PROGRESS IN THE UTILIZATION
OF GROUND WATER IN BRITISH COLUMBIA

By Val Gwyther, Consulting Engineer, Vancouver. Presented at the 6th British Columbia Natural Resources Conference, February 25-27, 1953, at the Water Panel Session. This is one of the earliest and relatively informative public presentations on groundwater issues in British Columbia.

> ***Recommendations.*** *Revisions to the Water Act or the passing of a Ground Water Act to protect this resource and its users is of utmost importance. The ground water resource is closely related to our surface waters inasmuch as they are dependent on each other. It appears that administration of both resources should be coordinated under the one branch, the Water Rights Branch. Powers of the Comptroller under the, revised or new act must, be far reaching for the protection of present users and the resource.* [Note: The B.C. government never passed groundwater legislation until 2004, although administrators and staff within government, and citizens, have been requesting this legislation since the 1950s.]

PURPOSE:

The purpose of this paper is to outline the uses of our extensive ground water resource to social, agricultural and industrial life of British Columbia, to describe briefly the nature of this resource together with its development and some economic aspects in the utilization of our ground waters. The subject is extremely interesting to those who are able to understand its possibilities, but its value in British Columbia to date does not appear to be fully appreciated.

INTRODUCTION:

In order to grasp the extent of the ground water resource in general we must realize that life of any type on the earth's surface or in the oceans is directly or indirectly maintained by passage of water through the formations of the earth's crust and the changes in mineral content that may occur to the water during this passage. The magnitude of this resource can be realized when we consider the precipitation and evaporation cycle which has been estimated at 16,000,000 tons of water every second on the earth's surface. In British Columbia, where heavy alluvial formations have been deposited during recession of continental glaciers, ground water is abundant but may only be available for water supplies where resorting of these formations has taken place.

Ground water is derived from precipitation, whether it be in the form of rain or snow, and also from watercourses which, under certain circumstances, contribute directly to adjacent ground formations. Alternatively, the major contributing source of water to our streams and rivers is the waters which have at some time passed through surface formations.

The nature of soil water has been classified under four types, namely, pore water, solvation water, adsorbed water and structural water. Pore water has all the physical and chemical characteristics of normal water. Solvation water is present only in very thin layers covering each soil particle and is that water which is retained in position by various internal forces near the particle surface. These two types of water are mobile and may be removed by hydrodynamic equipment. The remaining types can be considered immovable by ordinary means and will not be mentioned further. Pore water is, of course, the greatest in quantity, is more readily available and, therefore, forms a large percentage of ground waters avail-able for water supplies.

As we know, rain or snow after falling on the earth's surface percolates either through void spaces in overburden formations or through fractures in surface rocks. In overburden formations where the water table is some distance below the surface we have two definite zones of ground water, namely, the saturated zone and the zone of aeration. In the saturated zone all interstices are completely occupied with water. The zone of aeration can be divided into three belts, namely, the belt of soil moisture, the intermediate belt and the capillary fringe. The belt of soil moisture is the layer of soil or subsoil from which water is discharged to the atmosphere by evaporation from the soil and transpiration of plants. When water passes by percolation below this belt of soil moisture it is beyond recall of the roots of plants except in vapour form and proceeds towards the zone of saturation through the intermediate zone.

If we follow water downward into the intermediate belt and capillary fringe we find large quantities of water, but this water is essentially dead storage except in the capillary fringe where flow is appreciable. The top of the saturated zone is not clearly discernible in soils unless some pondage, such as a well or other open water, is available to ascertain this level. Water in the capillary, fringe is not available to ground water supplies in homogeneous formations due to capillary forces being of equal strength throughout. Reduction of particle size in the capillary fringe will subtract from the saturated zone, and alternatively, larger particle size will contribute to this zone.

GROUND WATER MOVEMENT AND STORAGE:

The passage of ground water and its velocity through any formation is dependent on a number of factors, mainly porosity, permeability of the overlying formations and the degree of fracturing and solubility in rock formations. The temperature of the water and, therefore, its viscosity, is also an important factor.

The availability of water in fractured rock can only be, ascertained by drilling and testing, although some indication of possibilities may be estimated from installations in similar formations. Diversions of water from rock formations are available in British Columbia but are usually of small capacities, while in overburden large developments are practical. It is in this overburden or alluvial material that our major resource of ground water, in quantity, exists.

The porosity of any formation is usually considered as the total percentage of voids in the formation or its ability to hold water, and permeability is the ability of the formation to transmit water and is the governing factor in yield. Alluvial deposits are relatively impervious in their natural state but by resorting in glacial outwash which occurs where comparatively high water velocities exist or have existed, their permeability is increased. Permeability may vary in vertical, oblique and horizontal planes and is usually higher in those planes corresponding to the laying down of the formations or their resorting.

Aquifers, the name applied to ground water reservoirs which are available for use, vary in size with the deposit, its overall porosity and permeability, percolation from precipitation and infiltration. Their specific yield or perennial capacity for diversion, without depletion, is extremely important in ground water control of an area. Their capacities can be increased by induced infiltration from natural water courses, by installation of surface water recharge basins or by well development to pass waters from surface supplies or upper permeable zones to the aquifer to be diverted.

Water table elevations in aquifers remote from contributing water courses do not necessarily immediately follow our seasons of intensive precipitation but may lag this cycle. Conditions in one aquifer recently investigated, indicated that high water table and, therefore, maximum storage existed in summer months and the low water table in the rainy season. This is, of course, due to the comparative slow movement of ground water in natural conditions.

It is not sufficient, to assume that our ground water resource is only that water which is yearly in existence in the surface formations through natural phenomena. The specific yield of any aquifer can be increased by induced infiltration from adjacent surface water courses or diversion from these water courses to the aquifer. In fact most large developments are predicated on this induced infiltration or recharge.

GROUND WATER QUALITY:

In order to appreciate the quality of ground water generally it may be advisable to show a comparison with surface waters which vary greatly with river stage in British Columbia. While accurate records are not available in our province, a group of ninety-eight surface supplies sampled at various places throughout the United States and at various periods of the year indicated that the turbidity varied from less than 1 p.p.m. to 27,500 p.p.m. and only one source showed a maxima of less than 10 p.p.m. and five sources less than 20 p.p.m. A similar condition exists in the impurities, colour and hardness.

During low velocities a large number of our stream waters are satisfactory for average quality water supplies, unless, of course, artificially contaminated. These waters require no treatment except for industry that may require high quality water. However, during average or flood periods the waters of practically all our streams are contaminated even with pondage prior to diversion. While undesirable in taste but otherwise satisfactory for human consumption, a large number of our municipalities divert and use this raw water at all river stages, but industry, particularly the pulp and paper industry, with high quality product is obliged to reduce the water impurities, particularly turbidity, colour and some injurious chemicals. It is problematic if at least part of this correction would not be advisable in some municipal supplies.

In ground water supplies a more satisfactory condition exists. Analysis of several test wells shows that all impurities, with the probable exception of hardness, are reduced to such an extent that the water is satisfactory for high grade pulp production without treatment. Hardness due to dissolved chemicals is usually higher than in adjacent watercourses. Let me illustrate by reference to a test made near Nanaimo in 1951. In this Cassidy development, test well water analysis showed that the maxima impurities for those sites selected for well development was turbidity 2 p.p.m., colour 3 p.p.m. and total hardness 60 p.p.m., but most of the tests were well below these figures. Hardness showed an increase of about 30 p.p.m. from adjacent stream analysis.

For human consumption high quality waters are not necessary. Colour, in quantities that usually exist in surface waters, is not detrimental and is usually not considered in waters of this province. All waters with less than about 100 p.p.m. are considered soft waters but supplies up to 500 p.p.m. are satisfactory and waters higher in hardness are in use.

It has been found that impurities usually decrease in quantity with continual pumping of any well, although this may not be the case in all developments. From analysis over a period of time it appears that a constant quality of water is available even with the seasonal surges of surface watercourses immediately overhead.

The temperature of ground water at depth usually approximates the average annual temperature of the atmosphere in the location considered and has been found to vary only slightly over the yearly period. This temperature condition of ground water, varying as it does between 40° and 45° F. for Pacific Coast developments, is of great benefit to some industries in the temperature condition alone and has further advantages over surface water supplies whose summer temperature may be 70° F., in reduction of algae and, therefore, turbidity.

DEVELOPMENT:

Ground water has been a. source of water supply for many centuries but in recent years its exploitation has been facilitated with fabrication of deep well turbine pumps, revised ideas of well screen uses and their manufacture, and special adaptation of wells to induced large diversions from aquifers, particularly those adjacent to natural water courses.

In general, types of development can be classified under three headings, namely, infiltration galleries, deep vertical wells, and horizontal collectors. Installations of all these types are in use at the present time in British Columbia and have their apparent advantages.

The ordinary back yard or fanner's open well can be classified as an infiltration gallery, and enlargement of this principle has been used to advantage in some small municipal water supplies in Eastern Canada, Great Britain and probably throughout the world. They depend on natural filtration and can only use those ground waters adjacent to the water table.

Vertical wells have been the subject of intensive study since the turn of the century. With satisfactory knowledge of the aquifer and proper installation they will develop an economic and secure water supply, usually of high quality. They are our only method of securing ground water from rock and deep permeable formations and are extensively used in shallow, confined and unconfined aquifers for smaller water supplies. Numerous installations for domestic use are drilled yearly in British Columbia and are economic in outlying districts. Satisfactory supplies have been made available for municipalities and industry. In larger supplies multiple well installations are usually necessary to obtain sufficient yield.

The horizontal collector is an efficient collection gallery that can be developed economically to depths of about 220 feet and in which the number, length and elevation of the intercepting galleries can be controlled at will. It consists of a concrete shaft sunk to desired elevation in an aquifer and sealed .at the bottom with a concrete plug. Horizontal screen pipes are projected like spokes in a wheel in any desired direction and in lengths up to and in excess of 300 feet. They are constructed under patent rights by Ranney Method Water Supplies.

These Ranney Collectors are being used in normal ground water aquifers remote from surface water, as infiltration units adjacent to water courses and as recharge units intercepting additional aquifers or surface waters and passing these waters to the pumping strata. In all, about 100 units have been installed in the United States and three in Canada. Total development yields to date, range from 1,500,000 to 123,000,000 gallons daily and vary in the development from one to seven collectors. The largest diversion was made available by six units which are installed on the bank of the Ohio River, a highly polluted water course. Horizontal collectors are suited to very shallow aquifers and also aquifers in close proximity to sea water due to their comparatively small drawdowns of the water table. Regulation of water temperature is possible by control of the various screen pipes at will.

The most important recent ground water development will serve to illustrate the importance of this resource to B.C. and indicate the possibilities. In the Cassidy ground water development which supplies the total process aud service water for the McMillan-Bloedel high grade bleached sulphate pulp mill at Nanaimo, B.C., the estimated requirements of high quality water were approximately 23 million gallons daily. A number of surface water possibilities were available and surveys were made of these sources of supply. In 1909 and 1910 maps were compiled by the Geological Survey, Department of Mines, Canada, showing topography, bedrock and surface geology of that part, of the east coast of Vancouver Island between Ladysmith and Nanaimo. This geological information indicated the possibilities of ground water at Cassidy in an extensive, aquifer of possibly ten square miles. A further report by a consulting geologist, confirmed these possibilities and a ground water engineer was retained to advise a test drilling program in the three most probable areas.

This test drilling indicated that ground water was available in sufficient, quantities in more than one section of the area investigated and, it further showed that the quality of this water was satisfactory for the high quality product which the manufacturers intended to produce. Economic studies of surface supplies and underground water supplies clearly indicated a considerable saving in both capital and yearly operational costs by developing the ground water resource.

The economic approach to the supply indicated that horizontal collectors based on the induced infiltration principle were most advantageous with possibly some augmentation from storage aquifers during low stages of the Nanaimo River and Haslem Creek. Three horizontal collectors were installed varying in capacity from about 15 to 7 million gallons daily. The Department of Fisheries, Canada, required at least, the minimum flow of the Nanaimo River be passed during the various runs of the salmon species. Three vertical wells were installed in what may be regarded as storage aquifers to comply with this requirement. These wells, installed as they were in aquifers of high permeability, will each discharge about four million gallons daily for short, periods but this quantity is probably considerably above the perennial yield of the aquifers. The continuous yield of the 3 horizontal collectors is probably in excess of 29 million gallons daily and the total development, possibly without sufficient security, is about 42 million gallons daily. It is a. pleasure; to know, that possibly no higher grade of product can be manufactured anywhere on this continent and possibly in the world than that produced with this raw material, the ground water supplies from the Cassidy area.

Ground water is going to be important in many areas in B.C. For instance investigations in British Columbia for ground water supplies are being made by geologists of the provincial government and the Department of Mines, Canada. In the Prince George area there appears to be 200,000 acres of land that could be adapted to agriculture if sufficient, water was available. The future development of this area will probably be dependent on securing satisfactory ground water sources. Provincial government geologists have been in the field for the past two seasons investigating this supply. A similar condition exists in the Fort St. John area where large acreage is available but surface supplies are either inadequate or not economic. Investigations by the provincial government for ground water are being undertaken in this locality.

Numerous small municipalities have secured domestic water from wells and this trend must necessarily increase. Vanderhoof has recently installed a well, 600 feet deep and now has a secure water supply from artesian aquifers. Hope has recently secured ground water for its municipal requirements from the extensive, aquifer on which the city is built. This aquifer would probably yield large quantities of high quality ground water if and when required in this area. Satisfactory supplies for Nanaimo, Ladysmith, Duncan and numerous other municipalities are possible and may be more economic than surface supplies.

In the southern interior of the province irrigation is necessary for successful agriculture and even in other areas with comparatively high precipitation, such as the lower Eraser Valley, irrigation is probably economic. Surface waters in some of these areas may be fully licensed and ground water sources will probably be more economical than building storage dams to obtain a higher controlled flow of the surface water supply.

In the lower Eraser Valley the Department of Mines, Canada, is investigating the possibilities of ground water as well as other natural resources. The District of Surrey appears to be underlain, by an extensive confined aquifer which seems to be interconnected and connected with surface watercourses. Possibly as many as 2,000 wells of varying sizes, depths and types of construction have been installed in this district alone with no comprehensive pattern to allow for future development of the total aquifer. This condition probably exists in other districts throughout the province.

No well developments to date in the province, with the possible exception of some small irrigation wells, have caused concern in intrusion of salt water to our ground water aquifers but this is probably due to avoidance of this possibility in our supplies. This difficulty can be expected with heavy pumping of any aquifers adjacent to tidal water if well drawdowns are sufficient, to induce infiltration of these saline waters and if the aquifer is connected to the ocean. In the Cassidy development, the aquifer was of sufficient extent to eliminate this difficulty. Near Seattle one well was drilled immediately above tidal high water in a confined aquifer and has been operating for some time with no noticeable saline content. In the Los Angeles area, where over seventy percent of water used is obtained from ground water over an extensive inland area, and where drawdown water table is increasing every year, a major problem of replenishment is anticipated due to intrusion of saline waters. The same condition exists in the Long Island area of New York where considerable over pumping is being done and where no surface waters for recharge are available, without, importation.

The pumpage of any well in any formation will lower the water table within the circle of influence of the well. The capacity of any well within the influence of the pumped well will be reduced unless sufficient natural or artificial recharge is being supplied to the aquifer to counteract this influence. Observations of all wells in the area during pumping and a knowledge of water table gradients is the approach to this problem of well interference.

ECONOMIC ASPECTS:

I have previously stated that the ground whaler development at Cassidy was more economic than surface water supplies and these were available in the area. Other preliminary investigations in the pulp and paper industry indicate that this condition exists in other parts of the province. In the chemical industry generally where quantity and quality water or its temperature are of importance, the selected location of these industries may be dictated on ground water possibilities, other facilities being equal.

Large areas of agricultural lands in the province are, at present, arid due to an apparent insufficiency of water but this supply may be well within the economic reach of these lands by ground whaler diversions. Even in the lower Eraser valley, which cannot, supply sufficient farm products for the population of the lower mainland, a considerable increase in practically all products would be available if irrigation were supplied, and this water appears available in ground water, at least in some districts. I have been advised that in unirrigated pasture lands in this area two acres are required to support one cow, but in irrigated lands one acre will support two cows, an increase of 300 percent. In other products a similar condition exists where the yield of potatoes increases about 200 percent, strawberries 200 to 300 percent, clover seed 100 percent and peas fifty percent. With this increase in yield it may be that the low Eraser valley could support, the population of the lower mainland.

In recent months the siting of two of our proposed provincial institutions has been predicated on a satisfactory supply of ground water. Smaller industries throughout the lower mainland have installed wells to either reduce or eliminate their annual water purchases. Some other industries have investigated this possibility.

The approach to any ground water development is probably more expensive than a surface investigation due to lack of visibility under the ground surface and, therefore, the necessity of test drilling. A prior knowledge of the geological history and possible sorting of the formation is helpful, together with topography of the area. However, the economic analysis of any water supply must consider both surface and ground water possibilities or a combination of both, bearing in mind the advantages of each in total water usage.

Surface water supplies in raw water form are usually lower in initial cost than ground water supplies if equidistant to point of usage. However, freezing conditions and difficult diversion works or storage requirements ma\ prove disadvantageous to the surface supplies. While there is an abundance of surface, water in British Columbia, economic diversions without prior pollution are, few in regions of intensive population and industry and these supplies will continue to lessen in number, quantity and quality in the future. Municipal supplies from surface water require large uninhabited reserves of drainage areas which may otherwise be productive in agriculture or industry. Diversions of these waters in flood stage, carrying sediment as it does, is hardly palatable and may be injurious to water works installations in general.

Quality demand of water varies with the different industry and with equipment within the industry. Where the yearly quality cycle of surface water is not acceptable and treatment is required, ground water, if available, is probably more economic. Lower and constant temperature water is an added incentive in some industries and is particularly adaptable to cooling installations.

RECOMMENDATIONS:

Users of surface water supplies, for any use or any quantity, are obliged to pay a nominal annual rental for this water and are thereby protected by our Water Act and its administration under the Minister of Lands and Forests and his Water Rights Branch. Users of ground water, in some diversions only, also pay these rentals, with possibly some hope that our Comptroller of Water

Rights is able to protect their investment. Alternatively, they may be obliged to purchase extensive areas of land and secure water licences on adjacent streams that, may be contributory to their producing aquifer or aquifers.

Revisions to the Water Act or the, passing of a Ground Water Act to protect this resource and its users is of utmost importance. The ground water resource is closely related to our surface waters inasmuch as they are dependent on each other. It appears that administration of both resources should be coordinated under the one branch, the Water Rights Branch. Powers of the Comptroller under the, revised or new act must, be far reaching for the protection of present users and the resource. These powers should include besides others:

1. The accumulation of hydrogeological information on all well installations throughout the 'province, as this information is necessary to estimate the extent, of the, resource and, therefore, the probable interference and embarrassment, of later installations to the original licence.

2. A restriction on pumping of the resource in any installation to the licencee's requirements and probably control of well depth to safe-guard the potential resource and users. This may not be possible in original licences in any aquifer but is of utmost importance with numerous wells in the same area.

3. Inspection by government personnel to records, in any matters pertaining to the resource, its perennial yield and other matters necessary for administration.

4. Expropriation of lands by licencees, as in the Water Act and clarification of surface rights and underground water.

5. The issue of licences for well installation of any type and rentals with priorities in the various uses. These licences and rentals should be a nominal charge as in the Water Act.

It may be that there is not sufficient clarity in the responsibilities of the Provincial and Dominion Governments in the matter of preliminary surveys in ground water areas. If this is so, no time should be lost in finalizing this responsibility or taking the necessary steps to accumulate, all information under one branch.

To date ground water is a neglected natural resource in British Columbia. We have little knowledge of its extent other than appreciating that it is of great value to the province. Our government collects practically no revenue from the resource which can, in time, be self-supporting. It is sincerely hoped that the government, public, industry and particularly engineers will awaken to its tremendous possibilities and that our government will see fit to allot a sufficient annual expenditure for its proper investigation, administration and publicity.

I would like to thank Mr. J. F. Miles, Mr. T. A. J. Leach, Mr. P. G. Odynsky and others of our Water Rights Branch, Mr. H. Nasmith of the Provincial Department of Mines and Dr. J. E. Armstrong of the Department of Mines, Canada, for their kindness and assistance in the collection of information for this paper.

MR. MILES: Ladies and gentlemen, I understand we have about nine minutes for questions.

DR. M.Y. WILLIAMS: Mr. Chairman, on this sixth meeting of our Natural Resources Conference, I am sure you would be disappointed if I didn't say something in regard to ground water because I have commented on this subject during all the preceding five gatherings.

It is with great satisfaction that I have listened to this paper today. It is the first time I think, that the ground water has been given anything like adequate attention. Three of the areas which I have mentioned previously as needing attention have already been enumerated. These are the Peace River, the Prince George area and the lower Fraser River. However, these are not exclusive and it has been brought to my attention during some field work during the last two summers that our beautiful Gulf Islands are limited in their population and possibilities, perhaps primarily by lack of adequate transportation and secondarily by proper water supply. I believe the water supply can be very greatly helped by proper attention. I should just like to emphasize the further need of geological investigation because the problem is in a broad sense a geological one.

In regard to the first paper, I wish to make just one remark, and that is that I do not see that any attention has been given to the growth rings of trees in connection with the past flow of stream valleys. Some of you are familiar with that work which has been done in Arizona in connection with the tree rings. Through use of them, we have gone back to the first decade of the Christian era and have pretty well predicted the climate and runoff for those very ancient periods. I found in connection with some preliminary work which I have clone in regard to Churchill, Manitoba, that you can rely on the records of the trees for the few years during which we have had records of runoffs. And by using the younger portions of the trees where the growth was vigorous, you can form a very good idea, as to what the runoff has been to the very beginning of the tree growth. I would suggest if the attention has not been called to the growth of rings in trees that you give it some consideration. I think that with a little care you will find it very useful.

MR. ROPER: Ladies and gentlemen, before the convenor and the speakers leave the platform on this Water Session, I am sure I express the sentiments of all of you in declaring that we have had a very interesting panel discussion on an abundant but very valuable natural resource.