and, where available, in diamond drillholes in the ore area during the period from July 1, 1946, to March 18, 1949. In addition, the geological formations cut in the Fad Shaft and the water level in the Holly Shaft and in the Windmill Well in Diamond Valley are shown on the chart.

The Fad Shaft was started in February, 1942. Little sinking was done before the latter part of 1945. The difficulty and expense of obtaining equipment, labor and supplies during and after the war, together with occasional stretches of heavy ground, greatly delayed the sinking. Down to 1350 feet depth, which was reached late in October, 1946, only a small flow of water was encountered in the shaft. As the depth became greater, the flow of water increased to slightly more than 1,000 gallons per minute. There was a further delay and expense in obtaining Diesel generator sets and pumps to handle this water. At 2,100 ft. depth the shaft passed from Hamburg Dolomite into the impervious Secret Canyon Shale. No additional water was encountered in the shale, but 1000 to 1200 gallons per minute continued to flow into the shaft from the higher formation. The shaft finally reached the objective of 2415 feet depth, 165 ft. below the proposed main 2250 level, at the end of November, 1947. On the way down, stations had been cut at the 1200, 1700, and 2000 foot levels. Sinking was discontinued and the shaft was allowed to fill with water to just below the 2250 level while the station was being cut on that level.

The station was nearly completed in March, 1947, with the flow of water gradually increasing to 1500 gallons per minute. A crosscut was started toward the orebody developed by drilling, from 800 to 1200 feet southwest of the shaft. A water door was installed, designed to withstand 250 pounds per square inch, equivalent to 550 ft. of head. The crosscut passed through the 400 foot Martin Fault, going from Secret Canyon Shale into Eldorado Dolomite. Little additional water was encountered on this fault, which also crossed a wing of the station. On March 25, 1948, about 30 feet beyond the Fault, or 170 feet from the shaft, one drillhole of a round in the face encountered high pressure water. The pressure was estimated by the management to be 450 lbs. per sq. in., equivalent to 1000 ft. head. The round was of course not shot. As new Diesel generators and pumps that were on order had not arrived, the flow, estimated by Mr. G. W. Mitchell at about 3000 gallons per minute, exceeded the capacity of the installed pumps. The water door was closed, but the cap on one of the three large pipes set in the door blew off. It was repaired, but blew off again. The pumps were drowned, and in about a day the water rose to 5,770 feet elevation, 1,055 feet above the 2,250 level. At one time the water was rising at the rate of 100 ft. per hour. Then it rose more slowly until by the middle of May, 1948, it was at 5,920 feet elevation, about 70 feet below the original water level.

The time from May 15, 1948, to December 16, 1948, was occupied in extremely costly and unsuccessful attempts to unwater the shaft. Additional Diesel generators and pumps were installed, but the flow of water increased as fast as the larger pumps could handle it. In the middle of November, when pumping increased to 9000 gallons per minute, the shaft was unwatered to 30 feet above the 2250 Level, but it soon rose again to 400 feet above the level. After August, 1948, the water became very muddy, and thick sediment settled in the shaft below the 2250 station. On December 16, 1948, after the fairly solid mud had risen 70 feet above the bottom, and the very gritty water was endangering the pumps, the attempt to unwater the shaft was abandoned. In about a day the water in the shaft rose 600 feet, to 5680 ft. elevation, and then rose more slowly, with a flattening curve, until on March 15, 1949, it stood at 5920 ft. elevation. Since that it has been rising very slowly.

The level of water in drillholes is misleading, because the holes had all become plugged near the points where they passed from Hamburg Dolomite into Secret Canyon Shale, at 5710 to 5750 feet elevation. In the latter part of October, 1948, Drillhole E was reopened through the shale and cased to just above the ore horizon. The water level in the drillhole quickly dropped to 5607 feet elevation, but then rose to 5620 feet. It stayed at this level until the pumps were stopped on December 16, 1948. Then it rose in a curve very close to that representing water in the Fad Shaft.

It may be a coincidence that the level at which the water level stopped going down in Hole E is practically the elevation of the intersection of the bottom of the Hamburg Dolomite with the Office Fault.

Drillhole D was not reopened until just after the pumps were stopped. Thereafter, as shown on the chart, it rose much more slowly than the water in the Shaft and in Hole E, but finally reached almost the same level. At one time the water level in Hole D was 130 feet below that in Hole E. This shows that the Hamburg Dolomite is only moderately porous. It casts doubt as to whether or not the lowest water level reached in Hole E was the actual level of the ground water table at that time.

It is worthy of note that the water level in the old Holly Shaft, 6500 feet north of the Fad Shaft, has risen only 4 feet, from 584 to 580 feet below the collar, since pumping stopped at the Fad. In the same period the water in the "Windmill" well in Diamond Valley, about 7 miles northwest of the Fad Shaft, rose only one foot. These changes were no greater than the usual seasonal changes. The water level in both places is 60 to 80 feet below the original water level in the Locan Shaft. There is nothing to indicate that pumping in the Fad Shaft had any effect on the water level in the Holly Shaft or in Diamond Valley.

The following table shows the principal changes in water level in the shaft and drillholes, with approximate amounts pumped:

		Elevation of Water at End				
Period	Days	in Drillholes	in Fad Sh.	change in Drillholes	Gal. per minute pumped	Total gallons pumped
7/1/46-10/25/46	120	± 6,000	5625	0	100	17,300,000
10/29/46-12/10/46	43	5,990	5560	-10	670	41,500,000
12/11/46-2/10/47	63	5,740	5490	-250	880	80,000,000
2/11/47-3/25/48	408	5,705?	4710	-35?	1120	657,000,000
3/26/48-5/15/48	51	5,885	5920	+180	0	0
5/16/48-6/15/48	30	5.750	5545	+134	2470	106,600,000
6/16/48-11/22/48	160	5,607	5140	-143	5820	1,341,000,000
11/23/48-12/16/48	23.5	5,620	5518	+13	8680	292,000,000

12/16/48-12/28/48	12.5	5,865	5850	+245	0	
12/29/48-2/28/49	62	5,920	5915	+ 55	0	
Total						2,535,400,000

The most startling thing about this table, as well as the chart, is the fact that after November 22, 1948, while the average gallons pumped increased from 5820 to 8680 gallons per minute, the level of water in the Fad Shaft rose 478 feet. The high pumping rate evidently started a greatly increased flow of water.

In the last 16 days of pumping, from December 1st to 16, 1948, fairly steady pumping at the rate of nearly 9000 gallons per minute brought the water in the Shaft down from 5150 to 5088 feet. At this rate of drop, the 2250 Level might have been unwatered in 4 to 6 months. The mud and grit in the water made this impossible.

DISPOSAL OF WATER

The water pumped from the Fad Shaft was piped to a point on the dump a few hundred feet north of the shaft; was run over a good weir for measurement; and then ran down the steep hillside to a north-running gulch down which it flowed into Diamond Valley, about five miles away. It divided in several channels in the valley, and finally spread out in a shallow pond about seven miles from the mine. The pond covered a maximum area of less than a square mile, with a depth of less than a foot except in an old gravel pit where it was six feet or more deep. The water apparently sank into the valley fill of gravel and clay or evaporated very slowly from the pond. On April 15, 1949, 4 months after pumping stopped, the ground was still muddy where the pond had been, and the gravel pit was filled to within 2 or 3 feet of the top. On April 28th the water in the pit had gone down only one or two additional feet. As water in the Windmill well about a mile north of this pit stands 80 feet below the surface, the clay and gravel of the valley floor are evidently resistant to percolation of water.

In order to find whether or not water was sinking into the ground near the shaft and so was being repumped, readings were taken by Company engineers at culverts where the water passed under roads. The first recorded reading, undated, and readings on November 16, 1948, gave the following results:

	1st Reading	Reading Nov. 16, 1948
Weir at shaft	5,000 gal. per min.	8,930 gal. per min.
Wood culvert 3/4 mi. North	4,893 " " "	-
Concrete culvert, H'way 50, about 3.5 miles North	5,775 " " "	9,350 " " "
Corrugated pipe culvert, H'way 20, about 5 miles North	4,884 " " "	8,681 " " "

These readings seemed to indicate that practically no water was getting back into the mine. However, measurements had been computed by surface velocities, measured by timing chips that floated through the culverts. The surface velocity was of course much greater than the average velocity. The quantities of water flowing through the two lower culverts (the wooden culvert having been washed out) were therefore recomputed according to accepted formulae, based on length and slope of culverts, the depth of water shown by the highest marks, and the character of the culvert. This computation gave the following results:

Maximum amount pumped - 9,000 gal. per min.
Max. flow through concrete culvert
under H'way 50 - 4,570 gal. per min.
Max. flow through corrugated culvert
under H'way 20 - 6,900 gal. per min.

At Highway 20 the stream made sharp turns at both ends of the culvert, and there is a reef of bedrock a few feet below the culvert, at practically the same level as that of the bottom of the pipe. These conditions probably slowed down the current and quantity to far below the 6,900 gallons per minute indicated by the formula.

As the stream is now dry, the maximum depth of water in the culverts is uncertain. The actual flow cannot be accurately checked. It seems possible that nearly half of the water pumped sank into the ground within three miles of the Shaft. The point where the water sank cannot be determined. A few hundred feet from the shaft the stream cut a channel through loose surface material to bedrock, which consists of thin bedded Pogonip limestone, dipping 20 degrees northeast toward the large Jackson Fault, which is hidden by soil. There are good sized solution pot-holes and openings between beds in the limestone. It is at least possible that much water sank into the ground within a few hundred feet of the Shaft, and found its way down the Jackson and the intersecting Martin Faults into underground channels leading to the fissure that brought in the heavy flow on the 2250 Level.

The 9000 gallons per minute pumped in the last month before the mine was allowed to flood may therefore include a large but uncertain amount of recirculated water.

DEDUCTIONS FROM WATER DATA

The data on water pumped and changes in water level were analyzed and compared with the pumping history at Bisbee, Globe, and Tombstone, Arizona; Ely and Jarbridge, Nevada; and Los Lamentos and other districts in Chihuahua, Mexico, that encountered great flows of water.

In nearly all of these mines it proved that the problem consisted of pumping out an underground "lake" in the cavities and porous areas in limestone, and at the same time pumping the inflow from surface water and other sources. The fault block that carries the water at Bisbee is many times as great as the downthrown orebearing block at Eureka. About 17 billion gallons were pumped in 27 years in Bisbee to unwater the Junction-Briggs-Campbell area from the 770 to the 2200 level. Sinking was carried on 300 to 400 feet at a time, and the successive levels were fairly well opened up before sinking was resumed. It seemed likely that about half the water pumped was from the water table, and the rest was new inflow. The total water pumped never exceeded 5000 gallons per minute while this plan was followed. Later on the shaft was sunk to the 2800 Level, with no intermediate work. With the 600 foot head a crosscut encountered a flow that exceeded the capacity of the pumps, and development of the bottom level had to be discontinued until the water table had gradually been lowered.

This example was more or less typical, with exceptions such as the following:

In the Old Dominion Mine in Globe the workings at the west end of the mine had been carried to a large cross fault under Pinal Creek, and under a deep deposit of gravel and conglomerate. After a particularly heavy cloudburst a water channel was opened from Pinal Creek to the 1200 Level, and the west end of the level was lost. It required pumping 9000 gallons per minute, compared with the normal 4000 to 5000 gallons, to recover the level. Thereafter deeper levels were stopped before they reached the Fault.

In Los Lamentos and one or two other Chihuahua lead districts, water was encountered below the level of the main rivers, 20 miles or more away. It could be pumped down 100 feet or more in small areas, but longer crosscuts brought in great flows that were never controlled. The limestone at Los Lamentos contained caves that were continuous for thousands of feet.

In Jarbridge crosscuts through a large fault on the 800 and 1000 Levels encountered heavy flows of water, below the valley level. The total water pumped increased to 12,245 gallons per minute, and operations were abandoned after a few months.

The deduction from these and many other examples is that in nearly all cases the water table can be successfully pumped down if shafts are not sunk too far at one time. In a very few places the flow has been so great that the orebodies did not justify the pumping expense.

At Eureka, an attempt was made to lower the water table in one lift from the original level, at 5965 feet elevation, to below the 2250 Level, at 4715 feet elevation. Both the Hamburg Dolomite and the Secret Canyon Shale were tight enough so that a relatively small flow was encountered in them. The general water table, as shown by the diamond drillholes, was lowered only 300 or 400 feet by sinking the shaft. Therefore, when the water course was encountered by the drillhole in the face of the 2250 Level crosscut, the effective head was 900 feet or more. The water did not come in on the Martin Fault, but may have come in on the Office Fault, which was directly connected with the orebearing Block I-A of Eldorado Dolomite. After pumping was resumed and the water had been lowered to below the 1700 Level, the high velocity resulting from greater pump capacity greatly enlarged the watercourse, so that the water level in the shaft came up from a low of 4770 to above 5100 feet. Pumping at the rate of 9000 gallons per minute was gradually lowering the water again when the mud and gravel stopped the pumping.

This condition resembles that at Bisbee much more closely than that at Los Lamentos and similar districts where pumping made practically no impression on the water table. It seems likely that if levels had been opened up at 300 to 400 feet intervals, instead of going more than 1250 feet below water level all at once, no serious difficulty would have been met with. At the worst, it might have required 3 or 4 years pumping at the rate of 5000 gallons per minute to unwater the ore area on the 2250 Level.

If, as seems possible, a considerable part of the flow in the last few months pumping at Eureka was recirculated water that ran down the Jackson Fault or other fractures, the problem may be much simpler. When pumping is resumed, this can readily be proved by introducing radioactive isotopes into the discharge stream, and testing the underground water with a Geiger counter.

An attempt was made to determine the source of the underground water by analysis of the mud and gravel remaining in the 2nd or 800 Level sump. Following are the analyses, made by Abbot A. Hanks, Inc.:

	Sample 1 Gravel	Sample 2 Mud in Bottom of Sump	Sample 3 Mud Adhering to Side of Sump
CaO	31.55%	21.96%	21.67%
MgO	10.41%	10.0 %	10.44%
SiO_2	12.01%	23.3 %	24.7 %
Al_2O_3	4.06%	8.34%	
FeO	3.19%	3.80%	
Loss on Ignition (equals theoretical CO_2)	36.16%	29.34%	

A spectrographic analysis of iron stained bits of rock picked out of the gravel of Sample 1 indicated 3 to 10% Pb, 1 to 5% Zn, and 5 to 10 oz. Ag. with much lime and iron and small amounts of other elements. This suggests that the watercourse passed through an orebody.

A "differential thermal analysis" of the sludge, made by Professor Joseph A. Pask of the University of California, indicated the following distribution of minerals:

Montmorillonitic clay		35-40%
Chloritic material		10-15%
Dolomite		20-25%
Calcite		25-30%
Goethite	approx.	3%
Carbonaceous matter	"	1%

As montmorillonite is often a surface clay material, this distribution suggests that part of the sludge may have been washed down from surface, possibly by circulated water.

Water analyses from various places gave the following results, in parts per million:

	HCO_3	Cl	NaCl	SO_4	Na_2SO_4	SiO_2	Ca	Mg	Tot. Sol.	Ca & Mg. Carb.	Alkalinity
Mine Water Oct.8/48	223.7	17.7	29.2	22.6	33.2	4.0	44.7	26.4	280.4	211.4	182
" " Mar.5/49	253.2	15.5	27.2	44.9	66.4	4.0	48.3	24.0	356.4	221.5	208
Fad Shaft May '49	250.1	28.4	46.8	35.6	52.7	5.6	45.7	25.1	328.4	218.8	205
D.DH E " "	79.3	24.8	40.9	51.9	76.8	7.6	14.6	6.3	192.4	62.8	65
Dft.to D.DH E" " (Small flow)	225.7	17.7	29.2	33.7	49.8	5.6	56.3	14.4	280.0	200.8	185
Well #1 Diamond Valley "	247.1	24.8	40.9	15.6	23.1	25.8	36.8	13.7	293.6	148.6	203
Ditch from Devils Gate 5/49	707.6	574.5	947.1	491.4	726.3	6.0	23.7	82.6	2465.6	320.00	655
Holly Shaft " "	247.1	28.4	46.8	21.3	32.2	6.4	53.2	19.7	296.8	215.1	203

The water analyses show that the large flow of water through Devils Gate is completely different from either the Diamond Valley water or the underground water. There cannot have been any drainage into the mine from this source.

The water in Well No. 1, in Diamond Valley, is more like the mine water. However, the much lower sulphate content in the well water, and the much higher silica, make it seem unlikely that there was any serious flow of water from the valley into the mine.

With a view to trying to determine the portion of water that came from lowering the water table and the portion that came from outside sources, comparisons were made in periods when the water table, both in drillholes and in the shaft, went down, and in succeeding periods when the pumps were stopped and water rose through similar vertical intervals. The water pumped while the water table was going down evidently came partly from the local water table and partly from a flow through watercourses from more distant areas. In the periods when the pumps were stopped the flow from outside equalled the amount that had been drained from the local water table. Following are the three most useful comparisons:

1. Unwatering drillhole area from 5884 to 5620 ft., or 264 ft. in 190 days, 5/16 to 11/22/48.
   Pumping Av. 5300 g/p/m or 1,447,000,000 gal. total.
   Refilled in 21½ days.
   Pumped from water table 540 g/p/m or 147,000,000 gal. total.
   Pumped from outside source, 4760 g/p/m or 1,300,000,000 gal. total.

2. Unwatering Fad Shaft from 5920 to 5088 ft., or 832 ft., in 213.5 days from 5/16 to 12/16/48.
   Pumping Av. 5670 g/p/m or 1,740,000,000 gal. total.
   Refilled in 62 days.
   Pumped from water table 1270 g/p/m or 390,000,000 gal. total.
   Pumped from outside sources 4400 g/p/m or 1,350,000,000 gal. total.

3. Unwatering to 5515 ft. level (1450 lev.) or 405 ft. in 33 days, from 5/16 to 6/18/48.
   Pumping Av. 2530 g/p/m or 120,000,000 gal. total.
   Refilled in 61 days.
   Pumped from water table 1645 g/p/m or 78,000,000 gal. total.
   Pumped from outside sources 885 g/p/m or 42,000,000 gal. total.

These computations are, of course, approximate, but they show that as rate of pumping increased, a much greater proportion of total water came from outside sources, and a smaller proportion came from the water table, either in drillholes or in the shaft. This may have been due either to opening up the underground channel so that more water flowed in from a distant source, or to recirculating water that ran down cracks from the surface, or both.

An attempt was also made to compute the possible annual amount of water added to the water table from the proportion of rain and snowfall that gets into the underground table. Mr. Aiken, of the Water Resources Division, U. S. Geological Survey, stationed in Ely, has estimated that about 7% of the annual precipitation of 12 to 15 inches at Eureka may get into the Water table, and the rest is evaporated or carried away by the surface drainage. The area that might be tributary to the Fad workings is most uncertain. It does not extend as far as the Holly Mine, 6500 feet north. In the Phoenix Incline the water table is reported in U. S. G. S. Monograph VII to have been 650 feet higher than in the Richmond Shaft, half a mile further north. Evidently in the mountain range in which the mines are situated, faults control the water table to a large degree, and surface water from only a comparatively small area would reach the mine workings.

The amount of water that might come in along fault zones from the deep gravel in Spring Valley and Diamond Valley is still more uncertain. A difference in water level of more than 1200 feet between the 2250 level, Fad Shaft, and the well in Diamond Valley, 7 or 8 miles away, did not affect the water in the well. The very slow seepage of water from the gravel pit into which the mine water eventually ran proves that there is no rapid or free circulation through the clay and gravel of the valley bottom. At the very worst, there might be a slow drainage of water that came into the part of Spring Valley south of, or above the mine, along faults and into the Fad Shaft area. The total drainage area of this part of Spring Valley is at most 8 or 10 square miles. If 7% of a 12 inch annual precipitation in this area goes into ground water, the total added to the water table would be only 125,000,000 to 150,000,000 gallons per year.

Even if the area from which surface water may drain into Fad Shaft workings is doubled, which is most unlikely, the amount of water that seeps into the workings from annual precipitation would be less than 1000 gallons per minute. The great flow of water evidently came from pumping down water that was already stored in cavities in the limestone and dolomite, and not from current additions to the water.

It is impossible to say how much water is stored in the area that must be drained. Mr. W. E. Romig is making a study of this problem. If the drop in water in the drillholes from May 15th to November 22, 1948, amounting to 884 ft., in 190 days, is representative, it might be necessary to pump 4.4 times 1,447,000,000 gallons, or 8,350,000,000 gallons to unwater the 2250 Level. The actual amount would probably be much smaller. As indicated by Case I of the computations on Page 23, most of the water pumped came from outside of the drained area. Part of this outside water may have come from recirculation of water already pumped, and part of it certainly drained watercourses to far below the lowest point reached by water in the drillholes. At the rate at which water was going down in the last 20 days of pumping, an additional 2 billion to 2½ billion gallons would have drained the 2250 Level.

It seems probable that with proper procedure, Block I-A on the 2250 Level can be opened up by pumping not to exceed 4 to 6 billion gallons of water, or less than double the amount of water already pumped. This would mean 5000 gallons per minute for 2 or 3 years.

This seems to be the worst condition that is likely to be encountered. If ore is found at a higher elevation, in any of the 3 places where indications are favorable, the water problem will be far less serious.

PAST EXPENSES

The terrific expenditures in the past should not indicate comparable expenses in the future. The work from 1945 to 1948 was carried on at a time when labor was scarce, inefficient and costly, and when supplies and equipment were exceedingly expensive and almost impossible to obtain. It was often necessary to buy any Diesels, pumps or other machines that could be obtained quickly, rather than the ones best suited to the job. The multiplicity of small units, added as the flow of water increased, made it necessary to build up a large mechanical department and shops. The cost of fuel oil was at a peak, costing 13.5¢ per gallon delivered. As a result, electric power cost 1.72¢ per kwh, and pumping from between the 1700 and the 2000 level cost from 28 to 35¢ per thousand gallons, including overhead.

Sinking the Fad Shaft cost approximately $640 per foot, including the cost of pumping up to 1600 gallons of water per minute. This also included nearly all of the heavy overhead expense at the mine; the cost of steel sets that were used for a large part of the depth, partly because good shaft timbers were not available; and the cost of concreting the shaft in sections where the ground was bad. The cost of stations and other expenses were correspondingly high.

The total expenditure of about $6,000,000 at Eureka is more than double the amount that would have been necessary in more favorable times.

A detailed analysis of past expenses can serve no useful purpose. If future expenses would be on the same scale, it is doubtful if any additional work would be justified. Fortunately, it seems reasonably certain that future costs will be much more moderate. The shaft is down and in good shape, ample machinery is on hand for future requirements, the cost of fuel oil and other supplies is decreasing, and ample mine labor is now available. The cost of unwatering the mine and of opening up deeper levels should not be excessive, compared with the possible size and grade of orebodies.

LESSONS FROM PAST OPERATIONS

Analysis of the attempts to unwater the mine shows five principal reasons for the past failure.

1. The shaft was sunk to below the 2250 Level in one lift, without making sure the water table was falling as the shaft was sunk. The resulting high pressure, when the water bearing structure was finally tapped, was so great that this rapid current eroded the sides of the watercourse, making the flow prohibitive. It is probable that if the ground had been drained a few hundred feet at a time, the total quantity of water would have been smaller.

2. The drillholes in the ore area were not reopened until near the end of the pumping campaign. As a result, there was no way to tell how rapidly the water table in the ore area was going down, and so how much hydraulic head would be encountered.

3. When the water door was put in, it was designed to stand the pressure that seemed likely, and not the maximum pressure that could conceivably be encountered. It would have been safer to design doors with a big factor of safety above the greatest possible pressure. A door that fails is worse than no door, as it causes the water to come with a rush that enlarges the watercourses.

4. No horizontal diamond drillhole was run ahead of the face of the 2250 Level crosscut. It seems to be better practice to carry such holes 50 feet or more ahead of the face where the water table may be far above the crosscut or other heading. While it is not certain that one drillhole would have hit the watercourse from which the large flow occurred, there would probably have been sufficient warning so that the crosscut could have been stopped until the position of the water table was measured. If the large, high-pressure flow had been encountered by a 50 ft. drillhole, it could have been controlled by a valve so that the water would never have exceeded the capacity of the pumps. The water could then have been pumped down gradually, and the position of the table would have been known at all times by measuring the pressure at the drillhole.

Another advantage of carrying a drillhole ahead of the face is the saving of head against the pumps. By connecting the casing to the pump suction, the effective head is reduced to that from the level of the water table to the surface.

5. The possibility that some of the water that had been pumped was flowing back into the shaft was not eliminated. The use of radioactive isotopes will make it easy to prove whether or not there is circulation and repumping.

By taking advantage of past experience, at Eureka and elsewhere, the cost and hazard of future unwatering can be greatly reduced.

FUTURE PROGRAM

It is impossible to plan a program that will cover all contingencies. There is a remote chance that no higher ore will be found, and that the cost of unwatering the 2250 Level will prove excessive. It is far more probable that valuable orebodies will be found on or above the 1700 Level. The cost of unwatering this level will be comparatively small, and the profit from the higher ore should more than pay for opening up the 2250 Level. The following program is therefore recommended, with the provision that results of the earlier stages may modify succeeding stages of the operation.

1. Preliminary Drilling

(a) Drill at least one vertical churn drillhole from the surface to determine the position of the Eldorado Dolomite in Block I-B northwest of the Bowman Fault. The first hole should be started 530 feet N 45 degrees W from the Locan Shaft. Sections indicate that this hole will cross the Bowman Fault into the Eldorado Dolomite at 1100 or 1200 ft. depth, and will reach the bottom of the dolomite at 1600 feet depth. There is a good chance that it may find strong mineralization or ore. If drilling is not too expensive, the hole should be continued through the Ruby Hill Fault to about 1800 feet depth, to see if the Hamburg Dolomite under this fault is mineralized.

If results of this hole are not conclusive, one or more additional holes should be drilled.

The churn drillhole should be cased, with casing perforated so that the water level in Block I-B can be measured when pumping is started.

(b) Continue Diamond Drillhole G, which was started from the 800 Level, to cut the bottom of the Secret Canyon Shale at about 580 feet depth and the Ruby Hill Fault at about 800 feet. The latter intersection will be at the horizon of the low grade, higher mineralization found in Holes B, C, and E. A second hole may be required to prove whether development of these beds near the center of the Eldorado Dolomite is likely to find ore. One of the holes should be continued into the footwall of the Ruby Hill Fault, to look for the dolomite that should underlie the quartzite.

(c) From the foot of the raise that leads from the Locan 900 Level (2nd Level Fad) to the Richmond 800, drill a 400 foot hole down 60 degrees southwest to develop the intersection of the Richmond Fault with the Hamburg Dolomite that underlies the quartzite. If the quartzite proves to be unexpectedly thick at this point, a second hole may be necessary, starting 100 feet further northwest and at a 70 degree inclination.

The drilling program will involve from 1800 to 3500 feet of churn drilling and 1000 to 1800 feet of diamond drilling. It will not be necessary to operate the Fad Shaft while the churn drilling is in progress. The drilling should be completed in eight months to a year. The total cost, including necessary overhead, is estimated as from $40,000 to $80,000.

2. Development on 1700 Level

It seems likely that the above drilling will find ore or promising mineralization on or above the 1700 Level of the Fad Shaft. The next step in the recommended development will be to pump the water down to this level, and to crosscut to the indicated orebodies.

The unwatering can best be done by the two submersible Byron Jackson pumps now on surface. These pumps have a capacity of about 2500 gallons per minute each. Diesel generators now installed should be more than adequate. Present station pumps can be used after pumps now under water are recovered and reconditioned. Suctions should be kept just below the 1700 Level, in order to prevent another mud flow that might be caused by excessive stirring up of water by suctions at the 2250 Level. Changes in water table should be measured regularly in the new churn and diamond drillholes. If radioactive tracers show that part of the water is being recirculated, the discharge water on surface should be piped or flumed well out into Spring Valley.

In order to avoid a large flow of high pressure water on the 1700 Level, it seems best to cut a small station on about the 1450 Level, and to do a little development on this level. If drillholes have found encouraging mineralization at this horizon, a crosscut should be run to the ore. Otherwise it will be sufficient to run horizontal diamond drillholes 1000 feet west and 700 feet southwest from the Shaft, to cut through the Bowman and Office Faults into Fault Blocks I-B and I-A. Water flowing from the holes can be controlled by valves so that the capacity of pumps is not exceeded. If the water does not exceed 5000 gallons per minute, unwatering the shaft to the 1700 Level can proceed while 1450 Level drilling is in progress.

As soon as the 1700 Level station pumps have been recovered and reconditioned, a crosscut should be started west or southwest on this level, directed toward the best showing found by drilling. For the first 500 feet or more, this crosscut will be in Secret Canyon Shale, and there will be no danger of a great flow of water. Thereafter a flat diamond drillhole should be kept at least 50 feet ahead of the face. If a large flow of water is encountered in the drillhole, the crosscut should be stopped until the flow decreases.

The time required for this second step in the development will depend on the amount that must be pumped to lower the water table to the 1700 Level. In May to July, 1948, the 1700 Level was recovered by pumping 2200 to 4600 gallons per minute for 2 months, or a total of 265,000,000 gallons. This would require only 37 days at 5000 gallons per minute. The inconclusive evidence of Hole E indicates that in the 2 months the water table in Fault Block I-A was lowered only to about 5700 feet elevation, 420 feet above the 1700 Level. While most of the remaining 420 feet will be in impervious Secret Canyon Shale in Block I-A, this horizon will be in Eldorado Dolomite in Block I-B, where the ore is likely to occur. It is possible that before Block I-B can be developed on the 1700 Level, it will be necessary to drain 2,000,000 square feet of dolomite for 400 feet depth. This might contain 5 or 10% of water filled cavities, or up to 600,000,000 additional gallons. Enlargement of the 2250 Level watercourses by the large flow in the last months of 1948 may have greatly increased the area that must be drained and the amount that must be pumped in future operations. The total amount of water that must be pumped before a crosscut can reach the possible ore area on the 1700 Level may therefore be from one billion to two billion gallons. This might require up to 10 months of pumping at 5,000 gallons per minute.

As there are almost sure to be unexpected delays, it is safer to assume that it will take 18 months from the time pumping starts until the promising areas are developed on the 1700 Level. A rough estimate of the cost of this development follows:

Pumping 5,000 gal. per min. for 18 mos., @ $0.17 per thousand gal., or $35,000 per month	$ 630,000
1450 Level Station and 1700 ft. of horizontal drillholes	25,000
Crosscutting and Drifting, 1700 Level, 2,000 ft. @ $30.00	60,000
Short Drillholes, 1700 Level, 1,000 ft.	5,000
Overhead, Insur., etc., $8,300 per month	150,000
Total	$ 870,000

The above estimate takes into account the reduced cost of fuel oil, and the reduction in overtime and other expenses that should be made in the future.

If, as seems possible, part of the water pumped in 1948 was re-circulated, the time and expense of the second step in proposed operations will be greatly reduced.

As nothing is known of the shape, size or character of possible ore-bodies above the 1700 Level, it is impossible to make an accurate estimate of the added cost of bringing the mine to production after a crosscut has reached the ore. This would include raising the Locan Shaft from the 1700 to the 1200 Level for a second exit, opening of service levels, and pumping and overhead expenses. Exclusive of a mill or other treatment plant, the added expense should not exceed $500,000.

3. Development of 2250 Level

If, as expected, ore is found above the 1700 Level, unwatering to the 2250 Level can proceed gradually, with intermediate levels planned as needed to mine the orebodies. In this case the cost of deeper development would be met by part of current profits.

If no ore is found above the 1700 Level, most of the development on the 1700 Level suggested above will still be necessary, in order to lower the water table gradually.

The next step will be to pump the water down to the 2000 Level station, at 5000 gallons per minute. This unwatering could probably start several months before the 1700 Level work is completed. Flat diamond drillholes should then be run 800 feet west and 500 feet southwest from the 2000 Level Station, through the Bowman and Office Faults, to make sure the water table in the ore area has been lowered to this elevation.

As soon as the volume pumped from the 2000 Level falls below 5000 gallons per minute, the shaft can be unwatered to the 2250 Level. A water door strong enough to withstand 1200 ft. head should then be constructed. The crosscut should then be driven to the ore, with a diamond drillhole at least 50 feet ahead of the face. This procedure will avoid any danger of losing the shaft through a sudden flow of water.

The amount of additional water that must be pumped in this third stage of development is uncertain. The total pumped in the 18 months of the second stage would be nearly 4 billion gallons, which should bring the water in the shaft nearly down to the 2000 Level. The total quantity estimated as necessary to lower the water table to the 2250 Level is most unlikely to exceed 6 billion gallons. This leaves slightly more than 2 billion gallons to be pumped in the third stage. The additional time required for this stage in the development would be about a year.

On this assumption, the estimated added cost of stage three would be as follows:

Pumping 5,000 gal. per min. for 12 months, @ $0.22 per thousand gal., or $45,000 per month	$540,000
2000 Level, 1300 ft. of drilling	10,000
2250 Level, Cleaning up and Water Door	15,000
2250 Level, 1500 ft. crosscuts and drifts	45,000

2250 Level, Short drillholes, 2,000 feet	$ 10,000
Overhead, 12 mos. @ $8,300	100,000
Total	$ 720,000

As in the second stage, if there was recirculation of water in 1948, the time and cost of Stage 3 will be greatly reduced.

The additional cost of bringing the property to production cannot be definitely estimated until the orebodies have been opened up. It will be necessary to raise to the bottom of the Locan Shaft, and to repair either the Locan or the Richmond Shaft to surface for a second exit. At least one service level must be run. Pumping and overhead will continue while the preparatory work is in progress. Assuming that none of this work is done on the 1700 Level, it will not be safe to figure on less than $1,000,000 for the extra mine expense before large scale production from 2250 Level ore can start.

4. Production

Because of the expense of pumping and overhead, it is essential to start production just as soon as possible.

If the five drillholes in Block I-A are representative of future ore that will be found, either above the 1700 or on the 2250 Level, the best plan will probably be to begin by shipping the richer ore to a custom mill and smelter in the Salt Lake Valley. The gross value of metals in ore of the grade of the 65 feet cut by Hole E, with lead at 15 cents and zinc at 10 cents per pound, is $67.95 per ton. As the ore is a heavy sulphide, the extra expense through milling in Salt Lake instead of near the mine would be comparatively small. The net return from such an ore, at the smelter, would be about $25.00 per ton. The cost of hauling 70 miles over a paved highway to Kimberly, and of railway freight to the custom mill, should not exceed $8.00 per ton, leaving a net of $17 per ton at the mine. This should more than cover the cost of mining, pumping, and overhead during the period while a treatment plant is being designed and built.

After a local plant is built, with operations at a fixed depth for several years, the quantity of water pumped will decrease. With production at the rate of 500 tons of ore per day, the pumping expense per ton will not be excessive. Based on experience of other mines where conditions are similar, the total cost of mining, milling, and overhead will be about $10.00 to $12.00 per ton of ore. This would give a fair profit above the possible return of nearly $15.00 per ton of average grade ore.

Until more is known about the size, grade, and position of the orebodies, no more accurate estimate can be made. If large orebodies are found, particularly on upper levels, it may be worthwhile to bring in electric power from Boulder Dam or natural gas from a pipe line that will pass through Elko.

If exploration for oil or gas now underway 30 to 40 miles east of the mine is successful, the power cost will be enormously decreased. The approximate estimate of costs given above should be a maximum, which may be greatly reduced by any of several possible developments.

CONCLUSION

The great expenditure and the fact that success is not certain makes it essential to secure favorable modifications in the underlying lease at Eureka. The time schedule in that lease cannot possibly be met. The royalty of 15% of net smelter returns is excessive, and should be modified to provide either for a much smaller royalty on smelter returns or a royalty on the net profit. Because present tax laws make it impossible to recoup a heavy investment unless the profitable operation is long-lived, future investment should be in return for notes that are payable out of first profits.

If a satisfactory lease is obtained, the preliminary drilling, at an estimated cost of $40,000 to $80,000, will be a remarkably promising speculation. There is a good chance that this work will find large and valuable orebodies on and above the 1700 Level. Such orebodies can be developed underground for an estimated cost of $870,000. The added cost of preparing a second exit and service levels, which would not be done until success is assured, might total $500,000. The total estimated expense before production starts would then be from $1,410,000 to $1,450,000. A treatment plant would be added later. This expenditure is likely to result in one of the greatest mining districts in the country.

If no ore is found above the 1700 Level, the venture will be less attractive. The future of the mine will then depend on the 800,000 tons of ore indicated by drilling on or near the 2250 Level, and on extensions of this deep ore that may add greatly to the tonnage. There is a remote chance that the flow of water on the 2250 Level may be so great that the cost of mining and development will be prohibitive. In this case the investment would be lost. It is far more likely that a total expenditure of $2,650,000, plus the cost of a treatment plant, will be adequate to prepare the deep ore for production. The possible profit would then be many times the investment. This possible profit fully justifies an attempt to unwater the 2250 Level even if no higher ore is found.

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San Francisco, California.
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