ENGINEER'S REPORT

ON THE PROJECTS OF THE

VOLCAN LAND & WATER COMPANY

H. HAWGOOD

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LOS ANGELES, CALIFORNIA

Volcan Land & Water Company's

Warner - Pamo and Pamo - Linda Vista

Power and Irrigation Projects.

San Diego County, California.

November, 1912.

The reports which follow enter in detail into the prospective costs and commercial productivity of the Warner & Pamo and Pamo - Linda Vista Projects. The conclusions therein formed are presented in a condensed form in the following two pages. On the first will be found the estimated cost of the works and the values which would be created by the contemplated projects, and on the second page, the expenditures needed for an initial installation sufficient to place the projects on a revenue footing.

Detail estimates of construction cost and revenue, for the Warner - Pamo Project, are to be found on pages 22, 23 and 25, and for the Pamo - Linda Vista Project, on pages 37 and 38

H. Hawgood

Estimate of Cost of the Warner - Pamo and Pamo - Linda Vista Projects, and of the resulting values.

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Warner - Pamo Project,

Cash cost of works, exclusive of water rights, lands and financing		$1,118,000
Pamo - Linda Vista Project,		
Cash cost of works, exclusive of water rights, lands and financing		2,096,000
		$3,214,000

Product.

Power, 3,900 KW., net annual operating earnings $261,000, capitalized @ 10%	$2,610,000	
Water, 5,200 Miners Inches (During irrigating season)	7,800,000	
	$10,410,000	

Sutherland and Santa Marta Auxiliaries.

Cash cost of works, exclusive of water rights, lands and financing	$800,000

Product.

Power, 1,500 KW., net annual operating earnings $133,000, capitalized @ 10%	$1,330,000	
Water, 1,000 Miners Inches (During irrigating season)	1,500,000	
	$2,830,000	

Summary.

Cash cost of works, exclusive of water rights, lands and financing	$4,014,000
Resulting created values	13,240,000

Estimate of cost of Initial Installation of the
Warner - Pamo and Pamo - Linda Vista Projects.
Cash cost exclusive of water rights, lands and financing.

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Warner Dam and Conduit			$549,385
Power Plant		$251,920	
50 miles Transmission line	192,500	444,420	$993,805
Temporary conduit from power plant to head of Pamo - Linda Vista Conduit, 4 miles			30,000
Pamo - Linda Vista Conduit, postponing greater part of cement lining			825,000
Part of San Clemente Reservoir			50,000
			$1,898,805
Engineering, Legal and Sundry expenses and contingencies, approx. 15%			284,195
			$2,183,000

If the purchasers to whom the power was wholesaled elected to build the transmission themselves, this amount would be reduced $220,000.

These works would produce 3,900 KW., (5,200 Horse Power), and deliver 2,200 Miners Inches continuous flow to Linda Vista, less seepage and evaporation losses. The above cost contemplates temporary omission of most of the lining of the conduit, and the seepage loss would amount to about twenty or thirty per cent, leaving an actual delivery of about 1,600 Miners Inches continuous flow, or 2,000 to 2,500 inches during the irrigation season, which is sufficient to take care, for the first three or four years of their life, of twenty to twenty-five thousand acres of orchards, if not cropped between the trees.

W a r n e r - P a m o
H y d r o - E l e c t r i c P r o j e c t .

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The Volcan Land & Water Company, by its Warner - Pamo Hydro-Electric project, plans the construction of a storage reservoir on the upper waters of the San Luis Rey River, of sufficient capacity to impound and control, for power purposes and subsequent irrigation use, the flow of the river from a catchment area of 210 square miles of mountainous country, the storm waters of which during times of heavy rains are discharged in great floods. The summer flow of the stream is small, and the project is essentially a storage one whose merit lies in the magnitude of the seasonal floods and the ability to store and distribute their waters as needed.

The water possibilities of the river have, for the past seven years been more or less under the observation of the writer, and during the last year and a half, they have, at the instance of the Volcan Land & Water Company, been the subject of close investigation and study. Data as to water supply, and related argument, follow in the latter part of this report, which part treats of the hydrological features of the project. The conclusions therein reached are to the effect that a flow equivalent to an average net discharge into the forebay of the projected power plant of 44.6 cubic feet per second can be

obtained, with an average power developement at the power house switchboard of 4,375 Kilowatts. These figures refer to the average output. On the basis of an average demand factor of 60% of the station capacity, the installation needed would be about 7,500 KW., calling for an hydraulic capacity in the conduit of 77 second-feet. The characteristics of demand are subject to variation from time to time, and a low limit on hydraulic capacity would be apt to prove detrimental to the most advantageous use of the property; with this in view the conduit and its adjuncts have been designed of a capacity of 87.5 second-feet, with an 8,500 KW. installation.

The execution of the project involves the construction of a 100-foot dam, a conduit 8.9 miles in length, forebay with pressure pipe 6,670 feet in length under a maximum head of 1,500 feet, and a power house and plant of 8,500 KW. capacity, with 50 miles of high tension transmission lines, at a total estimated cost of $1,150,000 for construction, exclusive of water rights, lands and financing, provision for which is separately made.

The estimated cost of the work is based upon designs for structures of an economic, permanent type, with low annual

maintenance and depreciation expenditures, and minimum loss of water and efficiency.

The prospective annual surplus from operation, over and above operating expenses, repairs, depreciation, interest on bonds and sinking fund, is estimated at about $61,000.

The estimates of cost and revenue are given in detail on pages 22, 23 and 25.

The field for the disposal of power would be in supplying domestic, industrial and municipal requirements in and around San Diego, Escondido, Del Mar, Oceanside and other places, and for the pumping of irrigation water on lands which have deficient surface supply, but which are underlaid by water bearing strata. The consumption of power for pumping has of late years assumed large propprtions, and is steadily on the increase. Thousands of acres of dry lands in the San Gabriel and San Bernardino Valleys, and on the neighboring coastal plain have by this means been brought into a state of profitable production, largely as orange orchards. Similar opportunities await developement in San Diego County within a reasonable radius of the prospective plant. Warner Valley itself could take a large percentage of the total output.

The consumption of power, as shown by averaging a large number of plants, is about 1 horse power to every 205 Miners Inches per foot of lift, or expressed in average acreage, 1 horse power to about 30 acres. The ordinary charge for power

for pumping is 2½ to 5 cts. per KW. hour. A large part, if not all of the output of the prospective plant could be disposed of at this rate if it were considered commercially best to develope the pumping business.

In forming an estimate of the earning capacity of the plant the pumping field has for the present been omitted and the revenue estimated on the basis of 1 cent per KW. hour, wholesaled to distributing concerns, with provision for fifty miles of transmission.

The estimated earning capacity of the project is confined in this report entirely to the revenue from power output. No valuation has been included for the water after discharge from the power house for the reason that water valuations can be best presented in connection with the Pamo-Linda Vista project, which, as the sequel of the Warner-Pamo, conveys this and other waters to their place of use.

Briefly stated in round figures, the project would carry a construction bond issue of $2,500,000, and after annually defraying interest and sinking fund for redemption of the bonds at maturity, together with all operating expenses, repairs and depreciation or renewals, would yield an annual surplus of $61,600 for dividends on capitalization. It is assumed that $1,000,000 of the bonds would be applied to the acquisition of the water rights and reservoir site, the vendors thereof retaining the right to the water after discharge from

the power house, and that $1,397,500 of the bonds would be sold to net 80 for construction purposes, and the remaining $102,500 of bonds used for rights of way, contingencies and reserve. This is advanced as a method of arriving at a commercial valuation of the project and not in any sense as saying how it would be financed, which is a subject foreign to this report.

Reservoir and Dam.

The reservoir site is situated at the lower end of the Valle de San Jose, generally known as Warner Ranch, about 43 miles north-easterly from the City of San Diego. The dam site is in the gorge where the San Luis Rey River leaves the valley and enters a narrow canyon. This canyon, with an average bottom width of less than two hundred feet, continues for thirteen miles, thence to the sea, thirty-seven miles distant, bottom lands and narrows alternate.

A dam 100 feet in height above the river bed will create a reservoir of 157,000 acre-feet capacity, covering an area of 4,800 acres. As evaporation enters largely into the question of net water supply, a criterion of the value of a reservoir site is given by the ratio of area to capacity. Under this test the Warner reservoir site compares favorably with well known San Diego County reservoirs.

Reservoir		Area per 1,000 Acre-feet capacity	Capacity of Full reservoir
Warner,	Projected	30.6 acres	157,000 ac-ft.
Pamo,	"	18.9 "	49,100 "
Sutherland,	"	24.2 "	16,290 "
San Clemente,	"	37.2 "	11,160 "
Santa Maria,	"	66.6 "	13,500 "
Lower Otay,	Constructed	24.3 "	35,793 "
Morena,	"	29.3 "	46,733 "
Escondido,	"	36.1 "	3,500 "
Sweetwater,	"	39.8 "	22,500 "
La Mesa,	"	44.8 "	1,850 "
Upper Otay,	"	55.2 "	16,282 "
Cuyamaca,	"	84.0 "	11,410 "

Table of the Capacity and Acreage of the Warner Reservoir Site.

Contour Elevation	Capacity above Outlet Acre-feet	Non-available Below outlet Acre-feet	Area Acres.
2618 Level of River Bed		0	0
2640 Level of Outlet Tunnel	0	500	55
2648	560		100
2658	6,800		1,095
2668	14,760		1,395
2678	35,450		1,840
2688	56,970		2,456
2698	86,510		3,498
2708	125,750		4,315
2715	156,500		4,800

The contour elevations are in feet above sea level.

The floor of the reservoir is a deposit of a sandy clay of alluvial or lacrustine nature, well adapted to dam building. The underlying formation is granitic.

The proposed dam, of earth, has a height of 100 feet, a crest length of 575 feet, and will require approximately 350,000 cubic yards of earth in its building. The exact quantity is indeterminate until the stripping on sides and

bottom to secure proper foundation and contact, is fully complete. A liberal provision for this is included in the above quantity.

In addition to the main dam there are two minor dams of small dimensions across depressions in the south ridge, shown by the accompanying contour map and crest line profile.

The dam is designed to have a water face slope of 1 : 3, protected by rip-rap, and a rear slope of 1 : 2 for the upper one-third and 1 : 2.5 for the lower two thirds, with two terraces or benches 12 feet wide, one at elevation 2655 and the other at 2685. Protection of the crest against waves is provided by a concrete parapet wall. A cross section of the proposed dam is shown in the accompanying drawings.

The front portion, to the extent of about two-thirds of the entire mass of the dam, is designed to be of selected impervious materials, laid in layers, sprinkled and rolled; the remaining rear portion of the dam to be of pervious material to insure that the plane of saturation, if saturation occurs, shall not intersect the line of the rear slope above its toe and cause slips.

It is designed to have one or more cut-off walls carried down to suitable foundation, to arrest percolation beneath the dam. One of these walls, of concrete, has been built. The excavation for the construction of this wall and eight borings with a core drill to a maximum depth of 149 feet, afford

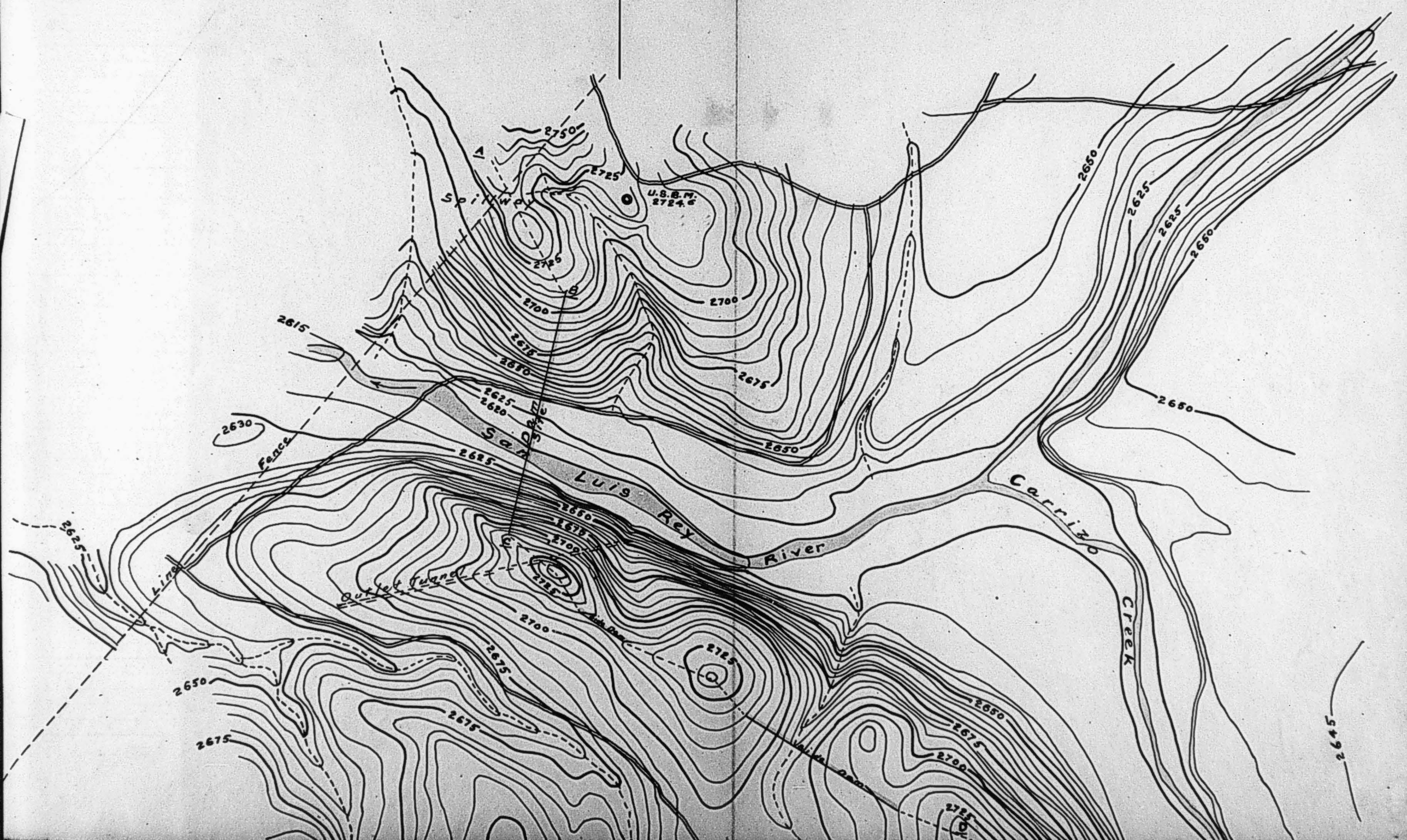
VOLCAN LAND & WATER COMPANY.

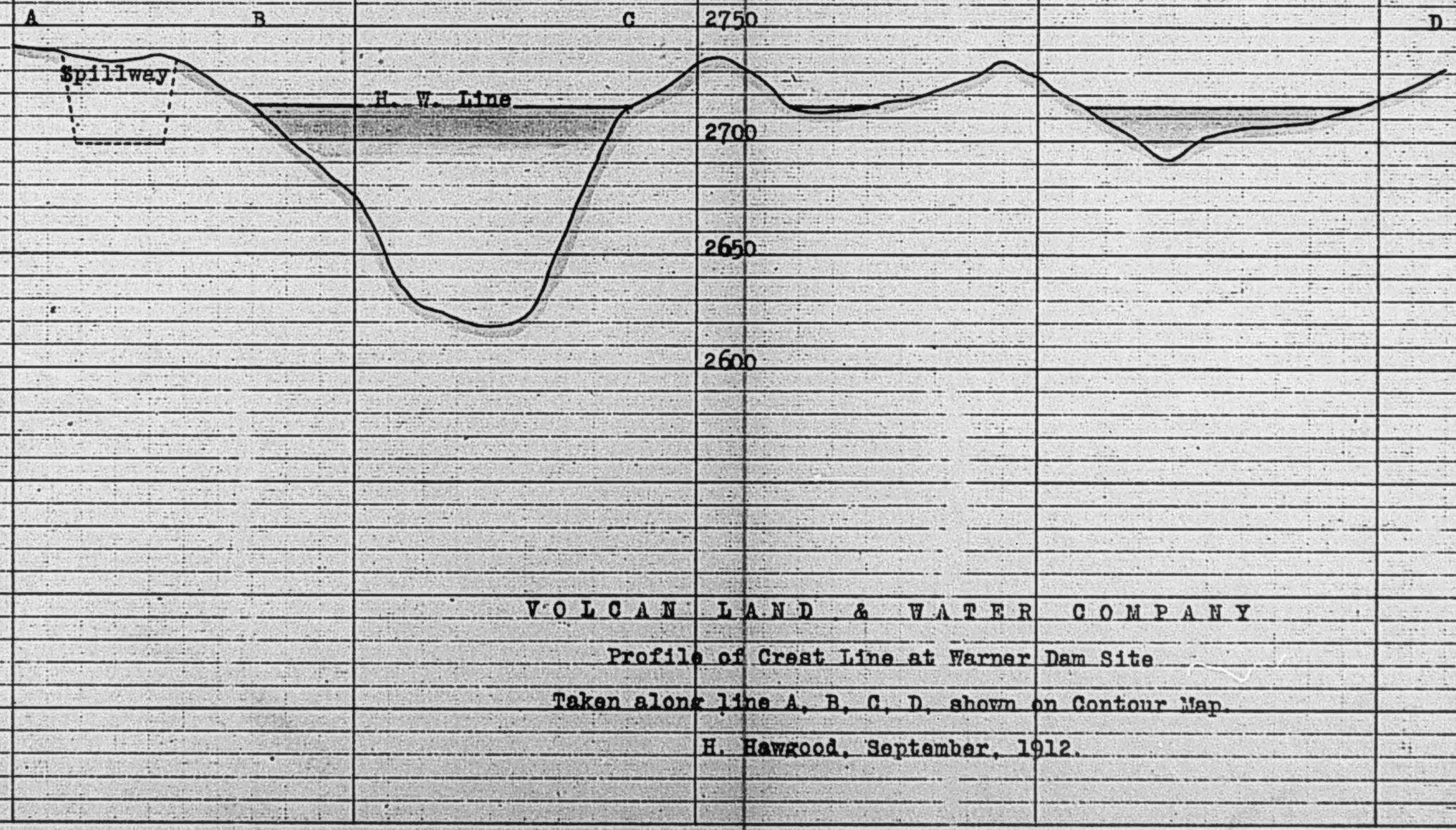
Contour Map of Warner Dam Site.

Contour Interval 5 Feet.

Scale 1 Inch = 200 Feet.

H. Hawgood, September, 1912.





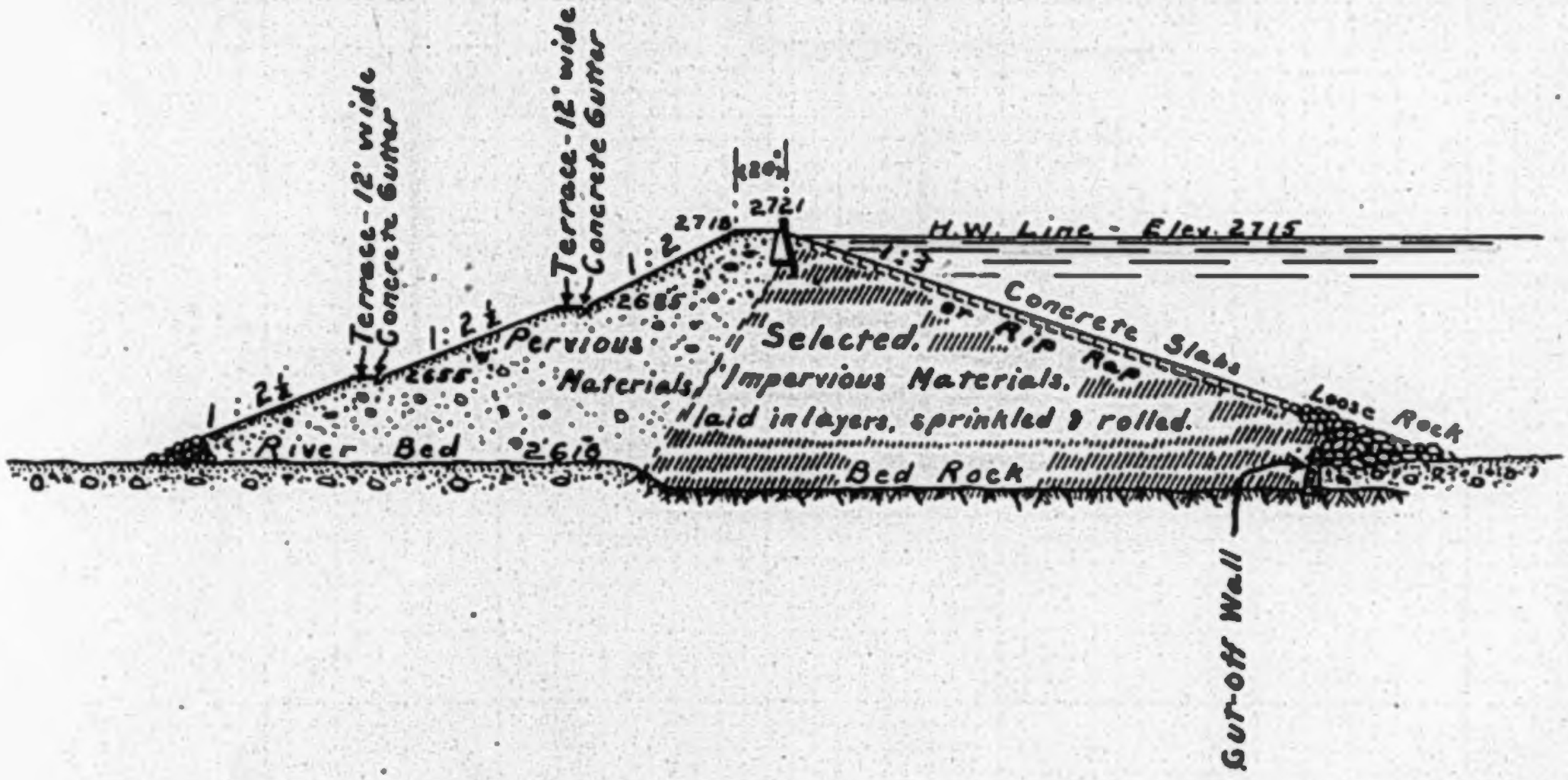
VOLCAN LAND & WATER COMPANY

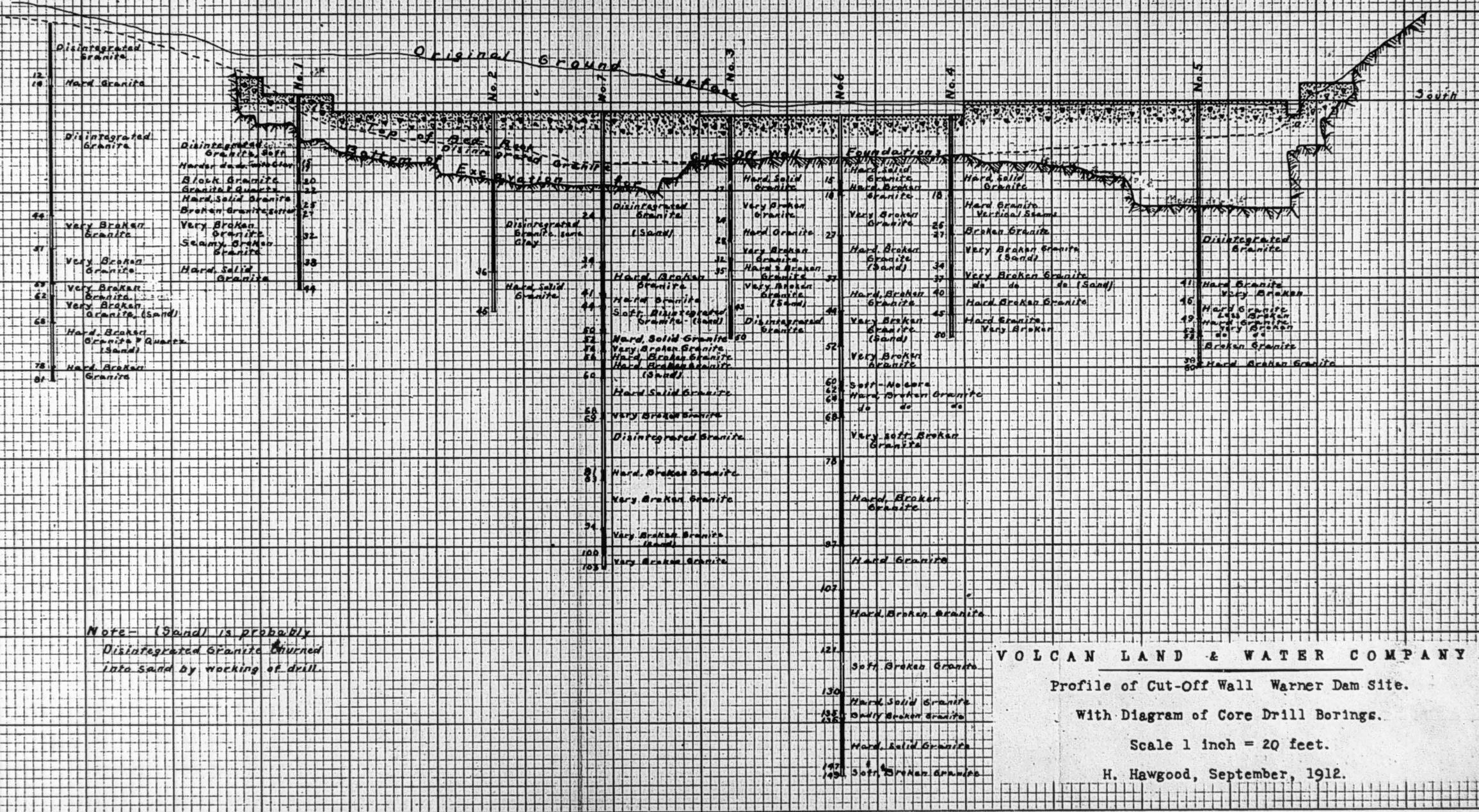
Profile of Crest Line at Warner Dam Site

Taken along line A, B, C, D, shown on Contour Map.

H. Hawgood, September, 1912.

Cross Section of Warner Dam.
Scale 1 inch = 100 feet.





Note- (Sand) is probably Disintegrated Granite churned into sand by working of drill.

VOLCAN LAND & WATER COMPANY

Profile of Cut-Off Wall Warner Dam Site.

With Diagram of Core Drill Borings.

Scale 1 inch = 20 feet.

H. Hawgood, September, 1912.

knowledge of the underlying formation.

A diagram illustrating the core-wall, bore holes and formations encountered is introduced.

The formation disclosed by the excavation for the core-wall and by the bore holes, is entirely granitic. The sand reported by the drillers is, in the writer's opinion after critical examination of several of the cores, nothing but the sand produced by the churning of the drill through disintegrated and soft granite. Intercalated beds or strata of sand is geologically inconsistent with granitic formation? The disintegrated granite encountered is common to Southern California; it is a highly impervious material which has disintegrated in place. The formation will form a safe foundation for the dam. There may be some percolation through it, but that is of no moment; an absolutely tight dam-site is a rarity: the Roosevelt leaks heavily through the formation flanking the dam, the Cold Springs and other dams of the U. S. Reclamation Service, and the Morena and Otay dams, in San Diego County, leak, leak, and many others could be dited. If the passage of the escaping water does not erode the formation, and the volume of the leakage is of no monetary importance, it may be disregarded. In the present case the possibility of erosion is extremely remote if indeed it exists at all, and no monetary loss would ensud from percolation. The Volcan Land & Water Company is obligated to preserve the prior water rights of the Escondido

Mutual Water Company, which concern diverts water from the river at a point several miles below; any percolation under the dam would but serve in preserving this right.

Even if the sub-formation were all sand, which it is not, it would not be prohibitive. There are numerous earth dams both in this country and India built on such foundation. The Jerome Park Reservoir, New York, is a well known case of a dam built partly on rock and partly on saturated quick sand, a foundation far inferior to the Warner site.

The board of Eminent engineers who reported on the Jerome Dam gave it as their opinion that the utmost that could be expected would be the percolation of a small amount of water.

On the north side of the Warner Dam Site there is opportunity to make a spillway of ample capacity, the cost of which is embraced in the estimate. Considering the large capacity of the reservoir, and the order and sequence of floods, a spillway appears somewhat superfluous. It would, however, be imprudent to dispense with one however remote the possibility of its need, and in no event can its construction be altogether a dead loss, for all the hard rock excavated could be used in rip-raping the face of the dam, and the remaining material in the rear body of the dam.

Outlet System.

Advantage is taken of the topography of the south flank of the dam-site to provide an outlet tunnel, length 640 feet, with gate tower control at the intake. There is no safer form of outlet than this.

The floor of the tunnel at the intake end is designed to be at elevation 2640, which is 22 feet above the bed of the river, leaving 500 acre-feet of unavailable water in the reservoir pocket below the tunnel. Further lowering of the tunnel would be uneconomical, it would be attended by an increased cost of conduit outweighing the value of the water gained.

Sedimentation.

There can be no apprehension of loss due to the filling of the reservoir by deposit of material carried in suspension or transported by the incoming waters. Observations and records at the Sweetwater Dam give reliable and pertinent data on this subject. Resurveys of that reservoir basin when it became empty demonstrated that during a period of 12 years sedimentation had taken place at the rate of slightly less than the half of one per cent of the inflowing water.

Applying this sedimentation rate to the estimated average inflow into the Warner Reservoir, that reservoir would be decreased in capacity by process of sedimentation at the rate

of one-eleventh of one per cent per annum. The process is too slow and occasion for remedial action too remote to call for consideration in this generation.

Conduit.

The conduit measured from intake at gate tower in the reservoir to head of pressure pipe line above power house in the Pamo Valley is 46,850 feet, (8.873 miles), composed as follows:

Tunnels, (6)		11,000 ft.	2.083 miles.
Steel & Concrete Flumes on	banks (3)	2,390 "	0.453 "
" " " " "	piers (17)	2,900 "	0.549 "
Excavated conduit, concrete lined		30,560 ft.	5.788 "
		46,850 ft.	8.873 miles.

The Volcan Land & Water Company has furnished contour maps of the country to be traversed by the conduit, platted from surveys made by its field engineers, and upon these maps, aided by his personal familiarity with the ground, the writer has projected an economic location for the conduit. The lengths which appear above and the quantities in the cost estimate which follows have been determined from this projection.

The conduit is designed for a conveying capacity of 87.5 cubic feet per second, with an uniform slope of 1 in 1000, using a value for "n" of 0.017 to meet the increased roughness which the sides and bottom will acquire with age.

The conduit has been projected upon a continuous uniform grade to avoid the losses which arise from accelerating the velocity through flumes and other structures with a view of reducing their dimensions. The relatively small amount which could be so saved would not in this case compensate for the losses of head and capacity which they entail.

A drawing of the typical cross section of the conduit is given on the profile attached. The cement lining can be hand placed or by the recent successful pneumatic device known as the "cement gun".

The ground to be traversed is structurally good, with few if any weak places. The expected excavation in earth, loose and solid rock is given in the cost estimate.

The six tunnels have the following individual lengths, listed in the order of their occurrence from the reservoir to the forebay.

No. 1,	Outlet Tunnel	640 ft.
2,		150 "
3,		1,400 "
4,		2,160 "
5,	Through divide between San Luis Rey and Santa Ysabel drainages	6,510 "
6,		140 "

There are no geological surface features to indicate that bad ground will be encountered in any of these tunnels. From his association with tunneling in the same range further down stream the writer is led to expect that very hard granite

would be encountered in the long tunnel.

The conduit terminates in a small forebay or compensating reservoir of 18.5 acre-feet capacity, created by damming a ravine. A larger reservoir would be desirable but is not obtainable except at exhorbitant cost.

It is conceivable that under certain commercial conditions, such as the selling of all the power output at a high price for peak loads, it would pay to substitute for an open conduit a closed pressure one connected directly with the pressure pipes to the power house, with the flow regulated at the the power house gates instead of at the reservoir outlet tower gates. It is a question to be considered when the manner of disposition of the power is established.

Pressure Pipes.

The length of pressure pipe required between the forebay and the Power House is, according to the Volcan Land & Water Company's preliminary surveys, 6,670 feet, with a maximum head on the lower end of 1,500 feet. These figures have been adopted for the purposes of this report, for if upon further examination and study any revision is made, it would be in the direction of betterment.

The economic diameters of the pipe have been determined to range from a maximum of 55" at the head to a minimum of 39" at the bottom, with a total weight of 2,041,000 lbs.

Estimate of Cost.
Warner - Pamo Project.

D A M .

240,000	cu. yds.	@ 38¢	$91,200.	
55,000	" "	@ 25¢	13,750.	
295,000	" "		104,950.	
Cut off walling			15,000.	
Rip rap, 117,000 sq. ft.		@ 20¢	23,400.	
Crest walling			8,000.	
			151,350.	
Spillway, Gate Tower & Gates			60,000.	$211,350.

C O N D U I T . Total length 46,850 ft.

Excavation,				
Earth,	96,000 cu. yds.	@ 18¢	$17,280.	
Loose Rock,	34,000 " "	@ 35¢	11,900.	
Solid Rock,	26,000 " "	@ 1.10	28,600.	
			$57,780.	
Tunnels,	6,510 ft.	@ $20.	$131,200.	
	4,490 "	@ 16.	71,840.	203,040.
Steel and Concrete Flumes.				
On banks	2,390 ft.	@ $3.75	$ 8,963.	
On 15-ft. Piers	2,430 "	@ $8.75	21,263.	
On 15 to 30 ft.	do 420 "	@ $10.75	4,515.	
On 30 to 50 ft.	do 50 "	@ $15.75	787.	35,528.
	2,900.			
Water passages under conduit				
	60	@ $100.		6,000.
Cement Lining, 30,560 lin. ft.		@ $1.00		30,560
Constructing Wagon Roads				5,000. 330,908.
Total hydraulic works to Forebay, Forward				$549,258.

Forward,		$549,258.
H Y D R O - E L E C T R I C P L A N T .		
Forebay		$ 5,400.
Steel Pressure Pipes, 2,041,000 lbs. @ 7¢ laid		142,870.
Buildings, 4,000 sq. ft. floor area		14,400.
Installation for 8,500 KW.		
Water Wheels and adjuncts @ $3.		
Generators " " @ 7.50		
8,500 KW. @ $10.50	89,250.	
	$251,920.	
Transmission.		
Step up and step down transformers 17,000 KW. @ $2.50	42,500.	
50 Miles steel tower line, 2 circuits #5 copper @ $3,000	150,000.	444,420.
		$993,678.
Engineering, Legal and sundry expenses and contingencies, (approx 12½%)		124,322.
Total		$1,118,000.

The cost of earthwork is based upon the use of steam shovels and individually operated machinery. If the construction of the Pamo-Linda Vista project of the Volcan Land & Water Company were being prosecuted simultaneously, the cost could be lowered by installing a central plant at or near Escondido and distributing the electric power for operating the various construction machines. Mush if not all of the electric appliances and copper of such a plant could be afterwards utilized at full value.

Local conditions as to summer water supply and the great

advantage of completing the dam in one dry season preclude consideration of an hydraulic fill.

The railway base for supplies would be Escondido, with distribution from that point probably by motor trucks. Good roads exist over practically the whole distance from Escondido to the power house site, 23 miles. On the pressure pipe incline, about 1.5 miles, a lifting device would be needed for handling the heavy pipe during construction, and this could be amplified and made of sufficient scope to handle motor trucks. From the head of the incline to Warner Dam, 9 miles, a good road could be made at moderate cost, one would be needed anyway for construction purposes whether it constituted the main highway for transportation of supplies or not. By this route the haul from Escondido to Warner Dam would be 33.5 miles. The alternative route is from San Diego, with a haul of 68 miles.

The average cost of cement on the work, with motor truck transportation, is estimated at $3.30 per barrel, the base price being the present commercial rate of $2.50 F. O. B. Escondido. A lower price could undoubtedly be obtained when the time comes to contract the needed supply, it is, however, best for estimate purposes to follow the high figure. The amount of cement needed is approximately twenty thousand barrels.

The foregoing estimate of cost being based upon preliminary surveys, has throughout leaned strongly to the conservative side, and there can be but little doubt that in the actual fitting of the work to the ground and the opportunity then afforded for detail economic study, that costs would be reduced.

Estimate of Annual Receipts and Expenditures.

Warner - Pamo Project.

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Receipts.

3900 KW. @ 1¢ per KW. hour =		
3900 KW. @ $87.60 per year		$341,640.
On switchboard at Power House	4375 KW.	
Transmission losses, (Transformers and line)	475 "	
Delivered	3900 "	

Expenditures.

Operating Expenses.

Power House, Transmission line and Miscellaneous	0.076¢ per KW. Hour.
General	0.024¢ " " "
	0.100¢ " " "

3900 KW. @ 0.1¢ per KW. hr. =
$8.76 per year $34,164.

Depreciation or Renewals.

Dam & Conduit, $618,000 @ 2%	$12,360.		
Power Plant, $283,000 @ 8%	22,640.		
Transmission Line $217,000 @ 5%	10,850.	45,850	80,014
$1,118,000			$261,626.

Fixed Charges.

Bonds, $1,397,500 @ 80 = $1,118,000 Const'n cost
" 1,102,500 for water rights & contingencies
$2,500,000

	Interest	6%	
	Sinking fund	2%	
$2,500,000 @		8%	200,000
Annual Surplus			$61,626.

P a m o - L i n d a V i s t a P r o j e c t .

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The Pamo - Linda Vista irrigation project of the Volcan Land & Water Company plans the construction of a dam across the canyon of Santa Ysabel Creek, a short distance below the point where the Pamo Valley enters from the north. This dam would create a storage reservoir in the lower part of the Pamo Valley for the collection of the waters of the Santa Ysabel coming in from the east and the waters from the power house of the Warner - Pamo project coming from the north. The catchment area naturally tributary to this reservoir site is 114 square miles of the upper Santa Ysabel drainage, to which would be added 210 square miles of the San Luis Rey drainage artificially made tributary by the Warner - Pamo project.

As future auxiliaries to the Pamo Reservoir, it is planned to dam the Santa Ysabel creek in the Sutherland Valley, about 7 miles above the Pamo Dam Site, and also dam the Santa Maria at its outlet, about 8 miles below the Pamo. Beyond securing control of these two additional sites, there is no apparent need of further expenditure upon them until such time as disposal of all the water production of the initial Pamo - Linda Vista construction shall have taken place.

The prospective water product of the Pamo Reservoir, including the increment from the Warner - Pamo project, is computed to be 72.4 second-feet, or 3,620 Miners Inches net, after

deducting evaporation losses in the Reservoir and conduits. The Sutherland auxiliary reservoir would add a further 140 Miners Inches net, and the Santa Maria 570 Miners Inches net.

The water quantities given above are for uniform, continuous flow, year in and year out; the equivalent thereof when the flow is concentrated into the irrigation period would be about 5,200 inches from the Pamo and 1,000 inches from the Sutherland and Santa Maria auxiliaries. It is on the irrigation season quantities that the ordinary value of $1,500 per Miners Inch is applied. The U. S. Department of Agriculture in a recent bulletin gives the value of gravity water at $1,500 to $2,000 per miners inch for citrus culture in the neighborhood of Pomona, Los Angeles County.

The hydrological data upon which the conclusions as to the prospective water yield are based are to be found in the latter part of this report.

It is planned to convey the greater part of the water to the now dry coastal mesa lands which extend in a belt varying from one to ten miles in width for forty miles northward from San Diego. The portion of these lands to which the present project is more particularly directed is that lying north of the San Diego River and south of Las Penasquitos Creek, containing a body of about 44,000 acres of land, of which, for lack of water, comparatively little is under cultivation. Where water has been obtainable, even in very limited quantities, the quality of the soil is evinced, as in the neighbor-

hood of Miramar, by good citrus orchards. The mesa lies at a general elevation of about 400 feet above sea level and is practically frostless.

About eight per cent of the water may be diverted from the main conduit 10½ miles below the Pamo Dam to supply lands near Escondido, a further quantity would be used by lands between the Bernardo and Poway Valleys; the remainder would suffice to serve about thirty-six thousand acres of the coastal mesa.

The project involves the construction of a masonry dam 185 feet high across the Santa Ysabel below the mouth of the Pamo Valley, and a conduit 24.8 miles in length, with a distributing reservoir at its coastal end in the San Clemente Valley, the formation of which reservoir requires a 65-foot earth dam.

The subsequent developements at Sutherland and on the Santa Maria would require the construction at the former place of a dam 125 feet high, with a diversion conduit from Black Canyon of about 1½ miles, and a conduit for power purposes 5 miles in length, with a power installation of 3,000 KW. capacity under a head of 900 feet. The discharge from the power house would be directly into the Pamo Reservoir.

The Santa Maria developement requires a 90-foot dam, a power conduit of 1½ miles in length, and the installation under 435 feet head of a 750 KW. plant. The discharge from the power house would be into the Pamo - Linda Vista main conduit at a point 8½ miles below the Pamo dam.

Reservoirs and Dams.

The Pamo reservoir site is situated immediately below the junction of the Pamo Valley with the canyon of the Santa Ysabel. In a direct line it is 32⅓ miles north-easterly from the City of San Diego. A dam of 185 feet in height, measured above the river bed, would create a reservoir of 49,100 acre-feet in capacity, covering an area of 925 acres. The exposure to evaporation at full reservoir is 18.9 acres per 1000 acre-feet of storage. This is a much lower ratio of exposure than any other reservoir constructed or projected in San Diego Co. A tabulation of the exposure of various reservoirs has been previously given in connection with the Warner - Pamo Project.

Subsequent studies in connection with the Sutherland reservoir may show it to be unnecessary to construct the dam to the full height of 185 feet.

Table of Capacity and Acreage of the Pamo Reservoir Site.

Contour Elevation.		Capacity above Outlet Acre-feet.	Non-available Below outlet Acre-feet.	Area Acres.
805	Level of Stream Bed		0	0
882	Level of Outlet	0	1740	80
895		2,560		120
905		3,340		170
915		5,630		230
925		8,680		320
935		12,390		401
945		16,790		476
955		22,320		615
965		29,360		709
975		36,560		810
980		39,260		870
985		43,260		900
990		47,360		925

The contour elevations are in feet above sea level.

The geological formation is granitic. Rock is visible on both sides and over part of the floor of the dam site, but no borings or test shafts have as yet been sunk to ascertain the character and position of the sub-rock. The general geological formation is similar to Warner, and there are grounds to expect that the dam foundations would be of the same general character. However, until sub-explorations have been carried out, any estimate of the cost of the foundation work must be purely a matter of judgment.

The hill sides have not been prospected with a view of determining the practicability of quarries for material for a rock fill dam, and the surface indications are not favorable to the probability of sufficient suitable rock being obtainable within reasonable distance for a dam of the rock fill type.

The dam contemplated in the subjoined estimate of cost is of the multiple arch type in concrete, such as built at Hume and at Bear Valley, above Redlands, and as now under construction by the Great Western Power Company on the Feather River at "Big Meadows", all in California.

The topography of the dam site is favorable to the excavation of a spillway of ample capacity on the north side of the stream. The discharge from the spillway would be into a lateral ravine emptying into the main channel sufficiently below the dam site to eliminate any fear of disturbance.

Outlet System.

It is designed for the discharge of the reservoir to be controlled by gate tower, with outlet through the masonry of the dam.

Sedimentation.

It has been previously stated in connection with the Warner Reservoir that the observed sedimentation of the Sweetwater Dam was at the rate of less than the half of one per cent of the inflowing water in Twelve years. At this rate any baneful effects from sedimentation are too remote to now require consideration. The water flowing into the Pamo Reservoir from the Warner project would be clear water, its sediment would be left in the Warner Reservoir.

Conduit.

The length of the conduit from the intake at the gate tower to a point about 600 feet beyond the western portal of the tunnel above the San Clemente Reservoir, would be 131,000 feet, (24.83 Miles), from which point the water would follow a natural watercourse to the reservoir, a distance of about 4,400 feet, with a fall of approximately 90 ft.

The conduit is composed as follows:

Tunnels, (22)	14,535 ft.	2.753 miles.
Steel and Concrete Flumes, (58)	11,485 "	2.175 "
Syphons, (11)	19,700 "	3.731 "
Excavated Conduit, Concrete lined	85,380 "	16,171 "
	131,100 "	24.830

These figures are based upon topographical maps furnished by the field engineers of the Volcan Land & Water Co.

The conduit is designed with a conveying capacity of 174 cubic feet per second, on a gradient of 1 in 1,000, using a value for "n", (Kutter's Formula), of 0.017.

The general cross section of the conduit as drawn on the profile attached. The cement lining can be applied in the usual manner, by hand as a plaster, or by the pneumatic "cement gun". The estimate of cost is for hand work, "gun" work, or "Gunite", as it is called, might cost less.

The ground to be traversed by the conduit is generally strong, with few, if any, weak spots. The computed quantities of excavation and its classification are given in the cost estimate.

The lengths of the twenty-two tunnels are as follows. The list runs in the order of their occurrence counting from the Pamo Reservoir to the San Clemente Reservoir.

No. 1	110	feet	No. 12	160	feet
2	80	"	13	440	"
3	600	"	14	720	"
4	1,400	"	15	590	"
5	310	"	16	220	"
6	210	"	17	240	"
7	220	"	18	660	"
8	175	"	19	2,140	"
9	360	"	20	410	"
10	390	"	21	120	"
11	1,940	"	22	3,640	"
	5,795	"		8,740	"
				5,795	"
Total				14,535	feet

Flumes.

The flumes are designed to be of steel, with concrete substructures. The lengths at various heights above the ground are given in the cost estimate.

Syphons.

There are eleven steel pipe crossings of ravines and valleys, of the following lengths and maximum heads. These are listed in the order of their occurrence, counting westward from the conduit intake.

	Length		Maximum head		
No. 1	960	feet	115	feet	Clevenger Canyon
2	540	"	165	"	
3	1,620	"	375	"	Santa Maria Canyon
4	1,010	"	100	"	
5	3,350	"	210	"	Carter Canyon
6	890	"	70	"	
7	1,220	"	180	"	Bowren Canyon
8	1,460	"	165	"	Rattlesnake Canyon
9	5,880	"	245	"	Poway Valley
10	2,300	"	180	"	
11	470	"	110	"	
	19,700	"			

San Clemente Reservoir.

The reservoir site is situated at the westerly end of the main conduit, on the eastern edge of the Linda Vista mesa, 12 miles north-easterly from San Diego and 10 miles from the ocean. Its function would be to absorb and balance the daily or monthly differences between the distribution to the

lands and the flow through the conduit, and so afford the necessary working elasticity between rates of supply and demand. It would also serve to collect water used for power during the non-irrigating period and conserve it for profitable use during the subsequent irrigation season. It would also have the important quality of guaranteeing, when full, four weeks' supply to the lands below should the main supply be shut off for repairs or any other cause.

The site is suitable for an earth dam. A dam 65 feet high would impound 4,500 acre-feet, which is sufficient for the purposes named.

Geologically the dam site is of marine formation, upheaved to its present elevation, and is of a compact argillaceous gravelly character. No sub-explorations have as yet been made. The surface indications are favorable to the site proving on test to be satisfactory.

The capacity of the reservoir at various contours is given in the following table, which is extended to a height of forty feet above the top of the contemplated dam.

Table of Capacity and Acreage of San Clemente Reservoir Site.

Contour Elevation.		Capacity above Outlet Acre-feet.	Non-available Below outlet Acre-feet.	Area Acres.
595			0	0
610	Level of outlet	0	150	22
620		610		41
630		1,120		61
640		1,880		91
650		2,940		123
660	Projected H.W.	4,380		163
670		5,810		203
680		8,420		238
690		11,010		280
7000		13,000		317

The contour elevations are in feet above sea level.

Sedimentation.

The question of sedimentation of the San Clemente Reservoir is entirely negligible; all the water which would enter it would be clear water, or essentially clear, having deposited its suspended matter in the reservoirs from which it would be drawn.

Distribution System to Lands.

Estimates of the cost of a pipe system conducting the water from the San Clemente Reservoir to the lands below, are not dealt with in this report, such matter being deemed to more properly belong to the associated land project, which would look to acquiring the dry lands and installing a distributing irrigation system adequate to its needs. It is,

however, to be said that the reservoir lies in such a location and at such an elevation as to be suitable to economic distribution.

Yearly expenditures.

The expenditures for the up-keep of the works would, by reason of their permanent type, be light. A small staff would take care of the reservoirs and conduits, beyond which there would be about 2% on the cost of the works for depreciation, and about 8% for interest and sinking fund on amount of bond issue.

Cost Estimate, Pamo - Linda Vista Project.

Dam and adjuncts					$700,000.
Conduit, Total length 131,100 ft. = 24.83 miles.					
Excavation,	Cu. Yds.				
Earth,	306,600	@	18¢	$55,188	
Loose Rock,	70,000	@	35¢	24,500	
Solid Rock,	53,200	@	$1.00	58,520	
				$138,208	
22 Tunnels,	7,120 ft.	@	$18.	$128,160	
	7,415 "	@	16	118,640	246,800
	14,535 "				
58 Steel & Concrete Flumes					
On 15' piers	8,820 ft.	@	$ 8	70,560	
" 15-30' "	1,455 "	@	11	16,005	
" 30-50' "	1,100 "	@	16	17,600	
" 50-65' "	110 "	@	19	2,090	
	11,485 "			$106,255	
End connections for 58 flumes		@	$80	4,640	110,895
Under Culverts, 50 @ $100					5,000
11 Syphons, Steel.					
Under head					
0 to 125'	10,760 ft.	@	$11	$118,690	
125 to 200'	4,710 "	@	17	80,070	
200 to 275'	3,730 "	@	23	85,790	
275 to 375'	470 "	@	30	14,100	
	19,700 "			$298,650	
End connections for 11 Syphons		@	$100	1,100	299,750
Cement Lining, 85,380 lin ft.		@	$1.26	107,579	908,832.
Roads					10,000.
San Clemente Dam, 65' high, 350,000 cu. yds.		@	70¢		245,000
					$1,863,832.
Engineering, Legal and Sundry Expenses and contingencies, approx. 12⅓%					233,768.
					$2,098,000

Expenditures and Revenue.

Delivery of water, care taking and running repairs	$6,000
General, miscellaneous and overhead	4,000
	$10,000.

distributed over 36,000 acres = $0.27[8] per acre per annum. The cost in the San Gabriel and San Bernardino valleys ranges from 48¢ to $1.30. A charge to cover this expenditure is made directly against the consumer, and is therefore no burden on the company.

The charging to the consumer in addition th the delivery cost, of the annual depreciation of the system, is a matter for the policy of the company. The annual depreciation would not exceed 2% on $1,890,000 = $ 37,800, which, distributed over 36,000 acres, amounts to $1.05 per acre.

The returns from disposal of water would come either from outright sale of stock carrying water rights appurtenant to the land, which would eventually lead to a mutual water company, or by the sale of water by measure to the consumer, the original organization being retained.

The handling of the lands, whose values would be multiplied by the water service, would probably be done through an associated organization, and is considered as not properly within the scope of this report.

Sutherland and Santa Maria Auxiliaries.

The Sutherland Dam Site is situated on the Santa Ysabel Creek, about 7 miles above the Pamo Dam Site, and about 5 miles above the nearest point on the high water line of the Pamo Reservoir. A catchment area of 53 square miles is naturally tributary to the Sutherland site, to which, by a diversion conduit od about 1½ miles in length there can be added a catchment of 15 square miles now emptying into the Santa Ysabel through Black Canyon.

Table of the Capacity and Acreage of Sutherland Reservoir Site.

Contour Elevation		Capacity above Outlet Acre-feet.	Non-available Below outlet Acre-feet	Area Acres.
1910	Level of Stream Bed		0	0
1943	Level of Outlet	0	200	22
1953		346		47
1963		946		74
1973		1,844		110
1983		3,163		150
1993		4,845		187
2003		6,959		236
2013		9,560		284
2023		12,656		335
2033	Projected HW.	16,290		391
2043		20,508		452
2053		25,590		524
2063		30,948		587
2073		37,132		649
2083		43,939		711

Elevations are in feet above sea level.

Hard granitic rock is exposed across the floor of the dam site. Subsequent studies may show that with the intention

of building the Sutherland Dam when needed, it would be economy to reduce the contemplated height of the Pamo Dam.

A conduit of about 5 miles in length would discharge the waters of the Sutherland Reservoir into the Pamo Reservoir, with a drop of over 900 feet available for generation of power, averaging 1,360 KW. This plant could be operated by one shift per day during the hours of peak loading, when the best rates would be commanded.

The hydraulic works are estimated to cost $560,000, and a power installation of 3,000 KW., $90,000.

Santa Maria.

This project plans the utilization of 57 square miles of catchment area of the Santa Maria Valley. A rock gorge affords a favorable site for the construction of a dam.

Table of the Capacity and Acreage of Santa Maria Reservoir Site.

Contour Elevation	Capacity above Outlet Acre-feet.	Non-available Below outlet Acre-feet.	Area Acres.
1263		0	0
1283	0	45	8
1293	55		23
1303	477		41
1313	1,093		80
1323	2,260		154
1333	4,455		286
1343	8,691		561
1353	13,500		900

Elevations are in feet above sea level.

The net quantity of water which would be developed is computed at 12 second-feet.

A conduit of 1½ miles in length, with a drop of about 435 feet into the main Pamo - Linda Vista conduit, would furnish facilities for the generation of 340 KW. This installation, like the Sutherland, could be operated to advantage as a peak load plant.

The hydraulic works are estimated to cost $126,000, and an hydro-electric plant of 750 KW., $24,000.

Hydrology of the Catchment Area of the San Luis Rey River drainage above the Warner Dam Site.

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The catchment area above and tributary to the Warner Reservoir Site contains 210 square miles. Of this area about thirty-five square miles lie in the broad Valle de San Jose, and the remainder on the encircling mountain slopes. The altitude of the area ranges from a minimum of 2620 feet above sea level at the dam site, to a maximum of 5570 feet at the summit of Volcan Mountain. The valley is open and grassy, with cottonwood trees bordering the streams, and Live Oaks and chaparral covering the lower mountain slopes, with Pines and Cedars predominating in the higher altitudes.

The various mountain and valley streams converging at the gorge in which is located the dam site, give rise to the San Luis Rey River, by which name the main drainage artery of the region is known from the dam site to its mouth at Oceanside, fifty miles distant.

The record of the discharge of the San Luis Rey at the dam site covers too short a period to be in itself directly conclusive as to the normal flow of the river and its periodic variations. At a point near Pala, twenty miles down stream from the dam site,

the U. S. Geological Survey maintained for some years a gauging station. The records of seven seasons, 1903-04 to 1909-10, both inclusive, are available. By combining these records with the dam site record, proper weight being given to each, a substantial estimate may be made of the quantity of water which could be impounded from year to year by the construction of the Warner Dam.

Warner received the run-off from 210 square miles, and the lower station from 321 square miles. The rainfall upon these areas is determinable from the records of the 31 rain gauges whose locations are shown on the chart. From these records the isohyetals of the normal precipitation, shown upon the map, have been projected. In determining the normal of stations having only short time records, reference has been made to the same period of time at stations of long record, where the ratio of the period in question to the true normal is clearly defined. The records of 61 seasons at San Diego, 36 seasons at Escondido, 24 seasons at Fallbrook, Poway and Cuyamaca, 19 seasons at Mesa Grande, 11 seasons at Santa Ysabel, and other records all bearing on the subject, have been consulted and used in the manner indicated in determining the normal rain distribution over the drainage areas under consideration. The results are given in the following tabulation.

(page 46)

Rain Chart.

— San Luis Rey, Santa Ysabel, & Santa Maria — Watersheds.

H Hawgood. Mar. 1912.

Temecula Creek

San Luis Rey

Santa Ysabel Creek

Sandridge Creek

27 El 1988

18 El. 2751

19 El. 4500

6 El. 3200

17 El. 4500

16 El. 5300

111 □ Ms (28.58 □ M)

31 El. 1700

5 El. 2772

21 El. 3165

20 El. 4600

210 □ Ms (54.15 □ M)

4 El. 2805

22 El. 2894

3 El. 2810

1 El. 2750

2 El. 2725

24 El. 3200

12 □ Ms (3.09 □ M)

15 El. 3480

26 El. 3000

23 El. 3600

14 El. 3350

25 El. 3600

7 El. 1050

114 □ Ms (29.3 □ M)

8 El. 3000

30 El. 827

35 30 25 20 18 16 16

20 18

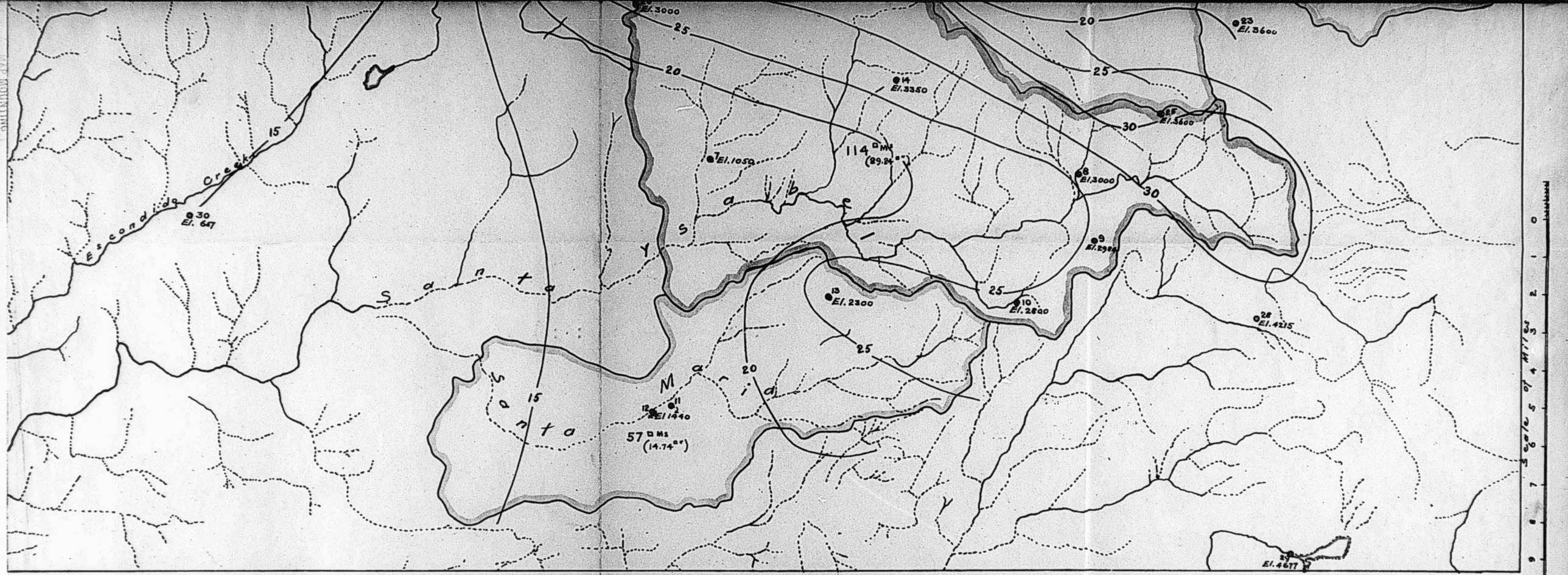
40 35 30 25 20 15

15

30 25 20

30 25 20 18 20 25 30 30

15


Escondido Creek
Santa Ynez
Santa Maria
15
20
25
30
114 □ Mls (89.24 sq mi)
57 □ Mls (14.74 sq mi)
30 El. 647
7 El. 1050
11 El. 1440
12
13 El. 2300
14 El. 3350
8 El. 3000
9 El. 2900
10 El. 2840
23 El. 3600
25 El. 3600
26 El. 4215
27 El. 4677
0 1 2 3 4 5 6 7 8 9
Scale of Miles

List of Rain Gauge Stations shown on Rainfall Chart.

Number	Name of Station	Length of record Seasons
1	Warner Dam Site	2
2	Damnon's	1
3	Monkey Hill	1
4	Warner, Summer Road	1
5	Puerte la Cruz	1
6	Deadman's Hole	1
7	Pamo	1
8	Santa Ysabel Ranch House	11
9	Santa Ysabel Store	1
10	Witch Creek	2
11	Ramona, (Verlague)	15
12	Ramona, (Sentinel)	1
13	Rose Glen	1
14	Mesa Grande, (Davis's)	19
15	Mesa Grande, (Angel's)	6
16	Nellie, (Palomar)	8
17	Mendenhall Valley	1
18	Oak Grove	1
19	Chihuahua Mt.	1
20	Eagle's Nest	1
21	Warner Springs	6
22	Warner Ranch House	1
23	San Felipe	1
24	Matagual	1
25	Volcan Mt.	1
26	Pine Mt.	1
27	Aguanga	3
28	Julian	26
29	Cuyamaca	24
30	Escondido	36
31	Head of Escondido Ditch	2

Upper or Warner Area 210 sq. miles			Lower or Pala Area. 111 sq. miles		
Rainfall inches per season	Square Miles	Percentage	Rainfall inches per season	Square Miles	Percentage
40 -	1.2	0.53	40 -	0.3	0.27
35 to 40	8.5	4.05	35 to 40	3.0	2.71
30 to 35	6.2	2.95	30 to 35	6.1	5.50
25 to 30	10.7	5.10	25 to 30	9.8	8.84
20 to 25	22.4	10.69	20 to 25	24.6	22.18
18 to 20	57.4	27.30	15 to 20	43.1	38.80
16 to 18	81.8	38.90	Under 15	24.1	21.70
Under 16	21.8	10.48			
	210.0	100.00		111.0	100.00

The run-off from the drainage areas can be represented by an equation of the form $y = f(x^n)$, where y = run-off and x = inches of rainfall, (seasonal). Study of Southern Californian streams gives to the exponent "n" a value in the neighborhood of 2. With this value, the relative producing power of the Warner and Pala areas, with the rainfall distributed as in the above tabulation, would be about as 65 : 35, and this ratio remains practically constant with values of "n" varying from 1.5 to 2.5. During the times when, after a dry season or succession of seasons, the depleted gravel beds below Warner are being filled by water from the Warner area, the flow past the dam site will bear a much higher ratio to the Pala station than 65 : 35. Reference to the records for 1906 shows that in

January the measured discharge at Warner's exceeded the total discharge at Pala by 34.2% and in February by 58.2%. Measurements made in March, 1912, following a succession of dry months, showed 71% of the simultaneous discharge at Pala.

The following excerpt from U. S. G. S. Water Supply Paper No. 213, page 74, describing this portion of the San Luis Rey River, is pertinent. "At a point below what is known as the Warner's Ranch reservoir site the river flows through a deep, narrow canyon with a heavy grade for a distance of about 10 miles. Below this point the grade is light, and the discharge is over sandy and gravelly beds, where the water soon disappears, again rising in small quantities near the town of Pala, where the gaging station is located."

Tabulation of discharge measurements at Warner & Pala, 1906.

Month	Warner Acre feet	Percentage of Pala	Pala Acre feet	Percentage
January	1,771	134.2%	1,320	100%
February	2,516	158.2	1,590	100
March	47,093	68.4	68,900	100
April	10,359	57.9	17,900	100
May	2,926	30.1	9,720	100
June	1,672	42.9	3,900	100
	66,337	64.2%	103,330	100%
July	)		1,170	
August	)		633	
September	) Not		220	
October	)Measured		184	
November	)		494	
December	)		4,880	
	4,869 = 7.34% of 66,337		7,581 = 7.34% of 103,330	
	71,206	64.2%	110,911	100%

No measurements were taken at Warner during the last six months of 1906. In the above table the discharge at Warner's for these six months has been estimated on the assumption that the flow for these six months bore the same relation to the flow of the previous six months as they did at Pala, where the measurements were taken, viz., that the discharge for the last six months of the year was 7.34% of that of the first six months.

In the following tabulation the Pala discharges, (3rd col.), for the seasons 1903-04 to 1909-10 are taken from the records of the U. S. Geological Survey. In the 4th column are the factors which, in consonance with the foregoing analysis of the relation between the discharges past the two stations are applied to the Pala measurements to determine the equivalent Warner discharges. To these quantities, acre-feet, thus determined is added a constant of 724 acre-feet, being the amount of the underflow definitely ascertained to exist at the dam site by the construction of the cut-off wall completed December, 1911. This sub-flow has been arrested by the"cut-off"wall, and would be impounded by the dam, and is therefore to be credited to the Warner discharge.

1	2	3	4	5	6
Season	Seasonal Rainfall in % of Normal	Discharge at Pala Acre-feet	Correction Factor	Discharge at Warner Acre-feet	Total at Warner Col. 5 - 724 for sub-flow Acre-feet
1903-04	51%	7,460	1.25	9,325	10,049
1904-05	134%	41,923	0.95	39,827	40,551
1905-06	161%	106,270	0.65	69,075	69,799
1906-07	106%	84,624	0.62	52,466	53,190
1907-08	87%	24,811	0.70	17,368	18,092
1908-09	108%	48,148	0.70	33,704	34,428
1909-10	97%	47,398	0.67	31,757	31,481
Mean	106.3	51,519	0.703	36,217	36,941

By plotting the values of Col. 2 as abscissae, and the corresponding values in Col. 6 as ordinates, and projecting a fair curve through these points, there results a curve of the form $y = f(x^{1.6})$, of which the numerical values range from 11,000 acre-feet for a 50% rainfall, to 101,000 acre-feet for a 200% rainfall, etc., etc.

It cannot be expected that this equation will give accurate results for each and every individual year, for the quantity of run-off varies not only with the total amount of the rainfall, but also with the manner of its distribution, whether it be spread in many light rains or concentrated in a few heavy down-pours. The manner of deducing the equation is, however, one

Discharge of
San Luis Rey River
at Warner Dam Site.
Acre-feet

100,000

75,000

50,000

25,000

50

Diagram of
Discharge of San Luis Rey River
at
Warner Dam Site.
E. Haygood.
July, 1912.

Seasonal Rainfall
in percentage
of Normal.

50 100 150 200 250

which balances the deviations to either hand, and given a sufficient number of observations or points from which to determine the curve, the resulting mean for a long term of years will be free from material error. In the present case there are seven observations ranging from 51% to 161% rainfall, and for seasons of both spread and concentrated rains; their relative disposition is also such as to be favorable to correct deductions. The resulting equation has been applied to the rainfalls of the thirty-six seasons from 1875-76 to 1910-11, and the mean run-off from the Warner basin for these thirty-six seasons, has been determined to be 51.4 second-feet. A period of thirty-six years will be recognized by engineers as one of length sufficient to insure a true mean.

The storage possibilities at Warner permit of the realisation to its full value of the mean of 51.4 second-feet, less the losses unavoidably incident to evaporation, which subject is discussed in detail in the article which follows.

Evaporation and net Discharge from Warner Reservoir.

Extensive observations of evaporation have been made at the Sweetwater Reservoir, near San Diego, and at the Cuyamaca Reservoir, in the mountains twenty miles southeasterly from Warner Reservoir Site. These observations form a logically

sound basis upon which to estimate the probable evaporation to be anticipated at Warner.

	Elev'n Feet	Mean Temperature	Evap'n per annum Inches.	Evap'n in percentage of catch	Exposure for Evap'n Acres per 1000 ac-ft.
Sweetwater	510	62°	54.0	15.0%	39.8
Cuyamaca	4670	49°	56.75	25.5%	84.0
Warner	2710	55°			33.0

Under the same climatic conditions, and at same elevation, the rate of evaporation would follow the degree of exposure, the deeper reservoirs suffering less than the shallower. The localities of lower temperature and higher humidity and elevation will be subject to the lesser evaporation. Many observations have been made at various times and places as to the effect of variations in these particulars; among the more recent are those of the U. S. Department of Agriculture in the northern part of California, and of Grunsky in the Salton Basin, San Diego County, published in Engineering News, Vol. 58, p.304-7, 1907, and Vol. 60, p. 163-6, 1908. These records show the increased evaporation due to an increase of 10° in temperature to average 1.03 inches per week. Assuming a difference of 12° during three summer months when evaporation is greatest, there would ensue a difference of 14.8 inches between the evaporation at Cuyamaca and that at Sweetwater, or 54 inches — 14.8 inches =

39.2 inches. This quantity has to be further corrected for relative elevation and exposure. According to the observations cited, the evaporation at an elevation of 4,670 would be sixty-nine per cent of that at 510 feet. The correction for relative exposure of the two reservoirs is as 84 to 39.8, or 210 per cent, and the combined correction for relative exposure and altitude is 2.10 x 0.69 = 1.45. Applying this factor to the previously determined 39.2 inches, there results 56.84 as the estimated evaporation of Cuyamaca Reservoir, computed on the basis of Sweetwater observations, with corrections for temperature, altitude and exposure: this is in harmony with the actual observed evaporation of 56.75 inches, and substantiates the correctness of the methods used, and justifies their use in estimating the probable evaporation that would take place from the Warner Reservoir.

Again, using the Sweetwater evaporation of 54 inches as a basis, the correction for Warner would be for a lower temperature of 5 degrees, 6.18 inches, reducing the 54 inches to 47.82. The factor for relative altitude is 0.88, and for relative exposure 0.83, making a combined factor of 0.73, which, applied to the previous 47.82 inches, gives 34.9 inches for the evaporation from the surface of the Warner Reservoir. This evaporation is met in part by the rain falling upon the surface of the water in the reservoir, the full quantity of which, amounting to 17 inches, is realized. In the computations for run-off,

the productive value of this depth of precipitation is valued at 14.6 per cent, and credited to that extent, leaving a balance of 85.4 per cent of 17 inches, or 14.5 inches to be deducted from the 34.9 inches gross evaporation, leaving 20.4 inches as the net loss from the reservoir surface.

Whatever evaporation is taking place under the natural conditions now existing over the area to be submerged by the reservoir is a direct present loss to the surface streams, which loss would terminate upon submersion. In this instance the loss is of sufficient magnitude to warrant its evaluation. A considerable portion of the floor of the projected reservoir is now occupied by damp lands and marshy places, in many instances created by springs, and in others by the shallow depth to ground water. No actual survey has been made of the various areas thus covered, but there is estimated to be in the aggregate about 500 acres. Of this area perhaps ten per cent lies in small pools an inch or so in depth around the grass stems, the evaporation from which would be approximately the same as from the free water surface of a reservoir. The evaporation from the remaining 450 acres of grass and damp lands would be equivalent to that from 300 acres or more of free water surface, making 350 acres in all of free water surface as the equivalent of the evaporative surfaces now existing within the reservoir boundaries.

No portion of this evaporation has received any credit in the stream discharge quantities, and therefore the evaporation

rate to be applied to these 350 acres is the full rate of 34.9 inches, amounting to 1,018 acre-feet per annum, eqdivalent to a continuous flow of 1.4 second feet.

A study of the losses due to evaporation shows that with an inflow from rain-fall and run-off in accordance with the $f(x)^{1.6}$ curve, the values of which are given by the diagram on page 50, to which is to be added a constant of 1,000 acre-feet for the terminated marsh land evaporation, and assuming that at the beginning of the season 1875-6 the Warner Reservoir existed and contained 75,000 acre-feet, (45.5% of full capacity), and assuming that an annual discharge of 33,000 acre-feet was maintained, and the rain-fall for each season was as shown by the Weather Bureau records, then by the end of the season 1890-91 the reservoir would have filled to its maximum capacity of 157,000 acre-feet, and would thereafter have gradually receded until at the end of 1903-04 the storage would have been depleted to its minimum of 500 acre-feet, and would have then risen until at the end of 1910-11 it would have become 41,700 acre-feet. The average discharge over and above evaporation for the entire 36 seasons would have been 32,000 acre-feet per annum, falling below this for one season only, 1903-04, and being for that season 29,500 acre-feet, or 92 per cent of the average. Average inflow 51-4 second-feet, average evaporation loss 14 per cent, and net discharge 44.2 second-feet. This is without assistance from any auxiliary steam plant, consequently the evaporation percentage is higher by reason of long

held over storage presenting larger surface areas than if greater drafts of water could be made during the plentiful years and the sparse years be eked out by an auxiliary plant, and thus smaller areas be presented to evaporating influences.

A second study has been made covering the same thirty-six seasons and assuming cooperation with a 1,500 KW. auxiliary plant. The initial storage was assumed at 50,000 acre-feet in the beginning of 1875-6, in 1890-91 it would have reached a maximum of 110,200 acre-feet, would have receded to a minimum of 3,200 acre-feet in 1903-04, and at the close of 1910-11 be 37,000 acre-feet. The average discharge would have been 32,912 acre-feet, or 45.5 second-feet, and the average evaporation loss 11.5 per cent, a gain of 2.5 per cent over operating without steam auxiliary, due to reduced areas of exposure.

On a previous page it has been shown that the expected evaporation should be 65% of that at Sweetwater, the records of which place give fifteen per cent of the total catchment as the evaporation loss. Sixty-five per cent of fifteen per cent is 9.75 per cent, or 1.75 per cent less than the results shown by the study, a sufficiently close agreement to give confidence in the accuracy of the reasoning which has been employed. It is also to be remembered that the Pala discharge measurements, which enter largely into the determination of the inflow, are admittedly below the true discharge quantities. These facts sustain the conclusion that the average net discharge under the conditions would be 45.5 second-feet.

Auxiliary steam plants are associated with most hydro-electric installations such as the one under discussion, consequently there can be no error in the general assumption of there being an auxiliary plant in conjunction with this project. The economic size of such a plant is related to the service to be supplied, and in the absence of data on that subject cannot behere determined, but it can be safely assumed that it would be not less than 1,500 KW.

The conservatism of the determination of the average run-off from the 210 square miles of catchment at 51.4 second-feet, or 0.245 second-feet per square mile, becomes apparent by considering that from the isohyetals of the rain chart and the demonstrated value of the run-off varying as $x^{1.6}$, the equivalent rainfall over the whole area is 20.4 inches, or 1.5 second-feet per square mile, and that the credited run-off of 0.245 second-feet per square mile represents but 16.5 per cent of this quantity.

In view of the fact that much of the run-off comes in the form of storm freshets, twenty per cent would be by no means an excessive estimate.

Evaporation and Seepage from Conduit.

The measured losses in the Dulzura Conduit of the Southern California Mountain Water Company form a criterion for the losses to be expected in the Warner - Pamo Conduit.

	Dulzura	Warner-Pamo
Tunnels	1.75 Mi.	2.083 Mi.
Open Conduit	11.63 "	6.790 "
of which Wood Flumes	0.85 "	0.000 "
Steel and Concrete Flumes	0.00 "	1.000 "
Total length	13.38 "	8.873 "

The Dulzura has cement lined sides, with natural rock bottom. The Warner Conduit is designed to be cement lined, both bottom and sides, and the flumes of steel and concrete.

The evaporation and seepage loss of the Dulzura is three per cent of the flow at the intake. Comparing the physical properties of the two conduits, it is reasonable to conclude that the loss in the Warner-Pamo Conduit would not exceed 2 per cent, and that with 45.5 second-feet delivered into it from the Warner Reservoir, 44.6 second-feet would be discharged at the forebay of the power plant in the Pamo Valley.

Verification of Discharge Quantity.

The use of the records of an adjacent stream to estimate or verify the discharge of another stream having sparse records, is a well recognized mode of proceedure. Immediately to the south of the Upper San Luis Rey drainage lies that of the Santa Ysabel, measurements of which stream were conducted by the U. S. Geological Survey during the four seasons 1906-07 to and including 1909-10.

The area above the gauging station on the Santa Ysabel is 128 sq. miles. The run-off for the four seasons named, the mean rainfall of which was slightly below normal, averaged 0.348 second-feet per square mile. On the basis of the isohyetals shown on the rainfall chart, and a discharge varying as the 1.6th power of the rainfall, the productivity of the San Luis Rey drainage above Warner, is, mile for mile, 73 per cent of that of the Santa Ysabel, and the corresponding run-off would be 0.348 x 0.73 = 0.254 second-feet per square mile. The flow of the San Luis Rey at Warner, computed on the basis of the discharge varying as the 1.6th power of the rainfall, which in turn is based on the Pala measurements, averaged for these four seasons 0.229 second-feet per square mile, or ten per cent less than the rate of 0.254 deduced from the Santa Ysabel measurements. This is strong evidence as to the conservatism of the methods by which the flow of the San Luis Rey has been determined from the available stream measurements. It follows from the very manner of making these measurements that they fail to account for all the water which passed. The greater portion of the run-off passes, as previously said, in floods, and where, as on the San Luis Rey at Pala and on the Santa Ysabel at the head of the San Pasqual valley, measurements were made but once or twice a day at most, much of the important flood waters must have passed unrecorded.

Further tests of the accuracy of the conclusions as to the discharge of the San Luis Rey is afforded by comparison with the measured discharges of the San Diego River and Cottonwood Creek, whose upper catchment areas are contiguous to one another and th the upper Santa Ysabel and San Luis Rey catchments. The following stream measurements are available for such comparison:

Season	San Luis Rey at Pala Acre-feet	Santa Ysabel at San Pasqual Acre-feet	San Diego at Descanso Acre-feet	Cottonwood at Barrett Acre-feet.
1906-07	84,624	35,756	50,570	37,380
1907-08	24,811	12,353	13,971	14,000
1908-09	48,148	45,765	42,943	26,625
1909-10	47,398	35,191	24,316	19,652
	204,981	129,065	131,800	97,657

According to the preceeding hydrological studies, the aggregate flow or discharge at Warner for the four seasons named is 67.8 per cent of that at Pala. Applying this factor to the foregoing data, the discharge of the San Luis Rey at Warner bears, for the four seasons, the following ratios to the other discharges:

San Luis Rey at Warner : Santa Ysabel Creek as 107.6 : 100
do do : San Diego River as 105.4 : 100
do do : Cottonwood Creek as 142.3 : 100

The average fun-off of these streams for the same period was Santa Ysabel Creek, 44.56 second-feet: San Diego River, 45.51 second-feet: Cottonwood Creek, 33.77 Second-feet.

Applying to these measured run-offs the San Luis Rey ratios, there results:

Run-off of San Luis Rey River at Warner
based on Santa Ysabel Creek measurements = 48.0 sec-ft.

based on San Diego River Measurements = 48.0 sec-ft.

based on Cottonwood Creek measurements = 46.6 sec-ft.

The computed run-off of the San Luis Rey for the same period is 48 second-feet, agreeing exactly with the run-off based on that of the two near-by streams, and within three per-cent of that of the more remote stream.

The results of these tests fully confirm the substantial accuracy of the methods upon which the flow of the San Luis Rey River have been determined, and short of actual measurements there could scarcely be a proof more complete.

Hydrology of the Catchment Area of the Santa Ysabel Creek above the Pamo Dam Site.

The catchment area of 114 square miles tributary to the Pamo Reservoir Site lies immediately to the south of the upper San Luis Rey drainage, with a common divide between the two water sheds for twenty-five miles. The altitude of the area ranges from 900 feet above sea level at the dam site, to 5570 feet at the summit of Volcan Mountain. The area is mountainous throughout, the stream channels are chiefly in canyons, with steep side slopes and occasional valley openings. The principal lateral valleys on the stream are the Pamo and Sutherland in both of which are reservoir sites. The country is well clothed with vegetation; the forest trees are of the Live Oak in the lower altitudes, with Pines and Cedars in the higher.

Observations of the discharge of the Santa Ysabel were made by the U. S. G. Survey during the seasons 1906-07 to 1909-10, inclusive, at a point about three miles down-stream from the Pamo Dam Site.

The following results of these observations are taken from the records of the Department.

Discharge of Santa Ysabel Creek measured at the Head of the San Pasqual Valley.

1906-07	35,756	Acre-feet
1907-08	12,353	" "
1908-09	45,765	" "
1909-10	35,191	" "

32,266 Acre-feet per season = 44.56 second-feet.

The drainage area above the gauging station was 128 square miles, making the average run-off 0.348 second-feet per square mile.

Of the 128 square miles of drainage above the station, the upper 114 square miles tributary to the Pamo Reservoir have a higher rainfall than the lower 14 square miles. The equivalent mean rainfall of the upper 114 square miles is 25.1 inches, and of the lower 14 square miles, 17.5 inches. Their relative productivity in run-off per square mile is as 100:55. On the basis of combined relative productivity and mileage, the upper 114 square miles produced 93.6 per cent of the discharge of the entire 128 square miles, or an average of 30,200 acre-feet, equivalent to a continuous flow of 41.7 second feet, or 0.366 second feet per square mile for the four seasons named.

The effect of rainfall fluctuations during the 36 seasons from 1875 to 1911 was treated at length in the discussion on the hydrology of the Warner Catchment area of the San Luis Rey River and reference is made thereto for details. The average flow for

the four seasons, 1906-10 from the Warner Drainage was computed as 48 second-feet, and the average flow for the entire 36 seasons as 51.4 second-feet; the same ratio would apply to the Santa Ysabel, and the average of 41.7 second-feet for the four seasons mentioned becomes 44.8 second-feet as the average for the longer period, and therefore the truer average of 36 seasons.

The Santa Ysabel is not as favorably conditioned as the San Luis Rey in the matter of reservoir sites of great capacity. A reservoir of 49,000 acre-feet can be constructed in the Pamo Valley, and one of 20,000 acre-feet in the Sutherland Valley, about seven miles up-stream from the Pamo Dam Site.

The Pamo Reservoir is of insufficient capacity to prevent loss by overflow of an appreciable quantity of water during very wet years, this would be obviated by the construction of the Sutherland Reservoir. Until, however, the disposal of all the water production of the Pamo Reservoir has been approached, there would be no apparent commercial reason to any investment at Sutherland beyond securing a control of the site.

EVAPORATION LOSSES AND NET DISCHARGE FROM PAMO RESERVOIR.

The losses from evaporation have been discussed in detail in connection with the Warner Reservoir, and reference is made to that discussion for details. The evaporation losses at Pamo, by reason of lower elevation and higher temperature, would

be somewhat higher than at Warner, on the other hand they would be lower by reason of greater relative depth of the reservoir and less exposure. After consideration of the respectife values of these items, it has been considered proper to adppt the same rate of net evaporation as determined for Warner.

A detailed study of the inflow and losses which would have taken place during the 36 seasons, 1875-1911, shows that by reason of frequent overflow, a discharge of only 34.2 second-feet could have been averaged out of the 44.8 second-feet average flow of the stream during the same period. The loss is comparatively heavy; a fubther loss, but small, would be sustained by the water discharged into the Pamo Reservoir from the Warner - Pamo Project. If water were let out of the reservoir simultsneously equal in quantity to that coming in from the Warner - Pamo Project, the surface area of the Pamo Reservoir would remain unaffected except by the inflow of the Santa Ysabel, thē fluctuations of which have been fully considered in arriving at the before stated average flow of 34.2 second-feet; such perfect balance could not, however, be practically maintained, and some slight loss would accrue to the Warner - Pamo inflow. This inflow has been determined in the discussion of that project to average 44.6 second-feet, 5 to 6 per cent of which, or say 2.6 second-feet, should suffice to cover its proportionate loss, leaving available 42 second-feet net.

The total average net discharge from the Pamo Reservoir into the Pamo - Linda Vista Conduit would be 34.2 + 42 = 76.2 second feet. With the construction of the Sutherland Reservoir and the additional storage thereby gained, overflow from the Pamo Reservoir would be prevented, with a resulting gain equivalent to an average of 3 second-feet. The Sutherland Reservoir also presents opportunity to generate power.

Hydrology of the Catchment Area of the Santa Maria Creek above the Santa Maria Dam Site.

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This catchment area of 57 miles lies directly to the south of the Santa Ysabel drainage, withnwhich it has a common divide for 10 miles. The area is hilly, with several valleys, the largest of which is the Ramona Valley, of 25 square miles. The hill sides have a covering of brush and Live Oaks. In altitude, the area ranges from about 1,200 feet above sea level at the dam site to a maximum elevation of 3,175 feet near Witch Creek, and on the divide between the Santa Maria and San Diego River drainages.

No measurements are available of the flow of the Santa Maria Creek. This can be computed from the discharge of the Santa Ysabel, on the basis of their respective isohyetals, as shown on the rainfall chart. On this basis, the discharge of the Santa Maria is 35.6 per cent of that of the Santa Ysabel, or 44.8 second-feet x 0.356 = 15.9 second-feet.

Evaporation Losses and Net Discharge from the Santa Maria Reservoir.

In point of elevation and temperature the Santa Maria Reservoir is not as well situated as Warner, and is also inferior in point of exposure, being a relatively shallower reservoir. After considering the relative value of this item, a net evaporation twenty-five per cent greater than Warner's is ascribed to the Santa Maria Reservoir. With the foregoing values of inflow and losses, a study has been made of the fluctuations which would have occurred during the 36 seasons, 1875-1911, and the following results obtained: That due to the limited capacity of the reservoir there would have been a material loss by overflow, and that the average discharge into the conduit would have been 12 sec-ft.

The Santa Maria Reservoir discharges through a conduit about 1½ miles in length into the Pamo - Linda Vista Conduit, with a drop of about 435 feet available for power, and with 12 second-feet of water, 340 Kilowatts can be generated continuously, or 680 Kilowatts for 12 hour service, switchboard measurement, which would be about the full capacity of the projected conduit.

Summary of Net Water Supplies.

Warner discharge to Pamo Reservoir	44.6	sec-ft.
do do to Linda Vista Conduit	42.0	" "
Santa Ysabel do do do do	34.22	" "
	76.2	" "
Conduit Losses, 5%	3.8	" "
Discharge to San Clemente Reservoir	72.4	" "

The above water quantities are, for convenience of use, expressed in terms of continuous, uniform flow, year in and year out. In practice there would be large discharge during the seven to eight months of irrigation season, followed by little or no discharge, except for power, during the winter months. The equivalent irrigation season flow would be about 5,200 Miners Inches.

Futube Water Developement.

Sutherland	3.0	sec-ft.
Santa Maria	12.0	" "
	15.0	" "

The equivalent irrigation flow would be about 1,000 Miners Inches.

These quantities are based upon the U. S. Geological Survey measurements of the San Luis Rey River at Pala, and of the Santa Ysabel at San Pasqual, and attention is again drawn

to the fact that for the seasons given, the measurements do not record the full flow of the streams, and that inferentially the above quantities are correspondingly low.

Ed Fletcher Papers

1870-1955

MSS.81

Box: 37 Folder: 13

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