REPORT ON PUMP TEST OF A WELL OWNED BY MARINELAND INVESTMENTS LTD. AT SAVARY ISLAND, B. C.

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No. 5
For identification
Exam. of Brown
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Of Court Reporter

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Background

An 8" diameter well was drilled in the summer of 1969 by John Friesen to supply water to the Marineland Investments Ltd. subdivision on D.L. 1372 and 1373 on Savary Island. The well was completed at a depth of 100' in sand with 5' of 8" well screen. The static level was about 70'. Upon completion it was pumped at 46 imp. gpm for over 50 hours, the water being discharged at the well site.

W. L. Brown of Robinson Roberts & Brown in a report prepared for Savary Island Property Owners Association suggested that re-cycling of the water from the pump discharge may have had some effect on the pump test and may have prevented sea water intrusion into the aquifer. To assess the effect of sea water intrustion Brown suggested running a longer test with discharge to the sea while observations of drawdown and water quality are made in wells on the north and south shores of the island.

In mid-April, 1970 the well was again pumped at a rate of about 25 gpm for 72 hours discharging to the north shore through a 1½" plastic discharge pipe. Water quality was not observed during this test.

In a letter of August 18, 1970 the B.C. Public Utilities Commission stated that a Certificate of Public Convenience and Necessity would not be granted until further pump testing was carried out. The P.U.C. specified a test of 21 days duration be carried out in the dry season to determine whether sea water intrusion occurs.

In a letter of August 27th on behalf of Marineland Investments Ltd., I proposed a pumping test procedure which I felt would comply with the requirements of the Public Utilities Commission. This was submitted with Mr. Lundy's letter of August 27 to the Commission. In their reply of September 4th the Commission suggested that my proposal would be more acceptable if it included the following:

(a) Establishment of an observation well close to the test well.
(b) Location of existing private wells.
(c) The private wells should be monitored during the test.
(d) The effect of rainfall and drought conditions should be taken into consideration.

Installations for test.

On September 10th R. Minshull & S. Iversen left Vancouve with equipment for Savary Island. I went to Savary Island on Saturday, September 12th and by evening all equipment had been moved to the old well site and a tent camp established close to the well site. On Sunday wash boring of the observation hole was started near the existing well. The generator was hooked up and the submersible pump in the well was found to be working; the well was used as a source of water for the wash boring and for the camp.

The observation well, called II, was installed using a small wash rig rented from Engineering Drillers Ltd. The hole was made by wash boring with drilling mud with A size diamond drill rods equipped with a chopping bit. The mid used was Quik-trol, an organic polymer containing no clay. We planned to drill to the aquifer just above the well screen of the existing well, place 1¼" steel pipe equipped with a Johnson drive point in the hole and drive the point further into the aquifer. The log of the hole is

0 - 5' dry silty sand, few stones

5'-8' sand

8'-about 10' tan clay

10' - 91' sand with several very compact beds, especially below 55'

The hard beds in the sand were remarkably compact and progress in them was slow. They seemed to be about 1 to 3 ft. thick. In this drilling method samples are very poor; theredid not seem to be any difference in cuttings from soft or compact beds. Mud loss was low until a depth of about 85' had been reached. All mud was gone by the time the hole reached the next compact bed at about 91'. The pipe and point were lowered to the bottom and flushed with clear water. An attempt was made to drive the point further using a 250 lb. hammer but this was completely unsuccessful, so driving was stopped to avoid breaking the pipe. The pipe and well point were flushed again with water which dropped quite rapidly in the pipe. The level in the observation well had not quite reached the same level as in the pumped well by the next day so it was again flushed with water. It took water from a hose coupled to the well pump at a rate estimated at 6 gpm under no pressure. This showed that the observation well was operating properly. However, the level in it remained almost constant in contrast to the tidel fluctuations of well I.

On September 15th a well point called III was installed on the south shore of the island at a point estimated to be as close as possible to the pumped well. There is a narrow (at high water) beach with an almost vertical bluff of sand about 75' high. The well point was located as close as possible to the bluff. A post hole auger was used to dig down as far as possible, about 8'. The hole went through about 3' of loose sand, then about one foot of coarse beach gravel and into compact fine sand. The well point was assembled with a 3' long .010" slot, 1¼" Johnson well point coupled to 1½" pipe. The well point was driven about 2½' below the auger hole with great difficulty using a 35 lb. slide hammer. A small pitcher pump was put on the pipe and the well point pumped at about 2 gpm for about ½ hour. It pumped fine sand for a while but after half an hour was producing very little sand. The water was very salty (over 6000 ppm chloride).

On September 16th a well point called IV was installed on the property of Mr. Bert Vowles east os his house on the north shore of the island. The method used was the same as described above and the point was placed about 18' below surface. The log of this hole is 0-5' midden debris, mostly shells, 5-5½' gravel beach, 5½'-16½' fine sand. It was pumped at about 2 gpm and water quality was good but contained some sand. Repeated pumping for water samples during the test reduced the sand to a negligible amount.

After the pump test was under way on September 20th another well point called V was installed east of the house on the property of Mr. Gordon Christopher. Permission for this was given by 'phone to Mr. Vowles by Mr. Christopher. The log of this hole is approximately the same as well IV.

Well points IV and V are located in line with the existing dug wells at the houses along the north shore. The dug wells are all located close to the high steep bank at a distance of about 100' from the high water mark. The points are about as close as possible to well I and are about the same depth as the existing wells. Samples could be taken from these at frequent intervals by brief pumping in contrast to the dug wells which require longer pumping to remove the volume of water standing in the casing.

After the test had been underway for about a week two attempts were made to install another observation well near the high tide level on the beach near well IV. These attempts were unsuccessful because of coarse cobble gravel about 3 - 4' below the present beach level. At 4' depth the wet sand had a distinct salty taste. The purpose of digging at this location was to try to reach a relatively impermable layer on which the water in the nearby wells is perched.

A wedge type (Tru-check) rain gauge was installed in an open space near the camp.

A 2" polyethylene plastic discharge pipe was run from the pumped well to the beach on the south side of the island. The pipe was coupled through a valve to the drop pipe of the pump; there were no leaks in this line. An open 45 gal. drum was placed on the beach at this discharge line and the rate of flow was measured by timing the filling of the barrel.

Water levels in the various wells were measured with an electric water level indicator. Quality of water from the various wells was determined in the field using a portable kit (CD 52 WR) manufactured by Hach Chemical Co. Inc., This kit can measure total hardness, ph, dissolved iron and chloride. Naturally in this situation, the important test is for chloride as a measure of sea water contamination. In order to check this samples were taken for chloride determination at a lab. in Vancouver.

A water level recorder was used to determine tidal fluctuation of water level in the various wells (except II which was too small in diam.) The recorder was a Model 40 Foxboro with a range of 0-15 ft. of water and a 24 hour chart movement. The recorder operates on water pressure. In a small hole there is a small error because of the volume of air in the tube and the pressure element but this is considered to be negligible in this situation.

A surveyors level was used to determine the elevations of the various wells. The datum is the zero datum of the Powell River tide recorder. Since there is no tide gauge on the island or at Lund the datum elevation was determined by using high water at the Savary Island Wharf and referring to the tide recorder chart for that particular day for Powell River. Datums are the tops of the well casings and not ground level. In the plots of tide and water levels there may be a small error in the relative elevation of the tide and the well levels. This is probably less than ½ foot.

Procedure followed during the test.

Mr. Iversen looked after the main part of the test. He lived at the tent camp near the well and took the observations. He checked water levels in all wells at least twice each day and checked water from the pumped well twice each day for chloride content. He took samples from wells IV and V each day (except when the recorder was installed) using the hand pump for about 5 or 10 minutes before taking the sample to make sure that the sample was not from the pipe. These samples were checked for chloride and often also for iron and hardness at the site using the field test kit.

In addition, Mr. Iversen took a number of samples from existing wells but only when the well owners were home and could operate the electric powered well pumps for a long enough time to get a fresh sample from the aquifer. We felt that samples from the dug wells which are generally cased with corrugated steel pipe would be representative of water in the aquifer only if they were pumped in order to dispose of the water in the casing which would be representative of former pumping.

The flow from well I was measured twice each day by observing the time re uired to fill an open 45 gallon drum located at the end of the discharge pipe on the south shore. The rain gauge was read after each rain. The total rainfall during the period from September 15 to October 7 was .91". Most of this fell between September 18th and September 22nd.

Pumping was started about 10 a.m. on September 16th but was only continued for about 4 hours because of difficulty with the engine generator set. It was started again at 1800 hours and ran continuously until 1828 hours on October 7th. The rate of flow started at 32.5 imp gpm. The rate was increased in the morning of September 18th in order to utilize more of the available drawdown. I felt that drawdown to about 90' - 91' would allow for additional drawdown during the 21 day test without going below the top of the screen at 95'. A steady rate of 37.4 imp gpm was maintained throughout the remainder of the test. The pump was stopped about once every two days to check oil in the engine.

<u>Water Quality</u>

No changes in water quality were observed in any wells during the test.

The water from well I is chemically different from that in the wells along the north shore which are all about the same. Samples from several wells on the north shore east of the wharf showed that water quality all along the north shore is about the same. The water in well I is soft, low in iron and slightly acid.

total hardness	70ppm	ph 6.8
dissolved iron	.1ppm	chloride 63 ppm
temp	48°F	

the water on the north shore is hard, higher in iron and neutral

total hardness	300	ph 7
dissolved iron	1.0 - 1.5	chloride 63 ppm
temp	48^{o} - 49^{o}	

Obviously both waters are from the same original source, precipitation on the island. They are not mixed with sea water or the chloride content would be higher. Perhaps the lower hardness of the water in well I can be explained by ion exchange in passage of the water through the slowly permable beds which may contain clays and other minerals with ion exchange properties. Perhaps the explanation lies in the fact that the water at well I may not have percolated as far through sediment from its source on surface as the water on the north shore which has moved laterally to the shore.

The salty water in well III is probably due to its close proximity to high water mark. Sea water flows into the aquifer at high tide (as shown by the water level recorder) reaching the well.

Drought conditions existed at the beginning of the test. This is normal for early autumn in that area. The condition of the soil was well shown when the mud pit was dug. It was dug on September 13th close to observation well II in dense bush to a depth of about 3'. At a depth of 3' the soil was dry and powdery. During the entire test only .91" of rain fell. I would estimate that this would hardly dampen the top foot of soil. By the time the test ended there had been no frost so that transpiration was still going on at a fairly high rate. I estimate, therefore, that conditions at the end of the test on October 7th would represent low groundwater conditions.

<u>Discussion of test results.</u>

The recorder was installed on well III (on the south shore) from the morning of September 16th to the afternoon of September 19th. During this time the water level from maximum high to minimum low changed about 1.25 ft. This is in great contrast to the tidal fluctuation which was about 14'. The recorder chart plot has been replotted on weekly rectangular paper in order to better see the shape of the curve. The curve has a distinct saw-tooth shape being much steeper on the rising portion than the falling part of the curve. This seems to indicate that the aquifer is being intruded by sea water during the highest part of the high tide; the water then drains away so the falling part of the curve is a depletion type curve. This pattern indicates that the well is underlain by a less permeable bed which cuts down the amplitude of the fluctuation and permits inflow of sea water only at highest tide. The phase of the tide curve from the well is one to two hours behind the tide gauge curve.

The recorder was then moved to well IV where it was left for two days. The amplitude of the tidal fluctuation in this well is a little less than in well III but as in III the rising part of the curve is steeper than the falling part.

A two day record was also obtained from well V and it shows a similar curve shape. As in the case of well III the phase of the well fluctuation is one to two hours behind the tide/

The recorder was then placed on the well being pumped and 5 days continuous record was obtained. Since pumping was maintained at a steady rate throughout, the record of fluctuation is probably exactly the same as would be obtained if the well were not being pumped. The average amplitude of the fluctuation on this well is a little less than 2 ft. and the curve is quite similar to the tide gauge curve which has been plotted with it. The tidal fluctuation in the well is about behind the tide. The undisturbed mean water level in this well is about 1' to 1½' above mean sea level estimated from tidal charts.

No tidal effect could be observed in well II, the observation well near the pumped well. It was not possible to install the recorder in this small diameter pipe but many observations, some at fairly frequent intervals, failed to detect any measurable tidal effect. The level in this well remained within a few tenths of feet of its original level throughout the test: this is about 1' to 1½' above mean sea level. One might conclude that this indicates that the underlying bed is quite impermeable because the level did not go down when the nearby well was drawn down about 20' for 21 days. However, an equally likely explanation is that the aquifer in which observation well II is located has high permeability compared to the underlying bed so that leakage downward into the local cone of depression caused by pumping was replaced without measurable drawdown.

Observation well II did not operate as had been originally intended in conjuction with well I. It is therefore useless in determining the transmissibility and coefficient of storage of the producing aquifer, but it has been invaluable in indicating the anisotropy of the sediments underlying the island and it shows clearly that pumping is from a confined aquifer. This brings up the question of why there is no tidal effect in the aquifer in which observation well II is located. It is below sea level and the permeability is fairly high as shown by drilling mud loss and the ability of the observation well to accept water at a fairly high rate. Perhaps it is not a confined aquifer and therefore tends to damp out the tidal fluctuations because of large inflow and outflow of water permitted by a water table aquifer. In contrast a confined aquifer would need to accept only a very small amount of water to produce considerable changes of head so far from the beach.

The data indicate that the hydrology of groundwater at Savary Island is quite complicated because of the geology. It is certainly not simply a pile of homgeneous sand surrounded by the sea. It is in fact made up of anisotropic sediments with much higher lateral than vertical permeability. However, the anisotropy does not seem to be general but occurs mostly in a zone near sea level and is probably due to compact silty beds in the sand. If the body of sand above sea level were strongly anisotropic we would expect to find springs along certain zones on the bluffs and we would also expect to see piping type failure of the bluffs. There are no signs of these phenonmena.

We know from the situation at Well I and Observation Well II that the slowly permeable bed separating the producing aquifer which shows tidal fluctuations and the one above in which observation well II is located is thin. In the observation well the top occurs at 91', elevation 10'. If we assume that the screen in well I is entirely below it at 95', it is not more than 4' thick. Such a thin bed is likely to be discontinuous and it may also not be flat. The behaviour of the observation wells III and IV also indicate the presence of slowly permeable beds on north and south shores at elevations of about plus 10'.

How does this complex system operate? Recharge from precipitation occurs only during the time of year of high rainfall and low evapo-transpiration. This water moves downward probably fairly rapidly to the relatively impermeable beds near sea level. Part of it (probably a small amount) moves laterally toward the shores and the rest continues its downward movement into the aquifer below sea level and through it laterally to the sea.

The water perched on a relatively impermeable bed near the north shore is not influenced by the pumping of well I. It is protected from sea water intrusion by the underlying relatively impermeable layer which permits a brief period of 4 to 5 hours of sea water intrusion at high water. This causes a rise of less than a foot at the wells which are about 85 to 135' inland from the high water mark. During the rise, sea water does not reach inland as far as the wells. It is likely though, that removal of large amounts of water from one or more of these wells would permit salt water to reach the wells during high tides. However, this would soon be corrected if pumping were stopped or slowed down.

With such a large tide as is found at Savary Island one would expect to find a broad zone of mixing of sea water and fresh water along the shore if the island were composed of isotropic sand. The confining layers prevent extensive flow of water into the aquifer at high tide and loss at low tide. The tidal fluctuation of approximately 2' found in well I does not represent a saturation of two feet of aquifer but merely a change of head of 2'. The amount of water flowing into the aquifer is a function of the elasticity of water and aquifer rather than porosity.

This test tells us little about the long term safe yield of the well. We do not know the true values of transmissibility and coefficient of storage. Knowing that the aquifer is a confined one we can estimate the coefficient of storage to be about 10^{-4}. The transmissibility using trial and error image well calculations is estimated to be about 10^4.

However these aquifer characteristics are of little importance in this problem. The problem is: does recharge during the winter months supply enough water to replace each year the water consumed in the dry summer and autumn months? Estimates of recharge indicate that there is more than enough water as long as about half or more of this water gets into the aquifer and is not discharged to the sea. A portion of the water removed from the aquifer for domestic use will return from septic tanks.

In situations of this type experience gained in water use will tell what is happening. Therefore it is important to collect accurate, systematic data in the future when the well is put into production.

The observation wells III and IV should be left in place for future observations although this test indicates that these wells are subject only to local effects. Obviously observation well II should be left. Observation of water levels in it may be useful in indicating when recharge is taking place.

Since the danger here is the occurrence of sea water intrusion the most valuable data can be from one or more observation wells in the confined aquifer between the production well and the shore. If sea water intrusion occurs it will start in the lower part of the aquifer because the fresh water is lighter and tends to float. Therefore a pair of observation wells located close together but with screens at different elevations, say (-) 20' and (-) 50' would be useful for this purpose. These could be constructed fairly economically using 2" washdown type well points equipped with single-pipe jets coupled to a single pump. Pumping these wells for a few minutes each week in the summer would procure water samples which would give warning of impending trouble. If such wells were located about 250' from the shore they would give plenty of warning. Monitoring of water quality during the recharge season would indicate whether invading sea water was being driven back by recharge.

Conclusions

This test shows the following:

1. The acquifer supplying water to well I is separate from that supplying the wells along the north shore. Pumping of well I has had no effect on the water quality or water levels in the wells along the north shore.

Conclusions: (continued)

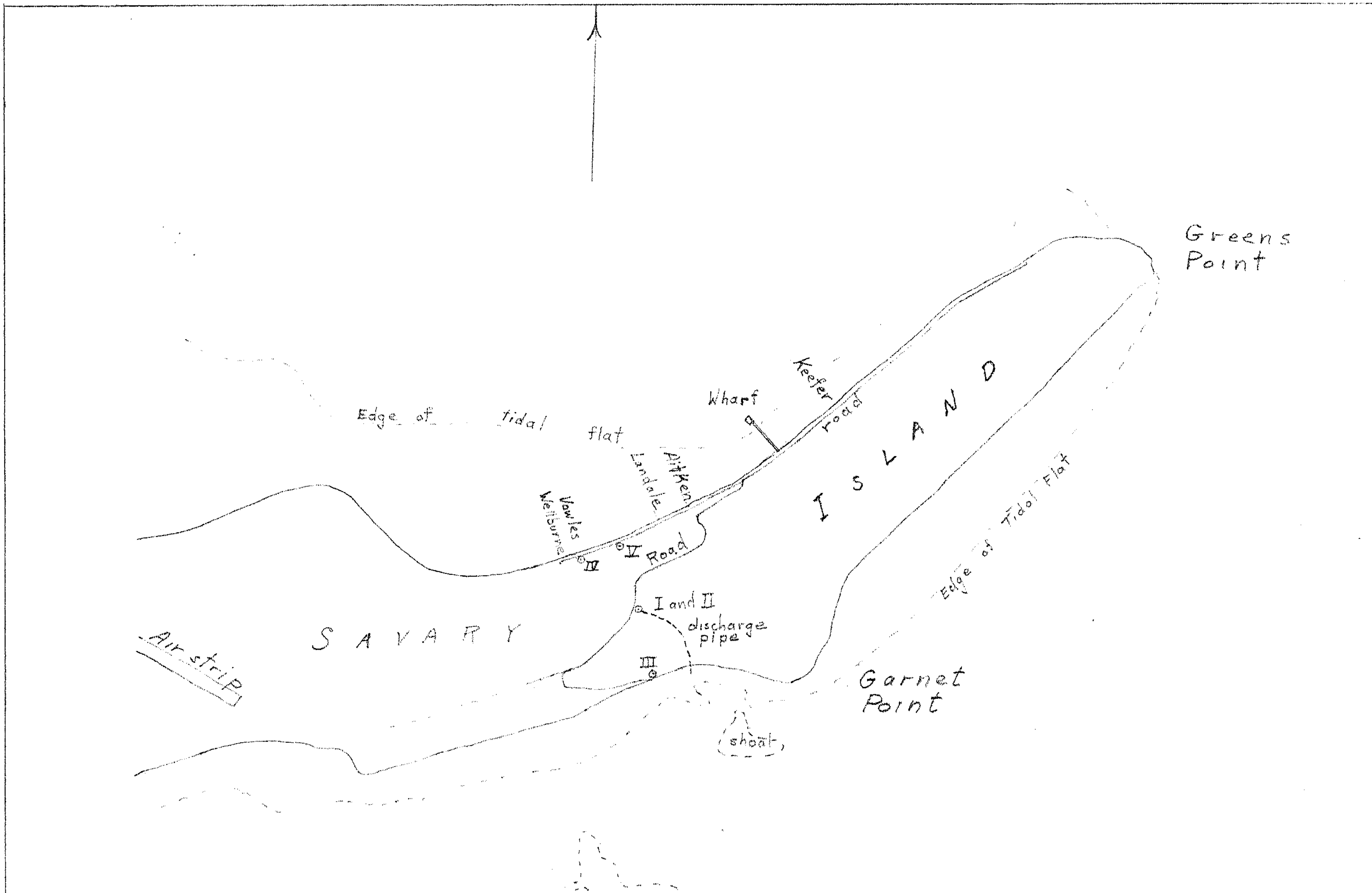
2. The aquifer supplying well I is a confined aquifer hydraulically connected to the sea below sea level.

3. The aquifer supplying the wells along the north shore is perched on a relatively impremeable layer and is subject to inflow from the sea only at high tide.

4. The water quality in both aquifers is good and was not changed by 21 days of continuous pumping of well I at a rate of 37.4 imp. gpm. The drawdown in the aquifer will not increase appreciably with time because of hydraulic connection with the sea.

5. It is possible to construct other small capacity shallow wells along the north shore. Prolonged pumping of wells in this area could cause local temporary sea water intrusion.

6. Well I appears to be properly constructed under the circumstances as the screen is located at the top of the aquifer, thus minimizing the possibility of sea water reaching the well.



East End of Savary Island
from air photo BC4319-157
Scale 1" = approx. 1/4 mi Nov. 1970

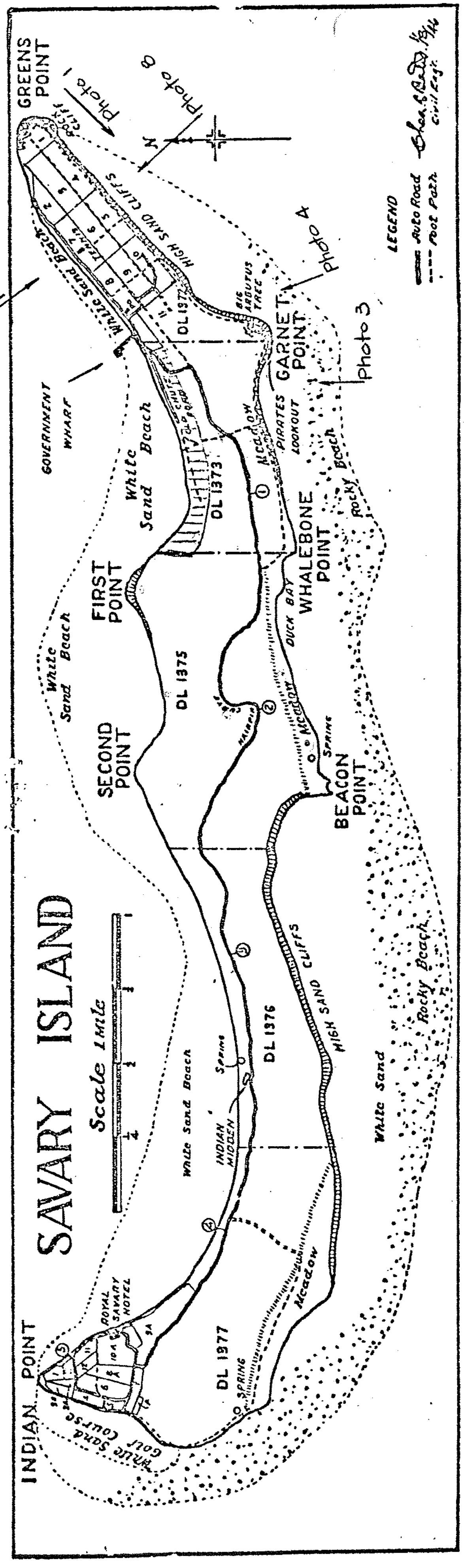

SAVARY ISLAND
Scale 1 mile
GREENS POINT
INDIAN POINT
FIRST POINT
SECOND POINT
GARNET POINT
WHALEBONE POINT
BEACON POINT
GOVERNMENT WHARF
HIGH SAND CLIFFS
White Sand Beach
White Sand
Rocky Beach
DL 1372
DL 1373
DL 1375
DL 1376
DL 1377
BIG ARBUTUS TREE
PIRATES LOOKOUT
DUCK BAY
Meadow
Spring
INDIAN MIDDEN
ROYAL SAVARY HOTEL
Golf Course
Photo 1
Photo 2
Photo 3
Photo 4
Photo 8
LEGEND
Auto Road
Foot Path

Plate A