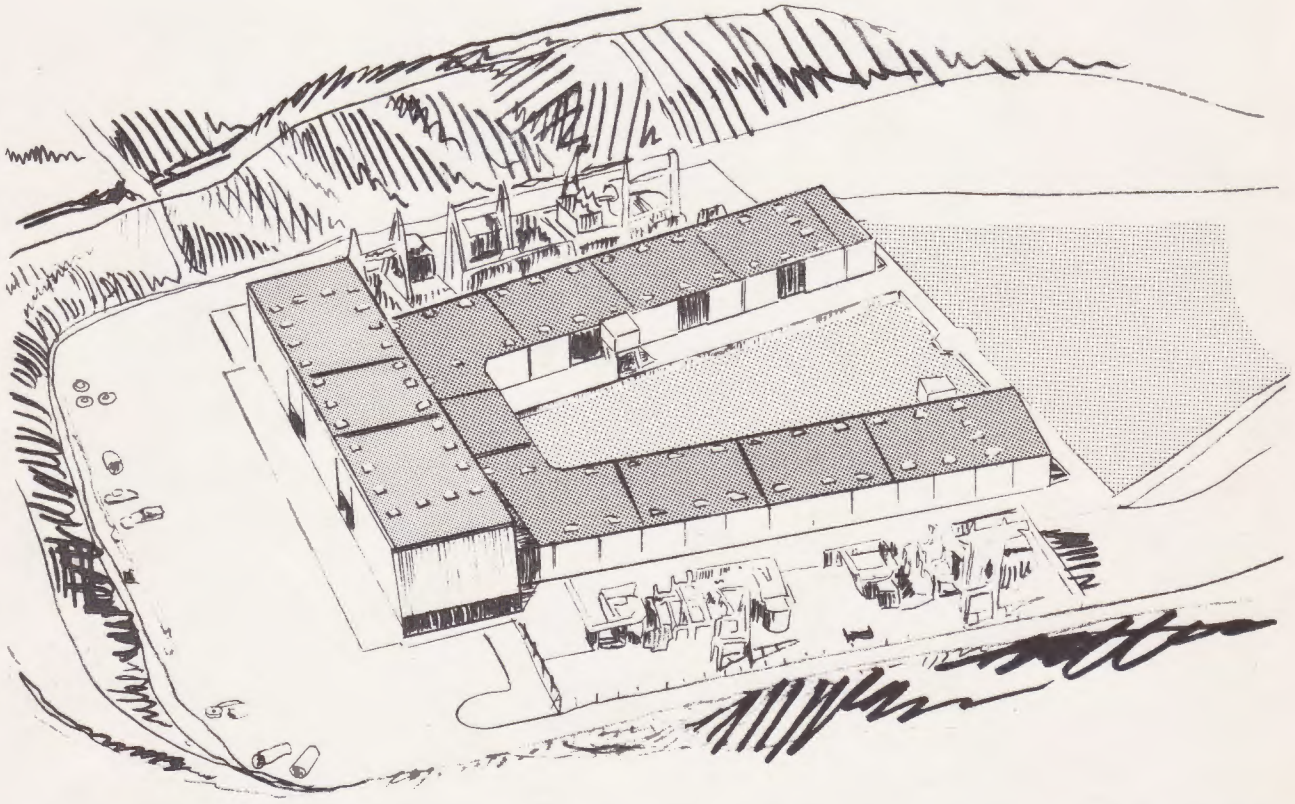
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

A.D. EDMONSTON PUMPING PLANT AND TEHACHAPI CROSSING



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A.D. EDMONSTON PUMPING PLANT AND TEHACHAPI CROSSING

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The CALIFORNIA STATE WATER PROJECT

HISTORY AND DEVELOPMENT

OF THE

A. D. EDMONSTON PUMPING PLANT

Presented before the committee on the Annual Review of the State Water Project of the California Water Commission at Fresno, California, on September 21, 1971, by Theodore W. Troost, Chief, Mechanical-Electrical Engineer, Department of Water Resources, The Resources Agency, State of California.

The first definitive report touching on the Tehachapi lift is the State Water Resources Board report, "Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of the California Water Plan", dated May 1951. This report contemplated the use of a series of six pumping plants on the alignment in Pastoria Canyon.

In 1952, a more thorough investigation of the A. D. Edmonston Pumping Plant was initiated, the results of which are summarized in the Division of Water Resources report, "Program for Financing and Constructing the Feather River Project as an Initial Unit of the California Water Plant", dated February 1955. This report introduced the concept of a single pumping plant located in Pastoria Canyon.

In 1955, the Bechtel Corporation was employed to make an independent review of the State's 1955 report of the water project. Its report recommended that studies be made of the use of multiple-stage, as well as the single-stage pumps in series, for this lift.

Between 1956 and 1959, further investigations were made of this portion of the aqueduct system. The results were published in Department of Water Resources Bulletin No. 78, "Investigation of Alternative Aqueduct Systems to Serve Southern California", dated December 1959. This report presented a single pumping plant, situated at the base of a ridge one mile east of Pastoria Canyon, which accomplished the pump lift through steam driven single-stage pumps arranged in series.

This was the system reviewed by the Chas. T. Main Corporation which, in its report of October 1960, entitled "General Evaluation of the Proposed Program for Financing and Constructing the State Water Resources Development System of the State of California Department of Water Resources", endorsed in general the State's engineering concept.

After publication of Bulletin No. 78, further studies were conducted to provide more refined technical and economic comparisons of single and multiple lift systems. The results of these studies are summarized in Department of Water Resources report, "Preliminary Design and Economic Evaluation of Tehachapi Single-lift and Multi-lift Pumping Schemes", dated December 1963. In this report, alternative alignments were considered that were located both in Pastoria Canyon and on the Ridge as presented in Bulletin No. 78.

The three schemes finally selected for intensive comparative evaluation consisted of the present single-lift, an equal two-lift, and an equal three-lift scheme. Multi-stage single flow, two-stage double flow and single-stage single flow pumps respectively were chosen for these studies. These evaluation studies included geology, exploration of seismic conditions, reliability, economics, manufacturing feasibility, experience and practicability of operation and maintenance.

Recognizing the extreme importance of obtaining the most dependable economical scheme for this unprecedented crossing, the Department engaged the firm of Daniel, Mann, Johnson and Mendenhall and their associated firm of Motor-Columbus in Baden, Switzerland to carry out a Research and Development Program for the three schemes to be compared. Also, concurrent with the Daniel, Mann, Johnson and Mendenhall's Research and Development Program, the Metropolitan Water District engaged the firm of Bechtel to make an independent comparison of the three schemes. Also, at the beginning of these studies a Board of Consultants termed the Tehachapi Crossing Consultant Board 1/ was formed for review of the engineering work and final results of the various surveys.

Since the greatest amount of experience existed in Europe on design and operation of high head plants, an exhaustive survey was made by the Department and these firms to obtain comparative information needed for selection of the best scheme for making the crossing. Pump model studies were also made of each type of pump to be used in each of the lift schemes and checked in the National Engineering Laboratory at East Kilbride, Scotland, an independent testing laboratory. Based on these model results, all pumps were determined satisfactory for its respective lift system.

As the comparative studies of the Ridge Route and Pastoria Route progressed, based on geologic investigations, it was found that the Ridge Route was more suitable for structures and the Pastoria Route was abandoned.

The studies then concentrated on the Ridge Route, and soon it was decided to eliminate the three-lift scheme based on being too hazardous and subject to earthquake damage due to the greater number of structures exposed to seismic activity. It was also concluded that this scheme would be more subject to misoperation

1/ John R. Hardin, Chairman, Russel G. Hornberger, Thomas M. Leps, E. C. Marliave, John Parmakian, Robert Sailer, Louis G. Puls

especially when operated in series with the three upstream plants.

Many months of intensive study was devoted in comparing the single-lift and two-lift schemes. Finally it was determined that the single-lift scheme was the most reliable due to exposure of fewer facilities to possible earthquake damage and being freer from operational hazards. The engineering studies culminating in the selection of the single-lift scheme utilizing four-stage, single flow pumps are contained in six volumes of Bulletin No. 164, compiled by the Department of Water Resources.

After giving careful consideration to reports and presentations made by the Bechtel Corporation, the Metropolitan Water District, Daniel, Mann, Johnson and Mendenhall and the Department's staff under the leadership of the late Donald P. Thayer, on May 8, 1965 the Board recommended adopting the single-lift concept using four-stage, single flow pumps and underground discharge lines for making the Tehachapi lift.

The plant as finally conceived will consist of 14 units with 11 to be installed now. The units are rated at 80,000 horsepower, 600 rpm, 315 cfs at a total head of 1,970 feet for lifting 4,100 total cfs from a normal forebay elevation of 1239 to a normal discharge elevation of 3165. Thirteen units are provided for the ultimate capacity of 4,100 cfs with one unit as a spare for maintenance overhaul.

In arriving at the final configuration of the present plant many different arrangements of various features were analyzed. I think it might be interesting to you to mention some of the major considerations.

At the outset of final design of the plant a so-called "in-line" building was used. Subsequently, a study of a "U-shaped" plant was made having 7 units per wing with two discharge lines, one for each wing. This arrangement was best suited to the site topography both from the standpoint of the plant and discharge pipe entrance into the adjacent hillside.

Due to the known seismic activity in this area, an acceleration factor of 0.5g was used by the structural designers instead of the more usual value of 0.1g. As mentioned above, seismic activity in this area influenced strongly the features selected for final design. Underground discharge lines were adopted mainly based on safety and dependability in the solid rock existing on the Ridge alignment.

In order to achieve best efficiency the highest practical specific speed was chosen considering pump speed, capacity and head. Higher than the selected speed of 600 rpm could have been used, but the U. S. Motor Manufacturers were hesitant to go higher due to high overspeed involved during transient conditions resulting in excessive centrifugal stresses and difficulty of machine fabrication, which was based on their experience with high speed

synchronous motors of the size involved. Thus, the more conservative speed of 600 rpm was used.

With regard to purchase of the pumps the bidding specifications were issued only to prequalified bidders based on DWR investigation of the bidders' experience and capability to furnish pumps the size of A. D. Edmonston pumps. It was also decided to award two separate contracts, one for seven pumps and the other four pumps to cover possible default in meeting scheduled deliveries for one reason or another. This move has proven to be a good decision since the East Wing pump was to be ready first, but now the West Wing pump will go into service first.

Three U. S. manufacturers were prequalified consisting of Allis-Chalmers with their affiliate Sulzer Bros., in Winterthur, Switzerland. Baldwin-Lima-Hamilton with their affiliate, Voith, Inc., Heidenheim, Germany; and Newport News Ship Building and Drydock Co., and their affiliate, Escher-Wyss of Zurich, Switzerland. Due to the high value of efficiency at this plant, amounting to $220,000 per one percent efficiency for each unit, the bids included an efficiency evaluation penalty which was to be based on a model efficiency. Each bidder built a model to about one-fifth scale which was tested at the National Engineering Laboratory located at E. Kilbride, Scotland, which is an independent laboratory. The tests were witnessed by representatives of Daniel, Mann, Johnson and Mendenhall and the results were delivered to Department of Water Resources at the time of bid opening. As a result of specified efficiency evaluation, Baldwin-Lima-Hamilton was low bidder on the first seven pumps and Allis-Chalmers was low bidder on the last four pumps. The low bid price on the first contract for seven pumps was $1,651,795 each and 92.2 percent efficiency and the low bid on the second contract for four pumps was $1,534,687 each and efficiency of 92.2 percent. Field performance test will be made to determine whether or not the predicted efficiencies have been met.

A conservative suction specific speed of 7,000 was used resulting in an impeller submergence of 71 feet, which is above the submergence where incipient cavitation was first noted on the model impeller. Another feature incorporated in this pump is the provision to permit removal of the first stage impeller from the bottom for maintenance. This added feature was obtained from European practice and avoids the need to disassemble the whole pump to maintain the critical first stage impeller.

The materials specified for the pumps was influenced by a wear test program conducted at the inlet of the aqueduct near Tracy. As a result of these tests and the European experience, a combination of 12 percent chrome and one percent nickel stainless steel was used for the impellers, diffusers, sleeves, labyrinth rings, and for other critical parts.

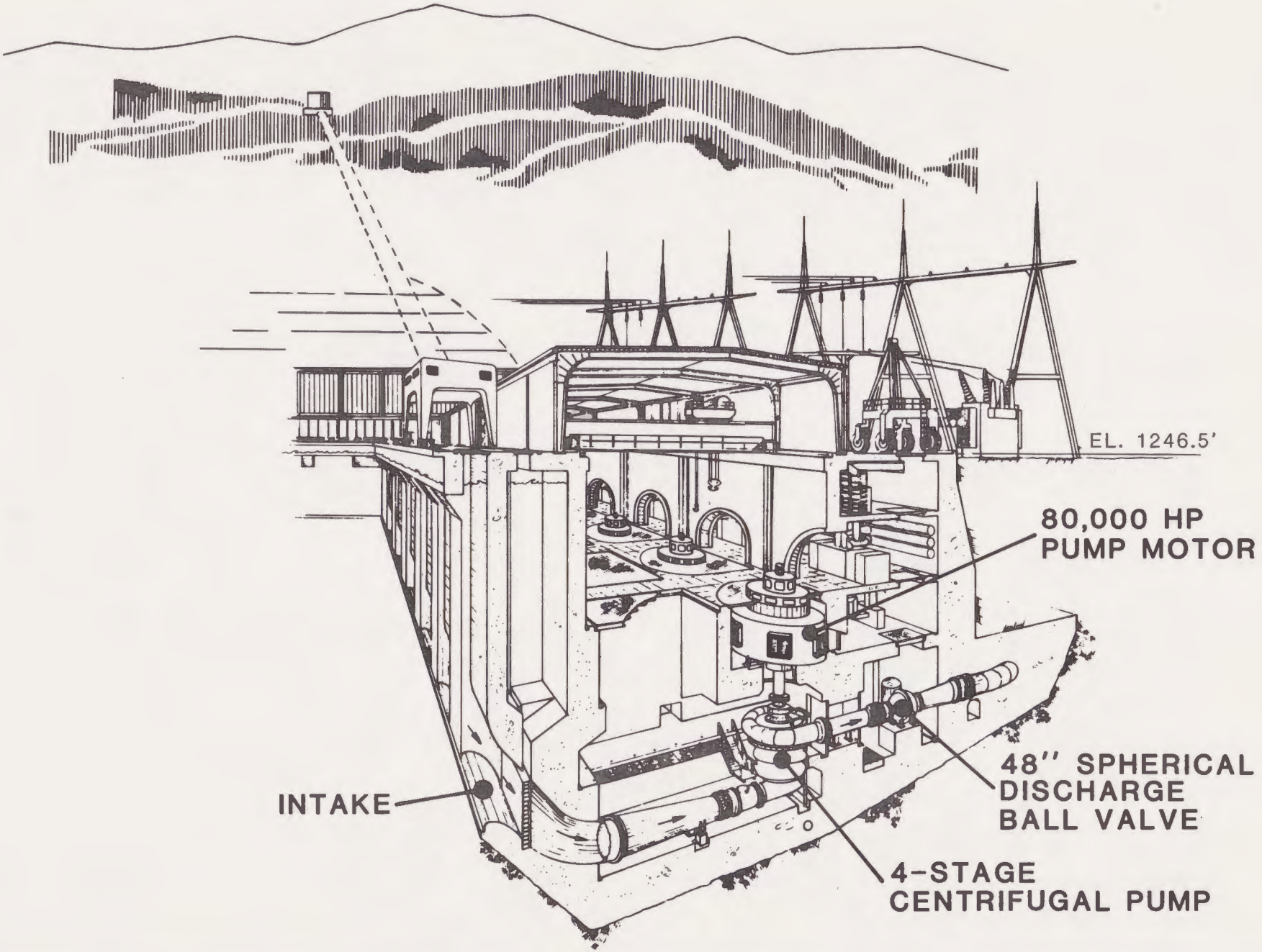
As you may know, starting 80,000 horsepower pumps presents a formidable problem which in this case was compounded by the necessity of starting the pump watered. This requirement was due to the close running clearances and distance between bearings. To accomplish this, two motor generator sets are provided, either of which can start any of the 14 pumps.

There are 14 discharge valves which were furnished by Allis-Chalmers and are now installed. These valves have both upstream and downstream seats for maintenance and shutoff purposes and have a two speed closure operator to limit reverse overspeed of the pump and penstock pressure rise. The high speed portion of the closing stroke of about 80 percent will be about 10 seconds and the remaining portion in about 20 seconds. These husky valves weigh 65 tons each and were pressure tested at 1,700 psi, which is 150 percent of closed valve pressure and water hammer pressure. A special rubber tired valve gantry crane was furnished for installing the valves. This gantry is completely hydraulic operated, requiring no outside power supply, and was furnished by McCafferty Crane Company in Los Angeles. Adjacent to the valves, compensating joints are provided to relieve the pump mounting of the hydraulic thrust due to the discharge pressure. It was determined that objectionable displacement of the pump axis could occur between loaded and unloaded pump since the pump case is not embedded. The application of this unique piece of equipment was obtained from European experience. It develops a counter force equivalent to the pipe diameter force.

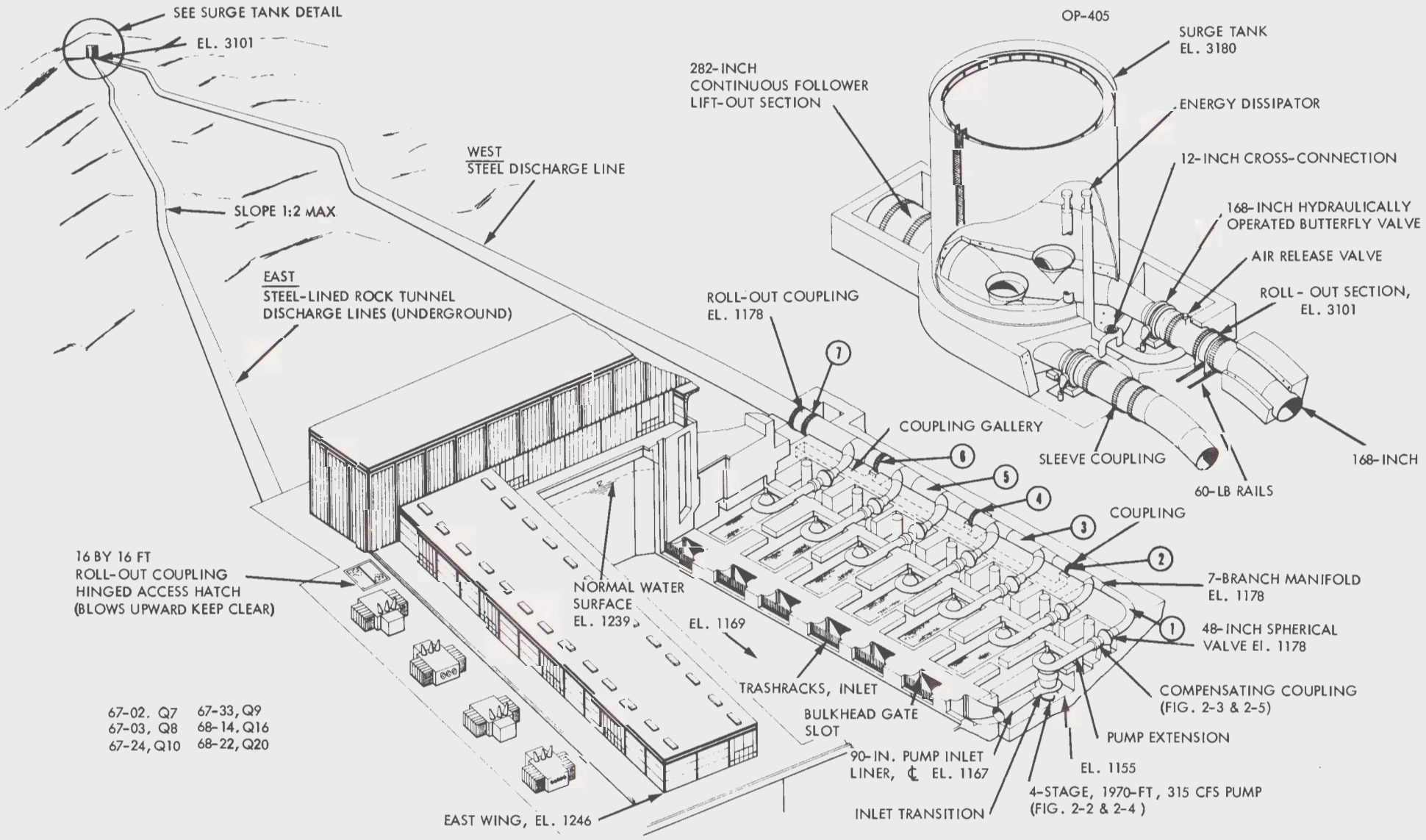
A special two-stage and multi-stage pump are also provided to fill the discharge lines. Provisions are also made for filling the second discharge line from an initial filled line. A special pressure reducing valve is located at the bottom of each discharge line to drain the line. This valve is of the multiple poppet type to dissipate the better than 1,900 foot head.

A. D. EDMONSTON PUMPING PLANT

COST:	$152,483,000
PUMP LIFT:	1926 feet STATIC HEAD - from 1239 feet normal forebay level to 3165 feet level in surge tank. 1926 feet lift plus friction loss in discharge lines - DYNAMIC HEAD.
PUMPS:	31 feet high, 16 feet diameter, weigh approximately 220 tons. 1 unit - 315 cfs = 141,750 gpm 14 units - 4410 cfs = 1,984,500 gpm East Wing - 7 pumps furnished by Baldwin-Lima-Hamilton of Philadelphia, PA. West Wing - 4 pumps furnished by Allis Chalmers of Milwaukee, Wisconsin. Last 3 pumps will be installed later.
MOTORS:	14 units made by Westinghouse are 80,000 h.p. each 14 units = 1,120,000 h.p. 600 rpm for pump and motor Pump and motor assembly is 65 feet high and weigh approximately 420 tons
DISCHARGE VALVES:	Allis-Chalmers Mfg. Co. - Type: 48 inch diameter, with movable seats. These valves weigh 65 tons and are operated by a 500 psi hydraulic system.
SURGE TANK:	62 feet high, 50 feet in diameter.
PURPOSE	Lift water from the California Aqueduct of the State Water Project over the Tehachapi Mountains and into Southern California.
UNIQUENESS:	The combination of volume of water and height of lift is greater than any other plant ever designed. The A. D. Edmonston Pumping Plant pumps are started with a motor-generator to prevent overloading of the utility company power lines and to save power while starting. The starting load can be up to ten times greater than the normal running load. The normal running load of <u>each unit</u> is approximately 60 million watts. This is enough power to light up 600,000 100 watt light bulbs. The total plant load can be up to 850 million watts. About 946 miles of wire and cable has been used for the electrical systems in the plant.



A.D. EDMONSTON PUMPING PLANT (West Wing)



MAIN WATERWAY

TEHACHAPI CROSSING

The concrete lined aqueduct, part of the State Water Project, starting at the Sacramento-San Joaquin Delta, flows south 293 miles (468.8 kilometers) where it meets the Tehachapi Mountains. These mountains form an arching barrier between the Coast Range Mountains to the west and the Sierra Nevadas on the east side of the San Joaquin Valley. This rugged barrier must be crossed to bring northern water to an arid Southern California. The facilities used to cross this barrier are known as the Tehachapi Crossing, a single reach about 10.6 miles (16.96 kilometers) long.

The planning for the Crossing was a major engineering endeavor. The engineering solution to raising 4,410 cubic feet per second (124.8 cubic meters per second) of water through a single lift of 1926 feet (587 meters) and tunneling 8 miles (12.8 kilometers) of the Tehachapi Mountains under adverse geologic conditions represents a major accomplishment. The Crossing is now one of the most noteworthy components of the State Water Project.

Geologic structures in the Tehachapi's are dominated by the Garlock Fault, second largest in California, which splits into two branches crossing the Project alignment and numerous other faults. The San Andreas fault passes about 5-1/2 miles (8.8 kilometers) from the south portal of the crossing's tunnel system. The problem facing the State Department of Water Resources was tobuild a system that would minimize earthquake damage and expedite repair.

Early studies of the Crossing were made of two alternatives: (1) high-level crossing requiring a high lift pumping plant and short tunnels of 8 miles (12.8 kilometers) and (2) low-level crossing requiring a low lift pumping plant but long tunnels of 26.7 miles (42.72 kilometers). The low-lift tunnels would penetrate the Garlock, San Andreas, Liebre and Clearwater Fault systems at considerable depth. The depth, adverse tunneling conditions, large construction costs and extreme difficulty of repair detracted from this system. A policy decision was made to use the high-level system crossing the major active faults at or near ground level for rapid repairs if the faults moved.

The Tehachapi Crossing facilities now consist of a single reach of 10.6 miles (16.96 kilometers) including a pumping plant of unprecedented capability, the giant A. D. Edmonston Pumping Plant, the tunnels and the Tehachapi Afterbay.

TUNNELS

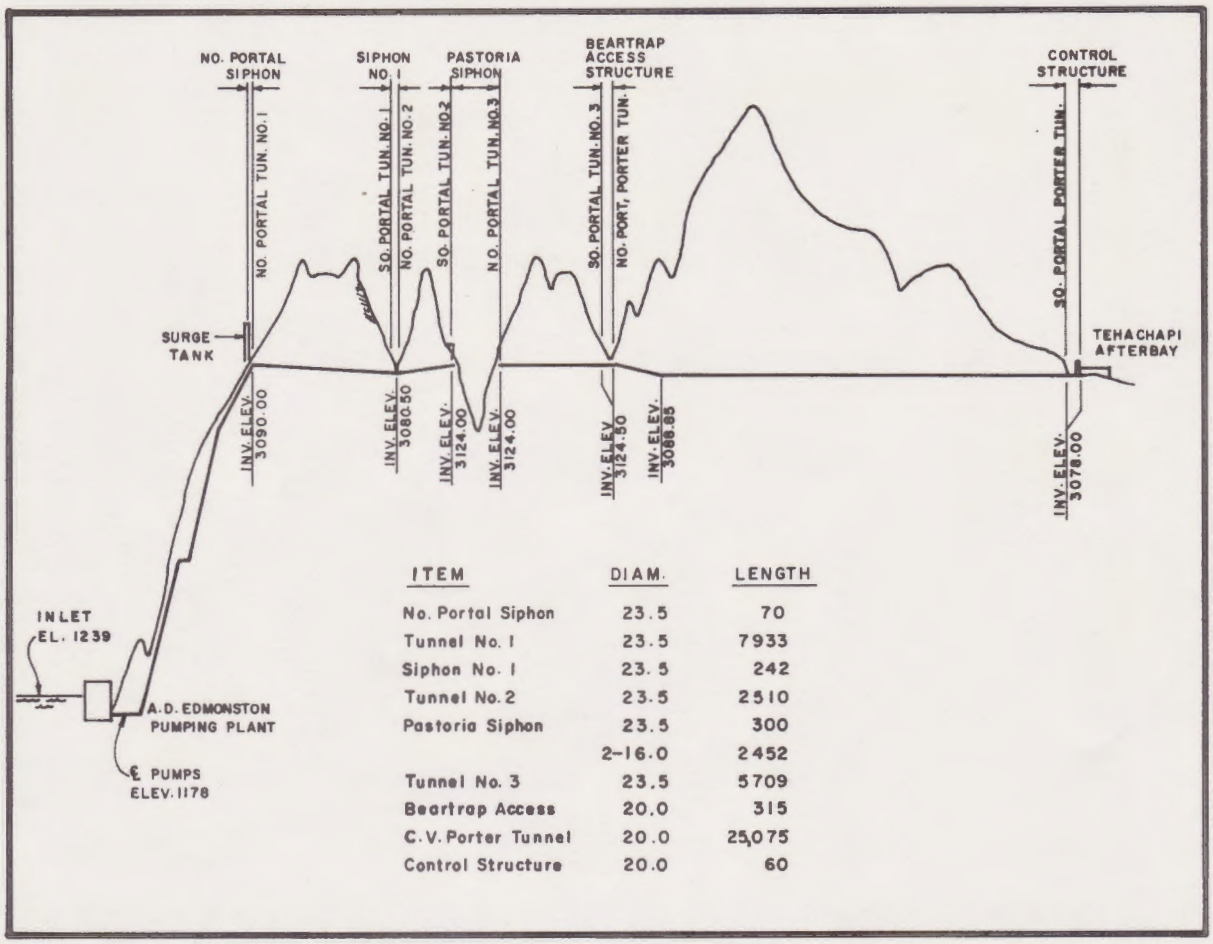
From invert elevation 3,090 feet (941.83 meters), water flows by gravity across the Tehachapi through four tunnels. The four tunnels are connected by siphons or cast-in-place pipe sections which provide access at critical fault crossings as well as operational access to the tunnels.

Pastoria Siphon, at the north branch of Garlock Fault, consists of bifurcated, reinforced concrete, transition structures; rectangular air-shaft sections; 16 foot (4.88 meter) inside diameter, steel, roll-out section; and one 16 foot (4.88 meter) steel barrel, another to be installed later. The length of the transition from tunnel section to siphon barrel is 109 feet. The air shafts serve three purposes: (1) provide siphon access, (2) accomodate bulkheads for isolating a barrel and (3) function as air vents.

Beartrap Access Structure at the south branch of the Garlock Fault is 315 feet (96 meters) long connecting Tehachapi Tunnel #3 and the Carley V. Porter Tunnel. This structure also giving access to the tunnels as well as the siphons all made of reinforced concrete, act as breaking points in the event of fault shifts saving tunnel damage and can be quickly repaired.

The Control Structure and Tehachapi Afterbay form a transition from the Carley V. Porter Tunnels south portal to the bifurcation (split) of the State Water Project to the West Branch and East Branch Aqueducts.

During initial operation of the Tehachapi Tunnels and Afterbay, no unusual difficulties were encountered, nor have there been any problems beyond routine maintenance. Following the February 1971 San Fernando earthquake, the Tehachapi Tunnels were drained for the first time and visual inspection was made of the entire length. The Tunnels and connecting siphons were in excellent condition. Subsequent inspections have resulted in the same findings.



ITEM	DIAM.	LENGTH
No. Portal Siphon	23.5	70
Tunnel No. 1	23.5	7933
Siphon No. 1	23.5	242
Tunnel No. 2	23.5	2510
Pastoria Siphon	23.5	300
	2–16.0	2452
Tunnel No. 3	23.5	5709
Beartrap Access	20.0	315
C.V. Porter Tunnel	20.0	25,075
Control Structure	20.0	60

Figure 188. Schematic Profile—Tehachapi Crossing

TABLE 16. Statistical Summary of Tehachapi Division to Bifurcation

Aqueduct Reach	Type of Conveyance	Inside Diameter (Feet)	Capacity (Cubic feet per second)	Length (Miles)
Tunnel No. 1	Lined tunnel	23.5	5,360	1.5
Siphon No. 1	Reinforced-concrete conduit	23.5	5,360	0.1
Tunnel No. 2	Lined tunnel	23.5	5,360	0.5
Pastoria Siphon				
First Barrel	Existing steel conduit	16.0	2,680	0.5
Second Barrel	Planned conduit	--	2,680	0.5
Tunnel No. 3	Lined tunnel	23.5	5,360	1.1
Beartrap Access Structure	Reinforced-concrete conduit	23.5 to 20.0	5,360	0.1
Carley V. Porter Tunnel	Lined tunnel	20.0	5,360	4.7
Afterbay	Lined channel	*	5,360	0.3
Canal	Lined channel to bifurcation	†	5,360	0.3

AQUEDUCT FEATURE

Check Structure: 1 two-radial-gate structure at end of afterbay
Wasteways: 2, one at Siphon No. 1 and one at low point of Pastoria Siphon
Blowoffs: 2, one at Siphon No. 1 and one at Beartrap Siphon

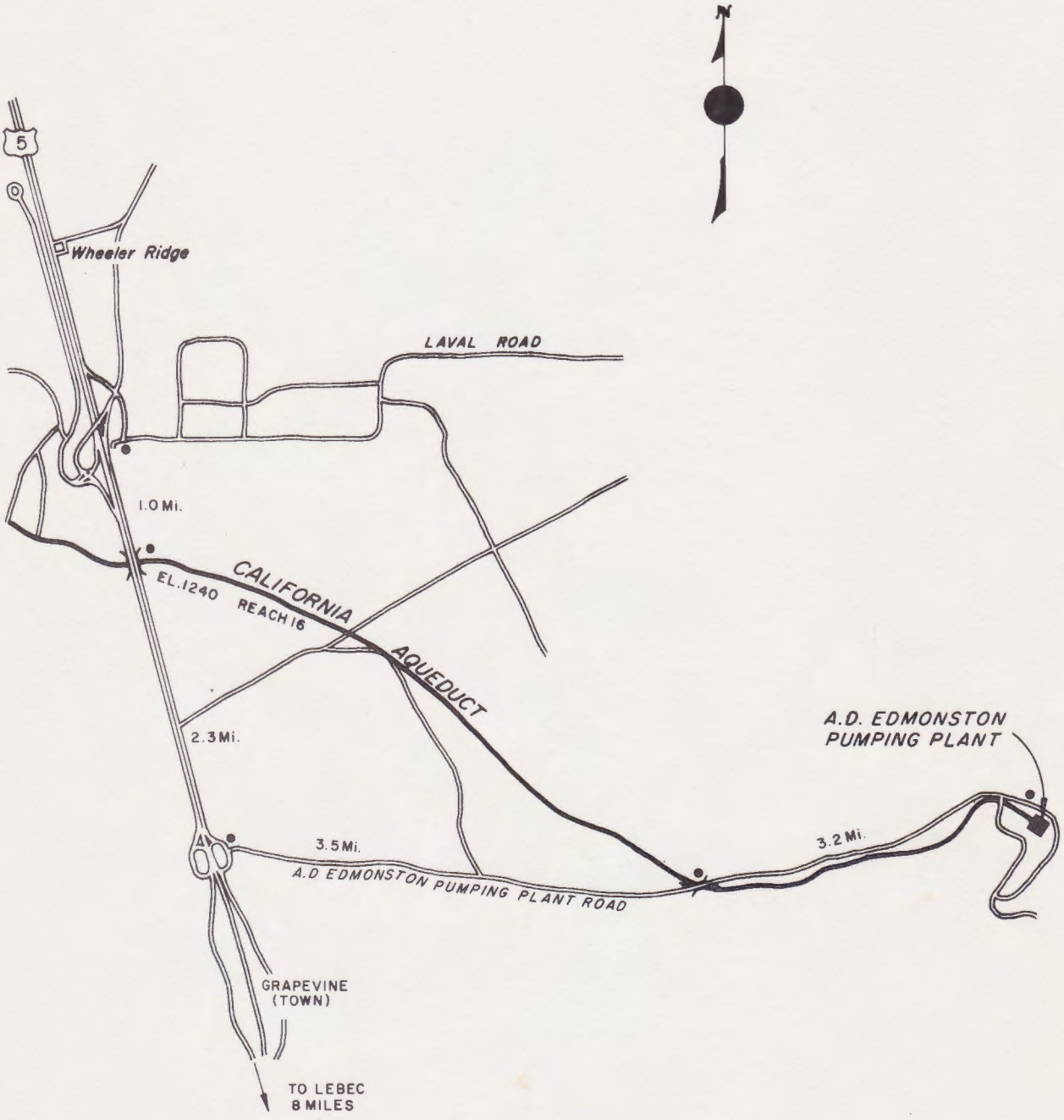
OPERATIONS

Flow control from A. D. Edmonston Pumping Plant control center with area control from San Joaquin Field Division; wasteway control manual on-site operation; afterbay gates (when installed) local automatic and manual, with area control from Castaic Operations and Maintenance Center

* Channel Data: Bottom width, 50 feet; water depth, 22 feet; side slopes, 3:1
† Channel Data: Bottom width, varies from 50 to 32 feet; water depth, 22 feet; side slopes vary from 3:1 to 2:1

Listed below are countries that have sent representatives to tour and study the A. D. Edmonston Pumping Plant:

U.S.A.
BRAZIL
CHAD
EGYPT
EL SALVADOR
UNITED KINGDOM
FRANCE
IRAN
KOREA
MEXICO
CHINA (TAIWAN)
NETHERLANDS
PAKISTAN
SPAIN
SYRIA
THAILAND
UGANDA
IVORY COAST
NIGERIA
TANZANIA
MALI
U.S.S.R.
SUDAN
EQUADOR
ISRAEL
CENTRAL AFRICAN REPUBLIC
RUMANIA
YUGOSLAVIA
PUERTO RICO
BELGIUM
JAPAN
CANADA
AUSTRALIA
COSTA RICA
CHILI
BOLIVIA
OKINAWA
SCOTLAND
SAMOA
ZAIRE
NEW ZEALAND
INDIA
JAVA
SAUDI ARABIA
TUNISIA
PEOPLES REPUBLIC OF CHINA
BANGLADESH
CAPE VERDE
GUINEA-BISSAU
INDONESIA
LESOTHO
MALAYSIA
NEPAL
NIGER
PALESTINE
PORTUGAL
LEBANON
SIERRA LEONE
NICARAGUA
SRI LANKA
KENYA
OMAN
PHILLIPINES
BULGARIA
ITALY
GERMANY
IRELAND
SOMALIA
GUINEA
REPUBLIC OF SOUTH AFRICA
SWEDEN
DOMINICAN REPUBLIC
DENMARK
URAGUAY
SWITZERLAND
SAN SALVADOR
ALGERIA
CZECHOSLOVAKIA
NORWAY
VENEZUELA



For Tour Information Please Call Weekdays (805) 858-2211

SITE ACCESS MAP