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Monthly Groundwater Budget for the Hopington Aquifer – Salmon River Area, BC

Golder Associates Ltd.

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Executive Summary

Preliminary monthly groundwater budgets were developed for seven aquifers in the Hopington – Salmon River Area of British Columbia in order to support groundwater allocation and licensing under the *Water Sustainability Act.* The study consisted of an evaluation of groundwater inflows and outflows in aquifers in proximity to the Salmon River, an environmentally sensitive watercourse currently subject to a Water Allocation Restriction. Provincial aquifer mapping in the study area was updated to reflect the improved understanding developed as part of extensive subsurface investigations conducted by Golder Associates Limited (2005; 2014). The groundwater budgets for the revised aquifers were prepared based on output from a previously developed surface water model and numerical groundwater flow model prepared for the Township of Langley. Groundwater budgets were developed in Microsoft Excel and included options to evaluate groundwater fluxes for average, wet and dry years, projected water demand scenarios, climate change effects, and implementation of stormwater best management practices. Qualitative assessments of groundwater availability were conducted and identified aquifers both with a greater capacity for available groundwater and those in which groundwater allocation should be approached with caution. Uncertainties and limitations of the high level groundwater budgeting methodology was assessed and recommendations to address data gaps and uncertainties proposed.

Contents

1. INTRODUCTION

The Salmon River watershed is located predominantly within the Township of Langley and partially in the City of Abbotsford. From its headwaters in the City of Abbotsford, north of Aldergrove, the Salmon River generally flows northwest across the Township of Langley (the Township), near Hopington, before turning north and flowing into the Fraser River at its confluence west of Fort Langley (see Figure 1 for location). Groundwater discharge, in particular from the shallow, unconfined Hopington Aquifer (Ministry of Environment Aquifer No. 35), helps sustain summer baseflow in the Salmon River which supports at least 15 species of fish, including the endangered Salish Sucker. A Water Allocation Restriction has been placed on the river, indicating that it is near or at full allocation. Declining groundwater levels in the Hopington Aquifer, as measured by the Provincial Groundwater Observation Well Network (PGOWN), have been observed at various locations. These declining groundwater levels correspond to increased groundwater use in the aquifer and increase the risk of lower summer baseflows and increased ecological stress to the Salmon River. As the Salmon River is the most important environmental receptor in the area of interest, the study area for the project is considered to be the Salmon River Watershed at surface (Figure 1) and the various aquifers that underlie it.

The British Columbia Ministry of the Environment (ENV) engaged qualified professionals to develop preliminary groundwater budgets for six mapped aquifers in the Hopington Aquifer - Salmon River Area. In addition to informing current water allocation, the groundwater budgets will be used to support licensing of new groundwater users under the authority of the new *Water Sustainability Act (WSA)*, which was brought into force on February 29, 2016. The groundwater budget study accomplishes these goals through achievement of the following objectives for the selected aquifers in the Salmon River watershed:

1. development of a conceptual groundwater model describing regional groundwater movement, groundwater recharge and interaction with surface water;
2. quantitative assessment of aquifer recharge and discharges, estimates of groundwater use, and estimates of water availability for groundwater licensing based on existing information for an average year, dry year and wet year; and
3. identification of data gaps and monitoring activities for improving estimates of groundwater fluxes and availability.

The original scope of work included developing water budgets for six aquifers in Salmon River watershed, mapped in accordance with the provincial Aquifer Classification System (Kreye and Wei, 1994; Ronneseth, 1994; Kreye et al., 1994). Subsequent to the provincial aquifer mapping in 1994, Golder Associates Ltd. (Golder), on behalf of the Township of Langley, completed a comprehensive aquifer mapping exercise in support of the development and update of a regional-scale numerical hydrogeological model for the Township that encompasses the Salmon River Watershed (Golder, 2005; 2014). As part of these studies, the regional aquifer delineations were significantly refined to reflect additional information and detailed interpretation. Consequently, the scope of work for the Hopington Aquifer – Salmon River Area groundwater budget was revised to account for the most recent aquifer delineation and the refined aquifers were carried forward for analysis.

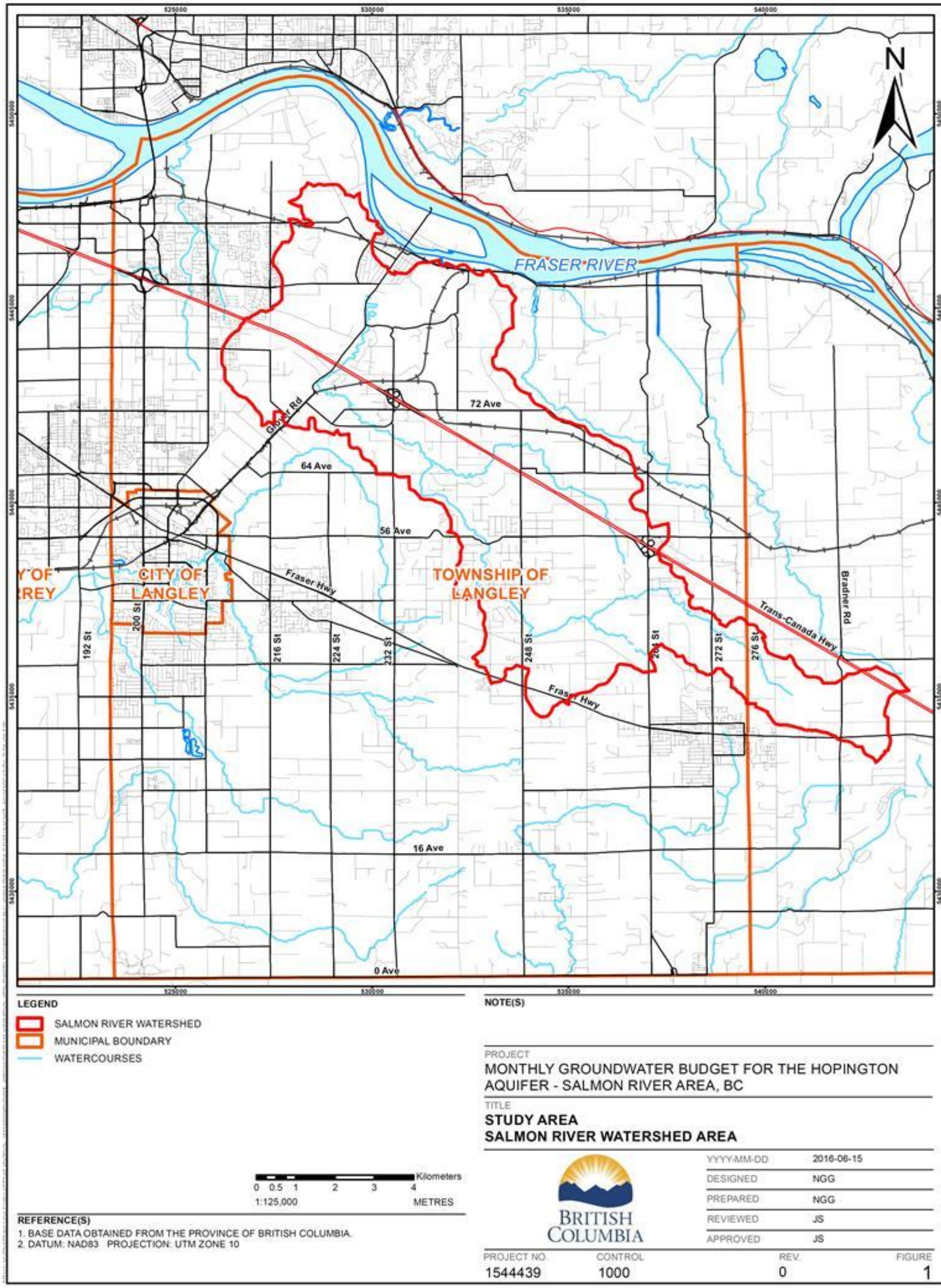

Figure 1 Study Area - Salmon River watershed area.

2. METHODOLOGY

Groundwater budgets were prepared in general accordance with the methodologies described in ENV's guidance document "Preliminary Conceptual Models and Water Budget Methodologies for Aquifers in British Columbia" (Hy-Geo Consulting, 2014) and previous groundwater budgets developed in other areas of the province (Bennett 2014; Hy-Geo Consulting, 2015). The budgets were developed in Microsoft Excel and were designed to be user-friendly and easily extendable both for additional aquifers and as new information becomes available for the aquifers described herein.

The development and update of the comprehensive, three-dimensional numerical groundwater model for the Township of Langley (Golder 2005, 2014) consisted of detailed aquifer mapping, compilation of hydrogeological information and meteorological data, estimates of current and future water demand, and the development of regional surface water and groundwater models. Once developed, the numerical groundwater model was used to evaluate hydrogeological implications of implementation of stormwater management best management practices (BMPs) and climate change impacts. For the water balance study provided in this report, the numerical groundwater model was used as a basis for the delineation of hydraulic connections between aquifers and surface features, and between aquifers, and for input parameters used in the water budgeting. The methodology by which this information was used for the development of the regional conceptual model are described below.

2.1 Update to Aquifer Mapping

A comprehensive review and analysis of subsurface conditions in the Township of Langley was undertaken by Golder (2005) to support the development of the numerical groundwater flow model. The investigation included an extensive data compilation exercise whereby hydrogeological information was obtained from public and private databases (i.e., water well records), visits to public and private agencies, and telephone inquiries. The data was assembled, reviewed and interpreted with the assistance of a local quaternary geology expert formerly from the British Columbia Geological Survey (Mr. Patrick Monahan). The interpretation was conducted on 14 North-South cross-sections and 15 East-West cross-sections spanning the entire Township of Langley and was further reinforced with spot checks in the field. The geologic interpretation identified a total of 45 permeable units which were subsequently grouped hydrostratigraphically by combining units that were hydrogeologically similar, in close proximity to each other and likely hydraulically connected. The result of the exercise was identification and delineation of 18 "major" aquifers and 8 "minor" aquifers that are roughly correlated to the previously mapped ENV aquifers with refined delineations and some reassignment of permeable units to other aquifers based on the more recent and extensive interpretation (hereafter referred to as the Golder aquifers). Minor aquifers were defined as aquifers of limited extent within the Township of Langley boundaries, distant from production wells and other major users, not hydraulically connected to other major aquifers, and assumed to have little effect on the water balance, groundwater flow regime and stream flow. The major aquifers were sub-classified as "unconfined", "shallow confined", and "deep confined" based on their character and relative elevation, with "deep" confined aquifers defined as confined aquifers located below approximately 0 m elevation. Figures 2 through 4 present the unconfined, shallow confined and deep confined Golder aquifers with respect to the Salmon River Watershed. Table 1 presents the correlation between the ENV and Golder aquifer interpretations, where defined in the Township of Langley. Detailed information on the Golder aquifer mapping and interpretation can be found in Golder's report (2005) prepared for the Township of Langley.

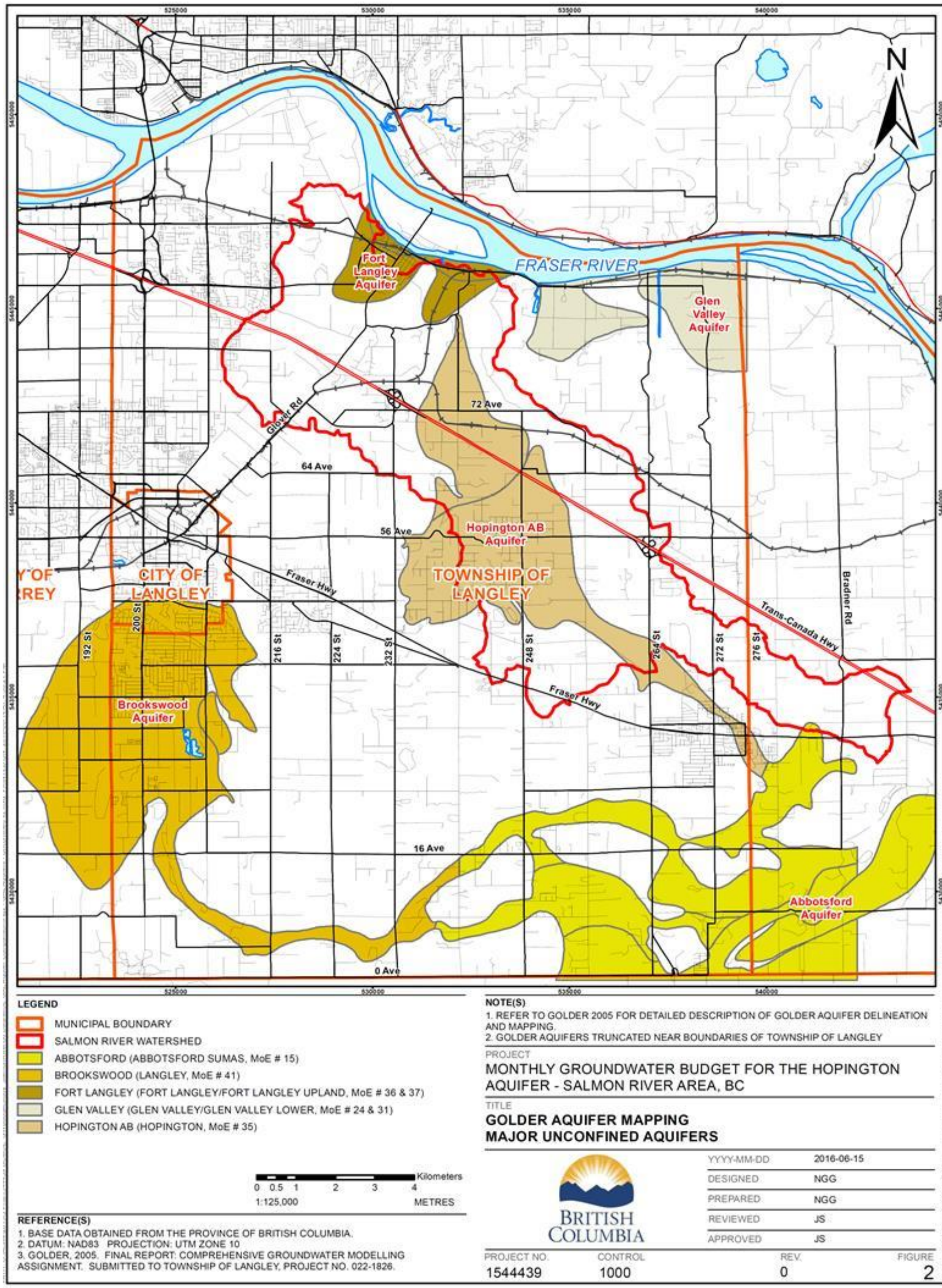

Figure 2 Golder aquifer mapping – Major unconfined aquifers.

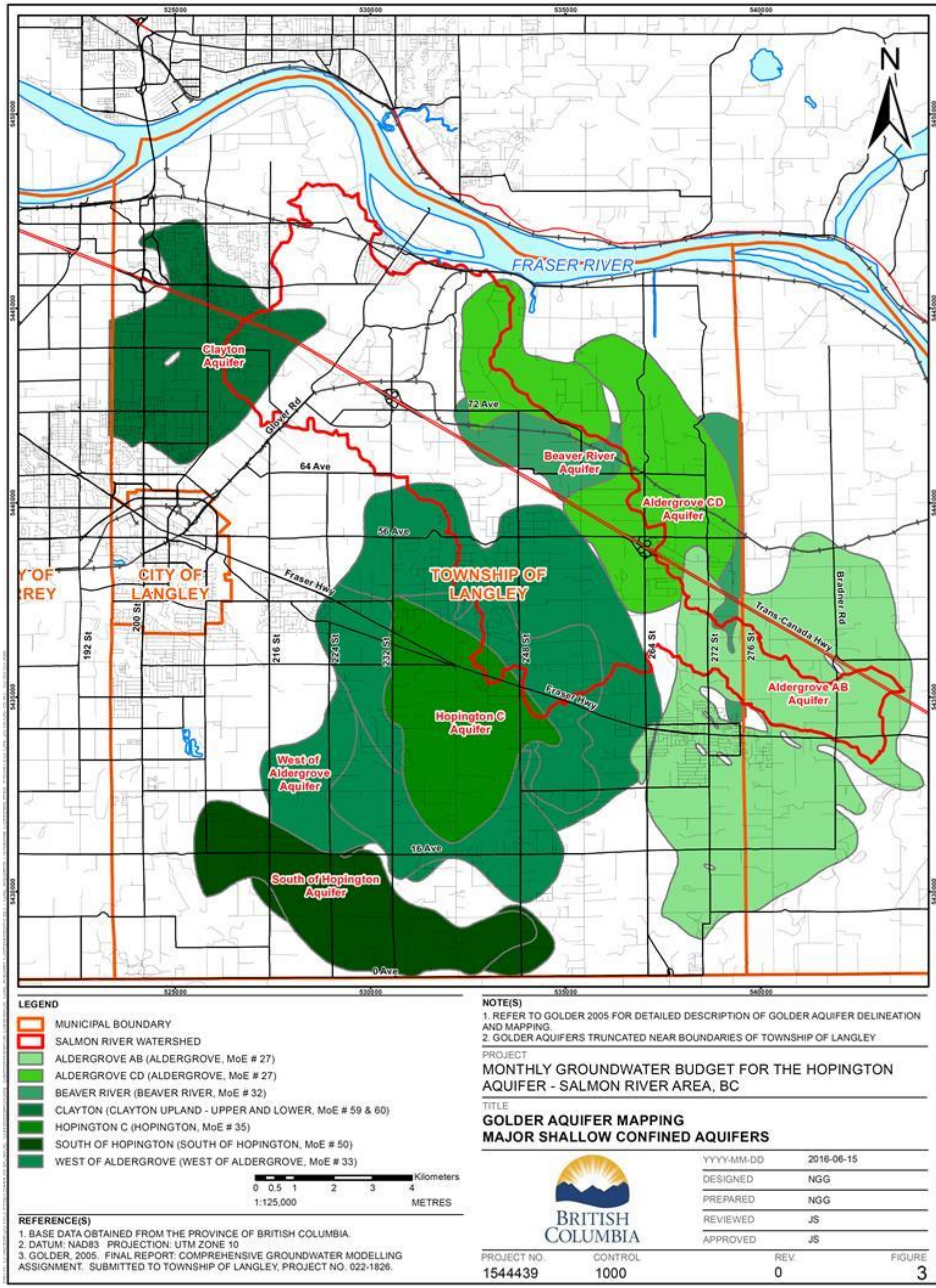

Figure 3 Golder aquifer mapping – Major shallow confined aquifers.

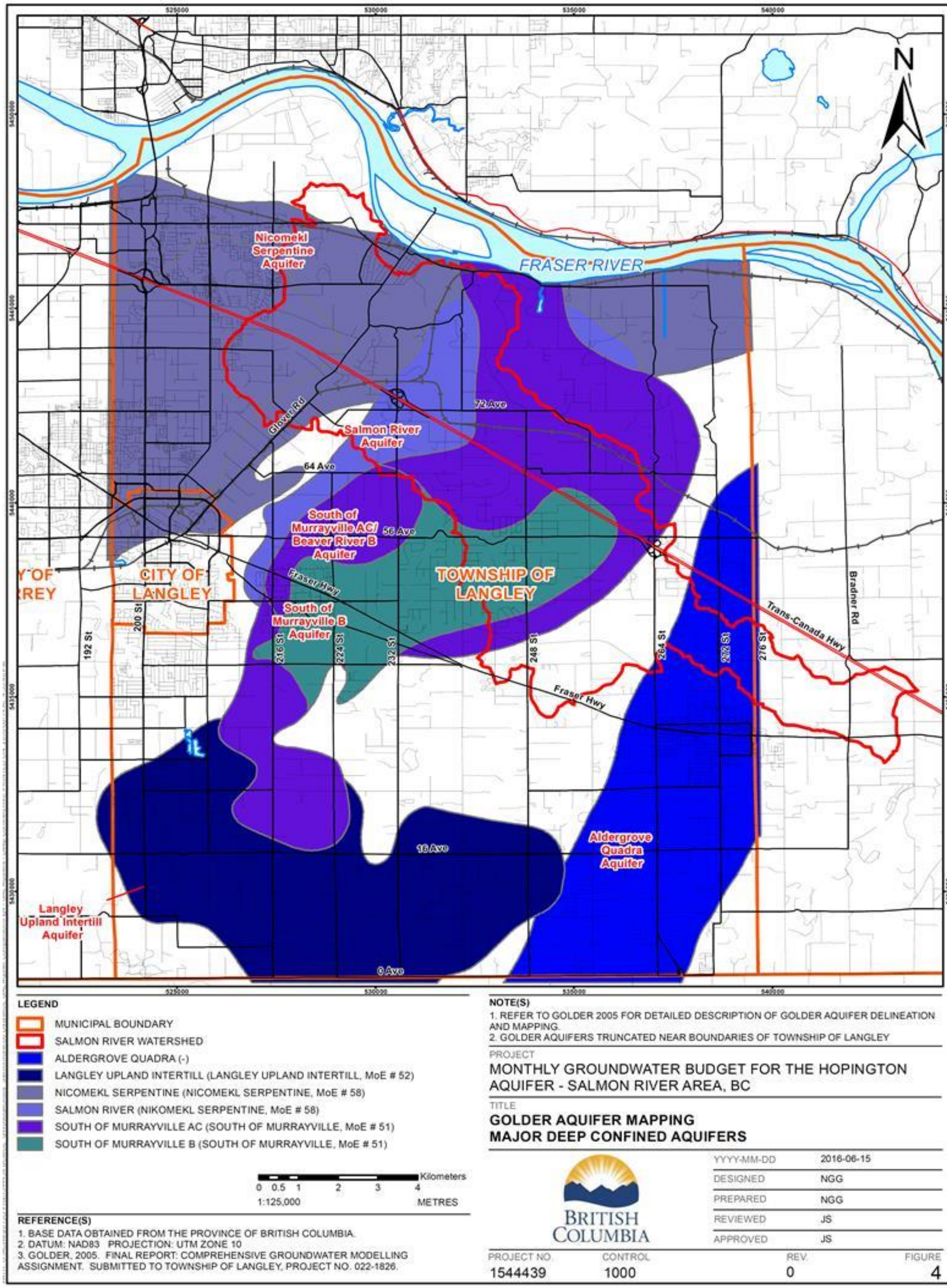

Figure 4 Golder aquifer mapping – Major deep confined aquifers.

TABLE 1 Correlation between Golder Aquifers and ENV Aquifers

ENV Interpretation		**Revised Interpretation (Golder, 2005)**			
Corresponding Aquifer	**Aquifer Number**	**Major Aquifer**	**Minor Aquifer**	**Aquifer Type**	**Area (km^2)[1]**
-	-	-	0 Ave	shallow confined	Unknown
Abbotsford-Sumas	15	Abbotsford	-	unconfined	33.4
Aldergrove	27	Aldergrove AB	-	shallow confined	47.2
		Aldergrove CD	-	shallow confined	27.9
-	-	Aldergrove Quadra	-	deep confined	41.3
Beaver River	32	Beaver River	-	shallow confined	23.8
Boundary Ave near Border	47	-	Border A	unconfined	Unknown
		-	Border B	shallow confined	Unknown
Langley/Brookswood	41	Brookswood	-	unconfined	33.2
-	-	-	Campbell River [2]	shallow confined	Unknown
Clayton Upland (Upper and Lower)	59 and 60	Clayton	-	shallow confined	18.8
Fort Langley / Fort Langley Upland	36 and 37	Fort Langley	-	mostly unconfined / confined	5.2
Glen Valley / Glen Valley (Lower)	24 & 31	Glen Valley	-	unconfined	9.3
Hopington	35	Hopington AB	-	mostly unconfined / confined	23.9
		Hopington C	-	shallow confined	16.5
Langley Upland Intertill	52	Langley Upland Intertill	-	deep confined	49.7
McMillan Island	72	-	McMillan Island	shallow confined	Unknown
Nicomekl Serpentine	58	Nicomekl Serpentine	-	deep confined	79.4
		Salmon River	-	deep confined	43.9
South of Aldergrove	34	-	South of Aldergrove	shallow confined	Unknown
South of Hopington	50	South of Hopington	-	shallow confined	34.7
South of Murrayville	51	South of Murrayville AC	-	deep confined	73.5
		South of Murrayville B	-	deep confined	22.9
-	-	-	Sperling	confined (locally exposed)	Unknown
-	-	-	West Langley [3]	shallow confined	Unknown
West of Aldergrove	33	West of Aldergrove	-	shallow confined	73.0

Note – Not all of the Golder aquifers are included in the current study.

[1] – Golder's revised aquifer areas are based on Golder (2005) and only include the areas of the aquifer that are contained approximately within the boundaries of the Township of Langley. Areas of minor aquifers are considered unknown as their boundaries are subject to uncertainty.

[2] – Two permeable units were tentatively grouped together for the Campbell River Minor Aquifer though the connectivity is poorly understood.

[3] – Four permeable units were tentatively grouped together for the West Langley Minor Aquifer though the connectivity is poorly understood.

Following consultation with regional Ministry of Forests, Lands and Natural Resources hydrogeologists the ENV has decided to adopt the more detailed Golder aquifer interpretation for the Hopington Aquifer – Salmon River Area groundwater budgets in recognition of the refined hydrogeological understanding achieved as a result of the detailed studies carried out by Golder on behalf of the Township of Langley. As a result, a spatial analysis of the ENV and Golder aquifers in relation to the Salmon River Watershed was undertaken to confirm and / or identify the aquifers that should be included in the groundwater budget analysis. Comparisons of the ENV and Golder aquifer interpretations for the six original ENV aquifers that were to be included in the groundwater budget (Hopington, Fort Langley, Fort Langley Upland, Beaver River, West of Aldergrove and Nicomekl Serpentine) are shown in Figures 5 through 9. Based on the spatial analysis and aquifer comparisons, seven aquifers were carried forward for the groundwater budget study. For comparison, the six original ENV aquifers and seven Golder aquifers selected for the groundwater budget analysis are presented in Table 2.

TABLE 2 Original ENV Aquifers and Selected Golder Aquifers for Groundwater Budget Analyses

Original Aquifers (ENV) for Groundwater Budgeting	Revised Aquifers (Golder) for Groundwater Budgeting	Comments
Hopington (No. 35)	Hopington AB	See Figure 5 for aquifer comparison. Hopington C Aquifer falls outside the Salmon River Watershed and was not included
Fort Langley (No. 36) Fort Langley Upland (No. 37)	Fort Langley	See Figure 6 for aquifer comparison. Fort Langley and Fort Langley Upland Aquifers are combined in the Golder interpretation
Beaver River (No. 32)	Beaver River	Golder Beaver River Aquifer differs significantly in extents due to re-interpretation of deeper permeable units
West of Aldergrove (No. 33)	West of Aldergrove	Golder West of Aldergrove Aquifer differs significantly in extents due to re-interpretation of permeable units along the western boundary
Nicomekl Serpentine (No. 58)	Nicomekl Serpentine	Golder Nicomekl Serpentine Aquifer differs in extent on the northern boundary
	Salmon River	Golder Salmon River Aquifer was previously integrated into ENV's Nicomekl Serpentine Aquifer however recent interpretation shows it is likely a separate hydrostratigraphic unit
Not Included	South of Murrayville AC	Golder South of Murrayville AC Aquifer includes a deeper permeable unit previously associated with the ENV Beaver River Aquifer; as a result significant portion of this aquifer falls within the Salmon River Watershed

2.2 Surface and Groundwater Modelling

A regional surface water model and an associated numerical groundwater flow model for the Township of Langley were previously constructed, calibrated and peer reviewed. The original models were developed in support of the Township's Water Resource Management Strategy (WRMS), with work initiated in 2002 and completed in 2005 (Golder, 2005). Subsequently, the surface water and groundwater models were updated as part of the Township's 2014 Assessment of Long-Term Groundwater Availability for Domestic and Public Use and for Aquatic Habitats (Golder, 2014).

The availability of the surface water and groundwater models allowed for extraction of data useful for the groundwater budget analysis (i.e. spatial representation and connectivity of aquifers, surface water – groundwater interactions and water demand estimates). The surface water and groundwater models are described in further detail in the sections below.

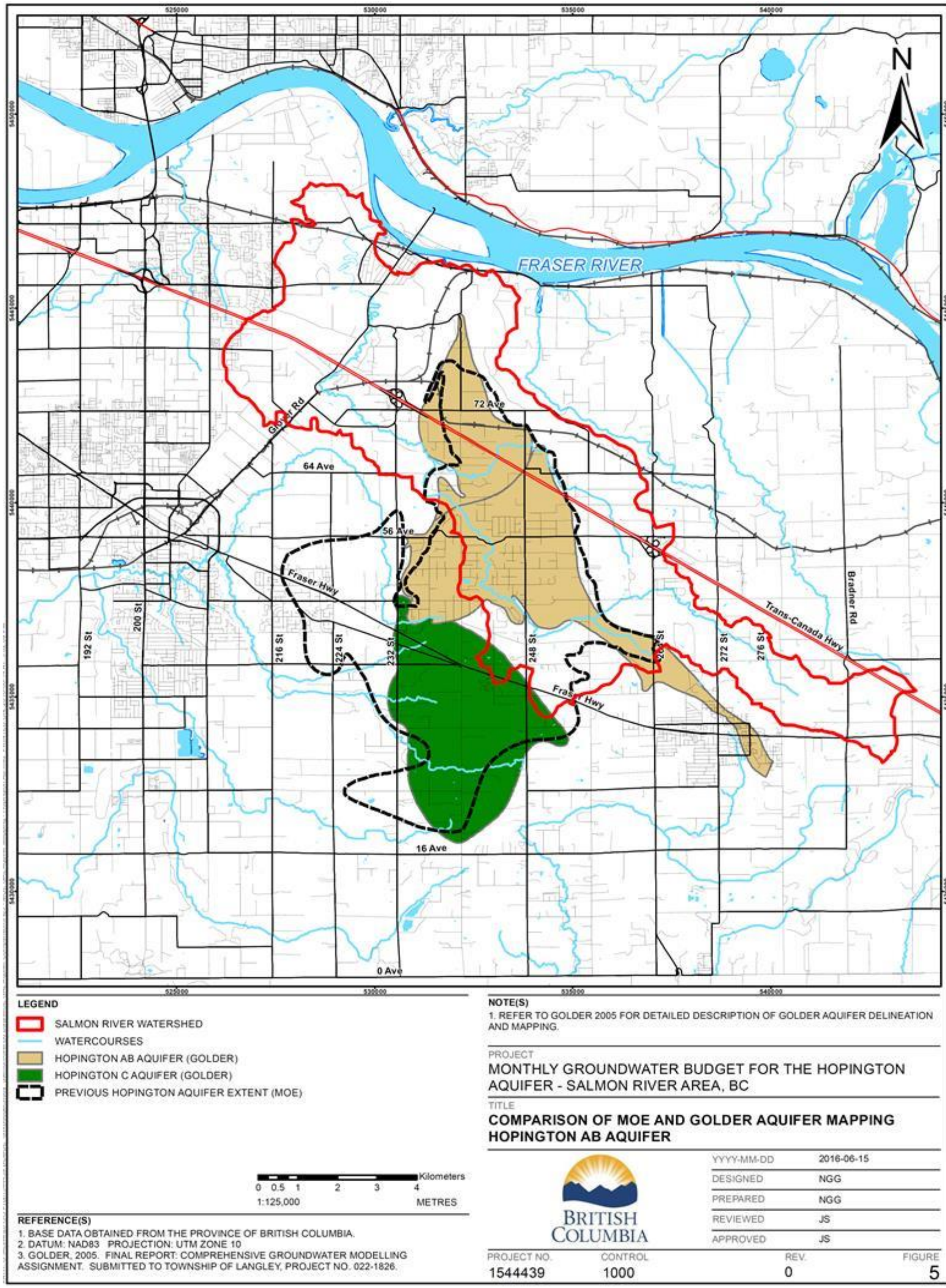

Figure 5 Comparison of ENV and Golder aquifer mapping – Hopington AB aquifer.

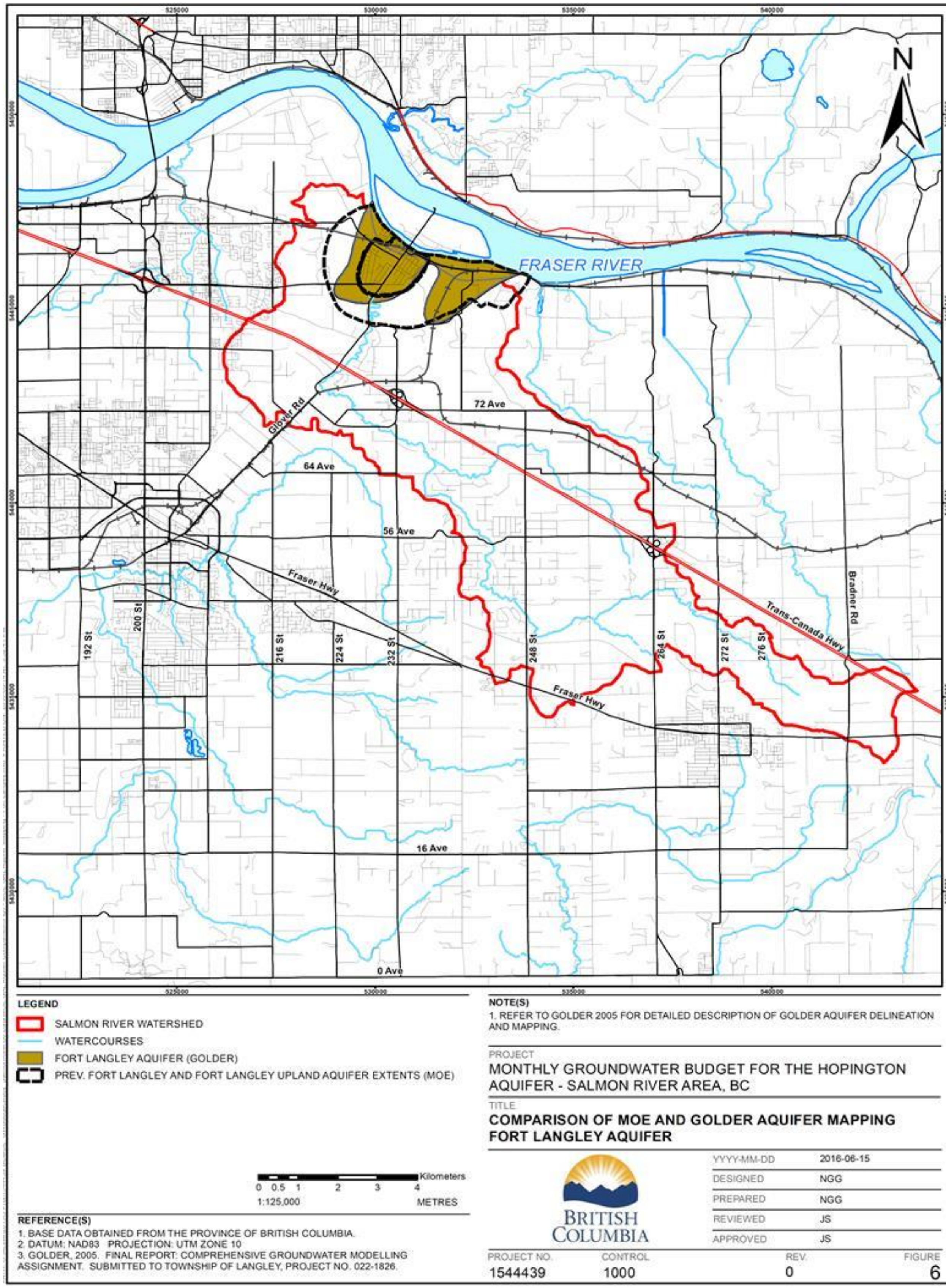

Figure 6 Comparison of ENV and Golder aquifer mapping – Fort Langley aquifer.

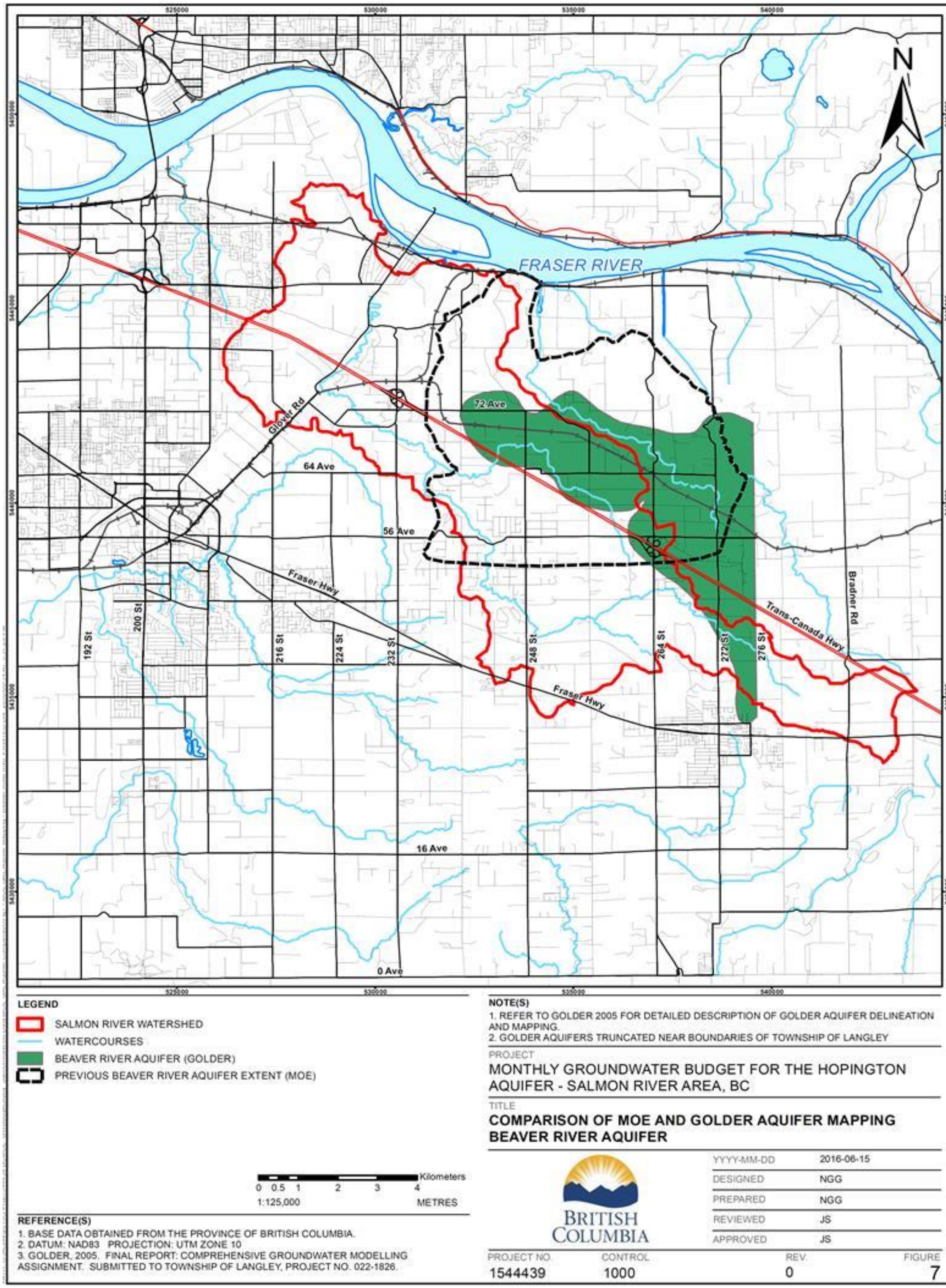

Figure 7 Comparison of ENV and Golder aquifer mapping – Beaver River aquifer.

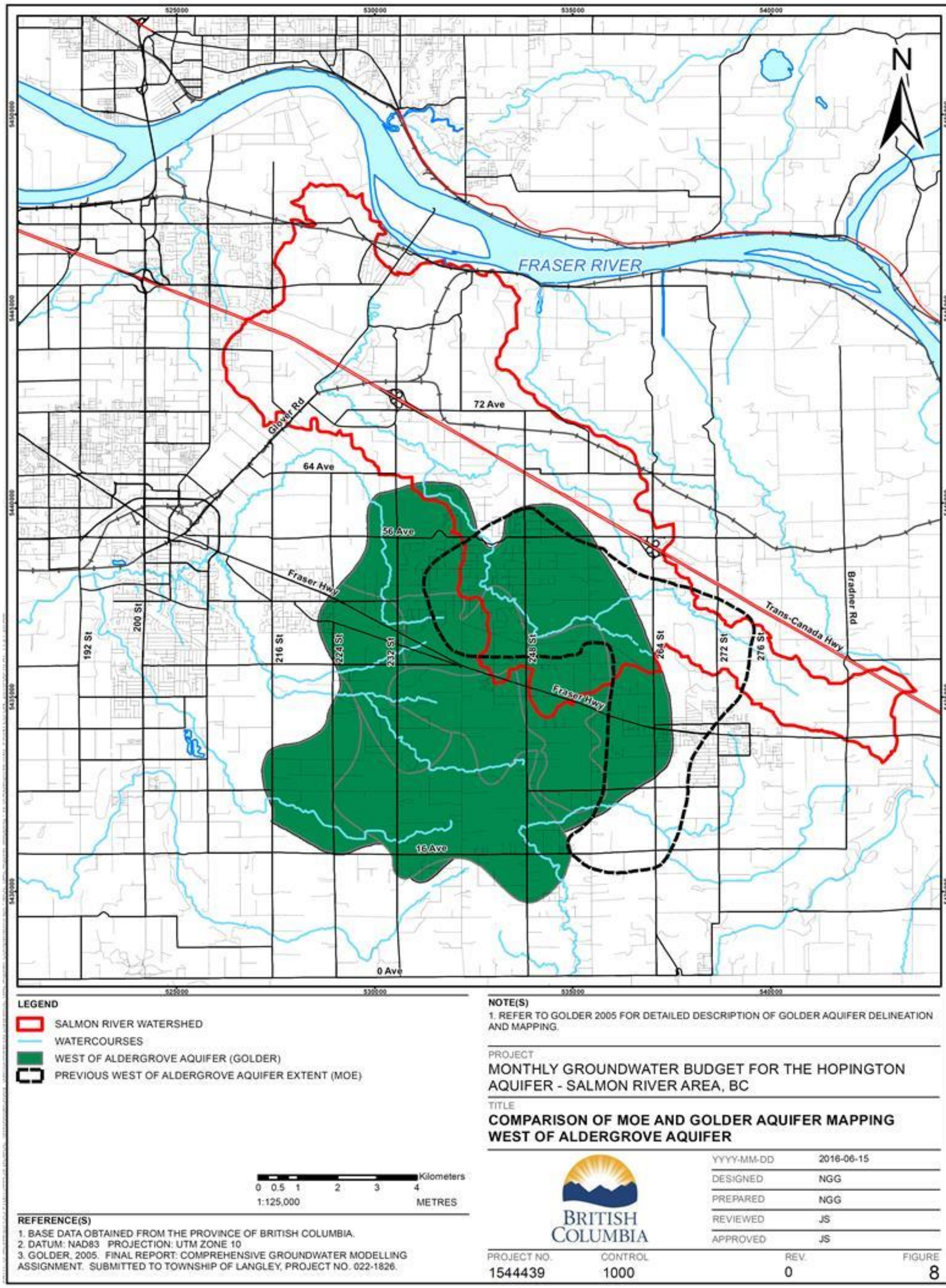

Figure 8 Comparison of ENV and Golder aquifer mapping – West of Aldergrove aquifer.

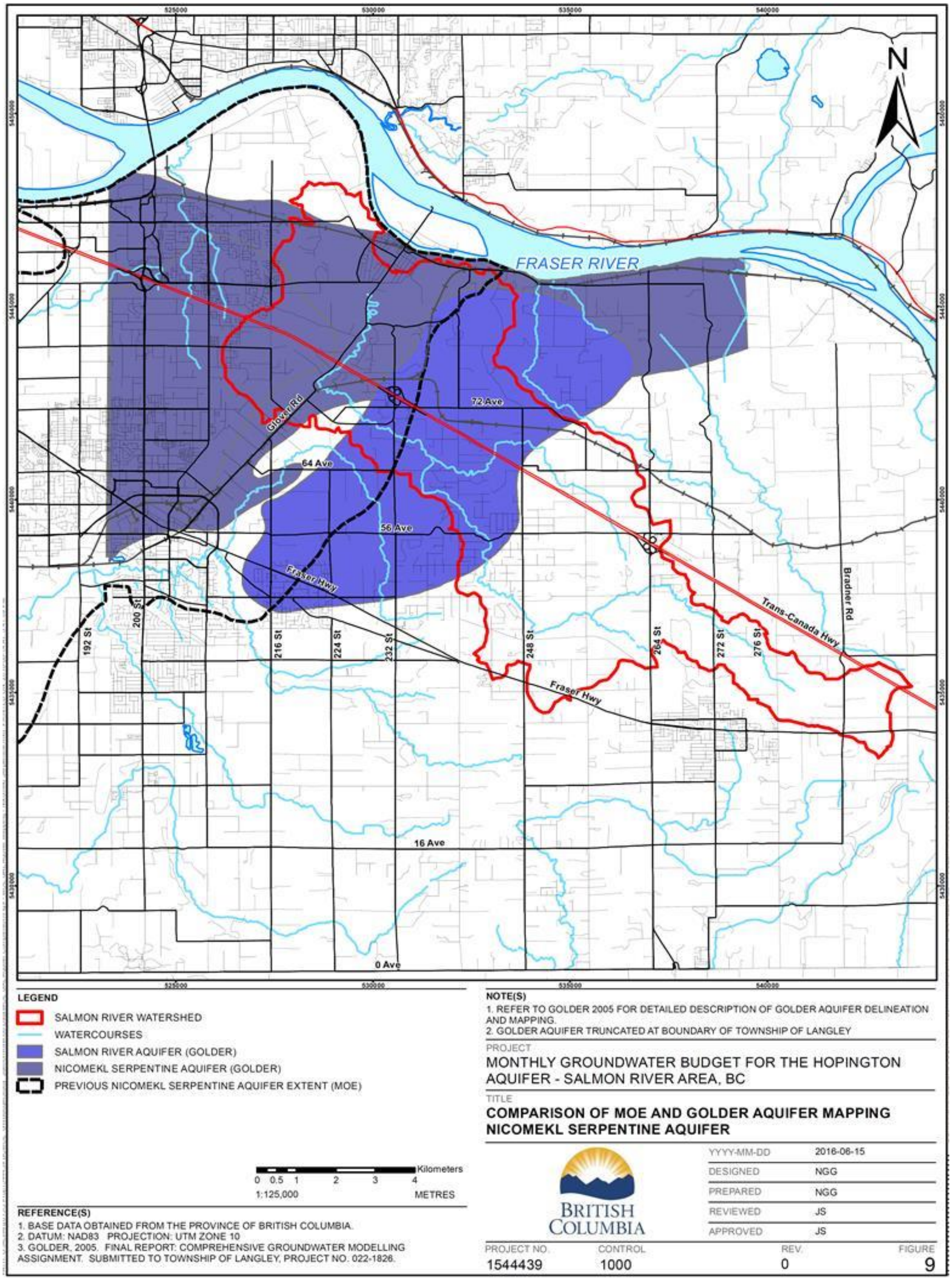

Figure 9 Comparison of ENV and Golder aquifer mapping – Nicomekl Serpentine aquifer.

2.2.1 Surface Water Model

A surface water model for the Township of Langley was developed in order to spatially estimate precipitation and surface and apportion the resultant water into watershed runoff, stormwater runoff, evapotranspiration, and recharge (natural and anthropogenic) based on various watershed characteristics. Estimates of watershed runoff and stormwater runoff on a watershed basis provide the means of estimating baseflow (BF) and recharge (RE). Baseflow is assumed to be the difference between watershed runoff, defined as all water which reports to surface water within the watershed, and stormwater runoff. After a review of methods for estimating watershed runoff and storm runoff, the U.S. EPA method (see Pandit and Gopalakrishan 1997) was selected for the study area by Golder (2005) as the most appropriate method for this study due to the ease of use, availability of impervious area data within the study watersheds, and the ability to assess the impact of urbanization on groundwater recharge and baseflow. Amongst other data sources, the modelling effort involved extensive analysis of surface water discharge data from Water Survey of Canada (WSC) hydrometric stations and meteorological and climatological data from Atmospheric Environmental Services (AES) climate stations within and in close proximity to the Township. A detailed description of the model construction and modelling methodologies used is found in Golder (2005). The 2005 surface water model was subsequently updated during the Township's 2014 Assessment of Long-Term Groundwater Availability (Golder, 2014). Updates to the surface water model included updates to meteorological, hydrometric, and evapotranspiration data. In the original surface water model presented in Golder (2005), total impervious area (% TIA) was the key parameter that determined allocation of precipitation to stormwater and watershed runoff, and the fraction of precipitation available for groundwater recharge. Total impervious area is a parameter that corresponds to the sum of all surface areas that typically shed rainfall as runoff, such as roof, street and parking area pavement, and other 'hard surfaced' areas that are drained rapidly to storm sewers or free flowing ditches. However, in the past ten years, the Township has implemented stormwater infiltration policies that promote infiltration of precipitation and decrease runoff. To account for the improvements these practices have made in enhancing groundwater recharge, Golder introduced effective impervious area (% EIA) into the surface water model for the 2014 study in place of the total impervious area used previously. Watershed characteristics, percent imperviousness and runoff apportioning were revised based on the most recent data. The surface water model was used to estimate recharge under current conditions, and under other scenarios related to the implementation of stormwater BMPs and climate change, and incorporated both current and future land use to account for the impact of impervious areas associated with urbanization. A detailed description of the surface water model updates is found in Golder (2014).

For the purpose of the Hopington Aquifer – Salmon River Area groundwater budget study, the previously-constructed Township of Langley surface water model was used to estimate precipitation, watershed runoff, stormwater runoff, evapotranspiration and recharge on a monthly basis for the Salmon River Watershed for input into the groundwater budgets. The model is based on precipitation data from three Environment Canada climate stations (1100240, 1104555 and 1104560) which were extended to 69 year records using data from the Abbotsford Airport station (1100030/1100031) and established relationships. The established methodology and relationships from the surface water model were utilized to estimate the water budget terms over the duration of 1945 through 2015 and subsequently used to identify the average, dry and wet years for the groundwater budgets. Dry and wet years were established by identifying the calendar year with the least and most amount of total estimated annual recharge, respectively, and by excluding years with large monthly outliers and that did not follow a typical recharge distribution (i.e. – dry period in summer, wet period in winter). The average year was established by utilizing average monthly values for the entire modelled period (1945-2015).

2.2.2 Groundwater Model

The development of the Township of Langley regional groundwater model involved a rigorous review and interpretation of subsurface conditions to inform the model construction and parameterization (see Section 2.1). Development of the model also included estimates of groundwater use / pumping from various sources (domestic, agricultural, industrial/commercial/institutional or ICI, and municipal), well capture zone analyses, simple water balances, and assessment of impacts of development on baseflow. The numerical model was originally constructed using MODFLOW 2000 (Harbaugh et al. 2000). The model code was updated to MODFLOW-NWT (Niswonger et al. 2011) in the 2014 update. MODFLOW is a numerical code developed by the United States Geological Survey to simulate three-dimensional, steady state or transient flow in heterogeneous porous media under a variety of boundary conditions and stresses. A detailed descriptions of the model construction, methodology, and calibration is found in Golder, (2005).

The 2005 groundwater model was subsequently updated during the Township's 2014 Assessment of Long-Term Groundwater Availability (Golder, 2014). Updates to the groundwater model included inclusion of additional borehole logs and well records, newly available hydrogeological reports,agricultural / anthropogenic return flows, hydraulic head data from municipal wells and the Provincial Groundwater Observation Well Network, and improved estimates of groundwater demand and use. Updates to well capture zones, assessment of land use changes, various groundwater demand and extraction scenarios, impacts to environmental baseflows and assessment of climate change impacts were also undertaken. The model was run as a steady state model with inputs and outputs represented as annual averages.

For the purpose of the Hopington Aquifer – Salmon River Area groundwater budget study, the previously-constructed Township of Langley groundwater model was used to directly inform the aquifer groundwater budgets. While no additional numerical modelling was undertaken, relevant data on aquifer delineation and connectivity, groundwater-surface water interactions, and estimates of groundwater use were extracted directly from the model runs and used within the individual groundwater budgets. The groundwater budget study utilized inputs and outputs from the Township of Langley groundwater model that represent average annual meteorological conditions and 2011/2012 conditions in the Township of Langley (pumping rates, water demand, etc.). For the purposes of the groundwater budgets, these inputs and outputs were disaggregated to a monthly basis using assumptions presented in Section 2.3.

2.2.3 Scenario Analyses

In addition to the water budget analysis for current conditions (representing dry, wet and average precipitation), additional water budget analyses were carried out to assess the effects related to future water demand, climate change and best management practices for stormwater management. The three additional water budget scenarios that were included in the analysis are outlined below, based on the availability of relevant data from the previously-constructed models:

- future groundwater demand – effect of increased groundwater demand (assuming moderate municipal withdrawals) at full build out in 2041;
- climate change effects – effect of variation in recharge due to climate change; and
- implementation of stormwater Best Management Practices (BMPs) – effect of increased recharge at full build out in 2041 as a result of improved stormwater BMP's.

2.3 Monthly Groundwater Budget Analyses

Groundwater budget analyses were prepared for each of the seven selected aquifers in the Hopington - Salmon River Area on a monthly basis for an average year, a dry year and a wet year. Integral to the development of the monthly groundwater budget analyses was utilizing the detailed subsurface characterization from the groundwater model. The methodology detailed in this section includes development of the aquifer conceptual models and parameterization of associated groundwater budget terms.

2.3.1 Aquifer Conceptual Models

In order to develop conceptual models for the aquifers, the ENV guidance document (Hy-Geo Consulting, 2014) was utilized to identify potential groundwater budget terms for each aquifer based on its aquifer type. Table 3, below, presents the aquifer type for each of the seven aquifers in the groundwater budget study.

TABLE 3 Aquifer and Associated Aquifer Type

Aquifer Name	Aquifer Type	Description	Relevant Groundwater Budget Terms (Hy-Geo Consulting, 2014)[1]
Hopington AB	Type 4a – Predominantly unconfined sand and gravel aquifer of glaciofluvial origin	Unconfined	P, Q^{SW}_{in}, Q^{GW}_{in}, $Q^{IRReturn}$, R, ET, ΔS^{GW}, Q^{SW}_{out}, Q^{GWpump}_{out}, Q^{GW}_{out}
Fort Langley	Type 1a – Predominantly unconfined aquifer along major rivers of higher stream order and Type 4a - Predominantly unconfined sand and gravel aquifer of glaciofluvial origin	Predominantly unconfined	P, Q^{SW}_{in}, Q^{GW}_{in}, $Q^{IRReturn}$, R, ET, ΔS^{GW}, Q^{SW}_{out}, Q^{GWpump}_{out}, Q^{GW}_{out}
Beaver River	Type 4c – Predominantly confined sand and gravel aquifer associated with glaciomarine environments	Shallow confined	Q^{SW}_{in}, Q^{GW}_{in}, ΔS^{GW}, Q^{SW}_{out}, Q^{GWpump}_{out}, Q^{GW}_{out}
West of Aldergrove	Type 4b – Predominantly confined sand and gravel aquifer of glacial or pre-glacial origin	Shallow confined	Q^{GW}_{in}, ΔS^{GW}, Q^{GWpump}_{out}, Q^{GW}_{out}
South of Murrayville AC	Type 4b – Predominantly confined sand and gravel aquifer of glacial or pre-glacial origin	Deep confined	Q^{GW}_{in}, ΔS^{GW}, Q^{GWpump}_{out}, Q^{GW}_{out}
Salmon River	Type 4c – Predominantly confined sand and gravel aquifer associated with glaciomarine environments	Deep confined	Q^{GW}_{in}, ΔS^{GW}, Q^{GW}_{out}
Nicomekl Serpentine	Type 4c – Predominantly confined sand and gravel aquifer associated with glaciomarine environments	Deep confined	Q^{GW}_{in}, ΔS^{GW}, Q^{GWpump}_{out}, Q^{GW}_{out}

[1] – Definitions for groundwater budget terms are found in Hy-Geo Consulting (2014).

Once the potential groundwater budget terms were identified, each aquifer was plotted in relation to the local area, other aquifers and surface water features in close proximity, municipal wells, and wells of large scale water users to assess and verify relevant process that needed to be included in the conceptual models. Subsequently, the Township of Langley surface water and groundwater models (Golder 2005, 2014) were reviewed in order to verify that there was available data for the groundwater budget terms and to identify other hydrological and hydrogeological processes that may not have been captured. As a result, all major inflows and outflows to each aquifer were characterized based on available knowledge in a representative groundwater budget equation and presented graphically on plots.

2.3.2 Parameterization of Groundwater Budget Terms

Parameterization of groundwater budget terms was accomplished by directly sourcing relevant information from the Township of Langley surface water and groundwater models. Table 4, below, presents the major groundwater budget terms and where the data was sourced from. The methodology for disaggregation of data into monthly estimates are also provided and a detailed description of the estimation of various flows using the aquifer connectivity derived from the model is presented in Section 2.3.3.

TABLE 4 Sources of Data for Groundwater Budget Terms and Disaggregation Method

Groundwater Budget Term	**Data Source and Disaggregation Method (if used)**
Groundwater Recharge	Derived from surface water model and groundwater model (Golder 2005; 2014). Monthly groundwater recharge estimates were calculated by the surface water model by translating monthly precipitation to evapotranspiration, runoff and groundwater recharge using the method described in Section 2.2.1. Methodology for estimates of evapotranspiration and anthropogenic recharge, used to inform the total groundwater recharge, are described below.
Inflow / Outflow to and From Surface Water Features	Derived from groundwater model (Golder 2005; 2014). Boundary conditions in the groundwater model were established by examining aquifer outcrops, seepage faces, surface water divides, surface water features and groundwater flow directions. Where the aquifer is directly connected to surface water, a specific percentage of the monthly surplus or deficits was added or removed from the next month's groundwater outflow to surface water. This percentage was derived via calibration to the observed hydraulic head fluctuation from PGOWN wells in the aquifer (where available).
Evapotranspiration	Derived from surface water model on a monthly basis and used by the surface water model to estimate groundwater recharge (Golder 2005; 2014).
Groundwater Inflows and Outflows to/from Aquifers	Derived from groundwater model (Golder 2005; 2014) and apportioned monthly using a constant linear distribution. Seasonal and monthly variations in inter-aquifer fluxes were assumed to be minor as a result of relatively small changes in observed hydraulic head gradients and varying degrees of hydraulic isolation from seasonal forcings. Groundwater average annual fluxes to/from aquifers were used to identify the presence and magnitude of hydraulic connections and hydraulic head fluctuations were used for calibration (see "Storage Change" section below).
Groundwater Inflow and Outflows to/from Aquitards	Derived from groundwater model (Golder 2005; 2014) and apportioned monthly using a constant linear distribution. Seasonal and monthly variations in fluxes to or from aquitards were assumed to be minor as a result of relatively small changes in observed hydraulic head gradients and varying degrees of hydraulic isolation from seasonal forcings. Groundwater average annual fluxes to/from aquitards were used to identify the presence and magnitude of hydraulic connections and hydraulic head fluctuations were used for calibration (see "Storage Change" section below).
Groundwater Outflow – Municipal	Derived directly from monthly municipal pumping records from the Township of Langley.
Groundwater Outflow – Private Industrial, Commercial and Institutional (Major / Minor)	Originally derived from metered water records from the Township of Langley and extracted from groundwater model (see Golder 2005; 2014 for methodology. Large volume industrial, commercial and institutional (ICI) water users or "major users" as determined by Golder (2005; 2014), were extracted from the model as extraction wells and have their own groundwater budget term. Low volume water users or "minor users" were lumped together and extracted from the model areally as a distributed boundary condition. Data for major users was disaggregated into monthly volumes by approximating local municipal monthly pumping distributions. Users of the groundwater budget model can select a monthly disaggregation method from a list of options (constant linear, approximate PET, approximate municipal use, or user-

Groundwater Budget Term	Data Source and Disaggregation Method (if used)
	defined) and apply percentage increases or reductions to account for the uncertainty in the minor water use. The default distribution for minor water users was to approximate municipal use.
Groundwater Outflow – Private Agricultural (Major / Minor)	Originally derived from land use and census data together with Township of Langley water metering (see Golder 2005; 2014). Comparison with the Ministry of Agriculture water demand model showed general agreement. Large volume agricultural water users or “major users” as determined by Golder (2005, 2014), were extracted from the model as extraction wells and have their own groundwater budget term. Low volume water users or “minor users” were lumped together and extracted from the model areally as a distributed boundary condition. Data for major users was disaggregated into monthly volumes by approximating local municipal monthly pumping distributions. Users of the groundwater budget model can select a monthly disaggregation method from a list of options (constant linear, approximate PET, approximate municipal use, or user-defined) and apply percentage increases or reductions to account for the uncertainty in the minor water use. The default distribution for minor water users was to approximate municipal use.
Groundwater Outflow – Private Domestic (Major / Minor)	Originally derived based on property size and per capita consumption and extracted from groundwater model (see Golder 2005; 2014 for estimation methodology). Private domestic users were generally all minor users and were lumped together and extracted from the model as a distributed boundary condition. Users of the groundwater budget model can select a monthly disaggregation method from a list of options (constant linear, approximate PET, approximate municipal use) and apply percentage increases or reductions to account for the uncertainty in the minor water use.
Groundwater Inflow – Irrigation / Septic Return, Pipe Leakage (Anthropogenic Recharge)	Extracted from groundwater model and implicitly incorporated in monthly estimates of applied recharge (see Golder 2005; 2014 for estimation methodology). Anthropogenic recharge is a small component of overall recharge (approximately 5%) and includes leakage from municipal servicing and recharge from domestic, ICI and agricultural water use. Municipal water leakage is estimated to be 15% of total water provided. Domestic and ICI users not connected to municipal sewers are expected to return 70% of water use back as recharge. Agricultural return was estimated at 30% of total water use based on professional judgement and current practices in the Fraser River valley. Water use by golf courses is estimated to return 50% of the total water use back as recharge based on increased overwatering. (Garcia-Fresna and Sharp, 2005)
Storage Change	Areal estimates for aquifers derived from the groundwater model (Golder 2005; 2014); surplus / deficit volumes are estimated by the monthly groundwater budget terms and are spatially averaged across the entire aquifer surface using specific yield or storativity depending on the aquifer type.
Inflow / Outflow across Aquifer Constant Head Boundaries	Constant head boundary conditions for an aquifer were utilized to approximate inflows / outflows from regions of the aquifer that were outside of the model boundaries (Township of Langley). For example the Nicomekl Serpentine Aquifer extends into Surrey on the west of the Township of Langley but is not directly simulated by the model and, as such, outflows were approximated by a constant head boundary.
Aquifer Specific Yield / Storativity	Initially derived from groundwater model parameters and calibrated to observed water table fluctuations from PGOWN wells on an aquifer-specific where available.

2.3.3 Hydraulic Connections

A methodology was formulated to allow aquifers or other components of the system to respond to external forcings (i.e. precipitation / recharge) and internal forcings (i.e. pumping from aquifers). This was accomplished by using the subsurface characterization from the Township of Langley groundwater model to create describe the hydraulic connections amongst the various hydrogeological components. In order to quantify groundwater flow between the connections, average groundwater fluxes predicted the Township of Langley groundwater model (Golder, 2014) were assigned to each aquifer connection. Considering that the seasonal changes in hydraulic heads measured in the aquifers within the Salmon River Watershed are relatively small, use of these average fluxes was considered appropriate for estimating monthly aquifer budgets. Discharge of groundwater from an aquifer to directly connected surface water features varies monthly based in part on the estimated surplus or deficit of water from the previous month.

2.3.4 Scenario Analyses

The scenario analyses were included in the groundwater budget model as modifiers to the water budget parameters. As such, they can be incorporated as part of any analysis for average, dry or wet years. Instructions for how to implement the scenarios are provided directly in the internal documentation of the spreadsheet groundwater budget model. The manner in which the scenario analyses were realized in the groundwater budget parameters are presented in Table 5, below.

TABLE 5 Scenario Implementation Methodologies

Scenario	Implementation Methodologies
Incorporation of Future Groundwater Demand at 2041 Build Out	70% increase in municipal water use, 50% increase from private water users (Golder, 2014) is assumed. These estimates are based on land use and population projections provided to Golder by the Township of Langley. Land use and population projections were converted to water use projections by the methods described in Golder (2014).
Effects of Climate Change	Increase of average recharge by 9% during the wet season (Oct – Mar) and increase in agricultural water use and residential irrigation of 15% in the dry season (Apr – Sep). These estimates are based on predicted changes in climate inputs (University of Waterloo, 2012) and expected changes in water use (BC MAGRI, 2013, Foti et al., 2010) and are described in further detail in Golder (2014).
Implementation of more ambitious Stormwater BMPs at 2041 Build Out	Assumed reduction in effective impervious area to 50% for new developments as a result of more ambitious BMP's. Only minor amounts of land in the Salmon River watershed are planned for new development, therefore recharge in this area is expected to decrease by only 1% in 2041 (Golder, 2014).

2.4 Estimation of Available Groundwater

Qualitative and relative estimations of available groundwater was accomplished via an analysis of the individual aquifer connections, the relative isolation from environmentally sensitive surface water features and the relative magnitude of the total throughput of the aquifer. In general, additional reductions of groundwater availability or increases in groundwater withdrawals are either at the expense of baseflow to surface water features or groundwater flow to adjacent aquifers and aquitards. The water balance analysis provides a generalized picture of available groundwater based on these interactions. However, we caution that the actual *sustainability* of groundwater withdrawals can only be assessed through comprehensive studies that evaluate the overall influence of these withdrawals on the environment, as described in Sophocleous (1997), Bredehoeft (1997) and Alley and Leake (2004).

3. RESULTS

An overview of the conceptual model of groundwater movement in the Salmon River Watershed, together with the results of the water balance analyses, is presented below.

3.1 Conceptual Model

3.1.1 Aquifers

Throughout most of the Salmon River Watershed, regional groundwater flow is generally directed towards the northwest. West of the Salmon River in the northwest corner of the watershed, groundwater flow is generally directed towards the southeast and northeast.

A summary of the conceptual model for each of the seven aquifers within the Salmon River Watershed is presented graphically in Figures 10 through 16. The figures illustrate overall groundwater recharge, areas of groundwater interaction with surface water, hydraulic communication between aquifers, and groundwater use for each of the aquifers.

3.2 Monthly Groundwater Budgets

Annual groundwater budgets for an average year, dry year and wet year are presented by aquifer in the sections below. Graphs plotting the monthly storage change for the average, dry and wet years, spatially averaged across the aquifer are also presented in the individual aquifer sections below. Detailed monthly accounting of groundwater budget inflows and outflows per aquifer for average, dry and wet years are presented in Appendix A.

Scenario analyses to the groundwater budgets such as utilization of future groundwater demand, assessment of climate change impacts, and the effects of BMP implementation are not directly presented in the report but can be implemented within the associated groundwater budget model as modifiers within the Excel spreadsheets for each aquifer.

3.2.1 Hopington AB Aquifer

Table 6, below, presents the major inflows and outflows for the Hopington AB Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the Hopington AB aquifer include recharge and inflow from aquitards. Major outflows from the aquifer include discharge to surface water features and pumping from minor groundwater users. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 17.

TABLE 6 Summary of Annual Groundwater Budget Results – Hopington AB Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Total Recharge	8233	25907	41949
In – Flow from aquitards	13002	13002	13002
In – Flow from Beaver River Aquifer	3631	3631	3631
In – Flow from Aldergrove CD Aquifer	1947	1947	1947
In – Surface water inflow – Salmon River	897	897	897
In – Surface water inflow - Others	768	768	768
Total Inflows	**28478**	**46152**	**62194**
Out – Discharge to Salmon River	22000	23737	26119
Out – Discharge to Nicomekl R. / Bertrand Ck.	2472	2692	2965
Out – Flow to aquitards	13543	13543	13543
Out – Pumping from private minor users[1]	4711	4711	4711
Out – Minor outflows to other units	1393	1393	1393
Total Outflows	**44118**	**46076**	**48731**
Surplus / Deficit	-15641	-	+13462
Annual Change in Groundwater Level in Relation to an Average Year (m)	-2.4	0.0	2.1

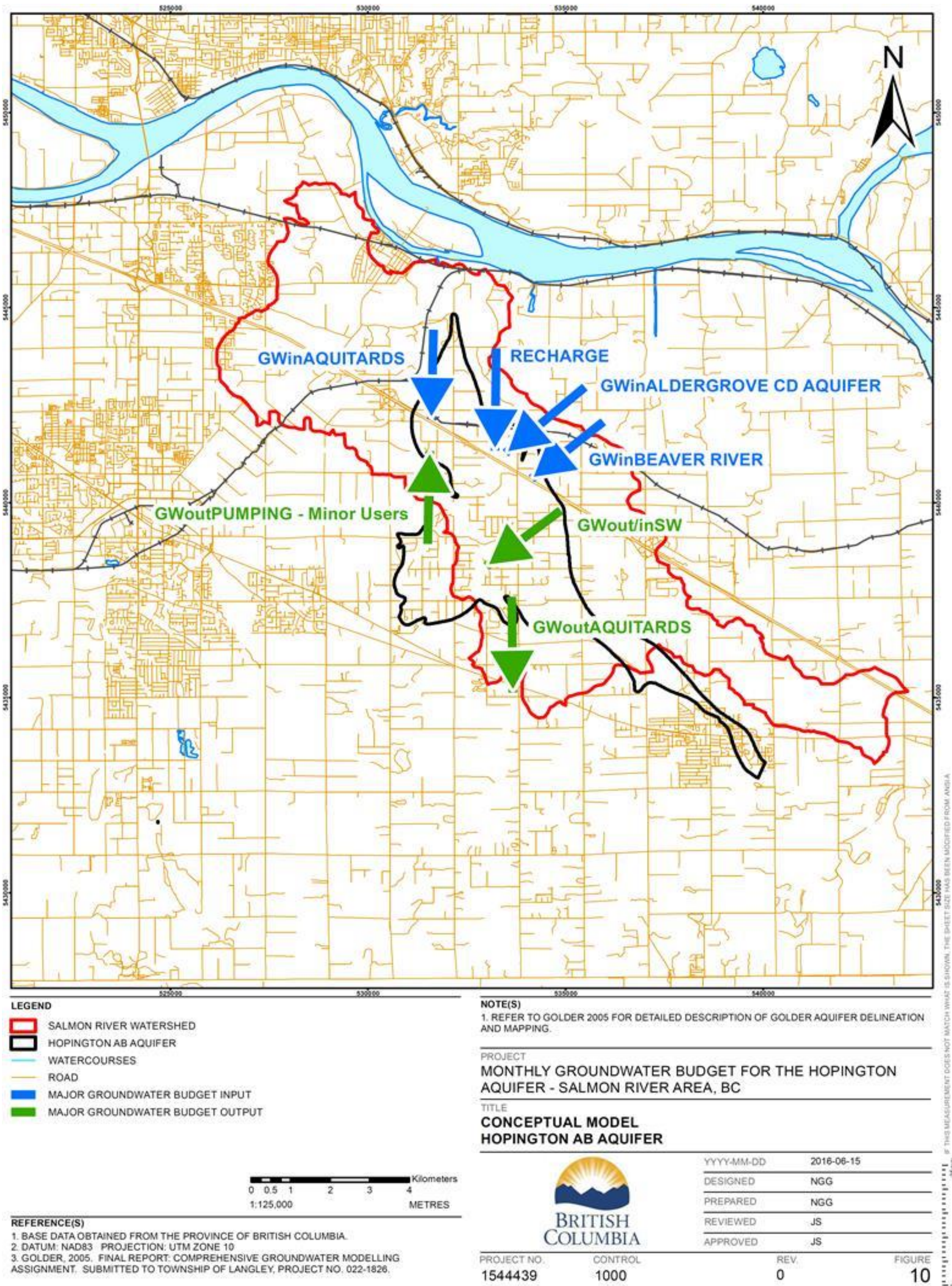

Figure 10 Conceptual model – Hopington AB aquifer.

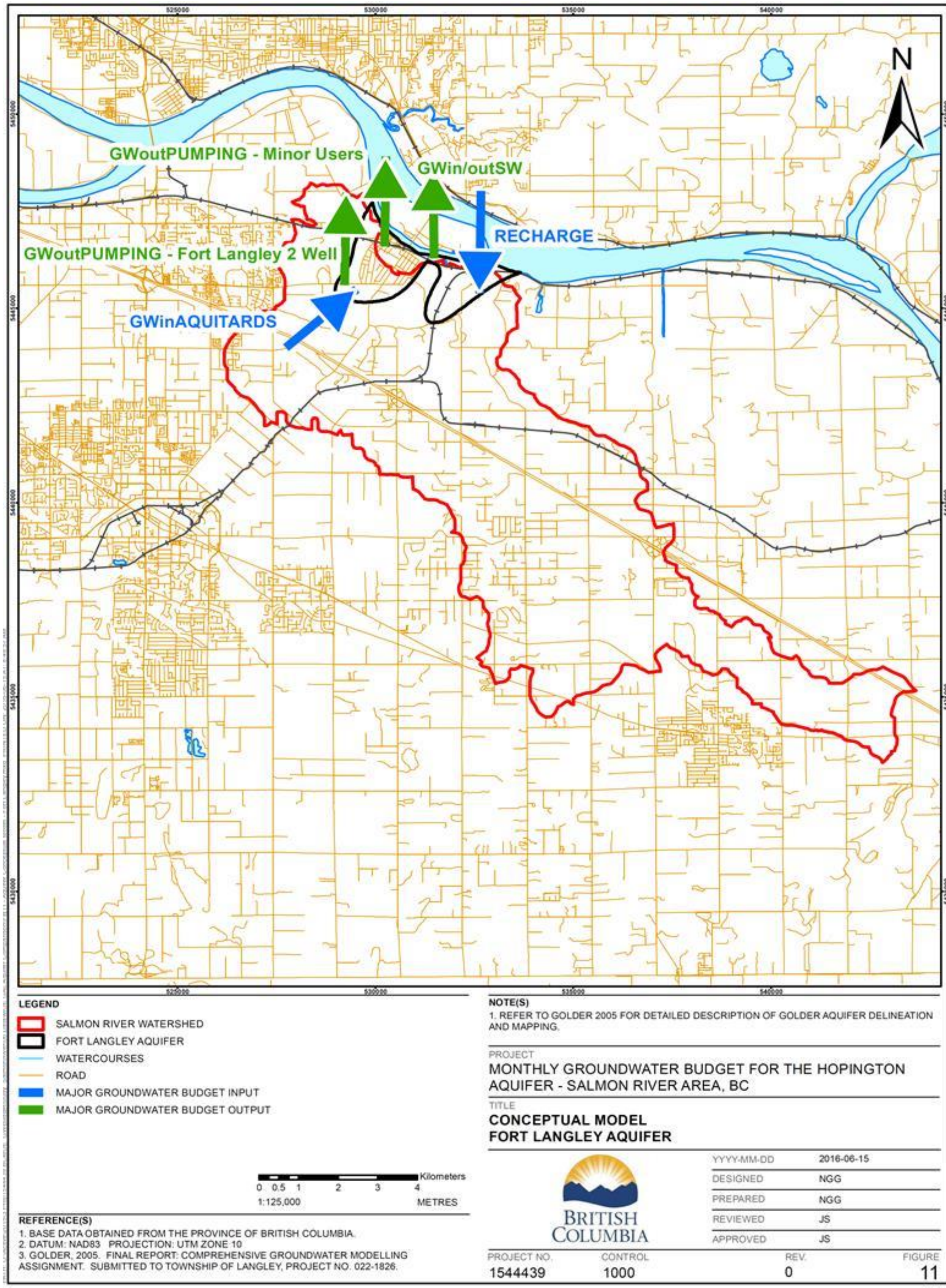

Figure 11 Conceptual model – Fort Langley aquifer.

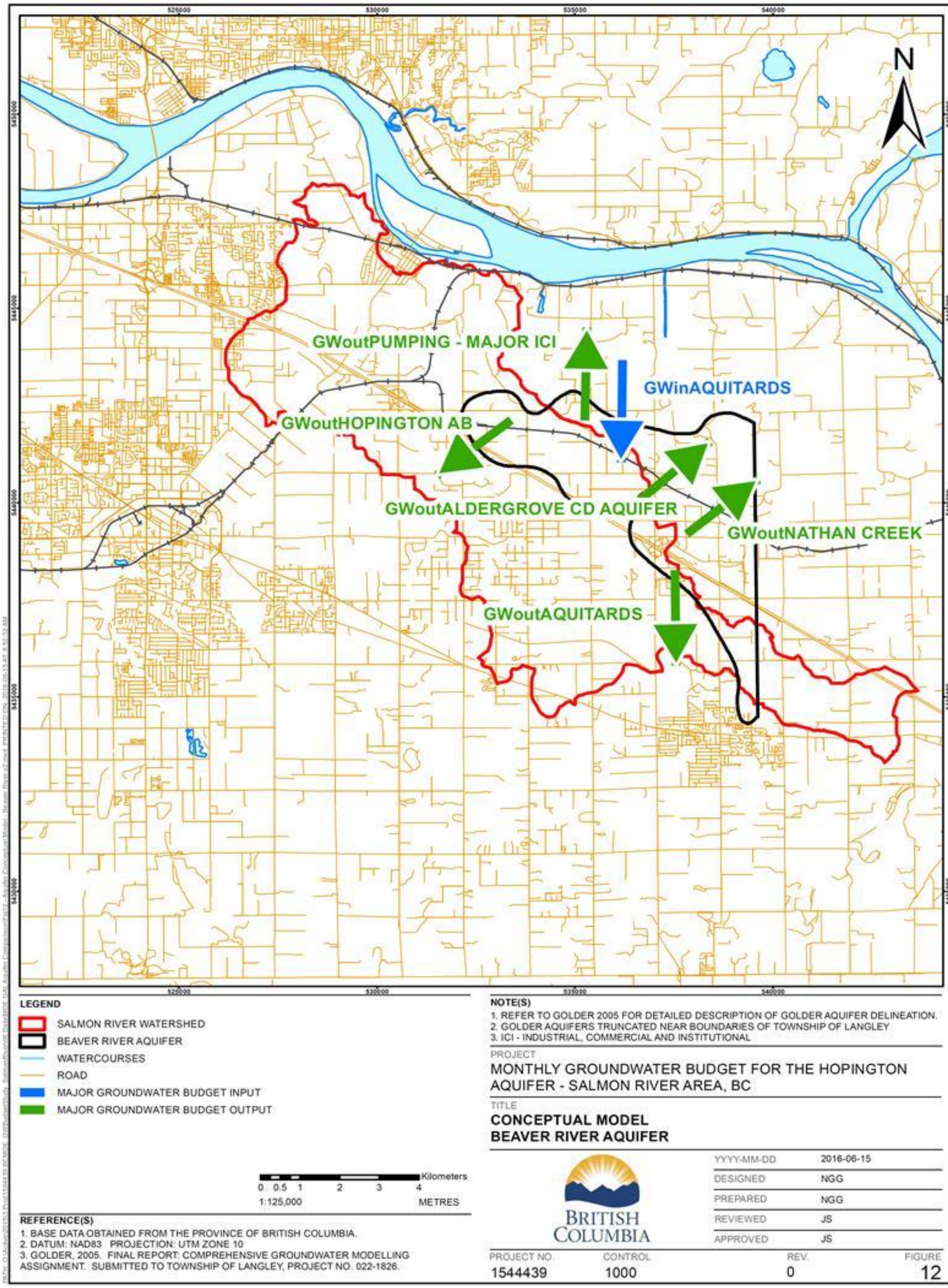

Figure 12 Conceptual model – Beaver River aquifer.

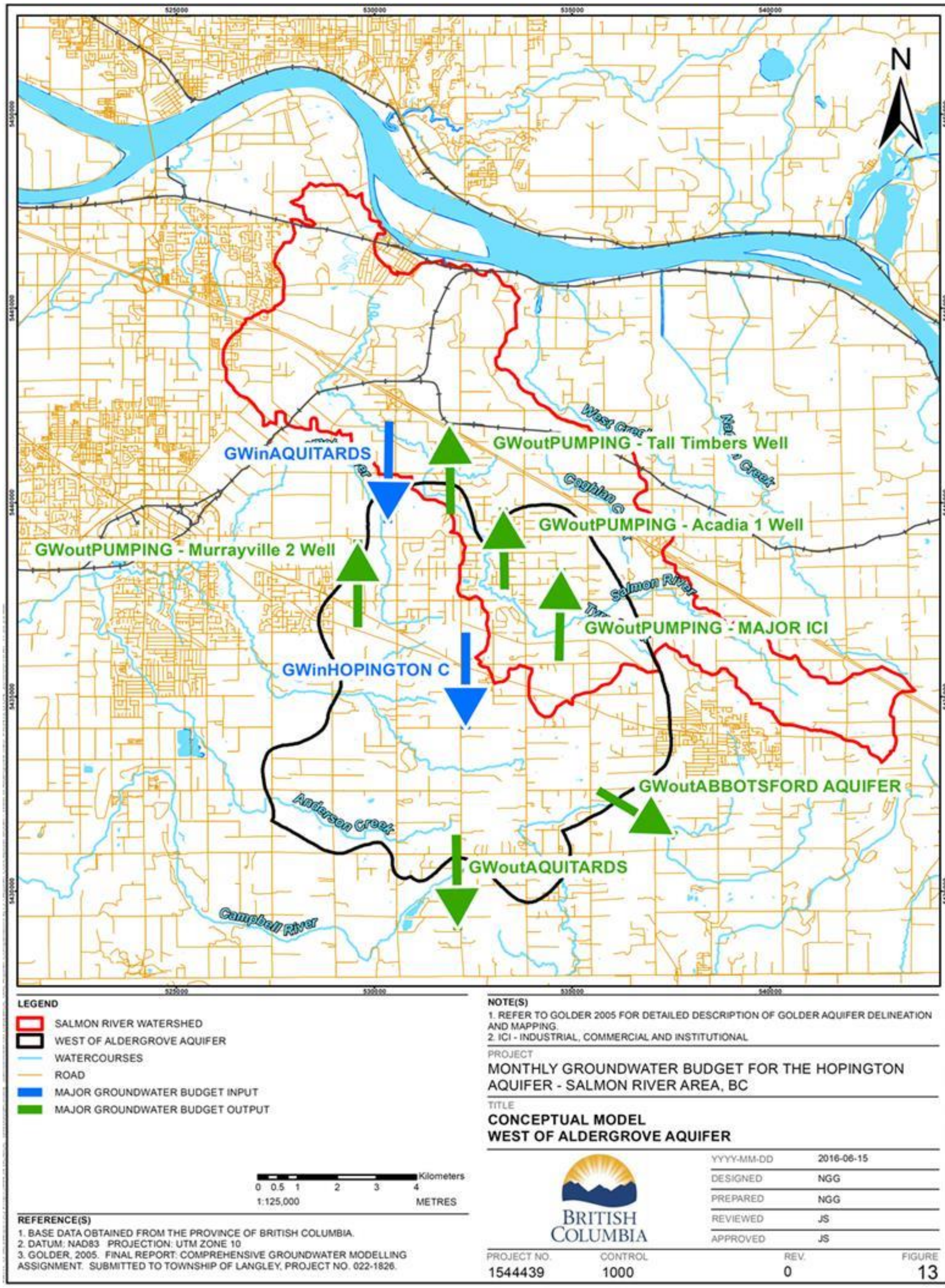

Figure 13 Conceptual model – West of Aldergrove aquifer.

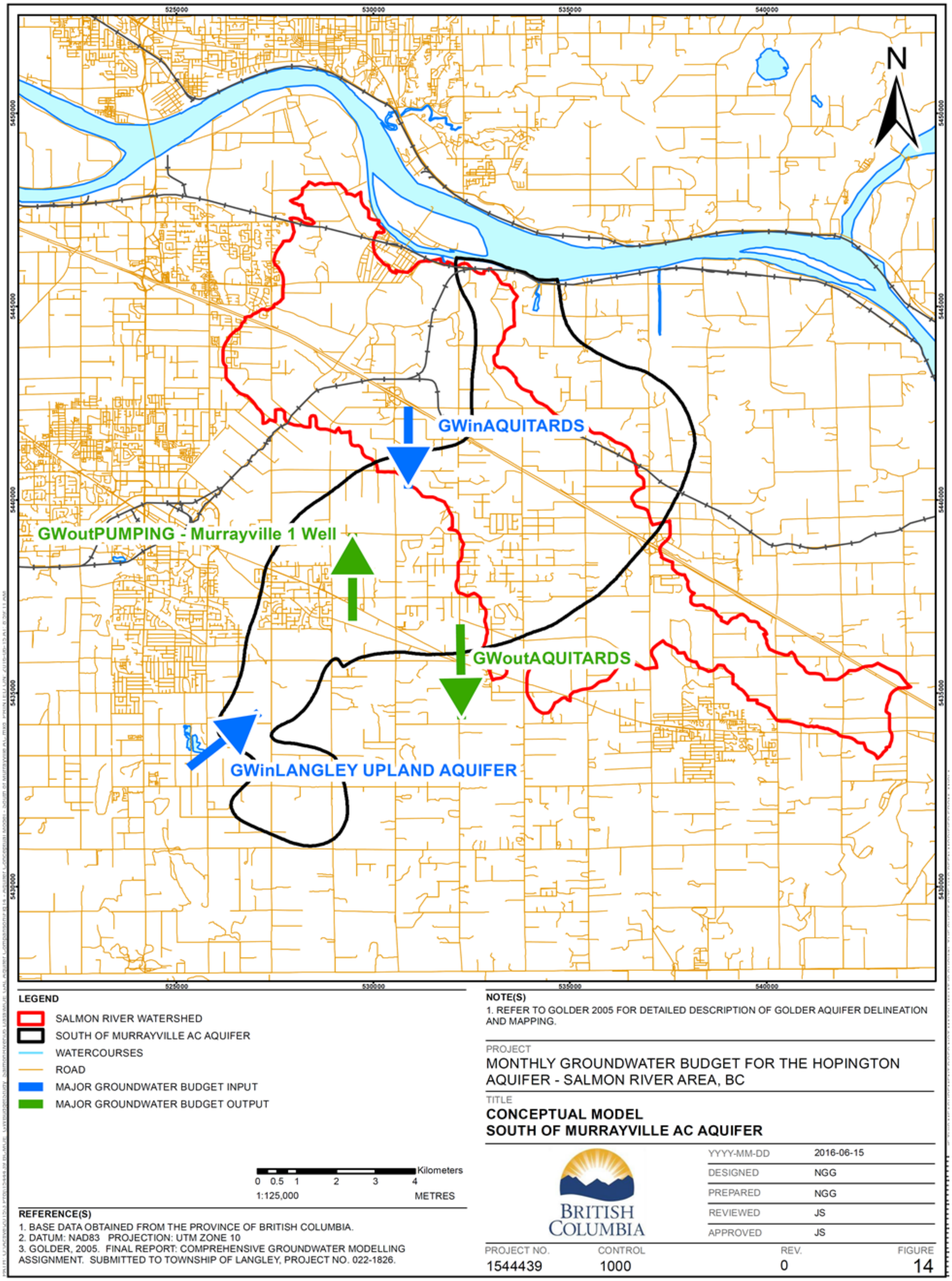

Figure 14 Conceptual model – South of Murrayville AC aquifer.

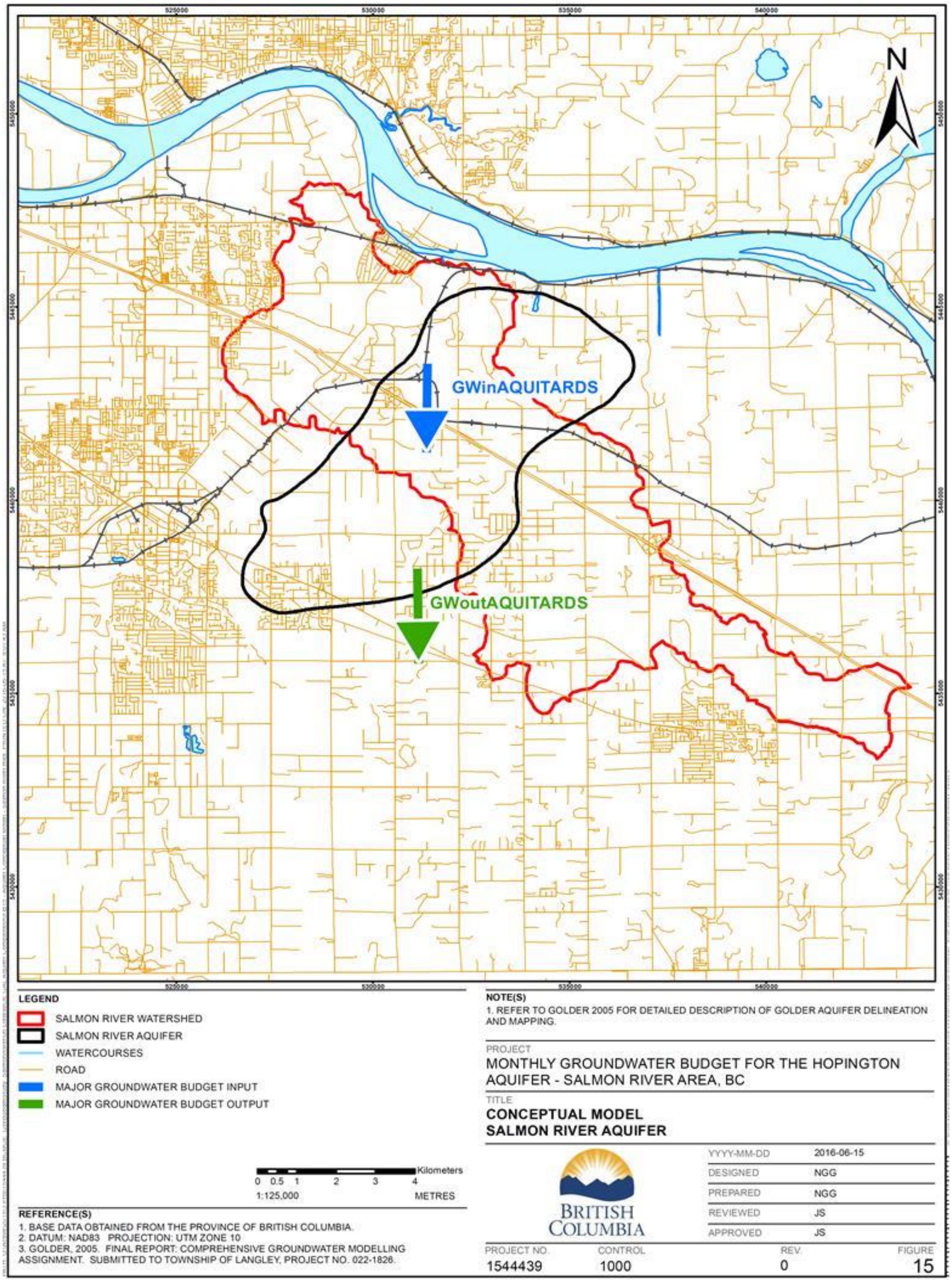

Figure 15 Conceptual model – Salmon River aquifer.

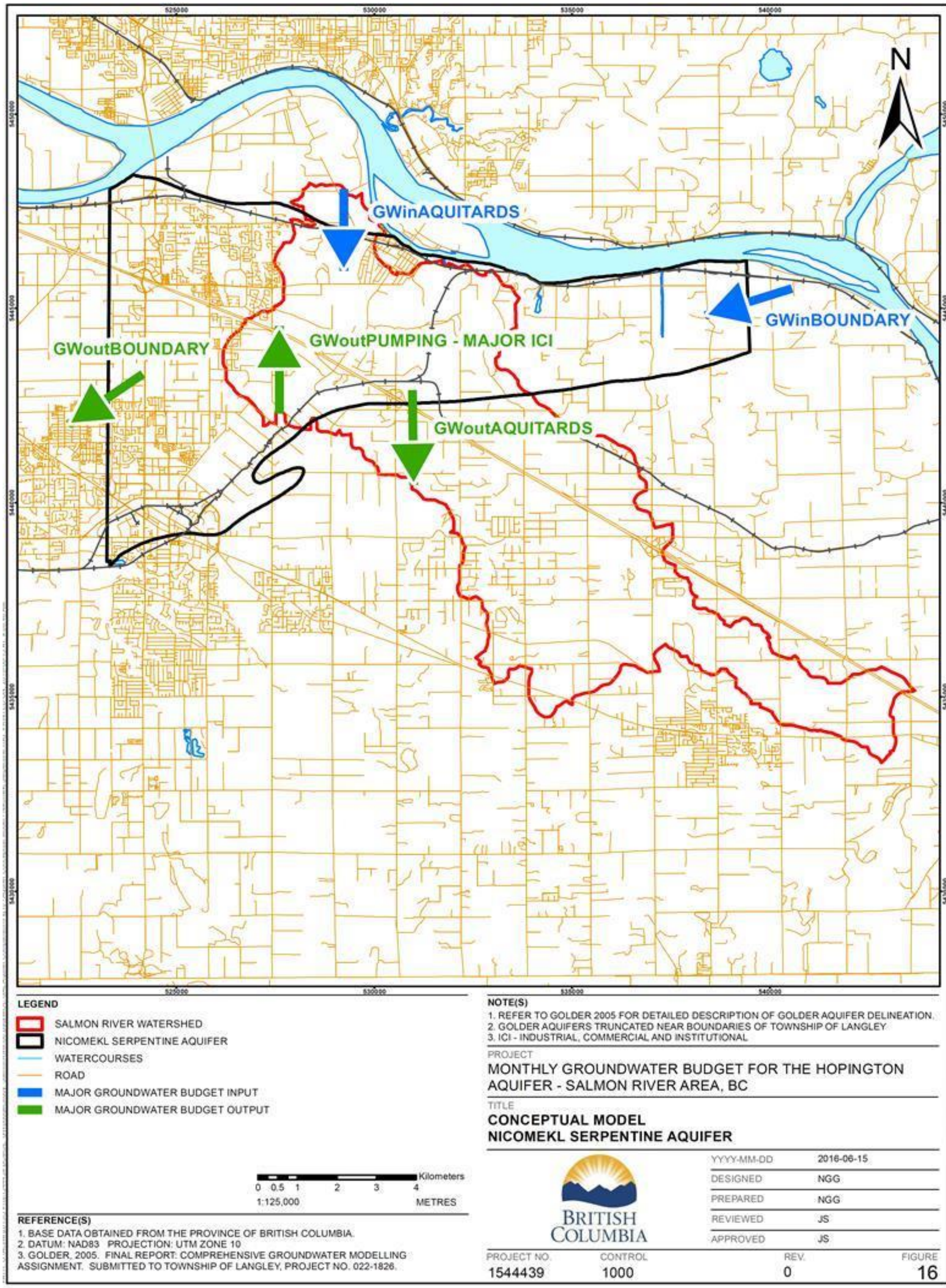

Figure 16 Conceptual model – Nicomekl Serpentine aquifer.

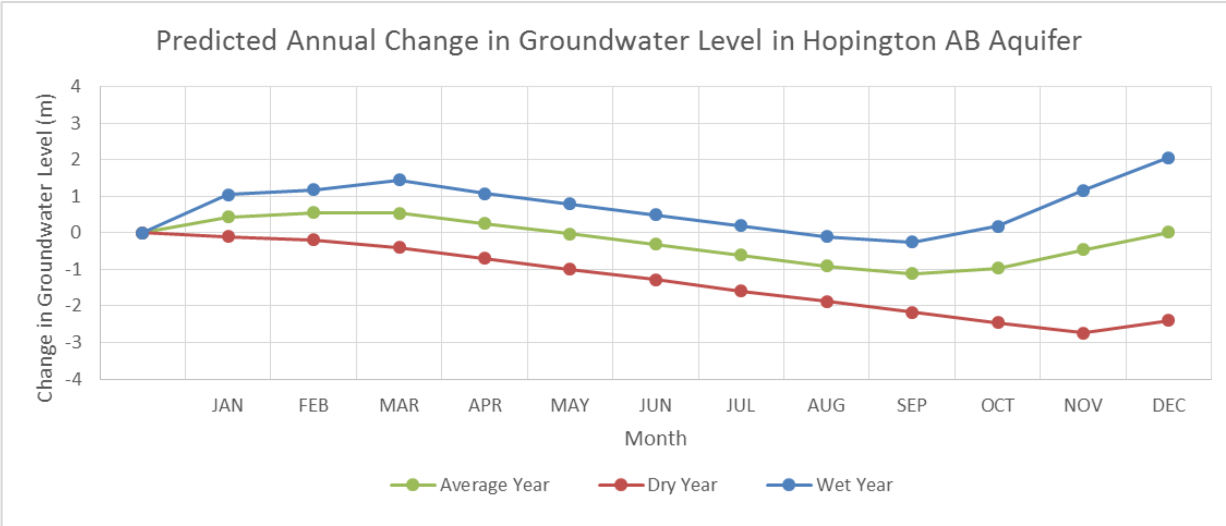

Figure 17 Predicted annual change in groundwater level in Hopington AB aquifer.

3.2.2 Fort Langley Aquifer

Table 7, below, presents the major inflows and outflows for the Fort Langley Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the Fort Langley Aquifer include recharge and flow from aquitards. Major outflows from the aquifer include discharge to surface water and pumping from the Fort Langley #2 municipal well. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 18.

TABLE 7 Summary of Annual Groundwater Budget Results – Fort Langley Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Total Recharge	2649	5956	9944
In – Flow from aquitards	12910	12910	12910
In – Surface water inflow	484	484	484
Total Inflows	**16043**	**19350**	**23338**
Out – Discharge to Fraser River	10377	9602	11680
Out – Discharge to Salmon River	1519	1616	1691
Out – Pumping from Fort Langley Well #2	7699	7699	7699
Out – Pumping from private minor users[1]	395	395	395
Total Outflows	**19991**	**19312**	**21465**
Surplus / Deficit	-3948	38	+1873
Annual Change in Groundwater Level (m)	-2.0	0.0	+0.9

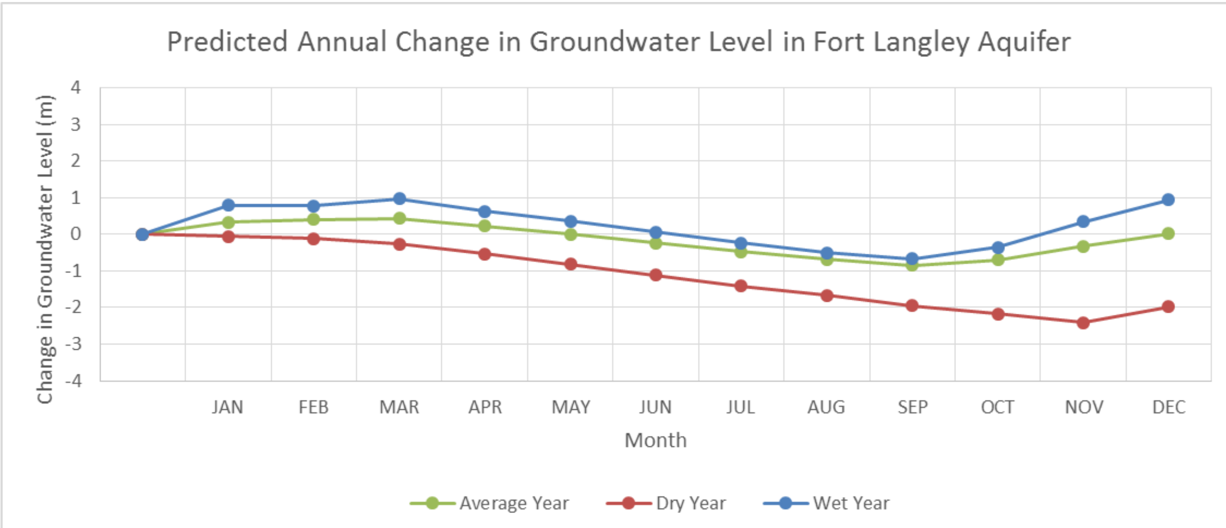

Figure 18   Predicted annual change in groundwater level in Fort Langley aquifer.

3.2.3   Beaver River Aquifer

Table 8, below, presents the major inflows and outflows for the Beaver River Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the Beaver River Aquifer include inflow from aquitards. Major outflows from the aquifer include outflow to aquitards and discharge to surface water. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 19. The Beaver River Aquifer due to its confined nature is generally hydraulically isolated from short time scale changes (i.e. 1 year) in recharge from dry and wet years. Prolonged periods of drier than average conditions could result in reduction in inflows from aquitards in response to reduction in recharge to the overlying units.

TABLE 8 Summary of Annual Groundwater Budget Results – Beaver River Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Flow from aquitards	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.	58331	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.
In – Flow from Aldergrove CD Aquifer		8712	
In – Flow from Nathan Creek		1303	
Total Inflows		**68346**	
Out – Flow to aquitards		36269	
Out – Discharge to Nathan Creek		13311	
Out – Flow to Hopington AB Aquifer		3630	
Out – Flow to Aldergrove CD Aquifer		11967	
Out – Pumping from major ICI user		3168	
Total Outflows		**68345**	
Surplus / Deficit		1	
Change in Storage (m)		0.0	

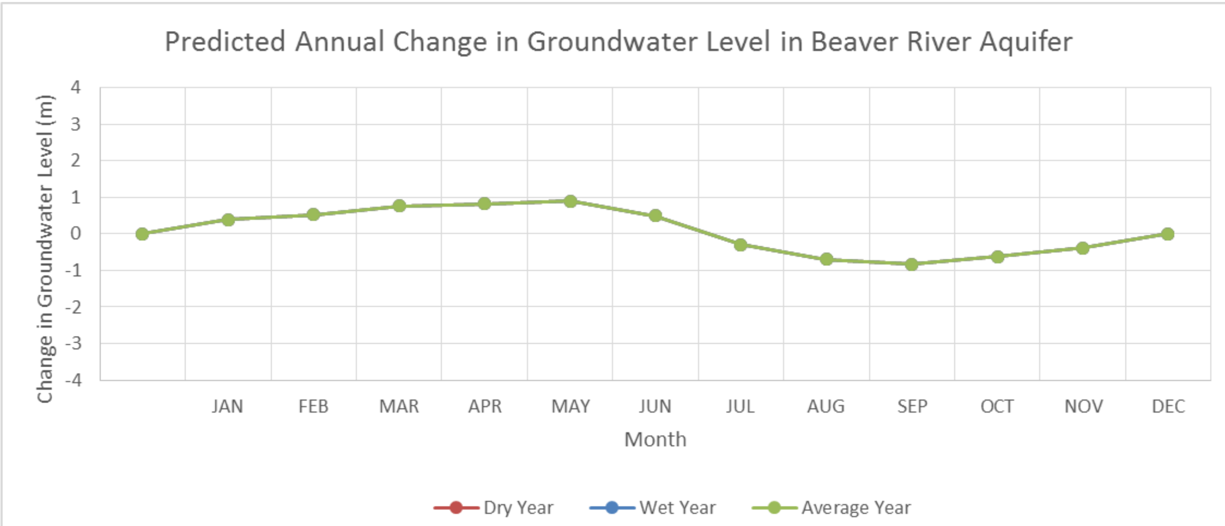

Figure 19 Predicted annual change in groundwater level in Beaver River aquifer.

3.2.4 West of Aldergrove Aquifer

Table 9, below, presents the major inflows and outflows for the West of Aldergrove Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the West of Aldergrove Aquifer include flows from aquitards and inflow from the Hopington C Aquifer. Major outflows from the aquifer include flows to aquitards, outflow to the Abbotsford Aquifer and pumping from the Murrayville B municipal well. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 20. The West of Aldergrove Aquifer due to its confined nature is generally hydraulically isolated from short time scale changes (i.e. 1 year) in recharge from dry and wet years. Prolonged periods of drier than average conditions could result in reduction in inflows from aquitards in response to reduction in recharge to the overlying units.

TABLE 9 Summary of Annual Groundwater Budget Results – West of Aldergrove Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Flow from aquitards	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.	77797	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.
In – Net inflow from Hopington C Aquifer		6037	
In – Minor inflows from other units		1196	
Total Inflows		**85030**	
Out – Flow to aquitards		75624	
Out – Flow to Abbotsford Aquifer		4924	
Out – Pumping from Murrayville 2 Well		1245	
Out – Pumping from Tall Timbers Wells		63	
Out – Pumping from Acadia #1 Well		25	
Out – Pumping from major ICI users		2713	
Out – Minor outflows to other units		436	
Total Outflows		**85030**	
Surplus / Deficit		-	
Change in Storage (m)		0	

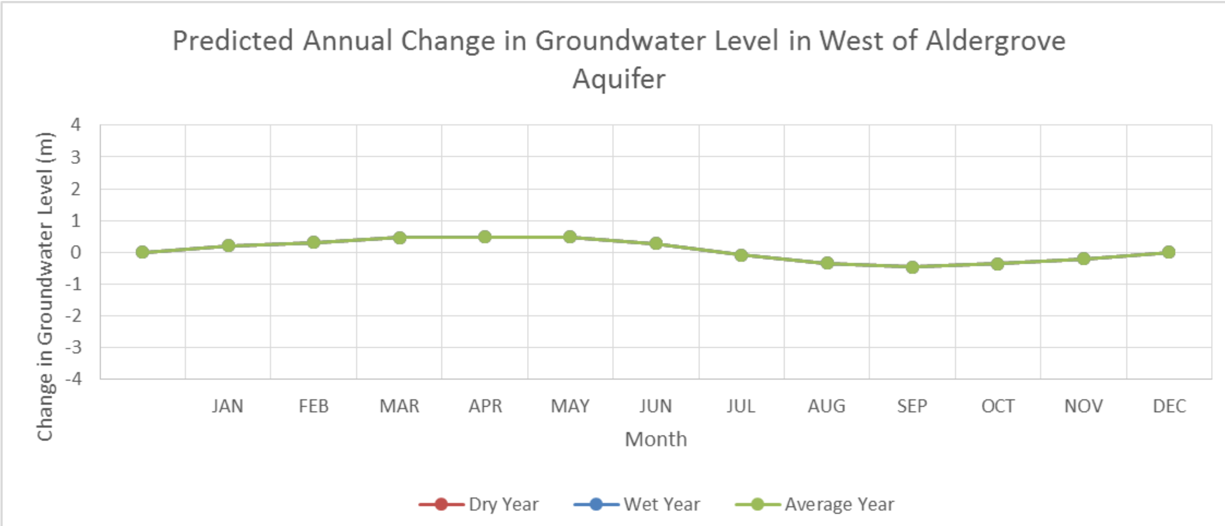

Figure 20 Predicted annual change in groundwater level in West of Aldergrove aquifer.

3.2.5 South of Murrayville AC Aquifer

Table 10, below, presents the major inflows and outflows for the South of Murrayville AC Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the South of Murrayville AC Aquifer include flows from aquitards and inflow from the Langley Upland Aquifer. Major outflows from the aquifer include flow to aquitards and pumping from the Murrayville 1 municipal well. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 21. The South of Murrayville AC Aquifer due to its confined nature is generally hydraulically isolated from short time scale changes (i.e. 1 year) in recharge from dry and wet years. Prolonged periods of drier than average conditions could result in reduction in inflows from aquitards in response to reduction in recharge to the overlying units.

TABLE 10 Summary of Annual Groundwater Budget Results – South of Murrayville AC Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Flow from aquitards	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.	55454	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.
In – Net inflow from Langley Upland Aquifer		1545	
In – Minor inflows from other units		67	
Total Inflows		**57066**	
Out – Flow to aquitards		56612	
Out – Pumping from Murrayville 1 Well		442	
Out – Minor outflows to other units		12	
Total Outflows		**57066**	
Surplus / Deficit		-	
Change in Storage (m)		0	

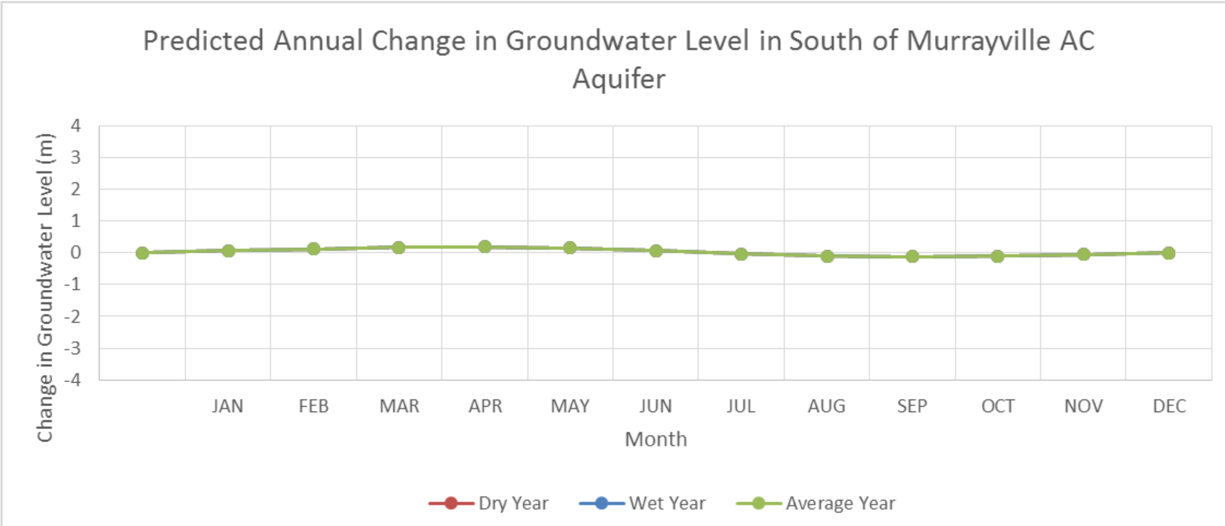

Figure 21 Predicted annual change in groundwater level in South of Murrayville AC aquifer.

3.2.6 Salmon River Aquifer

Table 11, below, presents the major inflows and outflows for the Salmon River Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the Salmon River Aquifer include flows from aquitards. Major outflows from the aquifer include flows to aquitards. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 22. The Salmon River Aquifer due to its confined nature is generally hydraulically isolated from short time scale changes (i.e. 1 year) in recharge from dry and wet years. Prolonged periods of drier than average conditions could result in reduction in inflows from aquitards in response to reduction in recharge to the overlying units.

TABLE 11 Summary of Annual Groundwater Budget Results – Salmon River Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Flows from aquitards	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.	36257	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.
Out – Flows to aquitards		36257	
Surplus / Deficit		-	
Change in Storage (m)		0	

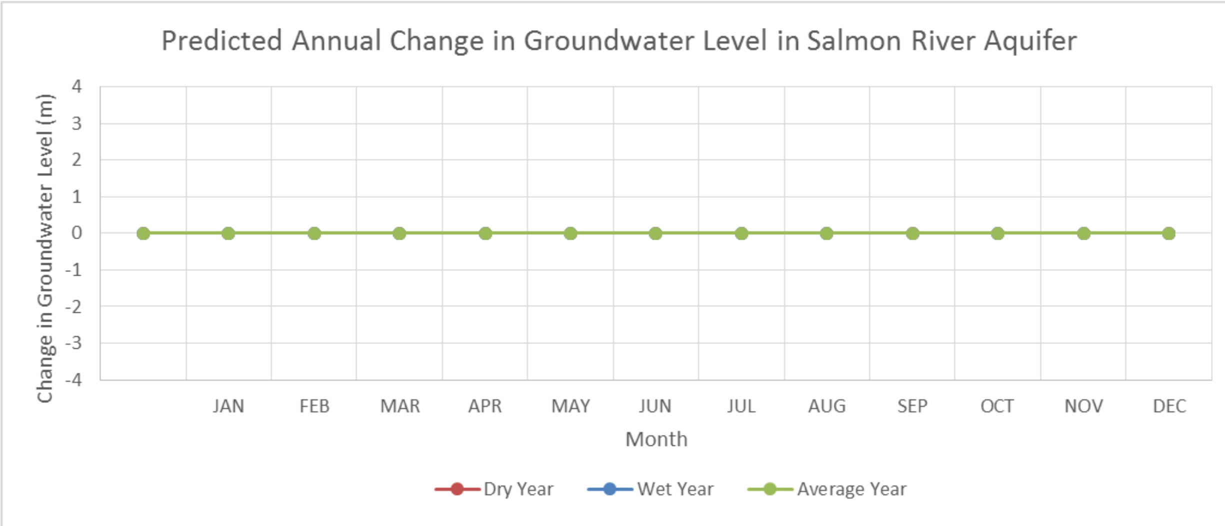

Figure 22 Predicted annual change in groundwater level in Salmon River aquifer.

3.2.7 Nicomekl Serpentine

Table 12, below, presents the major inflows and outflows for the Nicomekl Serpentine Aquifer, together with the associated surplus / deficit and change in groundwater storage for the dry, average and wet years. Major inflows to the Nicomekl Serpentine Aquifer include flows from aquitards. Major outflows from the aquifer include flows to aquitards and pumping from ICI sources. Subsequently, the monthly changes in groundwater storage, averaged over the total area of the aquifer, are presented for the dry, average, and wet years in Figure 23. The Nicomekl Serpentine Aquifer due to its confined nature is generally hydraulically isolated from short time scale changes (i.e. 1 year) in recharge from dry and wet years. Prolonged periods of drier than average conditions could result in reduction in inflows from aquitards in response to reduction in recharge to the overlying units.

TABLE 12 Summary of Annual Groundwater Budget Results – Nicomekl Serpentine Aquifer

Groundwater Budget Term	**Dry Year (m^3/d) - 1951**	**Average Year (m^3/d)**	**Wet Year (m^3/d) - 1971**
In – Flow from aquitards	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.	98254	Generally hydraulically isolated from changes in recharge therefore results are consistent with the average year.
In – Flow across boundary		12303	
Total Inflows		**110557**	
Out – Flow to aquitards		87109	
Out – Flow across boundary		22948	
Out – Pumping from major ICI user		500	
Total Outflows		**110557**	
Surplus / Deficit		-	
Change in Storage (m)		0	

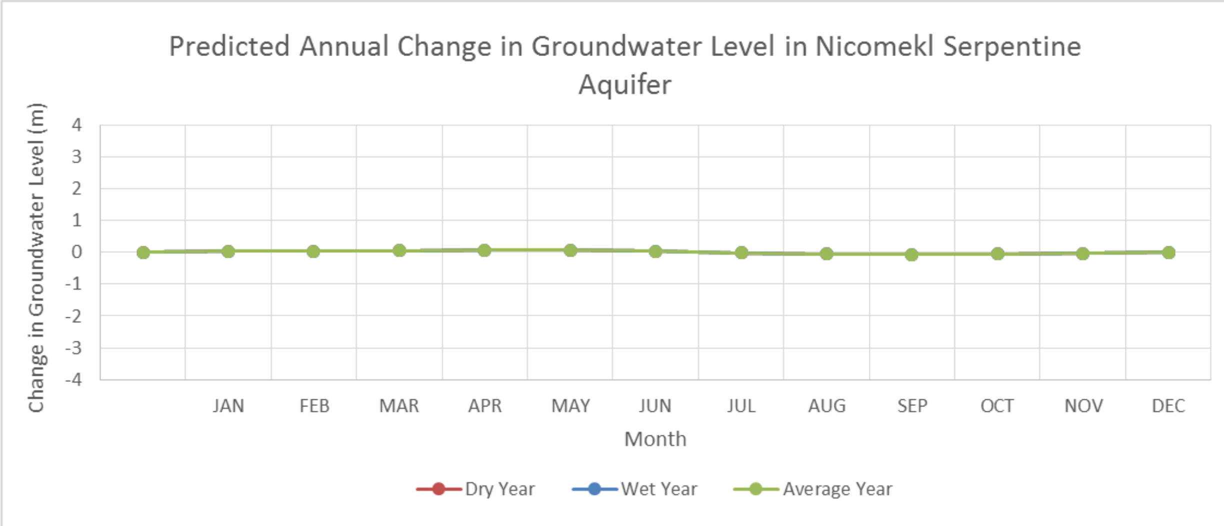

Figure 23 Predicted annual change in groundwater level in Nicomekl Serpentine aquifer.

3.2.8 Comparison of Hydraulic Head Predictions to Observations from the Provincial Groundwater Observation Well Network

As a comparative measure of calibration, estimated aquifer hydraulic head fluctuations on an annual basis from the groundwater budgets were compared to observed hydraulic head fluctuations in wells from the Provincial Groundwater Observation Well Network in the same aquifer, where available. Table 13 presents the ranges of estimated hydraulic head fluctuations for average, dry and wet years versus the observed hydraulic head fluctuations in active observation wells.

TABLE 13 Hydraulic Head Fluctuations in Provincial Groundwater Observation Wells

Aquifer	**Observation Well**	**Mean Observed Annual Head Fluctuation (m)[1]**	**Predicted Average Year Head Fluctuation (m)**
Hopington AB	Observation Well #354	1.8	1.7
Hopington AB	Observation Well #453	2.5 (one year of data only)	
West of Aldergrove	Observation Well #415	0.9	0.9
Fort Langley (unvalidated)	Observation Well #452	1.3 (one year of data only)	1.3

[1] – Data extracted from BC Groundwater Observation Well Network Data Explorer, where multiple years of data were available the mean observed annual head fluctuation was utilized.

The table shows good agreement between the average year head fluctuations predicted by the water balance analysis and the mean annual head fluctuations observed in available observation wells.

4. <u>ESTIMATED AVAILABLE GROUNDWATER</u>

As detailed in Section 2.4, the groundwater budgets for the Hopington Aquifer – Salmon River Area are high-level estimates conducted at a coarse scale due to uncertainty associated with the estimation of the major groundwater budget terms. Section 4.1 details the uncertainty associated with some of the major groundwater budget terms as estimated in Golder 2005 and 2014. Section 4.2 qualitatively assesses available groundwater in several of the aquifers based on the conceptual understanding developed during the groundwater budget study, recognizing that “available groundwater” is a subjective term and does not include sustainability assessment.

4.1 Groundwater Budget Term Uncertainty

Estimations of uncertainty associated with selected individual parameters utilized in the groundwater budgets (Golder 2005; 2014) are presented in Table 14, below. The uncertainty estimations are provided as a means to evaluate the overall uncertainty of the high level groundwater budgeting exercise. Reductions in uncertainty can be achieved by obtaining more or higher resolution data, performing a detailed sensitivity analysis, and/or utilizing a more detailed method (i.e. – regional or local scale flow model) provided there is adequate data.

TABLE 14 Uncertainty of Selected Parameters and Groundwater Budget Terms

Groundwater Budget Term / Parameter	Estimated Uncertainty (%) from Golder (2005; 2014)
Domestic / Minor Groundwater Users	+/- 50%
Major ICI / Agricultural Groundwater Users	+/- 50-100%
Anthropogenic Recharge	+/- 15%
Evapotranspiration	+/- 10%
Uncertainty in Modelled Baseflow Predictions	+/- 30-50%
Root Mean Squared Error (RMS) of Modelled vs. Measured Hydraulic Head Data in Groundwater Model	Approximately 7.5%

The overall uncertainty in groundwater fluxes between individual aquifers as predicted by the Township of Langley groundwater model is expected to be similar to the uncertainty in baseflow predictions listed in Table 14. As the groundwater budget exercise is a high level assessment that is subject to considerable uncertainty, a direct quantitative estimation of groundwater availability is not recommended as it would require additional information on water demand and instream environmental flow needs.

4.2 Qualitative Assessment of Available Groundwater

Despite variable uncertainty in the groundwater budget terms and parameters, a qualitative assessment of available groundwater can be used to identify preferred aquifers for future groundwater resource development or aquifers where additional groundwater development should be approached with caution. The qualitative assessment is based on the assumption that additional groundwater withdrawals (or reduction in recharge) ultimately affects either baseflow or groundwater flow / storage from adjacent aquifers and aquitards. Based on this assumption, aquifers with a greater capacity of available groundwater are those which are:

- more hydraulically isolated from sensitive surface water features and, as such, additional groundwater extraction is sourced from a greater and more diffuse areal extent;
- have higher throughput volumes, such that additional groundwater extraction or recharge reduction is comparatively small in relation to the total volume that passes through the aquifer at a given time; and
- proximal to a large recharge source (i.e. the Fraser River) whereby additional groundwater extractions can induce recharge from a comparatively "infinite" source water sourced from outside of the watershed.

Based on the above criteria, the Nicomekl Serpentine and Fort Langley Aquifers are qualitatively characterized to have greater amounts of available groundwater. The Nicomekl Serpentine Aquifer was identified due to its large spatial extent (in the Township and westward into Surrey) and comparatively high degree of hydraulic isolation from the Salmon River. The Fort Langley Aquifer was identified due to its close proximity to the Fraser River which allows potential wells to draw from a large source of constantly renewing water. Due to its depth and confined nature, ambient groundwater in the

Nicomekl Serpentine Aquifer is highly mineralized in some areas as a result of long residence times. As a result, additional groundwater resource development in this aquifer would need to ensure that the water is of sufficient quality for its intended purpose.

Aquifers with less capacity of available groundwater are considered to be those that:

- have lower total throughput volumes, such that additional groundwater extraction or reductions in recharge are comparatively large in relation to the total volume that passes through the aquifer at a given time;
- recharge comprises a relatively greater percentage of inflows to the aquifer, thus making the aquifer more susceptible to dry or drought conditions; and
- can reasonably be considered to be hydraulically connected to a surface water body of finite capacity in relation to groundwater fluxes and which provides a proportionally significant amount of flow to the surface water feature, particularly in areas of high environmental sensitivity (cold water streams, headwaters or low flow reaches).

Based on the above criteria, the Hopington AB Aquifer can be qualitatively considered to have less capacity for available groundwater and be more at risk for unsustainable groundwater withdrawals and allocations. The Hopington AB Aquifer receives over 50% of its total inflow on an average year from recharge and is more susceptible to prolonged dry periods or drought. In addition, the Hopington AB Aquifer provides a source of baseflow to several different surface water systems, including the Salmon River, Nicomekl River and Bertrand Creek systems, in areas which are more likely to be environmentally sensitive to flow reductions. Additional information on water demand, instream environmental flow needs and areas of groundwater discharge would be needed to evaluate the groundwater availability and sustainability of groundwater withdrawals for this aquifer. In general, overallocation depends upon an assessment of instream flow needs, current levels of allocation and seasonal / annual / multi-annual variability in precipitation. Additional pumping from unconfined aquifers will result in a reduction of either baseflow, storage or flow to other aquifers / aquitards to some degree with the proportion of water coming from baseflow likely to be highest during periods of low recharge (dry season). In the absence of a flow target, on the basis of the precautionary principle, additional water taking from unconfined aquifers should be done with caution.

5. DATA LIMITATIONS AND RECOMMENDATIONS

The development of a monthly groundwater budget provides valuable insight into the conceptual processes surrounding major inflows and outflows to an aquifer system, to the extent that these processes are reflected in the model and disaggregation procedure. Preliminary groundwater budgets by definition are constructed over large spatial and temporal scales and, as such, can be subject to high levels of uncertainly that results from data availability and the coarseness of the method. As the conceptual understanding of the aquifer system evolves and is accounted for in the groundwater budgets, these uncertainties are expected to decrease.

The data limitations and recommendations outlined in this section are discussed at scales relevant to higher level groundwater budgeting such as information that can significantly affect major inflows and outflows or that can alter the conceptual understanding of the aquifer. Recommendations to address the identified data limitations provide the opportunity to generate iterative improvements to the estimations of available groundwater and reduce uncertainty in the results.

5.1 Data Limitations

The availability of pre-existing regional surface water and groundwater models for the Hopington Aquifer – Salmon River Area provided a comparatively greater amount of high quality data and information than is to be expected for large-scale groundwater budgeting. However, though the data is detailed, numerous assumptions and estimates were required to generate the detailed datasets within the models. As a result, uncertainty associated with these assumptions and estimates represent limitations that can significantly affect the groundwater budget of an aquifer. Results from the Hopington Aquifer – Salmon River Area groundwater budgets show that evapotranspiration, estimates of recharge and baseflow as well as groundwater pumping can all be major forcings on the groundwater budget of an aquifer. Uncertainties associated with the underlying conceptual model of the aquifers also exist, for example, proper conceptualization of aquifer connectivity and groundwater levels, magnitude of surface water – groundwater interactions, and identification of major groundwater discharge zones. Establishing a safety factor to accommodate uncertainty for a high level exercise is difficult but, for the purpose of this study, can be considered to be on the order of 30-50% for groundwater flow and baseflow. A summary of the major data limitations include:

- estimations of actual evapotranspiration (AET) and associated recharge are limited to high level soil moisture accounting. Both components are major terms that affect how groundwater is apportioned to the aquifer and surface water;
- significant assumptions were required to estimate water use from domestic and agricultural groundwater pumping;
- The analysis relies on data generated from numerical modelling runs from a regional scale numerical model that was not specifically constructed or calibrated for local scale processes in the Salmon River watershed;
- limited continuous monitoring data was available to inform or verify the conceptual model or groundwater budgeting results via, for example, observation points such as observation wells, shallow piezometers close to watercourses, and baseflow measurements at multiple locations; and
- local hydrogeologic processes such as groundwater pumping and inter-aquifer flow have their effects averaged spatially across the aquifer.

In addition, groundwater divides and aquifers are not contiguous with the Salmon River Watershed divide and, as such, some aquifers and groundwater processes have not been included in the current groundwater budgets. For example, groundwater contributions to the Salmon River system mediated via aquitards in the Clayton Upland area and headwaters of the Salmon River have not been directly implemented in the groundwater budget.

5.2 Recommendations to Address Knowledge Gaps

Proper conceptual understanding and quantification of the large-scale inflows and outflows to the aquifer systems in the Hopington – Salmon River Area have significant policy implications (i.e. – development planning, water allocation and long term water management). Based on the improved conceptual understanding of the Hopington Aquifer – Salmon River Area developed during the groundwater budget study, practical recommendations to address knowledge gaps have been formulated. Similar to the data limitations, the recommendations have been developed at a scale appropriate for the groundwater budget study:

- With the recent introduction of provincial groundwater licensing as part of the *WSA*, annual reporting requirements of actual pumped volumes should be considered in order to provide better estimates of groundwater use in the area of interest and valuable feedback to the groundwater budget. The Township maintains a good quality database for ICI water users that are connected to the municipal network and this could be considered for private water users, for other jurisdictions or on a provincial level where possible.

- Irrigation method, annual cropping and livestock reporting should be considered to provide better estimates of actual evapotranspiration and associated recharge to aquifers to the area, which currently rely on coarse approximations and assumptions.
- A limitation of the current groundwater budget is that it is high level and does not account for local scale processes and flows in its calculations. The current study area and aquifers are in a relatively unique situation as there are located within the bounds of a previously constructed and calibrated numerical groundwater flow model. This study was based solely on the outputs and detailed characterization associated with the previously conducted average annual steady state model runs. To better estimate local scale processes and their responses to forcings, predictive model runs with or without a model update could be completed at timescales more relevant to the study goals. Many groundwater budgeting exercises are currently underway in British Columbia and the Salmon River watershed could act as a pilot study on how accurate and effective high level groundwater budgets are when compared to a more detailed numerical flow model.
- Additional continuous surface water monitoring locations should be implemented along the Salmon River in order to better quantify environmental baseflow conditions along the entire watercourse. As such, new monitoring locations should be chosen on the basis of how well they serve to verify potential groundwater-surface water interactions at prominent groundwater discharge zones (see point below) and at locations where instream environmental flow needs are most restrictive and/or sensitive to reductions in flow.
- Field verification of major groundwater discharge areas along the Salmon River should be performed and compared to the aquifer conceptual models to ensure that relevant hydrologic processes are captured and policy decisions are properly informed. Areas of particular interest include the headwaters of the Salmon River Watershed (in close proximity to Aldergrove AB and Aldergrove CD Aquifers), groundwater conditions in the Clayton Upland (area of relatively high topographic relief associated with the Clayton Aquifer), and shallow groundwater conditions in the Hopington AB Aquifer proximal to where the Salmon River flows. Potential field verification activities include site walkovers and flow measurements during low flow conditions, installation of shallow riverbank piezometers and seepage meters, or surface water profiling (thermal, conductivity / chloride, isotopes) to identify and / or confirm areas of significant groundwater discharge.
- Any observation wells or shallow piezometers that are part of concurrent or future studies in the area could be evaluated for inclusion into the long-term PGOWN.
- Additional observation wells provide important information to verify and feedback on the results of the groundwater budget analysis. Though specific siting of observation wells is a highly local procedure and out of the scope of this simplified study, if additional observation wells are to be considered they should prioritize aquifers that are important for instream environmental flow needs targets (Hopington AB Aquifer, Fort Langley Aquifer) or aquifers that are planned for large groundwater resource development that are not currently monitored. Selection of additional observation well locations should be conducted in consultation with the appropriate local governments and stakeholders.

6. SUMMARY

The Hopington – Salmon River Area groundwater budget provides a useful, high-level characterization of groundwater inflows and outflows for the seven aquifers that were analyzed. Of the seven aquifers, the Fort Langley Aquifer and Nicomekl Serpentine Aquifer qualitatively were assessed to have the greatest capacity for available groundwater and the Hopington AB Aquifer was assessed to have the greatest risk and vulnerability to environmental factors and overallocation. Further study should be completed to investigate the sustainability of future groundwater resource allocation and development in the area.

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APPENDIX A: GROUNDWATER FLOW BUDGETING MONTHLY RESULTS

Hopington AB Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	403062	364056	403062	390060	403062	390060	403062	403062	390060	403062	390060	403062	4745730
GW inflow from Aldergrove CD (m^3)	60357	54516	60357	58410	60357	58410	60357	60357	58410	60357	58410	60357	710655
GW inflow from Beaver River (m^3)	112561	101668	112561	108930	112561	108930	112561	112561	108930	112561	108930	112561	1325315
SW inflow to aquifer (m^3) - Nicomekl R. / Bertrand Ck.	23793	21490	23793	23025	23793	23025	23793	23793	23025	23793	23025	23793	280138
Recharge (m^3)	1945623	1176467	791398	100816	18200	14881	9732	15572	181746	1055938	2041589	2104094	9456055
SW inflow from Salmon River system (m^3)	27807	25116	27807	26910	27807	26910	27807	27807	26910	27807	26910	27807	327405
TOTAL	2573202	1743313	1418977	708151.2	645779.1	622216.3	637311.8	643151.3	789080.5	1683517	2648924	2731674	16845298

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	419833	379204	419833	406290	419833	406290	419833	419833	406290	419833	406290	419833	4943195
GW outflow to Aldergrove CD (m^3)	32705	29540	32705	31650	32705	31650	32705	32705	31650	32705	31650	32705	385075
GW outflow to West of Aldergrove (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW outflow from pumping - Private minor users (m^3)	131451	128378	126947	135320	157396	163194	167052	151159	153300	136155	133683	135445	1719480
GW outflow to SW (m^3) - Nicomekl R. / Bertrand Ck.	95979	92683	88955	80645	73011	69776	72763	72223	69954	75653	86853	104129	982623
GW outflow to Salmon River System (m^3)	862707	802493	777964	708850	648964	620913	646961	642591	622351	670342	759080	900741	8663956
TOTAL	1553153	1441761	1456882	1372894	1342387	1301963	1349793	1328989	1293684	1345167	1427695	1603331	16817699
SURPLUS/ DEFICIT (m^3)	1020049	301552	-37905	-664743	-696607	-679747	-712481	-685838	-504604	338351	1221228	1128342	27599
Equivalent GWL Change Across Aquifer (m)	0.43	0.13	-0.02	-0.28	-0.29	-0.29	-0.30	-0.29	-0.21	0.14	0.51	0.47	0.01
Cumulative GWL Change Across Aquifer (m)	0.43	0.55	0.54	0.26	-0.03	-0.32	-0.62	-0.90	-1.12	-0.97	-0.46	0.01	

Hopington AB Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	403062	364056	403062	390060	403062	390060	403062	403062	390060	403062	390060	403062	4745730
GW inflow from Aldergrove CD (m^3)	60357	54516	60357	58410	60357	58410	60357	60357	58410	60357	58410	60357	710655
GW inflow from Beaver River (m^3)	112561	101668	112561	108930	112561	108930	112561	112561	108930	112561	108930	112561	1325315
SW inflow to aquifer (m^3) - Nicomekl R. / Bertrand Ck.	23793	21490	23793	23025	23793	23025	23793	23793	23025	23793	23025	23793	280138
Recharge (m^3)	768322	470303	257711	0	0	0	0	0	0	0	0	1508709	3005045
SW inflow from Salmon River system (m^3)	27807	25116	27807	26910	27807	26910	27807	27807	26910	27807	26910	27807	327405
TOTAL	1395902	1037149	885290	607335	627580	607335	627580	627580	607335	627580	607335	2136288	10394288

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	419833	379204	419833	406290	419833	406290	419833	419833	406290	419833	406290	419833	4943195
GW outflow to Aldergrove CD (m^3)	32705	29540	32705	31650	32705	31650	32705	32705	31650	32705	31650	32705	385075
GW outflow to West of Aldergrove (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW outflow from pumping - Private minor users (m^3)	131451	128378	126947	135320	157396	163194	167052	151159	153300	136155	133683	135445	1719480
GW outflow to SW (m^3) - Nicomekl R. / Bertrand Ck.	104979	71624	80462	73113	72477	69556	72551	72094	69716	72690	69874	72990	902125
GW outflow to Salmon River System (m^3)	952707	632106	709249	647910	644646	619131	645241	641549	620428	646368	621708	648795	8029839
TOTAL	1652153	1250316	1379674	1304422	1337535	1299961	1347861	1327819	1291524	1318229	1273345	1320246	16103084
SURPLUS/ DEFICIT (m^3)	-256251	-213167	-494384	-697087	-709955	-692626	-720281	-700240	-684189	-690649	-666010	816043	-5708797
Equivalent GWL Change Across Aquifer (m)	-0.11	-0.09	-0.21	-0.29	-0.30	-0.29	-0.30	-0.29	-0.29	-0.29	-0.28	0.34	-2.39
Cumulative GWL Change Across Aquifer (m)	-0.11	-0.20	-0.40	-0.70	-0.99	-1.28	-1.59	-1.88	-2.17	-2.46	-2.74	-2.39	

Hopington AB Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)													
INFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW inflow from surrounding aquitards (m^3)	403062	364056	403062	390060	403062	390060	403062	403062	390060	403062	390060	403062	4745730
GW inflow from Aldergrove CD (m^3)	60357	54516	60357	58410	60357	58410	60357	60357	58410	60357	58410	60357	710655
GW inflow from Beaver River (m^3)	112561	101668	112561	108930	112561	108930	112561	112561	108930	112561	108930	112561	1325315
SW inflow to aquifer (m^3) - Nicomekl R. / Bertrand Ck.	23793	21490	23793	23025	23793	23025	23793	23793	23025	23793	23025	23793	280138
Recharge (m^3)	3795035	1427066	1449180	0	0	0	0	0	326559	1758965	3284328	3270253	15311385
SW inflow from Salmon River system (m^3)	27807	25116	27807	26910	27807	26910	27807	27807	26910	27807	26910	27807	327405
TOTAL	4422615	1993912	2076759	607335	627580	607335	627580	627580	933894	2386545	3891663	3897832	22700628

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)													
OUTFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW outflow to surrounding aquitards (m^3)	419833	379204	419833	406290	419833	406290	419833	419833	406290	419833	406290	419833	4943195
GW outflow to Aldergrove CD (m^3)	32705	29540	32705	31650	32705	31650	32705	32705	31650	32705	31650	32705	385075
GW outflow to West of Aldergrove (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW outflow from pumping - Private minor users (m^3)	131451	128378	126947	135320	157396	163194	167052	151159	153300	136155	133683	135445	1719480
GW outflow to SW (m^3) - Nicomekl R. / Bertrand Ck.	131479	116837	89466	91421	69731	69968	72489	72104	69715	78078	98089	122949	1082326
GW outflow to Salmon River System (m^3)	1212707	997925	782104	796043	622426	622464	644742	641624	620417	689965	849991	1053010	9533417
TOTAL	1938653	1661348	1461534	1470863	1312569	1303706	1347299	1327903	1291512	1367214	1529842	1774420	17786863
SURPLUS/ DEFICIT (m^3)	2483962	332564	615225	-863528	-684989	-696371	-719719	-700324	-357618	1019330	2361821	2123412	4913764
Equivalent GWL Change Across Aquifer (m)	1.04	0.14	0.26	-0.36	-0.29	-0.29	-0.30	-0.29	-0.15	0.43	0.99	0.89	2.06
Cumulative GWL Change Across Aquifer (m)	1.04	1.18	1.44	1.08	0.79	0.50	0.20	-0.10	-0.25	0.18	1.17	2.06	

Fort Langley Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)													
INFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW inflow from surrounding aquitards (m^3)	400210	361480	400210	387300	400210	387300	400210	400210	387300	400210	387300	400210	4712150
Recharge (m^3)	447305	270473	181945	23178	4184	3421	2237	3580	41784	242763	469368	483738	2173977
SW inflow from Fraser River (m^3)	15004	13552	15004	14520	15004	14520	15004	15004	14520	15004	14520	15004	176660
TOTAL	862519	645505	597159	424998	419398	405241	417451	418794	443604	657977	871188	898952	7062787

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)													
OUTFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW outflow to Fraser River (m^3)	334042	323204	309781	293301	266311	253839	261378	260664	257463	272582	312444	359744	3504751
GW outflow from pumping - Muni - Ft. Langley 2 (m^3)	214829	209807	207469	221152	257231	266707	273013	247039	250538	222518	218477	221357	2810138
GW outflow from pumping - Private minor users (m^3)	11022	10764	10644	11346	13197	13684	14007	12674	12854	11416	11209	11357	144175
GW outflow to Salmon River (m^3)	59876	52635	51410	48825	45200	43188	44495	44393	43705	46096	51560	58548	589931
TOTAL	619768	596410	579305	574624	581940	577417	592893	564770	564559	552613	593689	651006	7048995
SURPLUS/ DEFICIT (m^3)	242750	49095	17854	-149626	-162541	-172176	-175442	-145976	-120956	105365	277499	247946	13791
Equivalent GWL Change Across Aquifer (m)	0.33	0.07	0.02	-0.21	-0.22	-0.24	-0.24	-0.20	-0.17	0.15	0.38	0.34	0.02
Cumulative GWL Change Across Aquifer (m)	0.33	0.40	0.43	0.22	0.00	-0.24	-0.48	-0.68	-0.85	-0.70	-0.32	0.02	

Fort Langley Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	400210	361480	400210	387300	400210	387300	400210	400210	387300	400210	387300	400210	4712150
Recharge (m^3)	247211	151322	82920	0	0	0	0	0	0	0	0	485433	966885
SW inflow from Fraser River (m^3)	15004	13552	15004	14520	15004	14520	15004	15004	14520	15004	14520	15004	176660
TOTAL	662425	526354	498134	401820	415214	401820	415214	415214	401820	415214	401820	900647	5855695

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to Fraser River (m^3)	411917	304822	339596	314011	307447	292465	302357	301364	296330	305110	301033	311307	3787759
GW outflow from pumping - Muni - Ft. Langley 2 (m^3)	214829	209807	207469	221152	257231	266707	273013	247039	250538	222518	218477	221357	2810138
GW outflow from pumping - Private minor users (m^3)	11022	10764	10644	11346	13197	13684	14007	12674	12854	11416	11209	11357	144175
GW outflow to Salmon River (m^3)	71876	43574	48544	44888	43952	41810	43224	43083	42362	43618	43034	44503	554468
TOTAL	709644	568967	606254	591397	621828	614666	632602	604160	602084	582661	573753	588524	7296540
SURPLUS/ DEFICIT (m^3)	-47220	-42613	-108120	-189577	-206614	-212846	-217388	-188946	-200264	-167447	-171933	312123	-1440845
Equivalent GWL Change Across Aquifer (m)	-0.06	-0.06	-0.15	-0.26	-0.28	-0.29	-0.30	-0.26	-0.28	-0.23	-0.24	0.43	-1.98
Cumulative GWL Change Across Aquifer (m)	-0.06	-0.12	-0.27	-0.53	-0.82	-1.11	-1.41	-1.67	-1.95	-2.18	-2.41	-1.98	

Fort Langley Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	400210	361480	400210	387300	400210	387300	400210	400210	387300	400210	387300	400210	4712150
Recharge (m^3)	899612	338286	343528	0	0	0	0	0	77411	416962	778549	775213	3629560
SW inflow from Fraser River (m^3)	15004	13552	15004	14520	15004	14520	15004	15004	14520	15004	14520	15004	176660
TOTAL	1314826	713318	758742	401820	415214	401820	415214	415214	479231	832176	1180369	1190427	8518370

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to Fraser River (m^3)	448917	439441	346839	369208	293648	295915	301495	301579	296276	322057	388007	459871	4263254
GW outflow from pumping - Muni - Ft. Langley 2 (m^3)	214829	209807	207469	221152	257231	266707	273013	247039	250538	222518	218477	221357	2810138
GW outflow from pumping - Private minor users (m^3)	11022	10764	10644	11346	13197	13684	14007	12674	12854	11416	11209	11357	144175
GW outflow to Salmon River (m^3)	71876	62805	49579	52774	41980	42303	43101	43113	42355	46039	55459	65726	617110
TOTAL	746644	722818	614532	654480	606057	618609	631616	604406	602022	602029	673151	758312	7834677
SURPLUS/ DEFICIT (m^3)	568182	-9500	144210	-252660	-190843	-216789	-216402	-189192	-122792	230147	507218	432115	683693
Equivalent GWL Change Across Aquifer (m)	0.78	-0.01	0.20	-0.35	-0.26	-0.30	-0.30	-0.26	-0.17	0.32	0.70	0.59	0.94
Cumulative GWL Change Across Aquifer (m)	0.78	0.77	0.97	0.62	0.36	0.06	-0.24	-0.50	-0.67	-0.35	0.35	0.94	

Beaver River Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SW inflow from Nathan Creek (m^3)	40381	36473	40381	39078	40381	39078	40381	40381	39078	40381	39078	40381	475449
GW inflow from surrounding aquitards (m^3)	1808261	1633268	1808261	1749930	1808261	1749930	1808261	1808261	1749930	1808261	1749930	1808261	21290815
GW inflow from Aldergrove CD (m^3)	270072	243936	270072	261360	270072	261360	270072	270072	261360	270072	261360	270072	3179880
TOTAL	2118714	1913677	2118714	2050368	2118714	2050368	2118714	2118714	2050368	2118714	2050368	2118714	24946144

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1124339	1015532	1124339	1088070	1124339	1088070	1124339	1124339	1088070	1124339	1088070	1124339	13238185
GW outflow to Hopington AB (m^3)	112530	101640	112530	108900	112530	108900	112530	112530	108900	112530	108900	112530	1324950
GW outflow to Aldergrove CD (m^3)	370977	335076	370977	359010	370977	359010	370977	370977	359010	370977	359010	370977	4367955
GW outflow to Nathan Creek (m^3)	413341	373417	412863	399773	412729	399465	411931	411224	398625	412378	399724	413063	4858531
GW outflow from pumping - ICI - W. Creek Springs (m^3)	83350	83576	89154	92865	95438	109123	127285	113743	101019	90607	86233	83928	1156320
GW outflow from pumping - Private minor users (m^3)													
TOTAL	2104537	1909240	2109863	2048618	2116012	2064568	2147062	2132813	2055624	2110831	2041937	2104836	24945941
SURPLUS/ DEFICIT (m^3)	14177	4436	8851	1750	2701	-14200	-28348	-14099	-5256	7882	8431	13878	203
Equivalent GWL Change Across Aquifer (m)	0.40	0.12	0.25	0.05	0.08	-0.40	-0.79	-0.39	-0.15	0.22	0.24	0.39	0.01
Cumulative GWL Change Across Aquifer (m)	0.40	0.52	0.77	0.82	0.89	0.50	-0.30	-0.69	-0.84	-0.62	-0.38	0.01	

Beaver River Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SW inflow from Nathan Creek (m^3)	40381	36473	40381	39078	40381	39078	40381	40381	39078	40381	39078	40381	475449
GW inflow from surrounding aquitards (m^3)	1808261	1633268	1808261	1749930	1808261	1749930	1808261	1808261	1749930	1808261	1749930	1808261	21290815
GW inflow from Aldergrove CD (m^3)	270072	243936	270072	261360	270072	261360	270072	270072	261360	270072	261360	270072	3179880
TOTAL	2118714	1913677	2118714	2050368	2118714	2050368	2118714	2118714	2050368	2118714	2050368	2118714	24946144

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1124339	1015532	1124339	1088070	1124339	1088070	1124339	1124339	1088070	1124339	1088070	1124339	13238185
GW outflow to Hopington AB (m^3)	112530	101640	112530	108900	112530	108900	112530	112530	108900	112530	108900	112530	1324950
GW outflow to Aldergrove CD (m^3)	370977	335076	370977	359010	370977	359010	370977	370977	359010	370977	359010	370977	4367955
GW outflow to Nathan Creek (m^3)	413341	373417	412863	399773	412729	399465	411931	411224	398625	412378	399724	413063	4858531
GW outflow from pumping - ICI - W. Creek Springs (m^3)	83350	83576	89154	92865	95438	109123	127285	113743	101019	90607	86233	83928	1156320
TOTAL	2104537	1909240	2109863	2048618	2116012	2064568	2147062	2132813	2055624	2110831	2041937	2104836	24945941
SURPLUS/ DEFICIT (m^3)	14177	4436	8851	1750	2701	-14200	-28348	-14099	-5256	7882	8431	13878	203
Equivalent GWL Change Across Aquifer (m)	0.40	0.12	0.25	0.05	0.08	-0.40	-0.79	-0.39	-0.15	0.22	0.24	0.39	0.01
Cumulative GWL Change Across Aquifer (m)	0.40	0.52	0.77	0.82	0.89	0.50	-0.30	-0.69	-0.84	-0.62	-0.38	0.01	

Beaver River Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SW inflow from Nathan Creek (m^3)	40381	36473	40381	39078	40381	39078	40381	40381	39078	40381	39078	40381	475449
GW inflow from surrounding aquitards (m^3)	1808261	1633268	1808261	1749930	1808261	1749930	1808261	1808261	1749930	1808261	1749930	1808261	21290815
GW inflow from Aldergrove CD (m^3)	270072	243936	270072	261360	270072	261360	270072	270072	261360	270072	261360	270072	3179880
TOTAL	2118714	1913677	2118714	2050368	2118714	2050368	2118714	2118714	2050368	2118714	2050368	2118714	24946144

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1124339	1015532	1124339	1088070	1124339	1088070	1124339	1124339	1088070	1124339	1088070	1124339	13238185
GW outflow to Hopington AB (m^3)	112530	101640	112530	108900	112530	108900	112530	112530	108900	112530	108900	112530	1324950
GW outflow to Aldergrove CD (m^3)	370977	335076	370977	359010	370977	359010	370977	370977	359010	370977	359010	370977	4367955
GW outflow to Nathan Creek (m^3)	413341	373417	412863	399773	412729	399465	411931	411224	398625	412378	399724	413063	4858531
GW outflow from pumping - ICI - W. Creek Springs (m^3)	83350	83576	89154	92865	95438	109123	127285	113743	101019	90607	86233	83928	1156320
GW outflow from pumping - Private minor users (m^3)													
TOTAL	2104537	1909240	2109863	2048618	2116012	2064568	2147062	2132813	2055624	2110831	2041937	2104836	24945941
SURPLUS/ DEFICIT (m^3)	14177	4436	8851	1750	2701	-14200	-28348	-14099	-5256	7882	8431	13878	203
Equivalent GWL Change Across Aquifer (m)	0.40	0.12	0.25	0.05	0.08	-0.40	-0.79	-0.39	-0.15	0.22	0.24	0.39	0.01
Cumulative GWL Change Across Aquifer (m)	0.40	0.52	0.77	0.82	0.89	0.50	-0.30	-0.69	-0.84	-0.62	-0.38	0.01	

West of Aldergrove Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	2411707	2178316	2411707	2333910	2411707	2333910	2411707	2411707	2333910	2411707	2333910	2411707	28395905
GW inflow from Abbotsford (m^3)	21359	19292	21359	20670	21359	20670	21359	21359	20670	21359	20670	21359	251485
GW inflow from Brookswood (m^3)	12896	11648	12896	12480	12896	12480	12896	12896	12480	12896	12480	12896	151840
GW inflow from Hopington AB (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW inflow from Hopington C (m^3)	233089	210532	233089	225570	233089	225570	233089	233089	225570	233089	225570	233089	2744435
GW inflow from South of Hopington (m^3)	13702	12376	13702	13260	13702	13260	13702	13702	13260	13702	13260	13702	161330
TOTAL	2703231	2441628	2703231	2616030	2703231	2616030	2703231	2703231	2616030	2703231	2616030	2703231	31828365

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2344344	2117472	2344344	2268720	2344344	2268720	2344344	2344344	2268720	2344344	2268720	2344344	27602760
GW outflow to Abbotsford (m^3)	174003	157164	174003	168390	174003	168390	174003	174003	168390	174003	168390	174003	2048745
GW outflow to Hopington C (m^3)	45942	41496	45942	44460	45942	44460	45942	45942	44460	45942	44460	45942	540930
GW outflow to South of Hopington (m^3)	1829	1652	1829	1770	1829	1770	1829	1829	1770	1829	1770	1829	21535
GW outflow to Langley Upland Intertill (m^3)	3379	3052	3379	3270	3379	3270	3379	3379	3270	3379	3270	3379	39785
GW outflow to South of Murrayville B (m^3)	8339	7532	8339	8070	8339	8070	8339	8339	8070	8339	8070	8339	98185
GW outflow from pumping - Muni - Murrayville 2 (m^3)	22920	25929	28330	35525	41987	49580	59978	58956	48684	32984	25193	24360	454425
GW outflow from pumping - Muni - Tall Timbers (m^3)	2022	1546	1609	1697	2013	3278	3246	1741	1709	1109	1551	1475	22995
GW outflow from pumping - Muni - Acadia 1 (m^3)	501	525	492	596	719	1131	1537	1238	743	567	551	526	9125
GW outflow - ICI - Britco, Poppy Est., Spring Valley (m^3)	71379	71572	76349	79528	81731	93451	109004	97407	86510	77594	73848	71874	990245
GW outflow from pumping - Private minor users (m^3)													
TOTAL	2674658	2427939	2684616	2612026	2704285	2642120	2751600	2737178	2632325	2690090	2595823	2676070	31828730
SURPLUS/ DEFICIT (m^3)	28573	13689	18615	4004	-1054	-26090	-48369	-33947	-16295	13141	20207	27161	-365
Equivalent GWL Change Across Aquifer (m)	0.22	0.10	0.14	0.03	-0.01	-0.20	-0.36	-0.26	-0.12	0.10	0.15	0.20	0.00
Cumulative GWL Change Across Aquifer (m)	0.22	0.32	0.46	0.49	0.48	0.28	-0.08	-0.34	-0.46	-0.36	-0.21	0.00	

West of Aldergrove Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	2411707	2178316	2411707	2333910	2411707	2333910	2411707	2411707	2333910	2411707	2333910	2411707	28395905
GW inflow from Abbotsford (m^3)	21359	19292	21359	20670	21359	20670	21359	21359	20670	21359	20670	21359	251485
GW inflow from Brookswood (m^3)	12896	11648	12896	12480	12896	12480	12896	12896	12480	12896	12480	12896	151840
GW inflow from Hopington AB (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW inflow from Hopington C (m^3)	233089	210532	233089	225570	233089	225570	233089	233089	225570	233089	225570	233089	2744435
GW inflow from South of Hopington (m^3)	13702	12376	13702	13260	13702	13260	13702	13702	13260	13702	13260	13702	161330
TOTAL	2703231	2441628	2703231	2616030	2703231	2616030	2703231	2703231	2616030	2703231	2616030	2703231	31828365

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2344344	2117472	2344344	2268720	2344344	2268720	2344344	2344344	2268720	2344344	2268720	2344344	27602760
GW outflow to Abbotsford (m^3)	174003	157164	174003	168390	174003	168390	174003	174003	168390	174003	168390	174003	2048745
GW outflow to Hopington C (m^3)	45942	41496	45942	44460	45942	44460	45942	45942	44460	45942	44460	45942	540930
GW outflow to South of Hopington (m^3)	1829	1652	1829	1770	1829	1770	1829	1829	1770	1829	1770	1829	21535
GW outflow to Langley Upland Intertill (m^3)	3379	3052	3379	3270	3379	3270	3379	3379	3270	3379	3270	3379	39785
GW outflow to South of Murrayville B (m^3)	8339	7532	8339	8070	8339	8070	8339	8339	8070	8339	8070	8339	98185
GW outflow from pumping - Muni - Murrayville 2 (m^3)	22920	25929	28330	35525	41987	49580	59978	58956	48684	32984	25193	24360	454425
GW outflow from pumping - Muni - Tall Timbers (m^3)	2022	1546	1609	1697	2013	3278	3246	1741	1709	1109	1551	1475	22995
GW outflow from pumping - Muni - Acadia 1 (m^3)	501	525	492	596	719	1131	1537	1238	743	567	551	526	9125
GW outflow - ICI - Britco, Poppy Est., Spring Valley (m^3)	71379	71572	76349	79528	81731	93451	109004	97407	86510	77594	73848	71874	990245
GW outflow from pumping - Private minor users (m^3)													
TOTAL	2674658	2427939	2684616	2612026	2704285	2642120	2751600	2737178	2632325	2690090	2595823	2676070	31828730
SURPLUS/ DEFICIT (m^3)	28573.4	13688.62	18615.22	4004.059	-1053.73	-26089.8	-48369.1	-33947.1	-16295.5	13141.41	20206.57	27160.84	-365
Equivalent GWL Change Across Aquifer (m)	0.22	0.10	0.14	0.03	-0.01	-0.20	-0.36	-0.26	-0.12	0.10	0.15	0.20	0.00
Cumulative GWL Change Across Aquifer (m)	0.22	0.32	0.46	0.49	0.48	0.28	-0.08	-0.34	-0.46	-0.36	-0.21	0.00	

West of Aldergrove Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	2411707	2178316	2411707	2333910	2411707	2333910	2411707	2411707	2333910	2411707	2333910	2411707	28395905
GW inflow from Abbotsford (m^3)	21359	19292	21359	20670	21359	20670	21359	21359	20670	21359	20670	21359	251485
GW inflow from Brookswood (m^3)	12896	11648	12896	12480	12896	12480	12896	12896	12480	12896	12480	12896	151840
GW inflow from Hopington AB (m^3)	10478	9464	10478	10140	10478	10140	10478	10478	10140	10478	10140	10478	123370
GW inflow from Hopington C (m^3)	233089	210532	233089	225570	233089	225570	233089	233089	225570	233089	225570	233089	2744435
GW inflow from South of Hopington (m^3)	13702	12376	13702	13260	13702	13260	13702	13702	13260	13702	13260	13702	161330
TOTAL	2703231	2441628	2703231	2616030	2703231	2616030	2703231	2703231	2616030	2703231	2616030	2703231	31828365

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2344344	2117472	2344344	2268720	2344344	2268720	2344344	2344344	2268720	2344344	2268720	2344344	27602760
GW outflow to Abbotsford (m^3)	174003	157164	174003	168390	174003	168390	174003	174003	168390	174003	168390	174003	2048745
GW outflow to Hopington C (m^3)	45942	41496	45942	44460	45942	44460	45942	45942	44460	45942	44460	45942	540930
GW outflow to South of Hopington (m^3)	1829	1652	1829	1770	1829	1770	1829	1829	1770	1829	1770	1829	21535
GW outflow to Langley Upland Intertill (m^3)	3379	3052	3379	3270	3379	3270	3379	3379	3270	3379	3270	3379	39785
GW outflow to South of Murrayville B (m^3)	8339	7532	8339	8070	8339	8070	8339	8339	8070	8339	8070	8339	98185
GW outflow from pumping - Muni - Murrayville 2 (m^3)	22920	25929	28330	35525	41987	49580	59978	58956	48684	32984	25193	24360	454425
GW outflow from pumping - Muni - Tall Timbers (m^3)	2022	1546	1609	1697	2013	3278	3246	1741	1709	1109	1551	1475	22995
GW outflow from pumping - Muni - Acadia 1 (m^3)	501	525	492	596	719	1131	1537	1238	743	567	551	526	9125
GW outflow - ICI - Britco, Poppy Est., Spring Valley (m^3)	71379	71572	76349	79528	81731	93451	109004	97407	86510	77594	73848	71874	990245
GW outflow from pumping - Private minor users (m^3)													
TOTAL	2674658	2427939	2684616	2612026	2704285	2642120	2751600	2737178	2632325	2690090	2595823	2676070	31828730
SURPLUS/ DEFICIT (m^3)	28573	13689	18615	4004	-1054	-26090	-48369	-33947	-16295	13141	20207	27161	-365
Equivalent GWL Change Across Aquifer (m)	0.22	0.10	0.14	0.03	-0.01	-0.20	-0.36	-0.26	-0.12	0.10	0.15	0.20	0.00
Cumulative GWL Change Across Aquifer (m)	0.22	0.32	0.46	0.49	0.48	0.28	-0.08	-0.34	-0.46	-0.36	-0.21	0.00	

South of Murrayville AC Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	1719074	1552712	1719074	1663620	1719074	1663620	1719074	1719074	1663620	1719074	1663620	1719074	20240710
GW inflow from South of Murrayville B aquifer (m^3)	2093	1890	2093	2025	2093	2025	2093	2093	2025	2093	2025	2093	24638
GW inflow from Langley Upland Intertill aquifer (m^3)	67208	60704	67208	65040	67208	65040	67208	67208	65040	67208	65040	67208	791320
TOTAL	1788375	1615306	1788375	1730685	1788375	1730685	1788375	1788375	1730685	1788375	1730685	1788375	21056668

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1754972	1585136	1754972	1698360	1754972	1698360	1754972	1754972	1698360	1754972	1698360	1754972	20663380
GW outflow to South of Murrayville B aquifer (m^3)	372	336	372	360	372	360	372	372	360	372	360	372	4380
GW outflow to Langley Upland Intertill aquifer (m^3)	19313	17444	19313	18690	19313	18690	19313	19313	18690	19313	18690	19313	227395
GW outflow from pumping - Muni - Murrayville 1 (m^3)	8223	9613	9428	11695	16098	19686	21452	18684	15002	11780	9606	10063	161330
TOTAL	1782880	1612529	1784085	1729105	1790755	1737096	1796109	1793341	1732412	1786437	1727016	1784720	21056485
SURPLUS/ DEFICIT (m^3)	5494	2777	4290	1580	-2381	-6411	-7735	-4966	-1727	1938	3669	3654	183
Equivalent GWL Change Across Aquifer (m)	0.07	0.04	0.06	0.02	-0.03	-0.09	-0.11	-0.07	-0.02	0.03	0.05	0.05	0.00
Cumulative GWL Change Across Aquifer (m)	0.07	0.11	0.17	0.19	0.16	0.07	-0.03	-0.10	-0.12	-0.10	-0.05	0.00	

South of Murrayville AC Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	1719074	1552712	1719074	1663620	1719074	1663620	1719074	1719074	1663620	1719074	1663620	1719074	20240710
GW inflow from South of Murrayville B aquifer (m^3)	2093	1890	2093	2025	2093	2025	2093	2093	2025	2093	2025	2093	24638
GW inflow from Langley Upland Intertill aquifer (m^3)	67208	60704	67208	65040	67208	65040	67208	67208	65040	67208	65040	67208	791320
TOTAL	1788375	1615306	1788375	1730685	1788375	1730685	1788375	1788375	1730685	1788375	1730685	1788375	21056668

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1754972	1585136	1754972	1698360	1754972	1698360	1754972	1754972	1698360	1754972	1698360	1754972	20663380
GW outflow to South of Murrayville B aquifer (m^3)	372	336	372	360	372	360	372	372	360	372	360	372	4380
GW outflow to Langley Upland Intertill aquifer (m^3)	19313	17444	19313	18690	19313	18690	19313	19313	18690	19313	18690	19313	227395
GW outflow from pumping - Muni - Murrayville 1 (m^3)	8223	9613	9428	11695	16098	19686	21452	18684	15002	11780	9606	10063	161330
TOTAL	1782880	1612529	1784085	1729105	1790755	1737096	1796109	1793341	1732412	1786437	1727016	1784720	21056485
SURPLUS/ DEFICIT (m^3)	5494	2777	4290	1580	-2381	-6411	-7735	-4966	-1727	1938	3669	3654	183
Equivalent GWL Change Across Aquifer (m)	0.07	0.04	0.06	0.02	-0.03	-0.09	-0.11	-0.07	-0.02	0.03	0.05	0.05	0.00
Cumulative GWL Change Across Aquifer (m)	0.07	0.11	0.17	0.19	0.16	0.07	-0.03	-0.10	-0.12	-0.10	-0.05	0.00	

South of Murrayville AC Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)													
INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	1719074	1552712	1719074	1663620	1719074	1663620	1719074	1719074	1663620	1719074	1663620	1719074	20240710
GW inflow from South of Murrayville B aquifer (m^3)	2093	1890	2093	2025	2093	2025	2093	2093	2025	2093	2025	2093	24638
GW inflow from Langley Upland Intertill aquifer (m^3)	67208	60704	67208	65040	67208	65040	67208	67208	65040	67208	65040	67208	791320
TOTAL	1788375	1615306	1788375	1730685	1788375	1730685	1788375	1788375	1730685	1788375	1730685	1788375	21056668

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)													
OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1754972	1585136	1754972	1698360	1754972	1698360	1754972	1754972	1698360	1754972	1698360	1754972	20663380
GW outflow to South of Murrayville B aquifer (m^3)	372	336	372	360	372	360	372	372	360	372	360	372	4380
GW outflow to Langley Upland Intertill aquifer (m^3)	19313	17444	19313	18690	19313	18690	19313	19313	18690	19313	18690	19313	227395
GW outflow from pumping - Muni - Murrayville 1 (m^3)	8223	9613	9428	11695	16098	19686	21452	18684	15002	11780	9606	10063	161330
TOTAL	1782880	1612529	1784085	1729105	1790755	1737096	1796109	1793341	1732412	1786437	1727016	1784720	21056485
SURPLUS/ DEFICIT (m^3)	5494	2777	4290	1580	-2381	-6411	-7735	-4966	-1727	1938	3669	3654	183
Equivalent GWL Change Across Aquifer (m)	0.07	0.04	0.06	0.02	-0.03	-0.09	-0.11	-0.07	-0.02	0.03	0.05	0.05	0.00
Cumulative GWL Change Across Aquifer (m)	0.07	0.11	0.17	0.19	0.16	0.07	-0.03	-0.10	-0.12	-0.10	-0.05	0.00	

Salmon River Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)													
INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)													
OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
SURPLUS/ DEFICIT (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumulative GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	

Salmon River Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)													
INFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW inflow from surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)													
OUTFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW outflow to surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
GW outflow from pumping - Private minor users (m^3)													
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
SURPLUS/ DEFICIT (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumulative GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	

Salmon River Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)													
INFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW inflow from surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)													
OUTFLOW SOURCE / TYPE	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**ANNUAL**
GW outflow to surrounding aquitards (m^3)	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
GW outflow from pumping - Private minor users (m^3)													
TOTAL	1123967	1015196	1123967	1087710	1123967	1087710	1123967	1123967	1087710	1123967	1087710	1123967	13233805
SURPLUS/ DEFICIT (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumulative GWL Change Across Aquifer (m)	0	0	0	0	0	0	0	0	0	0	0	0	

Nicomekl Serpentine Aquifer – Average Year (1945-2012)

INFLOWS TO AQUIFER (AVERAGE YEAR - 1945-2012)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	3045874	2751112	3045874	2947620	3045874	2947620	3045874	3045874	2947620	3045874	2947620	3045874	35862710
GW inflow from boundary (m^3)	381393	344484	381393	369090	381393	369090	381393	381393	369090	381393	369090	381393	4490595
TOTAL	3427267	3095596	3427267	3316710	3427267	3316710	3427267	3427267	3316710	3427267	3316710	3427267	40353305

OUTFLOWS FROM AQUIFER (AVERAGE YEAR, 1945-2012)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2700379	2439052	2700379	2613270	2700379	2613270	2700379	2700379	2613270	2700379	2613270	2700379	31794785
GW outflow to boundary (m^3)	711388	642544	711388	688440	711388	688440	711388	711388	688440	711388	688440	711388	8376020
GW outflow from pumping - ICI - Trin. W. College (m^3)	13155	13191	14071	14657	15063	17223	20089	17952	15944	14300	13610	13246	182500
TOTAL	3424922	3094787	3425838	3316367	3426830	3318933	3431856	3429719	3317654	3426067	3315320	3425013	40353305
SURPLUS/ DEFICIT (m^3)	2345	809	1429	343	437	-2223	-4589	-2452	-944	1200	1390	2254	0
Equivalent GWL Change Across Aquifer (m)	0.03	0.01	0.02	0.00	0.01	-0.03	-0.06	-0.03	-0.01	0.02	0.02	0.03	0.00
Cumulative GWL Change Across Aquifer (m)	0.03	0.04	0.06	0.06	0.07	0.04	-0.02	-0.05	-0.06	-0.05	-0.03	0.00	

Nicomekl Serpentine Aquifer – Dry Year (1951)

INFLOWS TO AQUIFER (DRY YEAR - 1951)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	3045874	2751112	3045874	2947620	3045874	2947620	3045874	3045874	2947620	3045874	2947620	3045874	35862710
GW inflow from boundary (m^3)	381393	344484	381393	369090	381393	369090	381393	381393	369090	381393	369090	381393	4490595
TOTAL	3427267	3095596	3427267	3316710	3427267	3316710	3427267	3427267	3316710	3427267	3316710	3427267	40353305

OUTFLOWS FROM AQUIFER (DRY YEAR - 1951)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2700379	2439052	2700379	2613270	2700379	2613270	2700379	2700379	2613270	2700379	2613270	2700379	31794785
GW outflow to boundary (m^3)	711388	642544	711388	688440	711388	688440	711388	711388	688440	711388	688440	711388	8376020
GW outflow from pumping - ICI - Trin. W. College (m^3)	13155	13191	14071	14657	15063	17223	20089	17952	15944	14300	13610	13246	182500
GW outflow from pumping - Private minor users (m^3)													
TOTAL	3424922	3094787	3425838	3316367	3426830	3318933	3431856	3429719	3317654	3426067	3315320	3425013	40353305
SURPLUS/ DEFICIT (m^3)	2345	809	1429	343	437	-2223	-4589	-2452	-944	1200	1390	2254	0
Equivalent GWL Change Across Aquifer (m)	0.03	0.01	0.02	0.00	0.01	-0.03	-0.06	-0.03	-0.01	0.02	0.02	0.03	0.00
Cumulative GWL Change Across Aquifer (m)	0.03	0.04	0.06	0.06	0.07	0.04	-0.02	-0.05	-0.06	-0.05	-0.03	0.00	

Nicomekl Serpentine Aquifer – Wet Year (1971)

INFLOWS TO AQUIFER (WET YEAR - 1971)

INFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW inflow from surrounding aquitards (m^3)	3045874	2751112	3045874	2947620	3045874	2947620	3045874	3045874	2947620	3045874	2947620	3045874	35862710
GW inflow from boundary (m^3)	381393	344484	381393	369090	381393	369090	381393	381393	369090	381393	369090	381393	4490595
TOTAL	3427267	3095596	3427267	3316710	3427267	3316710	3427267	3427267	3316710	3427267	3316710	3427267	40353305

OUTFLOWS FROM AQUIFER (WET YEAR - 1971)

OUTFLOW SOURCE / TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GW outflow to surrounding aquitards (m^3)	2700379	2439052	2700379	2613270	2700379	2613270	2700379	2700379	2613270	2700379	2613270	2700379	31794785
GW outflow to boundary (m^3)	711388	642544	711388	688440	711388	688440	711388	711388	688440	711388	688440	711388	8376020
GW outflow from pumping - ICI - Trin. W. College (m^3)	13155	13191	14071	14657	15063	17223	20089	17952	15944	14300	13610	13246	182500
GW outflow from pumping - Private minor users (m^3)													
TOTAL	3424922	3094787	3425838	3316367	3426830	3318933	3431856	3429719	3317654	3426067	3315320	3425013	40353305
SURPLUS/ DEFICIT (m^3)	2345	809	1429	343	437	-2223	-4589	-2452	-944	1200	1390	2254	0
Equivalent GWL Change Across Aquifer (m)	0.03	0.01	0.02	0.00	0.01	-0.03	-0.06	-0.03	-0.01	0.02	0.02	0.03	0.00
Cumulative GWL Change Across Aquifer (m)	0.03	0.04	0.06	0.06	0.07	0.04	-0.02	-0.05	-0.06	-0.05	-0.03	0.00	

APPENDIX B: FIGURES FROM PREVIOUS REPORTS

Figures 26 – 30 from Golder Associates (2014) showing the model domain, grid and stratigraphy.

Figures E-3 – E-5 from Golder (2014) showing the locations of permeable units as interpreted by Golder (2005) as well as two representative cross-sections.

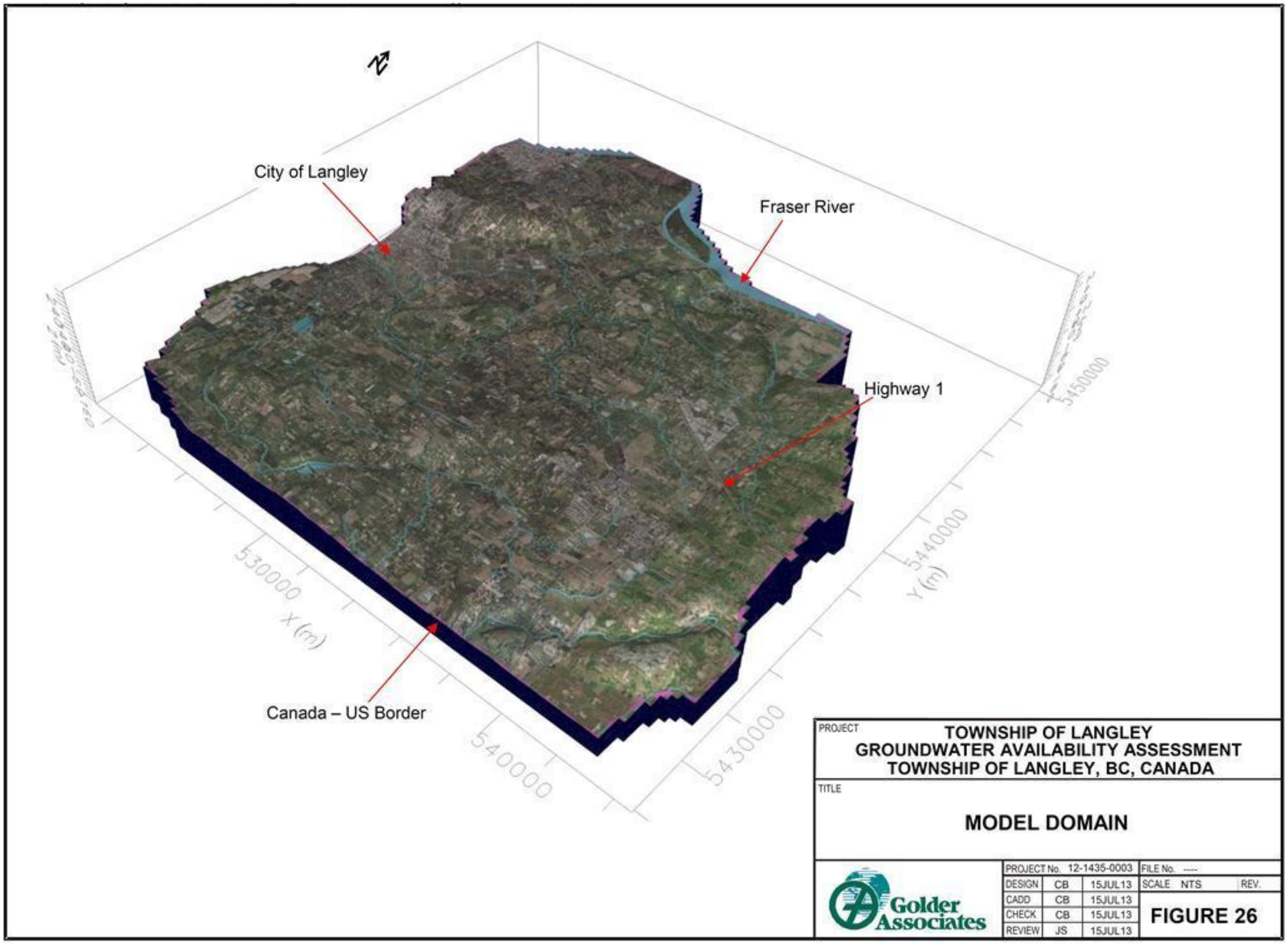

Figure B1 Groundwater model domain presented in the Golder Associates report (2014), Figure 26.

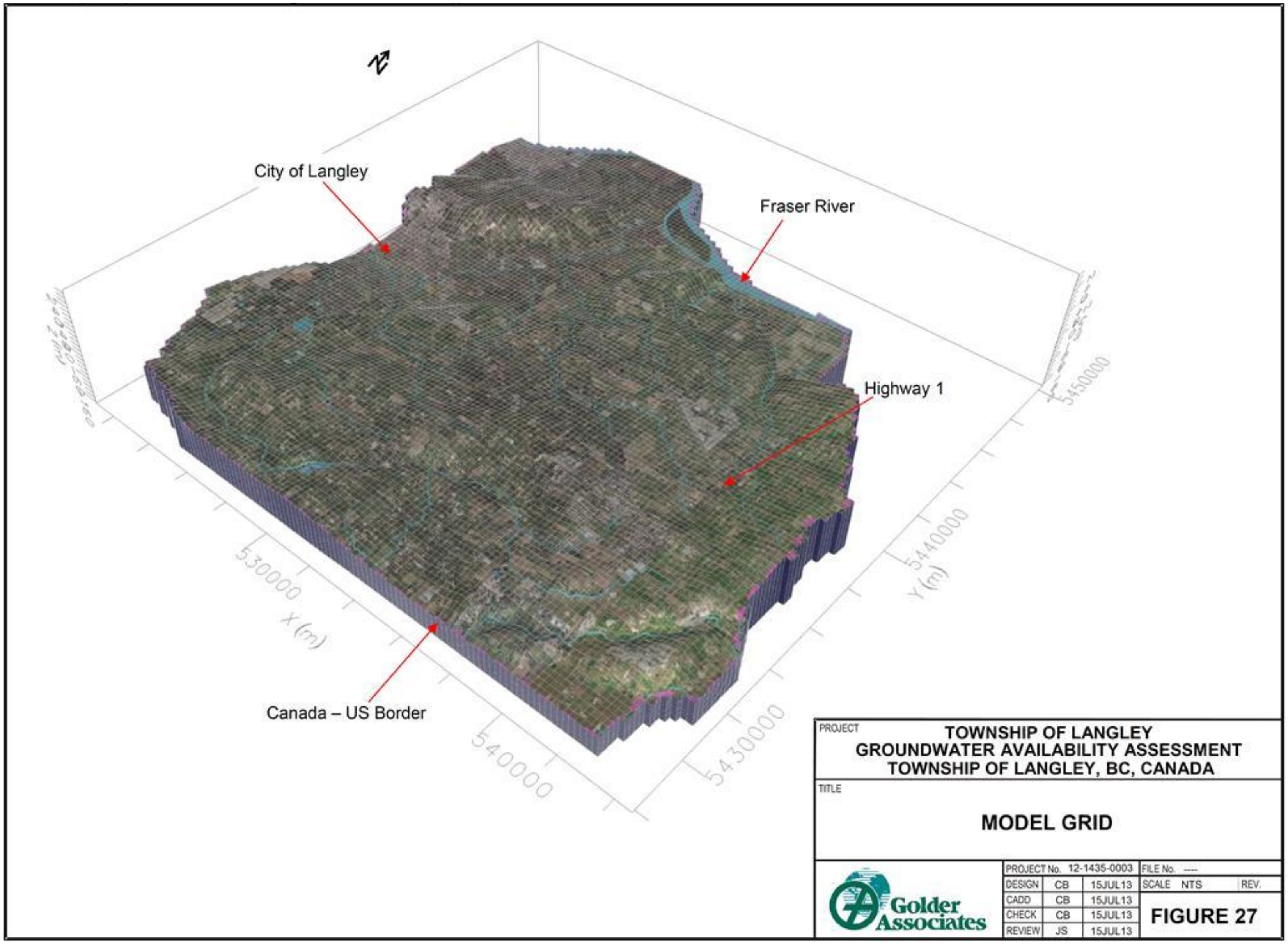

Figure B2 Groundwater model grid presented in the Golder Associates report (2014), Figure 27.

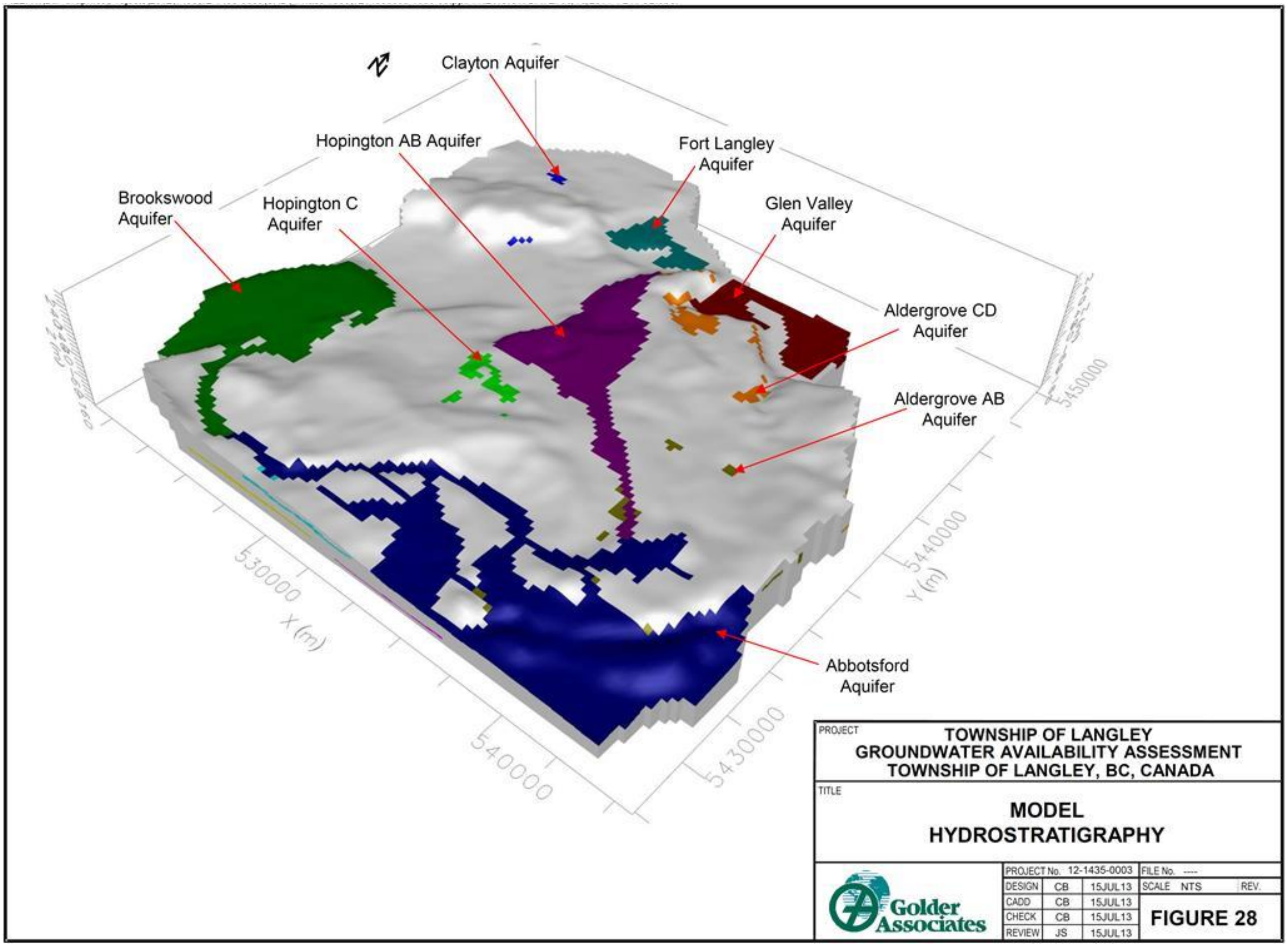

Figure B3 Groundwater model hydrostratigraphy presented in the Golder Associates report (2014), Figure 28.

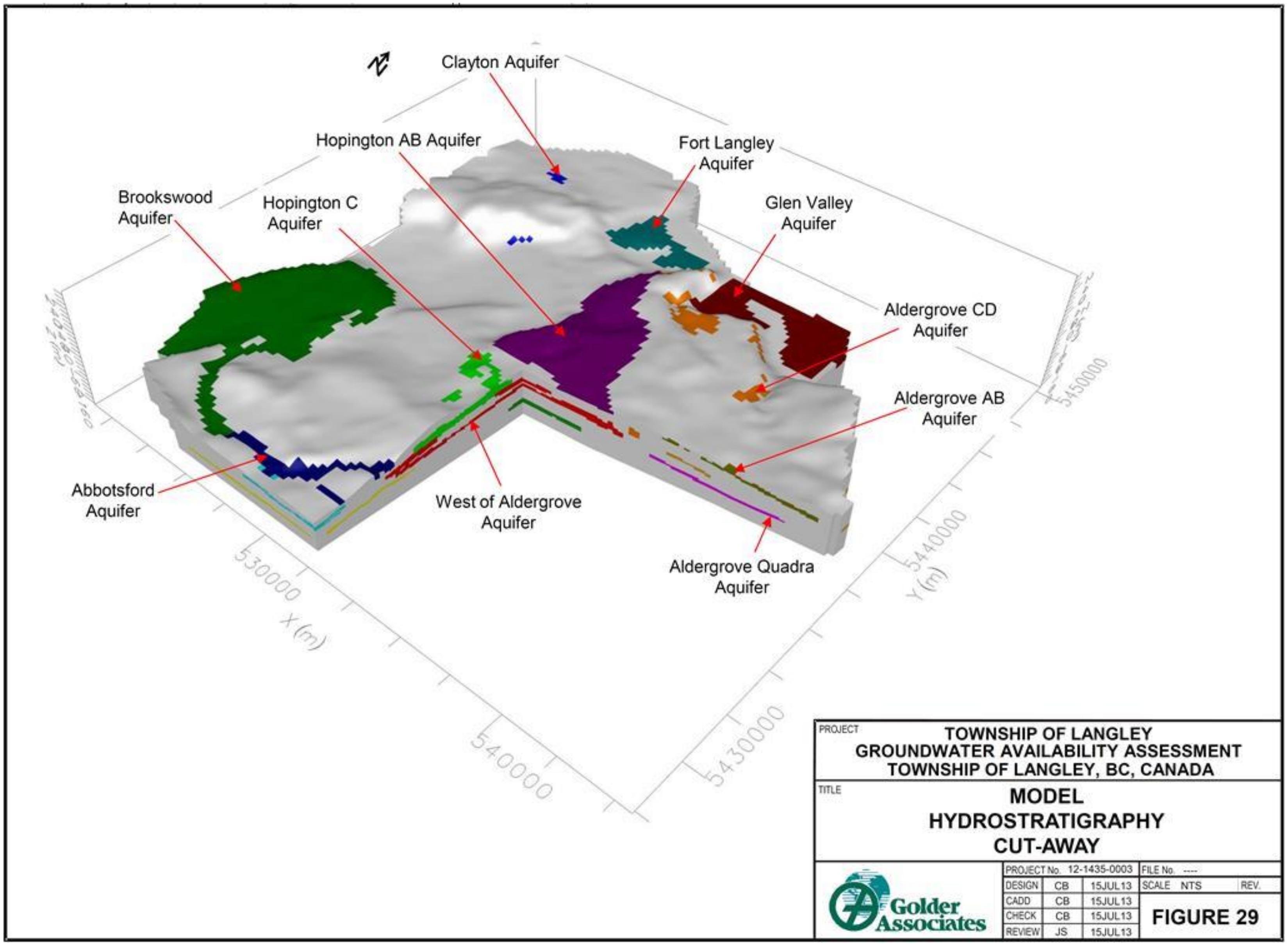

Figure B4 Groundwater model hydrostratigraphy cut-away presented in the Golder Associates report (2014), Figure 29.

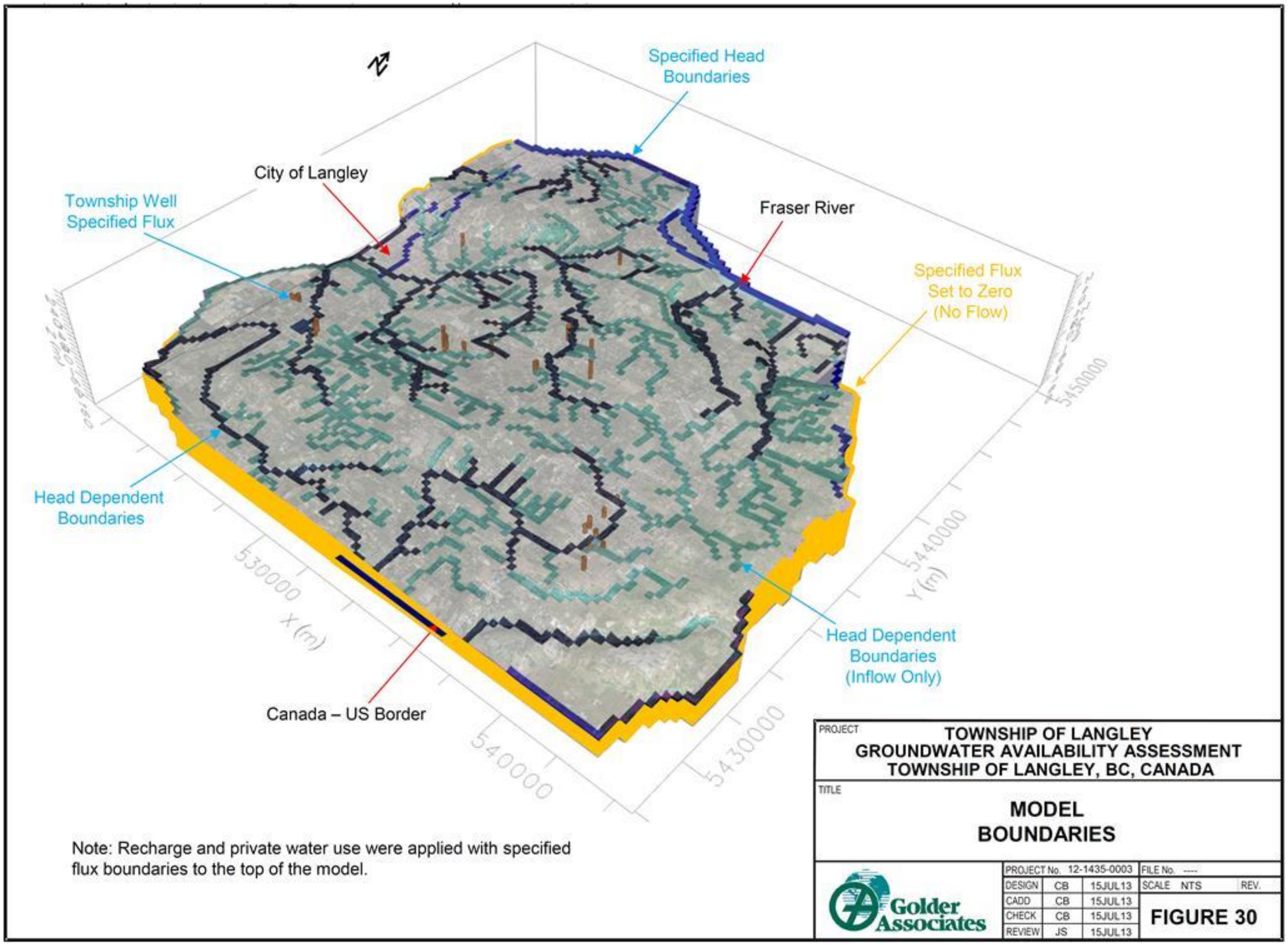

Figure B5   Groundwater model boundaries presented in the Golder Associates report (2014), Figure 30.

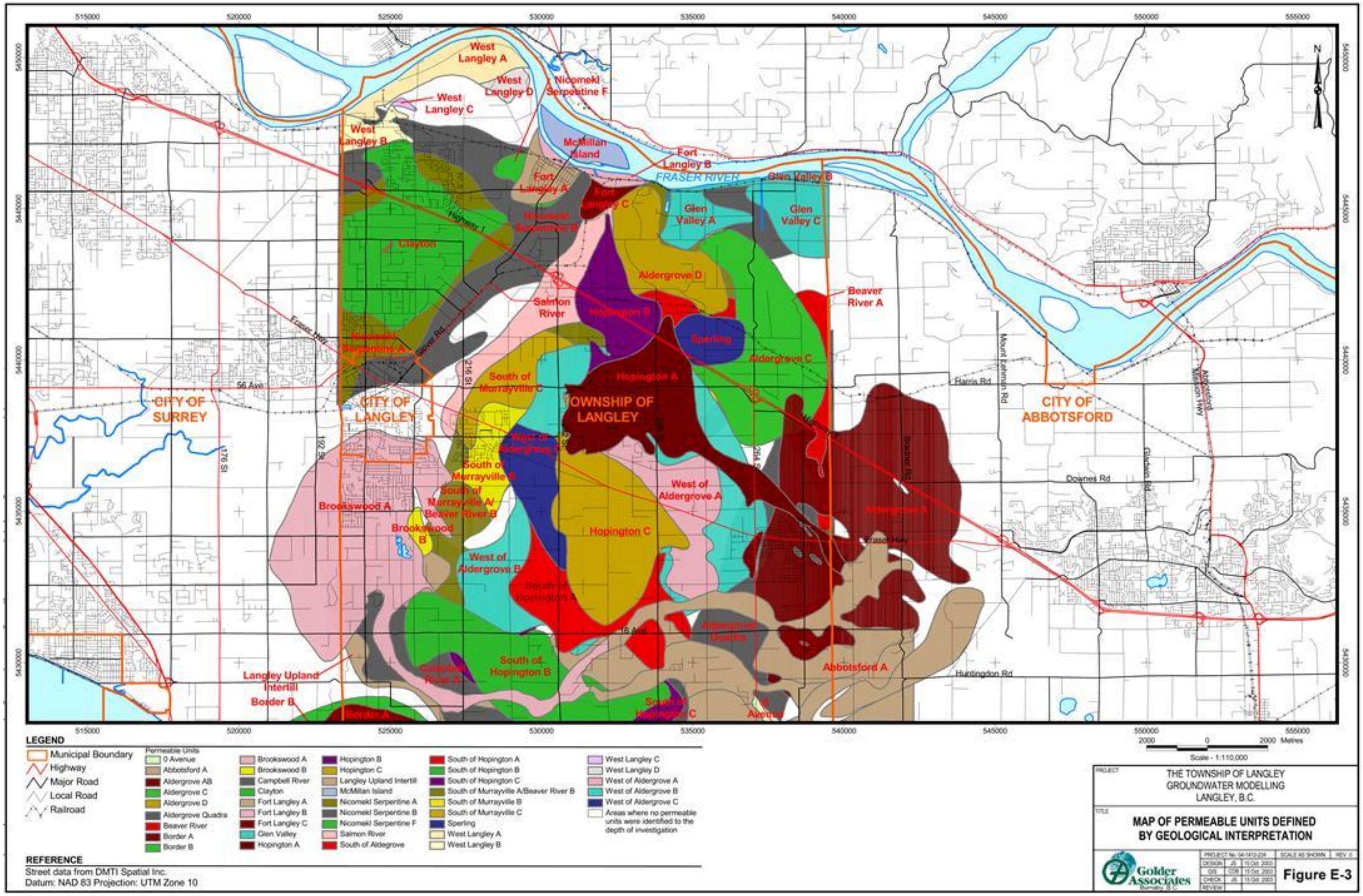

Figure B6 Permeable units defined by geological interpretations presented in Golder (2005). Figure from Golder Associates report (2014), Figure E-3.

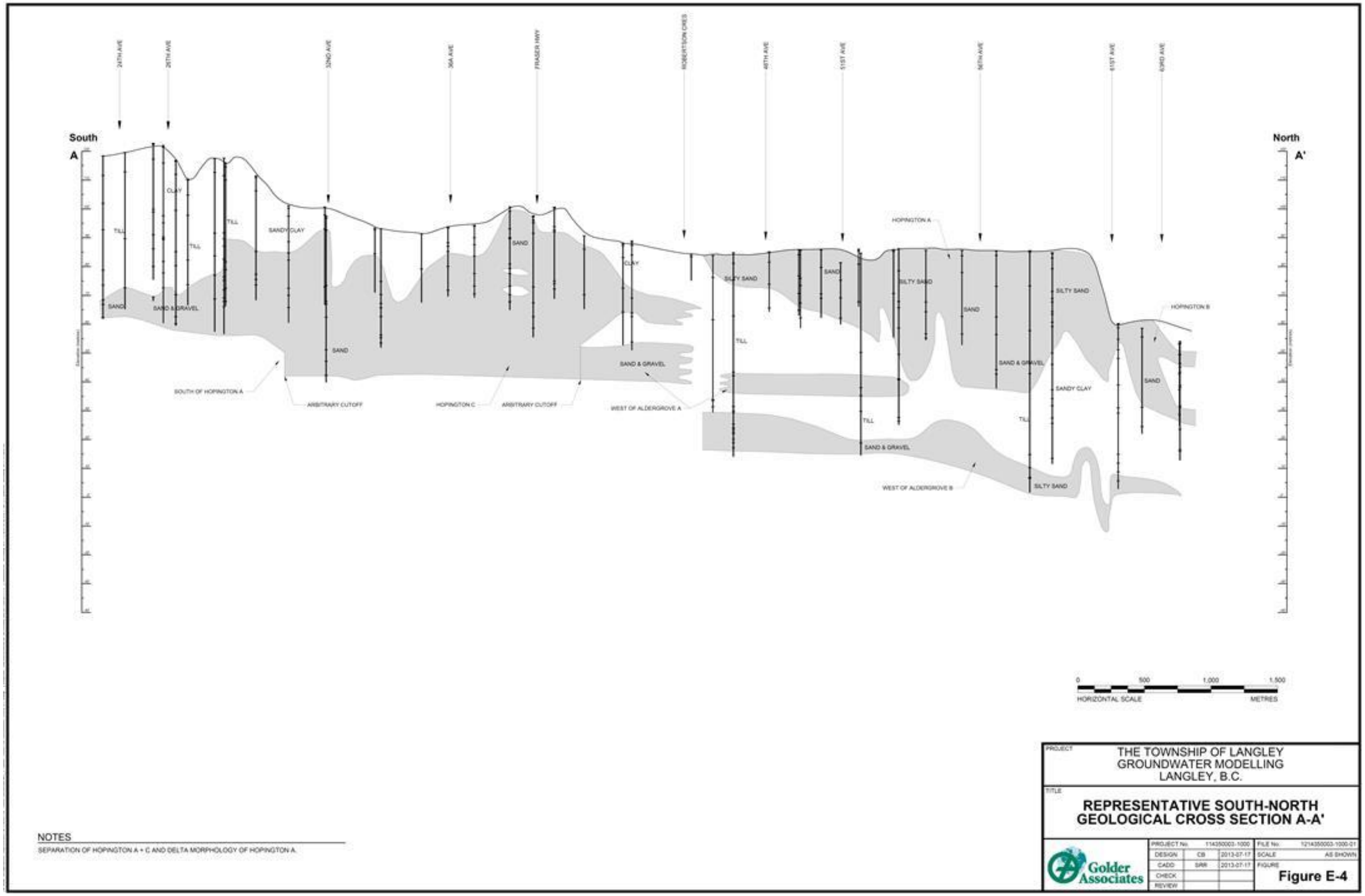

Figure B7 Representative south-north cross section defined by geological interpretations presented in Golder (2005). Figure from Golder Associates report (2014), Figure E-4.

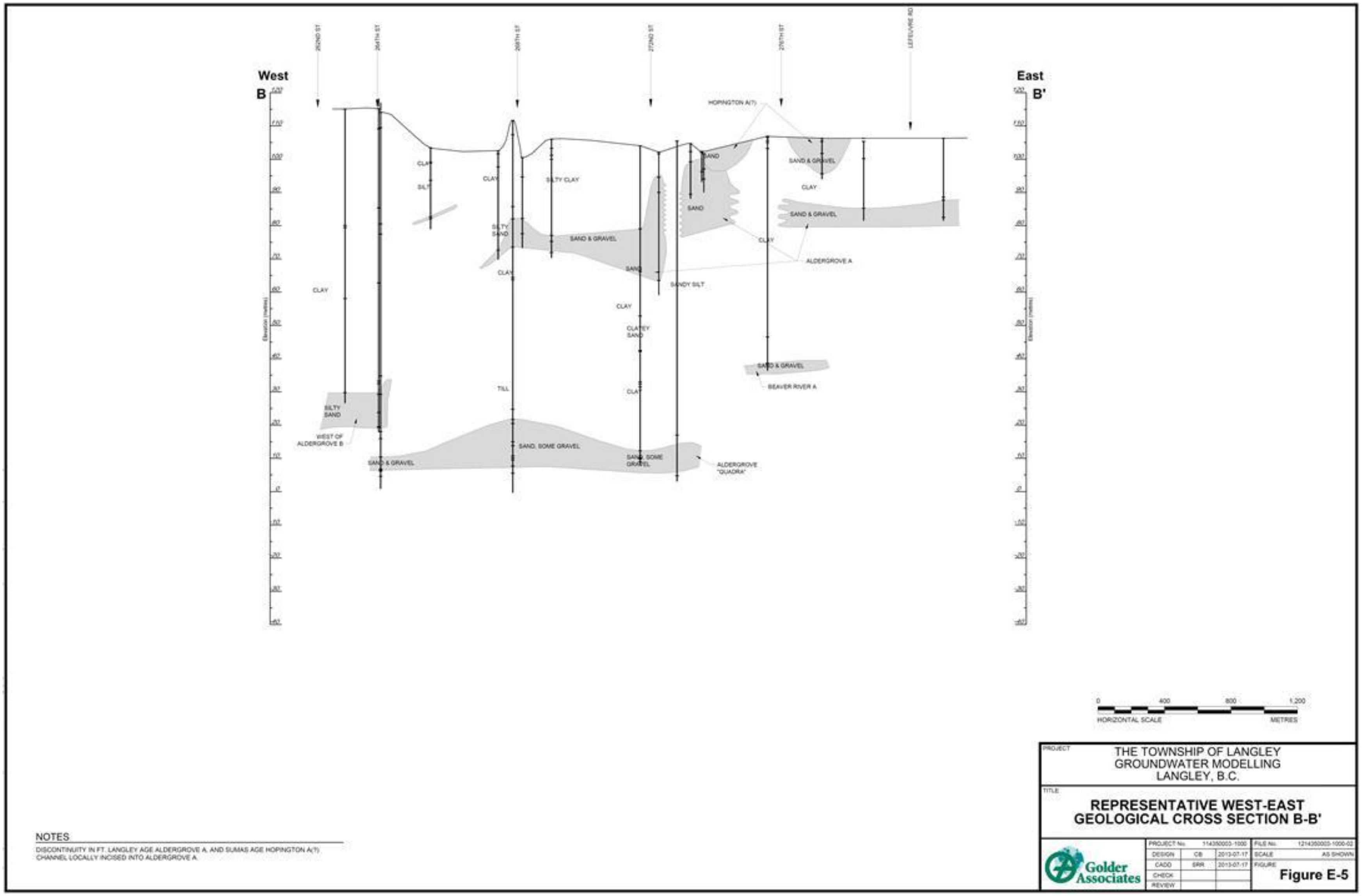

Figure B8 Representative west-east cross section defined by geological interpretations presented in Golder (2005). Figure from Golder Associates report (2014), Figure E-5.