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Creating and Delivering Better Solutions

AQUIFER PROTECTION PLAN
CITY OF MERRITT
MERRITT, BC

EBA File No: 0805-5875017

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AQUIFER PROTECTION PLAN

CITY OF MERRITT

MERRITT, BC

Submitted to:

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Merritt, BC

Submitted by:

EBA ENGINEERING CONSULTANTS LTD.
Kelowna, BC

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EXECUTIVE SUMMARY

The Merritt Aquifer is one of the most vulnerable and developed aquifers in British Columbia. The aquifer is the sole source of potable water for the City of Merritt. The City of Merritt currently extracts about 100 L/s (1,333 Igpm) from the aquifer via five production wells.

The majority of the production wells are located within a deep "trough" in the geographic centre of the aquifer. Drilling records suggest the trough may exceed a depth of 50m in some areas. Four of the City of Merritt production wells are located within this trough.

The aquifer is recharged by a combination of precipitation, leakage from the Coldwater and Nicola Rivers, and perhaps from Nicola Lake. The current rate of pumping generates large capture zones to form around and upgradient of the production wells. Due to the proximity of the wells from each other, the capture zones overlap.

Preliminary capture zone estimates suggest the ultimate time of travel within the aquifer ranges from a minimum of 5 years to greater than 10 years. Some data suggest that total extraction rates greater than 100 L/s may induce wide-spread well interference within the aquifer. Significant well interference will increase the size of the capture zones over time, and reduce travel times.

Capture zone analysis suggests the aquifer is vulnerable to contamination from many sources, including: industrial / commercial activities, agricultural activities, commercial transportation routes, sanitary sewer, flooding and specific sites of concern. The rate of groundwater movement within the aquifer, and the significant overlap of the City of Merritt production well capture zones, suggests contamination of the aquifer would likely result in simultaneous contamination of the production wells.

Due to the aquifer conditions (unconfined aquifer and shallow water table), the release of a contaminant at surface would quickly impact the aquifer. Contamination could trigger the deactivation of one or more production wells within a short period of time (within several months).

The recommended course of action for the City of Merritt is to first install a series of early-detection monitoring wells within the aquifer to detect contamination before it reaches the production wells. The City should then evaluate the aquifer as a whole to better quantify the groundwater resource and determine safe pumping rates. Finally, the City may compile the information gathered to refine the capture zone predictions using a computerized groundwater model.

A groundwater model would allow the City to plan the location of future wells (if possible) within the aquifer, determine their effect on existing wells and determine groundwater protection zones required to protect the potable water source.

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APPENDIX

1.0 INTRODUCTION

The City of Merritt ("the City") is located in the southwest interior region of British Columbia at the confluence of the Coldwater and Nicola Rivers (Figure 1). The City currently satisfies all potable water requirements via groundwater extraction from the Merritt Aquifer, located underneath the City. Merritt currently pumps about 100 L/s (1,600 USgpm / 1,333 Igpm) of groundwater from the aquifer via five production wells.

The B.C. Ministry of Environment (BCMOE) Aquifer Classification system categorizes the Merritt Aquifer as type "IA", identifying it as one of the most highly developed and vulnerable aquifers in the province. Less than 5% of aquifers identified in B.C. currently have this rating.

On May 17, 2002 Merritt retained EBA to complete an Aquifer Protection Plan[1] in accordance with a proposal submitted by EBA[2]. The main objectives of this study are as follows:

- protect water quality at the existing City production wells, and
- provide guidance regarding future investigations and studies required to protect the Merritt Aquifer.

2.0 BACKGROUND

2.1 Summary of Previous Investigations

The majority of previous investigations have focussed upon production well siting, completion, testing and rehabilitation. Based upon the results of the literature review, it appears only the BCMOE has reported upon the hydrogeology of the aquifer as a whole. A list of relevant documents reviewed during this study is presented in Section 9.

In a summary report written by the BCMOE entitled *An Aquifer System Classification for Groundwater Management in British Columbia*[3], all aquifers identified in B.C. were ranked. The ranking scheme was based upon aquifer development and vulnerability. The Merritt Aquifer received the fourth-highest ranking of 153 aquifers identified in B.C. at this time. This ranking suggests the aquifer is highly developed and highly vulnerable to contamination. In spite of the ranking, surprisingly little is known about the hydrogeology of the aquifer.

[1] Award letter from City of Merritt dated May 17, 2002.
[2] Revised proposal submitted to City of Merritt on May 16, 2002.
[3] BCMOE internet document available at http:wlapwww.gov.bc.ca/wat/aquifers/Aq_Classification/Aq_Class.html. Publication date unknown.

The most comprehensive report about the aquifer hydrogeology is presented within the BCMOE (1988) document. The report suggests aquifer boundary locations, thickness, hydraulic parameters and groundwater flow directions. Findings presented in the report are based upon the provincial well log registry.

Table I presents references specifically utilized to interpret lithology, completion data and hydraulic parameters of City production wells.

2.2 Project Scope

The scope of the project is presented below:

- delineate the Merritt Aquifer using existing data (including BCMOE aquifer classification maps),
- calculate and plot capture zones for the City of Merritt production wells,
- define preliminary Groundwater Protection Areas,
- compile an inventory of potential contaminant sources using City zoning maps (adapted from the Official Community Plan),
- identify risks posed to the Merritt Aquifer and the Groundwater Protection Areas, and
- develop measures for the general protection of the aquifer.

2.3 Project Approach

Upon award of this study to EBA, a literature review of previous engineering reports was undertaken. From the review, a conceptual model of the aquifer was developed.

Using the conceptual model as input data, a series of capture zones were calculated for each City production well. The capture zones were calculated using the "fixed-radius" method (as per our proposal). However, due to the complexity of the aquifer and significant overlap of the capture zones, additional analyses were undertaken. Additional analyses involved analytical and computerized methods.

Due to the complexity of the aquifer and the minimal amount of hydrogeologic data available, two potential capture zones scenarios are presented. Groundwater Protection Areas were developed based upon the results of this capture zone analysis. City zoning plans and utility drawings were then overlayed on the capture zones to determine risks posed to operating production wells and the Groundwater Protection Areas.

Finally, extensive recommendations were developed to suggest ways the City may develop a better understanding of the aquifer, refine the capture zones and protect the production wells.

3.0 HYDROGEOLOGY

This section presents a conceptual model of the Merritt Aquifer and a summary of production well pumping rates and hydraulic parameters. Please refer to Figure 1 for a plan of the aquifer and the location of current City production wells. Please refer to Tables I and II for a summary of production well completion data, pump test results and historical pumping rates.

3.1 Summary

A detailed interpretation of geological conditions resulting in the formation of the Merritt Aquifer is presented by E. Livingston (1970). Please refer to this reference as background. The summary below focuses on aquifer parameters relevant to this study.

Aquifer Boundaries

The Merritt Aquifer is interpreted to underlie the floodplain between the Nicola and Coldwater Rivers. A surficial geology map[4] of the area suggests the aquifer potentially extends east and west of Merritt. The aquifer may extend as far east as Nicola Lake and as far west as the confluence of the Nicola River and Guichon Creek (below the town of Lower Nicola). The surficial geology map also suggests the aquifer may be cut off by alluvial fan deposits below Lower Nicola.

Aquifer mapping conducted by the BCMOE suggests the most productive portions of the aquifer likely extend from the Coquihalla Highway to the western City limits of Merritt. The scope of this study does not include verification of the aquifer boundaries, thus we have assumed the aquifer is defined by the BCMOE boundaries (Figure 1). Based upon this assumption, the aquifer measures about 2.5 km north-south by 3 km east-west, resulting in a total area of about 7.5 km^2.

Aquifer Thickness

Based upon production well logs, the thickness of the Merritt Aquifer ranges from 5 to 50m. However, about 80% of the aquifer is interpreted to be less than 10m thick. Drill logs from the BCMOE public well registry suggest the presence of a deep "trough" within the aquifer. The trough is interpreted to extend from the May Street production well to Colletteville. The deepest part of the trough is interpreted to extend from the Fairley Park well to Colletteville.

The trough appears to run sub-parallel to the current course of the Coldwater River, suggesting it may be an infilled river channel. The trough may extend further west, but there is currently no data available to confirm or deny this hypothesis.

[4] Map 1393A. Surficial Geology of Merritt. Geological Survey of Canada Maps.

Aquifer Lithology

The composition of the aquifer is typically a mixture of sand and gravel with variable silt content to a depth of 10m. In the area of the trough, below a depth of 10m, well logs suggest the aquifer is composed of coarse gravel with distinct layers of silty sand and gravel. Boreholes completed through the aquifer suggest it is underlain by glacial till and/or soft clay.

Our literature search suggests that drilling in the aquifer has been restricted to only a few meters below the base of the aquifer. Thus, the presence of deeper aquifers and the depth to bedrock is unknown. However, private wells drilled at River Ranch northeast of Merritt suggest highly productive artesian aquifers may exist at depths exceeding 70m.

Aquifer Water Levels

Static water levels measured in the aquifer ranged from 1.9 to 4.3m below ground surface (Table I). Data suggest the shallowest static water levels occur at the Fairley Park well, located mid-way between the Coldwater and Nicola Rivers. This may suggest the presence of a water table mound between the two rivers. If this is true, then precipitation is likely a significant source of recharge to the aquifer.

The BCMOE installed a monitoring well (No. 296) at the intersection of Garcia Street and Coldwater Avenue in 1988 for the purpose of long-term water level and water quality monitoring (BCMOE, 1988b). A summary plot[5] of water levels, precipitation and trend statistics measured since 1989 is presented in Appendix A. Trend data from the monitoring well suggest aquifer water levels are sensitive to recharge from precipitation and seasonal flooding of the Coldwater and Nicola Rivers.

Due to the position of monitoring well No. 298, the water levels recorded in the well are interpreted to have at least some correlation with the total rate of groundwater extraction from the aquifer. The lowest groundwater levels recorded at the monitoring well (which occurred concurrent with low-flow periods in the local rivers) occurred during 1994, 1998 and 1999. This correlates with the highest pumping rates recorded at the City of Merritt production wells (i.e. exceeding 100 L/s).

Although this interpretation is preliminary (due to the lack of available observation well data) this correlation may suggest drawdown from the City production wells is currently having global impacts on the aquifer. If this interpretation is accurate, drawdown and well interference impacts will likely become more significant in the future, as the rate of groundwater extraction increases. However, this hypothesis cannot be validated without the installation of additional monitoring wells and long-term monitoring of aquifer water levels.

[5] This plot is available on the BCMOE website at
http:wlapwww.gov.bc.ca/wat/gws/obswell/obsw296.html

Groundwater Regime

The coarse composition of the Merritt Aquifer suggests the aquifer is unconfined[6]. An unconfined aquifer is recharged by precipitation and leakage from surface water bodies, such as the Coldwater and Nicola Rivers. Pump test data from the May Street production well appears to confirm this hypothesis. This well is likely recharged mainly by the Coldwater River.

Pump test data from the Colletteville and Voght Park wells, however, suggest the deep sand and gravel trough may be responding as a leaky-confined[7] aquifer. The data also suggest the Coldwater River may act as a recharge source for the trough, but preliminary modeling indicates the rate of leakage from the river may not be adequate to stabilize long-term drawdown within the wells. Recharge must also be coming from another source. We feel that groundwater flow from upgradient portions of the aquifer likely provide the conditions required to stabilize long-term production well drawdown.

Our hydrogeologic interpretations of the aquifer generally agree with those presented by E. Livingston, P.Eng. (1971) and Pacific Hydrology (1990). We recommend the City install a monitoring well network within the vicinity of the production wells. This will facilitate a better understanding of the hydrogeological condition in the trough and ensure adequate groundwater is available for the long-term requirements of the City. Routine water sampling of strategically placed monitoring wells would also provide early warning of deteriorating groundwater quality.

Aquifer Permeability

Hydraulic testing by others (Table I) suggests the transmissivity of the City production wells ranges from $1x10^{-2}$ to $8x10^{-2}$ m^2/s and aquifer hydraulic conductivity ranges from $6x10^{-4}$ to $2x10^{-3}$ m/s.

Hydraulic Gradient

For the purpose of this study, we have assumed a uniform westerly (lateral) gradient of 0.005 throughout the aquifer (including the trough). This gradient is approximately equivalent to the floodplain ground slope.

[6] In an unconfined aquifer, groundwater is exposed to atmospheric pressure. The aquifer is not pressurized or capped by low-permeability sediments.

[7] Leaky-confined aquifers are not directly exposed to atmospheric pressure. Low-permeability sediments that cap the aquifer reduce the rate of infiltration from precipitation.

We understand that lateral and vertical gradients within the aquifer are likely complex and dependant upon the proximity of recharge sources, river stages, aquifer boundaries, saturated thickness and the influence of production well drawdown. However, at this time, we feel that gradient estimates cannot be refined without undertaking a hydrogeologic mapping program of the Merritt Aquifer.

3.2 Operating City Wells

Locations of the operating City wells are presented in Figure 1. All of the wells, except for the May Street well, are located within the aquifer trough. City production well completion depths vary from 10.7m-bgs[8] (May Street well) to 45.1m-bgs (Colletteville well).

Production well data (Table II) indicate the total average-annual pumping rate has ranged from 83.9 to 109.0 L/s since 1993. Overall, the rate of groundwater extraction from the aquifer appears to be increasing with time. Simple linear-regression analysis suggests the City of Merritt will likely require about 120 L/s per year by 2010.

Production well data indicate the Voght Park wells provide about two-thirds (68%) of total potable water requirements. The remainder is provided by the Fairley Park, Colletteville and May Street wells.

Specific Capacity

Literature review suggests the specific capacity of the production wells ranges from 8 to 43 L/s/m[9]. Some of the wells have shown significant decreases in specific capacity with time. This is especially evident with the Colletteville and Voght Park wells during the past decade.

Decreasing specific capacity of the Voght Park wells, in particular, will result in significant increases in electrical operating costs. Based upon our experience, and general industry knowledge, once the specific capacity of a well falls by 40%, the production rate of the well typically begins to decrease exponentially with time. So it is very important to monitor the variation of well capacity with time and implement a monitoring and maintenance program.

We strongly recommend the City of Merritt investigate fluctuating specific capacity trends. Proactive and dependable methods of maintaining well capacity are available (rather than occasional acid-treatment). Recommendations from this study would likely provide significant long-term electrical cost savings for the City and prolong the life span of the wells.

[8] mbgs = meters below ground surface

[9] This measurement provides an estimate of the flow rate potential per unit of drawdown. For example, 43 L/s/m suggests 43 L/s can be pumped from the well per metre of well drawdown.

4.0 CAPTURE ZONE ANALYSIS

4.1 Assumption of Extraction Rate Sustainability

The following capture zone analyses of the City wells assumes the total rate of groundwater extraction from the aquifer does not exceed the rate of aquifer recharge. If pumping exceeds the rate of recharge, the capture zones will expand further and more quickly than the results presented in Section 4.4. A brief discussion of the current balance between groundwater extraction and aquifer recharge, as interpreted by EBA, is presented below.

Our preliminary calculations suggest the current rate of groundwater extraction by the City wells greatly exceeds the rate of aquifer recharge from <u>precipitation</u> (based upon the boundaries delineated by BCMOE). However, water levels in BCMOE monitoring well No. 296 suggest aquifer water levels have only decreased marginally since 1988. This observation emphasizes the fact that groundwater levels in the aquifer are in dynamic equilibrium with many recharge sources and discharge zones, including some or all of the following:

- precipitation,
- leakage from ephemeral creeks,
- lateral subsurface recharge (from the area east of the aquifer limits towards Nicola Lake),
- leakage and or discharge from the Coldwater and Nicola Rivers, and
- vertical flow within the aquifer.

Based upon observations and interpretations presented in Section 3.1, EBA concludes the current total rate of groundwater extraction from the aquifer (about 100 L/s) is likely sustainable for the long-term. However, future City water requirements may stress the aquifer beyond its capacity to produce water in a sustainable way. If this occurs, production well interference effects will become more significant, potentially leading to reduced well yields.

Due to the amount of water storage in the aquifer, short-term impacts from excessive pumping will likely not become significant for several years. Thus, we feel that capture zone analyses presented in Section 4.4 are valid for the short-term.

Increasing groundwater requirements and decreasing production well specific capacity may pose long-term concerns for the City and should be investigated. We strongly suggest Merritt undertake a Groundwater Resource Evaluation study to estimate rates of aquifer recharge, determine safe aquifer yields, suggest alternate source aquifers (to diversify the water supply) and test drill potential alternate / backup well locations. As a minimum, water levels from additional monitoring wells should be collected and analyzed on a regular basis.

4.2 Methods of Capture Zone Analysis

Capture zone analysis is performed using a variety of methods. The methods are presented below, ranked in order of increasing complexity, cost and data requirements:

1. Calculated fixed-radius,
2. Analytical equations,
3. Analytical element modelling,
4. Hydrogeologic mapping,
5. Numerical modelling.

Fixed-radius methods (Item 1) provide preliminary capture zone estimates at very low cost and require few data. Data requirements for this level of effort include individual well *pumping rates*, *screen lengths*, and aquifer *porosity* estimates. Capture zones calculated from this method are considered to be of low to moderate accuracy, depending upon the aquifer type. However, the results are usually conservative, ensuring protection of groundwater resources.

Analytical equations (Item 2) provide increased capture zone accuracy at low cost. However, additional data is required, relative to the calculated-radius method. Data requirements for this level of effort include individual well *pumping rates*, aquifer *hydraulic conductivity*, *lateral gradients*, *thickness* and *porosity* estimates. In general, this method requires a basic understanding of aquifer hydrogeology and the hydraulic parameters of each pumping well. Hydraulic parameters are typically calculated from individual well pumping tests. Capture zones calculated from this method are of moderate accuracy.

Analytical element modelling (Item 3) provides capture zone delineation at a moderate incremental cost to the analytical equation method. Data requirements are basically the same as the analytical equation method. However, a more detailed understanding of aquifer hydrogeology is required. Knowledge including aquifer *flow directions*, contribution from *recharge sources* and *barriers* to flow must be understood. Capture zones calculated from this method are considered to be moderately to highly accurate.

Hydrogeologic mapping (Item 4) significantly increases the accuracy of capture zones developed using analytical equations or models. The increased cost associated with this method is directly related to the construction of monitoring wells and long-term data collection. This method provides necessary information about aquifer hydrogeology to make significantly more accurate and reliable capture zone estimates. Hydrogeologic mapping is critical for aquifers where individual capture zones *overlap*, and *multiple sources* recharge the aquifer.

Numerical modelling (Item 5) is typically utilized when aquifer complexity is very high, many aquifer recharge sources exist, and zones of known contamination exist within previously defined capture zones. This method is also utilized to forecast time-dependant capture zone *migration* due to seasonal recharge patterns or proposed future pumping wells. Extensive monitoring data is required and the cost is high compared to analytical methods. However, the time required to prepare a numerical model (typically 2-3 years) usually reduces annual costs to a reasonable level.

4.3 Method Used for Study

As per our proposal, EBA originally planned to utilize fixed-radius methods to delineate conservative capture zones for the existing production wells. However, a literature review of previous pump tests revealed the hydrogeology of the aquifer was more complex than originally thought, especially regarding river leakage and the trough where the majority of the production wells are completed. The close proximity of the production wells and overlap of capture zones also made this method unsuitable.

Based upon the complexity of the aquifer and the availability of pump test data, EBA feels the analytical method will provide much more realistic capture zone estimates than the calculated-radius method. We have utilized both the calculated fixed-radius and analytical equation results to predict capture zones for the production wells.

The capture zones calculated for the existing wells are large relative to the size of the aquifer (see below) and they overlap. This finding compares well with discussions presented above regarding the high rate of groundwater extraction compared to the rate of aquifer recharge.

Due to the size and overlap of capture zones, EBA has also performed simplified analytical element model simulations to bound the upper and lower capture zone limits. However, please note there is currently not enough information available about the hydrogeology of the Merritt Aquifer to definitively predict capture zones utilizing the analytical element model. Thus, the results of the analytical element model will not be presented in this report. The data are available upon request.

4.4 Results

As discussed in Section 4.3, capture zone analysis for the City production wells utilized calculated fixed-radius, analytical equation and analytical element model analysis. Calculations of individual capture zones have not been summarized within this report. Data are available upon request.

Due to significant overlap of the capture zones and uncertainty regarding the amount of recharge to the aquifer from both the Coldwater and Nicola Rivers, we have prepared two potential capture zone scenarios, presented as Scenario A and B below.

4.4.1 Scenario A

Scenario A assumes the local rivers contribute significant recharge to the entire aquifer. Capture zones for this scenario (which include overlap effects) are presented in Figure 2. We consider this scenario representative of an unconfined or very leaky-confined aquifer condition with significant river leakage effects.

Colletteville, Fairley Park and Voght Park Wells

Scenario A suggests the one-year capture zone extends from near the confluence of the Coldwater and Nicola Rivers to about 300m east of the Fairley Park well. The one-year capture zone includes the Coldwater River. Contamination of groundwater within this zone or the Coldwater River would likely reach the Colletteville, Fairley Park and Voght Park #1 and Voght Park #2 production wells within one year.

The five-year capture zone prediction extends from the confluence of the rivers to about 800m east of the Fairley Park well. The ten-year capture zone prediction does not expand any further west than the confluence of the rivers, but it does expand further to about 1100m east of the Fairley Park well. These capture zones include the Coldwater and Nicola Rivers, and extend to the southern boundary of the aquifer.

May Street Well

The one, five and ten-year May Street well capture zones extend about 50m, 250m and about 400m southeast, respectively. The capture zones include the Coldwater River. Contamination of groundwater within these zones or the Coldwater River would reach the well within the time specified by the capture zones.

Conclusions

Scenario A analyses suggest the Colletteville, Fairley Park and Voght Park wells all extract groundwater from similar areas of the aquifer. This suggests <u>all</u> of the production wells (except the May Street well) would be affected simultaneously if contamination occurred. This would have serious implications for the City.

If one or two wells were shut down due to contamination, the City would be placed in a very difficult position because the current potable water requirements could not be met. This would occur because the City relies completely upon the aquifer as the primary potable water source. Diversification of the potable water source (i.e. extracting groundwater from different aquifers, or having emergency intakes on local rivers) would assist Merritt in avoiding this potential scenario.

4.4.2 Scenario B

Scenario B assumes the local rivers contribute moderate recharge to the aquifer. Capture zones for this scenario (which include overlap effects) are presented in Figure 3. We consider this scenario representative of a moderately leaky-confined aquifer condition with moderate river leakage.

Colletteville, Fairley Park and Voght Park Wells

Scenario B suggests the one-year capture zone extends from near the confluence of the Coldwater and Nicola Rivers to about 900m east of the Fairley Park well. The one-year capture zone includes the Coldwater River and a small portion of the Nicola River. Contamination of groundwater within this zone would likely reach the Colletteville, Fairley Park and Voght Park #1 and Voght Park #2 production wells within one year.

The five-year capture zone prediction extends from near the confluence of the rivers to the southern and eastern aquifer boundary (about 2700m east of the Fairley Park well). This capture zones includes the Coldwater and Nicola Rivers, and the May Street well.

May Street Well

The one-year May Street well capture zone extends about 500m southeast. The two-year capture zone extends to the southeastern aquifer boundary. The capture zones include portions of the Coldwater River. Contamination of groundwater within these zones or the Coldwater River would reach the well within the time specified by the capture zones.

Conclusions

As with the previous scenario, the Scenario B analyses suggest the Colletteville, Fairley Park and Voght Park wells each extract groundwater from approximately the same areas of the aquifer. This has similar implications of simultaneous well contamination as described in Section 4.4.1.

4.4.3 Comparison of Scenario A and B

The main difference between the two scenarios is the <u>time of travel</u>. The Scenario B analyses suggest travel times are much shorter than Scenario A. In our professional opinion, we feel the true rate of groundwater flow within the aquifer is bounded by the Scenario A and B results.

Without additional investigations of the aquifer hydrogeology and long-term water level measurement, we feel the capture zones presented above are the best possible representation of flow within the aquifer at this time.

We strongly recommend the City of Merritt implements an aquifer characterization and water-level monitoring program to better define the hydrogeology of the aquifer. This is especially important in the area of the trough, where the most productive wells are located. The most critical unknown is the response of the aquifer to fluctuating river levels (i.e. leakage and/or recharge patterns) and the seasonal directions of groundwater flow within the aquifer.

We recommend refinement of the capture zones through the use of hydrogeologic mapping (Section 4.2). We also recommend creating a computerized numerical model (Section 4.2) of the aquifer to simulate the effects of river leakage on aquifer recharge and to predict long-term drawdown patterns and well interference from the current production wells.

A properly calibrated numerical model would provide invaluable planning information for the City regarding long-term aquifer sustainability and potential future production well sites. It would also aid with the creation of action plans to deal with potential contamination of the aquifer and/or production wells.

5.0 EVALUATION OF WELL RISK

The final aspect of this study is an evaluation of well risk from potential contaminant sources. The main components of this risk evaluation include delineation of preliminary groundwater protection areas (GPA), identification of potential contaminant sources, and a list of specific protection measures. A discussion of these components is presented below.

5.1 Groundwater Protection Areas

The capture zone areas will vary significantly depending upon the hydrogeology of the aquifer. As discussed in Section 4.4, we feel it is premature to hypothesize which of the two potential scenarios (A or B) most accurately represent capture zones within the aquifer.

Nevertheless, groundwater supplying the production wells must be protected. Thus, we have outlined two preliminary Groundwater Protection Areas (GPA) for the City (Figure 4). These GPA will protect the quality of the aquifer supplying the production wells for the short-term[10].

[10] In this context, "short-term" is estimated to range from one to five years. The preliminary GPA is equal to the one-year capture zone for Scenario B and the five-year capture zone for Scenario A.

We have delineated the preliminary GPA using the conservative one-year capture zones presented in Scenario B. The conservative one-year capture zones were chosen because of the extent of capture zone overlap within the aquifer and the potential risk of simultaneous well contamination. We feel that a one year time period is likely the minimum time required by the City to make alternate arrangements for potable water, should contamination of the aquifer occur.

The remaining discussion in this section focuses upon the definition of the GPA.

5.2 Potential Contaminant Sources

As per the work scope outlined in the proposal, EBA has utilized the Merritt Official Community Plan (OCP) as the basis for identifying areas of the City where contamination at surface or shallow depth would impact the aquifer and GPA. We have categorized OCP zoning into risk designations of "high", "moderate" and "low". Figure 4 presents the results of the analysis.

In addition to City zoning, EBA has also reviewed utility and flood maps to locate other potential contamination sources. Commercial transportation, sanitary sewer lines and flood risks were identified as specific risks posed to the aquifer and GPA.

A discussion of the results of the risk analysis is presented below:

High Risk OCP Zoning

We interpret industrial areas pose the highest risk to the aquifer. Industrial areas are confined to the southernmost portion of the aquifer, and do not lie within the GPA of the Colletteville / Fairley Park / Voght Park wells. However, a significant portion of the May Street well GPA includes industrial areas.

These areas pose a significant risk to the aquifer because of the high-probability of point-source contamination. Industrial sites routinely handle toxic products during regular day-to-day activity, thus, the potential for contamination over the long-term is high. Industrial sites typically also handle significant volumes of high-strength (potent) contaminants. All of these factors suggest industrial areas pose a high risk, and require careful monitoring.

The type of contaminants that may potentially be released from industrial areas will vary depending upon specific site uses. Industrial contamination in the Merritt area may include the following:

- diesel fuel and gasoline,
- paint sludges,
- wood preservatives (chlorophenols, copper chromium arsenate, and creosote),
- acidic leachate and tannins from wood waste,
- metals from sand blasting.

Moderate Risk OCP Zoning

The aquifer and GPA are at moderate risk from commercial areas. The majority of commercial areas in the City are confined to the downtown core and narrow corridors along major roads. Commercial zones occupy a significant portion of the Colletteville / Fairley Park / Voght Park well GPA.

Point-source contamination from commercial areas pose lower risk to the aquifer and GPA, compared to industrial sites, due to limited site activity and the use of potential contaminants in smaller quantities.

Generally, risk posed to the aquifer from commercial areas is from businesses that have been located at the same location for a significant period of time (i.e. gas stations and dry cleaners). It is important to survey commercial areas to determine potential point-source contamination.

Low Risk OCP Zoning

The aquifer and GPA are at lowest risk from institutional, residential, park and agricultural zoning. These low-risk zones are located within the north, east and west portions of the aquifer. These areas occupy a significant portion of the Colleteville / Fairley Park / Voght Park well GPA and a small portion of the May Street well GPA.

Significant point-source contamination from these areas is considered less probable than at commercial or industrial sites. If point-source contamination were to occur, it would likely be of very small volume, compared to industrial or commercial areas.

Low-risk OCP zoning is more likely to produce non-point source contamination, which may include the following:

- street runoff containing hydrocarbons, cleaning chemicals, phosphates,
- nitrate and / or fertilizers, herbicides and pesticides from agricultural and gardening activities.

Commercial Transportation

Schedule B of the OCP presents routes for commercial transportation within the City. The Nicola Avenue truck route and Voght Street roadway pass through the Colletteville / Fairley Park / Voght Park well GPA. The shortest travel path from the route to a production well is estimated to be less than 500m (from Nicola Avenue to the Fairley Park well). The shortest travel path from Voght Street is also the Fairley Park well (a distance of approximately 700m).

The Houston Street / Pooley Ave truck route passes through the May Street well GPA. The shortest travel path from the route to the May Street Well is estimated to be less than 500m (from Houston Street).

If a significant spill were to occur along the roadways described above, contamination of wells would likely occur within a one year period.

In our opinion, Voght Street poses the greatest risk from the roadways because it is located directly upgradient of the aquifer trough, in which the most productive wells are completed.

Sanitary Sewer Pipelines

Functioning sewer pipelines pose very little risk to the aquifer. However, leaky or broken pipelines do pose serious risks to water quality. It is a generally accepted fact that even a properly functioning piping system will lose some of its fluid through joints and minor leaks. The greatest risk posed from sewage is the contamination of the aquifer by direct introduction of pathogens (such as *Colliforms*).

The risk posed to the production wells from the sewer generally increases with:

- increasing sanitary sewer pipe diameter (larger volumes of raw sewage may be introduced to the aquifer from broken or leaky larger-diameter pipelines),
- increasing pipeline flow (pressurized lines), and
- decreasing vertical distance between the sewer trench invert and the water table.

In the area of the Colletteville / Fairly Park / Voght Park GPA, sewer pipeline diameters generally vary from 100 mm to 200 mm. Only Coldwater Avenue and the western portion of the Nicola Avenue / Spring Street contain a 300 mm (or greater) diameter lines. A very short portion of 200 mm pipeline passes through the extreme east portion of the May Street GPA.

The distance between the sewer trench invert and the water table typically ranges between 1m and 3m within the Merritt Aquifer.

Risks posed to the aquifer and production wells from the sanitary sewer are interpreted as follows:

1. The greatest risk to the aquifer from sewage is along the 300 mm (and greater) diameter pipeline corridors. In particular, the Coldwater corridor is of concern because it is located directly above the aquifer trough where the most productive wells are located. We understand that this pipeline is also the oldest functioning sewer main in Merritt. Serious consideration should be given to replacing it, or closely monitoring this pipeline and discontinuing its use if significant leakage is detected.

2. Moderate risk is associated with the Colletteville and Fairly Park wells due to the proximity of a 200 mm sewer pipeline (Cleaseby Street) adjacent to the well heads.

3. Low risk is posed to the Voght Park wells from the many small diameter (150 mm) sewer lines due to the likelihood of high dilution from the Coldwater River.

4. Low risk is posed to the May Street wells because of the significant distance from small diameter (200 mm) sewer lines to the well.

Specific Sites of Concern

Several sites in the Merritt area have been identified which may pose long-term contamination risks to the aquifer. A list of the sites is presented below:

1. The Rapid Infiltration Basins (RIB)

   The RIB located southwest of the confluence of the Coldwater and Nicola Rivers processes sewage generated by the City. It is a potential point-source of bacteriological and nutrient contamination (i.e. Coliforms and nitrate).

   To our knowledge, there have been no reported incidents of production well contamination from the RIB. However, we are not aware of any monitoring wells currently used to detect off-site contaminant migration from the facility.

   Based upon our assumption of westerly groundwater flow and the ultimate downgradient reach of the capture zones, we feel the probability of contamination from the RIB is unlikely. However, there may be some potential for contamination during periods of low recharge to the aquifer (i.e. low river stage associated with low-flow conditions) when the capture zones may expand towards the west.

We strongly recommend installing monitoring wells between the RIB and the aquifer trough to confirm that discharge from the RIB is not migrating towards the production wells.

2. Lumber Mills

A memo prepared by BCMOE (1988a) suggests some mills in the Merritt area have historically used Chlorophenol to treat lumber. In particular, the Aspen, Ardew, NMV and Weyerhaeuser mills are believed to have used this potential contaminant. According to the document, Aspen and Ardew have installed monitoring wells to assess the presence of this contaminant in the groundwater and soil.

Sampling by the BCMOE in 1988 indicated that local soil contamination from chlorophenol was present at the Aspen and Ardew mills. Sampling of the mill and BCMOE monitoring wells yielded two samples (Aspen Mill and BCMOE Monitoring Well No. 296) with values exceeding aesthetic water quality guidelines. Chlorophenols were not detected in any production wells at that time.

The BCMOE (1988a) study concluded the following,

> *"... factors that would lessen the impact of chlorophenol contamination from the lumber mills are distance from the production wells, likely very high dilution from the aquifer and deep production well screen settings. Shallow depth of construction and proximity to the Ardew and NMV mills make the May Street well susceptible to contamination ..."*

EBA generally agrees with the conclusions and recommendations of the BCMOE (1988a) report that the degree and extent of chlorophenol contamination in the aquifer is unknown. Additional monitoring wells between the mills and the City wells are recommended.

3. Other sites

Other specific areas in Merritt that may pose long-term contamination risks to the aquifer include the landfill and abandoned coal mines. We recommend further investigation to quantify these risks.

Flood Risk

Risk is posed to the aquifer from flooding of the Coldwater and Nicola Rivers. Our analysis of flood mapping provided by the City of Merritt suggests the Colletteville and Voght Park wells may be subject to flooding during a 200 year event. We are unsure if the current well casings and pump houses have been elevated to protect against flooding.

We recommend assessing if the wells are flood protected, and if not, constructing flood protection for these wells. If the wells cannot be utilized during a 200-year flood, the total pumping capacity from the aquifer will be reduced by about 75%.

6.0 CONCLUSIONS

We conclude the following:

1. The productive portions of the Merritt aquifer are interpreted to extend over an area of about 7.5 km^2. The City of Merritt currently extracts 100 L/s from the aquifer via five production wells. The Voght Park wells provide about two-thirds (68%) of the City's total water requirements.

2. The hydrogeology of the Merritt Aquifer is complex and not well understood. The aquifer appears to be unconfined in the upper eastern portions of the valley, but leaky-confined in the area of a buried "trough", near the confluence of the Coldwater and Nicola Rivers.

3. The aquifer is composed mainly of sand and gravel, with coarser-grained sediments within the buried trough. The majority of the aquifer is interpreted to be less than 10m thick, except in the areas of the trough, which may be greater than 50m thick.

4. Static water levels within the aquifer are typically less than 5m below ground. The highest water levels are located within the center of the aquifer. This may result from mounding of the water table between the Coldwater and Nicola Rivers, suggesting precipitation is a source of recharge to the aquifer.

5. Trend data from BCMOE Observation Well No. 296 suggests river leakage plays an important role in recharging at least some portions of the aquifer. The trend data also suggest that average-annual groundwater extraction rates in excess of 100 L/s may be impacting the aquifer as a whole, potentially causing increased well interference.

6. Analytical capture zone analysis and simplified modelling suggests the current rate of pumping generates very large capture zones around the production wells. The capture zones currently overlap, which may result in simultaneous contamination of production wells if contamination of the aquifer occurs.

7. Total travel times within the aquifer are interpreted to range from five to greater than ten years, depending upon aquifer hydrogeology and recharge from the rivers. Groundwater Protection Areas were delineated using a conservative one-year capture zone.

8. The highest contamination risk posed to the aquifer is from industrial areas, commercial transportation along Voght Street, and the 300 mm sanitary sewer pipeline along Coldwater Avenue. The risk from these areas is significant because of their proximity to the high-capacity production wells and the aquifer trough.

9. Specific sites within Merritt which may pose a concern to long-term aquifer water quality are the Rapid Infiltration Basins and the lumber mills.

7.0 RECOMMENDATIONS

Throughout the report, we have presented recommendations to generally improve the understanding of the Merritt Aquifer hydrogeology, refine capture zone predictions and monitor groundwater quality (i.e. monitoring wells).

This section summarizes the recommendations, discusses the proposed monitoring well network, presents specific guidelines for further investigations, and presents general protection measures for the Groundwater Protection Areas.

7.1 Proposed Monitoring Wells

We recommend installing a monitoring well network throughout the aquifer. This network will provide early-detection of potential contamination, thereby reducing the probability of production well contamination (and temporary or permanent decommissioning). This would protect the potable water supply for the City. From a safety and economic perspective, monitoring wells would prove very beneficial to the City.

The monitoring well network would also provide locations where water levels and water quality may be measured on a long-term basis. This data would provide valuable information to the City regarding water quality and well interference trends. It would also provide information to build a better understanding of aquifer hydrogeology and quantify leakage from the rivers.

We propose the City install a total of ten monitoring wells throughout the aquifer within a short time frame. The cost of installing each monitoring well is estimated at $3000 to $7,500 (depending upon depth)[11]. This figure is quite reasonable when compared to the replacement cost of a production well, which would probably be in the order of $100,000 (including infrastructure costs)[12]. Figure 5 presents the locations of the proposed monitoring wells and the sequence in which we recommend they are drilled.

[11] Estimated cost includes drilling, casing, completion, and reporting.

[12] Estimated cost based on replacing Voght Park Well #2, includes drilling, casing, screen installation, well completion, development testing and reporting.

The monitoring program would involve measuring static water levels twice per month and sampling groundwater on a quarterly basis. Depending upon the monitoring results, the program could be adjusted accordingly in the second year, and beyond.

We feel the installation of monitoring wells and long-term monitoring is the single most important step the City can take to protect the groundwater supply of Merritt.

7.2 Future Investigations

We recommend the City undertake a comprehensive evaluation of the Merritt Aquifer. As with the monitoring wells, this program could be phased over several years. A summary of recommended investigations (in order of importance) are presented below:

1. Investigation of Decreasing Specific Capacity

   As discussed in Section 3.2, the Colletteville and Voght Park #2 wells have shown dramatic decreases in specific capacity with time. Because the cost of operating the wells increases in direct proportion to decreasing specific capacity, we strongly recommend the City investigate the reason for decreasing trends in specific capacity.

   Water wells are complex and dynamic structures. Over time, the aquifer near the well (within a radius of several meters) can become colinized by bacterial populations that effectively "clog" the well. Monitoring the variation of well capacity over time allows assessment of the growth of the bacterial population and schedule actions to mitigate and control this problem. If action is not taken in due time, the well can be permanently lost.

2. Groundwater Resource Evaluation

   The large overlapping production well capture zones suggest increasing groundwater extraction requirements may pose long-term aquifer sustainability concerns. Also, the potential addition of production wells within the Aquifer will likely expand the current capture zones and reduce travel times.

   We strongly suggest Merritt undertake a Groundwater Resource Evaluation study to quantify the dynamic response of the Merritt Aquifer to pumping and recharge, and to determine safe aquifer yields. This evaluation would include a hydrogeologic mapping program of the aquifer using all existing production, abandoned and monitoring wells (including the shallow wells installed several years ago to monitor leakage from the sanitary sewer network).

The evaluation should also focus upon diversifying the City's groundwater supply to include other aquifers[13]. Diversification will make the City potable water supply less dependant upon the quality of the Merritt Aquifer.

We recommend installing test wells and monitoring wells into potential aquifers, and performing pump tests to evaluate the potential safe yields of these alternate aquifers.

3. Annual Review

We recommend the City of Merritt undertake an annual review of groundwater extraction from the aquifer. The review would:

- evaluate water level trends at pumping and monitoring wells,
- summarize well utilization trends,
- update interpretations regarding aquifer hydrogeology and recharge patterns,
- update the position and size of the capture zones and Groundwater Protection Areas (using data from monitoring wells),
- provide an updated aquifer management plan (short- and long-term production rate forecasts, well rehabilitation schedules, etc…)

7.3 Protection of GPA

At this time, we feel the City of Merritt should focus upon protecting the GPA to ensure a safe potable water supply for the City residents. In addition to the installation of monitoring wells upgradient of the production wells (Figure 5), we recommend the following:

- install signs demarking the limits of the preliminary GPA,
- prohibit the transportation of hazardous or toxic liquids along Voght Street,
- educate local RCMP and City staff about the location of the GPA and setup a response plan to deal with emergencies within the GPA,
- regularly check and maintain sanitary sewer pipelines located nearest the production wells (especially the 300 mm diameter sanitary sewer along Coldwater Avenue),

[13] Other aquifers include the nearby Joeyaska Aquifer (Figure 2), and a potential high-yield confined aquifer located east of the Merritt Aquifer.

- regularly monitor production well water quality and water levels (whether pumping or not) and quality and interpret the data on a quarterly basis, and

- implement a public education program to involve the residents in protecting the drinking water resource.

8.0 CLOSURE

We trust this report provides a good reference for the City to begin the long-term process of aquifer protection. We wholeheartedly endorse the City's current plan to create a groundwater protection / development committee.
We would be pleased to form a part of the committee and have the opportunity to assist the City with additional investigations and monitoring in the future.

Respectfully submitted,
EBA ENGINEERING CONSULTANTS

PROFESSIONAL PROVINCE OF T.M. CARRIOU BRITISH COLUMBIA ENGINEER
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TABLE I
SUMMARY OF PRODUCTION WELL COMPLETION DATA AND HYDRAULIC PROPERTIES

WELL	YEAR OF COMPLETION	DIAMETER	COMPLETION DATA		STATIC WATER LEVEL		HYDRAULIC PROPERTIES				ESTIMATED SATURATED THICKNESS [m]	AQUIFER RESPONSE [2]	REFERENCES
			TOTAL DEPTH [m]	SCREEN INTERVAL [m]	DEPTH [m]	DATE MEASURED	SPECIFIC CAPACITY [L/s/m]	DATE MEASURED	TRANS-MISSIVITY [m^2/s]	HYDRAULIC CONDUCTIVITY [m/s]			
COLLETTEVILLE	Jul-78	10" (254mm)	49.1	37.6 - 45.1	4.10	Aug-78	43	unknown[3]	8E-02	2E-03	> 45.3	Single well pump test data suggests Leaky-Confined Aquifer (water level did not stabilize during test). Results similar to nearby Voght Park wells.	ELA (1978), MOE_{WMB} (1988), PHC(1990), AGRA(1996a,b)
					4.30	Sep-96	23	unknown[3]					
FAIRLEY PARK	Jan-66	12" (305mm)	29.9	19.2 - 25.3	1.86	Feb-71	17	1966	2E-02	1E-03	23.4	Pump test data not available. Assume aquifer is likely Leaky-Confined aquifer, similar to nearby Voght Park wells.	MOE_{WMB} (1988), PHC(1990)
							29	Jun-78					
MAY STREET	Oct-70	12" (305mm)	30.5	7.6 - 10.7	2.89	Oct-70	8.8	unknown[3]	1E-02	1E-03	7.8	Pump test data suggest Unconfined aquifer (water level stabilized early in test).	MOE_{WMB} (1988), AGRA(1992)
					2.90	1972	12	Dec-91					
VOGHT PARK #1	Jul-71	16" (406mm)	29.9	20.7 - 29.9	2.56	1971	8.7	Jul-71	5E-02	2E-03	26.2	Single well pump test data suggests Leaky-Confined aquifer (water level did not stabilize during test). Similar to adjacent Voght Park Well #2.	PHC (1990), ELA(1971)
					3.48	Sep-76							
VOGHT PARK #2	Sep-76	16" (406mm)	34.8	9.8 - 34.1	3.63	Sep-76	18	Sep-76	2E-02	6E-04	31.1	Observation well data suggests Leaky-Confined aquifer. Test suggests low storage and water level did not stabilize during test).	PHC (1990)
							8.0	Jan-90					

NOTES
1. All data summarized from historical reports prepared by engineering consultants and/or the Ministry of Environment.
2. Interpretation of aquifer type made by EBA.
3. Measurement date not provided in references.
4. Abbreviations are as follows:
   - AGRA HBT AGRA and AGRA Earth & Environmental
   - ELA E. Livingston Associates
   - MEP_{WMB} Ministry of Environment and Parks - Water Management Branch
   - PHC Pacific Hydrology Consultants

TABLE II
SUMMARY OF PRODUCTION WELL HISTORICAL PUMPING RATES

WELL		AVERAGE ANNUAL FLOW RATE									DESIGN VALUE [1]			% OF TOTAL	COMMENTS
		1993 [L/s]	1994 [L/s]	1995 [L/s]	1996 [L/s]	1997 [L/s]	1998 [L/s]	1999 [L/s]	2000 [L/s]	2001 [L/s]	[L/s]	[USgpm]	[Igpm]		
COLLETTEVILLE		0.0	0.0	0.0	0.0	13.4	14.9	4.6	15.4	9.6	10	156	130	10%	1997: Pump installed in spring and well used for remainder of year. 1998: Well used entire year. 1999: Well used during summer only. 2000-2001: Well used July 2000 through August 2001.
FAIRLEY PK.		17.4	14.2	13.2	5.2	25.7	19.7	23.9	16.4	22.8	21	333	277	21%	1993-1995: Pumping rate greatest from April to October of each year. 1996: Well used June to September. 1997-2001: Pumping rate greatest from April to December.
MAY ST.		5.2	4.4	4.2	1.2	0.9	0.0	1.6	1.2	0.9	1	19	16	1%	1993-1997: Pumping rate greatest from May to September. 1998-1999: Well used only July to September. 1999-2001: Well used intermittently.
V.P.G/E #1 OR 2?		43.4	6.2	5.2	15.6	4.2	7.5	22.8	20.9	23.5	22	355	296	22%	1993-1998: Well generally used April to September. 1999-2001: Well used throughout year.
V.P.VFD #1 OR 2		17.9	76.7	72.7	67.6	53.4	67.0	49.5	42.0	48.0	46	737	614	46%	1994-1997: Well used throughout year. 1997-2001: Well generally used from April to September.
TOTALS	[L/s]	83.9	101.5	95.2	89.6	97.6	109.0	102.3	95.8	104.7	101	1,600	1,333	100%	
	[USgpm]	1,329	1,608	1,509	1,420	1,547	1,727	1,622	1,518	1,660					
	[Igpm]	1,108	1,340	1,258	1,183	1,289	1,439	1,351	1,265	1,383					

5875017 Well Production Rate Summary.XLS

NOTES
1. Average pumping rate for 1999-2001.

FIGURES

TIME-SERIES PLOT OF GROUNDWATER LEVEL
MOE Observation Well No. 296 (Merritt, B.C.)