Also filed with Talks in JCF room 24/11/77.

November 17, 1975

Text of Lecture to Thetis Island Residents on "Methods to Evaluate and Develop the Groundwater Resources of Thetis Island" ~~to be~~ delivered by J.C. Foweraker on November 20, 1975 at the Thetis Island School. *

Ladies and Gentlemen: I have entitled this talk "Methods to evaluate and develop the Groundwater Resources of Thetis Island." First, however, I would like to take a few minutes to talk about Groundwater in general.

In my view Groundwater is one of our most precious resources. Many cities such as my home city of Christchurch, New Zealand rely on groundwater exclusively for water supply.

PICTURE NO. 1

"Groundwater" is commonly understood to mean water occupying all the voids within a geologic stratum, in other words it is a zone of saturation.

Groundwater occurs in permeable geologic formations known as aquifers - from the latin "aqua" meaning water and "ferre" meaning to bear. Aquifers are formations having structures that permit appreciable water to move through them under ordinary field conditions.

This picture shows types of intergranular pore spaces and bed rock fractures through which groundwater can move, provided the pore spaces are big enough. Clay is not called an aquifer because the tiny spaces between the particles are so small that water can not move through them in appreciable quantities.

Maps filed in JF's map cabinet.

## PICTURE NO. 2

Whe[illegible]does groundwater come from?

This question can best be answered by referring to a picture of the hydrologic cycle. Here we can see some of the precipitation soaking through the plant root zone and moving down to the groundwater reservoir. Precipitation is the source of essentially all our fresh groundwater. As you can see from the picture, groundwater eventually finds its way out to the ocean where it, along with other water sources, is evaporated once more to continue the hydrologic cycle.

## PICTURE NO. 3

It would be worthwhile to discuss briefly how groundwater occurs. This picture shows in more detail the subsurface and groundwater phase of the hydrologic cycle. The water table defines the upper limit of the saturated zone of the water table aquifer. It also defines the water level in this well drilled at "A". The artesian aquifer is confined between two clay beds and is recharged from precipitation in the upper right hand corner of the picture. The water level in wells drilled into this aquifer at "B" and "C" will rise high in the well due to the head of water and in the case of well "C" actually will flow over as a free flowing artesian well.

## PICTURE NO. 4

This picture shows a "perched" water table existing above a tight clay layer causing groundwater to seep out at the surface as a spring.

PICTURE NO. 5 (B.C. 7408 No. 282)

Springs in bedrock are often associated with faults. What is a fault? It is a ruptured rock zone along which there has been an adjustment to pressures. Dr. Muller of the Geological Survey helped me locat~~ed~~ these fault lines on this air photo of part of Thetis Island. Here we have the line of a fault along the left side of this lake, and another running southeast from the inlet of North Cove. Springs shown by the circles are closely associated with fault zones at three locations here.

PICTURE NO. 6 (B.C. 7409 No. 054)

Here is another air photo of Thetis showing the same features.

LIGHTS

MAP NO. 7

Faults can be very important zones for groundwater development, and when the rock is badly fractured in the fault zone it can store large quantities of groundwater. This map shows fault lines on Thetis Island according to Dr. Muller.

Now, I would like to discuss with you the information we have available about Thetis Island which will be useful for any future study of the groundwater resources of the Island.

MAP NO. 8 (Watershed Map of Thetis Island)

First We have prepared a watershed map for Thetis Island. The drainage pattern of the Island can be worked out by referring to this Watershed Map. You will note that we have outlined eight sub-basins or watersheds. The watershed boundaries coincide with the topographic divides between sub-basins. The size of a watershed and the amount of precipitation falling on it are important factors in calculating potential for groundwater recharge.

MAP NO. 9 (Geology of Thetis and Kuper Island)
If we are going to study groundwater we must first understand the geology. The geology of Thetis Island is illustrated on this map by Michael Simmons which I have coloured in.

The striped blue colour represents the Late Cretaceous Cedar District Formation and it is distributed mainly in the interior of the island and along the southeastern coastline. The formation consists of mudstones, siltstones and sandstone.

The orange colour represents the resistant sandstones and conglomerates of the De Courcy Formation. This formation is distributed along the northeast coast where it forms Pilkey Point and the caprock of Moore Hill. It also crops out along a strip extending from the base of Burchell Hill to Foster Point. Fault blocks located along North Cove and in the interior of the Island, also are composed of this formation.

The green colour represents the Late Cretaceous Northumberland Formation. Much of this formation consists of mudstones which weathers easily. The rocks are mapped from the shoreline of North Cove to north of Burchell Hill, and from the north shore of Preedy Harbour to the southern flank of Burchell Hill.

The [illegible]d striped area is mapped as the Geoffrey Formation which consists mainly of sandstones and extends from Fraser Point to Crescent Point.

MAP NO. 10

This is a Water Well Location Map for Thetis Island. Various symbols are shown to differentiate between drilled wells, dry drilled wells, dug wells, dry dug wells, flowing artesian wells, non-flowing artesian wells and springs. Each of the well locations shown on the map refer to a well record card. I have an example of these cards which I will circulate. We have about 110 cards on file in the Groundwater Section for Thetis Island. As there is no legislation in force at the present time to require well drillers to submit logs of the wells they drill, our records are likely to be incomplete. Fortunately, we have established a close liaison with the British Columbia drilling industry and private consulting firms and together with our field staff who collect records from drillers throughout British Columbia we have built up a file of some 30 to 40 thousand well records for the Province as a whole. Well inventories need constant updating and our well location map here is no exception. I have shown in red, on this map, well records that indicate possible yields of over 10 gallons per minute. Spring locations are shown in green.

MAP NO. 11 (Data Worksheet)

Some of the data on the well record cards are shown on this work sheet. Such things as well depth, well completion, groundwater level, well yield, etc., are placed around these well symbols, and give a ready reference on well information for the Island.

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### MAP NO. 12 (Hydrochemical Worksheet)

During the summer of 1971 about a dozen samples of water were taken from Thetis Island wells and springs and analyzed with field chemistry kit equipment by the Groundwater Section Staff. The six major chemical constituents of the samples analyzed have been assigned a distinctive colour on the pie diagram made for each sample. Blue represents Carbonate and Bicarbonate, brown is for sulphate, green is for chloride, purple for Na and K, yellow for Mg and orange for Ca. The total dissolved solids are also given for each sample.

For example this well at the north end of the island has total dissolved solids of 660 parts per million, the major constituents being sodium and chloride which combine to give salt. This well near the south end of the island has a similar chemical composition, but the concentration of salt is higher and the total dissolved solids reach 1180 parts per million.

In contrast the water from this spring west of Moore Hill is soft with a total of only 82 parts per million total dissolved solids.

This ends my summary of the very limited groundwater data that we have about Thetis Island. In order to evaluate and develop the Groundwater Resources on Thetis Island would require a considerable input of time by qualified groundwater geologists, engineers and technicians. Also considerable sums of money would have to be found for test well drilling, sampling and monitoring programs.

Detailed groundwater investigations have, however, been carried out by our Groundwater Section in the Gulf Islands, particularly on Mayne Island and I

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would like to show you now some slides to illustrate the work we undertook in connection with our evaluation and development of groundwater supplies on that Island.

## SLIDE NO. 13

This slide shows the location of Mayne Island within the outer chain of the Gulf Islands. The island is located on the southeast side of Active Pass where the ferries pass through on the way to Tsawwassen. The area of Mayne Island is approximately 8.9 square miles.

## SLIDE NO. 14

Like the other Gulf Islands, Mayne Island has steep southwest facing cliffs and more gentle sloping surfaces to the northeast which reflect the dip or inclination of the underlying bedrock. Prominent valleys are present to the southwest and southeast of Mount Park, in the Horton Bay area, and between Miners Bay on the west and Bennett Bay on the east.

## SLIDE NO. 15

The bedrock on Mayne Island consists of shales with some sandstone shown in yellow, sandstones with some shale shown in red, conglomerate which looks a bit like a very coarse concrete mix shown in green and down in the left hand corner of the map sandstone and conglomerate shown in blue.

The prominent ridges and topographic highs such as Mount Park and Hall Hill are composed of resistant and less fractured sandstone and conglomerate, while the valleys and bays are carved out of less resistant shale beds.

The map also shows a number of "transverse" faults cutting across the island and I would draw your attention to the most prominent central fault zone as I will be referring to this again later.

SLIDE NO. 16

A short experimental geophysical survey was carried out on the Island to delineate water bearing fault zones. First, an electrical resistivity survey was run across known fault lines, then a seismic survey was run. This slide shows a seismic shot blast on one of the faults. The geophysical program was only partially successful however, but I believe it was worthwhile.

SLIDE NO. 17

Test well drilling, observation well construction, down-hole electric logging and pumping tests were also carried out. Here we have a picture of a rotary rig drilling one of our test wells. In all, we drilled seven test wells on the island.

SLIDE NO. 18

This is a picture taken during operations on one of our test wells after flowing artesian conditions were encountered. This well was drilled to 518 feet and ended up in salty water. A second well nearby was completed at 200 feet above the salt zone and gave the largest yielding well of fresh water on the island.

### SLI[illegible]NO. 19

This slide shows pumping test equipment and a trailer belonging to our Groundwater Section.

### SLIDE NO. 20

This slide shows the tripod used for lowering the "down hole" geophysical tools into the well.

### SLIDE NO. 21

Here we have ~~the~~ a well equipped truck used for the down hole logging. The red box contains a lead shield to house the radio active probes.

The equipment is hydraulically operated.

### SLIDE NO. 22

This slide of the control panel shows an oscilloscope for monitoring the down hole logging and to see that the tools and equipment are working properly. The charts are printed on a clear film and there is equipment to make blue prints of the film trace at the site.

### SLIDE NO. 23

Here we have a down hole caliper and a density log made for two of our Mayne Island test wells.

These logs tell us many things about the subsurface geology.

For example, a fracture located about 105 feet in well No. 4 is shown on the density or gamma gamma log and also the caliper tool log. This is correlated

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with a peak in the density log at well No. 6.

SLIDE NO. 24

Water quality studies were directed towards two specific goals on Mayne Island.

Firstly to find out how much the groundwater quality varied throughout the island and the depth limits of the potable water zone. Secondly to interpret how and where groundwater moves on the island.

For this study Groundwater Division personnel collected 175 water samples from springs and wells.

This slide shows the total dissolved solids on Mayne Island in the spring, and shallow wells of the 0-50 foot depth zone. Over 95 percent of the total area of the island has groundwater with total dissolved solid values less than 400 parts per million at this depth zone. Only two small areas on this map have T. D. S. values which approach or exceed the maximum drinking water standard of 1,000 ppm at this depth of 0 to 50 feet.

SLIDE NO. 25

The total dissolved solids in this map are for the 50-150 foot depth zone. The non-potable water is located around the main central fault zone which cuts the island in two.

SLIDE NO. 26

This third total dissolved solid map for the 150-300 foot depth zone; shows

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that even at this depth most areas of the island to the north, west and south have total dissolved solid values well below 400 parts per million and water quality is good. Also on the eastern side of the island chemical concentrations are higher, but quality is still acceptable. The dominant change from the previous map is the expansion at depth of the poor quality water into the interior valley basin.

SLIDE NO. 27

The second goal of the water quality studies is to interpret the direction and nature of groundwater movement. As groundwater remains in contact with an aquifer through time and distance, hydrochemical variations between different sampling locations can be measured.

In the map legend of this slide more chemically advanced waters on the island are shown in increasing order from top to bottom. By far the largest area of this map which includes all shallow wells and springs is occupied by water from the least chemically advanced zones shown in white. The large green band, which stretches along the major fault line and into the interior basins is predominantly composed of water from a slightly more chemically advanced zone. The other patches of blue, red, purple and yellow represent even more chemically advanced or older waters.

SLIDE NO. 28

The hydrochemical grouping in the 50-150 foot depth zone shows greatly increased zones of more chemically advanced water such as the yellow colour along the central fault zone.

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SLIDE NO. 29

In [illegible] third and last hydrochemical grouping map for the 150 to 300 foot depth zone, we find along the central fault zone the more advanced yellow coloured zone has spread southwards to Navy Channel and eastward towards the interior basin area.

SLIDE NO. 30

So much for hydrochemical maps:

In this slide the colours bear no relationship to the previous hydrochemical maps. Here we show that the average elevation at the lower limit of the potable groundwater zone is, for the area in red, at about 75 feet above sea level, as one moves out from this central area through the yellow and green zones the elevation of this boundary drops to 50 feet below sea level. From this map then, we can visualize a zone of salty water in the form of an elongated mound with its crest line coinciding with the centre of the major central fault zone.

SLIDE NO. 31

Here are two cross-sections of groundwater movement drawn across Mayne Island. This theoretical flow model is a simplified system and variations in the fractured bedrock will locally modify the flow systems. Groundwater moves downward from the topographic highs and then moves upwards into the valley floors. The upward movement in the valley area from deeper zones partly explains why water samples in these low regions often have higher chemical concentrations of salts than those higher on the surrounding hill sides. The appearance of the salt water on a fault zone then, is interpreted to be a result of the upward movement of a deep flow system into this fractured fault area.

SLIDE NO. 32

The interpretation of groundwater flow systems can help us explain the behaviour of the hydrographs shown on this slide which were prepared from observations well records taken on Mayne Island.

(In this hydrograph we show waterlevel in the well in feet along the left. side of the graph against time shown along the bottom of the chart.

The recorder hydrograph for WR - 110 - 73 shows a markedly slow response to precipitation and appears to peak in the first half of March/73. The water quality was found to be salty in this well and we believe this observation well is completed in the upward path of a deep flow system present in the central fault zone.

The recorder hydrograph for WR - 111 - 73 shows a good response to precipitation, the hydrograph peaks correspond to periods of maximum precipitation during the months of December and January. Good quality water is also found in this well. Here is a good indication (we believe) of rapid groundwater movement through the fractured bedrock media in response to local recharge from precipitation.)

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SLIDE NO. 33

The difficulties in establishing the lower limits of the potable water bearing zone outside areas of known control on Mayne Island have made it necessary to construct a theoretical model of the Island. The model is based on data we have available at the present time. Outside areas of known control, the bottom of the potable water bearing zone was determined by extrapolating the available data using regression analyses run with the aid of a computer.

Estimates were next made of the groundwater in storage within the potable water bearing zone.

SLIDE NO. 34

This slide shows the demand/storage percentages for each groundwater region. A pie diagram in each region shows todays water supply demand in black, as a percentage of the groundwater storage available from the rocks.

Based on water requirements only we have calculated for our theoretical model that the limit for residential development on Mayne Island will be one residence or home for every three acres of land - a useful guideline.

LIGHTS

I would like to end this talk by saying that in my own opinion the goal of a groundwater development and management program whether it is for Mayne

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Island or for Thetis Island should be the optimum use by the community of the resource, *but* that groundwater development should *not* reach the stage where water quality is endangered or where the annual replenishment of the supply is exceeded.

J C Foweraker

Alternate text for page 10 [illegible]

with a [illegible]ak in the density log at Well No. 6.

SLIDE No. 24

In our water quality studies we wanted to first find out how much the groundwater quality varied throughout the island and the depth limits of the potable water zone. For this study Groundwater Section Personnel collected 175 water samples from springs and wells and from these water quality analyses, we made a number of chemistry maps.

This slide shows the total dissolved solids on Mayne Island in the spring, and shallow wells of the 0-50 foot depth zone. Only two small areas on this map have T. D. S. values which approach or exceed the maximum drinking water standard of 1,000 ppm at this depth of 0 to 50 ft.

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This third total dissolved solid map for the 150-300 foot depth zone; shows expansion at depth of the poor quality water into the interior valley basin.

SLIDE No. 27

The second goal of the water quality studies is to interpret the direction of groundwater movement and water chemistry helps us have. This slide shows how we can group younger and older zones of near surface groundwaters according to their chemistry.

### SLIDE No. 28

The hydrochemical grouping in the 50-150 foot depth zone shows greatly increased zones of older "more chemically advanced" waters such as the yellow colour along the central fault zone.

### SLIDE No. 29

Here is a map for the 150 to 300 foot depth zone.

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J C Foweraker