

A History *Of* the
Municipal Water Department &
Hetch Hetchy System



SAN FRANCISCO PUBLIC UTILITIES COMMISSION

This 2005 edition of *San Francisco Water and Power, A History of the Municipal Water Department and Hetch Hetchy System* celebrates the extraordinary events and memorable leaders who conceived, designed and built San Francisco's water system with foresight to provide today's Bay Area with high quality drinking water supplies. San Francisco's water system developed over time from the streams and wells of its earliest days to today's complex system of dams, reservoirs, tunnels and pipelines that brings water from the high Sierra Nevada by gravity across California to join from the East Bay and San Francisco Peninsula.

San Francisco's need for reliable water supplies after the devastation of the Great Earthquake and Fire of 1906 brought the brightest engineers of their day to meet the challenges of hydraulic engineering across more than 160 miles of wilderness, developing new technologies and construction techniques, mastering impassable terrain and intractable financial woes to complete the incredible water works that fosters the high quality of life and economic strength that our 21st century San Francisco Bay Area enjoys.

San Francisco Water and Power traces water flow from household taps back to the sources - through the city's distribution system, Bay Area pipelines and tunnels to the storage reservoirs in the Peninsula and East Bay, across the San Joaquin Valley and through the foothill pipelines, tunnels and hydroelectric power plants in the Mother Lode, up through the mountain tunnels to the dams and impounding reservoirs in the high Sierra Nevada to Mount Lyell in Yosemite National Park - the ultimate source of San Francisco's water and power resources.

The first seven decades of San Francisco's municipal water supply story is about the development of local water sources by entrepreneurial water companies, including the brilliant water system designed by the Spring Valley Water Company, a private enterprise, that brought water supplies from within San Francisco,



Tueeulala Falls

on the Peninsula and across San Francisco Bay to meet the demands of a burgeoning city. San Francisco purchased the fully developed, mature Spring Valley water works in 1930 at a cost of \$39,962,606.51.

The Hetch Hetchy Project had its birth in the Raker Act of 1913, which granted the City water and power rights-of-way on the Tuolumne River in Yosemite National Park. The entire system is the realization of a concept planned since the 1860's for an aqueduct from the Sierra Nevada watersheds to San Francisco. In 1934, mountain water supplies first reached the San Francisco Peninsula, twenty years after construction started, representing an investment by the people of San Francisco of more than \$100 million. The system was engineered to deliver Hetch Hetchy supplies entirely by gravity to the regional Bay Area.

Integration of the Hetch Hetchy aqueduct with local water storage and delivery systems provides San Francisco and its neighboring communities with an assured supply of high quality drink-

ing water to meet their changing needs.

The San Francisco Public Utilities Commission recently initiated a major, multi-billion dollar water system improvement program to rebuild its aging water system in response to concerns about increasing vulnerability to service disruptions in a major seismic event, or from a prolonged drought. Plans are in place to upgrade, replace or augment critical facilities to ensure the San Francisco Bay Area continues to receive reliable, high quality water supplies into the future.

Editors, June 2005

*To those who dream
and carry on unsung*

San Francisco Water & Power

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**SAN FRANCISCO'S
EARLY WATER SOURCES**



The seed for San Francisco's municipal quest for drinking water was sown in 1769, when Don Gaspar de Portola and Jose Francisco Ortega reconnoitered the Peninsula and discovered San Francisco Bay. Padre Juan Crespi recorded the tortuous trek in his diary. The seed was watered in 1773 by the exploratory expedition of Fernando Rivera y Moncada and Padre Francisco Palou. Palou returned to the tip of the 50-mile-long peninsula with Juan Batista de Anza in 1776 when they founded Presidio Pueblo, a military town, and Mission San Francisco.

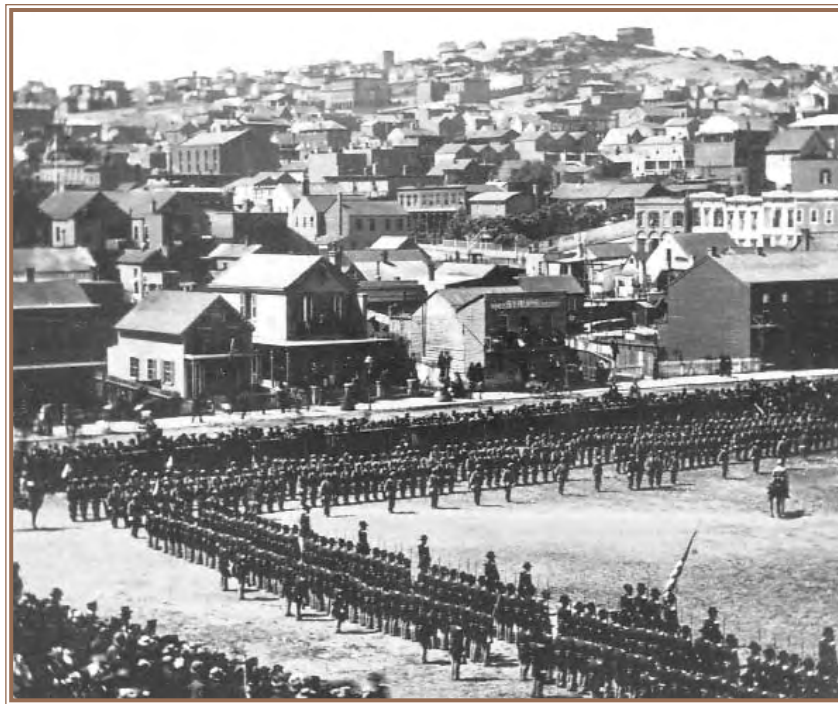
The area is favored with a mild, maritime climate. But the site they selected was bounded on three sides by the salt water of the Pacific Ocean and San Francisco Bay, and lay in the center of a region geographically classified as semi-arid. The seed of the quest for water took root.

SPANISH RULE

Unlike some of Spain's earlier colonies in the New World, the Alta California had never been the site of a highly developed indigenous civilization. No public works existed -- neither cities, roads, reservoirs nor aqueducts.

Casual local water sources were adequate for the Presidio Pueblo and Mission. The soldiers and their families took their water from Laguna del Presidio (Mountain Lake), Arroyo del Puerto (Lobos Creek) and several springs, including El Polin, near the encampment. Mountain Lake and Polin Spring continue to produce water, though not potable. Lobos Creek continues to supply over two million gallons a day (MGD) to the Presidio of San Francisco.

Anza located Mission San Francisco near the *ojo de agua*, or small stream, which he named Arroyo de los Dolores. Originating on the heights of what is now called Twin Peaks, the stream generally followed the line of 18th Street into Laguna de Manantial, or Lake Dolores, which emptied through Mission Creek into Mission Bay (China Basin), originally called Ensenada de los Llorones.



Washington Square, San Francisco 1862

July 4th Celebration

Dolores Lake and Stream have long since been filled in and built over. A portion of Mission Creek and Bay can still be found between Berry and Channel Streets from 7th Street to China Basin. The name Dolores remains on the street fronting the Mission, the Mission chapel, a church built adjacent to the chapel much later, and a nearby neighborhood park.

Under Spanish royal rule, the Presidio Pueblo and Mission shared the placid, uneventful life common to all settlements in the California province. Life was slow moving and confined to the Presidio Pueblo and Mission grounds. Visits by Spain's galleons brought old world luxuries and political instructions from Mexico. Spain kept Alta California isolated. Visits by foreigners were not encouraged.

FIRST SETTLEMENTS

When Spain's royal rule over Yerba Buena and California was ended in 1821, Mexico opened Mission lands to settlement under the Secularization Act of 1833. Longstanding isolation policies were broken down, relaxing economic and political barriers to foreign commerce. Trade ships, hide droghers and whalers entering San Francisco Bay found anchorage at Yerba Buena Cove,

just north of the present-day Ferry Building, better than at the Presidio anchorage favored by the Spanish galleons. Mexican Governor Figueroa established a trading post at Yerba Buena Cove and named William A. Richardson, an Englishman, as harbormaster.

A settlement grew at the Cove to service and do business with the visiting ships. The original trails that connected the Presidio Pueblo to the Mission and thence south, were joined by additional tracks to the new Mexican pueblo growing on the Yerba Buena shore.

There wasn't much of a settlement yet in December 1835, when Richard Henry Dana, Jr., who later authored the great 1840 American classic, *Two Years Before the Mast*, was a 20-year-old crew member aboard the Boston drogher, *Alert*, laying at anchor in the Cove. Twenty-four years later he reminisced,

It was in the winter of 1835-36 that the ship Alert, in the prosecution of her voyage for hides on the remote and almost unknown coast of California, floated into the vast solitude of the Bay of San Francisco. Our anchorage was between a small island, called Yerba Buena, and a

gravel beach in a little bight or cove of the same name, formed by two projecting points. Beyond, to the westward of the landing place, were dreary sand hills, with little grass to be seen, and a few trees, and beyond them higher hills, steep and barren, their sides gullied by the rains. Some five or six miles beyond the landing-place, to the right, was a ruinous presidio, and some three or four miles to the left was the Mission of Dolores, as ruinous as the presidio, almost deserted, with but few Native Americans attached to it, and but little property in cattle. Over a region far beyond our sight there were no other human habitations, except a shanty of rough boards, put up by a man years in advance of his time, named Richardson, who carried on a very small retail trade between the hide ships and the Indians. The next year Richardson built a one-story adobe house on the same spot, which was long afterwards known as the oldest house in the great city of San Francisco.

Richardson's 1836 pretentious one-story adobe was the Casa Grande. It stood near Clay Street and Grant Avenue until 1852. The Pueblo of Yerba Buena, a town government organized by 450 residents, was overtaken by the U.S.S. *Portsmouth*, commanded by Captain R. B. Montgomery, on July 9, 1846. Montgomery appointed his lieutenant, Washington Bartlett, who was bilingual, to be the first American *Alcalde* or Mayor. Bartlett proclaimed the name of the Pueblo to be San Francisco.

THE GOLD RUSH

During the somnolent days of Yerba Buena, after Dana's visit and before the Gold Rush, San Franciscans took their water from a few streams, springs and wells. These sources were no longer adequate by 1849, so householders bought water by the barrel. Water peddlers competed in the streets with barrels in carts serving regular water routes. Some had barrels slung across the back of a donkey. A footnote in history identifies one such entrepreneur as Juan Miguel Aguirre, who took water from several locations. During

periods of scarcity, Señor Aguirre reportedly charged as much as one dollar in gold for a bucket of drinking water, his thriving business earning some \$30 a day.

In 1851, the Sausalito Water and Steam Tug Company was barging the precious fluid across the bay by tank steamer from springs on the Marin shore, using some 65 water carts to supply San Francisco households. That same year, the Mountain Lake Water Company was formed to bring water from Mountain Lake in the Presidio.

Within the two years, 1850-1852, San Francisco was entirely destroyed by fire six times, with staggering losses of property, and was as often rebuilt. By 1859, the city was solidly built of brick and stone with nearly 100,000 inhabitants having all the accomplishments of wealth and culture. They also had

vivid, fresh memories of wide-spread conflagrations and never enough water for fire fighting.

IMPACT OF THE GOLD RUSH

In excerpts from Theodore H. Hittell's *1897 History of California, Vol. II*, he describes the rush of adventurers over land and by sea to the gold mines west of San Francisco. In one year, 1849, the population of California swelled to over 100,000, many skilled in trades and crafts, who emigrated from all regions of the country and around the world to seek their fortune in the Sacramento hills.

The earliest important notice of the gold discovery, which appeared in the Atlantic States, was published in the Baltimore Sun newspaper on September 20, 1848. But by that time private letters from the Pacific coast,



Miners pan for gold circa 1850

Photo credit: historichay49.com

filled with the wonderful story, had commenced reaching their destinations. Those of the recipients, who had faith in their correspondents, believed; but for several months the general public heard with incredulity. The private letters urged relatives and friends to sell out at almost any sacrifice and start at once for California. Friends compared letters, which all gave the same account and the same advice. Doubt began to vanish and enterprising men to prepare for the grand exodus. Everybody began to talk about California.

The people were in a ripe state for adventurous emigration. The Mexican war, besides stimulating enterprise, had thrown upon the country numbers of vigorous young men, inured to travel and hardships, without regular employments, and ready for new campaigns which promised unlimited rewards of wealth; while in every state there were numbers of all classes eager to better their condition and contemptuous, in the face of the accounts they received, of suggestions of doubt or difficulty or danger. Very soon after the first public notice appeared,

all the newspapers from one end of the country to the other were full of the subject. It everywhere became the topic of conversation and discussion. The arrival of newer accounts and larger consignments of gold served to confirm and increase the feeling and it rapidly grew all absorbing-first into an excitement and then into what was called a fever. It soon became certain that there would be a grand rush for the gold mines...

Immense numbers of trains or caravans of emigrants, with covered wagons usually drawn, by oxen, started on their way from the western frontiers across the plains. There was a continuous stream of them, which, by the time the first ships from the Atlantic ports reached San Francisco, stretched across the continent and began pouring over the Sierra Nevada into the Sacramento and San Joaquin valleys. It presented a sight that had not been seen before and may not be seen again...

San Francisco's search for increasing quantities of potable water attempted to keep pace with the rapid growth and development of that sleepy pueblo into a major world metropolis. The sudden birth and overnight develop-

ment of this city during the Gold Rush sparked a dynamic municipal quest for new sources of drinking water.

A. W. VON SCHMIDT AND THE FIRST WATER WORKS

After a two-year effort, the Mountain Lake Water Company ran out of money in 1853, and was granted the first of several time extensions to bring water from Mountain Lake. In 1856, the San Francisco City Water Works, popularly known as the Bensley Company, was franchised by San Francisco Order No. 46. The next year, Alexei Waldemar von Schmidt, the chief engineer of the Bensley Company, dammed the mouth of Lobos Creek and brought two million gallons of water a day by flume and tunnel around Fort Point, through the Presidio and under Fort Mason, to the Black Point Pumping Station at the foot of Van Ness Avenue. The Lobos Creek water was then pumped through two sets of heavy double-force pipes to the Francisco (elevation 135 feet) and Lombard (elevation 306 feet) Reservoirs on the north slope of Russian Hill.

The U.S. Census of 1860 reported San Francisco's population as 78,000. The forecast was for growth - agriculture was being developed in addition to gold and silver mining. Seeing opportunity in the Bensley endeavor, George H. Ensign obtained a water charter from the California Legislature in 1858 and organized the Spring Valley Water Works. He laid a few pipes from an intermittent spring arising on Mason Street, about 100 feet north of Washington Street and some 1,000 feet west of Portsmouth Square. That spring had been a source for Juan Aguirre and others who peddled water during the Gold Rush days. It gave the neighborhood and Ensign's water works its name - Spring Valley. The spring is covered over today, but it continues to produce water beneath the foundations of the Municipal Railway's Cable Car Barn at Mason and Washington Streets.

Ensign's franchise from the Legislature in 1858 was to lay down pipes. Because the spring did not yield more than 5,000 gallons per day, it was considered so insignificant that the usual



Water seller in San Francisco 1855



*Sunset District, San Francisco 1936
(Sunset Reservoir site right rear)*

provisions for supplying water free for all municipal purposes were omitted, except for fire extinguishing.

Later, this omission resulted in 11 years of litigation and was the cause of much indignation and bad feeling. Spring Valley sued San Francisco for water charges for municipal purposes, until a new State Constitution was adopted in 1880, placing water rate fixing with the Board of Supervisors. Fixing the water rates was then an annual squabble within the Board of Supervisors until 1911, when the Constitution was amended, placing the State Railroad Commission in charge of fixing San Francisco's water rates.

Although Schmidt was the chief engineer and a founder of the San Francisco City Water Works, he had a dispute with the company, which refused to pay for a water meter he invented. Vowing to get even, Schmidt left the Bensley Company in 1860 to become the chief engineer and a leading stockholder of the Spring Valley Water Works. He developed Ensign's franchise and took over the meager Islais Creek water supply of the Islais and Salinas Water Company, which had built a small dam west of the old Mission Viaduct near Rock House Gulch (Glen Park Canyon). The Islais Creek water was carried through a flume around the hillside to the old

Brannan Street Reservoir between 16th and 17th Streets.

The upper limit for Bensley Company production from Lobos Creek was two million gallons per day. Spring Valley was Bensley's stiff competitor and strong rival from 1862, but initially its spring and creek production could come up with only 200,000 gallons per day.

PILARCITOS DAM AND RESERVOIR

Convinced the city needed more water than could be produced locally by the limited sources within San Francisco, Schmidt turned the quest southward, to the San Mateo County lands excluded by San Francisco's 1856 consolidation of the City and County. He promised San Francisco that water from the Peninsula would soon be delivered to the city.

Pilarcitos Creek reaches the Pacific Ocean at Half Moon Bay. The upper Pilarcitos tributary watershed is less than half a square mile, but the drainage is on the western slope of the coastal mountains with elevations reaching 1,875 feet. Having the highest average annual rainfall on the Peninsula - measuring 49 inches - Pilarcitos is the most productive of the Peninsula reservoirs.

Schmidt started constructing the first facility, a small earth dam impounding 65 million gallons of water, across Pilarcitos Canyon 11 miles south of San

Francisco. Tunnel No. 1 was driven through Cahill Ridge from Pilarcitos to San Mateo Creek in 1861 - a work considered a stupendous undertaking for those days. Constantly observed and reported on by the press, Spring Valley accelerated construction work during May and June. Crews worked around the clock for ten months, cutting the 1,500-foot tunnel through solid rock. The *San Francisco Alta* boasted that "on driving the two ends of the tunnel together in the center of the hill, they struck inside of half an inch on the line and grade."

In August 1865, Spring Valley finished building the first of its major distributing reservoirs in San Francisco, Laguna Honda Reservoir on Seventh Avenue at an elevation of 373 feet. Pilarcitos water was delivered by flume and pipeline to Laguna Honda by gravity flow. The pipeline was destroyed by the 1906 earthquake and never replaced. However, a portion of Tunnel No. 1 remains in service to this day, connecting with Tunnel No. 2 to take flows from Pilarcitos Reservoir through Cahill and Sawyer Ridges to San Andreas Reservoir.



Pilarcitos Dam under construction 1866

WHAT'S IN A NAME?

THE DISAPPEARANCE OF THE “SAN ANDRÉS VALLEY”

As the history of this dam and its works north of Pilarcitos unfolds, its name changes from San Andrés to San Andreas.

When Spring Valley's Hermann Schussler built the works, the dam, pipeline, conduit, reservoir and lake were called San Andrés, after the valley.

That the valley was named San Andrés by the first Spaniards in Alta California is well documented in California history. Also Spring Valley records, Water Department files and San Francisco Public Utilities Commission documents, up to some three decades ago, refer to San Andrés Dam, Pipeline, Reservoir, and Lake from historical record and the presence of a usurper, San Andreas, as the name of the valley and Spring Valley's works.

With piqued curiosity, we pursued this mystery, the disappearance of San Andrés.

First thoughts were, that since Andrea is the feminine form of the Spanish Andrés, perhaps there had been a woman in history whom the Spaniards wanted to recognize. However, in Spanish grammar, Andrea is singular and Andreas is plural. If Spain's explorers had named this valley, as they did some of Alta California's geography, for a female saint, they would have used the feminine Santa Andrea and if for more than one Andrea - Santas Andreas. Although the Roman Catholic Church Rota lists a Saint Andrew - San Andrés -

we have no record of a Saint Andrea. Had there been a sainted Andrea, it is doubtful that the Spanish padres would have erred grammatically in her name.

So at what point or period in time did we substitute San Andreas for the San Andrés of old? And why did we call it San Andrés in the first place?

Padre Crespi's detailed log of Portola's reconnaissance of 1769 tells of Sergeant Juan Ortega being sent out with a party to establish landmarks. Upon Ortega's return, Portola turned inland on November 4, and crossing the hills north-eastward, the party went down into a *cañada*, or valley, followed it south and then camped. Hubert Howe Bancroft, authoritative researcher of Alta California early chronicles, explains, "They have crossed the San Bruno hills from just above Point San Pedro to the head of the *cañada* in a course due west from Millbrae." Bancroft continues, "Next day they march down the same *cañada*, called by them San Francisco, now San Andrés and San Raimundo, for three leagues and a half, having the

main ridge on the right, and on the left a line of low hills which obstruct their view of the bay."

Today that *cañada* is the site of San Andreas Lake, Lower Crystal Springs Reservoir, Upper Crystal Springs Reservoir and San Andreas Cañada south of the Pulgas Water Temple. The valley identifies the San Andreas Rift Zone on topographic maps.

Four years after Portola and Ortega, Fernando Rivera y Moncada and Francisco Palou went back along the same route and Bancroft says, "crossing the low hills into the *cañada* that had been followed in 1769, to which, or to a locality in which, they gave the name Cañada de San Andrés on November 30, 1773, the feast day of the saint."

By 1776, the Cañada de San Andrés was an established feature of Spanish maps. After founding the Presidio Pueblo and Mission San Francisco, Anza's route back to Monterey was through the Cañada

de San Andrés, which he followed for six-and-a-half leagues. He suggested establishing a second bay mission in the Cañada de San Andrés, which would serve as a stopping place - *escala* - between Monterey and San Francisco. An *escala* was established as an outpost of the Mission San Francisco, but it was located in what is now downtown San Mateo.

There is strength and clarity in Hermann Schussler's writings and records. He constructed the dam, conduit and pipeline in the late 1860's, and was Spring Valley's Chief Engineer for fifty years. Spring

Valley's records and Schussler's logs are consistent in referring to valley and water works as San Andrés.

Not so in the official county maps of the time. In its 1946 "California Place Names," the University of California Press cites the 1877 San Mateo County map as authority for claiming the Dam and Reservoir were San Andreas from the beginning, while acknowledging San Andrés as the name of the valley.

But there is an earlier San Mateo County map, that of 1868, which locates the Cañada San Andrés and San Andrés at the location to be filled by the reservoir. The San Andrés Creek from the north, the San Mateo Creek from the northwest, and the Laguna Creek from Lake Raymundo to the south, came together at Crystal Springs, the former hotel resort, which was immediately upstream from today's Crystal Springs Dam.

Dr. Alan K. Brown of the San Mateo County Historical Association, in his 1975 "Place Names in San Mateo County," tells of San Andrés Creek (between San Andrés Lake and Lower Crystal



Hermann Schussler (second from right) 1906

Springs Lake), receiving"... its name from the valley at its head in Spanish times. The San Andrés Road up the creek was built in 1855 and named by around 1860. The southern part of the present road was opened in 1889, and is often called the Sawyer Camp Road, because it joins the old route at that point."

With regard to San Andrés Lake, Dr. Brown said, "The reservoir has been so called ever since it was created in 1868; it fills most of San Andrés Valley...The full Spanish form of the name was in at least as common use as the American translation down to 1880. The map spelling has been San Andreas, a common American corruption, since the 1850's, but the local spelling has never been really settled. The Spring Valley Water Company and, to some extent, its successor, the San Francisco Water Department, have always held out for San Andrés, and San Andrace has not been unknown. The United States Geographic Board declared for San Andreas twice, in 1907 and in 1931."

In his definitive "Sketch of the Geology of the San Francisco Peninsula," Andrew Cowper Lawson, Professor of Geology at the University of California, placed the name San Andreas, in 1893-1894, on the valley drained by the San Mateo Creek, on Spring Valley's dam, on the reservoir lake and on a creek, which once shared headwaters with San Bruno Creek. Lawson incidentally located, but did not name, two geological faults along San Mateo and Pilarcitos Creeks. He would later identify the San Mateo Creek Fault as the San Andreas Rift and the source of San Francisco's disastrous earthquake.

With professional and official acceptance of his paper, Lawson's status as the authority on geology of the San Francisco Peninsula was established. There is no challenge to his geological study here. Besides authoring the initial and definitive geology of the Peninsula, which was entered into the Congressional Record, Professor Lawson guided University of California Geology studies. Generations of student geologists, seismologists and engineers learned of the San Andreas Rift, Valley, Dam and Reservoirs - San Andrés fell by the wayside.

Within days following the 1906 Earthquake, Schussler invited Professor Charles Derleth, Jr., of the University of California's Civil Engineering Department, to examine the Spring Valley Water Company waterworks and earthquake repairs in progress. In May 1906, Derleth reported: "The waste-way conduit connecting it (Pilarcitos Reservoir) to San Andrés Lake is also intact." However, the professor made at least nine other references to the dam, conduit and pipeline, as San Andreas.

Later, California's Governor Pardee named Professor Lawson to chair the State Earthquake Investigation Committee. The Commission's report was published in May 1908. Lawson's introduction described the valley named in 1773 as the Cañada of San Andrés. Lawson said, "The fissure (of the fault) follows an old line of seismic disturbance which extended...southerly obliquely across the Coast Ranges... This line is marked by features due to former earth movements and will be referred to as a rift...To distinguish it from other rifts...it will be referred to more specifically as the San Andreas Rift, the name being taken from the San Andreas Valley on the peninsula of San Francisco, where it exhibits a strongly pronounced character..."

Andrés is a well known name, quite familiar in 19th century California history. San Andreas is the Amador town identified with

San Andreas Ravine, named by Mexican miners in 1848. There was also a Native American Chief of the Cahuilla tribe near Riverside who carried the Mexican name "Captain Andreas." Lawson confirmed his own 1894 report naming the valley. San Andrés remained on Spring Valley, Water Department and San Francisco Public Utilities Commission records for the next four decades - but it was a losing battle. In government and popularly, the earthquake fault was the San Andreas. Spring Valley continued to use San Andrés for the dam and its works. But when the Water Department took over Spring Valley operations in 1930, San Andrés Valley works were, more and more, called San Andreas. The notoriety of the San Andreas Fault, the source of San Francisco's Earthquake, pushed aside the San Andrés name. San Andrés and San Andreas were used interchangeably - which concerned those charged with keeping the record straight.

"It was just over thirty years ago," recalled Ed Fonseca, retired Manager of San Francisco's former Suburban Division, "that we saw more and more misnaming of the dam and related waterworks. Sometimes it was San Andrés, but more often San Andreas." Fonseca resolved the confusion almost single-handedly. In 1951, he started encouraging the use of San Andreas to designate all Water Department works named San Andrés.

Asked why he opted for San Andreas, Fonseca recalled, "San Andreas as the name of the fault is accepted by state, federal and local authorities. The fault has received lots of publicity since 1906. It's on all maps of the area and it's world famous - San Andreas is more popular than San Andrés."

The San Francisco Public Utilities Commission Annual Report for 1952-53 settled the matter without further discussion by labeling as San Andreas all facilities previously called San Andrés.

With one brief exception since then, reports, maps and other references to the dam, reservoir, conduit and pipeline have been to San Andreas. The one published exception is the Hetch Hetchy Water and Power Systems map drawn by Charles L. Reed in 1958. Revised in 1966, the map still locates the San Andrés Reservoir west of Millbrae.

Less than 15 years later, the dust had settled and there was no question of the name. At the dedication of the San Andreas Water Treatment Plant in 1972, the welcoming brochure employed only San Andreas Lake and San Andreas Dam.

As best as can now be reconstructed from written record and living memory, this is the history of how the Spanish San Andrés became San Andreas, a name probably of Mexican origin and certainly of dubious grammar.

These were the milestones of San Francisco's quest for water when 21-year-old Hermann Schussler came to California from Zurich, Switzerland in 1864. Born in the village of Rastebe in the Grand Duchy of Oldenberg, Schussler spoke little English. But armed with studies in civil engineering at the Universities of Karlsruhe and Zurich, and with some engineering experience in Switzerland, he rode in on horseback with a carpet bag for his personal belongings.

HERMANN SCHUSSLER

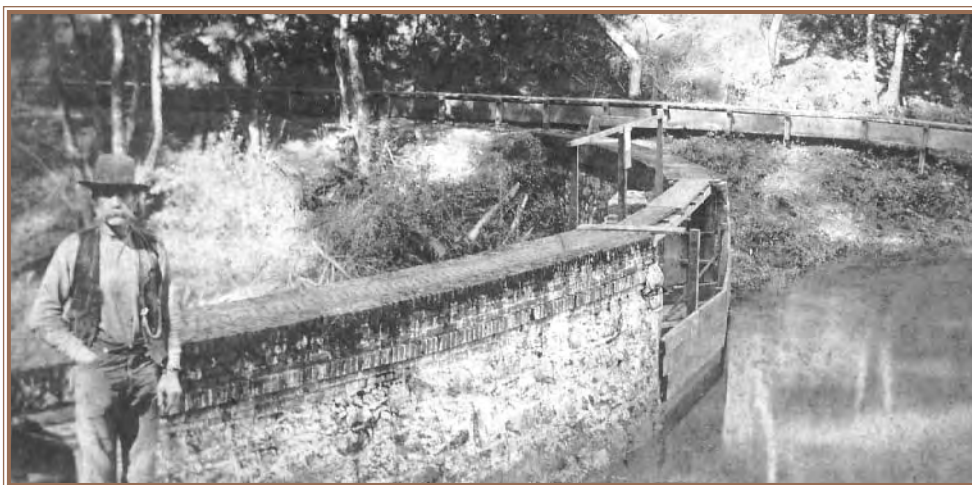
Calvin Brown, who succeeded Schmidt as Spring Valley engineer, hired Schussler on October 8, 1864, and put him to work building the second, larger Pilarcitos main dam. In early 1865, Schussler started Tunnel No. 2 through Sawyer Ridge on the Pilarcitos conduit line.

Meanwhile, in addition to Laguna Honda on Seventh Avenue, Spring Valley had built reservoirs on Clay, Market and Buchanan Streets with a total capacity of 46 million gallons. In 1864, the Bensley Company was faced with soil eroding into its Lobos Creek aqueduct. Muddy water was being delivered to Bensley customers and the company needed clear water to settle the turbidity. Where to get clear water? The problem was solved in an unusual manner - the company tapped a Spring Valley main and sold the blend to its customers!

The irregularity was discovered and gleefully exposed by the press with a good deal of facetious writing. The ridicule hastened the end of the Bensley Company and Schmidt saw the realization of his vengeful vow. Spring Valley bought out the Bensley Company (the San Francisco City Water Works) on February 13, 1865.

It was about this time that Schmidt became convinced that San Francisco would soon outgrow its water supply on the Peninsula. He left Spring Valley in 1864, revealing his plans to use Lake Tahoe as a water supply, though not necessarily for San Francisco.

In May 1866 at the age of 23, Schussler was named Chief Engineer of the



Stone Dam and Flume 1872

entire Spring Valley Water Works. He raised the main Pilarcitos Dam to a height of 70 feet in 1867. Constructed of dry rolled fill with a puddled clay core, it was then one of the world's highest earth dams, impounding 600 million gallons of water. Eight years later, in response to San Francisco's increasing water needs, Schussler raised the dam to 95 feet, with a 520-foot crest length and a one-billion-gallon (3,070 acre feet) capacity. The dam underwent repairs years later in 1972 to reconstruct the dam's upstream face.

While surveying for the Pilarcitos pipeline, Schussler noticed level ground in the San Andrés Valley and rerouted the pipeline to the higher ground towards Millbrae. He noted that for a distance of nearly three miles, the valley rose only ten or fifteen feet, making it an ideal site to collect and store water runoff from the nearby mountain range. Foreseeing the possibility, Schussler located the new pipeline advantageously for future reservoir development.

The Pilarcitos Dam project launched Schussler with Spring Valley. His career was to span a half-century, leaving his mark for all time on the dams, reservoirs and aqueducts serving San Francisco and its customers in San Mateo, Santa Clara and Alameda Counties.

Schussler's ingenuity and foresight gave San Francisco water works on the Peninsula and in Alameda County that provide nearly 15% of its water supply today:

- San Andreas Dam and Reservoir
- Stone Dam
- Upper and Lower Crystal Springs Dams and Reservoirs
- Sunol Filter Galleries and Pleasanton Well Field
- Calaveras Dam and Reservoir
- Niles Canyon Aqueduct
- Bay Division Submarine Pipelines.

Hermann Schussler retired from the Spring Valley as Chief Engineer in 1909. He remained in private practice until his death in 1919.

SAN ANDREAS DAM AND RESERVOIR

As daily demand for water gradually increased, Schussler's thoughts returned to the storage potential of San Andrés Valley, and he showed it to Spring Valley's executive board early in 1868. The board bought the valley and four or five square miles of the watershed. In April, Schussler started damming the San Andrés Valley and building its independent pipeline.

In the high valley just west of the Junipero Serra Freeway (I-280), San Andreas Reservoir is the first lake encountered south of San Francisco. A catchment and storage facility, it is on a branch of the San Mateo Creek, 2.5 miles north of Pilarcitos. Runoff is from some 4.4 square miles of watershed, supplemented by over 2.5 square miles of contributing areas, whose runoff waters are diverted into the reservoir

by nearby tunnels through Sawyer Ridge from San Mateo Creek.

San Andrés Reservoir entered water operations for San Francisco in November 1870, and the dam was raised five years later by Schussler. From the Millbrae tunnel portal, the water entered a 30-inch pipeline to College Hill Reservoir in San Francisco. There it connected with a 22-inch main that led to 25th and Valencia Streets, joining the meshwork of city pipes. When increased to its height of 105 feet with a crest length of 960 feet, it provided its present storage capacity of 6.19 billion gallons of water (19,000 acre feet).

The San Andreas Fault passes under the eastern abutment of the dam and although there was an eight-foot shearing movement along the rift during the 1906 earthquake, there was no damage to the dam.

There are three outlets from San Andreas. The oldest, south outlet was plugged with 50 feet of concrete in 1983 to eliminate any possibility of a destructive, uncontrolled flow in the event of a severe earthquake or other

disaster. North and center outlets serve as raw water sources for the Harry W. Tracy Water Treatment Plant pump station, which boosts the water to the plant. The plant serves the 54-inch San Andreas Pipeline No. 2 and/or the 66-inch San Andreas Pipeline No. 3, which feed Sunset and Merced Manor Reservoirs in San Francisco. High-pressure water can also be carried to the Sunset Supply Line.

The Harry W. Tracy Water Treatment Plant is the main supply source for the Peninsula communities situated at the higher elevations and northwest of the plant. Water from this high zone can be added to the low zone supplies through the pressure reducing valves at Capuchino Valve Lot.

STONE DAM

Immediately after San Andreas started service as an impounding reservoir for San Francisco, Schussler developed water on the western side of Montara Mountain. The 1,650 acre watershed gives rise to Pilarcitos, Lock's, Apanolio and Corinda Los Trancos Creeks, all emptying into the Pacific Ocean at Half

Moon Bay. The diversion planned to use gravity flow and make the creeks tributary to San Andreas Reservoir.

Development began in June 1870, and Lock's Creek Tunnel, now Stone Dam Tunnel No. 1, was drifted from Pilarcitos Creek through Cahill Ridge to San Mateo Creek. Flumes were constructed from Lock's, Apanolio and Corinda Los Trancos Creeks to the tunnel. The Lock's Creek Line was the result, and instead of flowing to the ocean, the water from these creeks was diverted to San Andreas Reservoir, about fifteen miles northeast.

Pilarcitos Creek rises on the eastern side of Montara Mountain and flows through a narrow gap in the range to the west. Upper Pilarcitos Creek is intercepted by Pilarcitos Dam, but the watershed below the dam is also extremely productive.

To exploit this lower watershed, the Stone Dam diversion was placed in the deep narrow canyon about two miles south of Pilarcitos Dam. In 1871, a flume 4,500 feet long was built south from the dam to carry the lower Pilarcitos water to Lock's Creek Tunnel, where it was added to the flow to San Andreas Reservoir.

Stone Dam is constructed of rubble masonry, granite blocks quarried below the dam site, and topped with a brick coping, laid herring-bone fashion. It is a thin-arch dam, the pioneer example of this construction method. The small reservoir has a capacity of five million gallons (15.4 acre feet).

The Lock's Creek development produced two million gallons of water per day. Its use was discontinued in 1898, but the Stone Dam diversion remains in use today.

Lower Pilarcitos Creek's flow is now diverted through the Stone Dam tunnel and concrete pipes into San Mateo Creek and Lower Crystal Springs Reservoir. The Coastside County Water District, which serves Half Moon Bay and other seaside communities, takes delivery of up to 2.5 million gallons per day of raw water supplies from Pilarcitos Reservoir by gravity.



Workers drill Lock's Creek Tunnel 1870



Lower Crystal Springs Dam under construction 1887

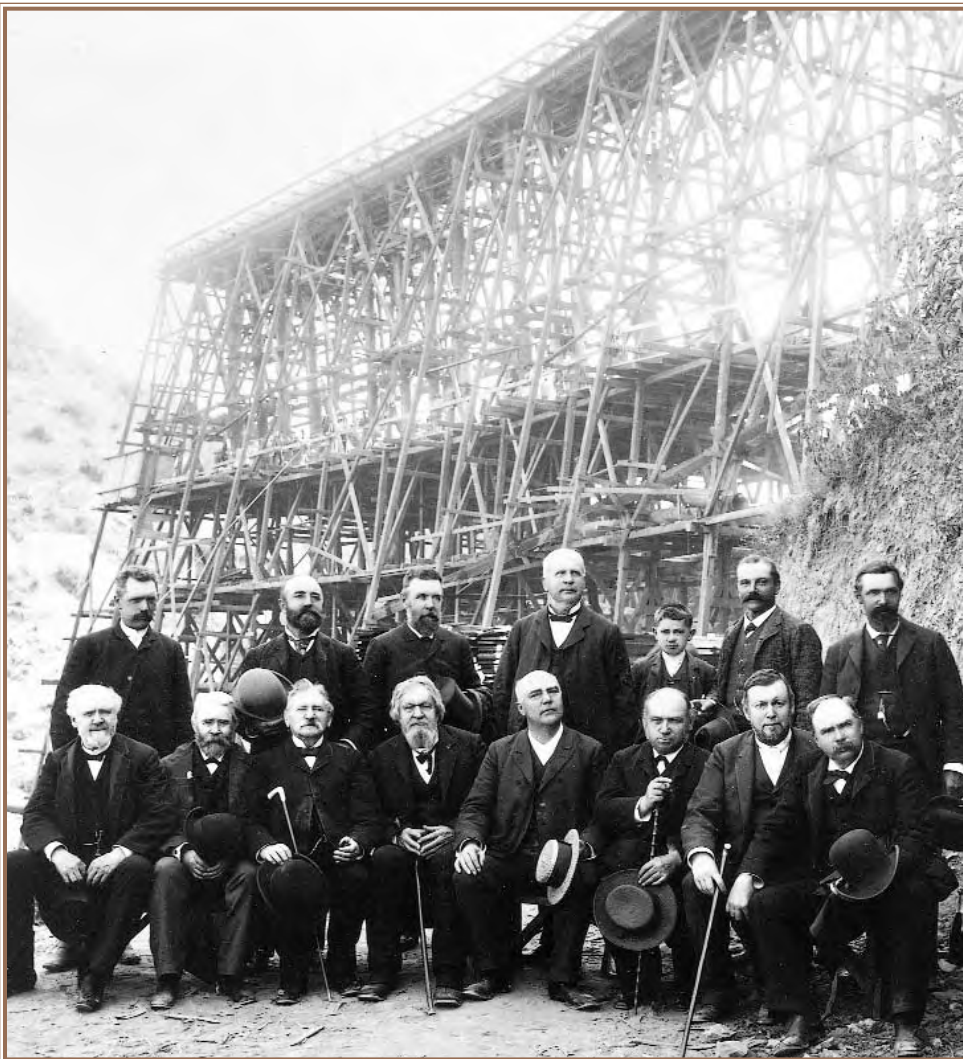
UPPER CRYSTAL SPRINGS DAM AND RESERVOIR

Built in 1876 of earth with a puddled-clay core, Upper Crystal Springs Dam is 520 feet long and 70 feet high, separating the upper and lower Crystal Springs lakes three miles from the southern end. Since 1923, the dam has supported the roadbed for the state highway to Half Moon Bay.

The first outlet for Upper Crystal Springs Reservoir was a brick-lined, horseshoe-shaped tunnel, six feet high, five-and-a-half feet wide and 775 feet long on the east side of the dam. A 90-foot-deep, brick-lined shaft at mid-tunnel gave access to a 42-inch regulating gate to control water from the reservoir.

In 1885, a 42-inch pipe was laid in the tunnel from the regulating gate beyond

the outside portal of the outlet tunnel. To keep its crest above the water and accommodate the relocated stage roadbed to Spanish Town (Half Moon Bay), Upper Crystal Springs Dam was raised in 1891 by an earth fill. The original outlet tunnel was broken during the 1906 earthquake, some 20 feet of the line fractured by a lateral earth movement of five-and-a-half feet. The earthquake damage was ultimately repaired and on August 28, 1924, the original tunnel was restored to provide free, unregulated flow between the Upper and Lower Crystal Springs Reservoirs.



Spring Valley Water Company Directors 1890

LOWER CRYSTAL SPRINGS DAM AND RESERVOIR

The newer Lower Crystal Springs Dam, on San Mateo Creek below the junction of its main branches, was built by Schussler in 1888. It was raised a few feet in 1890, and again in 1911 to its present height of 154 feet. It is 176 feet wide at the base and 600 feet long at the crest. A full gravity type, the arched dam is built up of interlocking concrete blocks formed and poured in place. The design permits a future increase in height of 45 feet. Two outlet towers were constructed near the dam, one in 1891 and the other 40 years later. Although the fault line of the San Andreas Rift is only 400 feet west of the site, the concrete dam showed no damage from the 1906 earthquake or the 1989 Loma Prieta quake.

With a 35-square-mile catchment area, Lower Crystal Springs Dam impounds 22.6 billion gallons of water (69,380 acre feet), forming a lake nine miles long, one mile wide at its widest and about 122 feet deep at its deepest. The lake has a surface area of 1,492 acres

and covers portions of the early Spanish grant *ranchos* of Cañada de Raymundo, de las Pulgas, Feliz and San Mateo.

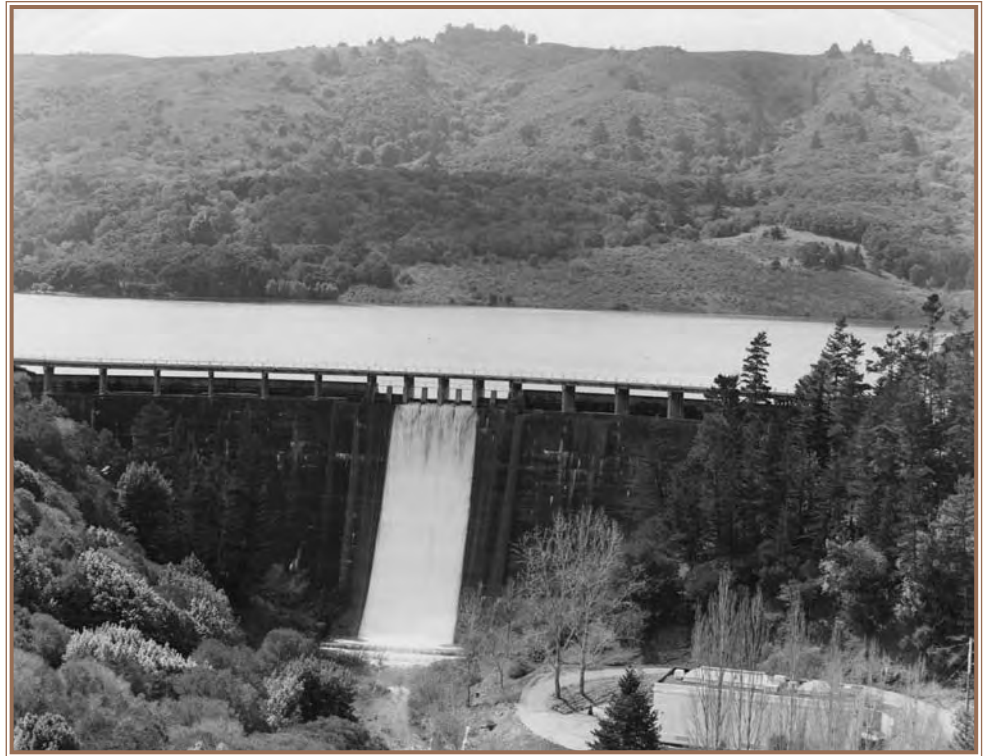
Lower Crystal Springs Reservoir was celebrated in October 1934 as the final destination of San Francisco's water supplies from Hetch Hetchy Reservoir, which traveled more than 160 miles across California from its source in the Sierra Nevada to the Peninsula. Still today, the reservoir impounds Hetch Hetchy water supplies intended for future delivery to Peninsula and San Francisco customers.

In 1976, the American Society of Civil Engineers designated Lower Crystal Springs Dam as a California Historic Civil Engineering landmark. During its construction, Hermann Schussler invented a number of construction techniques used to this day, such as washing aggregate, machine mixing of concrete, roughening existing surfaces to ensure adhesion, curing by covering and wetting, and staggered joints. Spring Valley installed a bronze plaque at the dam commemorating Schussler, by translating and inscribing the epitaph of Sir Christopher Wren in Saint Paul's Cathedral in London, "*Si Monumentum Requiris, Circumspice*" ("If you seek his monument, look about you").

Fred C. Herrman was appointed the chief engineer of Spring Valley in 1911. He relinquished the position in 1914, engaging in general practice as a consulting engineer and rendering valuable service to Spring Valley during the Rate Case of 1915-1917.

George A. Elliott was appointed the chief engineer in 1914. He remained in that position until the municipal takeover of Spring Valley by San Francisco on March 3, 1930.

In 1967, the State of California was planning to lay a 4.2-mile section of the Junipero Serra Freeway (I-280), then under construction, along the shore of Crystal Springs Lake. San Francisco invoked a federal law, and obtained assistance from the U.S. Department of Interior, which has a voice in the use of federal highway funds, to force the relocation of the freeway to its current alignment along



Lower Crystal Springs Dam with Crystal Springs Pump Station at its base 1938

the crest of Pulgas Ridge. In spite of its relocation, the freeway offers some of the most beautiful views of California's coastal woodlands on the West Coast.

CRYSTAL SPRINGS PUMP STATION

Crystal Springs Pump Station lies at the foot of Lower Crystal Springs Dam. Built in the late 1880s together with the dam and its outlet works, the pump station was designed to boost Crystal Springs water at low reservoir levels to the higher grade line of San Andreas Reservoir and for delivery to University Mound Reservoir in southeastern San Francisco. Originally rated at 25 million gallons per day, the pump station was upgraded in 1933 and 1949 to pump a maximum of 70 million gallons per day to San Andreas Reservoir.

SUNOL FILTER BEDS AND PLEASANTON WELL FIELD

Along with its development of water sources on the San Francisco Peninsula, the Spring Valley Water Works turned its attention to water sources across the bay in Alameda County. Land was bought in Calaveras

Valley, fed by streams from Mount Hamilton. Spring Valley also acquired the Vallejo Mills properties near Niles, consisting of a dam, brick flume and mill constructed in the 1840s by Don Jose de Jesus Vallejo, a brother of General Mariano Guadalupe Vallejo. These properties afforded excellent locations for new reservoirs to serve the increasing demands of Spring Valley Water Work's customers.

Sunol Valley is a gravel-filled depression of about 1,300 acres at the upper entrance to Niles Canyon in Alameda County. The entire Alameda Creek drainage of some 630 square miles flows through this area and is restrained at the canyon entrance. The Filter Beds were completed along with the Sunol Aqueduct in 1900. Sunol Dam, a concrete structure 31 feet high, backs up the creek drainage to saturate the gravel beds. The groundwater percolating through the gravel beds is collected through a concrete tunnel, or filter gallery, 8,985 feet long, pierced with screened brass pipes and tapped by 38-inch perforated concrete pipes. Dependable yield is five million gallons daily, but under flood conditions, the galleries will produce up to 20 million gallons of water per day.



Sunol Filter Galleries 1906

Some years after the Hetch Hetchy Aqueduct was completed, in 1948 San Francisco placed Irvington Pump Station in service. The pump station was designed to transport water under pressure from the Sunol Aqueduct to Hetch Hetchy's Bay Division pipelines, but is no longer in service. Sunol Valley groundwater is still collected and may be pumped to San Antonio Reservoir or the Sunol Valley Water Treatment Plant.

Spring Valley held extensive artesian lands in the Livermore Valley, a natural basin tapped by 100 wells into the deep gravel bed, which ranges in depth from 200 to 750 feet. Spring Valley's Chief Engineer Schussler decided that these gravel beds, like those of Sunol Valley, were good water sources. He started drilling the wells in 1898. In 1909, a 30-inch pipe was installed to transmit the water from Pleasanton to Sunol.

Spring Valley's water exports from the Pleasanton Well Field later drew the water table of the Livermore Valley to an undesirable low level, affecting the rights of other overlying landowners in the valley. Since 1949, the San Francisco Water Department has stopped exporting groundwater from the valley. But the water is still

pumped for local use by the City of Pleasanton and Alameda County Water Conservation and Flood Control District, Zone 7.

SUNOL WATER TEMPLE

The Spring Valley Water Company built the Sunol Water Temple in 1910 to mark the confluence of its three East Bay water sources - Alameda Creek, the Sunol filter galleries and Pleasanton artesian well field. Designed by renowned San Francisco architect Willis

Polk, the temple is an elegant, circular pavilion of twelve fluted columns surmounted by a peaked clay tile roof and copper finial of three dolphins tail to tail. It is modeled after the Temple of Vesta in Tivoli Gardens, built in the 2nd century B.C. atop a cascade of waters from the Apennine Mountains captured from afar and sent via aqueduct to supply the homes and bathhouses of ancient Rome. The temple frieze quotes Isaiah 41:18: "I will make the wilderness a pool of water and the dry lands springs of water. The streams whereof shall make glad the city."

Seriously damaged in the Loma Prieta earthquake of 1989, Sunol Water Temple was beautifully restored in 2001 with support from an active community organization, Save Our Sunol. The restoration won the prestigious 2001 Preservation Design Award from the California Preservation Foundation.

CASTLEWOOD WELLS

Castlewood, a small town just south of Pleasanton in the East Bay, receives a free water supply of 90 million gallons per day in perpetuity from San Francisco, under an agreement reached in the 1890s with Phoebe Apperson Hearst. Phoebe's late husband George Hearst, a prominent local businessman, owned major interests in the Comstock, Homestake and Anaconda mines, the



Sunol Water Temple

largest silver and copper mines in America's history, as well as one of San Francisco's hometown newspapers, the *Examiner*. Castlewood continued to receive water from groundwater wells in the fertile valley.

CALAVERAS DAM AND RESERVOIR

In 1877, San Franciscans were still uneasy and questioning the adequacy of their water supply. Despite the increasing volumes of water being brought into the city by Spring Valley Water Works, there never was really enough, and memories were fresh of the numerous fires that had devastated the young city. The Board of Supervisors frequently used water rates, which they controlled, as election issues. Spring Valley owners, questioning the adequacy of these rates, showed reluctance to invest capital in developing additional water sources. San Franciscans again started talking about building their own water system.

A special study committee, headed by City Engineer T. R. Scowden, recommended on April 19, 1875 that San Francisco buy a reservoir site on the border of Alameda and Santa Clara Counties, as the beginning of a future municipal water supply. The city was unable to act quickly and Spring Valley effectively blocked this threat of competition by promptly purchasing the land and water rights for itself.

The site is well situated to impound water from a number of streams flowing down the gorges of the Coast Range into Alameda Creek and the Sunol Valley. Two of these streams, Smith and Isabel Creeks, after circling Mount Hamilton, unite to form the Arroyo Hondo which flows through Calaveras Valley.

Construction of the hydraulic fill dam did not start for another 38 years, until 1913. At that point, the Spring Valley Water Company had purchased the Spring Valley Water Works. A series of misfortunes and engineering errors culminated in a failure of the partially completed dam on March 24, 1918, when the upstream face of the dam



Calaveras Dam and outlet tower 1926

sloughed off and the water gate tower collapsed. The engineering diagnosis was that the hydraulic fill had been improperly compacted, leaving voids in the center of the dam. San Francisco City Engineer Michael O'Shaughnessy, foreseeing San Francisco's future purchase of Spring Valley's assets, turned his attention to the Calaveras construction. Unofficially, he kept "a watchful eye on this proposition so that the city will not inherit a 'gold brick' if it should take this property over."

The dam was completed in 1925. At 230 feet high at the crest, it was the highest earth-fill dam in the world, impounding 31.55 billion gallons (96,860 acre feet). The lower portion is built up by hydraulic fill method and the upper part with a rolled clay core supported on either side by loosely dumped material containing a large proportion of rock. The dam is 1,200 feet long and 1,500 feet wide at the base. The dam was strengthened in 1975 to meet then current earthquake standards -- a \$1.6 million project of the 1972 water bond program.

The first significant East Bay addition to San Francisco's local water supply system, Calaveras Reservoir has a watershed area of 101 square miles flowing into Calaveras Creek and Arroyo Hondo, and 35 square miles flowing into Upper Alameda Creek, for a total of 136 square miles.

In 1925, water from Calaveras Reservoir was delivered to neighboring customers via a network of distribution pipelines, and to San Francisco through the Niles Canyon Aqueduct and submarine pipelines under San Francisco Bay to Spring Valley Water Company's Peninsula transmission system. Since 1966, Calaveras Reservoir water is filtered at the Sunol Valley Water Treatment Plant prior to entering the Hetch Hetchy Aqueduct at the Alameda Siphons.

In 1931, the Upper Alameda Creek Diversion Tunnel was completed from Upper Alameda Creek to Calaveras Reservoir, as planned by the Spring Valley Water Company. The tunnel increased available watershed supplies to fill Calaveras Reservoir.

In 2001, the San Francisco Public Utilities Commission initiated a study of the seismic safety of Calaveras Dam, given increasing industry-wide concerns about the fitness of hydraulic fill dams and the dam's proximity to the Calaveras Fault. Calaveras Reservoir water levels have been lowered to protect the dam at the direction of the California Department of Safety of Dams, and a reconstruction project is under way to replace it.



*San Francisco purchases Spring Valley Water Company, City Hall 1930
(Michael O'Shaughnessy at far left)*

Municipal efforts to buy out the Spring Valley Water Company had been a source of constant controversy from as early as 1873, when San Francisco's first attempt to purchase it was turned down by the voters because the price was too high. The voters usually found the sale price offered by Spring Valley to be higher than they were willing to pay.

PURCHASE OF SPRING VALLEY WATER COMPANY

A half-century of farsighted leadership by a succession of mayors and engineers finally paid off on March 3, 1930, when San Francisco purchased the Spring Valley Water Company for \$39,962,606.51, creating the San Francisco Water Department under the Board of Public Works. Nelson A. Eckart, Hetch Hetchy Chief Assistant Engineer under City Engineer O'Shaughnessy, was named the first General Manager and Chief Engineer of the newly acquired waterworks.

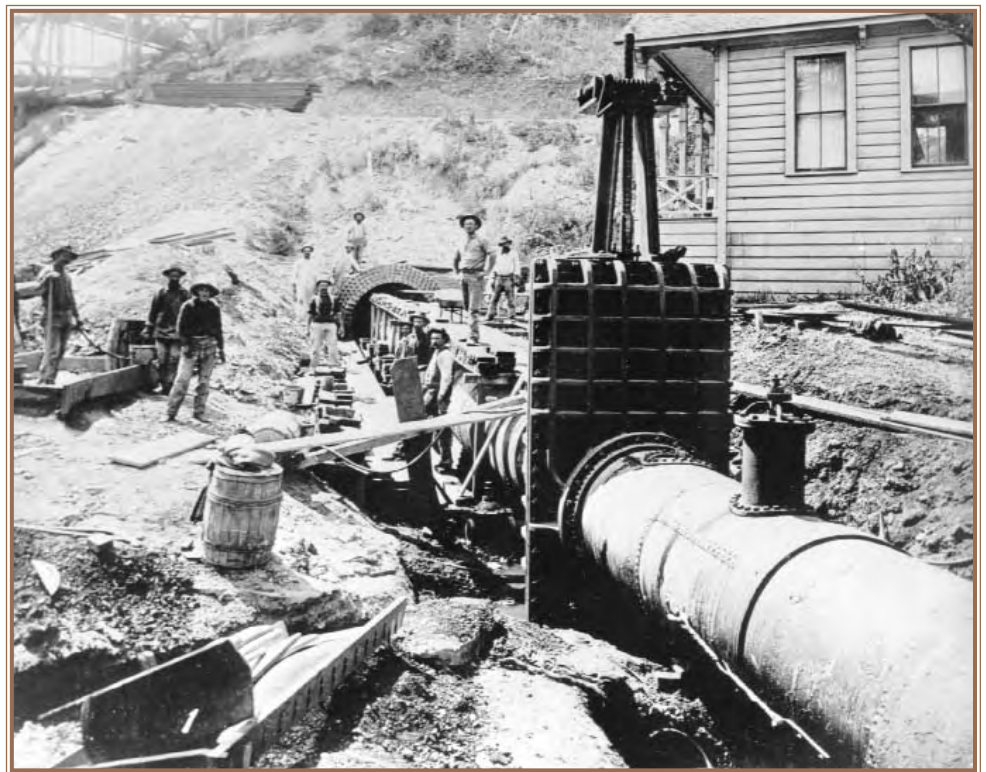
At the time of the takeover, the Spring Valley Water Company's assets were considerable, including Pilarcitos, San Andreas and Crystal Springs Dams and Reservoirs on the Peninsula; Calaveras Dam and Reservoir, Sunol Filter Galleries and Pleasanton Well Fields in the Sunol Valley, Niles Canyon Aqueduct, transmission pipelines, pump stations and tunnels in the South Bay and Peninsula, as well as the reservoirs, pump stations and distribu-

tion pipelines that served the City of San Francisco. Spring Valley also turned over their riparian water rights and rights-of-way necessary to protect, divert and use their water supplies and facilities. In 1934, the Hetch Hetchy Aqueduct was completed and Sierra Nevada mountain water supplies were available to integrate with the San Francisco's lately - acquired municipal water system.

TURNER DAM AND SAN ANTONIO RESERVOIR

The latest addition to the Alameda Division's water supply, Turner Dam and San Antonio Reservoir, was completed by the San Francisco Water Department in 1965 at a cost of \$9.4 million, which included the dam, outlet works, spillway and related equipment and accessories. The dam is named for James H. Turner, former General Manager and Chief Engineer of Hetch Hetchy, and former General Manager of Public Utilities for San Francisco.

Originally sited by the Spring Valley Water Works in 1875 and mentioned in the 1912 Freeman Report to provide storage adjacent to the Hetch Hetchy Aqueduct, the reservoir is situated on La Costa (San Antonio) Creek, a tributary of Alameda Creek about three miles southeast of Sunol. The reservoir impounds 16.5 billion gallons of water (50,650 acre feet), the runoff from a 40-square mile watershed yielding over 1.7 billion gallons of water annually. Additionally, the reservoir can provide storage for water from Hetch Hetchy and other sources to meet high period-



Lower Crystal Springs Dam outlet works under construction 1888

ic demands in the South Bay Area and assure water service during possible interruptions of Hetch Hetchy supply.

Turner Dam is a compacted, earth-fill structure 195 feet high, 2,160 feet long and 1,075 feet wide at the base. As with Calaveras supplies, water from San Antonio Reservoir is sent to the Sunol Valley Water Treatment Plant for filtration before entering the Hetch Hetchy Aqueduct at the Alameda Creek siphons.

CITY DISTRIBUTION SYSTEM

Having its origins in the first pipelines laid in 1857 by the San Francisco City Water Works (Bensley Company) from the Lombard and Francisco Reservoirs, and in the early system George Ensign installed at Spring Valley in 1858, San Francisco's complete water distribution system has grown over the past 125 years into a dozen reservoirs and auxiliary tanks at various elevations, pumping stations, and an amazing network of 1,191 miles of pipeline of various diameters all tucked out of view under the city streets.

Built on hills, San Francisco's geography ranges in elevation from sea level to 900 feet. Totally urbanized with homes at the highest elevations, the hills posed challenges and complicated hydraulic situations for water engineers. Their genius created a series of different pressure districts, which incorporate the oldest water works, reservoirs and pipelines with the newest additions and improvements into a modern, efficient, and integrated water distribution service.

Local water produced from Bay Area sources together with Hetch Hetchy water from the High Sierra is delivered into the City, mostly by gravity flow, through four Peninsula transmission mains: San Andreas No. 2, Crystal Springs No. 2, Sunset Supply Line, and Baden-Merced, each discharging into one or more of three terminal distribution reservoirs. From these reservoirs, the water is gravity fed or pumped into eight covered distribution reservoirs, at elevations of 135 to 800 feet, and smaller storage tanks, strategically sited



Black Point Flume and Pump Station, Lombard St. Hill circa 1900

at elevations of 370 to 900 feet. The individual pressure districts being served vary greatly in area and can usually be supplied by more than one of these sources.

San Francisco's municipal storage reservoirs can hold at capacity nearly 416 million gallons, about a five-day supply for the city. In addition, there is an emergency supply immediately available within the city at Lake Merced and Laguna Honda which together hold 2.6 billion gallons. In order of their size, the reservoirs are ranked by their capacities in millions of gallons:

| | |
|--------------------|---------|
| Lake Merced* | 2,565.0 |
| Sunset** | 176.7 |
| University Mound** | 140.9 |
| Laguna Honda* | 44.0 |
| Sutro | 31.4 |
| College Hill | 14.1 |
| Summit | 14.0 |
| Stanford Heights | 12.9 |
| Merced Manor** | 9.5 |
| McLaren Park Tanks | 8.0 |
| Lombard | 6.0 |
| Hunter's Point | 1.1 |
| Potrero | 1.0 |

* Emergency supply

** Terminal reservoirs for regional water supplies, shared in emergencies by San Francisco and its suburban wholesale water customers in the Bay Area Water Supply and Conservation Agency.

Due to its age and deteriorating condition, Lombard Reservoir was recently replaced with a larger reservoir, now filled with other sources of water from San Francisco's water system.

Francisco Reservoir, built before the Civil War with a capacity of 2.5 million gallons, is no longer in service.

The underground transmission and distribution mains, ranging in size from two inches to 60 inches in diameter are maintained and operated by the City Distribution Division. Water delivery is monitored to 170,000 services, some of which require as many as a dozen water meters. Along with the ongoing program of repair and annual replacement of nearly 10 miles of deteriorated pipes, worn meters are replaced at the rate of some 6,800 per year.



San Andreas Reservoir (foreground) looking east to San Francisco Bay

San Francisco water supply is kept clean and clear, even during times of heavy rainfall and ground erosion, because a great deal of effort is expended throughout the water supply system by skilled water quality professionals. Housed in modern facilities and laboratories in Millbrae and Burlingame, Water Quality Bureau staff monitor and control water quality and treatment to meet increasingly stringent state and federal requirements and regular monitoring by the California Department of Health Services.

San Francisco's water quality goals and standards are high - no water-borne disease has ever been traced to its local Bay Area or Hetch Hetchy supplies.

San Francisco protects its water sources from pollution. Hetch Hetchy sources in the Sierra Nevada were originally relatively secure from sources of contamination. However, increased recreational use of the watersheds by equestrians, hikers and backpackers now require strict sanitary controls to be enforced throughout these areas.

The system-wide sampling and testing responsibilities of the Water Quality Bureau range from Hetch Hetchy's highest elevations to the complexities of the City Distribution System. Water Quality staff operate stations along the aqueduct and distribution lines for lime treatment, fluoridation and chloramination. At the Rock River Treatment Plant, calcium oxide (CaO) is added to the

Hetch Hetchy water. The calcium oxide is slaked by water to form calcium hydroxide (Ca(OH)₂), resulting in water more alkaline on the pH scale to inhibit its corrosive action on pipelines, storage tanks and household plumbing.

Waters delivered to San Francisco and consumers north of Crystal Springs have been fluoridated since 1952, in accordance with a program mandated by the voters in 1951. Fluoridation results in a significant reduction in the incidence of dental decay for San Francisco children. Construction of a new fluoridation facility in the East Bay is under way to provide system-wide fluoridation by the end of 2005.

ENVIRONMENTAL STEWARDSHIP AND WATERSHED PROTECTION

A watershed is a basin bound by ridges, such as hills or mountains, that collects rainfall and snowmelt flowing downhill in the streams, rivers and lakes in the valley below. Watersheds create links between everything that lives or lies within them. What happens upstream affects the quality of the natural environment of the plants, animals and people that live downstream, and the health of the watershed influences the quality of the water that is eventually collected for drinking water.

San Francisco protects the natural resources entrusted to its care, and continuously monitors the health and condition of its watersheds to ensure high source water quality and preserve

valuable habitat for the creatures who live there. Watershed protection includes managing land use; monitoring rare and endangered species of plants, animals, birds and fish; controlling erosion; preventing wild fires; and providing public access that protects environmental values while providing recreation opportunities for respite from urbanization.

In the San Francisco Bay Area, there are two watersheds that contribute to the total water supply of the system: the Peninsula and Alameda Creek Watersheds. The Peninsula Watershed encompasses 23,000 acres surrounding three drinking water storage reservoirs, Crystal Springs, San Andreas and Pilarcitos. A unique natural resource located adjacent to the highly urbanized communities of San Mateo County, the watershed hosts a variety of habitats and supports the highest concentration of rare, threatened and endangered species in the entire nine-county region. The Peninsula Watershed is part of the Central California Coastal Biosphere Reserve and has been designated by California as a Fish and Game Refuge.

The Spring Valley Water Company purchased the lands, farms and woodlands surrounding likely reservoir sites on the San Francisco Bay Peninsula in the late 1800's, ensuring a secure water supply for San Francisco and preserving valuable natural resources for the future. San Francisco's purchase of Spring Valley's assets in 1930 entrusted

the city with the future care and protection of this watershed.

In 1969, easement agreements were made between the federal and state governments and with San Francisco and San Mateo County to preserve the Peninsula Watershed for water supply and open space purposes. The agreements limit the uses of 19,000 acres, including Upper and Lower Crystal Springs Reservoirs, San Andreas Lake and watershed lands east of Montara Mountain for purposes of water supply and ecological preservation. A scenic and recreational easement covers the 4,000 acres in the southeast section between the lakes and Pulgas Ridge. The Golden Gate National Recreation Area administers these easements for the federal government. The watershed had been protected from public access until recently, when a 10-mile stretch of trail along the ridgeline was opened to hikers, cyclists and equestrians for guided tours.

In contrast, San Francisco owns only one-third, or 36,000 acres, of the southern Alameda Creek Watershed. This watershed consists of rolling grasslands and native oak woodlands in the East Bay. Like the Peninsula Watershed, it has been protected since the mid-1800s. However, it has been leased for grazing, nursery and quarry operations. The drainage area of this watershed is far greater than the area San Francisco owns, so the city has less control over the quality of the water in the streams and creeks that feed Calaveras and San Antonio Reservoirs. Here, land uses, urban encroachment, recreation and other activities could adversely affect water quality. But Alameda County planners have joined with the lovers of open space to maintain a wilderness environment close to major population areas that also serves as a nesting habitat for golden eagles in Alameda County.

Within the highly urbanized neighborhoods of San Francisco, some water system facilities provide recreational opportunities to city dwellers. Reservoir roofs and other properties provide public facilities operated by the San Francisco Recreation and Park Commission, including tennis courts,

parks, playgrounds, golf courses and neighborhood green space. The award-winning demonstration Garden for the Environment at Seventh Avenue at Lawton was developed in 1991 in cooperation with the San Francisco League of Urban Gardeners, the City Recycling Program, the Recreation and Park Department and many other civic groups, to provide hands-on workshops on low-water-use landscaping.

In the Sierra Nevada, San Francisco's preservation and maintenance of hiking trails in the Hetch Hetchy watershed have resulted in thousands of backpackers and hikers preferring the scenic Grand Canyon of the Tuolumne to the overdeveloped and overcrowded Yosemite Valley. The city also funds National Park Service backcountry patrols and educational programs to minimize human impacts on the fragile wilderness.

Because of its effective watershed management policies in the Sierra Nevada and responsible recreational use in its watershed, San Francisco's Hetch Hetchy water supply is exempt from filtration requirements set by the U. S. Environmental Protection Agency and the California Department of Health Services.

San Francisco's environmental stewardship not only protects the high quality of its drinking water sources in both the Sierra Nevada and the Bay Area,

but also preserves areas rich in natural aesthetics and biodiversity for the benefit of travelers, leisure recreationists, educators, scientists and environmentalists. The character of these areas are a treasured heritage for future generations to enjoy.

SUNOL VALLEY WATER TREATMENT PLANT

Activated at its dedication on September 14, 1966 by Mayor John F. Shelley, Governor Edmund G. "Pat" Brown and Interior Secretary Stewart Udall, the Sunol Valley Water Treatment Plant was San Francisco's first filtration installation resulting from the nation's drive for clean water.

Constructed at a final cost of \$10.5 million, the plant filters water from Calaveras Reservoir, five miles to the south, San Antonio Reservoir to the north, and the nearby Sunol underground sources. It has the added capability of filtering up to 80 million gallons per day (MGD) from the Hetch Hetchy Aqueduct. The plant's original design capacity of 80 MGD was expanded in 1976 to 160 MGD.

The filtration plant was financed from water rate revenues that serviced the \$115 million bond issue approved by San Francisco voters in 1961.

Using \$47 million in revenue bond funds approved by San Francisco vot-



Sunol Valley Water Treatment Plant



Harry W. Tracy Water Treatment Plant aerial view

ers in 1984, the Sunol Plant was upgraded in 2002 to include new state-of-the-art sedimentation and back-wash water systems, chemical feed systems and water quality laboratory facilities, seismic upgrades and renovated building systems. There are plans for future upgrades to provide treated water storage, install pre-treatment disinfection facilities, and expand the capacity of the plant.

The old Calaveras Pipeline from the reservoir to the treatment plant was replaced in 1991 along a similar alignment.

HARRY W. TRACY WATER TREATMENT PLANT

The Harry W. Tracy Water Treatment Plant is a key element in the Peninsula supply system, filtering water from San Andreas Reservoir for delivery to consumers on the San Francisco Peninsula. The plant, formerly known as the San Andreas Water Treatment Plant, was built at a cost of \$7.6 million, and started operation on August 8, 1972 with an original capacity of 80 MGD. The plant was expanded in 1992 to provide a combined treatment capacity of 160 MGD. The \$55 million improvements installed ozone pretreatment to provide more effective disinfection, and built new filtration units to meet Peninsula water needs through the year 2030.

In early 1994, the expanded plant was dedicated in a special ceremony and

renamed in honor of longtime Water Quality Manager Harry W. Tracy. Tracy was a lifelong employee, serving from 1937 until his death in 1985. As Water Quality Bureau Manager, he led the City's and water industry's efforts to prevent contamination of water supplies through watershed protection. Tracy also led efforts to certify water treatment plant operators to assure that water quality standards were met.

WATER TREATMENT PROCESSES

Water produced from San Francisco's local watersheds is treated by the Sunol and Tracy Plants with processes of pretreatment, flash-mixing, acid/base (pH) adjustment, coagulation, flocculation, sedimentation, filtration and final disinfection.

As water enters the plants, several chemicals essential to the treatment process are added in proportion to the flow and thoroughly flash-mixed. These chemicals include chloramine or ozone for disinfection, alum or polyelectrolyte for coagulation, liquid fluoride to aid in the control of tooth decay, and coagulant aids as necessary to assist in the flocculation process.

The alum or polyelectrolyte added in the flash-mixing forms a white mineral precipitate that coagulates into snowflake-like particles of silt, clay, bacteria and other foreign matter. Coagulant aids are added to assist the formation of strong, heavy flocculent

particles which settle out quickly during the sedimentation process.

Sedimentation basins accept water directly from the flocculation basins. The water remains in sedimentation for a couple of hours. This is where the flocculent particles settle to the bottom as sludge, carrying with them any impurities. The sludge is removed from the basins by a scraper and deposited into trenches. Sludge is directed to settling, or sludge, basins.

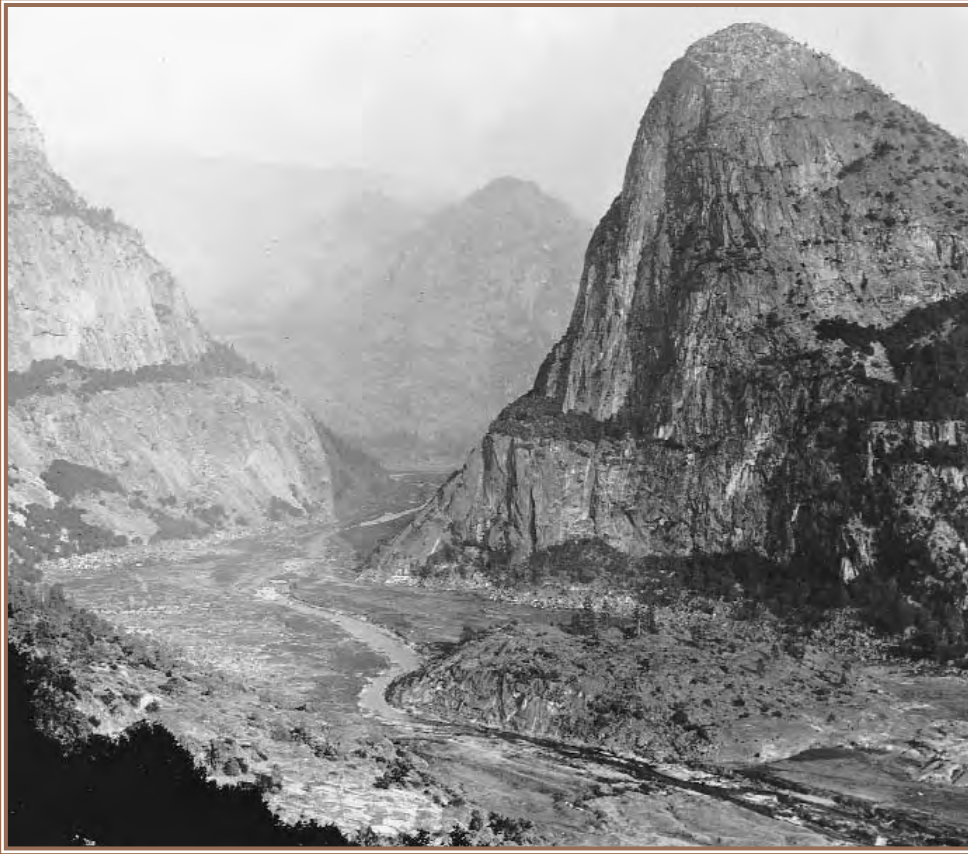
From the sedimentation basins, settled water moves to filters where it flows down through a bed of graded anthracite coal underlain by a bed of fine sand. The filters remove the last particles of sediment and foreign matter, producing a sparkling clear water free of turbidity and bacteria. Before they start to clog and lose efficiency, filters are automatically flushed clean of trapped material by back-washing with clean water.

The final step in the treatment process is a controlled dosage of chloramine just sufficient to ensure absolute safety of the water for home use. At the same time, caustic soda is added to make the water less corrosive to metal pipelines and home plumbing. Final chemical additions help to ensure the water will be delivered to home consumers with the same high quality it has when it leaves the filtration plant.

In 2004, San Francisco changed its residual disinfectant from chlorine to chloramine to reduce formation of disinfection byproducts, which may be harmful. New chloramination facilities were built at San Antonio Pump Station in Sunol and the Harry Tracy Plant to add chloramine before delivery to customers.

**SAN FRANCISCO
SEARCHES FOR WATER**





Hetch Hetchy Valley 1918

When A. W. von Schmidt left the Spring Valley Water Works in 1864, he went on to general civil engineering practice. His most notable achievement in San Francisco was the successful destruction of Blossom Rock, a navigation hazard in the Bay some one-half mile northeast of Pier 39. A later and lesser known enterprise was Schmidt's effort to tap the Sierra Nevada watersheds, not so much for San Francisco, although the city would have benefited from Schmidt's success, but rather to irrigate both the Nevada Desert and the California Central Valley. Achieving only limited success and later forming the Bay Cities Water Company to exploit the Sacramento and American Rivers, Schmidt blazed a trail to the Sierra Nevada for others who later looked to the mountains for San Francisco's water.

In May 1882, J.P. Dart, an engineer for the San Francisco and Tuolumne Water Company, proposed a route for bringing water from the Tuolumne River, upstream from Jacksonville, to San Francisco. In 1888, George M. Harris

pointed out the possibility of the Hetch Hetchy Valley and Tuolumne River water supply to Mayor E. P. Bond, offering to sell his rights to the entire length of the Tuolumne for \$220,000. John Henry Quinton, a Los Angeles engineer, investigated Hetch Hetchy and the Tuolumne, reporting to the U.S. Geological Survey in 1891. The U.S. Geological Survey Annual Report 1899-1900 included a study recommending Hetch Hetchy as an adequate water source for San Francisco.

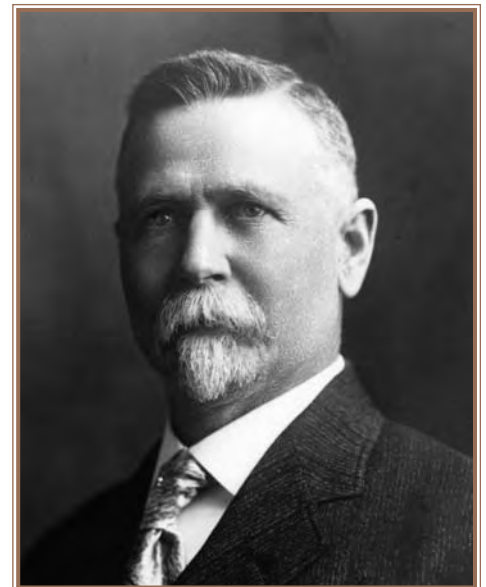
These were some of the numerous investigations and studies into additional sources of clean drinking water for San Francisco. Farsighted civic leaders began to realize that the only satisfactory solution to the problem was municipal ownership of assured water sources. However, the Spring Valley Water Company owned or controlled all local Bay Area water sources as far away as the Coast Range in Alameda County. The decision was made - San Francisco must look beyond the Coast Range for a future water supply, to the Sierra Nevada along California's eastern border.

For a city with a population of less than 350,000 at the time, supported by only a few scattered communities around the Bay, this was a tremendous challenge. From the city it is 50 miles across the Coast Range, another 50 miles across the San Joaquin Valley, and still another 50 miles through the foothills to the high Sierra Nevada, or just about 150 miles! The situation and task had to be met if the city and Bay Area were to continue to grow.

CARL GRUNSKY'S INVESTIGATION

Mayor James Phelan directed City Engineer Carl E. Grunsky to study 14 possible water sources during 1900 and 1901:

- Spring Valley Water Works
- San Joaquin River
- Lake Tahoe
- Clear Lake and Cache Creek
- Yuba River
- Stanislaus River
- Feather River
- Mokelumne River
- American River
- Tuolumne River
- Sacramento River
- Bay Shore Gravels
- Eel River
- Bay Cities Water Company



Carl Grunsky 1901



James D. Phelan 1901

Grunsky's investigation established the superiority of the Tuolumne River system in the Hetch Hetchy Valley for the following basic reasons:

- Quality of water
- Largest amount of water available
- Largest and finest reservoir sites
- Freedom from conflicting legal claims
- Hydroelectric power possibilities

Grunsky and Marsden Manson, who was later appointed City Engineer, shared Mayor Phelan's enthusiasm for Hetch Hetchy. They knew before the study was completed that the Tuolumne River had to be the answer to San Francisco's problem.

TUOLUMNE RIVER LOOKS PROMISING

The Tuolumne, with its source in a perpetual glacier on 13,000-foot high Mount Lyell, drains 652 square miles of watershed in rugged granite mountains sloping west from the Sierra Nevada crest. Over 90% of the watershed is at elevations above 6,000 feet. In an unsurpassed natural setting, the Tuolumne flows through the northern Stanislaus National Forest. The river emerges from the foothills into the valley near La Grange and merges with the north-flowing San Joaquin River some ten miles west of Modesto.

Having decided in 1901 that the best move for the city was to develop the Tuolumne River watershed, the Mayor and city engineers, remembering Spring Valley's preemptive move in the Calaveras Valley in 1875, quietly and quickly put up their own money to send engineer J. B. Lippincott into the Sierra Nevada for the necessary surveys.

On July 29, 1901, Mayor Phelan filed for water rights as a private citizen and on October 15, 1901, he applied for water rights and reservoir rights at Hetch Hetchy and Lake Eleanor. He assigned his interests to the city in 1903. Acting publicly in the city's name would have risked losing out to the private capital of speculators.

As Manson later put it, "If we had attempted an appropriation through the Board of Supervisors, the cat would have been out of the bag - so we paid the expense ourselves."

San Francisco's first application to develop Hetch Hetchy was denied by Interior Secretary E. A. Hitchcock on June 20, 1903, and the denial was reaffirmed on September 22. Hitchcock claimed the Interior Secretary had no authority to make the grant. It wasn't until 1906 that an earlier Attorney General's opinion came to light, advising the Interior Secretary that he did in fact have such authority.

In early 1906, some 1,200 land owners in the Modesto and Turlock Irrigation Districts, claiming they feared for their rights to the Tuolumne water, petitioned the San Francisco Board of Supervisors to abandon the Hetch Hetchy Project. The Board, controlled by Mayor Eugene E. Schmitz, who succeeded Mayor Phelan in 1902, promptly adopted resolution No. 6949 in February, formally abandoning Hetch Hetchy.



Wild and scenic Tuolumne River



Great Earthquake and Fire 1906

1906 GREAT EARTHQUAKE AND FIRE

The devastating earthquake of April 18, 1906, and the failure of the water system to curtail widespread destruction by three days of fire following the great shake, refocused San Francisco's attention on a secure, reliable water source.

After news of the great earthquake reached them, *Collier's Weekly* telegraphed Jack London, the most popular American writer of his time, to write an eyewitness account. London, who with his wife Charmian rode on horseback forty miles from their home in Glen Ellen to the city, described the scene vividly in his "Story of An Eyewitness" published on May 5, 1906, excerpted below.

Story of An Eyewitness

The earthquake shook down in San Francisco hundreds of thousands of dollars worth of walls and chimneys. But the conflagration that followed burned up hundreds of millions of dollars' worth of property. There is no estimating within hundreds of millions the actual damage wrought. Not in history has a modern imperial city been so completely destroyed. San Francisco is gone. Nothing remains of it but memories and a fringe of dwelling-houses on its outskirts. Its industrial section is wiped out. Its business section is wiped out. Its social and residential section is wiped out. The factories and warehouses, the great stores and newspaper buildings, the hotels and the palaces of the nabobs, are all gone. Remains only the fringe of dwelling

houses on the outskirts of what was once San Francisco.

Within an hour after the earthquake shook the smoke of San Francisco's burning was a lurid tower visible a hundred miles away. And for three days and nights this lurid tower swayed in the sky, reddening the sun, darkening the day, and filling the land with smoke.

On Wednesday morning at a quarter past five came the earthquake. A minute later the flames were leaping upward. In a dozen different quarters south of Market Street, in the working-class ghetto, and in the factories, fires started. There was no opposing the flames. There was no organization, no communication. All the cunning adjustments of a twentieth century city had been smashed by the earthquake. The streets were humped into ridges and

depressions, and piled with the debris of fallen walls. The steel rails were twisted into perpendicular and horizontal angles. The telephone and telegraph systems were disrupted. And the great water-mains had burst. All the shrewd contrivances and safeguards of man had been thrown out of gear by thirty seconds' twitching of the earth-crust...

At nine o'clock Wednesday evening I walked down through the very heart of the city. I walked through miles and miles of magnificent buildings and towering skyscrapers. Here was no fire. All was in perfect order. The police patrolled the streets. Every building had its watchman at the door. And yet it was doomed, all of it. There was no water. The dynamite was giving out. And at right angles two different conflagrations were sweeping down upon it...

On July 21, 1906, the Board of Supervisors received 11 new proposals for water sources. Mayor Schmitz appointed a panel of engineers on July 30 to study the proposals. When the panel resigned without making a recommendation, rumors were rife that the engineers would not put their stamp of approval on the one source that was apparently favored by the Schmitz administration.



Aftermath of Great Earthquake and Fire 1906

Recommendation or no, the Board of Supervisors Committee on Water Supply selected the Bay Cities Water Company proposal that the city buy its system for \$10.5 million. Afterward, the Board asked the city engineer to report on the Bay Cities property, which had its genesis in Schmidt's early investigations of the Sierra Nevada as a San Francisco water supply. Bay Cities depended on water from the south fork of the American River and the north fork of the Consumnes River.

This high-handed action was apparently the last straw for financier Rudolph Spreckels, *San Francisco Bulletin* editor Fremont Older, former Mayor Phelan and others. The Bay Cities deal was just another in a long series of corruptions, but it infuriated advocates of clean government and launched a series of investigations into graft and corruption, which came to trial in 1907 and 1908.

San Francisco's political boss, Abe Ruef, crony and benefactor to Mayor Schmitz, was sentenced to 14 years in the state penitentiary -- he actually served five years in San Quentin. Mayor Schmitz, who had been a violinist and president of the Musicians' Union when Ruef gave him the political nod and blessing as Mayoral candidate, was also convicted and sentenced to five years, but the Mayor's conviction was reversed in appellate court. Before resigning, 16 members of the Board of Supervisors testified for the prosecution.

Rebuilding from earthquake damage, investigations and trials delayed development of the city's Hetch Hetchy interests. Old, dim memories of the city in flames due to lack of water were now refreshed and brought into vivid, sharp focus.



Tuolumne River near its source

RENEWED INTEREST IN HETCH HETCHY

On April 22, 1908, Manson filed duplicates of the Phelan maps with Secretary Garfield, because the federal government had returned the originals in 1903 and they had been destroyed in the 1906 earthquake and fire. He signed these rights over to the city for one dollar.

During this time, the city again requested a permit from the Department of the Interior to build a water system in Yosemite National Park. In July 1907, hearings on the request were held in San Francisco before the Secretary of the Interior James Garfield. It was during these hearings and in briefs filed subsequently with Garfield, that the Modesto and Turlock Irrigation Districts agreed with the city of San Francisco that their share of the water would be

2,350 cubic feet per second, "off the top, before the water became San Francisco's supply."

With a convicted Mayor, the office devolved briefly upon Supervisor Charles Boxtton, one of the 16 who later resigned. Boxtton was followed in the Mayor's Office by Dr. Edward Robeson Taylor and Patrick Henry McCarthy. San Francisco was getting ready for James Rolph, Jr. to enter the scene in 1912.



Construction at O'Shaughnessy Dam (Michael O'Shaughnessy at far left) 1922

The long, hard fight to build a dam and related installations within Yosemite National Park was on. The Park was created by Congress on October 1, 1890, but at the time it did not include Yosemite Valley and Mariposa Grove.

Congress had given them to California for park and recreation uses in the 1864 Yosemite and Big Tree Grants signed by President Lincoln. In 1906, the State ceded these properties back to the federal government and they were added to Yosemite.

On May 11, 1908, after deliberating for ten months following the July 1906 hearings, Interior Secretary Garfield granted limited permission for reservoirs, dams, aqueducts and rights-of-way, with primary rights at Lake Eleanor and secondary rights at Hetch Hetchy. The Taylor Board of Supervisors accepted the Garfield Permit and a \$600,000 bond issue was approved on the June 4, 1908 ballot to purchase lands in and around Lake Eleanor and Hetch Hetchy Valley. San Francisco voters gave a 20 to 1 majority in 1910 to a \$45 million bond issue to start construction of the Hetch Hetchy system.

The troubles began anew. Opposition cropped up from four major sources: the private Spring Valley Water Company, the Turlock and Modesto Irrigation Districts, the National Park Service supported by vocal environmentalists, and the power promoters, including Sierra Ditch and Water Company, who had competing water rights claims in the Lake Eleanor basin and additional claims in the Cherry Creek basin.

A new Interior Secretary, Richard A. Ballinger, took office in Washington. On February 25, 1910, he issued San Francisco an order to show cause why the section of the Garfield Permit applying to Hetch Hetchy Valley should not be revoked. This would have left the city with development rights only in the Cherry Creek Canyon and Eleanor Creek areas, clearly insufficient for San Francisco's needs.

Secretary Ballinger held hearings to discuss his show-cause order and it was from these hearings that the Board of Army Engineers was born. On May 10, 1910, Secretary Ballinger requested that the War Secretary appoint a Board of Army Engineers to evaluate the Hetch Hetchy proposal. The Board was also asked to compare the Hetch

Hetchy idea to a number of alternatives. In 1910 and 1912, the city negotiated for the purchase of the Sierra Ditch and Water Company's holdings in the Tuolumne Basin, and between 1908 and 1911, San Francisco filed for additional water rights in the Tuolumne Basin.

JOHN R. FREEMAN'S PLAN FOR HETCH HETCHY

During this period, the city hired John Ripley Freeman, a world-famous hydraulics engineer from Providence, Rhode Island, who was later to become an engineer for the New York Board of Water Supply. In 1912, he published a preliminary design for the Hetch Hetchy system, the Freeman Plan, which the Board of Army Engineers considered along with reports on alternative water supplies.

The eventual report of the Board on February 19, 1913 supported the Freeman Plan and San Francisco's contention that Hetch Hetchy Valley and Reservoir be retained in the permit, largely because the alternative would have been much more expensive and required the city to acquire water rights in other basins. But it was now clear to



John Ripley Freeman 1922

all that a permit from the Secretary of the Interior would forever be subject to the whims of succeeding administrations. The only reasonable relief available to the city would be an outright grant of the necessary privileges from the Congress itself - enactment of a Hetch Hetchy grant act.

THE RAKER ACT

Representative John Edward Raker of Manteca fired the first shot in Congress by introducing HR 112 on the floor of the House of Representatives on April 7, 1913. That bill would not be passed by the House, nor would the three compromise bills following: HR 4319 on April 25, HR 6281 on June 23, and HR 6914 on July 18. In June of 1913, representatives of the city and the Modesto and Turlock Irrigation Districts met in Washington D.C. to hammer out their differences. It was during these meetings that they came to a compromise regarding protection of district water rights that allowed for a 2,350 to 4,000 cubic-feet-per-second system. It was HR 7207, introduced on August 1, entitled the "Hetch Hetchy Act" but popularly known as "The Raker Act," that met the needs of San Francisco and overcame the objections of those opposing the Hetch Hetchy Project.

The House adopted the Act on September 3rd under the guiding lead-

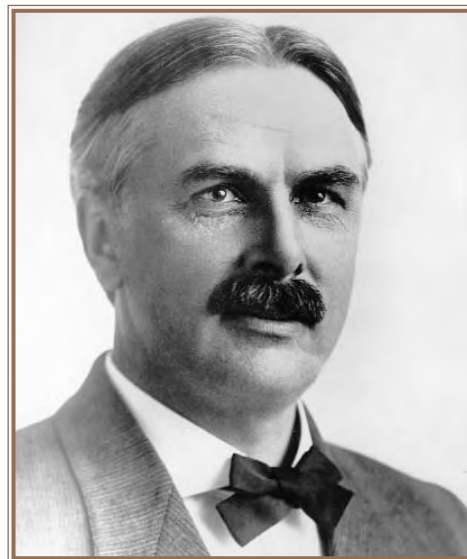
ership of Congressman William Kent. It was he who had purchased over 400 acres of redwoods in Marin County to save the trees from destruction, then gave the grove to the United States. In 1908, that grove became Muir Woods National Monument.

BATTLE FOR SENATE APPROVAL

The battle for the Raker Act moved to the floor of the Senate. Congressional debate on the Raker Act covers hundreds of pages in the *Congressional Record*. The *Record* also lists scores of letters, pro and con, from all parts of the nation. Newspapers from coast to coast took editorial stands on the proposed Hetch Hetchy development.

First the caucus rooms, then the floor of the Senate itself, became arenas for an extended and heated battle. Spring Valley and its agents made inflammatory claims and charges. San Francisco's plans were supported by the War Secretary's Board of Army Engineers.

Except for the Spring Valley Water Company, who fought to keep its monopoly as San Francisco's water provider, most of the opposition to the Hetch Hetchy plan came from outside California. National interest was fanned by dire and ominous forecasts from environmentalists. A large photo of Wapama Falls, with the caption "Will be Destroyed by the San Francisco



John E. Raker, U.S. Representative 1914

Plan," was published by the weekly magazine *New York Independent* on October 30th. A group claimed that Hetch Hetchy would ruin Yosemite Valley 26 miles to the south, and that the Calaveras Big Trees would die of thirst, although they are over 30 miles away!

Some scientists viewed the project as the restoration of an ancient lake at the site. Ansel F. Hall published his *Handbook of Yosemite National Park* in 1921, while he was an information officer for the National Park Service. The chapter, "Geology of Yosemite National Park," was authored by University of California Geology and Mineralogy Professor Andrew C. Lawson, remembered for chairing the State Earthquake Investigation Commission and naming the San Andreas Rift Zone. Lawson described how glaciers scooped out the Hetch Hetchy Valley and, on receding, dropped glacial debris at the lower entrance to the valley forming a basin for a tarn, or mountain lake, which collected sediment from the melting ice above and built out the level valley floor. Lawson said, "The lake which will soon be created in Hetch Hetchy Valley by the dam at its outlet, now being built by the City of San Francisco, will be but a restoration on a larger scale of the lake which once existed there. The new lake will seem very natural in its mountain setting."

Other academia were of a different view. The presidents of Harvard University and Radcliffe College joined with their faculties and sent impassioned pleas to the Senate to "save Hetch Hetchy" from San Francisco.

However, San Francisco had never stood alone - support was widespread, coming from the California Legislature, every major California city, and all the neighboring communities of the greater San Francisco Bay Area.

Pennsylvania's Governor Gifford Pinchot, a former National Forester and one of the nation's most respected environmentalists, provided significant support for San Francisco's cause.



Hetch Hetchy Railroad crossed river gorges to reach the construction site 1919

In the Senate, the fight for Hetch Hetchy was led by such statesmen as Key Pittman of Nevada, George C. Perkins of California, George W. Norris of Nebraska, Charles S. Thomas of Colorado, Henry L. Myers of Montana, and William H. Thompson of Kansas.

SAN FRANCISCO EXAMINER TIPS SENATE SUPPORT

But the clincher had to be the active support of William Randolph Hearst, editor and publisher of the *San Francisco Examiner* and head of a coast-to-coast chain of newspapers.

Hearst sent a special staff from the *San Francisco Examiner* to Washington, D.C. On the morning of December 2, 1913, a 16-page Washington edition of the *Examiner* was published and placed on the desk of every senator. On the front page were statements in support of Hetch Hetchy from Vice President of the United States, Thomas R. Marshall, Secretary of State William Jennings Bryan, Secretary of the Interior Franklin K. Lane and Secretary of Agriculture David F. Houston. The historic *Examiner* also printed a telegram from the Modesto and Turlock Irrigation Districts advising of their joint meeting and decision to support San Francisco.

The heavyweight opposition to Hetch Hetchy had vanished. The Modesto

and Turlock Irrigation Districts ended their dissatisfaction with the Raker Act once they were assured that their rights were protected and they would actually benefit from electric power surpluses. (However, the Modesto Irrigation District subsequently withdrew its support of the bill at the last minute.)

Opposition from the Spring Valley Water Company subsided when a special clause was included in the Act providing that all of the water from sources near San Francisco be used before water from the Tuolumne could be diverted. This clause protected Spring Valley's investment in all properties and rights up to the full amount of their water-producing capacity.

Even Spring Valley's President William Bourn decided that the handwriting was on the wall and the city was determined to prevail. His address to the Board of Supervisors on May 19, 1913 was later read to the Senate and entered into the *Congressional Record*, with telling effect. Bourn said, "...there is nothing in my life that I regret as much as the

water situation in San Francisco today. It is doing the city more harm than the earthquake ever did to it." He continued, "The city's object was opposed by the Spring Valley Water Company, the irrigationists of the Turlock - Modesto Irrigation Districts, the promoters of several water schemes, which the city did not want, and by a small group of men who based their objections on a love of nature and opposed creation of a lake where a canyon now exists. All of this opposition, except that of the nature lovers, is withdrawn."

The Senate adopted the Raker Act during the night session of December 6, 1913.

RAKER ACT PRESERVES WILDERNESS

No opposing voice spoke more fervently during the Congressional debates than John Muir, the famous naturalist and lover of the wilderness. Muir was an organizer and the first president of the Sierra Club, serving in that position for 22 years following the club's founding in San Francisco on May 28, 1892.

Today, as then, John Muir is held in high esteem by the men and women of Hetch Hetchy. They share his love for the wilderness and his concerns for its preservation. To the present time, the name of John Muir is mentioned frequently in this beautiful and protected valley.



Hiker enjoys Sierra Nevada backcountry

There is no doubt that the Yosemite Valley, 26 miles to the south of Hetch Hetchy, is the crown jewel of Yosemite National Park. But its pristine beauty is marred by the ravages and pollution of 100 years of tourism, from which Hetch Hetchy Valley and its wilderness trails have been spared.

Hetch Hetchy waters, while sustaining millions of people in the San Francisco Bay Area, are no barrier keeping people away from the absolute stillness and majestic vistas of the Sierra Nevada wilderness. Those willing to leave their autos, campers or motorcycles will find good hiking trails open from the trailhead at O'Shaughnessy Dam. The best of these back country roads and trails, long planned for public use by John Freeman in 1912, were built by and are maintained with funds from the City and County of San Francisco.

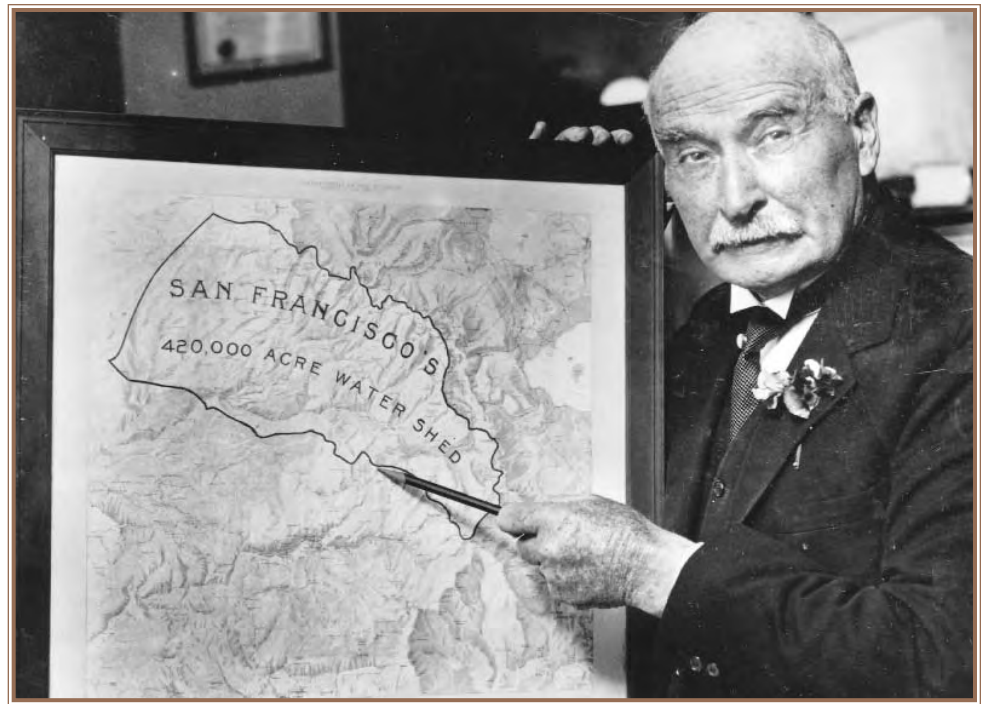
Upon signing the Raker Act into law on December 19, 1913, President Woodrow Wilson said, "...it seems to serve the pressing public needs of the region better than they could be served in any other way, and yet does not impair the usefulness or materially detract from the beauty of the public domain."

In Washington, members of Congress and President Wilson regarded the Raker Act as an excellent demonstration of the "conservation for use" policy. Though the issue was to flare up periodically during later years, the fight for the right to build the Hetch Hetchy Project was over.

RAKER ACT PROVISIONS

The Raker Act has been criticized as a free gift to the city. The Act grants to San Francisco rights-of-way and public lands use in the areas concerned to construct, operate and maintain reservoirs, dams, conduits and other structures necessary or incidental to developing and using water and power. However, the Act imposes many conditions and obligations upon the city, stipulating, among others, that San Francisco is required to:

- Recognize the prior rights of the Turlock and Modesto Irrigation



Michael M. O'Shaughnessy presents Hetch Hetchy Project 1932

Districts to receive water they can beneficially use, up to specified amounts of the natural daily flow, for direct use and storage.

- Construct miles of scenic roads and trails in Yosemite National Park, and donate them to the United States.
- Get started on the work of dam building at Hetch Hetchy and complete it as rapidly as possible.
- Enforce specific sanitary regulations within the watershed area.
- Develop electric power for municipal and commercial use.
- Not divert beyond the limits of San Joaquin Valley any more of the watershed waters than is required for its own domestic or municipal purposes, excluding irrigation use.
- Pay an annual rental starting at \$15,000 and rising to \$30,000 after 20 years.
- Not sell or give Hetch Hetchy water or power to a private person or corporation for resale.

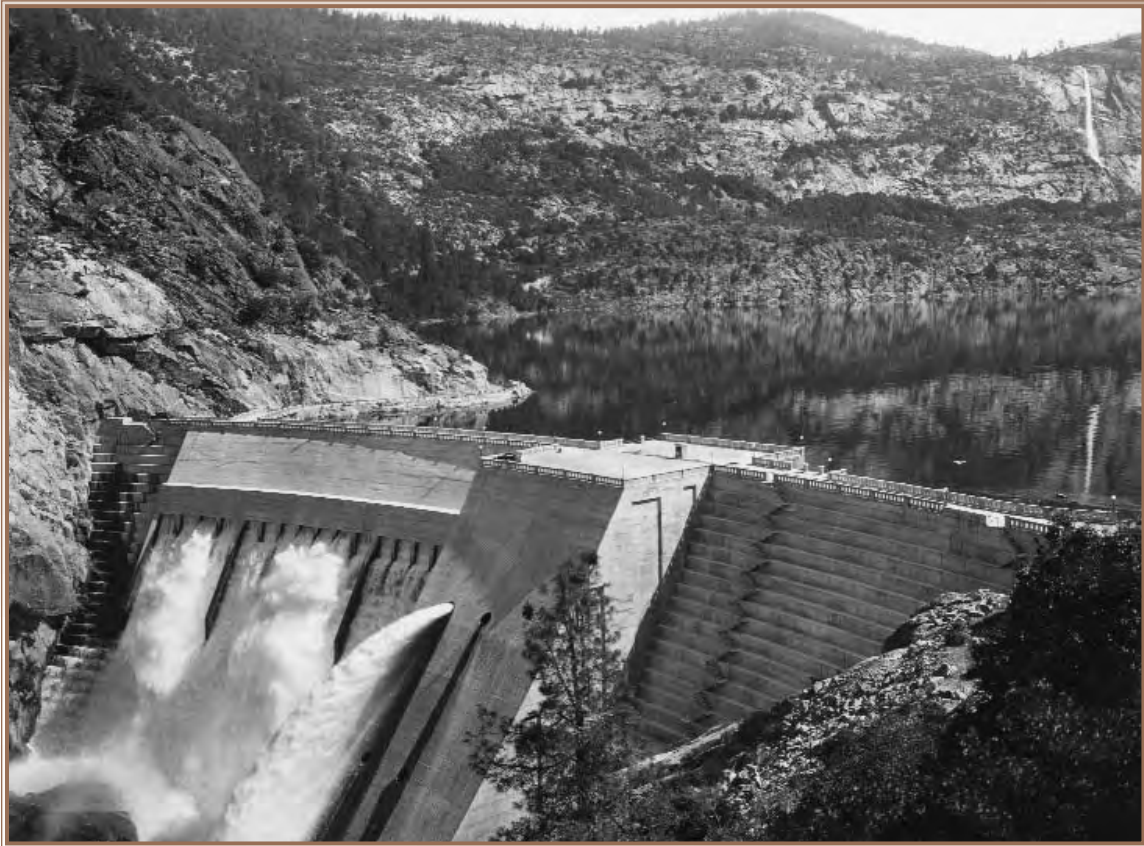
Congress pointedly disclaimed any intent to interfere with California state laws relating to the control or appropriation of water. This was of extreme importance to San

Francisco, because the city holds water rights under California law - not the Raker Act.

The Raker Act required the city to develop hydroelectric power, which would be a natural byproduct of the Hetch Hetchy water supply development. According to the Interior Secretary, this would reduce fuel oil use in California. The federal government was strongly committed to a policy of conservation.

The Act was ratified by San Francisco in the Spring of 1914, and the Hetch Hetchy construction program started immediately.

SAN FRANCISCO BUILDS HETCH HETCHY PROJECT

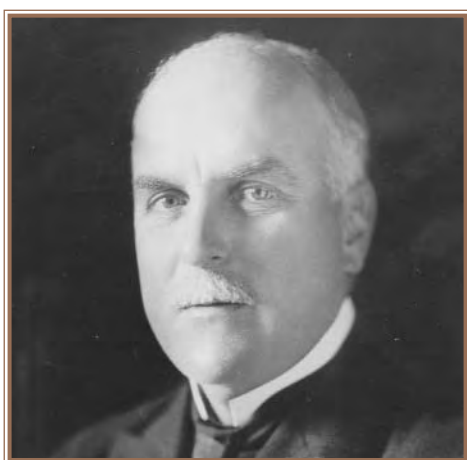


The initial architects of Hetch Hetchy were City Engineers Carl E. Grunsky and Marsden Manson. Grunsky directed the surveys that selected the Tuolumne River as the city's source and acquired some of its rights. Manson devoted his time almost exclusively to the project for twelve years, and continued his efforts even after he was out of office. In 1908, he conducted a survey in the mountains under Drenzy Jones, a former Tuolumne County surveyor, with two San Francisco assistant city engineers, Leslie W. Stocker and Louis Mercado.

CITY ENGINEER MICHAEL M. O'SHAUGHNESSY

San Francisco was still in the midst of one of history's greatest reconstruction projects, that of rebuilding the city ravaged by the earthquake and fire of April 1906.

James Rolph, Jr., affectionately known as "Sunny Jim," assumed the office of Mayor on January 8, 1912. Less than nine months later, on September 1, he appointed Michael Maurice O'Shaughnessy as City Engineer, with the caveat, "...you will answer only to me!" The peppery Irishman took the Mayor at his word. It is no accident that those who worked on the Hetch Hetchy Project referred to him as "The Chief."



James "Sunny Jim" Rolph, Jr. 1931

With a Bachelor of Engineering degree from the Royal University of Dublin, Ireland, O'Shaughnessy had sailed around the Horn, arriving in San



O'Shaughnessy Dam, upstream face 1923

Francisco in 1885. Finding no employment in the city, his first jobs were designing a street system for Mill Valley and helping to raise Marin County's Alpine Dam. O'Shaughnessy was 48 years old and the chief engineer of the Southern California Mountain Water Company in San Diego when Mayor Rolph summoned him to San Francisco.

The time was right for men like Rolph and O'Shaughnessy. Rolph was to become a dynamic and powerful chief executive, trusted and beloved by the people. He would serve as San Francisco's Mayor until he was elected Governor of California in 1931.

O'Shaughnessy was a first-rate engineer. As the right hand of the masterful Rolph, O'Shaughnessy made the Hetch Hetchy Project move. Work on Hetch Hetchy began in earnest in 1914, eight years after the city's great earthquake and fire. The city was loaded with engineering talent of the highest order - city engineers and private consultants ready for any challenge that tested their imagination. Some of the finest engineers of the time signed up with San Francisco because they liked the concept of Hetch Hetchy and they respected "The Chief."

But whereas "Sunny Jim" was charming and gracious, making every stranger his friend, O'Shaughnessy, although respected by those who worked for him, could become somewhat abrasive, a trait that was to give him trouble as the project neared completion.

There is no shortage of anecdotes about the colorful O'Shaughnessy, the man of action! On the long list of his many admirers we find, among others, the name of Jack London. Of those who sat through the Senate debate on the Raker Act, a significant number came primarily to see "The Chief" in action.

HETCH HETCHY SYSTEM DESIGN

If there is a secret behind Hetch Hetchy's phenomenal construction success, it must be that one of the most talented groups of engineers ever to come together did so as a working team. From the first days of construction, the Hetch Hetchy challenge attracted gifted engineers. That attraction, or perhaps fascination, continues today.

Not only were there nearly impassable mountains and attendant engineering problems, there were other obstacles - a 75 percent increase in prices

between 1913 and the World War I Armistice, attempts at political interference and foot-dragging on appropriations. But San Francisco had earned the sobriquet, "The City That Knows How," and Hetch Hetchy was built.

San Francisco now went back to the Freeman Plan. It was a preliminary project design with detailed estimates for the development of a 400-million-gallon-per-day storage and transmission system from the Sierra Nevada to the San Francisco Peninsula.

O'Shaughnessy sent his team on foot and on horseback into the High Sierra for the final field surveys, while he and his staff polished the Freeman Plan to add capacity to the project, ease the supply and construction problems, and schedule the work to lessen the expense to the taxpayers.

The resultant work plan was to build the dam at Hetch Hetchy initially to about three-quarters of its final height, developing about 60 percent of the reservoir capacity. The aqueduct from the mountains westward would be completed to Moccasin Creek and a powerhouse put in operation at the site as soon as possible. Another aqueduct section, 23 miles long, would be built in the Coast Range from Alameda Creek, south of Sunol in Alameda



Hetch Hetchy tramway (Michael O'Shaughnessy at left rear) 1919



O'Shaughnessy Dam under construction at night 1921

County, across the Bay to Pulgas Portal in San Mateo County. This section of the aqueduct - the Bay Division - would be ready to carry Spring Valley water as their East Bay properties were developed, earning immediate income for the city. Later the Bay Division could carry Hetch Hetchy water as the system was built westward across the San Joaquin Valley. The remaining sections of the aqueduct were to have the Tuolumne waters ready for delivery when Spring Valley sources were used to capacity, but not before then, to minimize the financial burden on San Francisco.

The magnitude of the project was vast in scope, involving dams, reservoirs, conduits, powerhouses and a 150-mile-long aqueduct. But in the mountains, accessibility was a problem. The Sierras are difficult for mountain climbers, affording only few areas where horses can be maintained. Into this area, all manner of machinery and equipment had to be transported and thousands of workmen had to be accommodated and supplied. Nevertheless, electrically driven drills bored into granite, dynamite was a moving force, and the Hetch Hetchy Project engineers considered no area inaccessible to them.

WATER SUPPLY FOR BAY AREA

The Freeman Plan of 1912 called for diversions of 60 million gallons of water per day from the Tuolumne River basin to serve the city's needs until well into the 21st century. However, upon advice of the Board of Army Engineers in 1913, San Francisco found itself assuming leadership to provide for the water needs of the entire Bay Area, requiring ultimate development of the Tuolumne River to produce 400 million gallons per day. This was the amount necessary to supplement the local production capability of the existing Peninsula and East Bay sources of the Spring Valley Water Company.

The pressure on San Francisco to develop a water supply for the entire Bay Area was relieved in the early 1920's, however, when East Bay cities elected to find and develop their own water supply from the Mokelumne River. Without undue strain, San Francisco was thereby able to meet the ever-increasing requests for additional water from her own citizens and also from the mushrooming suburban areas and industrial complexes in a 50-mile radius south and east of the city.

DESIGN DECISIONS

The building of Hetch Hetchy is a fascinating saga, mainly due to its geographic challenges. System design evolved over time as O'Shaughnessy considered the best way to secure San Francisco's water supply for the next 100 years. Hydraulics, durability and capacity for expansion drove O'Shaughnessy's decisions. He located facilities to maintain the hydraulic grade line for a gravity-flow system rather than pumping water across California, built tunnels instead of pipelines where possible for their capacity, longevity and ease of maintenance, and strengthened dam foundations to support additional storage in the future. O'Shaughnessy's design also took advantage of the mountainous sites to generate hydroelectricity from the water supply before delivering it to the Bay Area.

The construction work was conducted in separate contracts that spanned over 160 miles between the High Sierra dam site and the Bay Area. Precise design and construction were required to connect the several segments as they were built into a cohesive water supply system. Dams and powerhouses in the high country, conduits and tunnels throughout the system, pipelines in the San Joaquin Valley, and even across and under San Francisco Bay were to be constructed. The system was planned to permit later additions to various parts as the need arose, without changing its basic design or operations.

Hetch Hetchy was built as economical as possible, but where additional labor was necessary to eliminate future expense or unreasonable maintenance cost, that work was done. Succeeding years have amply demonstrated that the builders of Hetch Hetchy acted wisely.

The total initial cost of the Hetch Hetchy development - up to the first direct delivery of Tuolumne River water to San Francisco in October 1934 - was just over \$100 million. The cost was met solely by the city, without State or Federal assistance. At the price, San Francisco bought a bargain!

GROVELAND HEADQUARTERS

Before building the essential elements of the system, it was first necessary to get into the mountains with packers and guides, often using chartered stagecoaches and freight wagons out of Groveland, a small mountain town left over from the Gold Rush. It sits astride the Big Oak Flat road into Yosemite. With the coming of San Francisco's work forces into the area, Groveland was revitalized, booming for a decade as headquarters for the Hetch Hetchy Project. The quiet mountain village found itself suddenly with office and hospital buildings, homes for officials and their families, and shops and operating headquarters for a full scale railroad, bringing the first locomotives and cars that some in Groveland had ever seen. Hetch Hetchy workers and equipment helped with extensive road improvements in the district. They improved the water supply and started a sewer system. They also resurveyed Groveland and nearby Big Oak Flat to correct inaccurate surveys made during the Gold Rush days.

HETCH HETCHY RAILROAD

Preliminary planning for the Hetch Hetchy Project revealed the need to build transportation, electrical power and sawmill facilities to support con-

struction of the large-scale dams and tunnels in the back country. Plans were developed to build a railroad, sawmill and powerhouse in advance of dam construction.

In the rugged and remote country of the High Sierra, the first priority was a reliable, high-capacity and all-weather form of transportation to move heavy machinery, bulk materials and supplies, and workers into the mountains to the new dam site. Clearly, a railroad was the answer.

So, San Francisco built the Hetch Hetchy Railroad, a 68-mile-long, standard gauge railway, from Hetch Hetchy Junction, some 26 miles east of Oakdale, to the rim of the Hetch Hetchy Valley. Built for some \$3 million, Hetch Hetchy Railroad saved at least ten times its cost in cement hauling alone. It was completed in October 1917, and operated around the clock during the construction of the dam, using one rented locomotive and six of its own.

Hetch Hetchy Railroad operated as a common carrier from July 1918 to February 1925, subject to rules of the California Railroad Commission. It abided by railroading practices, publishing time tables and tariffs. Trains traveled at 8 miles per hour top speed on very steep grades, greater than four percent, and



Roundhouse crew at Groveland 1922



Early Intake Tramway carries visitors to dedicate the dam 1923

around extremely sharp curves, some 30 degrees or a 190-foot radius. The highest elevation on the line was 5,064 feet at Poopenaut Pass.

But it was a different sort of railroad. Mayor Rolph was president of the line, Chief O'Shaughnessy was vice president and general manager. There was considerable informality in its operation - the management consisted of civil engineers, not locomotive engineers.

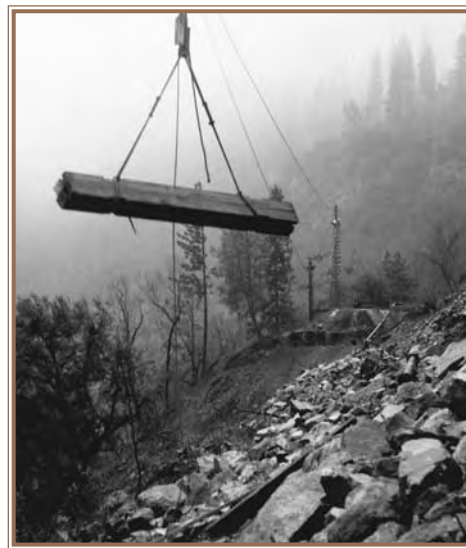
To generate revenues for its operation, the railroad hauled freight for timber companies and others doing business in the Sierra, charging 12½ cents per ton mile for carload lots. It also carried the mail and provided passenger service. Passengers paid 7½ cents per mile. Weekend excursion groups of 40 to 100 San Franciscans would leave the city by Pullman sleeper Friday night, catching the Hetch Hetchy train on Saturday morning. Public support for bond issues was essential to finance the ongoing construction, so Hetch Hetchy excursion trains took community groups to various camps to view the work in progress, with meals and overnight accommodations being provided at bunkhouses. After two days in the mountains, the groups were returned to their Pullmans on Sunday evening and they arrived in San Francisco ready for work Monday morning. The fare for this mountain holiday was about \$30.

Most of the mountain construction work was completed by the mid-1920s, but the railroad was kept in use for another two decades, mostly for winter supply and maintenance while motor roads were snowbound. The railroad was again used for construction in the 1930s to haul materials and workers to raise O'Shaughnessy Dam to its current height of 430 feet. The State Emergency Relief Act provided some 600 maintenance workers to help rebuild the Hetch Hetchy Railroad bed and tracks. But this time Hetch Hetchy did not run the railroad. Sierra Railway came in with the low bid and railroad operations started again on May 13, 1935.

The tracks were removed in 1949, and parts of the right-of-way were used by State Highway 120 in Big Oak Flat, as well as the Cherry Oil Road to Camp Mather and beyond to the O'Shaughnessy Dam. One of Hetch Hetchy's original six locomotives can still be seen at Yosemite National Park, where it is on display.

THE SAWMILL

The original Hetch Hetchy Sawmill was located at Canyon Ranch in Yosemite National Park, near a large forest owned by San Francisco about 4.5



Aerial boists move heavy timber 1918

miles from the Hetch Hetchy construction site. Eight million board feet were sawed from 1915 through 1918. In 1919 after the timber stand was exhausted, the mill was moved to Hog Ranch, some nine miles from the O'Shaughnessy Dam site. The operation was discontinued in 1924, after 21 million board feet of lumber had been cut. The mill was later dismantled, and Hog Ranch is now San Francisco's summer recreation camp, Camp Mather, christened by O'Shaughnessy after Stephen T. Mather, the first Director of the National Park Service and later Assistant Secretary of the Interior. The old mill pond at Hog Ranch is now a fine swimming lake for Camp Mather's summer visitors. A smaller sawmill operated at Lake Eleanor through 1918.

EARLY INTAKE POWERHOUSE AND LAKE ELEANOR

O'Shaughnessy's plans for building the Hetch Hetchy Project involved working at night on dam construction, a visionary idea at the time. He needed a good, dependable source of electricity to run the boring drills, construction tools and other equipment, as well as provide full illumination in the dark, forested mountain work sites. Along with the railroad and sawmill, building a powerhouse was an early priority for O'Shaughnessy.

San Francisco built the tiny Early Intake Powerhouse on the Tuolumne River about 12 miles downstream from Hetch Hetchy. Construction started in August 1917, supervised by Assistant Chief Engineer Nelson A. Eckert. Early Intake was equipped with three 1,500-horsepower Francis turbines connected directly to three 2.3-kilovolt (kV) generators.

To assure continuous operation of the powerhouse, O'Shaughnessy needed a reliable and plentiful supply of water. He built the first dam of the Hetch Hetchy Project on Eleanor Creek. The dam is a multi-arch concrete design, 1,260 feet long and 70 feet high, creating a reservoir impounding 27,100 acre feet. It was completed quickly, placed in operation only ten months after the start of construction in August 1917.

Prior to the dam, Lake Eleanor was a typical shallow glacial lake.

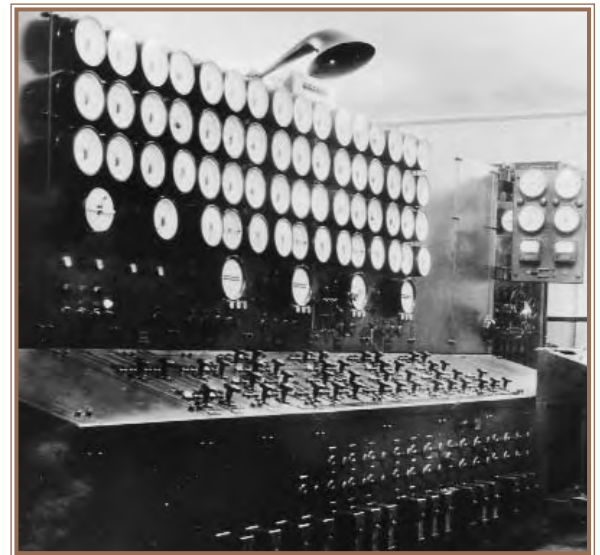
Also in 1917, a small 4-foot diversion dam was built to move Cherry Creek waters into Lower Cherry Aqueduct. A three-mile long transmission system of flumes, pipes, tunnels and concrete-lined canals along the service road, the Aqueduct delivered the combined Cherry Creek and Lake Eleanor waters at 200 cubic feet per second to the hillside 345 feet above Early Intake Powerhouse.

The 22 kV transmission lines, rated the equivalent of 4,000 horsepower, carried the power 11 miles east to the O'Shaughnessy Dam site, and 22 miles west to Moccasin. A two-mile line was taken into Groveland and the Hetch Hetchy headquarters.

Electrical generation began in May 1918. In 16 years, the powerhouse produced \$550,000 worth of power for Hetch Hetchy construction and \$750,000 in cash revenues from commercial power sales. Early Intake Powerhouse continued to operate until 1967, adding its production to that of the Moccasin Powerhouse. Since 1960, water retained by Eleanor Dam is diverted through the mile-long Eleanor-Cherry tunnel to Lake Lloyd (Cherry Lake).



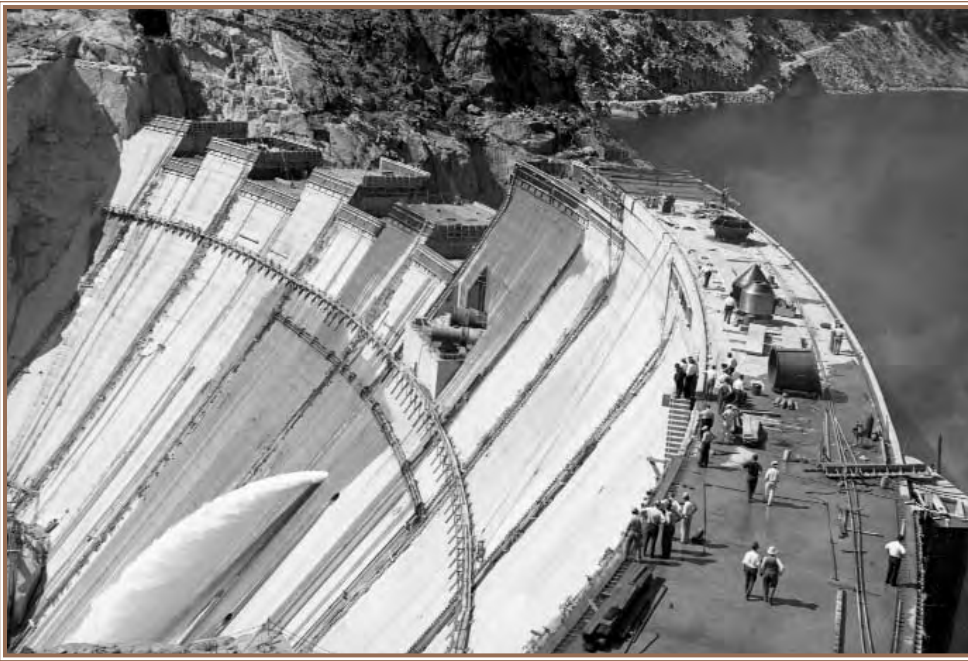
Eleanor Dam under construction 1918



Moccasin power meters 1925



Original Moccasin turbines 1924



O'Shaughnessy Dam being raised 1937

O'SHAUGHNESSY DAM AND HETCH HETCHY RESERVOIR

With completion of the Hetch Hetchy Railroad, Sawmill and Early Intake Powerhouse, the infrastructure was in place for O'Shaughnessy to begin work on the major Hetch Hetchy facilities. Preliminary work began in 1915 to create a reservoir collecting and storing the runoff from 459 square miles of rugged granite mountain watershed. The dam construction contract was awarded to Utah Construction on August 1, 1919.

Built of cyclopean concrete, a process in which about eight percent granite plums - blocks of stone ranging in size from one cubic foot to five or six cubic yards - are embedded in plain concrete, the dam is of the arch-gravity type. It has five vertical contraction joints, sealed by sheet copper strips, with inspection wells and ladder-ways at the construction joints.

Initially, 30 feet was considered an ample depth for the dam's foundations. But test boring of the ancient glacier's terminal moraine discovered that the retreating glacier had dropped untold tons of boulders, with intervening layers of sand, to depths of more than 90 feet below river level. At the downstream toe of the dam, bedrock was reached at 61 feet. But at the upstream

toe, the glacial debris had to be removed to a depth of 101 feet.

Preliminary construction involved driving a 1,000-foot-long diversion tunnel to carry the Tuolumne waters past the foundation excavation during dam construction. The tunnel is 23 feet wide and 25 feet high through solid granite.

It took nearly four years of day and night operations in all seasons to pour the concrete brought in by the Hetch Hetchy Railroad. This totaled as much as 2,000 cubic yards in a day, with the one-month record being 41,178 cubic yards. The dam was completed to its initial height of 226.5 feet, with a storage capability of 206,000 acre feet of water. At its dedication on July 7, 1923, it was acclaimed as the largest single structure on the West Coast.

When the mountain water reached San Francisco in 1934, the city's engineers headed back to the Sierra to increase the height of the O'Shaughnessy Dam and add to the capacity of Hetch Hetchy Reservoir. San Francisco had approved a \$3.5 million bond issue for this project in November 1933. Transbay Construction Company made the low bid of \$3,219,965 and construction started in January 1935.

The dam was raised 85.5 feet in elevation in 1938, and enlarged to a length

of 910 feet at the crest and a width of 298 feet at the base, impounding its present 360,360 acre feet of water. The side-channel-type spillway has three drum gates installed in 1950, providing additional storage when the reservoir is full. Total cost of the dam, including its subsequent enlargement, was \$12.6 million.

By the time this project was finished, the economy of Tuolumne County had been given a timely boost. The nation was making its way out of the Great Depression. San Francisco was offered a 30 percent grant from the National Relief Administration, provided that all available unemployed Tuolumne workers were put on the job.

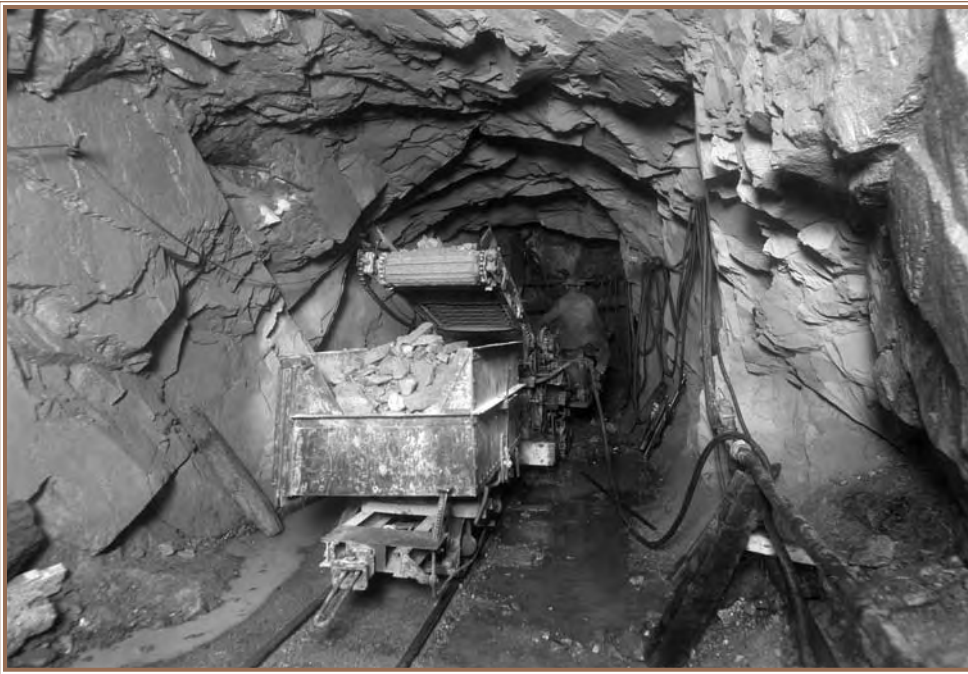
Water from Hetch Hetchy Reservoir can be released through 14 outlet conduits in O'Shaughnessy Dam. Of these, three outlets move San Francisco's drinking water into Canyon Power Tunnel for hydroelectric power generation at Hetch Hetchy's powerhouses before the water makes its way across California to the Bay Area.

The other 11 outlets are regulated by manually-operated valves ranging from three to six feet in diameter. Water is released into the Tuolumne River downstream of the dam to maintain river flows for fish habitat and recreational uses, including whitewater rafting.

MOUNTAIN TUNNEL

At about the same time that preliminary work started on the O'Shaughnessy Dam during the summer of 1917, city employees of the Hetch Hetchy Project began constructing Mountain Tunnel from Early Intake to Priest Reservoir above Moccasin. The tunnel is unlined for 38 percent of its length, and was drilled to a diameter of 13.5 feet through solid granite. The rest of the tunnel is ten feet in diameter and lined with concrete. Shaped like a horseshoe, the tunnel is designed for a flow capacity of 470 million gallons per day.

O'Shaughnessy considered all private contracting bids for the Mountain Tunnel to be extravagantly high and rejected them. The excruciatingly diffi-



Mucking machine in Priest Tunnel 1919

cult work was therefore assigned to Hetch Hetchy's city forces, taking the best of men, and putting the engineers' skills to an acid test.

The excavation work was conducted from twelve working faces. The headings from each face had to match up, horizontally and vertically, when crews working toward each other "holed through." Of the working faces, four were portals, four were from adits (passageways leading to the tunnel) and four started from the bottom of the two shafts - Second Garrote Shaft, 786 feet deep, and Big Creek Shaft, 646 feet.

The tunnel was completed in 1925 at a cost of \$25 million. Most of Mountain Tunnel is an average of 1,000 feet below the surface. Where it crossed the gorge of the South Fork of the Tuolumne, it was interrupted by a 9.5 foot-in-diameter pipe, 225.5 feet long. In the mid-1960s the pipe was replaced by a U-shaped tunnel under the stream bed.

PRIEST RESERVOIR AND BYPASS

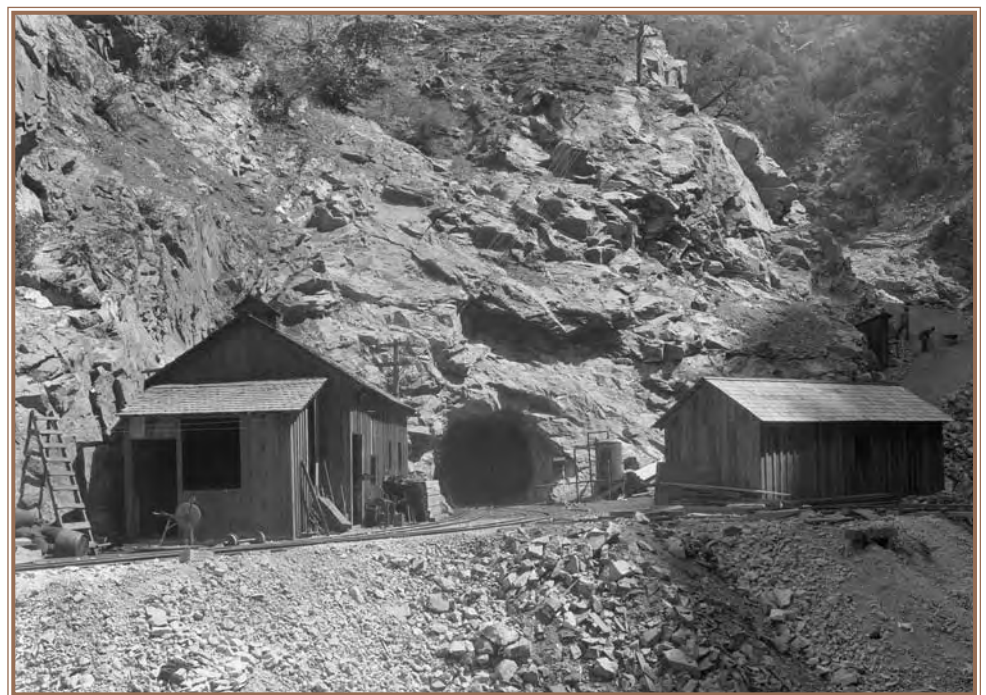
The west end of Mountain Tunnel comes out some 19 miles east of Early Intake. Hetch Hetchy water is dis-

charged into Priest Reservoir, a regulating reservoir for forebay capacity and flexible operation of the Moccasin Powerhouse. Located near the top of Priest Hill, an hydraulic and earth-fill dam was built around a concrete core to capture the full force of the Hetch Hetchy flow from Mountain Tunnel. Rattlesnake Creek, a tributary of

Moccasin Creek, was diverted away from the reservoir to prevent pollution of San Francisco's drinking water source.

Priest Dam is 148 feet high, 1,600 feet long and 660 feet wide at the base. It was built by Hetch Hetchy forces at a cost of \$1 million. A concrete-lined spillway protects against overtopping and a tunnel serves as an additional outlet to drain the reservoir.

In 2003, Hetch Hetchy forces managed and inspected the construction of a \$13 million Priest Bypass pipeline, 19 feet in diameter and 17 inches thick, below the water level of the reservoir. The 1,200 foot-long bypass connects Mountain Tunnel to Moccasin Power Tunnel, fully enclosing the Hetch Hetchy supply until it reaches Moccasin Powerhouse in the Sierra foothills. Completed in 2004, the pipeline was designed to bypass Priest Reservoir in the event of water quality concerns, such as high turbidity from hillside runoff, bank erosion or forest fires.



South Fork tunnel portal and buildings 1918



Old Moccasin Powerhouse under construction 1924

MOCCASIN POWER TUNNEL

A concrete gate tower controls and regulates water release through Moccasin Power Tunnel to the brow of the hill above Moccasin. A 160-foot-high surge shaft is near the downstream end of the tunnel. The power tunnel is 5,370 feet long, horseshoe-shaped, concrete-lined, narrowing from 19 feet to 13 feet in width, with a capacity of 800 million gallons per day. Completed at a cost of \$1.3 million, the power tunnel connects with three penstocks, 5,349 feet long, which direct the water into the Moccasin Powerhouse 1,316 feet below. The penstocks were originally built for \$2.5 million.

OLD MOCCASIN POWERHOUSE AND CAMP

The old Moccasin Powerhouse, no longer operational, is designed in California Mission style with a tile roof and arched arcades. Located on the bank of Moccasin Creek near the junction of State Highways 49 and 120 - the Mother Lode Stage Coach and Big Oak Flat Roads - the powerhouse rests at the foot of the infamous Priest Grade leading to Stanislaus National Forest and Yosemite National Park. An arduous passage from the earliest days, the old Priest Grade climbs 1,575 feet in two miles. The new road, State Highway 120 - across Grizzly Gulch from the original - makes the same climb in eight miles. The name came from the Priest Station Hotel at the top

of the grade, operated by Mrs. William Priest until 1905.

The old powerhouse is slated for historical preservation. At 225 feet long, 98 feet wide and 67 feet high, with massive foundations resting on bedrock, the powerhouse and its machinery cost \$2.4 million to build in 1925. During its 44 years of active service, four generators rated at 20 kilowatts (kW) each produced \$115 million worth of electrical power.

Moccasin Camp, the original foothill headquarters for construction and maintenance of the entire Hetch Hetchy water storage, power and aqueduct system, continues to function as the hub of the Hetch Hetchy Operations Division to this day. The lower camp near Moccasin Reservoir



Moccasin Camp 1920

was designed in the style of the old powerhouse, a cozy neighborhood of California Mission stucco cottages with Spanish tile roofs, housing the administrative offices, shops and the families of some Hetch Hetchy staff. In addition to their daily management, operations and maintenance duties, residents of Moccasin Camp are essential emergency personnel, forming a volunteer unit that works together with the National Park and Forest Services staff to control forest fires in San Francisco's 650 square miles of Sierra watershed.

NEW MOCCASIN POWERHOUSE AND RE-REGULATING RESERVOIR

New Moccasin Powerhouse, adjacent to the old powerhouse site, went into service in 1969, with two outdoor generators, each rated at 50,000 kVA. Built for \$8.3 million, the new powerhouse uses more sophisticated technology requiring less staff time for operations and maintenance, and earns \$250,000 more annually than the old plant did.

Moccasin Re-regulating Reservoir, created by an earth-fill dam 50 feet high and 855 feet long, functions as an afterbay for Moccasin Powerhouse, to collect the fluctuating flows resulting from hydroelectric power generation. Drinking water for San Francisco enters the Foothill Tunnel upstream of Moccasin Dam at the afterbay gate tower.

Should the need arise, San Francisco's drinking water can be diverted at the Moccasin Reservoir Bypass directly into Foothill Tunnel, without surfacing at Moccasin Reservoir.

A later concrete dam, 321 feet long, was built upstream of the afterbay to prevent the potentially muddy and debris-filled waters of Moccasin Creek from contaminating the reservoir. Moccasin Creek waters are diverted through the 2,900-foot-long Moccasin Creek Diversion Pipeline, laid on the floor of the afterbay and discharged downstream along the original creek bed.

Water formerly spilled at Moccasin is now harnessed to produce hydroelectric power by a \$10 million low-head generating plant, which went into

operation at Moccasin in 1986 with a rating of 3 megawatts (MW). Low-head generating plants provide additional peak production for municipal and industrial electrical loads.

FOOTHILL TUNNEL

From Moccasin, San Francisco's drinking water continues westward in an entirely enclosed conduit of tunnels and pipes until it reaches Pulgas Water Temple in the San Francisco Bay Area. The first leg of this journey is the 15.8-mile Foothill Tunnel through the Sierra Nevada's western foothills. At Oakdale Portal, south of Knight's Ferry, connection is made with the San Joaquin Valley Pipelines.

Tunnel construction started in 1926. Construction headquarters had been moved from Groveland to Hetch Hetchy Junction in November 1925. After the opening of Pedro Adit, the tunnel was soon drilled and blasted from ten separate construction faces - four from two shafts at Hetch Hetchy Junction and Rock River, four from Pedro and Brown Adits, and two from the tunnel portals.

The Foothill Tunnel line crosses the Tuolumne River canyon at Red Mountain Bar, some five miles west of Moccasin. The river crossing was made with an inverted siphon - 770 feet of steel pipe 9.5 feet in diameter, located in a trench blasted from bedrock and embedded in concrete 18 inches to two feet thick. The pipe interior is

coated with 1.5 inches of cement mortar.

The Red Mountain Bar siphon was not initially required, but the canyon would soon be flooded to a depth of 80 feet by Don Pedro Lake. The Don Pedro Dam was being constructed at the same time as O'Shaughnessy Dam by the Turlock and Modesto Irrigation Districts.

During the three years of work on the Foothill Tunnel, a narrow gauge railway was laid from the east bank of the Tuolumne to the Brown Adit, 1.5 miles away, and into the tunnel itself. A siding was built on the west side of the river alongside the Hetch Hetchy Railroad main line. The river was crossed by a half-mile-long, Lidgerwood steel cableway high above the canyon. A hoisting system suspended between two towers, the cableway could carry a five-ton load of supplies and men from the main railroad siding across the river canyon to the narrow gauge line in two minutes. At the time, the Lidgerwood cableway set a world record in span length for a hoisting and conveying cable line; later, similar cableways were used to build Hoover Dam and the Panama Canal.

Work on the Foothill Tunnel was started from six work camps by Hetch Hetchy city forces. City workers installed the water systems, power and telephone lines, roads, camps and other facilities necessary to support construction, and also drove some 1,000 feet of tunnel to expose the geology in the work face headings to private contractors to bid on some of the remaining work.

Three of the work camps were subsequently turned over to contractors who bid successfully on the project. Not

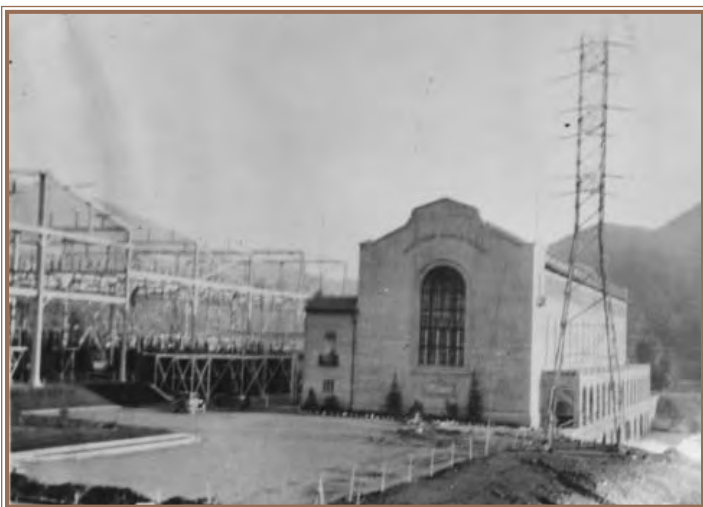


Moccasin Penstocks 1923

only did a spirit of competition grow between the city's work forces and those of private contractors working on adjacent tunnel sections, but direct comparisons of costs for similar work became possible.

Completely outworking the private contractors, Hetch Hetchy's workers set a new record for one month's tunneling excavation in March 1926 - 781 feet at the Hetch Hetchy Junction east heading. Six months later city forces broke their own record at the same work face - 803 feet in September - setting a new national record for this type of work.

Foothill Tunnel was completed in 1929, at a total cost of \$8 million. Chief O'Shaughnessy later reported that tunneling costs for city work came to \$35.53 per foot, while contractor cost was \$40.49. City costs for placing concrete lining came to \$36.11 per foot, while the average contractors' cost was \$47.38.



Old Moccasin Powerhouse 1923

SAN JOAQUIN PIPELINES

From Foothill Tunnel, Hetch Hetchy waters are piped under pressure 47.5 miles across California's San Joaquin Valley through three pipelines, built over a period of 37 years.

O'Shaughnessy anticipated the San Francisco Bay Area's growing need for water, and provided a 100-foot right of way for the aqueduct, sufficient space to build four parallel pipelines over time. The fourth bore has yet to be built, but is in the planning stages now, more than 70 years after the first pipeline was completed.

Water supplies enter the San Joaquin Pipelines at Oakdale Portal, where valves control the flow in all three lines, and is discharged into the Coast Range Tunnel at Tesla Portal, seven miles south of Tracy. Dropping below sea level, the pipelines pass 15 feet under the deep San Joaquin River and nearby Elliott Cut, where they are supported by timber piles and encased in reinforced concrete jackets.

Construction of Pipeline No. 1 started in 1931 and was completed the next year. The pipe is welded and riveted steel with a diameter that varies from 56 to 72 inches. Originally coated with asphalt and wrapped with asphaltum felt, in 1953 the interior asphalt lining was removed and replaced with cement mortar. At a construction cost of \$5 million, the capacity of Pipeline No. 1 is 70 million gallons per day.

Pipeline No. 2, with a capacity of 80 million gallons a day, was completed in 1953 in response to regional growth during the baby boom. With an inside diameter of 61 inches throughout its length, the line includes 28.5 miles of welded steel pipe, coated and lined with cement mortar, and 18.5 miles of reinforced concrete pipe. The line cost \$12.3 million to build.

Pipeline No. 3 is the largest of the three with a capacity of 150 million gallons a day. East of the San Joaquin River it is 78 inches in diameter, lined with coal tar enamel. Completed in 1968 at a cost of \$19.5 million, it doubled the aqueduct capacity to a total for all three pipelines of 300 million gallons per day.



Coast Range Tunnel workers outside Mitchell Shaft 1934

At the San Joaquin River crossing, automatic pressure relief valves on all three lines discharge into the river in case of excess pressure.

COAST RANGE TUNNEL AND CONSTRUCTION DELAYS

One of the largest and most dramatic of the Hetch Hetchy undertakings, the Coast Range Tunnel is the final leg of the journey for Sierra Nevada waters before reaching the San Francisco Bay Area. This 28.5-mile-long tunnel through the Coast Range Mountains is in two sections - a 25-mile-long continuous tunnel from Tesla Portal to Alameda Creek, which was the longest in the world upon completion, and a 3.5-mile segment from Alameda Creek to Irvington Portal near Mission San Jose. At Alameda Creek, the two tunnel segments are connected by a multiple-pipe, inverted siphon, one-half mile long across the creek and Sunol Valley. The short section of tunnel through the Coast Range between the Alameda Siphons and Irvington Portal is now called Irvington Tunnel.

At the Alameda Siphons, interconnecting pipelines were built to transport local water supplies from San Francisco's reservoirs in the East Bay to the Sunol Valley Water Treatment Plant,

and back to the Hetch Hetchy Aqueduct for transmission through the Bay Division pipelines.

O'Shaughnessy's master plan for Hetch Hetchy scheduled tunnel construction to start in the winter of 1925, but the work was delayed awaiting approval of the budget by the city's Board of Supervisors. When the budget was finally adopted in 1927, tunnel drilling started without delay.

Part of the two-year delay was caused by an increasing number of critics who viewed with alarm the hazardous working conditions, including flammable gases, groundwater, quicksand and swelling ground. Some engineers and political groups wanted the Hetch Hetchy water pumped over the Coast Range to save time and the expense of tunneling. O'Shaughnessy proved that a pipeline providing 60 million gallons per day, plus the pumping costs, would cost almost as much as a 200-million-gallon-per-day gravity-flow tunnel. Also, the pipeline would require a supplementary line in 12 years, while the pumping costs would go on forever!

Possible earthquakes were also forecast by tunnel critics. This threat was well known to the engineers; fracture areas of two earthquake fault lines were

identified. The tunnel was designed to withstand earth tremors - some sections of the concrete-lined tunnel were even given flexible joints, innovative at the time.

Swelling ground was also a problem. Under Crane Ridge, at a depth of 2,500 feet, the 18-foot-in-diameter tunnel bore, supported and braced by timbers 18 inches square, was squeezed by ground swelling. In 24 hours the tunnel bore was reduced to three feet all around, turning the heavy timbers to kindling. In a few days the tunnel became so narrow that workers crawled through with difficulty.

To solve this problem, Hetch Hetchy engineers excavated the tunnel bore to an oversize diameter and sprayed thick rings of gunite, a slurry of cement mortar and water, on the tunnel walls, to stabilize them, leaving a one-foot gap for the swelling ground. As the ground-supporting gunite lining set up, it developed sufficient strength to hold before the swelling ground filled the gap. The problems have not recurred after a half century of constant use. Regular inspections confirm the tunnel to be virtually as sound as the first day water passed through it.

Lined entirely with concrete, three feet thick in some places, the 10.5-foot-diameter tunnel follows the general line recommended in the 1912 Freeman Plan. O'Shaughnessy's engineers moved the final route a little to the south to avoid, as much as possible, areas to the north suspected of producing noxious and flammable gases, especially hydrogen sulphide and methane, which were anticipated in the marshier areas.

DISASTROUS EXPLOSION - 12 LIVES LOST

With the start of construction, the 25-mile-long Coast Range tunnel was divided into seven work sections or headings by the two portals at Tesla and Alameda East, and five shafts: Thomas, Mitchell, Mocho, Valley and Indian Creek. Methane gas was first detected in Mocho Shaft and more stringent precautionary safety measures were imposed.

Despite the precautions and safety measures, however, the gang working on the east tunnel of the Mitchell Shaft encountered methane gas on July 17, 1931. In the resultant explosion twelve lives were lost. Several investigations following the tragedy concluded that Hetch Hetchy had conducted tunneling operations under the most strict safety methods used in California and the nation. The Alameda County Coroner's Jury found San Francisco and its agent Hetch Hetchy blameless. Although impossible to isolate the cause conclusively, the investigations established that neither electric wires nor locomotives had ignited the gas. Both Wolf Safety Lamps used for the detection of flammable gases were broken. In violation of safety rules, matches and smoking materials were also found in two of the victims' pockets.

These and other problems delayed construction progress. At times during the depression years, investment money was in short supply and several work headings were shut down for various periods pending the sale of bonds to finance the work.

O'SHAUGHNESSY BLAMED FOR DELAYS

By 1932, O'Shaughnessy had been City Engineer and Chief of the Hetch Hetchy Project for two decades. Delivery of Sierra Nevada water to San Francisco was still two years away from realization. Construction delays due to lack of financing, troublesome geological conditions and the loss of

twelve lives, fueled the concerns of critics and officials who blamed O'Shaughnessy. The arrival of Hetch Hetchy water to a thirsty city was postponed because of the extra time it took to tunnel through the Coast Range. O'Shaughnessy's fiery temperament and abrasive manner over the years was starting to bear bitter fruit. Long-held grievances of important people who had been publicly challenged and rebuffed, resurfaced when Mayor Rolph, who had championed O'Shaughnessy in tough times, left San Francisco for Sacramento, having been elected Governor of California in 1931.

The new City Charter of 1932 went into effect following the purchase of the Spring Valley Water Company, forming the San Francisco Public Utilities Commission to control the Hetch Hetchy Project, San Francisco Municipal Railway, Water Department and Airport. A new management team was appointed to run the utility, and O'Shaughnessy was removed from his post as Chief Engineer. Edward G. Cahill was appointed the first General Manager of Utilities and Lloyd T. McAfee, an Assistant Chief Engineer under O'Shaughnessy, replaced his former superior as Manager and Chief Engineer of the Hetch Hetchy Project. The former Chief O'Shaughnessy was given an office in the Water Department and the title "Consulting Engineer," but he was effectively sidelined from an active role in construction and, according to accounts at the time, consulting with him was discouraged.



Construction workers in Coast Range Tunnel 1930



Construction of submarine sections of Bay Crossing Pipeline No. 1 1925

The new Charter required a competitive bidding process to complete the Coast Range Tunnel construction. Hetch Hetchy also had the right to bid and came in at \$5,257,665, over half a million dollars less than the next lowest bid. When city forces finished the project, they still had some \$1.5 million left over. In addition to the twelve men, the tunnel cost \$28 million to build.

The final holing through of the Coast Range Tunnel came on January 5, 1934, between the Mitchell and Mocho access shafts, in the presence of, among others, Mayor Angelo Rossi, SFPUC Commissioners Lewis Byington and Erwin Eddy, and Utilities General Manager Edward Cahill. The Coast Range Tunnel was the last of facilities to be built in the aqueduct that stretched more than 160 miles across California to bring the mountain waters of Hetch Hetchy to the San Francisco Bay Peninsula. To honor the system's engineer, the ceremony of drilling through the last 12 inches of tunnel was briefly halted until O'Shaughnessy could arrive to take the first handshake from foreman Pete Peterson.

BAY CROSSING PIPELINE NO. 1 - SPRING VALLEY FINANCES START OF CONSTRUCTION

From Irvington Portal, the Hetch Hetchy waters only had to travel another 25 miles to reach the Peninsula. Spring Valley's Alameda Pipeline, built in 1888, consisted of 20 miles of riveted steel pipe 36 inches in diameter, followed by a 6,400-foot section of two submerged 16 inch pipelines on the floor of San Francisco Bay, too small to carry planned Hetch Hetchy water supplies. Spring Valley's deliveries were also constrained by the submarine pipes, and they became interested in San Francisco's proposals for a new Bay Crossing Pipeline.

By the time San Francisco was ready to build the first Bay Crossing Pipeline, it appeared that all of the \$45 million originally authorized in 1910 to construct Hetch Hetchy had been expended. The city planned to request authority from San Francisco voters in October 1924 to issue \$10 million in revenue bonds to complete the project, but that would result in an unacceptable construction shut down of nearly two years, laying off some 500 trained men with no guarantee of their return when work resumed. An alternative,

to hold an early, special election for an interim \$1 million bond issue was also rejected, due to its high \$35,000 cost, a work stoppage of six months or more, and accompanying worker layoffs.

Rather than go for the \$1 million bond issue and its associated costs and delays, Hetch Hetchy approached the Spring Valley Water Company for financing to begin construction of the transbay line. Under the terms of the 1911 State Railroad Commission order, the water arbiter at the time, and the 1922 agreement between Spring Valley and San Francisco, the city acquired an option to buy the Spring Valley Water Company and its assets to integrate with the Hetch Hetchy system once completed. Spring Valley agreed to cooperate with the city's request, and advanced four annual payments of \$250,000 each, as pre-paid rent for its use of the Pipeline No. 1.

The private company did not make any money on this deal. It used its own good credit to borrow the money at the lowest available rates. San Francisco compensated Spring Valley for the interest costs so that the water company neither made nor lost money on the transaction. But, at the same time, Spring Valley was required to borrow money to finance its own construction work.

In an *Oakland Tribune* editorial on December 12, 1924, referring to "controversies which have hindered and threatened to halt the work...", the *Tribune* opined, "In the light of history, it seems a little incongruous that at the most critical period in the Hetch Hetchy war, and when the money was not available, the much-maligned Spring Valley Water Company came to the front to furnish the funds to complete the job. Volumes might be written on the subject, but suffice to say the company is to be commended... regardless of the fact that those who berated it and made it a target are some of those who are most prominent in Hetch Hetchy circles..."

Pipeline No. 1 was constructed 60 inches in diameter in a trench 25 feet deep in the mud and 75 feet below the

water surface at Newark Slough and Dumbarton Strait. Completed in 1925 at a total cost of \$6 million, the 21-mile-long line was put to use immediately per the agreement with Spring Valley Water Company to augment their own small line carrying Alameda waters to the Peninsula. When Pipeline No. 1 entered service, Spring Valley's Peninsula storage contained only 70 days water supply for the city.

Construction on the 1.7-mile long Pulgas Tunnel, the western terminus of the Hetch Hetchy Aqueduct in San Mateo County, was started June 23, 1922. By 1924 it carried Spring Valley water under a lease agreement six years before the city was to purchase the private water system in 1930.

BAY DIVISION PIPELINE NOS. 2, 3 & 4

In October 1924, San Francisco voters approved an additional \$10 million to complete the Coast Range Tunnel and Bay Crossing, but this new money was not to be available until after January 1, 1925.

To increase water delivery capacity on the Hetch Hetchy Aqueduct, construction started on Bay Crossing Pipeline No. 2 in the summer of 1934, a few months after completion of the Coast Range Tunnel. Running parallel to Pipeline No. 1 in the same right-of-way across San Francisco Bay, Pipeline No.



Crystal Springs Pipeline No. 1 after earthquake 1906

2 is slightly larger at 62 to 66 inches in diameter. It was completed in 1936 at a cost of \$4 million.

Pipeline Nos. 3 and 4 are each 34 miles long and rather than cross the Bay, they follow an underground right-of-way around its south end. The Bay Crossing Pipelines were renamed Bay Division Pipelines, which together with the two new transmission lines, were numbered 1 through 4 by date of construction. Separating the four pipelines into two pairs along very different alignments created operational advantages for delivery reliability, providing insurance against the loss of water supplies in a major earthquake or other natural disaster.

The Bay Division Pipelines differ in composition along their alignments, depending on their underlying ground or submarine conditions, consisting in portions of riveted steel, welded steel, reinforced steel cylinder and pre-stressed concrete. Completed in 1956, No. 3 is 72 to 78 inches in diameter and cost \$10 million to build. Pipeline No. 4 is the largest, with a diameter ranging from 84 to 96 inches. Its final eight-mile link was completed on June 14, 1973 at a cost of \$5.6 million, bringing the total transbay transmission capacity to 307 million gallons per day.



Bay Division Pipeline No. 1 on Trestle Bridge 1925

CRYSTAL SPRINGS BYPASS TUNNEL

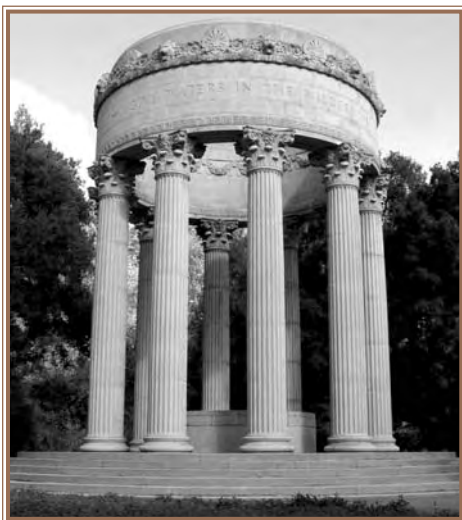
The Crystal Springs Bypass Tunnel was the realization of a Water Department plan to bring water directly from the Hetch Hetchy Aqueduct and the Sunol Filtration Plant into San Francisco and northern San Mateo County, bypassing Lower Crystal Springs Reservoir to streamline water deliveries and avoid the additional costs of surface water treatment on the Peninsula.

The tunnel was designed as a 3.25-mile-long bypass, nine feet in diameter and lined with concrete. Along with its connecting pipeline to the existing Crystal Springs Pipelines, the tunnel was completed in 1968 at a total cost of \$8.6 million.

In 1975, a new \$4.6 million, 60-million-gallon covered balancing reservoir, was built with its attendant pumping station near the Pulgas Water Temple, to coordinate the flows through Pulgas Tunnel into Crystal Springs Reservoir.

PULGAS WATER TEMPLE

The Pulgas Water Temple, bordering the Crystal Springs Reservoir, marks the terminus of the Hetch Hetchy aqueduct that conveys Tuolumne River water more than 160 miles from the Sierra Nevada to the San Francisco Bay Area. On October 28, 1934, the rush of Hetch Hetchy mountain water greeted a festive crowd of dignitaries gathered at the temple to celebrate its arrival.



Pulgas Water Temple 1940



Dedication ceremony for completion of Hetch Hetchy System, Pulgas Water Temple 1934

With vivid memories of the fire that had raged unchecked for lack of water following the 1906 earthquake, San Francisco rejoiced in its new secure, plentiful supply of high quality drinking water.

A new temple was designed in the Beaux Arts style by William Merchant, a San Francisco architect trained by Bernard Maybeck, completed in 1938. Merchant's design featured fluted columns and Corinthian capitals to reflect the architecture of ancient Greeks and Romans, whose engineering methods were used to build the new water system. Artist and master stone carver Albert Bernasconi brought Merchant's drawings to life. The frieze above the columns expresses the city's joyful relief at its new source: "I give waters in the wilderness and rivers in the desert, to give drink to my people."

O'SHAUGHNESSY TRAGICALLY MISSES HISTORIC DAY

By October 1934, San Francisco voters had authorized seven bond issues for a total of nearly \$102 million to finance the Hetch Hetchy work: \$600,000 in 1910, \$45 million in 1910, \$10 million in 1924, \$24 million in 1928, \$6.5 million in 1932, \$3.5 million and \$12.1

million in 1933. The terrible cost in human life to bring a secure, high quality water supply from the Sierra to San Francisco was 89 workers, including 12 workers lost in the Coast Range Tunnel disaster.

The first flow of mountain water into the San Francisco distribution system was an historical event, celebrated nationally on the occasion via radio on October 24, 1934. Accompanied by the Municipal Band, San Francisco Public Utilities Commission President Lewis Byington introduced the builders of Hetch Hetchy. Interior Secretary Harold Ickes, Mayor Angelo Rossi and Supervisor Jesse Coleman addressed the assembly and the nation over the Columbia Broadcasting System (CBS) coast-to-coast network, paying tribute to Chief O'Shaughnessy, but he was not there to hear it. Tragically, in the early morning hours of Friday, October 12, the 72-year-old O'Shaughnessy passed away at his home, after complaining of a pain over his heart.

CHERRY VALLEY SYSTEM

After raising O'Shaughnessy Dam in 1938, Hetch Hetchy engineers moved on to Cherry Creek Canyon, about 17 miles northwest. The Raker Act had authorized a third impounding reservoir in this valley to provide additional supply reliability and develop new energy resources.

San Francisco and the Modesto and Turlock Irrigation Districts had mutual interests in a new storage reservoir on Cherry Creek. San Francisco wanted to assure the reliability of its supply, while the two Irrigation Districts faced increasing demands for irrigation supplies from expanding agricultural development in the Central Valley.

Developing storage on the Cherry River, a tributary of the Tuolumne, would enable San Francisco to satisfy its obligations for daily releases to the two Irrigation Districts as required under the Raker Act, while preserving the high quality Hetch Hetchy supply for San Francisco's domestic water use.

The Army Corps of Engineers also became interested in the city's discussions about water storage facilities in the Cherry Valley, to address their concerns about ongoing damage from flooding on the lower reaches of the Tuolumne and San Joaquin Rivers.

Starting exploratory work in the Cherry Valley in 1941, San Francisco spent \$200,000 over the next eight years to protect its rights and program the way until the four interested agencies entered into a cooperative agreement in 1949.

The agreement provided and required that:

- San Francisco and the Modesto and Turlock Irrigation Districts would modify their existing facilities, construct new facilities, and operate them to reserve reservoir space for protection against Tuolumne River floods, in accordance with regulations established by the Corps of Engineers.
- San Francisco would construct a reservoir in Cherry Valley immediately.

- The Irrigation Districts would develop a new, larger reservoir on the lower Tuolumne at a later date, below the old Don Pedro Dam, inundating it.
- Upon completion of this larger New Don Pedro Reservoir, all flood control operations on the Tuolumne would be transferred to it.
- For flood control benefits, the Federal Government would pay \$9 million toward construction of the \$13 million Cherry Valley Reservoir and a subsequent amount (about \$5.4 million) toward building the New Don Pedro Reservoir.
- For the right to use a stipulated amount of storage space in New Don Pedro, San Francisco would pay \$45 million toward its construction.

The Cherry Valley project started in 1950. Heavy equipment had to be carried to the work site, so 26 miles of roads were built through rugged canyons and over mountain ridges. Power was supplied by a 10-mile-long power line on wooden poles from the venerable Early Intake Powerhouse. A diversion tunnel, 17 feet in diameter and a quarter-mile long, was drifted around the dam site.

Six years later, in 1956, the huge Cherry Dam was complete - 330 feet high above bedrock, 2,600 feet long, and 1,320 feet thick at the base. A composite earth and rock embankment dam, the central impervious core is of compacted, decomposed granite. The diversion tunnel was made a permanent outlet.

The reservoir formed by Cherry Dam, informally called Cherry Lake, was named Lake Lloyd in honor of Harry E. Lloyd, who was General Manager and Chief Engineer for Hetch Hetchy from 1952 to 1961.

Freeman's Plan contemplated a much smaller Cherry Lake, diverting to a much larger Lake Eleanor, which in turn would divert via a tunnel to Hetch Hetchy Reservoir for delivery to San Francisco. The Raker Act provisions granting Modesto and Turlock significantly increased water diversions during the spring runoff necessitated a change in the system's design. The Cherry system was reconsidered, and a new design developed principally to generate hydroelectric power for San Francisco, and divert the system's water supplies downstream to New Don Pedro Reservoir to satisfy the City's obligations to the Irrigation Districts.



Cherry Dam and Lake Lloyd (Cherry Lake) 1960

A six-mile-long, horseshoe-shaped pressure tunnel, 12 feet wide and 12.5 feet high, was bored through granite from Cherry Dam to Dion R. Holm Powerhouse to generate hydroelectric power before the water was returned to the river for delivery to the Irrigation Districts. The tunnel has a 400-foot-tall surge shaft and a rock trap near the downstream portal.

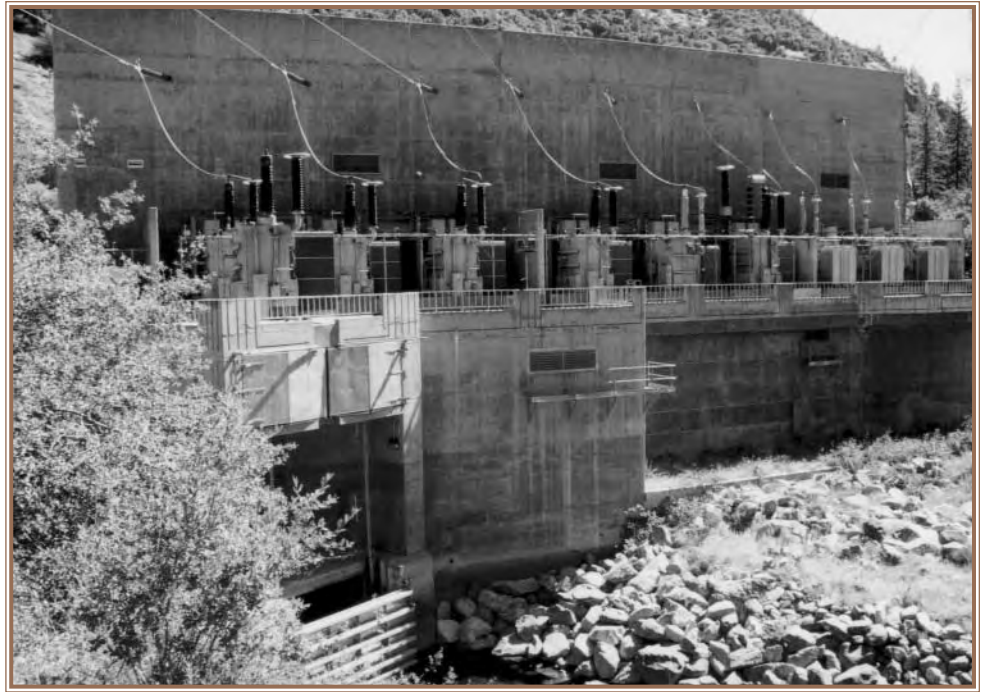
The Lake Eleanor watershed, which has a higher yield than the small lake can hold, supplements storage in the Cherry system via the Cherry-Eleanor Aqueduct and Pump Station, a mile-long tunnel drilled through the ridge between the two lakes which drains Eleanor water into Lake Lloyd.

DION R. HOLM POWERHOUSE

Development of the two additional hydroelectric power plants in the Hetch Hetchy system was delayed until the early 1960s to consider disposition of the energy created in compliance with Raker Act provisions. Since San Francisco does not own its municipal electric distribution system, Hetch Hetchy energy is delivered at bulk transmission voltages to other agencies for resale, or for wheeling, or transport, to the city's municipal loads and customers under contractual agreements with Pacific Gas and Electric Company (PG&E).

Dion R. Holm Powerhouse on the Cherry River, six miles downstream from the Cherry Valley Dam, came on line in 1960, and is the largest of the three Hetch Hetchy powerhouses. Each of its two vertical-shaft, turbine-driven generators is rated at 82,500 kilovolt amps (kVA). Voltage is stepped up to 230 kilovolts (kV) to transmit the power 1.5 miles to the Early Intake Switchyard.

Water for the powerhouse comes from the Cherry Power Tunnel and enters a 6,800-foot-long steel penstock. Tapering from 7.5 feet in diameter at the top to 5 feet at the powerhouse, the penstock drops the water 2,100 vertical feet. To withstand the high pressure, the penstock pipe is made from steel plate increasing in thickness from less than one inch at the top to 2.5 inches at the bottom.



Robert C. Kirkwood Powerhouse 1968

The Holm Power Plant, Tunnel, Penstock and all equipment except transmission lines represented an investment of \$25 million for San Francisco.

The powerhouse was named after Dion R. Holm on August 25, 1967 to memorialize the former City Attorney who served as Hetch Hetchy counsel during the early operating years and who was a devoted advocate of the water and power system.

CANYON POWER TUNNEL

The 11-mile-long Canyon Power Tunnel takes Hetch Hetchy water from the base of O'Shaughnessy Dam through a steel pipe, nine feet in diameter, encased in concrete. Mainly unlined, it is horseshoe-shaped, 14 feet wide and 14.5 feet high. Sloping 10.5 feet to the mile, the pressure tunnel can deliver 970 million gallons per day.

Completed in 1965 at a cost of \$11 million, at its greatest depth Canyon Power Tunnel is 2,000 feet below the surface.

ROBERT C. KIRKWOOD POWERHOUSE

Water for Kirkwood Powerhouse comes from the Canyon Power Tunnel and enters a 1,955-foot-long welded steel penstock, bifurcated in the last 65 feet when the third turbine was installed. Portions of the penstock are exposed on the hillside, anchored to their foundation with stressed tendons. The penstock drops the water 1,245 vertical feet.

The powerhouse was dedicated on August 25, 1967 to the memory of Robert C. Kirkwood, the General Manager of Public Utilities from 1959 to 1964, who passed away while in office. Cost of the penstock was \$2.3 million and for the powerhouse, \$5.6 million.

In 1988, a third generator was installed at Kirkwood Powerhouse at a cost of \$47.5 million with a production capacity of 46,665 kVA, nearly one thousand times more powerful than the original turbines. This unit permits the powerhouse to use the full capacity of Canyon Power Tunnel during spill periods and provides sufficient power generation capability during maintenance periods on the other turbines. The original two vertical shaft turbines are rated at 43,125 kVA.

Kirkwood and Holm Powerhouses are normally operated by remote control from Moccasin Powerhouse, some 20 miles to the west. Remote operations start and stop generating units, adjust generator speed and voltage, take readings and perform switching. The Moccasin control room not only operates the three power plants, it also monitors their output into the 115 kV and 230 kV power transmission systems to Early Intake Switchyard.

Hetch Hetchy's power plants generate over 1.8 billion kilowatt hours (kWh) of electricity a year. Roughly 40% of that goes to satisfy San Francisco's municipal needs, including the Municipal Railway and street lighting. The balance is sold to central California irrigation districts and industrial customers.

POWER TRANSMISSION LINES

Two high voltage systems, normally independently operated, deliver Hetch Hetchy power to the Turlock and Modesto Irrigation Districts, and to the Pacific Gas and Electric Company (PG&E). Each delivery system includes its own line, switchyards, substations, circuit breakers, transformers and automatic protective equipment.

The Moccasin-Newark line operates at 115 kV for its 98.5-mile length. The three phase (six wires) circuits are carried by 506 steel towers, each 97 feet tall, except at the San Joaquin River crossing where they are 208 feet tall. Following the Hetch Hetchy Aqueduct right-of-way as far as Tesla Portal, the line was built during 1923 and 1924, terminating at the PG&E Newark substation.

Power generated by Holm and Kirkwood Powerhouses starts from the Early Intake Switchyard on a separate steel tower transmission line operating at 230 kV, double circuit. Via Moccasin, the line carries the power 48 miles to Warnerville substation near Oakdale, where the voltage is reduced to 115 kV for delivery to Turlock's Oakdale Substation and Modesto's Station J, 12.5 miles further down the line.

The circuits of the two lines are interconnected to the extent that the Moccasin-Newark line is tapped by irrigation district substations, while Warnerville is the terminal connection point with the PG&E 230-kV transmission system.

NEW DON PEDRO DAM AND RESERVOIR

As specified in the 1949 cooperative agreements with San Francisco and the Army Corps of Engineers, Modesto and Turlock Irrigation Districts proceeded



Hetch Hetchy power transmission towers 1924

with their construction of a massive new dam, about 1.5 miles downstream from the Don Pedro Dam they had built on the Tuolumne in 1923. At its completion, the old Don Pedro Dam had been the highest dam in the world. Now, less than half a century later, it was to lie 200 feet beneath the surface of a tremendously expanded reservoir, with a 165-mile-long shoreline, extending 24 miles into Moccasin Creek to the doorstep of Moccasin Powerhouse.

The San Francisco Public Utilities Commission invested \$45 million of the 1961 voter-approved \$115 million water system bond issue in the project, in return for a Hetch Hetchy credit of 740,000 acre feet of exchange water storage space in the new reservoir. The exchange storage created a water banking account for flows in excess of San Francisco's required water releases to Modesto and Turlock Irrigation Districts. San Francisco banks water in New Don Pedro during periods when daily runoff exceeds the Districts' flow entitlements under the Raker Act. This allows the City to later divert at its upstream facilities more water than it would be otherwise entitled to in exchange for a debit in the water bank. Along with San Francisco's investment in New Don Pedro Reservoir, the Army Corps of Engineers contributed \$5.4 million for flood control.

Construction on New Don Pedro Dam started in 1967. A massive rock-fill dam rising 585 feet, it creates New Don Pedro Lake, inundating the old dam upstream under 250 feet of water. The new reservoir stores more than two million acre feet of water. Total cost of the project was \$100 million.

On May 22, 1971, nearly 3,000 persons gathered for the dedication ceremonies and an address by San Francisco Mayor Joseph L. Alioto, followed by a beef barbecue hosted by the Turlock Irrigation District.

In 1996 during its reauthorization review of New Don Pedro Dam, the Federal Energy Regulatory Commission (FERC) required additional environmental releases from the dam to increase downstream flows for fish habitat in the San Joaquin River. San Francisco agreed to pay \$3.5 million to the Irrigation Districts in lieu of releasing stored supplies from its water bank.

LOMA PRIETA EARTHQUAKE TESTS WATER SYSTEM

The great unknown about the magnificent system engineered to bring water from the mountains to San Francisco was how it would fare in a major earthquake. The Hetch Hetchy Project tunnels and pipelines had been constructed more than a decade after the Great Earthquake and Fire of 1906. Many original Spring Valley transmission mains that survived the 1906 temblor were still in place, and San Francisco reservoirs, built on bare hills in the late 19th century, now overlooked densely populated neighborhoods.

In preparation for the real thing, the San Francisco Public Utilities Commission had been conducting regular earthquake drills, testing regular transmission from various sites in the city, preparing priority response scenarios, and assigning field representatives to assess potential damage sites, including mains, reservoirs and pump stations. After every small earthquake, engineers checked the dams, tunnel portals and above-ground pipe supports for cracks or signs of strain.

On October 17, 1989, the Loma Prieta Earthquake struck shortly after 5:00 p.m., just prior to the scheduled start of the first game of the Bay Bridge World Series in San Francisco's Candlestick Park. Centered in Santa Cruz about 60 miles south-southeast of San Francisco on the San Andreas Fault, the magnitude 6.9 earthquake gave the city a major jolt, and its first field test of the water system's structural integrity and reliability under severe seismic strain.

Although the water mains in the Marina District failed, and there were pockets of low pressure in certain areas of the city caused by power failure, ninety-seven percent of customers in San Francisco had no loss of water supply. On the Peninsula, the dams and transmission lines were unaffected. The careful design of San Francisco's water system infrastructure withstood the attenuated force of the earthquake,



Bay Division Pipelines on trestle bridge

enabling the system to meet most fire-fighting needs, except in the Marina, and supply the 2.4 million people in the Bay Area who depended on it.

Reliable delivery systems and earthquake preparedness continue to be very high priorities for San Francisco. Experts predict the very high probability of a major earthquake, magnitude 6.7 or greater, in the Bay Area within the next 30 years. Such an earthquake would impact San Francisco's infrastructure to a much greater extent than Loma Prieta, severely damaging transmission and distribution pipelines throughout the region, and potentially leaving customers in the city and its suburbs without safe drinking water for thirty days or longer. To improve system reliability in seismic events, San Francisco is taking steps to upgrade its water infrastructure, build new facilities with operational flexibility to provide alternate routes for water supplies when the main transmission system fails, and create interconnections with neighboring water systems to provide needed water supplies in an emergency.

REBUILDING SAN FRANCISCO'S WATER SYSTEM

San Francisco began to develop its water system improvement program in the late 1990's through a series of studies, reports, and authorizations. In 1998, a water supply planning effort was initiated in partnership with San Francisco's regional wholesale water customers in the Bay Area Water Supply and Conservation Agency (BAWSCA), culminating in the Water Supply Master Plan issued in April 2000. The plan recommended a water resource strategy of demand management, facilities improvements, and development of additional supplies.

Concurrent with water supply planning, the regional partnership cooperated on reliability studies of San Francisco's water system facilities to assess their vulnerability to earthquakes, landslides, fire, flood, and power outages. The studies produced recommendations for capital improvements to strengthen critical facilities against damage from natural events that could interrupt water service to the greater San Francisco Bay Area.

These planning studies led to San Francisco's development in 2002 of an ambitious long-term capital improvement program, along with strategic business and financial plans to accomplish it. The capital improvement program was adopted by the San Francisco Public Utilities Commission (SFPUC) in May 2002. A few months later, San Francisco voters approved the city's \$1.6 billion portion of the cost to rebuild the water system and provide for its long-term stewardship.

In response to concerns from BAWSCA members about the risks to their communities if San Francisco's water service should be disrupted in a major seismic event, the California legislature enacted three bills in 2002, including Assembly Bill No. 1823, the Wholesale Regional Water System Security and Reliability Act. The bill requires San Francisco to proceed with due diligence on those capital improvements necessary to secure regional water delivery reliability for the future.

The water system improvement program has since been reconsidered and revised to reflect priorities determined by the service and performance goals established for the water system. The program is designed to:

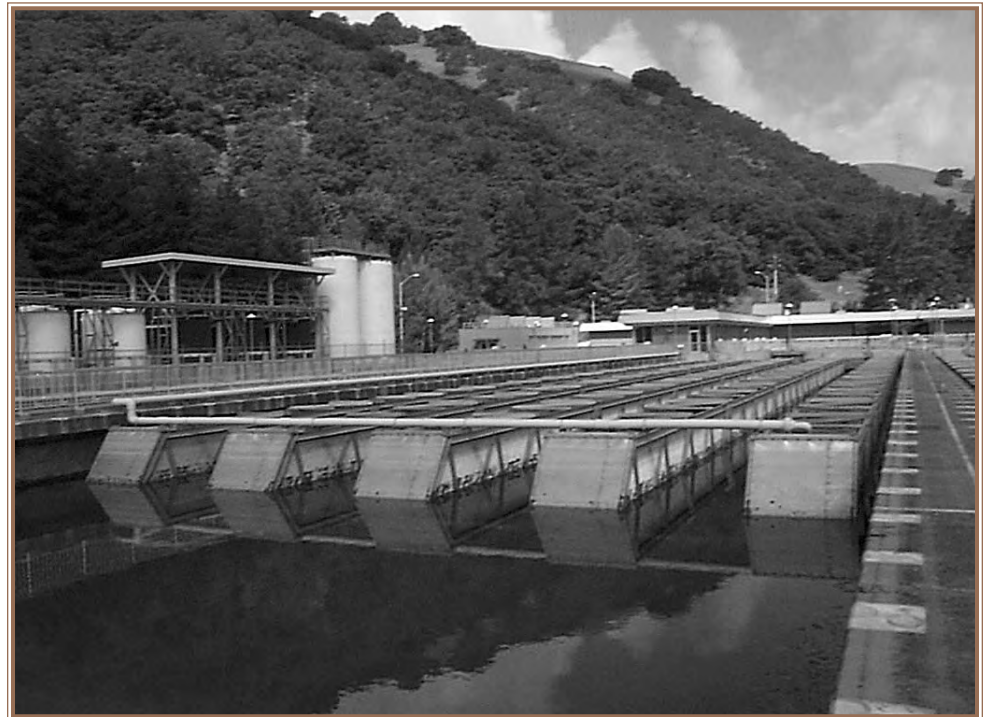
- Provide high quality water to reliably meet current and foreseeable local, state and federal requirements;
- Reduce system vulnerability to damage from earthquakes;
- Increase system reliability by improving redundancy needed to accommodate outages;
- Improve short-term water supply reliability and drought protection;
- Set forth long-term options to address water supply shortages and manage drought;
- Enhance sustainability through improvements that optimize protection of the natural and human environment;
- Provide improvements resulting in a cost effective, fully operational water system.

Achieving a reliable water system requires facility improvements that strengthen the reliability of water storage, treatment and delivery operations, as well as provide sufficient flexibility to operate the system despite facility outages from a catastrophic event, construction shut-down or planned maintenance. System redundancy may be achieved by providing expanded capacity in existing facilities, building a parallel facility, or creating an operational alternative.

Rebuilding the water system includes a variety of capital improvements. New tunnels and pipelines along the Hetch Hetchy aqueduct are planned to improve regional delivery reliability. Reservoirs, tanks and pump stations will be strengthened throughout San Francisco to reliably provide water supplies for public health and fire-fighting in an emergency. To maintain a healthy water supply, facility upgrades are planned to integrate new technologies and equipment into existing treatment plants. Facilities that are aging, in deteriorated condition or vulnerable to failure will be replaced with new facilities to achieve desired reliability objectives.

SUSTAINABILITY PLANNING

San Francisco is undertaking development of a Sustainability Plan as a strategic management tool to integrate and achieve a continuing balance of social, environmental and economic objectives through its policies and practices. San Francisco and its regional wholesale water customers have made a significant, long-term commitment to the future of their water system. It is critical that the SFPUC appropriately manage the physical and financial risks to its water system on behalf of ratepayers, and to make wise decisions on investments which value the unique natural resources, regional diversity, economic complexity and treasured quality of life of the San Francisco Bay Area today and in years to come.



Sumol Valley Water Treatment Plant improvements

APPENDICES



- 1769 Expedition of Portola and Ortega
 1773 Nov 30 Expedition of Moncada and Palou
 1776 *Jul 4 America's 13 original colonies formally declare independence from English rule*
 Presidio Pueblo and Mission San Francisco established
- 1800**
- 1825 *Spanish royal rule in California ends*
 1833 Mexican Secularization Act opens California to world trade
 1835 Trading post established at Yerba Buena Cove
 1836 First adobe building built at Yerba Buena
 1846 *Jul 9 Captain John B. Montgomery, USS Portsmouth, claims Pueblo of Yerba Buena for U.S.*
 Pueblo of Yerba Buena renamed Town of San Francisco
 Population of San Francisco estimated at 800
 1848 *Jan 24 Gold discovered at Sutter's Mill in Coloma, CA*
 1849 Drinking water sold by the barrel and bucket in San Francisco's streets
 Gold Rush swells San Francisco's population to 40,000
Dec 24 Christmas Eve fire devastates San Francisco; \$1 million in damages
 1850 San Francisco devastated by fire four times in peak of Gold Rush; damages more than \$6 million
Sep 9 California becomes 31st state admitted to the Union
 1851 Mountain Lake Water Company formed
 Sausalito Water and Steam Tug Company imports water by barge from Marin
Dec 14 Sixth major fire in city destroys 3,000 homes over a square mile; \$12 million in damages
 1853 Groundbreaking ceremonies at Presidio for Mountain Lake municipal water supply
 1856 San Francisco City Water Works granted franchise; first pipelines laid in the city
 San Francisco's population drops to 30,000
Jul 1 City and County of San Francisco Consolidation Act takes effect
 1857 San Francisco City Water Works brings water from Lobos Creek
 1858 Spring Valley Water Works franchised by State Legislature
 1860 Alexei W. von Schmidt becomes Chief Engineer of Spring Valley Water Works
 U.S. Census reports San Francisco population at 78,000
 Spring Valley takes over Islais and Salinas Water Company
 1861 San Francisco City Water Works builds Francisco Reservoir near Russian Hill
 First Pilarcitos Dam and Tunnel built on Peninsula
Apr 12 Southern Confederacy opens fire on Fort Sumter; SC to start Civil War
 1862 *Jul 4 Pilarcitos water supply reaches San Francisco in time for festivities*
 Spring Valley Water Works now rivals San Francisco City Water Works
 1864 A. W. von Schmidt leaves Spring Valley Water Works for private practice
Oct 8 Spring Valley hires Hermann Schussler to raise Pilarcitos Dam
 City Water Works, faced with silt in its water, taps into Spring Valley water main
 1865 Hermann Schussler starts second tunnel in Pilarcitos Aqueduct
Central Pacific Railroad starts western line of transcontinental railroad through Niles Canyon
Feb 13 Spring Valley buys out San Francisco City Water Works
 1866 *May Hermann Schussler named Chief Engineer of Spring Valley Water Works*
 1867 Main Pilarcitos Dam completed to height of 70 feet; first dam submerged
 1868 Spring Valley Water Works buys San Andrés Valley and Watershed
Apr Hermann Schussler starts construction of San Andrés Dam
Aug Spring Valley Water Works acquires rights to Lake Merced
 1869 Spring Valley Water Works sues San Francisco to pay their bills for municipal water supplies
May 10 Golden spike driven into the final tie of the first transcontinental railroad
 1870 State legislature considers bill by A. W. von Schmidt to provide Lake Tahoe water to the City
Jun Lock's Creek Line Aqueduct (Stone Dam Tunnel No. 1) started
 1871 Stone Dam and Lock's Creek Tunnel completed
Apr Mayor Thomas Selby vetoes Board of Supervisors \$6 million bond issue for Lake Tahoe supplies



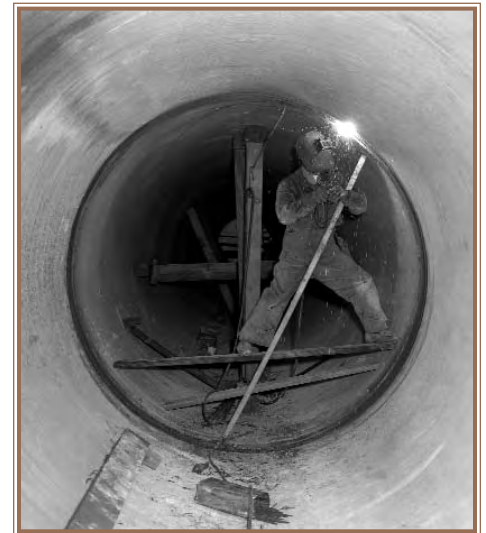
E. R. Bottimore, watershed keeper on patrol 1924

- 1873 San Francisco makes its first offer to buy out the Spring Valley Water Works
- 1874 H. Schussler raises Pilarcitos and San Andrés Dams to 95 feet each
- 1875 *Apr 19* City Engineer T. R. Scowden recommends that San Francisco buy Calaveras site
 Spring Valley Water Works buys Calaveras land and water rights
 San Francisco again offers to buy out Spring Valley Water Works
- 1876 *Mar 10 Alexander Graham Bell speaks over the first telephone*
- 1877 Upper Crystal Springs Dam completed to height of 70 feet
 Spring Valley Water Works declines San Francisco's buyout offer of \$11 million
- 1880 New State Constitution gives San Francisco Board of Supervisors authority to fix water rates
- 1882 *Sep 4 Thomas Edison opens first commercial plant to generate electricity in New York City*
May John P. Dart, San Francisco and Tuolumne Water Company, proposes Tuolumne River water for San Francisco
- 1888 San Francisco Mayor E. P. Bond buys Tuolumne River water rights for \$200,000
- 1890 H. Schussler completes Lower Crystal Springs Dam and first outlet gate tower
- 1891 John Quinton surveys Tuolumne River as potential San Francisco water source
 H. Schussler raises Lower Crystal Springs Dam parapet and builds second outlet gate tower
- 1898 Spring Valley Water Works stops use of Lock's Creek Aqueduct, drills in Pleasanton Well Field
- 1900**
- 1900 *Jan 8* New City Charter requires development of municipal water supply
 U.S.G.S. 21st Annual Report recommends Hetch Hetchy for San Francisco's water supply
 Spring Valley Water Works completes Sunol Aqueduct and Filter Beds
- 1901 *Feb 15* Congress permits the Interior Secretary to grant rights-of-way through Yosemite
July 29 As private citizen, Mayor James Phelan files for water rights on Tuolumne River
Aug 12 City Engineer Carl Grunsky recommends Tuolumne River out of 13 sources considered
Oct 15 Mayor Phelan applies to Interior Secretary Ethan Hitchcock for reservoir sites in Sierra Nevada
- 1903 Spring Valley Water Company buys out Spring Valley Water Works
Jan 20 Secretary Hitchcock denies San Francisco's application to develop Hetch Hetchy
Feb 20 Mayor Phelan assigns all Hetch Hetchy water interests to San Francisco
Dec 17 Orville and Wilbur Wright take first flight over dunes at Kitty Hawk, NC
- 1906 Board of Supervisors adopts resolution No. 6949 abandoning development of Hetch Hetchy
Apr 18 Great Earthquake disrupts San Francisco's water supply; fires rage for three days
May 26 A. W. von Schmidt dies at age 85
- 1907 U.S.G.S. declares name of San Andrés Valley to be San Andreas
- 1908 *Apr 22* City Engineer Marsden Manson files duplicates of Phelan's maps with Interior Secretary James Garfield
May 11 Secretary Garfield grants City limited permission to develop Hetch Hetchy and Lake Eleanor
- 1909 Hermann Schussler retires from Spring Valley Water Company
- 1910 Diversion tunnel constructed at Lake Eleanor dam site
 Sunol Water Temple, designed by noted architect Willis Polk, built to celebrate Sunol Valley waters
Jan 14 San Francisco overwhelmingly approves \$45 million bond issue to build Hetch Hetchy
Feb 25 Interior Secretary Richard Ballinger withdraws Hetch Hetchy from Garfield Permit
Apr 13 City purchases Eleanor Basin lands and water rights for \$400,000
May Secretary Ballinger asks War Secretary Jacob Dickinson to assign Board of Army Engineers to consider Hetch Hetchy Project
- 1911 California Constitution grants Railroad Commission authority to fix water rates
 Crystal Springs Dam raised to 154 feet
Jun 22 City purchases Cherry Basin land and water rights for \$600,000
- 1912 *Jan 8* James "Sunny Jim" Rolph becomes Mayor of San Francisco
Jul 15 John Freeman publishes his plan to develop Hetch Hetchy, Eleanor and Cherry Valleys
Sep 1 Mayor Rolph hires Michael M. O'Shaughnessy as City Engineer
Nov City attends hearings before Interior Secretary Walter Fisher on Hetch Hetchy Project



*Roughening the crest of O'Shaughnessy Dam
1937*

- 1913 Feb 19 Board of Army Engineers recommends Hetch Hetchy as best supply for San Francisco
 Mar 1 Interior Secretary Fisher refuses further permits without Congressional authority
 Jul 3 Spring Valley starts construction of Calaveras Dam
 Aug 1 Rep. John E. Raker, California, 2nd District, introduces Hetch Hetchy Act to Congress
 Sep 3 & Dec 6 House & Senate, respectively, adopt Raker Act
 Dec 19 President Woodrow Wilson signs Raker Act into law
- 1914 Spring San Francisco ratifies Raker Act
 Apr Surveys start for Hetch Hetchy Railroad route
 Jul Contractors begin building Hetch Hetchy roads at Hog Ranch (now Camp Mather)
- 1915 Jul 21 Canyon Ranch sawmill starts operations to provide lumber for Hetch Hetchy
 Sep 1,000-foot tunnel built inside cliff at O'Shaughnessy Dam site to divert Tuolumne River
 Dec 6 Construction of Hetch Hetchy Railroad starts
- 1916 Aug 11 Construction of Lower Cherry Aqueduct starts
- 1917 Apr 6 *U. S. enters World War I after German submarines sink five American ships*
 Summer Lower Cherry Diversion Dam completed
 Jul Drifting Mountain Tunnel begins at Early Intake and South Fork
 Aug Construction starts on Eleanor Dam
 Oct Hetch Hetchy Railroad begins operation
- 1918 Mar 24 Calaveras Dam fails during construction; Michael O'Shaughnessy monitors reconstruction
 May 6 Early Intake (Lower Cherry) Powerhouse starts operation
 Jun Eleanor Dam completed to height of 70 feet
 Sep 18 City begins commercial sale of surplus Early Intake power to PG&E for revenue stream
- 1919 Apr Hermann Schussler dies at age 77
 Jun Hetch Hetchy Sawmill moves to Hog Ranch (now Camp Mather), nearer the dam site
 Aug 1 Utah Construction Co. awarded contract to build O'Shaughnessy Dam
- 1920 Jan 16 O'Shaughnessy Dam Diversion Tunnel completed
- 1921 State Railroad Commission directs Spring Valley to raise Calaveras Dam
 Fall Construction of Moccasin Powerhouse and Priest Dam starts
- 1922 Jun Construction of Moccasin Power Tunnel starts
 Jun 23 Construction of Pulgas Tunnel at Crystal Springs starts
 Jul Construction of Moccasin Penstock starts
 Aug 17 San Francisco obtains option to buy Spring Valley Water Company; agrees to build transbay pipeline
- 1923 Apr 6 O'Shaughnessy Dam completed to a height of 226.5 feet, capacity 206,000 acre feet
 May 18 Contract awarded to begin construction of Bay Crossing Pipeline
 Jul 7 O'Shaughnessy Dam dedicated to its builder
 Oct 2 Construction of Early Intake Diversion Tunnel starts
 Oct Priest Dam completed
- 1924 Sawmill operations at Hog Ranch (Camp Mather) terminated
 Jan Construction begins on trestle bridge across Dumbarton Strait for Bay Crossing Pipeline
 Aug 27 Pulgas Tunnel completed
 Aug 28 Upper Crystal Springs Dam Tunnel, damaged in 1906, restored to use
 Oct 7 \$10 million bond issue for Foothill and Coast Range Tunnels approved
- 1925 Calaveras Dam completed to height of 215 feet
 Apr 10 Early Intake Diversion Dam completed
 Jun 1 Moccasin Penstock completed
 Jun 2 Mountain Tunnel complete, first water delivered to Priest Reservoir
 Aug 14 Moccasin Powerhouse begins commercial operations
 Sep 12 Bay Crossing Pipeline No. 1 placed in partial service
 Nov 27 Hetch Hetchy moves its construction staging area from Groveland to Hetch Hetchy Junction, near Foothill Tunnel
- 1926 Feb 4 Foothill Tunnel construction starts from Pedro Adit
 May 21 Bay Crossing Pipeline No. 1 enters full service



Welding inside Bay Division Pipeline No. 4 1966

- 1927 Apr Construction of Coast Range Tunnel starts
 May Construction of Mocho Shaft on Coast Range Tunnel starts
May 20 Charles Lindberg flies the Spirit of St. Louis 1,000 miles across the Atlantic Ocean
- 1928 San Andrés Dam raised to 105 feet
 May 1 \$24 million bond issue approved for Coast Range Tunnel and San Joaquin Pipelines
 May 1 \$41 million bond issue approved to purchase Spring Valley Water Company
 Jul 19 Construction of Moccasin Dam starts
 Dec 6 Foothill Tunnel holed through
- 1929 Sep Foothill Tunnel completed
Oct 29 Stock market crashes; nation enters Great Depression
 Nov Moccasin Dam and Reservoir completed
- 1930 Mar San Francisco purchases Spring Valley Water Company for \$39.96 million
 San Francisco Water Department created under Board of Public Works
- 1931 Second outlet tower built at Crystal Springs Reservoir
 Jul 17 Mitchell Shaft methane gas explosion in Coast Range Tunnel cost lives of 12 crew
- 1932 Jan 8 New Charter puts Hetch Hetchy and Water Department under San Francisco Public Utilities Commission
 May 3 \$6.5 million bond issue passed to complete Coast Range Tunnel
 Jul 9 San Joaquin Pipeline No. 1 completed
- 1933 *Worst year of Great Depression: unemployment reaches 25%, stocks drop 80% of their value*
 Nov 7 Two bond issues approved: \$3.5 million to raise O'Shaughnessy Dam, and \$12.1 million to construct second Bay Crossing Pipeline and City Distribution System improvements
- 1934 Jan 5 Coast Range Tunnel holed through from Mocho to Mitchell Shaft
 Feb 24 Alameda Creek Siphon No. 1 completed
 Aug 24 Construction of Bay Crossing Pipeline No. 2 started
 Oct 12 Michael M. O'Shaughnessy dies at 72, just days before Hetch Hetchy Aqueduct is finished
 Oct 24 First Hetch Hetchy water flows into Pulgas Water Temple at 10:12 a.m.
 Oct 28 City celebrates completion of Hetch Hetchy water system at Pulgas Water Temple
- 1935 Nov 18 Construction starts on Moccasin diversion works
- 1936 Jun 22 Bay Crossing Pipeline No. 2 completed
 Aug 31 Moccasin Reservoir Bypass diversion works completed
 Dec 16 Interior Secretary Harold Ickes approves plan for disposition of Hetch Hetchy power
- 1938 Jul 1 O'Shaughnessy Dam raised 85.5 feet, to its present capacity of 360,360 acre feet
- 1941 *Dec 7 Surprise Japanese air attack on U.S. fleet at Pearl Harbor; U.S. declares war*
- 1945 Jun 22 Exploratory work at Cherry River dam site starts
 Jul 2 Secretary Ickes approves new power disposition contracts as compliant with the Raker Act
- 1946 May 11 Hetch Hetchy starts power delivery to Modesto's Station J
- 1947 Nov 4 \$25 million bond issue approved to construct San Joaquin Pipeline No. 2 and Bay Division Pipeline No. 3
- 1948 Feb Irvington Pump Station moves water from the Sunol Aqueduct into Hetch Hetchy pipelines
- 1949 Hetch Hetchy Railroad tracks removed
 Nov 8 \$4 million bond issue approved to construct Cherry Valley Dam; federal government promises \$9 million
- 1950 Jun 9 SFPUC celebrates opening of first portion of San Joaquin Pipeline No. 2 west of Oakdale
 Dec Rock River Lime Treatment Plant completed
- 1951 Jun Construction of 22,000-volt power line from Early Intake to Cherry Valley Dam site starts
- 1952 Oct 17 San Joaquin Pipeline No. 2 enters service for entire 47.5-mile length
- 1953 Mar 25 San Joaquin Pipelines No. 1 and No. 2 operate jointly for the first time
 Aug Construction of Cherry Valley Dam starts
- 1954 May 18 Cherry Creek water diverted at dam site
- 1955 Oct 27 Cherry Valley Dam dedicated
 Nov 8 \$54 million bond issue approved to construct Canyon and Cherry River power projects
Dec 1 Rosa Parks refuses to give up her bus seat in Montgomery, AL; puts face on segregation
- 1956 Bay Division Pipeline No. 3 completed
 Mar 15 First joint operation of Hetch Hetchy and Lake Lloyd (Cherry Lake) for flood control



Construction of Stone Dam Flume 1871

- 1957 Aug 30 Construction of Cherry Power and Eleanor-Cherry Tunnels starts
- 1958 Sep 16 Construction of Cherry Powerhouse begins
- 1959 Jan 26 Cherry Power Tunnel is holed through
Apr 6 New transmission line from Early Intake to Moccasin completed
May 18 Eleanor-Cherry Tunnel is holed through
- 1960 Mar 6 First water diversion to Lake Lloyd (Cherry Lake) through Eleanor-Cherry Tunnel
Jun 17 Cherry Power and Eleanor-Cherry Tunnels completed
Aug 1 Cherry Powerhouse begins commercial operation
Aug 25 Early Intake Powerhouse ceases operation after 46 years
- 1961 Feb 24 Water deliveries begin to Lawrence Livermore National Laboratory
Nov 7 \$115 million bond issue approved to build San Joaquin Pipeline No. 3, New Don Pedro Reservoir, Bay Division Pipeline No. 4, San Andreas Water Treatment Plant and Turner (San Antonio) Dam
- 1963 Nov 22 *President John F. Kennedy assassinated in Dallas, TX; nation mourns*
- 1964 Jun 24 Canyon Power Tunnel is holed through
- 1965 Turner Dam completed to 195 feet, forming San Antonio Reservoir
Feb 26 Canyon Power Tunnel is completed
Jun 30 Hetch Hetchy system delivers 220 million gallons to Bay Area, a new record
Nov 3 First water delivered to Groveland Community Services District
- 1966 Sep 14 Sunol Valley Water Treatment Plant activated
- 1967 Aug 25 Robert C. Kirkwood Powerhouse dedicated
Sep 1 Construction on New Don Pedro Dam starts
- 1968 Mar 29 San Joaquin Pipeline No. 3 enters service
- 1969 Jan 27 New Moccasin Powerhouse begins operation
Feb 7 Old Moccasin Powerhouse taken out of service after 44 years
Jul 16 *“One small step for man; one giant leap for mankind” - Apollo 11 lands on the moon*
- 1970 May 28 New Don Pedro Dam topped out
- 1971 May 22 New Don Pedro Dam dedicated
- 1972 Pilarcitos Dam upstream face repaired
Jun 14 Bay Division Pipeline No. 4 completed
Aug 8 San Andreas Filtration Plant activated
- 1974 Aug 9 *President Nixon resigns in response to public outcry over Watergate scandal*
- 1975 Calaveras Dam strengthened
Jul 1 City negotiates and extends PG&E contract covering power wheeling, supplementary energy and standby service
- 1976 Sunol Valley Water Treatment Plant expanded to 160 million gallons per day
Lower Crystal Springs Dam designated Historic Civil Engineering Landmark
- 1982 Feb San Andreas Pipeline No. 3 placed into service
- 1984 Spring Construction starts on power line from new Moccasin Low-Head Power Plant
Nov \$104 million bond issue approved to rebuild water treatment plants and pipelines
- 1986 Moccasin Low-Head Power Plant starts operation
- 1987 First year of prolonged, six-year drought
- 1988 New Crystal Springs Pipeline No. 3 placed in service to South San Francisco
Kirkwood Powerhouse Unit 3 goes into operation
Long-term power contracts signed with PG& E, Modesto and Turlock Irrigation Districts
May Drought deepens; 25% mandatory rationing imposed in San Francisco
- 1989 San Andreas Water Treatment Plant expanded to 120 MGD
Oct 17 *6.9 Loma Prieta Earthquake strikes San Francisco and Monterey Bay regions*
Nov 9 *Berlin Wall between East and West falls; Cold War is over*
- 1991 Unprecedented fifth critically dry year in Sierra Nevada
SFPUC builds connection to state’s South Bay Aqueduct to transfer purchased water supplies
Calaveras Pipeline replaced throughout its length
Apr Hetch Hetchy Reservoir reaches dangerously low levels; 45% mandatory rationing imposed
Nov Board of Supervisors mandates recycled water use for irrigation and flushing waste



Automobile crossing South Fork 1925

- 1992 Heavy winter storms recharge San Francisco's local and Sierra Nevada reservoirs
SFPUC assesses feasibility of using local aquifers as new drinking water sources
- 1993 California Department of Water Resources declares drought over; rationing rescinded
- 1994 Feb Dedication of Harry W. Tracy (formerly San Andreas) Water Treatment Plant
Jul Muni removed from SFPUC, which retains control of Water and Hetch Hetchy enterprises
- 1996 Mar Federal Energy Regulatory Commission (FERC) reauthorizes New Don Pedro Dam
Jul Clean Water Program moves to SFPUC, which now governs all water enterprises
- 1997 Nov 4 \$304 million bond issue passed to upgrade water treatment facilities and make seismic improvements
- 1998 Jul 75th Anniversary Celebration commemorating completion of O'Shaughnessy Dam.
- 2000**
- 2000 *May California Energy Crisis hits San Francisco Bay Area hardest; rolling blackouts are frequent*
Sep Alameda Watershed Management Plan adopted by SFPUC
- 2001 SFPUC completes intertie with Santa Clara Valley Water District system for emergency supplies
Jun Peninsula Watershed Management Plan adopted by SFPUC
Sep 11 Terrorists hijack commercial airliners to bomb World Trade Center in New York City
Dec SFPUC adopts Interim Shortage Allocation Plan to amend wholesale water agreements
- 2002 Jan 18 California enacts the Wholesale Regional Water System Security and Reliability Act (AB 1823) to protect the interests of SFPUC suburban customers in Hetch Hetchy system improvements
Nov 5 \$1.6 billion bond measure approved to rebuild Hetch Hetchy water system; voters establish citizen advisory and bond oversight committees, and a rate fairness board
- 2003 \$50 million in process and facility upgrades to Sunol Valley Water Treatment Plant completed
- 2004 Jan Priest Reservoir Bypass completed; disrupts delivery of Hetch Hetchy supplies without service impacts
Feb San Francisco changes to chloramine residual disinfection to improve drinking water quality



Celebration of San Francisco's purchase of Spring Valley Water Company, City Hall Rotunda 1930

San Francisco City Water Company General Managers

1858 - 1860 Alexei Waldemar von Schmidt

Spring Valley Water Works General Managers

1860 - 1864 Alexei Waldemar von Schmidt
 1864 - 1866 Calvin Brown
 1866 - 1909 Hermann Schussler
 1911 - 1914 Fred C. Herrmann
 1914 - 1930 George A. Elliott

San Francisco Water Department General Managers

1930 - 1948 Nelson A. Eckart
 1949 - 1957 George W. Pracy
 1957 - 1963 James H. Turner
 1963 - 1965 Oral L. Moore
 H. Christopher Medbery
 1965 - 1976 Arthur H. Fry, Jr.
 1976 - 1978 Kenneth R. Boyd
 1978 - 1984 Eugene J. Kelleher
 1984 - 1985 Arthur Jensen (Acting)
 1985 - 1986 Dean W. Coffey
 1986 - 1989 James D. Cooney
 1989 - 1990 Arthur Jensen (Acting)
 1990 - 1999 John P. Mullane

**San Francisco Water Enterprise
 Assistant General Managers**

2005 - Michael Carlin

**San Francisco Power Enterprise
 Assistant General Managers**

2005 - Barbara Hale

**Hetch-Hetchy Water and Power
 General Managers**

1912 - 1932 Michael M. O'Shaughnessy
 1932 - 1942 Lloyd T. McAfee
 1942 - 1945 James H. Turner
 1945 - 1952 Axel O. Olson
 1952 - 1961 Harry E. Lloyd
 1961 - 1979 Oral L. Moore
 1979 - 1985 Dean W. Coffey
 1985 - 1986 Theodore L. Chung (Acting)
 1986 - 1988 Dean W. Coffey
 1988 - 1993 Anson B. Moran
 1993 - 2000 Lawrence T. Klein
 2000 - 2001 Laurie Park (Acting)
 2002 - 2004 Marla Jurosek & Don Larramendy (Acting)
 2005 - Don Larramendy

**San Francisco Public Utilities Commission
 General Managers**

1932 - 1945 Edward G. Cahill
 1945 - 1956 James H. Turner
 1956 - 1958 T. N. Bland
 1959 - 1964 Robert C. Kirkwood
 1964 - 1970 James K. Carr
 1970 - 1976 John D. Crowley
 1977 - 1979 John B. Wentz
 1979 - 1983 Richard Sklar
 1983 - 1986 Rudolf Nothenberg
 1986 - 1988 Donald J. Birrer
 1988 - 1989 Dean W. Coffey
 1989 - 1993 Thomas J. Elzey
 1993 - 2000 Anson B. Moran
 2000 - 2001 John P. Mullane
 2001 Lawrence Klein (Acting)
 2001 Steven Leonard (Acting)
 2001 - 2004 Patricia E. Martel
 2004 - Susan Leal



San Francisco supervisors visit the Sierra Nevada 1917

San Francisco Water and Power by Warren D. Hanson, 1985

Subsequent editions: 1987, 1994, 1999, 2002 and 2005

Mr. Hanson wished to acknowledge former San Francisco Public Utilities Commission employees James H. Leonard and Ted Wurm for their careful and attentive editing of the 1967 and 1979 editions, and to draw the reader's attention to Mr. Wurm's *Hetch Hetchy and its Dam Railroad* (Howell-North Books: 1973 *et seq*) as a valuable reference.

Additional sources include:

San Francisco Water, published quarterly 1922 - 1930 by Spring Valley Water Company, Edward F. O'Day, editor.

San Francisco Water and Power, published for the San Francisco Public Utilities Commission by the Bureau of Engineering, 1935 and 1947.

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San Mateo County Historical Association, College of San Mateo.

Society of California Pioneers.

Congressional Record - 1893/1894; 1899/1900; 1912/1913.

"Hetchy" by R. W. Taylor.

"The Top of the Peninsula." by Marianne Babsal (Historic Resource Study, Golden Gate National Recreation Area, National Park Service, 1990).

History of California, Hubert Howe Bancroft, 1963-1970.

Yosemite's Hetch Hetchy Railroad, Ted Wurm (Stauffer Publishing: 1990, 4th ed., rev.)

Annual Reports of the San Francisco Water Department.

Annual Reports of the San Francisco Public Utilities Commission.

Municipal Reports, 1850-75.

Of special and valued assistance was Gladys Hansen, former Curator of the San Francisco Room at the San Francisco Main Library, to whom the author and editors owe a deep debt of personal gratitude. Ms. Hansen's research into the true number of casualties from the 1906 Great Earthquake and Fire is invaluable to San Francisco's history.

Anne Milner and Franz Hansell contributed to updating the 1994 edition of *San Francisco Water and Power*.

For the 1999 edition, the editors wish to acknowledge the special contributions of San Francisco Public Utilities General Counsel Thomas M. Berliner and Deputy City Attorney Joshua D. Milstein in reorienting the text chronologically to unfold the compelling story of San Francisco's search for water and the landmark Hetch Hetchy building program. Thanks to the firm JRP Historical Consulting, Inc. for reviewing the text for accuracy.

The 2005 edition contains significant revisions by editors Frank Kukula, Christopher Nelson and Mary Williams to update the text and photographs. They wish to acknowledge the special contributions of Photography Archive Librarian Katherine du Tiel for her zeal in locating new historical photographs; Hetch Hetchy Water & Power archive librarians Claudia Day and Katherine Jose for their diligent research; and senior operations managers in the San Francisco Public Utilities Commission water and power enterprises for their careful review of new inclusions to the text.

The editors gratefully acknowledge Mimi Chu Reyes, a superb graphic designer, who is responsible for the new look of this 2005 edition.

PHOTO CREDITS:

Front cover photo: O'Shaughnessy Dam and Hetch Hetchy Reservoir

Page 1: San Andreas Reservoir and Watershed

Page 19: Headwaters of Tuolumne River in winter

Page 28: O'Shaughnessy Dam and Hetch Hetchy Reservoir 1926

Page 48: Hetch Hetchy Railroad snowplow 1932

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