Record of Water Supply on Lanai
(ms J.T. Munro, Feb. 18, 1958)

Mansucript of James T. Munro, based on 40 years of work on Lanai in the field of water development.

When the ancient Hawaiians first arrived on Lanai several hundred years ago, they no doubt found the same relatively dry island we know today.

They found drinkable, brackish water in shallow wells they dug in places in shore along the north and east coasts and in the Kaumalapau and Kaunolu gulches.

They found the small springs and seeps in the Kaiholena, Kapano, Waiapaa and Waiakeakua gulches in the central part of the island that usually dried up each summer.

They also found in the upper Maunalei gulch the only perennial stream on the island, emanating in the stream bed above and below the present upper tunnel. It probably flowed to sea only during freshets and above average wet periods. It normally percolated into the stream bed and disappeared entirely at various point downstream, depending on rainfall conditions.

The natives used this stream to grow taro until goats, left by early voyagers, increased to great numbers and denuded the steep walls of the gulch. This caused rocks to roll on the natives who finally abandoned the gulch. The original taro patch terraces are still visible above the pump station.

Other than dew shaken from bushes on the upper lands, these were the only sources of water on the island available to the various populations over the years, estimated by Dr. Kenneth Emory of the Bishop Museum at some 3,000 people circa 1800. With such populations widely scattered over the island, their water problems can be readily imagined.

About 1890 the Hayseldens built the now abandoned rectangular 400,000 gallon Kaiholena reservoir and piped in water from the small stream farther up the Kaiholena gulch that ran each winter. If favored by summer “naulu” showers

In that area, this supply furnished piped water to the original Koele ranch headquarters all year. During dry years the ranch resorted to hand-pumped water out of cement-lined cisterns filled by rain water off the roofs of the buildings.

During the Hawaiian sugar boom in the late nineties [1890s], the Maunalei Sugar Company was formed to grow sugar cane along the coast between Kahalepalaoa and Lae Hi Point, under the management of William Stoddard.

First, the company drilled the existing well at Keomuku—designated as Pump No. 1 on the Lanai Kuleana map—some 800 feet from the beach inshore from Charles Gay church [Lanaihale Church].

The sugar company originally installed a steam engine driven centrifugal pump on this well and grew seed cane on the area around the well site before the company failed. Charles Gay pumped water form the well to grow alfalfa on irrigated terraces for pig raising in this same area for several years up to 1927.

According to a check made in 1936, this well is 60 feet deep from a surface elevation of 16 feet, with the water table some three feet above sea level, and is said to be cased with six-inch pipe. After four hours of pumping at about 400 gallons per minute, the salt content of this water at that time was about 79 grains per gallon.

An inspection on December 11, 1957, found the original steam boiler, engine, and belt driven centrifugal pump still lying scattered around the well site. Gay's nine H.P. Union gasoline engine and belt driven centrifugal pump was still in operating position. It was used last during World War II to irrigate papayas and bananas, but the salt content of the water was said to be high for these fruits. The cut-stone walled sump is caving in, and the

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Sump will sooner or later by filled with freshet mud and the well lost unless provision is made to protect it.

For irrigation of the sugar company's proposed cane fields, Stoddard said they drilled twelve 12 inch well 80 feet deep, about 25 feet apart, connected by a tunnel intersecting the walls below the water table. This led the water into the pump sump where on three million gallons a day and one five million gallons a day pump were installed.

Pumping at three million gallons a day resulted in 35 to 50 grains of salt a gallon, five million gallons a day, 75 grains, and it was found impractical to operate both pumps together at eight million gallons a day.

Honolulu Chinese invested in the company when it was originally organized and had three payments on their stock when the disastrous Honolulu Chinatown fire prevented them from making further payment. This resulted in the enterprise failing for lack of funds before irrigation water was required to give the wells a prolonged test. The pumps were removed and sold, ending the first and last major development of coastal water on Lanai to date.

During Charles Gay's ownership of Lanai, between 1903 and 1910, followed by the Lanai Company, shallow stock-watering windmill wells were dug along the coast at Kapoho, Naha, Kahemano, Kahea, Keomuku, Nahoko, Hauola, Maunalei, Kahue, Kanaele, Awalua, and in Kaumalapau gulch, all since abandoned.

No checks for salinity of these wells were ever made other than by taste. The wells towards Awalua and Kapoho were the most saline.

It might be added that in past years several people occupying Kuleanas on the coastal flat between Keomuku and Lae hi Point dug trenches into the water table from which they pumped brackish water for watermelon growing. This is the same system now being used by Dr. Gordon Nightingale on Molokai for

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"saline farming." This method skims the fresher water off the top of the water table and is superior to the former method of drilling wells along the coast to depths below the sea level.

As a result of serious water shortages at Koele during the dry seasons, Charles Gay hauled up the Maunalei gulch from the beach a 12 H.P. gasoline engine-driven, high pressure, 30 gallons a minute triplex pumping plant and installed it at the sight of the present high-lift pump station at the elevation of 1,000 feet above sea level.

The pump intake was located some 3,600 feet upstream in a dammed-up pool, 200 or 300 feet higher than the pump. A two inch galvanized pipeline from the pool was connected to the pump, supplying water to the pump under pressure. This water was pumped under a static head of about 1,000 feet through a two and one half inch galvanized pipeline, up the same ridge used today, and over the ridges into Kaiholena reservoir to furnish emergency water supplies for domestic and stock demands.

This system was in occasional use up to 1917. It is interesting to note that the original two-inch intake pipeline is still in use between the upper and lower tunnels after about fifty years in service.

The excessive cost of packing gasoline on mules from the beach prompted Gay to try a set of power windmills to drive the pump, but the erratic winds up the gulch blew the mills down. A subsequent attempt by the Lanai Company in 1911 with heavier windmills met with the same results.

The purchase of Lanai, including some 20,000 sheep, by the Lanai Company, Limited, in 1910 was a speculative venture. Among other promotional projects under the ranch management of George C. Munro, prospecting for a substantial water supply was undertaken in 1910 with the excavation of the horizontal

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lower tunnel in Maunalei gulch at a portal elevation of 1,103 feet, entering the east wall a feet above the stream bed.

This was recommended by a man named Jorgensen of Hamakua Ditch fame on Hawaii. Prospects for securing water here were based on the existence of the perennial surface stream, which probably averaged less than 50,000 gallons a day, and the assumption that a much larger stream was probably flowing in the originally eroded out V bottom of the gulch, long since buried by talus fill eroded off the walls of the gulch.

This tunnel was completed in 1911, measuring approximately 1,000 feet to he farthest end, where the present average flow of around 250,000 gallons a day was fortunately encountered the night before orders were issued to discontinue excavation.

The stream enters the top of the tunnel heading, flowing in through water-worn gravel and boulders, possibly indicating a buried stream bed, but the V bottom of the original stream was never located. As there were no plans for the use of this water, it joined the surface stream at the portal and at times flowed as far down the sharp bend in the gulch below Shaft 2, until 1917.

Prior to starting the excavation of the tunnel, the zigzag trail into Maunalei above Shaft 2 was completed. Gasoline for emergency pumping was then packed on mules down this trail from Koele. With a ten-gallon drum of gasoline strapped on each side of a pack saddle, trains of two or three mules would make two trip a day into Maunalei to keep the old unmuffled engine banging away 24 hours a day.

The pack mules were careful to walk on the outer edge of the trail, but at times the can next to the wall would strike a protruding rock and the contents would leak over the mule’s side, causing his hair to come off.

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During this time the Lanai Company also built the three-million gallon storm water reservoir directly back of the ranch manager’s home at Koele. A ditch and wooden fluming up the Kaiholena gulch delivered freshet water into the reservoir, adding to the livestock water supply, and was in use up to early Hapco days.

After Messrs. H.A. and F.F. Baldwin bought the Lanai Company in 1917, continuing under the same management, the writer supervised improvements to the water system laid out by J.H. Foss, civil engineer with the Baldwin plantations on Maui.

The gasoline engine pumping plant in Maunalei was replaced with an 18-inch Pelton water-wheel belt driving Worthington 3-1/2” x 8: vertical, triplex, single acting pump. This was located on the flat

below Shaft 2 at an elevation of 802 feet. A redwood board dam three feet high was concreted into the floor and walls of the lower tunnel a short distance inside the portal, and some 5,000 feet of six-inch redwood stave pipe was laid from the dam to the Pelton wheel.

The pump was fed from the original pool in the stream above the lower tunnel by the original two-inch pump suction pipeline plus additional pipe to the new pump. Sufficient power was developed by the Pelton wheel to pump some 20 gallons a minute under a static head of 1,200 feet through a standard tow-and-one-half inch pipeline up the ridge below Shaft 2 to the Kaiholena reservoir.

This installation ran continuously, without fuel cost, furnishing an adequate water supply for the Koele domestic requirements and the livestock watering system, by then extended over all the upper land and down to Manele.

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Driving the Pelton wheel was the first use made of the lower tunnel water, which was discharged from the water wheel into the gulch, and from there it ran to waste. This pumping plant was replaced by Hapco in 1924.

The other major improvement was the laying of some 18 miles of gravity line from the lower tunnel dam, elevation 1,103 feet, down and out of the Maunalei gulch below Shaft 1 to the west and around the end of the island approaching Honopuu, elevation 300 feet. This line started with two-and-one-half inch galvanized pipe and ended with three-quarter inch. Along with some branch line, including one to the east at Shaft 1, this system distributed water to livestock over some 200 square miles of pasture land.

Pipe for these lines was supplied by the Kahului Railway Company on Maui, most of it being landed along the north coast and hauled to location by a 30 H.P. Caterpillar front-wheel steered tractor with a four-wheeled trailed made up with steel wheels from the abandoned portable drill rig boiler. This old tractor is till lying alongside the road above Manele.

The Hawaiian Pineapple Company purchased Lanai from the Baldwins in December 1922, and after nine months of developing plans, work was started under the management of H. Bloomfield Brown. David E. Root was Resident Engineer in charge of further planning and construction.

Root was from “Dry-dock” Smith’s engineering office in San Francisco, the firm that planned the harbor development. Among others hired to assist Root, the writer came from Maui to Hapco in September 1923, to take charge of the development and operation of the water system and other responsibilities, taking over as Plantation Engineer in February 1926, on Root’s departure.

With the Hawaiian Dredging Company’s camp at Kaumalapau, two road con-

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struction camps on the Kaumalapau Hill, and with the increasing population at Lanai City adding to the normal ranch demands on pumping and water distribution facilities, a rigid conservation of water was necessary. In a drastic effort to conserve, the water supply to the kitchen sinks was restricted to an orifice about 3/32” in diameter, which was most effective for many years.

The continuing development of the new water system during 1924 included excavation of three pipeline tunnels between Maunalei gulch and Kaiholena, building the existing living quarters and pump house on the site of Gay’s pump station in Maunalei, installing a 6” x 10” vertical, triplex, single-acting pump (still in service), laying a four-inch standard galvanized extra heavy pipeline from the pump up the ridge to the portal of the first tunnel, and building a 2,300 volt power line from the city into the pumping station in Maunalei. All material and equipment required in Maunalei was hauled by truck from Lanai City to the edge of the gulch and skidded down the zigzag trail by manpower.

When these installations were complete, the water-wheel-driven pump was shut down and all hands on the island spent one day carrying the water soaked six-inch wood stave pipe up the trail out of Maunalei for installation in the tunnels between Maunalei and the four 10,000-gallon redwood tanks above the Kaiholena reservoir. There was great urgency involved in this operation as the reservoir was almost empty. The matter came close to being one of shipping personnel off the island or barging water in.

Finally the 3-1/2" by 8" VTSA pump from the abandoned Pelton wheel station was relocated at the new pump station. In 1931 a second 6" x 10" VTSA pump was added, increasing the pumping capacity to two 100-gallons a minute

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pumps and one 50-gallons a minute pump, which sufficed till around 1940.

In 1924 the recently abondoned three-million gallon city storage reservoir was built below the old rectangular Kaiholena reservoir.

About this time the upper tunnel recommended by Root was dug, developing some 50,000 gallons a day which was piped into the lower tunnel supply.

The first city water distribution system from the reservoir consisted of three-inc galvanized mains with one-inch take-offs for each block, all of which changed in 1928 to the existing plain Class C eight-inch, six-inch, and four-inch cast-iron pope-grid layout system of distribution and fire protection which has since been added to in certain areas.

About a year after Dexter Fraser took over management of Lanai in 1935, Hamilton P. Agee, then head of our research department, pointed out the need for overhead irrigation as insurance against possible costly losses of pineapple fruit production on Lanai. He feared recurrences of drought conditions such as were recorded prior to Hapco's purchase of Lanai. This stimulated interest in further water development.

W.O. Clark, ground water geologist with Hawaiian Sugar Planter's Assn. first suggested further excavation in the upper and lower tunnels in Maunalei without the use of blasting powder which he believed might open cracks through which the existing flows might disappear. Considerable costly footage was dug in the upper tunnel and some ten feet in the lower tunnel with no increase in flow.

Excavation in the upper tunnel was done with pneumatic digging tools run by air from an electric-motor-driven 115 foot air compressor at the pump station which pumped the air through the long water pipeline to the tunnel.

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Clark then recommended excavation of Shaft 1 at its existing site some two miles from the beach at a portal elevation of 294 feet, entering the east wall of the Maunalei gulch.

The Maunalei power line was extended down the ridge into the gulch to the portal location to operated an air compressor, blower, hoisting winch, and lighting. As the management wished to expedite progress, a labor contract was set up with a tunnel crew of our own men, paying on a schedule of increasing prices per foot on increasing average daily progress each month.

With the inducement of this contract, excellent progress was made and after excavating 582 feet of 30 deg. slope shaft. The water table was reached at 2.5 feet above sea level with the water testing 36 grains of salt to the gallon. A horizontal tunnel 536 feet long was dug with the floor six inches below the water level. After several months of pumping tests raising the salt content to 77 grains, this

development was abandoned in June 1937, for lack of quality and quantity. (For details, see Stearn's U.S.G.S. Bulletin No. 6, page 78.)

Dr. H.T. Stearns, who at that time was Senior Geologist in charge of the U.S. Geological Survey Ground Water office in Honolulu, recommended the Shaft 2 development some four mile from the beach at a portal elevation of 851 feet on the southwest wall of the gulch. It was assumed that fresh water would be found at this point as some unknown elevation above sea level.

Housing and equipment were moved up from Shaft 1 simultaneously with construction of the first truck road up the gulch, and excavation was started in January 1937 under the same labor contract.

To everyone's surprise, water developed at an elevation of 735 feet after 242 feet of 30 deg. slope shaft had been excavated. Assuming it to be

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Perched water, determined efforts were made to continue the slope shaft, but after excavation had been extended some 30 feet in continuous solid hard rock, horizontal test holes entered into loose material, admitting water under pressure. This indicated the possibility of basal water filled to the high level by the dike complex, evident on the gulch walls in the area.

It was then decided to drill a well, if possible to sea level, but prior to obtaining drill equipment a vertical six foot square shaft was dug on the assumption of there being a possibility of breaking out into loose material at a practical depth for a pumping test.

On reaching a depth of 51 feet, still in solid hard rock, vertical test holes indicated 34 feet more of solid rock before entering loose material, and as the shaft had begun to cave in dangerously, further excavation was abandoned. Extending the slope shaft and excavating the vertical shaft was somewhat like digging a hole in the ocean, the excavation having to be de-watered from the original water level after each round of blasting—a slow, and costly process.

Arrangements were then made with the William Mullen Drilling Company of Honolulu to drill a 20-inch hole using rotary drilling equipment. With a driller by the name of Phoenix in charge, they moved in with a set of old oil well drilling gear, including a homemade draw-works.

First, 52 feet of 22-inch casing was set in the open shaft, cemented into the bottom, and the shaft back filled. Drilling was started, circulating water, which proved impractical for removing the drill cuttings. A mud pump was secured for the drillers, and using Palawai mud, 201 feet of hole was drilled for a total depth of 261 feet from the pump chamber floor to the bottom of the hole, after a difficult struggle with poor equipment and wearing out of a considerable number of Hughes rock bits.

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Additional details on the Shaft 1 and Shaft 2 developments are to be found in U.S.G.S. Bulletin No. 6, "Geology of Ground Water Resources of Lanai and Kahoolawe" by Dr. Harold T. Stearns, pages 78 and 90. This survey was made in 1936 and the report printed in 1940. It includes all rainfall, tunnel flows, and pumping records available up to and including 1939. Unfortunately , the report is out of print and copies are becoming scarce.

Dr. C.K. Wentworth made a geological and ground water survey and report in 1924 or 1925. Dr. Palmer of the University of Hawaii made a short report on Lanai shortly before Wentworth's report. Copies of all these reports are available at the Honolulu office library.

As I recall, no casing was set in the Shaft 2 well below the 52 feet of casing since a probe test proved the hole so crooked a much smaller casing was indicated. Fortunately it has not been necessary to set the pump below the 52 feet of the original casing.

The present deep-well pump in Shaft 2 was originally purchased to dewater the excavation of the vertical shaft with a capacity of 700 gallons a minute discharge at the portal. On completion of the drilling, and with the eight-inch standard black pipe discharge line out of Shaft 1 relocated in Shaft 2 , a short pump test was run, indicating a possible safe yield of somewhat under that capacity.

An additional bowl was added to the pump assembly; and the eight-inch pipe, ending a short distance above the portal, was extended with six-inch Transite pipe to the pump station manifold, resulting in the present delivery of 300 gallons a minute from Shaft 2. The upper and lower tunnel flows were piped directly into the pump station suction manifold under the lower tunnel head which automatically throttles the Shaft 2 delivery dependent on pump demand and the pump station by-pass regulation.

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Since the Maunalei tunnel water is cheaper to pump than Shaft 2 water, it is well to make every effort to pump all the tunnel flows. In order to secure all the available water in the upper tunnel, our practice over the years has been to throttle the cross connection between the upper tunnel line and the lower tunnel line just above the pump station, maintaining a full column of water in the line up to a point below the upper tunnel intake, reflecting a pressure gauge reading equal to the static head less friction loss. Once an adjustment has been made that delivers the entire flow , an increase or decrease in pressure indicated increased or decreased flow calling for throttle adjustment.

Whenever both tunnel flows alone, or the combination of tunnel flows and Shaft 2 pumping are insufficient for the high-lift pump's demand to pump all available water in both tunnels, it is necessary to open and adjust the by-pass valve between the pump intake and pump discharge manifolds in the pump station until the intake in the lower tunnel is neither taking air nor overflowing the intake dam. When these adjustments are made, all available water in both tunnels is being pumped.

Stearns has recommended re-establishing the recording of flows in both tunnels and the water level in the Shaft 2 well to check whether or not the draft on the upper five wells is reducing the available water in Maunalei. Water-level recorders are necessary in the lower tunnel and on the well in Shaft 2.

Since the upper tunnel does not flash after heavy rains nor fluctuate much more than from 35 to 40 gallons per minute, according to previous records, the system described above to secure the entire flow from this source should furnish a water meter record satisfactory for practical pur-

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Poses. This is, of course, provided reasonable adjustment is maintained on the throttle valve. It might be added that when pumping is shut down or when pumping less than the available water in both tunnels, the upper tunnel water overflows the lower tunnel intake dam so that there is continuous metering of the upper tunnel flow.

To add to the pumping flexibility in the Maunalei pump station, the mud pump from Shaft 2 was added to the pumping battery and a second four-inch extra heavy discharge pipeline was laid up the pali about 1940.

In 1949 the pump station was repiped. The two 6" x 10" VTSA pumps were retained and equipped with the present 50 H.P. 440-volt motors for a capacity of 150 gallons a minute each. Two new Worthington horizontal, duplex, double-acting pumps with 100 H.P. motors replaced the 3-1/2" x 8" VTSA pump and the mud pump.

The mud pump was wrecked due to lack of adjustment of the Timken bearings on the crankshaft. Since the two horizontal pumps are of the same design, it will be necessary to maintain scheduled

adjustments of these bearings.

Toward the end of 1944 Hamilton Agee's warning was again given considerations. Dr. Stearns advised drilling a test hole to sea level at the present Well 1 location, which is at an elevation of 1,267 feet. Justification for prospecting here was based on Stearns' assumption that basal water would be found at some elevation above sea level due to the faulting in this area. It was further assumed that if water was developed in insufficient quantity for fruit production insurance, at least it would be helpful in producing planting material in the event of a serious drought.

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Since no core drilling experience and equipment for such a depth were available in the Territory, the Camay Drilling Company of Los Angeles was hired September 1945, on a per diem basis with rotary equipments. They were to drill a 12-inch test hole, and if a bail test showed the water level at a satisfactory elevation they were to ream it out in successive stages to 15 inches, 17-1/2 inches, and finally to 20 inches for the installation of 18-inch casing which was already ordered.

Their rig was too light for the rough drilling that developed, but they finally drilled a 12-inch hole to sea level. After much difficulty they reamed the hole out to 17-1/2 inches, but it was agreed that we stood a good chance of losing the hole if they tried to open it to 20 inches, so a string of 12-inche casing was ordered.

In the meantime, as a result of the high water level in Well 1, Stearns enthusiastically recommended a well at the present Well 2 site, an elevation of 1,909 feet. This hole was drilled 1,006 feet deep and cut much easier than Well 1. The bail test indicated the water level was at the amazing elevation of over 1,500 feet above sea level. The hole was reamed successfully and the 18-inch stovepipe casing originally secured for Well 1, was installed. The drill rig was moved back to Well 1, and after completing installation of the 14-inch casing the Camay crew left Lanai with their equipment in April 1946.

To test the two wells, the present Well 1 one-half-million-gallons-a-day submersible, 440-volt, motored deep-well pump was purchased and installed in Well 2 and run with a portable Caterpillar generator. Pumping test were most gratifying. A six-inch Army portable pipeline was run

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Around the top of field 5457 and connected into the city distribution system to augment the Maunalei supply which was again becoming short due to further increasing demand.

The well supply behaved so well that it was decided to add a full-scale irrigation test during the summer of 1947 in field 5409. The army line was re-laid from the well site into Palawai, connecting into a line from the city to the piggery serving both the city and the irrigation project.

Following this, a one-million-gallons-a-day pump replaced the one-half-million-gallons pump in Well 2 and the latter pump was installed in Well 1 along with a booster pump.

Water from Well 2 contained but two or three grains of salt a gallon. However, Well 1 water tested at some 40 grains a gallon for some unexplainable reason. As continued pumping did not improve this condition, it was decided not to pump this water into the distribution pipeline to avoid aggravating interior pipeline corrosion. The water from Well 1 has, therefore, been used as a separate supply on adjacent fields.

Although there had been no dry conditions to demonstrate the wisdom of irrigation for crop insurance, the management was convinced it would pay off in the event of serious drought and decided on further water development in 1949. On Stearn's recommendation, Samson & Smock, Ltd. of Honolulu was hired to core drill test holes at the present sites of Wells 4 and 5. Water levels

developed higher than in Well 2; consequently it was decided not to test drill the Well 3 location but to drill a final test hole at Kaiholena, which drilled to 1,200 feet deep with the water level developing at an elevation of 1,060 feet.

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The Camay Drilling Company was again engaged with a fixed contract price to dill Well 3 and a cost-plus arrangement for Wells 4 and 5. An Emsco 66-foot Type 8KH drill tower was purchased from East Mau Irrigation Company by Hapco, and Camay came in with heavier equipment than on the previous occasion.

Well 3 was a series of misadventures. First, at a depth of about 600 feet a twelve-inch bit with 30 feet of eight-inch drill collar was lost. Attempts to fish and to by-pass it failed, forcing the drillers to skid the tower over for a new hole. They completed 1,200 feet of hole with a satisfactory water level. They reamed it for 18-inch casing, but the hole was so crooked it had to be reamed to 25 inches before the casing went in after many attempts.

Tex Patterson, then in charge of Camay's operation on Lanai, convinced his office in Los Angeles to drill Wells 4 and 5 to 25 inches at the outset and proceeded on that basis at Well 4, completing 1,178 feet of hole and running in 18-inch casing in record time.

At Well 5 he lost mud circulation shortly after starting. Drilling without mud was another new experience. However, he completed 1,122 feet of hole and ran in casing without serious difficulty.

Patterson suggested that for future drilling in our normally broken up structure we consider the employment of a cable tool or percussion drilling gear calling for less equipment and providing the possibility of drilling a straighter hole. Such equipment for the size of hole we have drilled on Lanai is now available here at Samson & Smock, and probably others.

Meanwhile, the present Well 5 pump was secured and short pumping tests run on Wells 3, 4, and 5 with amazingly uniform productive results. Later

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a duplicate pump was secured for Well 4, but the well was not bailed before installation and the pump set so deep that apparently the motor entered the settlement of drilling mud in the bottom of the hole, eliminating necessary motor cooling, and the motor burned out after a short run.

The installation and removal of this pump indicated an obstruction part way down in the well which photographs taken at the point proved an unexplainable inward bulge in the casing. This was finally successfully swaged out by Samson & Smock, Ltd.

Meanwhile, the pump motor was rebuilt and the factory and installed in Well 3 where it has remained. Some time later a third pump of this model was purchased and installed in Well 4.

As all pump motors (except the pump in Well 1) now have stainless steel motor casings, our experience indicated that these pumps should not be pulled until the annual efficiency checks dictate they should be removed because of loss of pumping efficiency. When pumps are pulled they should not be reinstalled before the wells are bailed of mud and drill cuttings. A matter that should be given consideration when reinstalling pumps i the depth of pump settings. Since the drawdown in all the wells has not been so great as originally anticipated, some of the pumps are probably set deeper than necessary.

On the basis of several pump failures, the bulge in the casing in Well 4, and encouraging results from irrigation during the dry conditions in 1953, the management again called for consideration of further water development. The Lanai Plantation was now under the management of W.W. Aldrich.

Stearns was again called upon and, reporting under date of January 29, 1954, recommended the Shaft 3 project which has been a further successful development.

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It has resulted in doubling the pumping capacity of Well 2 and locating an estimated 100 million gallons per year standing approximately 70 feet above the tunnel back of a fault. This lies six to ten feet beyond the heading of the horizontal tunnel 745' 6" feet from the pump chamber. Records to date seem to indicate that this water did not previously enter the Well 2 compartment but flowed off to sea in some other direction.

Recent estimates by Stearns and Keith Anderson indicate the average safe yield from the five wells and the Maunalei supply at a total of 635 million gallons which roughly equals the current average annual irrigation field spray, and domestic demands.

In recent years the policy has been to use the full capacity of the existing available water and irrigation facilities to increase annual fruit production under normal rainfall. Whether or not this will aggravate the problem of maintaining uniform production during periods of severe dry conditions is a questions that probably will not be answered until such a period has been experienced.

It will be necessary to continue the charted water level record on each well, particularly those taken prior to commencement of pumping for irrigation each year, in order to maintain pumping controls within recharge capacities.

To the late Hamilton P. Agee goes credit of his foresight in stimulating appreciation of the need for irrigation of pineapple on Lanai. To Dr. Harold T. Stearns, our consulting geologist, goes credit for our record of 100 per cent success in water development for the past 20 years. To Harry A. White, former President of Hawaiian Pineapple Company and now Chairman

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of the Board, goes credit for his continued insistence on development of the present irrigation system.

The writer wished to express his appreciation for the opportunity to have had a part in Lanai's water problems the past 40 years and for the association with those involved in this work.

James T. Munro

Honolulu, Hawaii
February 18, 1958.

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