GEOLOGIC CONDITIONS AT MATILIJA DAM AS DISCLOSED BY EXCAVATIONS FOR SPILLWAY APRON

by

Thomas L. Bailey
Consulting Geologist
Ventura, Calif.

Original File Z1-4

COUNTY OF VENTURA
STATE OF CALIFORNIA

OFFICE OF
COUNTY SURVEYOR
COURTHOUSE, ROOM 4
VENTURA, CALIFORNIA

ROBERT L. RYAN
County Surveyor
R. L. STUMP
Principal Engineer
KATHRYN NEVILLE
Deputy

R. E. RICHARDSON
Chief Deputy Surveyor
RICHARD H. JAMISON
Hydraulic Engineer
CHAS. H. MANGOLD
Structural Engineer

September 15, 1947

Honorable Board of Supervisors
Ventura County Flood Control District
Ventura, California

Gentlemen:

Herewith I hand you a copy of a report by Dr. Thomas L. Bailey, Consulting Geologist, entitled, "Geologic Conditions at Matilija Dam as Disclosed by Excavations for Spillway Apron".

I asked Dr. Bailey, in behalf of the District, to report on foundation conditions after the apron was excavated, because I felt it was very necessary that the District have a representative present at the time the State and the Contractor had geologist representatives on the job. This was on August 13, 1947. The following day Mr. Donald R. Warren and Dr. Buwalda, his geologist, visited the site and probably a report will be presented to the Board from that source.

With the filing of this report, I feel that the Board has done everything in its power to develop basic information and technical opinions on the matter of the Matilija Dam, which information will supplement the knowledge of the Division of Dams and of the Designing Engineer supervising the construction of the dam.

As there was no Consulting Board appointed for this project it appeared necessary at times to obtain independent information and advice on problems and the Board cooperated with this office in employing those consultants recommended, such as Dr. Berkey and Dr. Bailey.

It is recommended that a copy of Dr. Bailey's report, be sent to the Donald R. Warren Company and also to the Division of Dams.

Yours very truly,

Robert L. Ryan

ROBERT L. RYAN
Engineer Ventura County
Flood Control District

RLR/s
encl.

FILED
BOARD OF SUPERVISORS
SEP 15 1947
L. E. HALLOWELL, Clerk
By James W. Poot
Deputy Clerk

September 9, 1947

The Board of Supervisors
Ventura County Flood Control District
Ventura, California.

ATTENTION: Mr. Robert L. Ryan

Gentlemen:

This will transmit to you my report entitled "Geologic Conditions at Matilija Dam as Disclosed by Excavations for Spillway Apron." You recently requested me to study the foundation rocks revealed by these excavations in the absence of Dr. Charles P. Berkey. It should be considered a supplementary report to that of Dr. Berkey that was filed with you on May 25, 1947.

The foundation rock beneath the floor of the central part of the dam is severely fractured, faulted and crushed almost to a sandy powder. I would not have recommended a dam at this site knowing these conditions, but, as it is practically completed and we need the water, all reasonable methods to bolster it and prevent its failure should be taken. I have suggested several steps that I believe to be necessary to make the dam as safe as possible without unreasonable expenditures. It is probable that the dam will hold if the foundation of the dam and apron are adequately strengthened. However, I am frankly worried by the crushed zone under the central part of the dam and whether it will stand up after it has been thoroughly soaked with water for months or years. Will it soften up after several years and cause the center section to crack and settle? Will water seep through the fractured sandstone so rapidly as to start enlargement of certain fracture planes and erosion of the weak foundation rock? I can not feel confident that they won't.

In view of the tremendous energy of the falling water the downstream end of the spillway apron is particularly vulnerable unless a strong retaining wall is built or the apron is lengthened, or both.

Therefore, a very careful and regular inspection for signs of cracking or leakage should be maintained at the Matilija Dam and the dam drained at the first signs of excessive leakage or erosion under the dam.

Respectfully yours,

Thomas L. Bailey

THOMAS L. BAILEY
Consulting Geologist

TLB:kd

GEOLOGIC CONDITIONS AT MATILIJA DAM AS DISCLOSED BY

EXCAVATIONS FOR SPILLWAY APRON

* * * * * * * *

Foreword

Following Dr. Charles P. Berkey's inability to return to Ventura County to inspect the recently revealed foundations of the Matilija Dam, I was requested by the County Surveyor, Mr. Robert L. Ryan, on behalf of the Ventura County Flood Control District, to make this inspection and report my findings to you.

Accordingly I postponed another urgent job a few hours and visited the dam on August 13 in company with Mr. Ryan, Mr. Leonard Stump and Mr. John Herdfelder. Several geologists and engineers for the State and the Contractors were also on the ground. I spent about an hour studying intensively the bedrock of the spillway floor and the rocks on which the dam itself rests, which were exposed for a vertical distance of 3 to 4 feet beneath the concrete of the dam. I regret being unable to spend a longer time there while the entire apron floor was exposed, but believe I saw all the essential features including numerous springs issuing from the floor and two beneath the dam.

On August 23, I visited the dam site again in company with Mr. E. E. Everett, and spent the morning studying in more detail the rocks on which the dam rests, much of which were still exposed, the abutments, including the bear hole beneath Blocks M, N, and O (much of which was still open) and a large section of the apron floor below Blocks D, E and F which had been cleaned off and was surrounded by wooden forms for concrete.

I made two more trips in company with Robert L. Ryan, on August 30 and September 1. Most of the apron was poured and the rocks at the base of the dam were covered with concrete at this time. We also inspected the bear hole and left abutment next to it. Only a small amount of water had collected in the space below the outer edge of the apron. I wish to express my appreciation to Mr. Ryan for his valuable assistance and cooperation.

Mr. Everett has made a masterful study of the requirements for the spillway apron when subjected to floods like those of February 20, 1914 and March 2, 1938 and was kind enough to give me the benefit of his study and research. Everett's report was presented to the Ventura Engineers' Club on April 11, 1947 and was filed with the Board of Supervisors shortly thereafter. I hereby acknowledge my sincere thanks to Mr. Everett for his excellent advice on the hydraulics of the spillway. In addition to the highly pertinent information contained in his report he gave me orally a great deal of valuable information and advice not contained in his report so that I have a much better comprehension of the stresses to which the dam, spillway apron and its bedrock foundations, and the stream channel below the apron will be subjected, by future floods comparable to that of 1914.

The design of the dam and spillway is outside my province as a geologist but the effect of such a flood on the rock foundations and the bed of Matilija Creek below, especially as it may affect the dam's ability to stand up without being undermined at the downstream end, is clearly part of my duty as Geological Consultant to the District. The history of previous dams shows that the majority have failed during severe floods. Considering the terrific property damage and possible loss of life that would be caused by a 160-foot wall of water if the Matilija dam should break during a flood, to say nothing of the initial cost of the dam, I feel that all reasonable precautions should be taken to make the dam as safe as possible and I am sure the Board of Supervisors and the overwhelming majority of people living in District I and the rest of the county must feel the same way.

As was the case with Dr. Berkey, I was called in as Geological Consultant after the dam was nearly complete and when people needed water. The most I can do now is express my unbiased opinions as a geologist who has worked 12 years in Ventura County and mapped the geology of much of the county including the area surrounding the Matilija dam and most of District I, and make recommendations on how to make the dam as safe and valuable as possible without unreasonable precautions and expense.

GENERAL STATEMENT OF GEOLOGY

The rocks on which the Matilija dam is built are mainly Middle Eocene gray sandstones in layers or beds 1 to 10 feet thick. The sandstone beds are separated from each other by much thinner beds or lamellae of indurated but softer black shale from 1/2 inch to 12 inches thick and averaging only a few inches across. Where fresh and unfractured the sandstone is hard, strong, nearly impermeable to water and quite capable of supporting the arch-type Matilija dam without danger. This sandstone with its interbedded shale was originally deposited horizontally on the floor of the ocean which covered this region in Eocene time. Now the sandstone and shale beds are standing on end or practically vertical. Their average dip is 85 degrees NW (overturned slightly past vertical). This change from their original horizontal to the present nearly vertical position was caused by slow mountain making movements which buckled and folded up the layers of rock to form the Santa Ynez Mountains in Pliocene and Pleistocene time - a few million to several thousand years ago. The process was slow and gradual and it probably required one to three million years to squeeze and arch up these rock layers to their present vertical position. Where the pressure was too intense or rapid for the rocks to fold or bend they locally broke and slipped past each other along crushed or shear zones that are called faults by geologists. Such faults are zones of weakness that are generally utilized by streams in deepening their valleys or canyons because such crushed belts erode many times faster than hard, uncrushed rocks of the same age. The gorge in Matilija Canyon across which the dam is built is such a fault zone although the movement of the rocks layers on one side with respect to those which originally connected on the opposite side has not been great - probably not over 100 feet. Therefore, the offset of the layers could not be detected before stripping of the site for the dam without detailed geological studies, including many borings. Such studies were not made. The fault zone could have been found by preliminary borings.

CONDITION OF THE ROCK BENEATH FLOOR OF DAM AND SPILLWAY APRON.

The excavation of some 20 to 40 feet of Matilija Creek bed boulders and gravel as well as the upper 3 to 4 feet of bed rock below these creek channel deposits for the 6-foot concrete apron exposed the concrete base of the dam for the entire length of the floor plus the lower part of both abutments. The area so stripped was about 300 feet long and 20 to 70 feet wide. A vertical cut 3 or 4 feet high in the rock on which the downstream edge of the dam rests gave an excellent idea of the strength and cohesion of the bed rock on which most of the dam as well as the downstream apron are built. Therefore, this report will supplement the report Dr. Chas. P. Berkey made to the District a few months ago. Berkey was unable to inspect in place the rock on which most of the dam rests, because the floor was covered with gravel, mud and water, and had to rely on samples collected by others from beneath the central blocks and on sketches made by others. The abutments and "bear hole" were exposed well enough for Dr. Berkey to study in detail personally so that I spent little time on them.

The principal features brought out by my observations of the rock floor beneath the central part of the dam and spillway apron are as follows:

1. Practically all the rock floor beneath the central quarter of the dam (under Blocks E, F and G and parts of D and H) consists of white or very light gray soft sandstone which has been so severely crushed and shattered that most of it can be easily powdered between the

fingers. It is difficult to find a hard fragment larger than a few cubic inches and the harder pieces of sandstone near the outside edges of this crushed zone are cut by numerous closely spaced intersecting fractures that tend to make the rock break into diamond-shaped or rhombohedral pieces. In my opinion, the white color of the sandstone is due primarily to crushing. If a piece of the normal gray sandstone is crushed in a vise or with a sledge hammer the thoroughly crushed portion of the sandstone will appear white. All of us are familiar with the fact that glass -- even dark glass -- when crushed into a powder will appear white. This white color of crushed sandstone or glass is due to the reflection and refraction of the light by countless fracture planes or fracture surfaces between individual tiny fragments. Some of the white color is due to hydration and leaching of some of the sand grains and the natural cement that originally bound the sand grains of the sandstone together, but the principal reason for the white color is the crushing of the natural cementing material between the sand grains and many of the sand grains themselves into a sandy powder.

Many of the original feldspar sand grains have been changed into a white clay mineral, probably Kaolin, by the leaching and hydrating action of water percolating through the crushed rock. The quartz sand grains that comprise at least half of the sandstone are very little affected by percolating water and are still sand grains or fragments of the original grains. The presence of this altered feldspar (clay) between the quartz sand grains makes the rock somewhat impervious to water so that water impounded above the dam probably will not leak very badly beneath the dam through this crushed zone. However, some leakage through definite fracture planes especially on both sides of the crushed zone will occur at first, until the floor of the reservoir has been covered with a thick layer of silt. Most of the springs issuing from the floor of the apron just below the dam come from the two borders of this crushed zone, beneath Blocks A to C and H to J. These springs will be discussed later.

This crushed and faulted sandstone seemed to be supporting the dam with no sign of sagging when observed on August 13 and 23. However, I can not rule out the possibility that after it has been thoroughly saturated with water from the reservoir for some years it will become too weak to support the dam and allow the central part to sag and settle. This may cause the dam to crack and even to fail.

I soaked a coherent fragment of the crushed sandstone in a glass of water and at the end of 6 hours about half of it had disintegrated into clayey sand.

2. A fault zone consisting of 5 or 6 fault planes in a band 4 feet wide **passes** diagonally under the dam below Block F. Each of these nearly vertical (dip 75 to 88° West) fault planes is lined with black to dark gray, slickensided gouge 1/2 to 2 inches thick. This gouge is a clay-like substance composed of completely crushed and dragged out rock including considerable crushed black shale that gives it the dark color. It is compact and tough in its present unweathered condition but, when exposed to the weather long, it will change into a soft plastic light gray or buff clay, like the so-called clay seams

(weathered gouge) between sandstone blocks at the "bear hole" under Block N and acjacent blocks, that caused the State to condemn this part of the dam foundation until this material and the loose sandstone blocks were cleaned out.

3. Another parallel fault zone about 4 feet wide and also with 5 or 6 vertical fault planes lined with similar dark gray gouge passes diagonally under Block G. As was the case with the fault zone under Block F, about 40 feet to the southwest, this fault zone heads (strikes) about 15 degrees West of due North (N 15° W). Fortunately, these faults make an angle of 45 to 55 degrees with the face of the dam. This is much safer than if the faults passed directly under the dam at right angles to its face but, if possible, dam sites cut by faults are to be avoided because such faults or crush zones are zones of weakness and require close and extensive grouting and other precautions to hold the fractured rock fragments together and prevent excessive seepage beneath from undermining the dam.

SPRINGS BELOW DAM AND APRON

As mentioned previously the largest springs, some of them flowing (on Aug. 13) 5 gallons a minute or more of cool, fresh water generally with a sulphur (hydrogen sulphide) odor, issue from fractures in the sandstone of the apron a few feet to about 20 feet downstream from the edge of the dam and a few feet below its base. Considerable water also comes from the base of the gravel and boulders at the downstream end of the apron.

One good sized spring of clear, cool, fresh sulphur water issues from a fracture plane only 6 inches below the concrete near the center of Block G. It comes out of two or three fracture planes a fraction of an inch apart; these fractures are roughly parallel to the face of the dam and dip 20 to 30 degrees upstream (under the dam). This spring had doubled in size in 10 days from about 1 gallon a minute or less when first observed on August 13 to about 2 gallons a minute when studied again on August 23. It is now undeneath the apron and presumably was piped into the drainage system of the apron. Another small seepage of water was noted just below the base of Block F.

These springs or seepages may be pre-existing springs (some of which were known from the sulphur water here before the dam was built); they may be water seeping under the dam from the small pool above the dam (a hydrogen sulphide odor was noted by myself in springs that flow into the impounded pool a short distance above the dam so that the presence of hydrogen sulphide does not rule out some seepage under the dam); or, more probably, this water may be a mixture of impounded water that has seeped under the dam with water from pre-existing springs. Whether any of this water coming out as springs below has passed beneath the dam could be easily determined by dumping some non-poisonous, harmless dye into the water of the pool above the dam and watching for water of the same color below the dam. Dye of a purple color, such as permanganate of potash could be readily traced if it passed under the dam and is commonly resorted to in order to detect seepages under dams.

Particularly if it comes from pre-existing springs with a high head, this water may be dangerous because of the upward pressure of water on the base of the dam and apron. This is known as uplift pressure. Unless the water from springs issuing directly below the concrete is entirely conducted away by tile or pipe drains the uplift pressure of the water may cause the apron or even the dam to buckle up and become useless. Strong uplift pressure will be created by water seeping from the reservoir, when the latter is full, up under the dam or apron.

ABUTMENTS: As both abutments were studied by Dr. Berkey I did not spend much time on them. When observed on August 23, most of the loose, rusty-brown weathered and fractured sandstone and shale at the "bearhole" beneath Block N and adjacent blocks had been cleaned off but a large pillar of this weak material about 5 feet high was left, presumably to support the weight until the concrete had been poured in the rest of the hole under the left abutment.

A large hole still exists in the vicinity of Block N and this must be filled with solid concrete before there is danger of a flood filling the reservoir lake above the dam to this level - by November of this year. When viewed on September 1, in company with Mr. Ryan this pillar of unsafe fractured material had been removed leaving a large rectangular hole under the dam some 30 feet long and 8 to 10 feet high. As far as could be determined from surface inspection the present floor of this "bear hole" is composed of competent only slightly weathered sandstone and shale. This will probably be safe for the abutment foundation here provided it is well grouted.

The sandstone at or near the top of the left abutment is rusty-brown and considerably weathered but this will be mostly above the water level when the reservoir is full and should not constitute a menace.

DANGEROUS CONDITION AT OUTER EDGE OF SPILLWAY APRON

As shown by the attached drawing, "Enclosure 1, the spillway apron, 6 feet thick, is about 67 feet wide opposite the center of the dam. It narrows to about 20 feet toward the left abutment and to about 30 feet at the foot of the right abutment. The surface of the apron is nearly flat, sloping about 3 degrees (6 per cent grade) toward the dam. The southwestern third or so of the apron slopes toward the right (southwest) abutment 4 to 10 degrees (7 to 17 per cent grade) except for a steeply northward sloping wall about 15 ft. wide at the foot of the right abutment. This construction of the apron produces an irregular shallow basin the deepest part of which is close to the right abutment. Below (southeast of) the downstream edge of the apron there stands now a nearly vertical cut or cliff from 20 to 30 feet high of unconsolidated boulders and gravel (stream bed deposits of Matilija Creek). The front of this easily eroded cliff at present is separated from the downstream end of the apron by a trench to bed rock 4 to 6 feet wide, part of which is used to collect seepage water and waste water from the construction operations. The water collecting at the southwest end of this trench is pumped up over the cliff into the stream bed a short distance downstream.

The design of the apron has been changed so that its surface slopes toward the dam only about 6 per cent instead of the twenty per cent originally contemplated. This is safer than the steeper slope, as pointed out by E. E.Everett.

It is my understanding that the cliff of loose gravel and boulders just downstream from the apron is to be left in its present form without support. This is a dangerous condition because the top of the easily eroded gravel cliff will be the outlet of the stilling pool at the base of the waterfall and the face of the cliff will be saturated with water as soon as the stilling pool fills up with water pouring over the dam. The southwest slope of the surface of the apron from near the center of the dam to the foot of the right abutment will start a strong eddy or whirlpool at the foot of the falls as the pool below the dam fills with water. When this gravel cliff becomes soaked with water, especially when subjected to lateral scour by the whirlpool, the boulders and pebbles from this cliff will fall down on the apron and fill up much of the pool. As it now stands (before the cliff caves on to the apron) the pool near the right abutment and a few feet below the base of the dam will have amaximum depth of 40 or 50 feet which is a fairly effective cushion. From the center of the apron northeastward (toward the foot of the left abutment) the water will be shallow and have little stilling effect on the powerful turbulent water falling over the dam during or after a heavy rain. In fact the northern part of the apron with its southward slope will probably be covered with a thick sheet of very turbulent rapidly southward flowing water directed at the gravel cliff just back of the apron and at the right abutment. There will be insufficient cushioning effect of tail water on the northeastern half of the apron during a severe storm when 6 feet of water or more will be rushing over the top of the dam. The now nearly vertical gravel cliff will soon be reduced to an inclined surface sloping toward the dam. Waves of agitated water (Everett's hydraulic jump) can rush up this slope causing erosion and probable severe damage to property below during floods. The filling of the deeper part of the stilling basin with debris will reduce the depth of the water and the effectiveness of the tail water cushion. The stilling pool should be at least 40 feet deep (fide E. E. Everett) or 1/4 the height of the fall to be effective. Not only that, but the boulders and pebbles scouring around in the whirlpool on the southern part of the apron, during floods will act as abrasive tools and will wear down the surface of the concrete apron by the formation of pot-holes. After the gravel cliff is worn away by the overflow from the first big storm or two, the downstream edge of the apron will very probably be attacked and undermined by the swirling waters. Blocks of the apron will begin to cave off and if the process is permitted to continue upstream, the dam itself will be undermined. The crushed sandstone beneath the central part of the apron and dam is so soft that it will be easily washed out once the apron starts to break up. If this undermining process began during a storm like that of 1914 or even 1938 the water below the dam would be so deep and turbulent that the undermining probably could not be detected. The dam itself might fail because it could not be drained during such a flood. With its small outlet some time will be required to drain a full reservoir above the dam even if it weathered the storm and the damage was detected. Most dams fail during floods when not much can be done to strengthen them.

The dangerous condition just downstream from the apron can be avoided or greatly lessened by one of the two following methods:

1. Lengthen the spillway apron to 126 feet as recommended by Mr. Everett. A concrete sill should be placed in the stream channel at the outlet of the stilling pool also.

This will entail the removal of some 25,000 yards of stream gravel and boulders to lengthen the apron an extra 55 or 60 feet and will be expensive but it will also be safer.

2. Fill in the space between the downstream end of the apron and the gravel cliff with a strong, nearly vertical, concrete retaining wall at least 3 feet thick at the top. The top of this wall should be level with the bed of Matilija Creek which has an elevation of 975 feet a short distance downstream from the apron. It will have a maximum height of about 40 feet above the top of the apron. This retaining wall will serve two purposes:

(a) It will support the gravel cliff back of the apron and prevent the rapid filling of the stilling pool with debris washed from this cliff. Some slabs of sandstone will also probably fall from the right abutment above but they should not be serious.

(b) The top of the concrete wall will act as a hard sill or lip and greatly slow down erosion by the water flowing out of the stilling pool.

In order to slow down erosion still farther and prevent possible undermining of the retaining wall and apron the bed of Matilija Creek should be lined with a thin layer of concrete for 20 feet or more below the retaining wall or sill. This channel lining can be replaced as the downstream end of it is undermined by each flood at small cost.

RECOMMENDATIONS

Although I would not have recommended that a high dam, particularly of this thin type, be built at this badly faulted site, the dam is there and we must try to make it hold. Unless Dr. Berkey's and my recommendations stated below are followed I can not vouch for its safety, much as I would prefer to do so. It will probably hold if they are followed.

1. Build a strong concrete retaining wall to the elevation of the stream bed (975 feet) just back of (downstream from) the outer edge of the spillway apron. (A safer alternative to this is to extend the length of the apron to 126 feet but I believe that a concrete sill or retaining wall at the end of the apron is needed anyway).

2. Line the stream channel downstream from the retaining wall with concrete for a distance of 20 feet or more.

3. Follow Dr. Berkey's recommendation by making a grout curtain (grout holes 50 feet deep and 5 feet apart under Blocks C to H inclusive and 10 feet apart under the remainder of the floor of the dam. Many of these holes should be drilled at steeply inclined angles so that they pass beneath the dam and the grout will be forced into the rocks under the dam and those that form ~~and~~ the floor of the reservoir just above it. If the crushed sandstone under the central part of the dam will not take grout, then 6 or 8 inch or larger holes 5 feet apart should be drilled and filled with concrete to act somewhat like pilings.

Better yet, drill alternate holes on one side of the dam and the other in between them on the opposite side.

4. Continuous cores should be taken from every fifth hole (25 feet apart) and made available immediately to study by your geologist. The information from these cores should be very valuable, especially in case of future trouble. I have recovered excellent cores of loose sand by using reverse circulation which floats the cores out on the mud stream.

5. Ten or more core holes 50 feet deep should also be drilled in a staggered line across the floor of the reservoir a short distance above the dam and the cores made available for immediate study by your geologist. Whether or not an upstream apron as recommended by Dr. Buwalda should be built will depend on what these core holes show. If the lower part of the reservoir for more than 50 feet above the dam is extensively underlain by crushed sandstone the water would seep under such an apron so that it would not be very effective in my opinion. If less pervious or sounder rock is found a short distance above the dam such an upstream apron would be highly desirable if placed on bed rock or with a cut-off trench to bed rock.

6. Careful inspection for seepage under the dam and apron, particularly for the first appearance of muddy water when the dam is not spilling, should be made at least once a week during dry weather and, continuously or several times a day during storms. Muddy water from beneath the apron when the water in the reservoir above is clear or the reservoir is not full will indicate erosion under the dam and it should be drained as rapidly as possible. Muddy water is said to have appeared

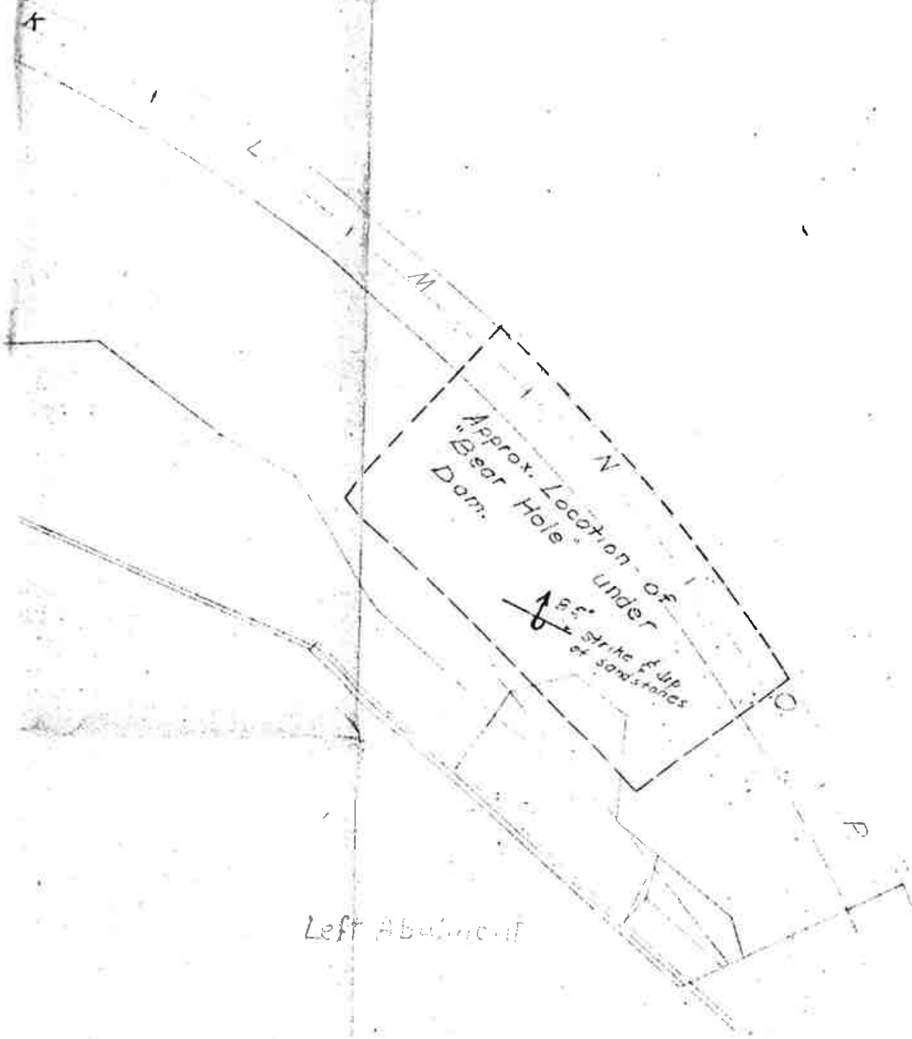
from beneath the St. Francis dam at least two weeks before it failed.

7. As a check on seepage under the dam I suggest that some dye such as potassium permangante be dumped into the small pool that has now collected above the dam supplemented by more water from the diversion pipe. This dye colors the water purple and can be detected when diluted to one part in 10 million (Legget, Geology and Engineering, page 359, 1939, McGraw-Hill & Co.). It is harmless in such weak concentrations.

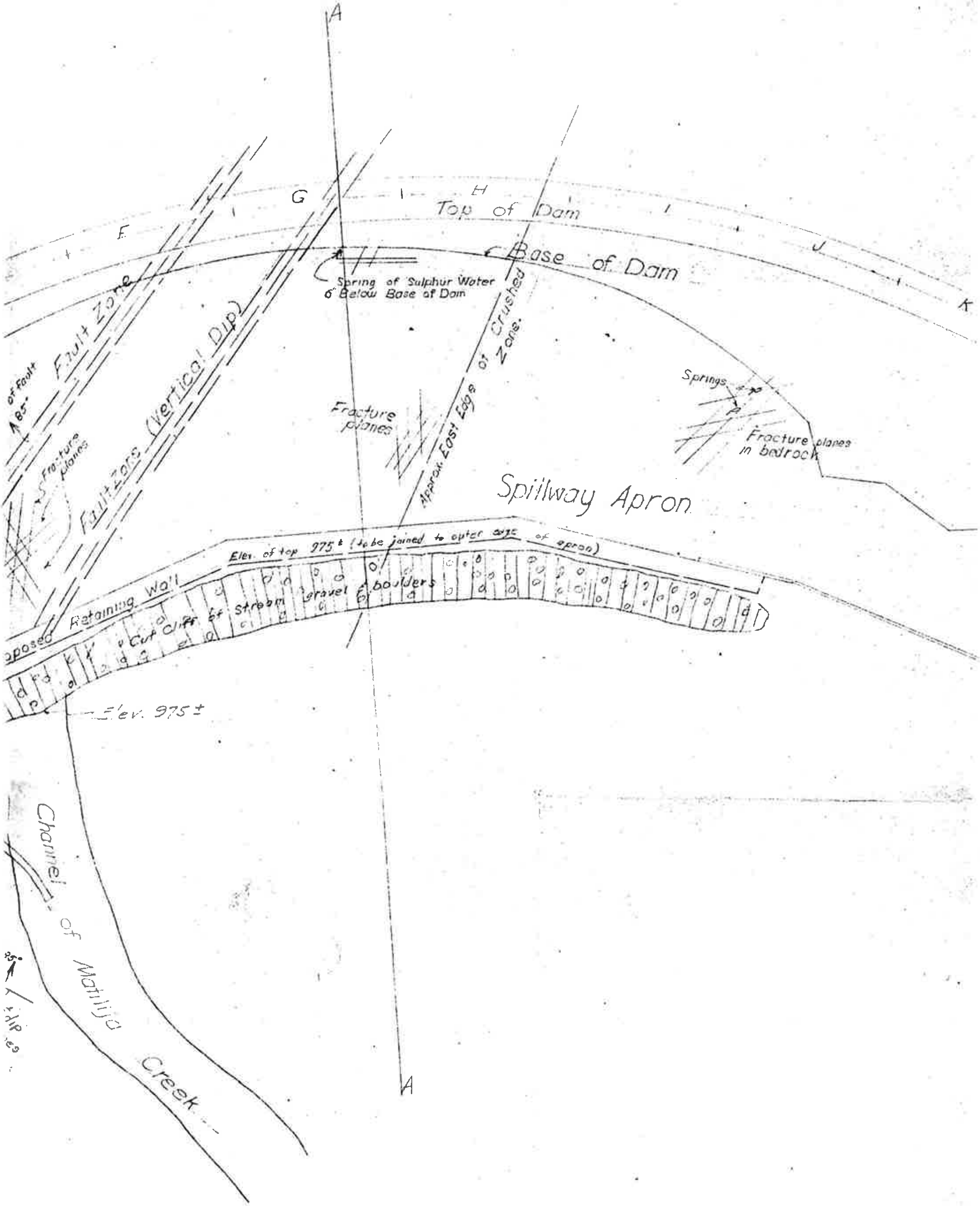
Respectfully submitted,

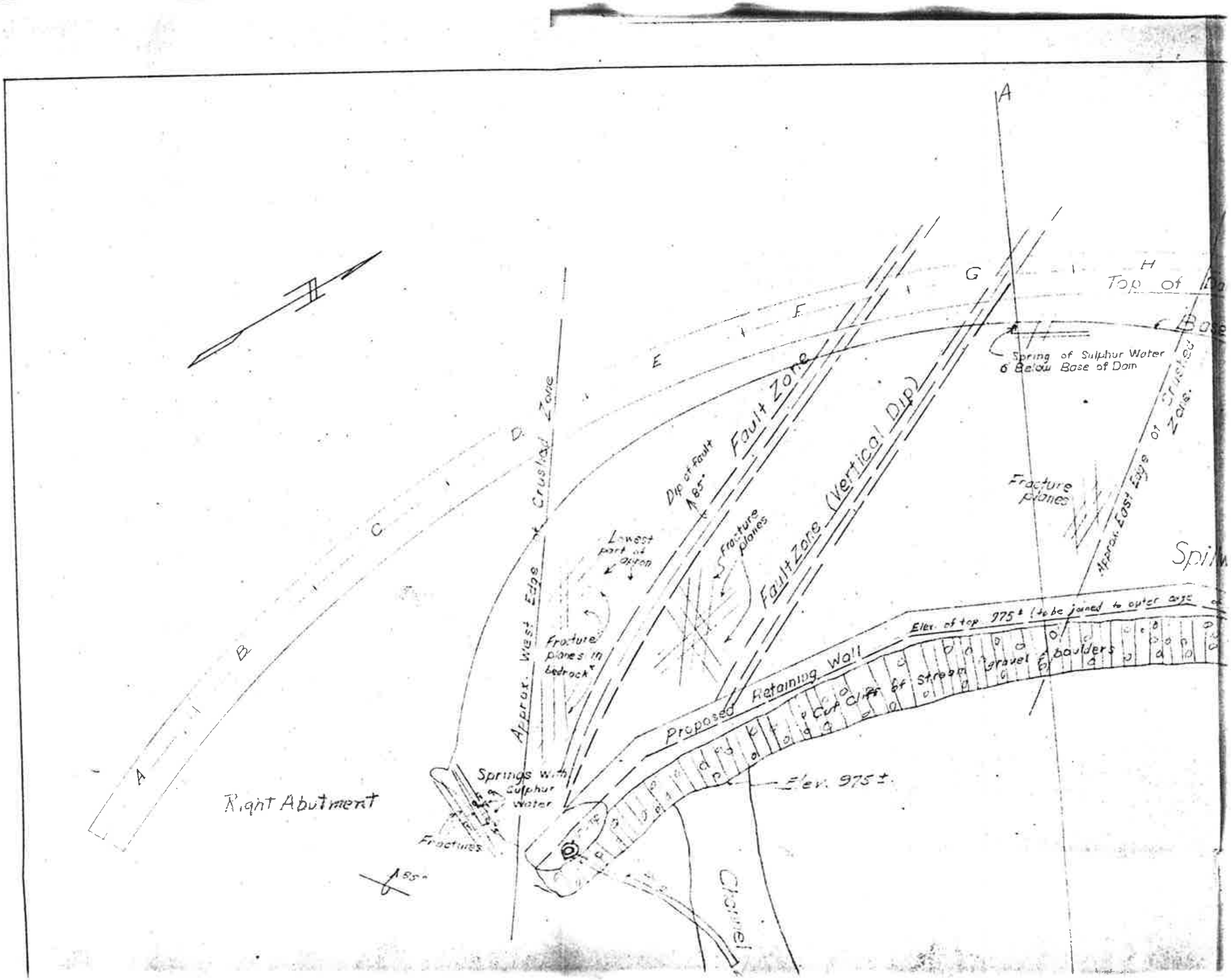
Thomas L. Bailey

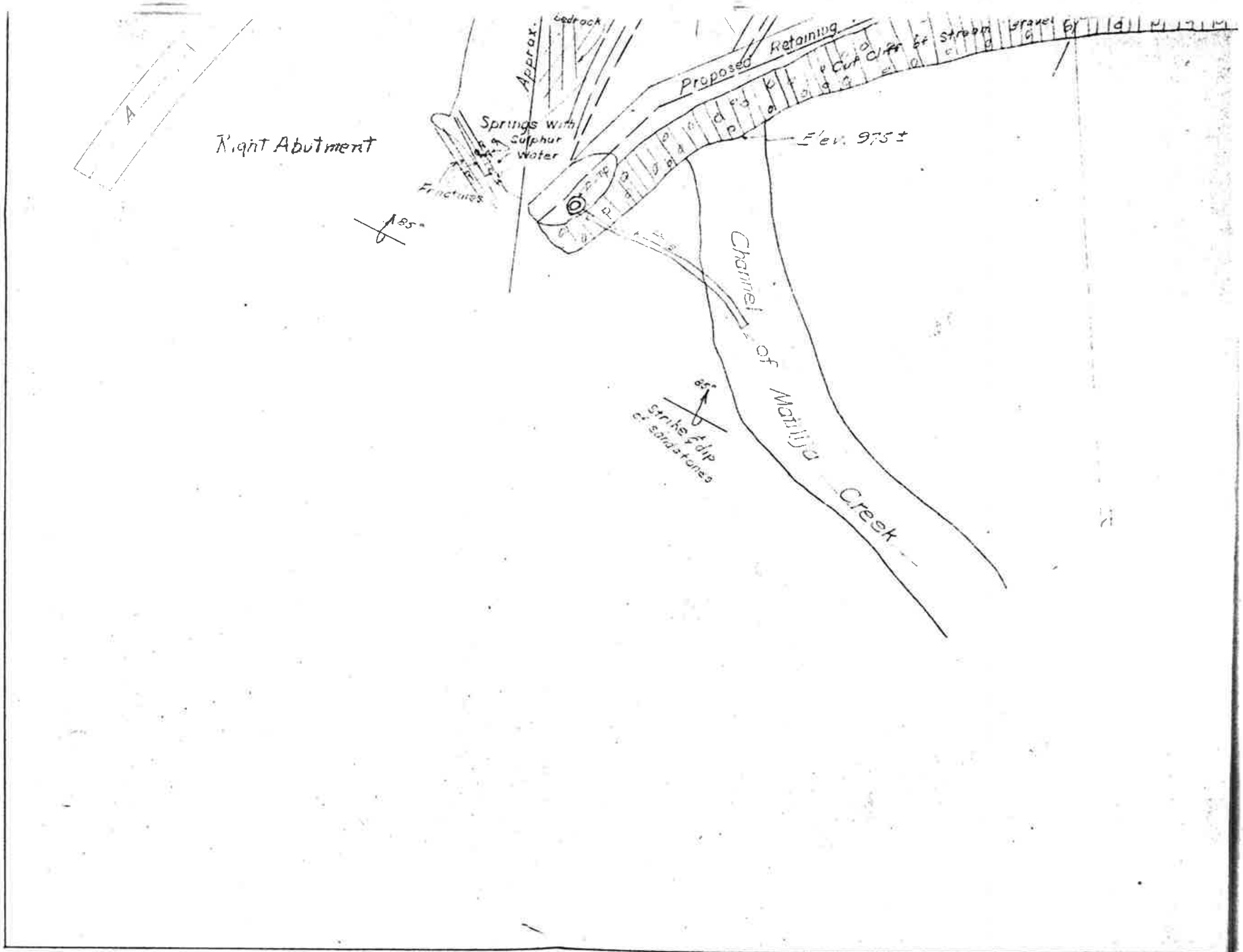
September 9, 1947



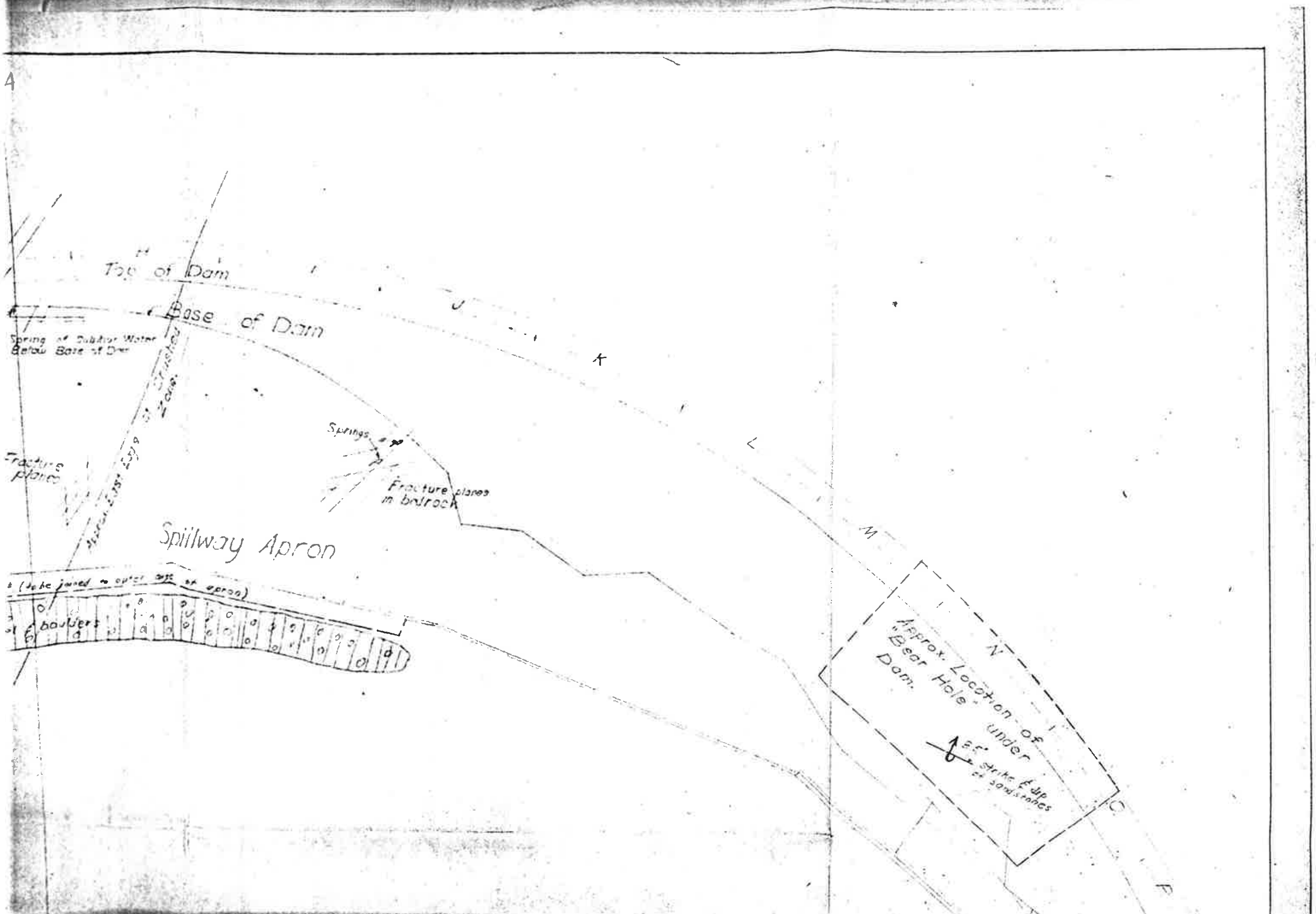
MATILIJA DAM
CONCRETE APRON
OLOGICAL STUDY BY
THOMAS L. BAILEY
Scale 1" = 20'
September 1947

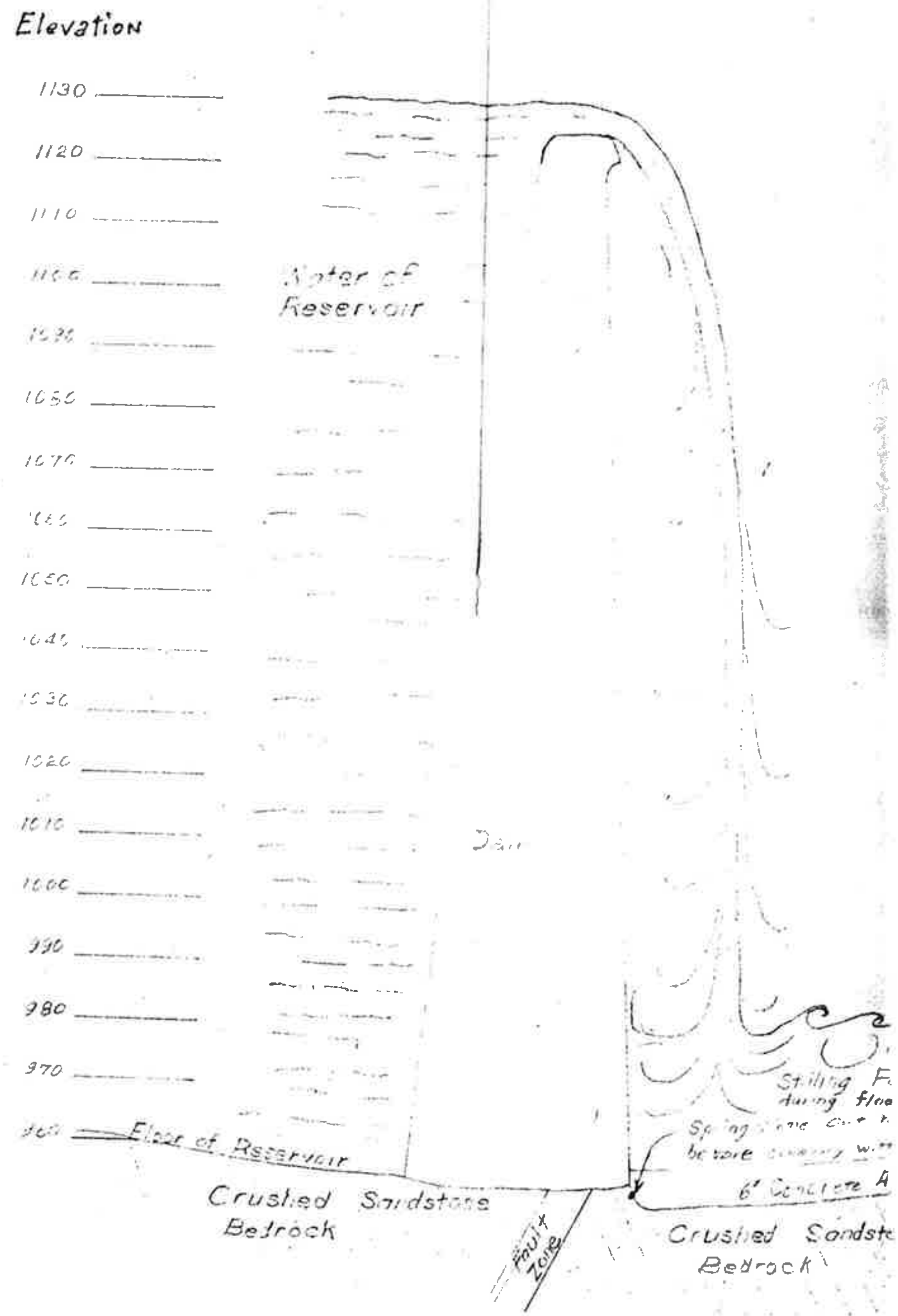

A
G
H
F
Top of Dam
Base of Dam
J
K
Spring of Sulphur Water
6' Below Base of Dam
Fault Zone
Fault Zone (Vertical Dip)
of Fault
85°
Fracture planes
Fracture planes
Approx. East Edge of Crushed Zone
Springs
Fracture planes in bedrock
Spillway Apron
Elev. of top 975± (to be joined to outer edge of apron)
Retaining Wall
Cut Cliff of Stream gravel & boulders
Elev. 975±
Channel of Matilija Creek
A


A
A
B
C
D
E
F
G
H
Spring of Sulphur Water
6' Below Base of Dam
Approx. West Edge of Crushed Zone
Approx. East Edge of Crushed Zone
Fault Zone
Fault Zone (Vertical Dip)
Dip of Fault 85°
Fracture planes
Fracture planes
Lowest part of apron
Fracture planes in bedrock
Proposed Retaining Wall
Cut Cliff of Stream gravel & boulders
Elev. 975±
Springs with Sulphur water
Fractures
Right Abutment
85°
Channel



A
Right Abutment
Approx.
bedrock
Proposed Retaining
Cut Cliff of Stream
gravel
Springs with Sulphur Water
Fractures
85°
Elev. 975±
Channel of Matilija Creek
85°
Strike & dip of sandstones


Top of Dam
Base of Dam
Spring of Subsur Water Below Base of Dam
Fracture planes
Springs
Fracture planes in bedrock
Spillway Apron
boulders
Approx. Location of "Bear Hole" under Dam.
35° strike & dip of sandstones
H
J
K
L
M
N
O
P

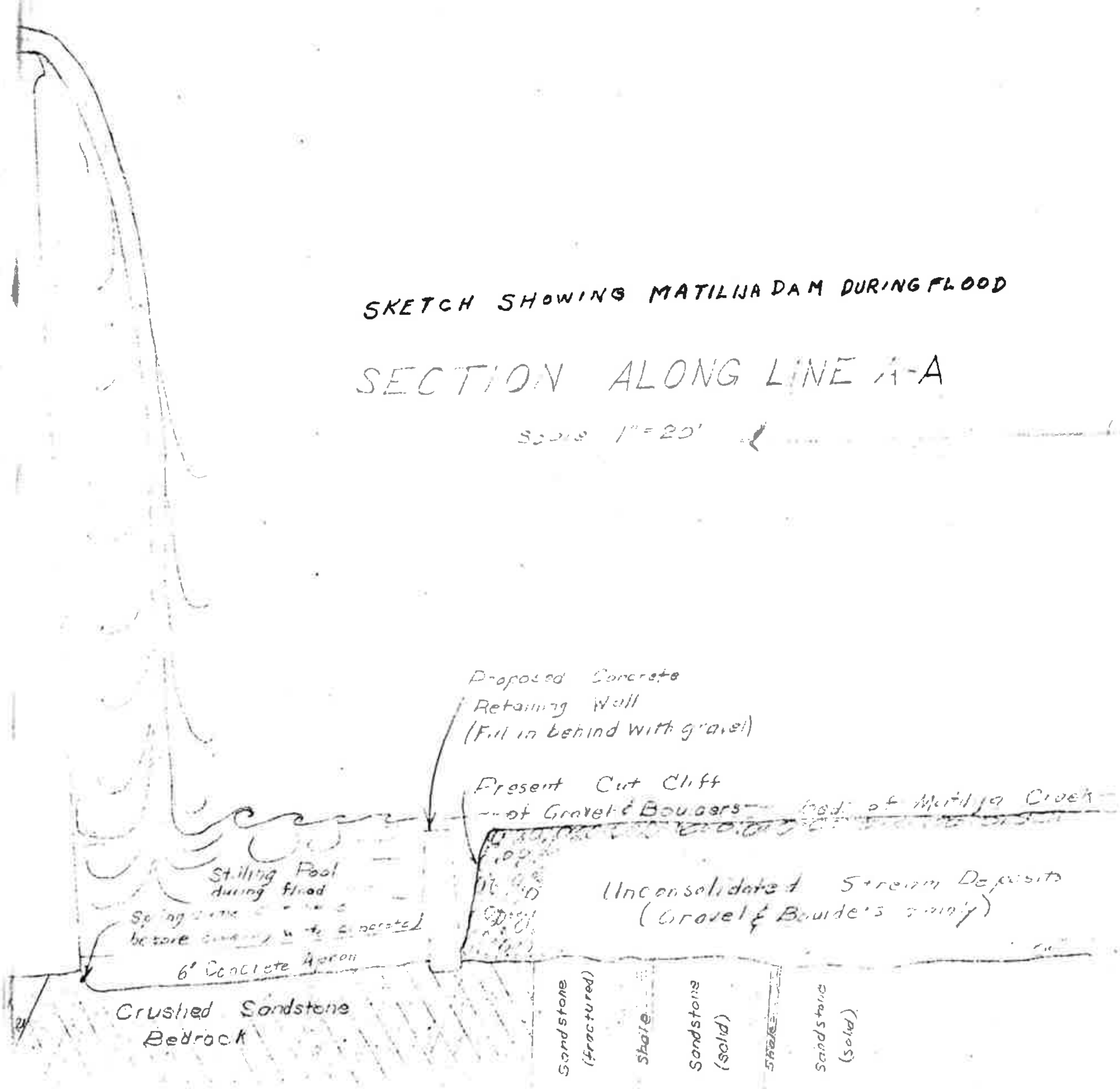


Elevation
1130
1120
1110
Reservoir
980
970
Floor of Reservoir
Crushed Sandstone
Bedrock
Fault Zone
Crushed Sandst
Bedrock
6' Concrete

SKETCH SHOWING MATILIJA DAM DURING FLOOD

SECTION ALONG LINE A-A

Scale 1" = 20'



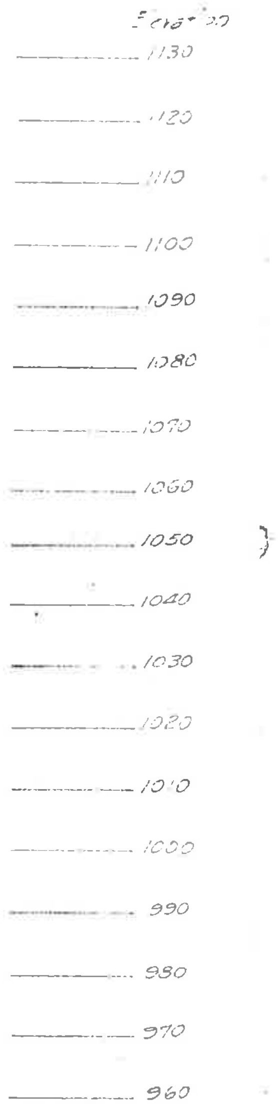
MATILIJA D

SHOWING CONDITIONS IN FLO

GEOLOGICAL STUDY

Scale As

Sept



MATILIJA DAM

[C]ONDITIONS IN FLOOR OF SPILLWAY APRON

[G]EOLOGICAL STUDY BY THOMAS L. BAILEY

Scale As Noted

September, 1947