Township of Langley – Flowing Artesian Well Project

Phase One: Identification of Potential Flowing Wells

Vicki Carmichael, P.Ag.

Groundwater and Aquifer Science

Water Stewardship Division

Ministry of Environment

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1 Introduction

The Township of Langley (TOL), in collaboration with the Ministry of Environment (MOE) and the Ministry of Agriculture and Lands (MAL), has developed a water management plan under Part 4 of the *Water Act* to help ensure safe and sustainable groundwater for the community. The Township's Water Management Plan proposes policies and regulations to protect local groundwater resources for community use as well as to promote healthy aquatic habitat. The Water Management Plan was submitted to the Minister of Environment[1] for consideration in November 2009.

One of the thirty recommendations in the Plan addresses identifying flowing artesian wells and making sure the flow is stopped or controlled (Recommendation 7). The lead agency responsible for implementing this recommendation is the Ministry of Environment. Implementation of this recommendation will help prevent wasting groundwater and help to ensure that there is a sustainable supply of water for the community for generations to come. In addition, owners of recently drilled flowing wells will be in compliance with the *Water Act* with respect to stopping and controlling flow (e.g., Section 77 of the *Water Act*).

The MOE, following up on the intent of the draft Water Management Plan, began the flowing artesian well project in 2009 and worked with staff from the Township of Langley in scoping out a three phase framework for the flowing artesian well project:

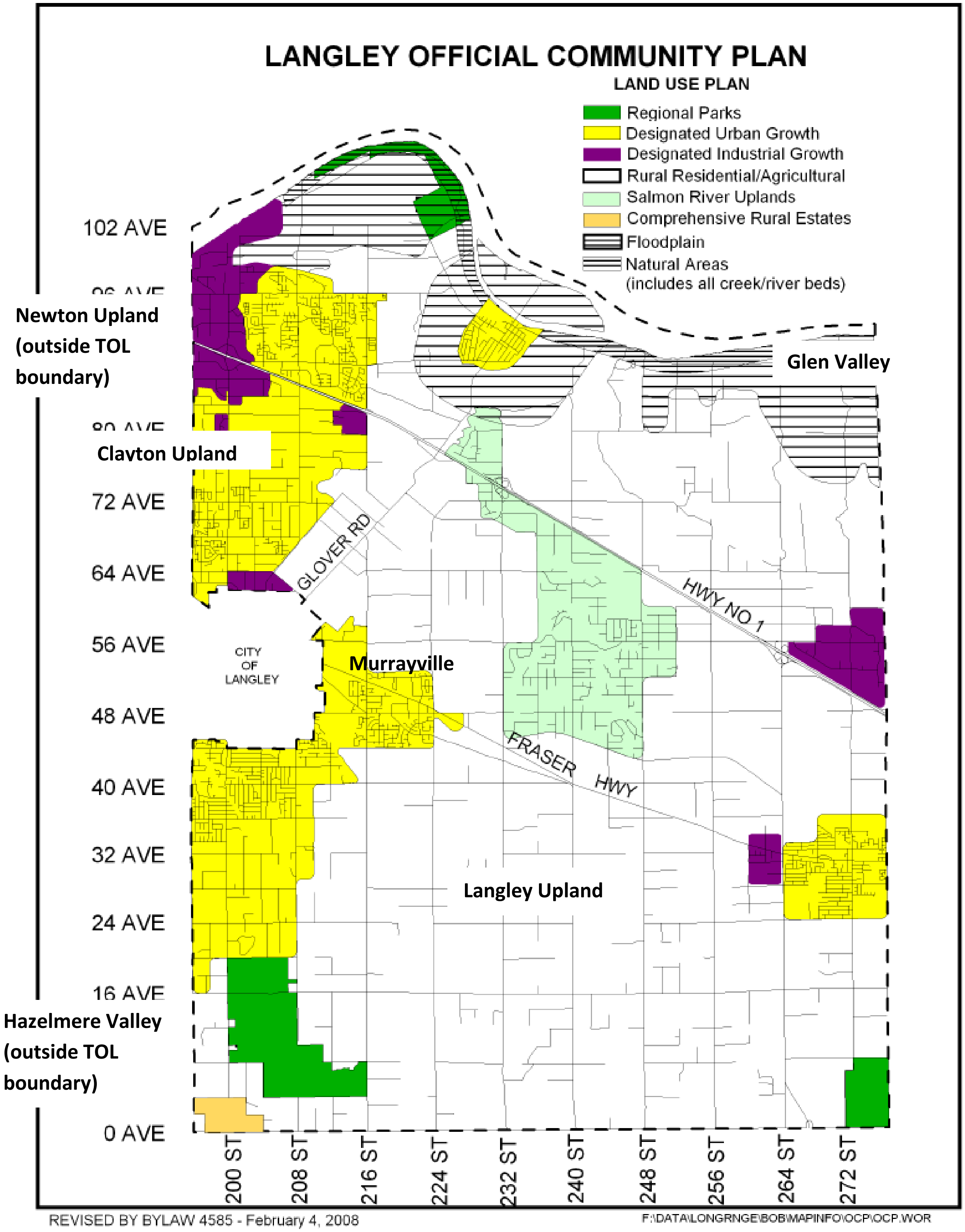
- Phase 1 – Data collection, compilation and assessment and strategy scoping;
- Phase 2 – Conduct pilot to develop and inform finalization of implementation strategy; and
- Phase 3 – Implement, evaluate and report out on the project.

This report provides the results of Phase 1 work (e.g., collect, compile and assess the existing, readily available flowing artesian well data and information) to help inform the potential scope of the project and development of strategies for stopping or controlling flowing artesian wells in the Township of Langley.

The study boundaries are geographically restricted to the Township of Langley, British Columbia (as is the TOL's Water Management Plan - see Figure 1). Both new flowing artesian wells and existing uncontrolled flowing artesian wells are included in this project.

[1] Now the Ministry of Forests, Lands and Natural Resource Operations.

Figure 1. Project study area, showing land use in the Township of Langley's Official Community Plan.

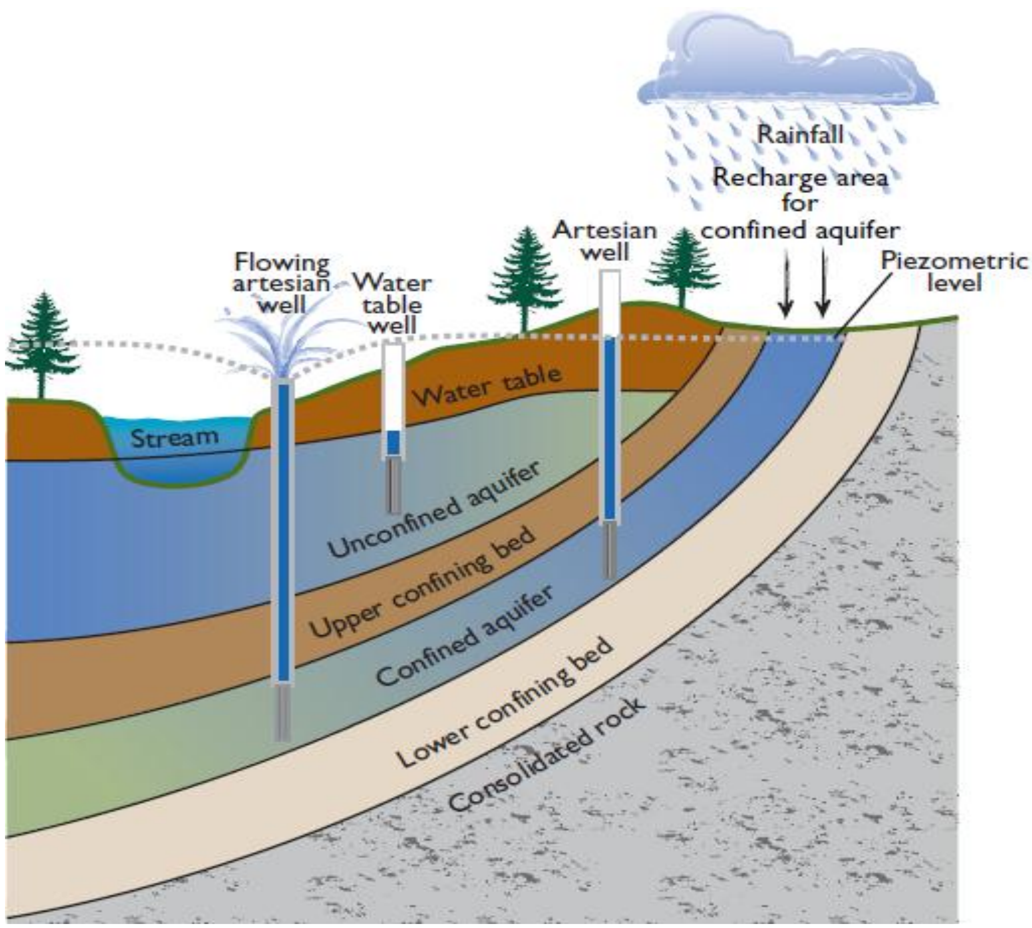


2 Background

2.1 Flowing Artesian Wells

Flowing artesian wells are generally drilled into confined[2] aquifers. Water enters the confined aquifer at the recharge area or the exposed portion of the aquifer at a higher elevation and percolates down through interconnected pore spaces. The water rises upward in an artesian well due to the pressure confined in the aquifer. Where the pressure in the aquifer is great enough, the water rises above the local ground level and the well flows (see Figure 2). An artesian well is drilled into the confined aquifer and under artesian pressure rises above the top of the aquifer but doesn't reach the land surface. A flowing artesian well is drilled into the confined aquifer at a location where the pressure within the aquifer forces the groundwater to rise above the land surface naturally without a pump.

Figure 2. Artesian (to the right) and flowing artesian wells (to the left) drilled into a confined aquifer.



[2] Confined aquifers are found between layers of low permeability rock or overburden.

Wasted water from an uncontrolled flowing artesian well can be significant. For example, an uncontrolled well flowing at 10 US gallons per minute (gpm) or 0.63 L/s can waste 5.25 million gallons (~20,000 m^3) per year, which is equivalent to approximately 8 Olympic size swimming pools. Artesian flow can lower the confining pressure in the aquifer which can decrease the yield from neighbouring wells (i.e., decrease the available drawdown in the well) and flow (e.g., decrease the hydraulic gradient) from springs (i.e., decrease groundwater availability). In addition, erosion, flooding, damage and/or subsidence and sinkhole formation can be associated with uncontrolled flow.

An artesian flowing well is considered to be brought under control or controlled when the entire flow is conveyed through the production casing to the wellhead, the flow can be stopped indefinitely without leaking on the surface of the ground (see Figure 3) and the flow does not pose a threat to property, public safety or the environment.

Figure 3. Flowing artesian well brought under control by equipping the well with a flow control device (e.g., cap and valve) to stop the flow with no leakage.

There are three keys to stopping and controlling artesian flow when drilling a new well:

1) Assessing if flowing conditions are likely to be encountered by reviewing existing information (e.g., existing well construction reports, MOE's flowing artesian well coverage, field knowledge).

2) Designing the well properly to contain the artesian flow (e.g., install surface casing, equipping the well with a flow control device).
3) Properly constructing the well.

Stopping and controlling existing artesian flow can be difficult and costly and will depend, among other things, on:

- how the well was constructed;
- the artesian pressure and flow; and
- the thickness of the confining layer available to install the surface casing.

For existing flowing wells, these are important things to identify.

2.2 Hydrogeological Setting

The Fraser Lowland occupied by the TOL is underlain in most places by more than 300 metres of surficial materials whose depositional environments are fluvial, marine or glacial (Halstead, 1986). Halstead (1986) subdivided these surficial deposits based on grain size and depositional environment into five hydrostratigraphic units (A to E) as follows:

- <u>Hydrostratigraphic unit A</u> includes clay, stony clay and silty clays with varying stone content as well as silty lenses, sandy silts and in some places marine shells. It is found at or near the surface and is commonly less than 30 metres thick. At or near its base, a sand layer with thin lenses of till forms a permeable unit, which yields sufficient amounts of water for domestic use.

- <u>Hydrostratigraphic unit B</u> is a lower permeability unit (i.e., an aquitard) of glaciomarine origin. It comprises stony clays with shells; although this unit appears to have a greater clay content than unit A. It is reported to be as much as 90 metres thick and can be found in the Langley Upland area, in the Nicomekl and Serpentine river valleys and in the Fort Langley area.

- <u>Hydrostratigraphic unit C</u> consists of deltaic sands and gravels of glaciofluvial origin. These deposits are as much as 40 metres in thickness and are locally overlain by clay. These permeable deposits contain water table aquifers and overlie the stony clays of unit B. Discharge of groundwater (i.e., springs) at the margins of these raised deltas contributes to the flow in streams, including Anderson Creek, Salmon River and Fishtrap Creek.

- <u>Hydrostratigraphic unit D</u> includes tills and till sequences (e.g., till and proglacial sand and gravel outwash deposits), which were deposited during a variety of glacial processes. Tills are not continuous across the valleys but underlie the uplands (including the Langley Upland area) at an elevation plus or minus 15 metres in relation to present sea level. These till units help form major confined aquifer systems with water quality characteristic of the sodium bicarbonate type.

- Hydrostratigraphic unit E is typically found at depths of greater than 90 metres and is comprised of older sediments of marine origin interbedded with estuarine and fluvial deposits (fine sand, silt and clayey silts). The residence time for groundwater reaching these formations is expected to be considerable such that the water quality is slightly saline, characteristically of the sodium-chloride type.

Of particular interest to this study are areas where there are documented artesian conditions. Flowing artesian wells in the TOL are found mainly in hydrostratigraphic units D and E. According to Halstead (1986), the following areas (see Figure 1) are known to have artesian pressures:

- The Glen Valley area is underlain by a thick series of silty clays. Wells in this area typically intersect till at about 140 metres depth, underneath which there is a confined flowing artesian aquifer with poor water quality (likely unit E). Most of the wells in the Glen Valley area are high-yielding flowing artesian wells. It is likely that the deeper flow system in unit E extends over to this area.

- The Serpentine Valley is mainly filled with marine sediments, up to 300 metres thick (Unit E). These sediments have been mapped and classified as Aquifer Number 58 by MOE (Kreye and Wei, 1994). Along the west side of this valley, adjacent to the Newton Upland which is outside the TOL boundaries, local groundwater is found to be under artesian pressure for wells drilled up to 60 metres depth.

- In the Clayton Upland area, there are a series of thick till sequences, which are thought to be associated with melting during the glacial wasting process. To the southeast of this area, there are many flowing artesian wells sourced from permeable units (e.g., likely unit D) from depths up to 100 metres within the valley sediments. Flowing artesian wells in this area are currently not within the boundary of a deeper mapped aquifer but may be part of Aquifer Number 58.

- In the Langley Upland area, wells typically drilled to depths of up to 60 metres intersect multi-till sequences (unit D) that are under sufficient artesian pressure to flow. Along the northwest edge of the Langley Upland, extensive deltaic deposits (unit C) contain a water table aquifer up to 30 metres thick. Aquifer Number 52 has been delineated in this area.

- In the Hazelmere valley which is outside the TOL boundaries, flowing artesian conditions are intersected by wells drilled to depths ranging from 90 to 100 metres. Flowing wells in this area are likely drilled into Hydrostatic Unit D and are in either Aquifer Number 50 or 52.

- Near the Murrayville area (approximately between 40th to 48th Ave and 224th to 232nd Street) domestic supplies are obtained from flowing artesian wells that are drilled up to 40 metres deep and are likely in Unit D.

It is likely that the hydrostratigraphic units D and E form a large regional flow system but, due to the aerial extent of this flow system not being well defined, individual aquifers have been delineated and mapped (Kreye and Wei, 1994). The next section (Section 2.3) of this report discusses the mapped and classified aquifers in the area of the Township of Langley.

2.3 Mapped and Classified Aquifers

There are 20 aquifers mapped and classified by MOE within the boundaries of the TOL including both confined and unconfined unconsolidated (e.g., sand and gravel) aquifers as shown in Table 1. However, reported flowing artesian wells were located in only 6 of these mapped aquifers.

The majority of the flowing wells in the TOL (e.g., 58% of all the flowing wells) are drilled into Aquifer 58 (Nicomekl-Serpentine Aquifer). However, there are 202 flowing artesian wells (40%) that are currently not within the boundaries of mapped and classified aquifers as shown in Figure 4. For some of these reported flowing well in unmapped aquifers, the current aquifer boundaries need to be altered to include a grouping of wells that it likely in one of the 6 mapped aquifers. For instance Figure 4 shows a clustering of wells just outside of Aquifer 34 at the US Canada border. It is likely that the boundary of Aquifer 34 should be extended to include these wells.

Figure 4. Mapped aquifers in the Township of Langley (grey boundary) where reported flowing artesian wells (blue dots) are located.

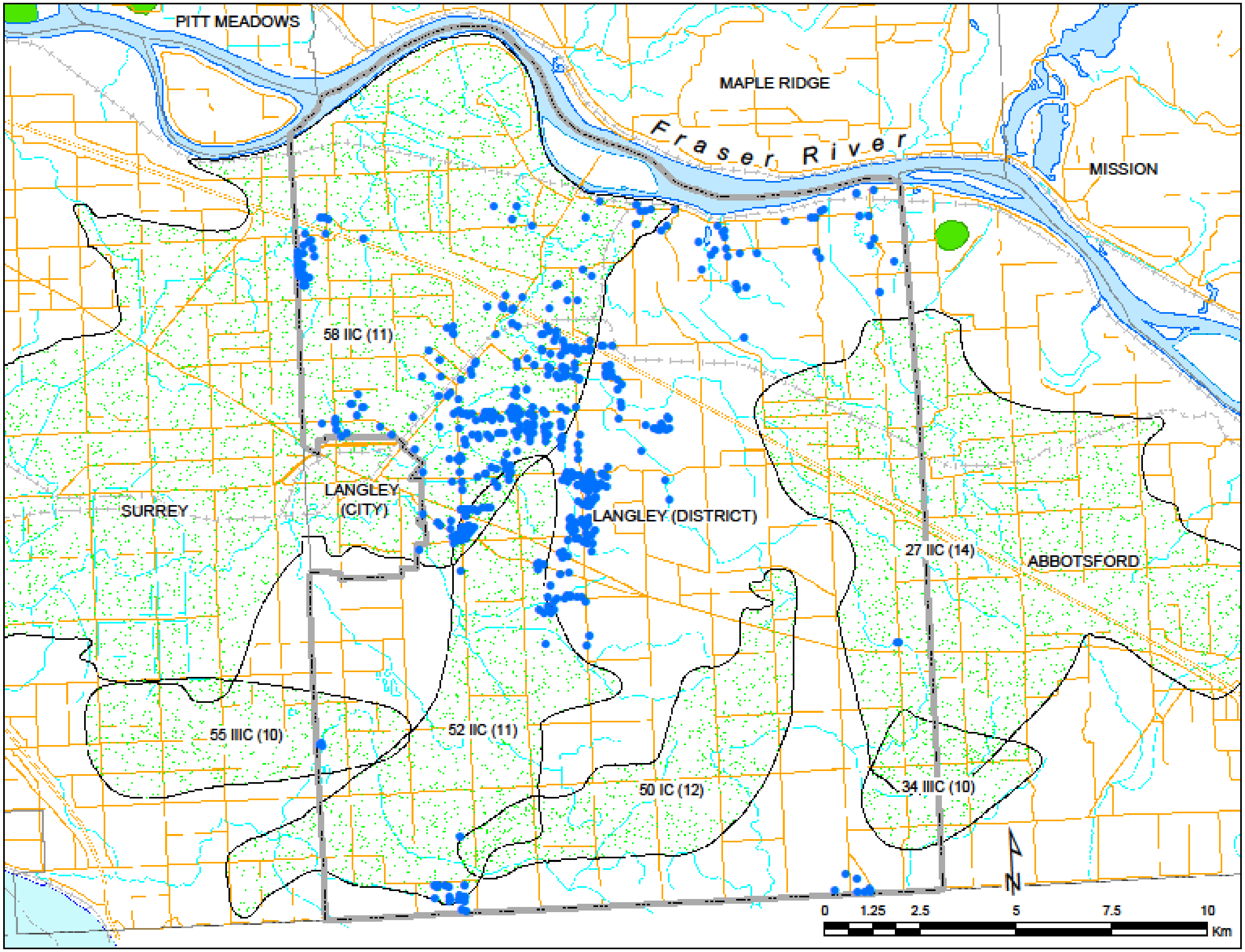


Table 1. Provincially mapped and classified aquifers in the Township of Langley. Bolded aquifers are where flowing artesian wells have been found.

Aquifer name or Area	Hydrostrati-graphic Unit[1]	Aquifer #	Aquifer Classification[2]	Aquifer Type[3]
Abbotsford-Sumas Aquifer	C	15	IA	Unconfined sand and gravel aquifer of glaciofluvial origin
Glen Valley	C	24	IIIB	Confined sand and gravel aquifer of glacial or pre-glacial origin
Aldergrove Aquifer	**C**	**27**	**IIC**	**Confined sand and gravel aquifer of glacial or pre-glacial origin**
Glen Valley (Lower)	E	31	IIIC	Confined sand and gravel aquifers associated with glaciomarine environments
Beaver River	E	32	IIC	Confined sand and gravel aquifers associated with glaciomarine environments
West of Aldergrove	D	33	IIIC	Confined sand and gravel aquifer of glacial or pre-glacial origin
South of Aldergrove	**D**	**34**	**IIIC**	**Confined sand and gravel aquifer of glacial or pre-glacial origin**
Hopington	C	35	IA	Unconfined sand and gravel aquifers of glaciofluvial origin
Fort Langley	C	36	IIA	Unconfined fluvial or glaciofluvial aquifer along river or stream
Fort Langley Upland	C	37	IIIA	Unconfined sand and gravel aquifer of glaciofluvial origin
Langley/Brookswood Aquifer	C	41	IA	Unconfined sand and gravel aquifer of glaciofluvial origin
Boundary Avenue	C	47	IIB	Unconfined sand and gravel aquifer of glaciofluvial origin
South of Hopington	**D**	**50**	**IC**	**Confined sand and gravel aquifer of glacial or pre-glacial origin**
South of Murrayville	E	51	IIIC	Confined sand and gravel aquifers associated with glaciomarine environments
Langley Upland/Inter-till	**C/D**	**52**	**IIC**	**Confined sand and gravel aquifer of glacial or pre-glacial origin**
Hazelmere Valley	E	53	IIC	Confined sand and gravel aquifer of glacial or pre-glacial origin
Grandview	**E**	**55**	**IIIC**	**Confined sand and gravel aquifers associated with glaciomarine environments**
Nicomekl-Serpentine Aquifer	**E**	**58**	**IIC**	**Confined sand and gravel aquifers associated with glaciomarine environments**
Clayton Upland (Upper)	D	59	IIC	Confined sand and gravel aquifer of glacial or pre-glacial origin
Clayton Upland (Lower)	E	60	IIC	Confined sand and gravel aquifers associated with glaciomarine environments

1 As per Halstead 1986 and Kreye and Wei, 1994.

2 Aquifer classification refers to a system developed to classify aquifers in term of level of development and vulnerability (Berardinucci and Ronneseth, 2002)

3 Aquifer type refers to a system (Wei et al, 2009) that was developed to categorize aquifers in British Columbia based on geological and hydrological considerations.

3 Phase 1 Project Description

3.1 Objectives

The objectives of Phase 1 of the Flowing Artesian Well Project include:

1. Identifying potential flowing artesian wells and well owners in the Township of Langley from existing well construction reports from the Ministry of Environment to help define the scope of the problem;

2. Developing relevant maps and spreadsheets on flowing artesian wells to inventory potential flowing artesian wells and to categorize them by types of well owners to help assess voluntarily compliance to stop or control their flowing well(s);

3. Updating the provincial WELLS database so that drillers working in the Township will know where flowing artesian wells are likely to occur and have an opportunity to be prepared for flowing well conditions during drilling; and

4. Compiling information to inform the development of strategies to implement the project

3.2 Methodology

In order to meet the project objectives, the following data collection and compilation and data assessment tasks were carried out.

3.2.1 Data Collection and Compilation

i. Contacting staff from other jurisdictions who have been involved in similar projects to find out how these projects where funded, conducted, etc. Provincial groundwater staff from PEI, Nova Scotia and Manitoba were contacted and referrals were provided for other contacts. In addition, the director of a flowing artesian well closure project in Florida was contacted.

ii. Reviewing the provincial wells database (i.e., WELLS) to find out how many flowing artesian wells had been previously identified within the TOL boundary.

iii. Reviewing hardcopy well construction reports from the Ministry of Environment's well record library to find additional flowing artesian wells in TOL (i.e., for many wells flowing conditions at the time of drilling had not been entered into WELLS). Using BCGS map grid system (1:2500), hardcopy well construction reports in grids with previously identified flowing artesian wells were reviewed as well as reports in adjacent grids. If a flowing well was identified in a grid adjacent to an identified flowing well, all hardcopy reports in the “new” grid were reviewed. This was repeated until no further flowing wells were found in the hardcopy well construction report library for the study area.

iv. Updating WELLS with information on the identified flowing artesian wells from the hardcopy report, including reported information on the casing and screen and the artesian pressure, flow and yield.

v. Generating an Excel database for flowing artesian wells and include the flowing well’s attributes, information on the well owner, information on the aquifer the well is drilled into and the thickness of the confining layer.

vi. Generating a list of flowing artesian well owners by searching the Land Title database for the property that the flowing well is located on, their street address and property information from cadastral information. This information was compared with the well owner information in WELLS.

3.2.2 Data Assessment

i. Preparing maps on:
   a. locations of reported flowing artesian wells (based on flowing conditions noted in the well construction report at the time of drilling), observation wells, stream gauges, etc; and
   b. Depth of flowing well, artesian pressure and yield, confining layer thickness and depth to aquifer.

ii. Reviewing the hydrographs from all the Ministry of Environment’s observation well data in the Township of Langley to assess whether these observation wells could be used to evaluate effectiveness of the project. Hydrographs for each observation well were generated and assessed for trends.

iii. Consulting local drillers to find out if there are any additional areas of flowing artesian wells.

iv. Analyzing the flowing artesian well data to better understand their characteristics, e.g., well depths, artesian flow and pressure, as well as correlating flowing well locations to specific geographic areas or aquifers.

v. Generating a list of owners where voluntary compliance is likely to be achieved (e.g., drinking water supply wells, commercial and industrial wells, large irrigation wells, etc.) from the list of flowing artesian wells owners.

vi. Generating a list of flowing wells where the artesian pressure and flow were high at the time of drilling to assist in prioritizing flowing wells for inspection and action.

vii. Preparing a report on the results of the work done in Phase 1 (i.e., this report).

4 Results and Discussion

4.1 Provincial WELLS database information

The initial review of the provincial WELLS database identified 117 flowing artesian wells in the Township of Langley (TOL).

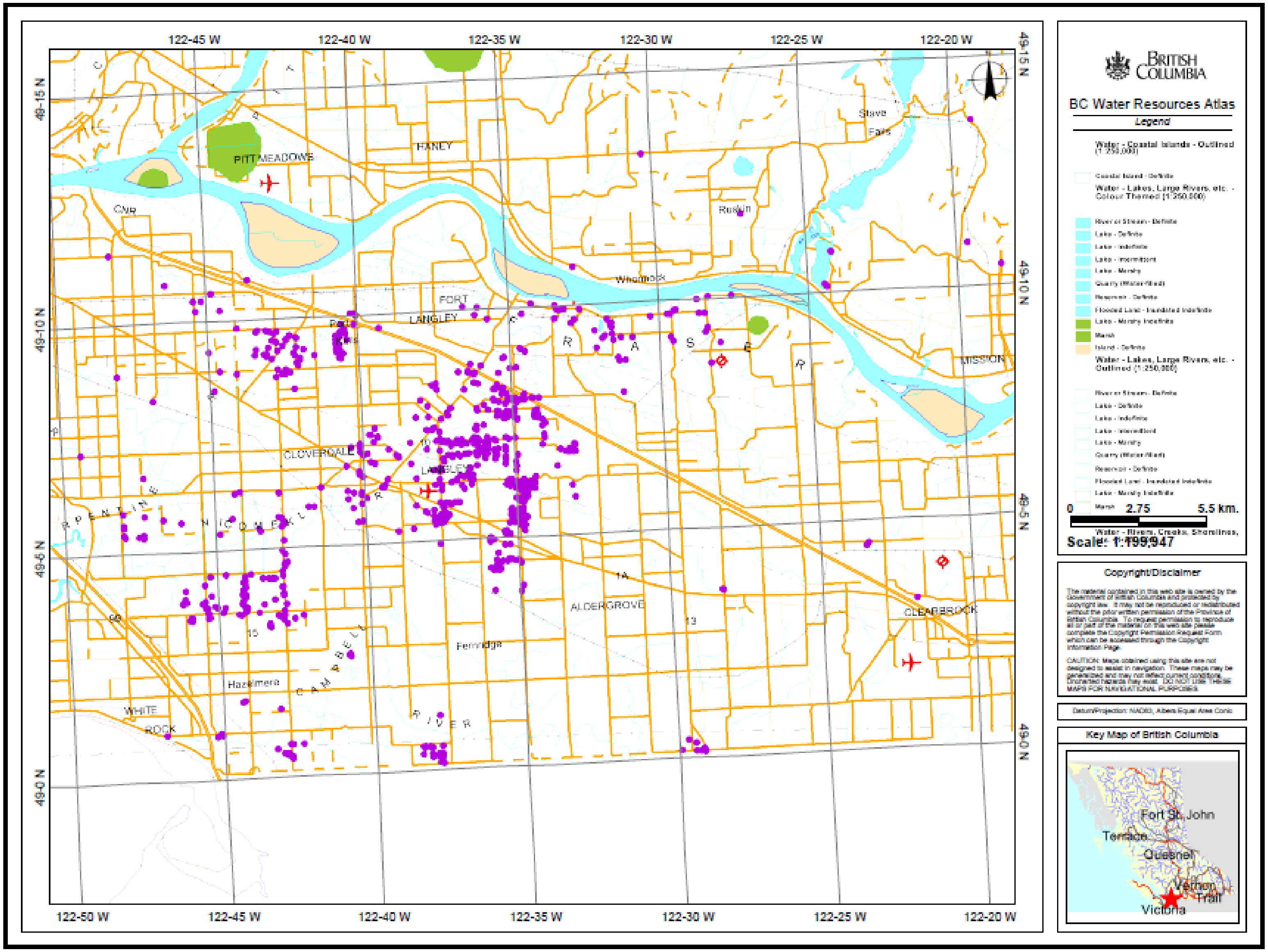
A search of the hardcopy well construction reports from the Ministry of Environment's well record library was completed using the BCGS grid system and the locations of 117 previously identified flowing wells (see Section 3.2.1 on methodology). At the completion of this search, an additional 385 flowing artesian wells were located bringing the total number of flowing wells to 502 as shown in Figure 5. At the time of writing this report, there were 6220 wells registered in WELLS in the Township of Langley which means that flowing artesian wells comprise 8% of all the wells in the TOL.

This should not be considered as a complete listing of all flowing artesian wells as the submission of well construction reports is not mandatory in BC and there were drillers in the TOL who have not provided the ministry with their reports in the past and/or at present. It also should be noted that these wells were reported to be flowing at the time of drilling and may or may not be flowing anymore due to decreased confining pressure in the aquifers (see Section 4.1.5).

Updating WELLS occurred concurrently with this review, i.e., as a flowing artesian well was identified from the hardcopy well construction report, WELLS was updated for those wells where flowing conditions had not previously been indicated. The following fields were updated, if data was available:

- Artesian flow and pressure (where available);
- Well diameter and yield; and
- Casing and screen information.

Figure 5. Reported flowing artesian wells (purple dots) in the Township of Langley reported in WELLS. This information is accessible via Imap or the BC Water Resource Atlas.



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4.1.1 Well Use

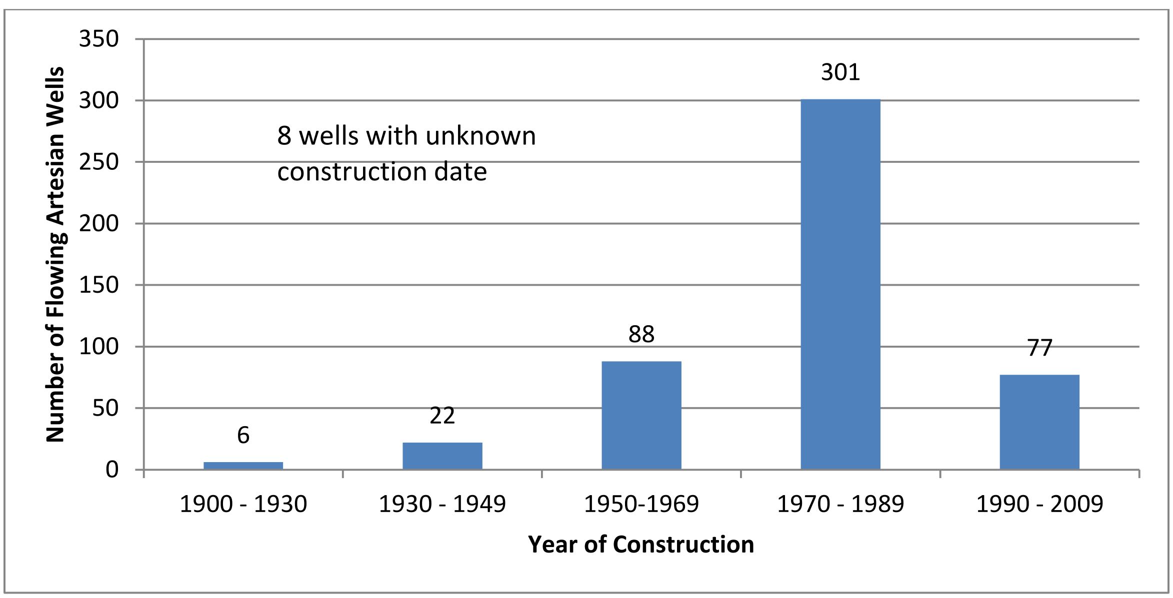
The majority of flowing wells reported (355 wells or 70%) did not have a use recorded by the driller on the well construction report. Most of the flowing wells without reported use were assigned a use based on the diameter of the well (e.g., a well ≤6 inches in diameter is normally assumed to be a well used for domestic purposes) or the well owner's name. The following well uses were identified:

- 27 agricultural use wells;
- 39 industrial use wells;
- 7 wells associated with government organizations;
- 22 drinking water supply wells; and
- 407 domestic wells (117 reported and 290 assumed).

4.1.2 Date of Construction

There were 49 wells with a "1950" provided as the year of construction. It should be noted that "1950" was used as a default date for wells drilled before that time. The majority of the flowing wells were drilled between 1970 and 1990 (see Figure 6). There are many older wells (e.g., 23% were drilled before 1970) which implies that some of these wells may no longer be in use, the casings for these wells may not be in good condition and/or the flow rates and pressure may have changed over time (i.e., they may no longer be flowing). Another logistic issue associated with these older wells is that they may be abandoned, not maintained and/or difficult to locate on the ground. It appears that less flowing wells were drilled from 1991 to 2009 which may be indicative of less confining pressure in the aquifers these wells are drilled into and/or possible lack of submission of flowing artesian well construction reports by some local drillers.

Figure 6. Year of flowing artesian well construction.



4.1.3 Depths of flowing artesian wells

Well depths were available for 487 of the reported flowing wells. Mapsheet 1 and Figure 7 shows the distribution of flowing well depths. The average depth of the flowing artesian wells in TOL was 200 feet (61 meters) and the maximum depth was 917 feet (280 meters).

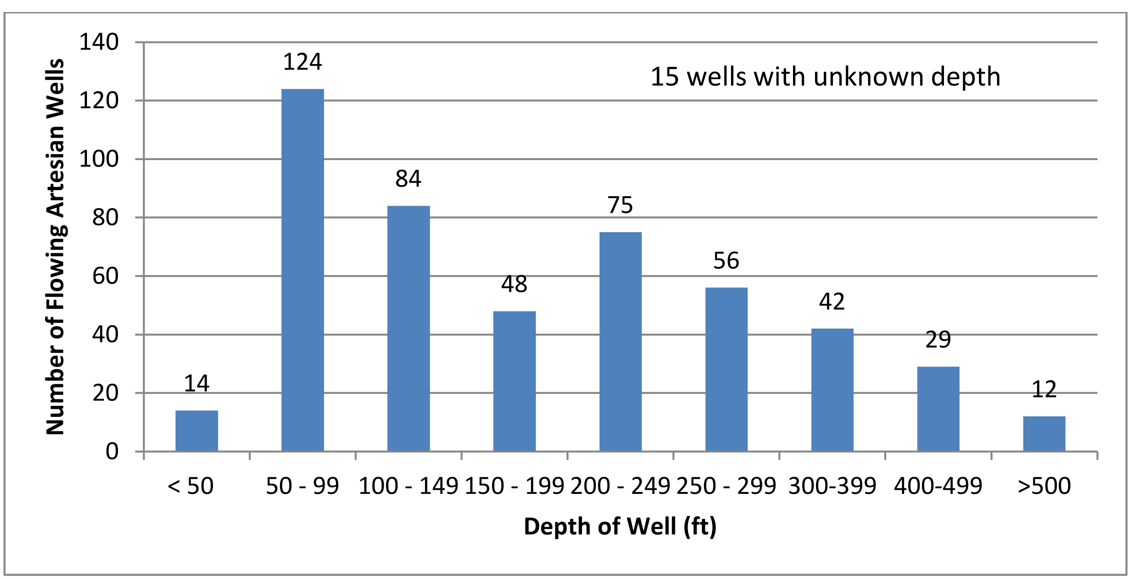
Using this information in conjunction with the well diameters, approximate well volumes can be calculated to get an idea of the amount of grouting needed if these wells were to be closed. The majority of wells (>50%) had well volumes ranging from 0.5 to 3 m^3.

Most of the flowing wells are 6-inches in diameter (283 well or 56%) and it is assumed that most of these wells are being used for domestic purposes. There are 32 flowing wells (6%) with larger diameters (e.g., greater or equal to 8 inches) which are likely municipal drinking water or irrigation wells.

Deeper wells (>500 feet or >150 meters) are drilled into Aquifer 58 in the Nicomekl River at lower elevation (e.g., 20 meter elevation) as shown on Mapsheet 1. In the Hopington area there is a ridge at 40 to 60 meter elevation where flowing artesian conditions are evident found at less than 200 feet (61 meters) depth - see the area within and south of "inset 2" on the map. These wells are likely completed into a different unmapped aquifer formation than the deeper wells to the east.

Knowing the depth and location of existing flowing artesian wells is useful information for well drillers working in the Township of Langley. Figure 7 may be misleading, as it shows a trend towards decreasing number of flowing artesian wells found at deeper depths. This trend can be misinterpreted as the depth of the flowing well is tied to the depth of the aquifer formation, which can vary from location to location.

Figure 7. Depth of flowing artesian wells.



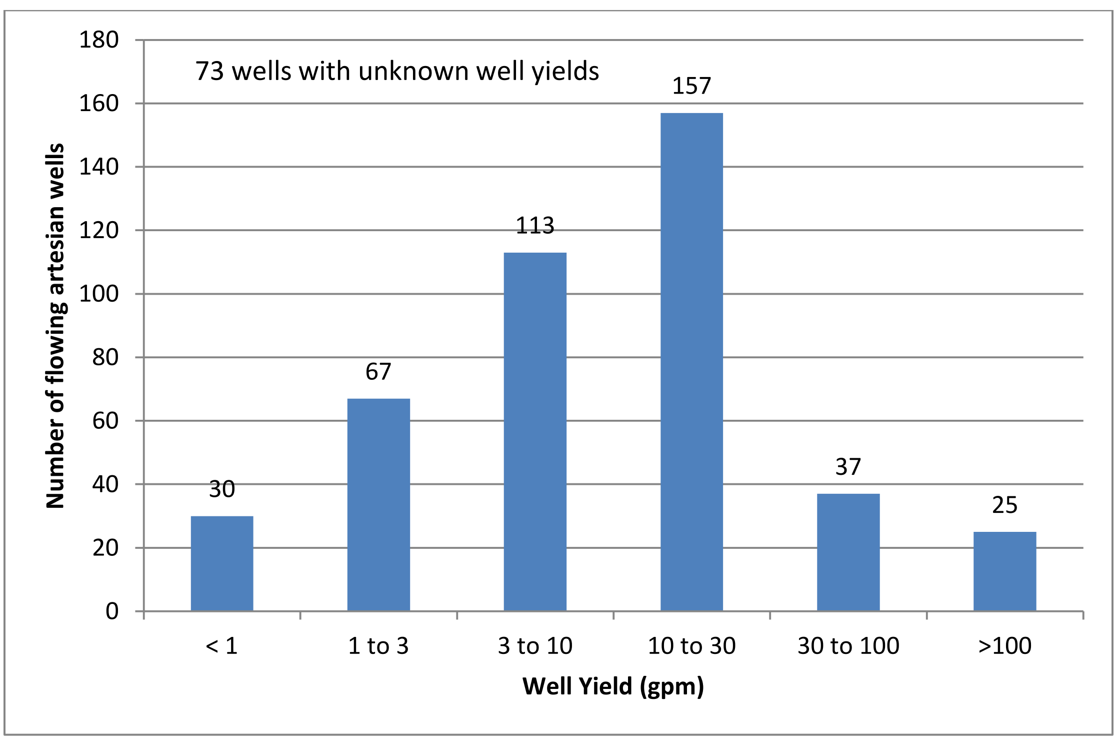
4.1.4 Well Yields

There were a total of 425 wells where well yields were reported by the driller as shown on Mapsheet 2. The well yields from the flowing wells ranged from <1 gallon per minute (gpm) to 600 gpm (see Figure 8). The well yields were estimated at the time of drilling and may not be reflective of current conditions, i.e., the well yields could be much less due to decreasing pressure in the aquifer(s). In addition, well yield reflects the maximum yield the well is capable with pumping, not the artesian flow rate which is generally lower.

In the Glen Valley area there are several flowing wells with well yields greater than 100 gallons per minute. Other high yielding wells are found in the ridge in the Hopington area and the small number of wells on the eastern and western borders of the township.

Most of the flowing artesian wells in the TOL are low yielding wells – 41 % of the flowing wells have yields less than 10 gpm. This would imply that the artesian flow for these wells is likely to be low as well. Twenty-five flowing wells (5%) had yields greater than or equal to 100 gpm. These wells may be challenging to deal with as most of these high-yielding wells were drilled in the 1970s and 1980s and the condition of the casings may not be optimal for controlling flow. There are a large number of wells with yields between 10 to 30 gpm (157 wells); depending on the artesian pressure, flow on these well may also be difficult to control.

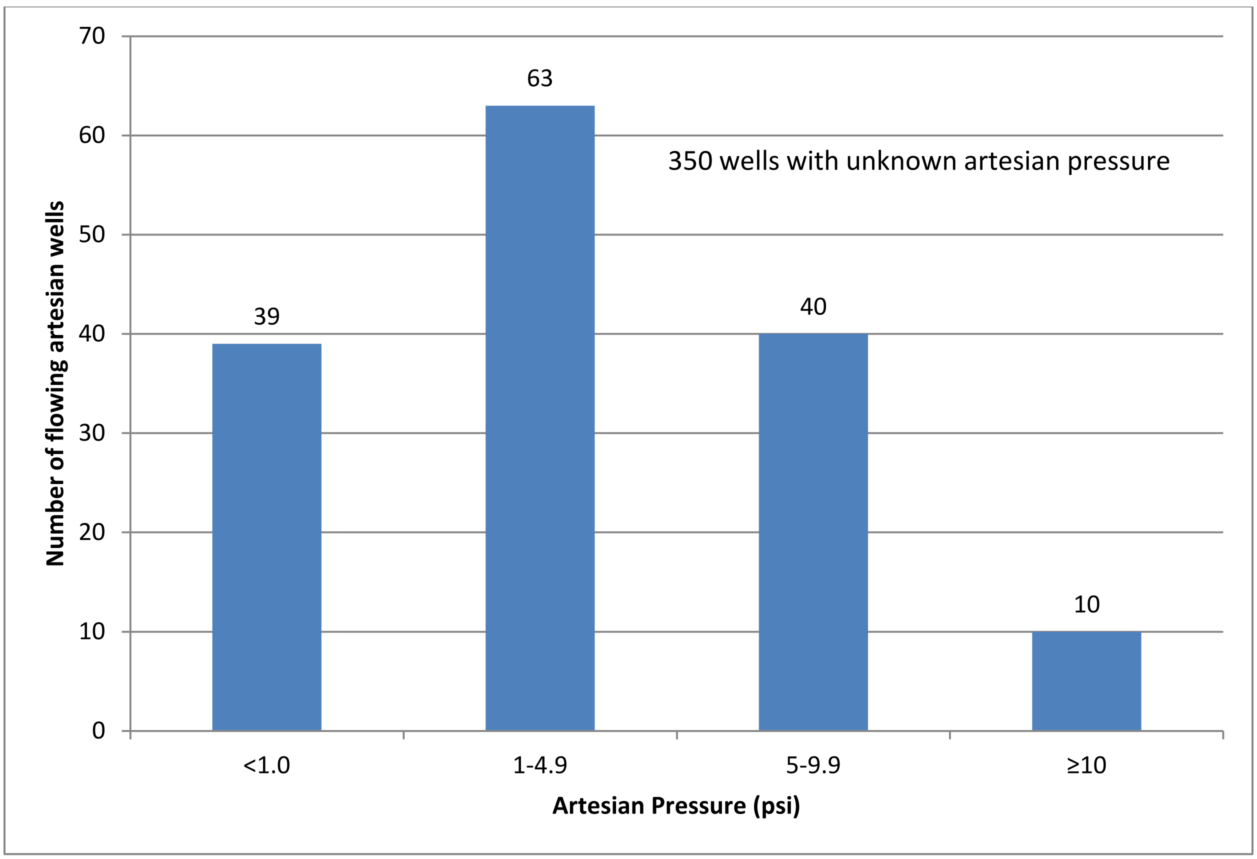
Figure 8. Reported well yields for flowing artesian wells.



4.1.5 Artesian Pressure and Flow

Artesian pressures were recorded for 152 flowing wells as shown in Figure 9 and Mapsheet 3. Artesian pressure was estimated by the driller in terms of feet of head, e.g. how high the water will rise above ground naturally. Relatively high artesian pressure was noted in 10 wells where the pressure was greater than or equal to 10 psi (pounds per square inch). All flowing wells with reported pressures of ≥10 psi are drilled into Aquifer Number 58 (Nicomekl-Serpentine aquifer) and are interspersed throughout this aquifer. There were some higher pressures in flowing wells observed in the ridge by Hopington as well (e.g., 5 to 9.9 psi). Most of the other wells had low artesian pressures at the time of drilling. Flow on these wells with low artesian pressure may be easier to control.

Figure 9. Artesian pressure.



Artesian flow values were available for 300 wells as shown in Figure 10. The well yield and the artesian flow values were the same for 140 wells but for 131 wells the artesian flow and well yield values were different (i.e., the well yields for all but 6 of these 131 wells was higher than the corresponding artesian flow) which implies that these wells had pumps installed to increase the well's productivity.

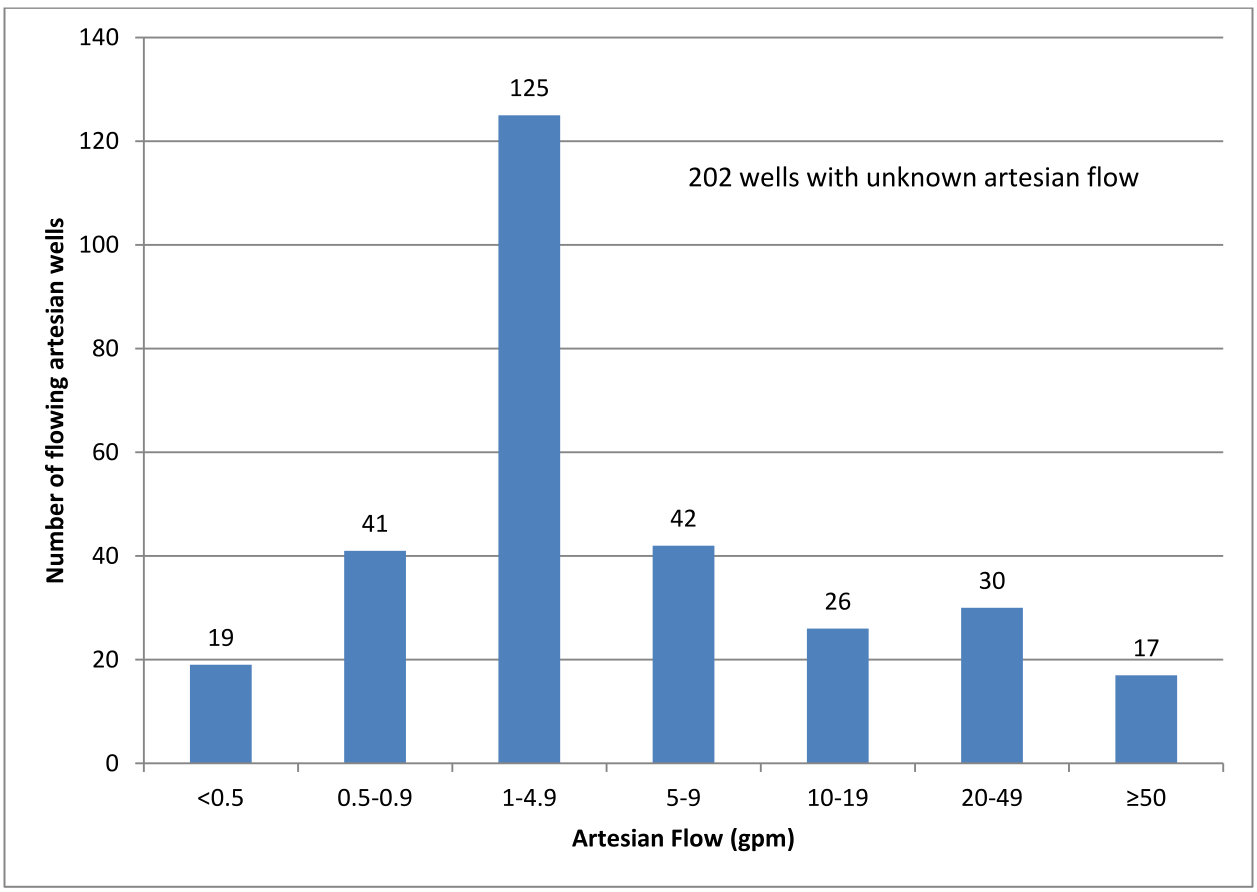
Artesian flows ranged from 0.03 to 400 gpm with an average flow of 13 gpm and a median of 2.5 gpm. Again, it should be noted that these values were recorded at the time of drilling and conditions today could be quite different, i.e., the pressure and flow could have decreased over time.

There were 72 flowing wells where both the flow and pressure were low (≤10 gpm and ≤10 psi). Controlling the flow on these wells may be more easily done than wells with higher flows and artesian pressures.

Artesian pressure was greater than or equal to 5 psi and the artesian flow was greater than or equal to 10 gpm for 14 flowing wells. These wells may be considered as "priority" wells to stop or bring the flow under control. In addition, the wells with yields greater than 100 gpm (24 wells) could be prioritized – the artesian pressure for these wells ranges from 0.74 to 13 psi.

The current status of the artesian flow and pressure is not known and will need to be verified in the field.

Figure 10. Artesian flow values.



4.1.6 Confining Layer Thickness and Depth to Aquifer

The confining layer thickness was estimated by examining the driller's lithology (where available) for the flowing wells and is shown on Mapsheet 4. Confining layers were estimated for 422 of the flowing wells; the remaining 80 wells did not have any or sufficient lithology to make an estimate.

A comparison of confining layer thickness for different aquifers is shown in Table 2 and is apparent when looking at Mapsheet 4. Wells drilled into Aquifer 58 have a thicker confining layer than flowing wells completed into other aquifers although there were some wells assigned to this aquifer with a thinner confining layer. These wells likely tap into an unmapped shallower confined aquifer formation that overlies Aquifer 58.

Table 2. Confining layer thickness information for different aquifers in the Township of Langley.

	Aquifer 58	Aquifer 52/50	Aquifer 34	Aquifer 55
Average (ft)	187	71	81	26
Median (ft)	174	65	84	14
Minimum (ft)	10	15	64	8
Maximum (ft)	556	185	97	57
Total number of reported flowing wells	283	128	7	3

Estimated depths to the flowing artesian aquifers are shown on Mapsheet 5. These estimated depths were obtained using the depth to the top of the well screen, where provided. There were 292 flowing wells where screen information was provided. As with the confining layer thickness, Mapsheet 5 shows that flowing water is found at deeper depths for wells drilled into Aquifer 58.

Both these maps will be useful to drillers working in the Township of Langley to assist them in knowing where flowing artesian conditions occur and to be prepared with the right tools and materials at the job site to deal with flowing artesian conditions.

4.2 Review of Well Owner Information

The well owner information was reviewed to gain a better understanding of the number and types of well owners for the purpose of prioritization. As reported in Section 4.1.1, 70% of the flowing wells did not have a use recorded by the driller on the well construction report. All well owner names were reviewed and assigned to a well use category. Key words were used to determine whether the well use was either commercial/industrial, irrigation, water supply or private domestic. For instance, well owner names with either "farm", "nursery", "dairy", etc. were assigned to the agriculture use category. Similar determinations were used to assign the flowing wells into the other categories, (e.g., industrial wells, wells belonging to government organizations, municipal water supply wells and domestic wells).

The 2006 cadastral or legal surveying data was acquired and used to assess current ownership of lands on which the identified flowing wells are located. Well owner names and addresses for flowing wells were checked by overlaying cadastral and well location layers and seeing if there was a match between the current legal boundary information or cadastral for properties where flowing well are located and the information provided at the time the well was drilled and registered in the provincial WELLS database. A match was achieved if both the current and historic flowing well address were the same, which confirmed that the well is likely located on the right property. A partial match was noted if the address information had some similarities. This information is important as contact will need to be made with these well owners for inspection purposes as the project progresses.

There are limitations to this review due to the fact that many flowing wells may not have been accurately located. For instance, there were 5 flowing wells where a PID number (i.e., Land Title Property Identifier) was not available because the wells are currently shown to be located on roads. In these situations, the well was either not located correctly originally or the well is now covered by a road.

In addition to checking the address information, the well owner name was used to compile a list of flowing well owners to aid with the development of an implementation strategy. For instance, part of the strategy to stop and control the flow from the reported flowing wells could be to identify well owners who may voluntarily control or stop the flow of their well(s), (e.g., industrial wells, well owned by public agencies and corporations, agricultural wells and municipal water supply wells). The flowing wells were broken down into the following categories:

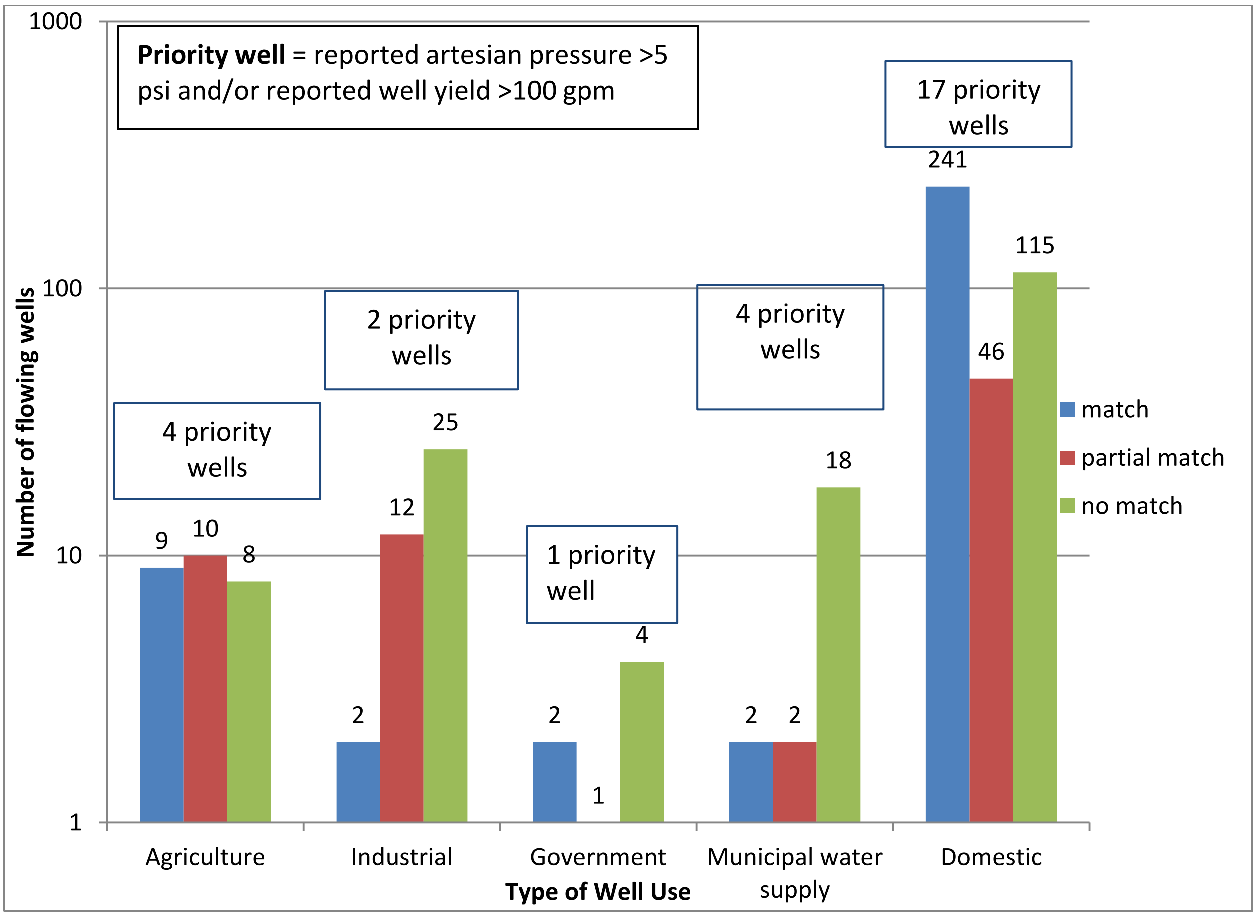
- Agricultural wells – 27
- Industrial wells – 39
- Wells owned by government organizations - 7
- Municipal water supply wells - 22
- Domestic wells - 402

Another strategy could be to focus on flowing wells with relatively high artesian pressure and flow, i.e., priority wells. A list of 28 of these priority wells was developed where either the reported artesian pressure was >5 psi and/or the reported flow was >100 gpm.

Figure 11 shows the numbers of wells by well use type broken down by whether there were address/name matches, partial matches or no matches. This figure also shows the number of priority wells within each of the well uses.

There were many flowing wells (170 flowing wells) where no address or name match was found. These wells may be more difficult to locate and will require someone with local legal property knowledge to look at the location of these wells and resolve their current ownership and property address and to determine if the property has been subdivided since the time of drilling.

Figure 11. Results of cross referencing reported well owner information with current cadastral data. Priority wells for each type of well use are shown. Note: vertical scale is logarithmic.



These lists provide a starting point for developing and implementing different strategies to stop or control the flow of these wells.

4.3 Information from Well Drillers in Langley

An informal discussion with several Fraser Valley well drillers (e.g., Jim Clark, Walt Perry, A&H Drilling Ltd.) was done to determine if there were any “missing” areas where flowing artesian conditions have been encountered. An in-depth discussion with all the drillers in the area was not done due to time constraints. In general, drillers confirmed that the areas of flowing artesian wells were represented on the maps reviewed. Drillers noted that there are likely many more flowing artesian wells and there are several drillers who have put in many flowing wells and not submitted their well construction reports to the Ministry.

There are a number of drillers and drilling companies that work in the Fraser Valley including:

- Clark Drilling Service Ltd. (Jim Clark)
- Ground Force Systems Inc. (Rick Cronin)
- Fred Cudlipp
- Field Drilling Contractors Ltd. (Larry Field)
- Columbia Water Wells Ltd. (Robert Franks)
- Union Pumps (Saul and Miles Hock)
- Langley Water Wells Ltd. (John Mankowski)
- Nor-West Drilling Ltd. (Timothy Oster)
- Pepin Enterprises (Alfred Pepin)
- Perry’s Well Drilling (Walt Perry)
- A & H Well Drilling Ltd. (Richard William)

In addition to the above, there are a number of drillers no longer working that have drilled wells in the Langley area, including Sven and Bert Williams. These drillers have a wealth of knowledge and experience of drilling wells in this area. There is likely a number of well construction reports that were not submitted to the Ministry. It may be worthwhile to contact and visit some of the older drillers to see if these well construction reports could be accessed and used in the project.

4.4 Management of flowing artesian wells in other jurisdictions

Staff from several provinces and the state of Florida were contacted to find out if they had any existing flowing artesian well control programs. Florida and Manitoba both had flowing artesian well programs.

4.4.1 Florida

Robert Schultz, the Assistant Director of the Groundwater Program for the St. Johns River Water Management District was contacted and interviewed.

Florida passed legislation in 1953 requiring the control of flowing artesian wells. Historically these wells were used for agriculture and due to changes in land use through legislation in the 1970s, many of these flowing wells were no longer needed. A well abandonment program was established, which provided incentives to land owners to close their wells, (e.g., cost sharing program).

In the St. Johns River Water Management District, cost-sharing varies and is dependent on the cost sharing incentives each district offers. Estimates for abandoning wells vary from about $600 to close a 2-inch diameter well to $30K-50K to close more complicated flowing wells, (e.g., high pressure and flow). In cases where the well is very difficult to abandon or control, a French drain is built to divert the flowing water. Each district hires a contractor, (e.g., driller) to do the work, as they found it was easier to hire one contractor to do all the work.

Work is prioritized based on whether there are cost sharing programs in place in the district and if there is a threat to aquatic resources or property damage. They try to seek voluntary compliance wherever possible, but if a land owner is "forced" through regulatory requirements to close their well, the entire cost is covered by the land owner. There has been a significant outreach component to their program.

4.4.2 Manitoba

Sarah Coughlin from Manitoba Water Stewardship was contacted and interviewed.

According to provincial legislation, the responsibility to seal an abandoned well rests with the owner of the well (the landowner). There are 18 Conservation Districts in Manitoba and several of these Conservation Districts offer incentive programs to land owners such as sealing abandoned wells. In addition, the Prairie Farm Rehabilitation Administration (PFRA) provides financial assistance to eligible landowners to help with sealing abandoned wells.

The bulk of the abandoned wells are simple to seal and done by a local backhoe operator but when they encounter a flowing well, qualified personnel are brought in to conduct the work. Costs can vary from $1200 to over $60,000 for these flowing wells. They tend to try to stay away from the closure of flowing artesian wells due to the complexity and cost.

Candidate wells for their programs are found through:

- Landowners making applications to the program for a well on their land;
- Conducting well inventories; and
- The provincial well database.

4.4.3 Other jurisdictions

Staff from other jurisdictions that were contacted include:

- George Sommer (PEI) –flowing artesian wells are not common and they have not had to deal with this issue.
- John Drage (Nova Scotia) – the flow rates on flowing wells are not that high due to limited topographic relief and at present they do not expect a change in current practices unless they start to see groundwater shortages in areas with uncontrolled flowing wells.

4.6 Provincial Observation Wells in the Township of Langley

There are 12 provincial observation wells in the TOL vicinity but only six of these wells are currently active - see Table 3. Four of the active observation wells were drilled as replacement wells in recent years. Hydrographs for all the observation wells are in Appendix 1 and their locations are shown on Mapsheet 1 (Well Depths).

There was an observation well (OW4) in Aquifer 52 but it became inactive in 2003 and a replacement well has not been established. It appears that the groundwater level in OW4 showed a decreasing trend, (i.e., it has dropped 3 meters since 1962 when monitoring began) and was still declining when it was deactivated.

The majority of observation wells in Langley are drilled into and are monitoring unconfined unconsolidated aquifers such as Aquifers 41 (Langley/Brookswood aquifer) and Aquifer 35 (Hopington aquifer) – see Table 3. Observation wells in both of these aquifers continue to show decreasing trends except for OW 353 (a replacement well) which shows a slight increasing trend since 2004, when it was established. The hydrograph for OW 361 is not reflective of ambient aquifer conditions (in Aquifer 27), as it was recently discovered that there was a hole in the casing, which was allowing water from a shallower unit to enter the well. This observation well has since been repaired.

Existing observation wells are mainly found in unconsolidated, unconfined aquifers. These aquifers are not likely in hydraulic connection with the deeper confined aquifers due to the thick confining layer and are therefore not directly useful in understanding the artesian pressure conditions in the deeper aquifers. There are no active or inactive provincial observation wells in Aquifer 58, which is the aquifer with most of the flowing artesian wells. There are two flowing wells located in Aquifer 27 where there is one existing observation well; however, these flowing wells are not representative of the majority of flowing wells in the TOL.

Table 3. Provincial observation wells in the Township of Langley[1] - active observation wells are bolded.

Observation Well (OW) #	Well Tag Number (WTN)	Aquifer #	Period Covered	Active/Inactive
12	18623	41 (IA)	1964-2002	Inactive
360	**84697**	**41 (IA)**	**2000-present**	**Active (replaced OW 12)**
13	18626	41 (IA)	1964-2003	Inactive
275	**44936**	**41 (IA)**	**1981-present**	**Active**
353	**84689**	**41 (IA)**	**2003-present**	**Active (replaced OW 13)**
328	29852	35 (IA)	1994-2002	Inactive
354	**84688**	**35 (IA)**	**2004-present**	**Active (replaced OW 328)**
7	17455	35 (IA)	1962-2002	Inactive
359	**84686**	**35 (IA)**	**2004-present**	**Active (replaced OW 7)**
361	**84691**	**27 (IIC)**	**2005-present**	**Active**
4	17459	52 (IIC)	1962-2003	Inactive
5	17452	59 (IIC)	1962-2004	Inactive

[1] Note that in the Township of Langley Aquifers 24, 50, 55 and 58 are not monitored.

4.7 Data Gaps and Limitations

There are a number of data gap and limitations to the existing data, including:

- locations of known flowing artesian wells may not be accurate and need to be confirmed;
- artesian flows and pressures were not provided for many flowing wells;
- flowing wells are identified at the time of drilling and many of these wells may no longer be flowing – current flow conditions are unknown;
- the condition of the identified flowing artesian wells is unknown and needs to be assessed;
- provincial mapped aquifer boundaries, where flowing artesian wells have been identified need to be redefined; and
- there are no provincial observation wells that can be used to monitor effectiveness of the flowing artesian well project once implemented because the main aquifers with flowing artesian conditions are currently not being monitored.

5 Discussion and Conclusion

5.1 Provincial WELLS database review and location of flowing wells

The review of available well construction reports at the Ministry of Environment has identified a large number of flowing artesian wells (e.g., 502) reported at the time of drilling in the Township of Langley. However, it is likely this only represents between 30-60% of the total flowing artesian wells in the area because submission of well construction reports is voluntary. There could be potentially over 1000 flowing wells that have been drilled in the TOL based on anecdotal evidence.

The work to date is solely a desk-top exercise using existing MOE well information. Flowing well locations and conditions need to be confirmed in the field. The effort required to locate all the existing flowing artesian wells in the Township of Langley may be prohibitive due to the costs and resources needed to complete this task given the age of the flowing wells and the challenge to find them in the field.

Inspecting the flowing wells should provide a better understanding of the status and condition of the known flowing wells in the TOL and enable the development of strategies to bring the known flowing artesian wells under control.

Implementing a cost-sharing incentive program to either stop or control the flow of artesian wells will be dependent on funding and resources but is likely to be the best approach to voluntarily stopping or controlling flowing artesian wells in the TOL.

However, in the meantime, the mapsheets generated as a part of this study will be useful to drillers working in the TOL to assist them in knowing where flowing artesian conditions occur so they can be prepared to deal with flowing artesian conditions.

5.2 Discussions with other Jurisdictions

Some of the lessons learned from discussions with other jurisdictions are:

- There is a need to hire qualified professionals for situations where high artesian flow and pressure are found. These situations can be costly to deal with and need to have the appropriate qualified contractors and equipment.
- There may be situations where the most practical solution is to let the artesian water flow to a ditch or drain.
- A key to a successful program is to offer financial incentives or subsidies to encourage well owners to deal with their flowing wells.
- Hiring one drilling company or driller to do all the work has been successful in Florida and may be an approach to consider in TOL.

- It is better to try to achieve voluntary compliance, if possible, but ensure that there is a legislative framework to mandate closure or control, if needed.
- Outreach and education on flowing wells enhances the control program by making the well owners aware of the issues and solutions.

5.3 Provincial Observation Wells

Existing provincial observation wells, mainly completed in unconfined aquifers, are not directly useful in understanding the conditions in confined artesian aquifers. The review of the provincial observation well network in the TOL indicates that there are no existing provincial observation wells that could be used to monitor effectiveness of the flowing artesian well program.

6 Recommendations

6.1 Further identification and field assessment of flowing artesian wells

As previously discussed, the effort required to locate all the existing flowing artesian wells in the TOL may be prohibitive. Therefore, it is recommended to target discussions with several drillers, especially those that have not provided well construction reports to the MOE on a regular basis, to acquire further information on flowing artesian well locations in a relatively cost-efficient manner. This may contribute to the overall coverage to get a better estimate of the total number of flowing wells.

After collecting further flowing well information from drillers, the potential next step could be to conduct a field assessment on a select number of priority flowing artesian wells to (i) verify the current condition and use of the flowing wells; (ii) assess the number of flowing wells in the TOL (i.e., other flowing wells may be identified during the field assessment survey); and (iii) identify issues and assess potential remedial action(s) for these wells.

The list of well owners and addresses generated from the cadastral data can be used to select a sample of flowing wells to be used in a field assessment survey. TOL staff should first review the list to determine if the locations/addresses match. If 50 wells are selected (10% of the total study wells) and four inspections are completed each day, it is estimated that this work will take about 12-13 days to complete. A procedure for conducting the flowing well field assessment needs to be developed prior to hiring a co-op student or contractor and could be fine tuned during the initial field assessments.

After the field assessment is completed, the next steps could include:

- developing strategies to stop or control the flow;
- firming up the scope of the project and seeking funding to establish a cost-sharing program;
- conducting initial remedial work, if necessary, on the TOL wells, if funding is available;
- holding a one-day workshop with key stakeholders and partners to present the findings of Phase 1 and to develop strategies and measurable objectives for the project; and
- developing communication strategies and outreach tools to advise flowing well owners of the reasons for and benefits of the project as well as to promote stopping and controlling existing flowing artesian wells and promote proper well construction of wells to be drilled where flowing conditions are likely to be encountered.

Implementing a cost-sharing incentive program to either stop or control the flow of artesian wells will be dependent on funding and resources but is likely to be the best approach to voluntarily stopping or controlling flowing artesian wells in the TOL. However, in addition to funding, strategies that will not require funds should be reviewed and considered, such as:

- addressing controlling artesian flow through the TOL permitting process;
- developing a well closure by-law for areas that TOL provides a water service;
- issuing an order under the *Water Act* to stop or control the flow;
- promoting proper flowing artesian well construction practices to local well drillers at the regional BC Ground Water Association meeting;
- identifying and communicating with flowing well owners who are likely to comply without funding; and/or
- establishing a process for drilling authorizations under the Water Management Plan.

6.2 Mapped Aquifers and Observation Wells

It is the interpretation of the author that the current mapped boundaries of some aquifers need to be extended by MOE:

- The boundary of Aquifer 58 needs to be extended to include outlying wells (e.g., 55 wells found in adjacent areas to the current mapped aquifer) as these wells are likely in the same aquifer. Additional geological investigations may be needed for this confirmation.

- There is a group of wells in the Hopington area that are likely part of Aquifer 52 (or 50) and the current boundaries need to be adjusted.
- Along the US/Canada border there are flowing wells that are currently not in a mapped and classified aquifer. Those wells close to the Surrey boundary are likely in Aquifer 50 or 52. Those wells in the Aldergrove area by the border may be completed in the Fort Langley formation of Aquifer 34. The boundaries of the noted aquifers need to be confirmed and updated based on the additional field data.
- Aquifer 58 likely extends into Glen Valley and the aquifer boundary should be altered.

There are currently no provincial observation wells that could be used to evaluate the effectiveness of the flowing well control program unless an observation well is drilled by the Ministry of Forests, Lands and Natural Resource Operations into Aquifer 58 or an existing well is equipped with monitoring equipment.

6.3 Development of Performance Measures for Project

Performance measures are used to report on the success or failure of a project. It is recommended to develop performance measures to report on the success or failure of future phases of the project.

Ideally, an observation well drilled into the same aquifer as most of the flowing artesian wells could be used to measure the effectiveness of the project. For instance, the recovery of the artesian pressure of the aquifer over time could provide an indication of whether the project is achieving its objectives. A complicating factor is that the hydrograph is affected by continuing groundwater development. Unfortunately, there currently are no observation wells drilled into the aquifer formation(s) the TOL flowing wells are sourcing, with the exception of the two flowing wells in Aquifer 27.

Feasible performance measures to consider for the project are:

- Number of flowing wells closed that are no longer in use and
- The amount of water saved if the flowing well is brought under control or closed.

Other performance measures could include:

- Reduction of property damage from uncontrolled flow and
- Improvement to aquatic ecosystems from uncontrolled flow.

However, these measures are difficult to assess and quantify.

7 Acknowledgements

Maps in this report were prepared by Rick Hardy from the Science and Information Branch of the former Water Stewardship Division (WSD). The report was reviewed and comments were provided by Kevin Larsen and Asher Rizvi from the Township of Langley, Michele Lepitre and Mike Simpson from the Ministry of Forests, Lands and Natural Resource Operation and Mike Wei from the Ministry of Environment.

8 References

Berardinucci, J. and Ronneseth, K. 2002. Guide to using the B.C. Aquifer Classification Maps for the Protection and Management of Groundwater. Victoria, BC: Ministry of Water, Land and Air Protection.

Golder Associates, 2003. Conceptual model (Phase 2) comprehensive groundwater modelling assignment Township of Langley.

Ground Water Protection Regulation http://www.bclaws.ca/

Halstead, E.C. 1986. Ground water supply – Fraser Lowland, British Columbia, National Hydrology Research Institute, NHRI Paper No. 26.

Halstead, E.C., 1978. Nicomekl-Serpentine Basin Study, British Columbia. Sci. Ser. No. 94. Inland Waters Directorate, Fisheries and Environment Canada.

Kreye, R., and M. Wei, 1994. A Proposed Aquifer Classification System for Ground Water Management in British Columbia. Ministry of Environment, Lands and Parks, Water Management Division. Victoria, British Columbia. 68pp.,7 maps.

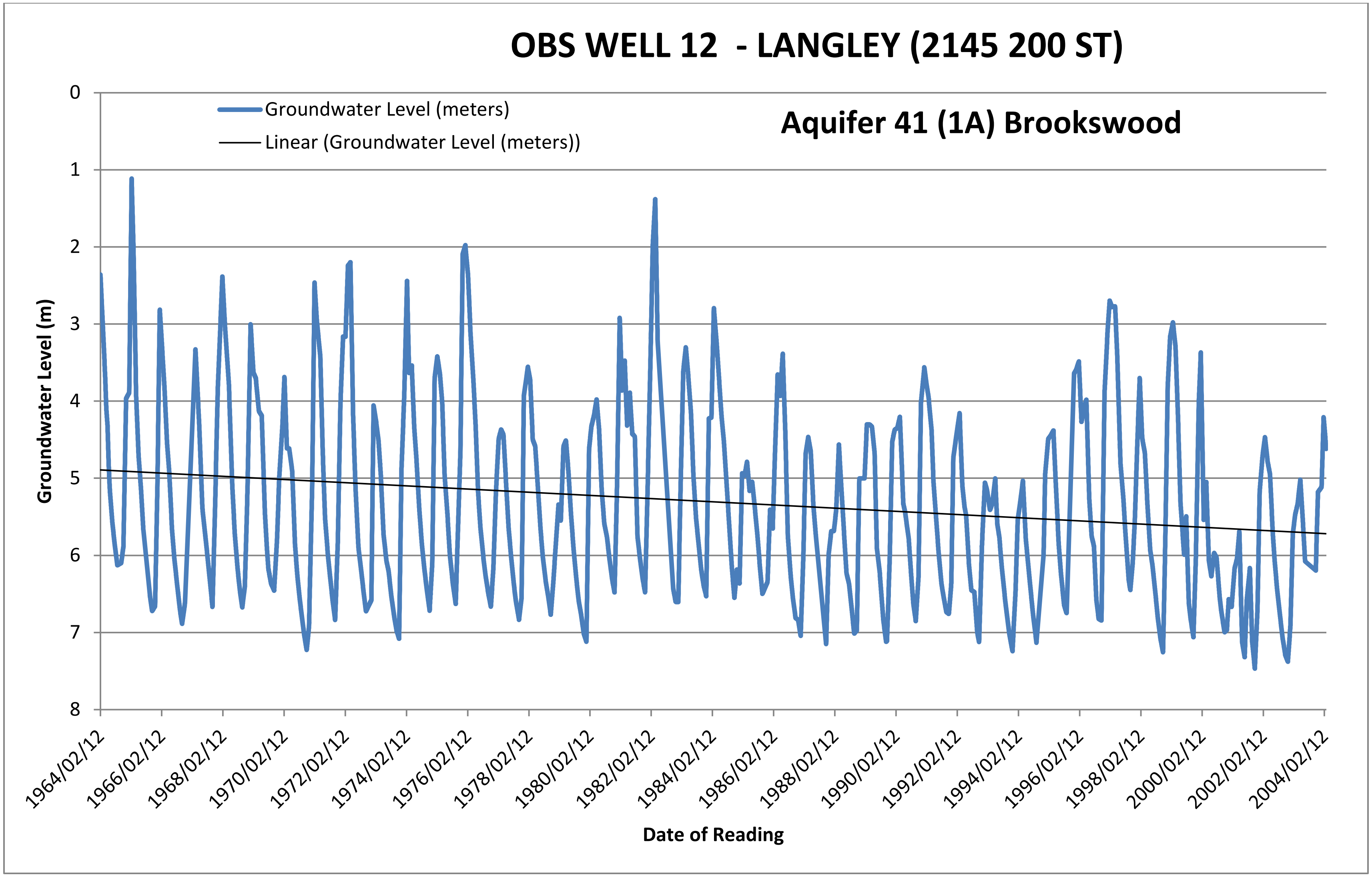
Ministry of Environment, 2009. Flowing Artesian Wells, Water Stewardship Information Series. http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/brochures_forms.html

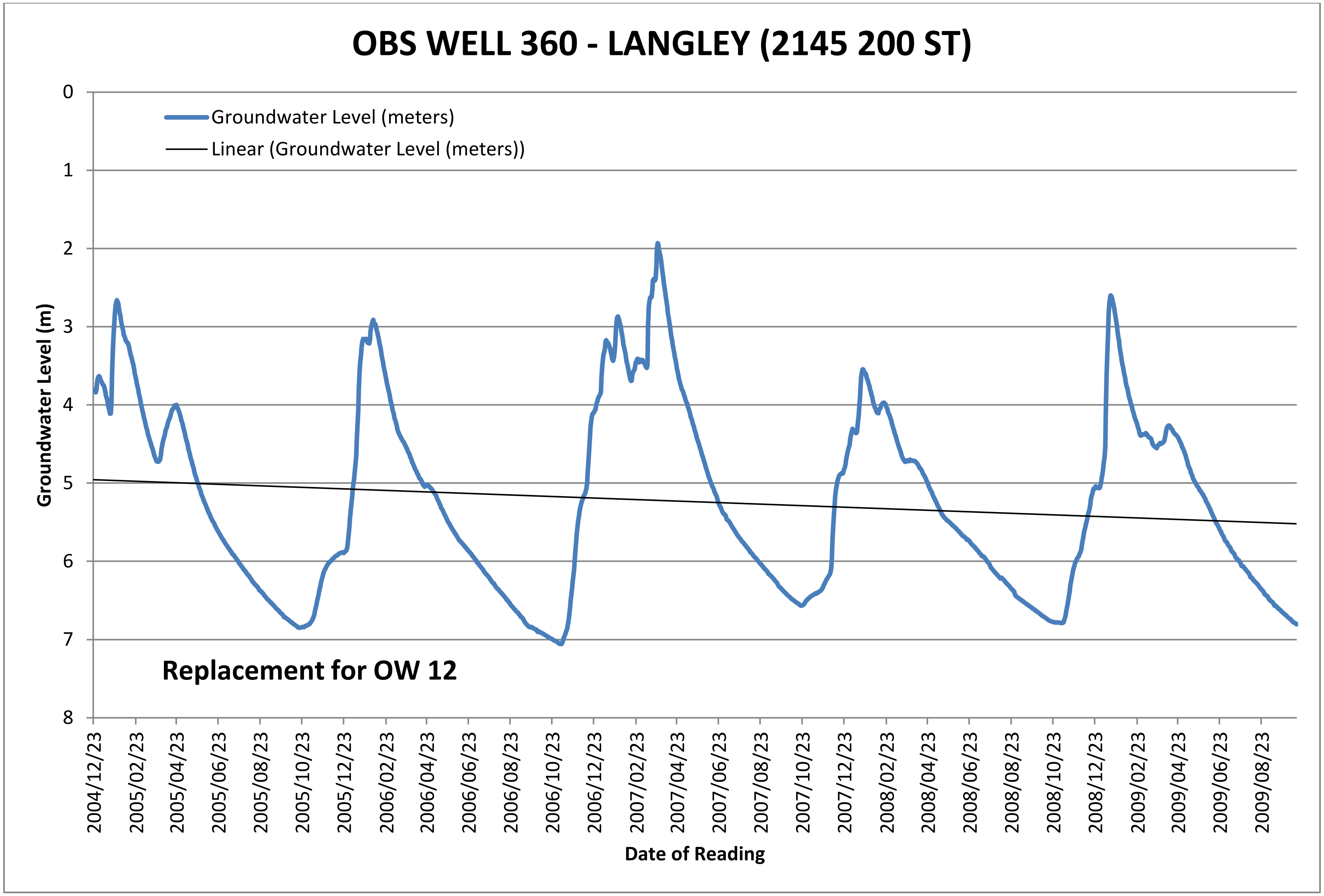
Township of Langley Water Management Plan, November 2009. Prepared on behalf of: Township of Langley. Prepared by: Inter-Agency Planning Team (Township of Langley, Ministry of Environment, and Ministry of Agriculture and Lands). Final Report, 51 pages.

http://www.tol.ca/Default.aspx?TabID=168&fid=101

Wei M., Allen D., Kohut A., Grasby S., Ronneseth K. and Turner B., 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater, Streamline Watershed Management Bulletin, Vol. 13/No. 1 Fall 2009, http://www.forrex.org/streamline/ISS41/Streamline_Vol13_No1_art3.pdf

Appendix 1 – Hydrographs for Provincial Observation Wells in the Township of Langley





OBS WELL 360 - LANGLEY (2145 200 ST)
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Replacement for OW 12
Groundwater Level (m)
Date of Reading
0
1
2
3
4
5
6
7
8
2004/12/23
2005/02/23
2005/04/23
2005/06/23
2005/08/23
2005/10/23
2005/12/23
2006/02/23
2006/04/23
2006/06/23
2006/08/23
2006/10/23
2006/12/23
2007/02/23
2007/04/23
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2007/12/23
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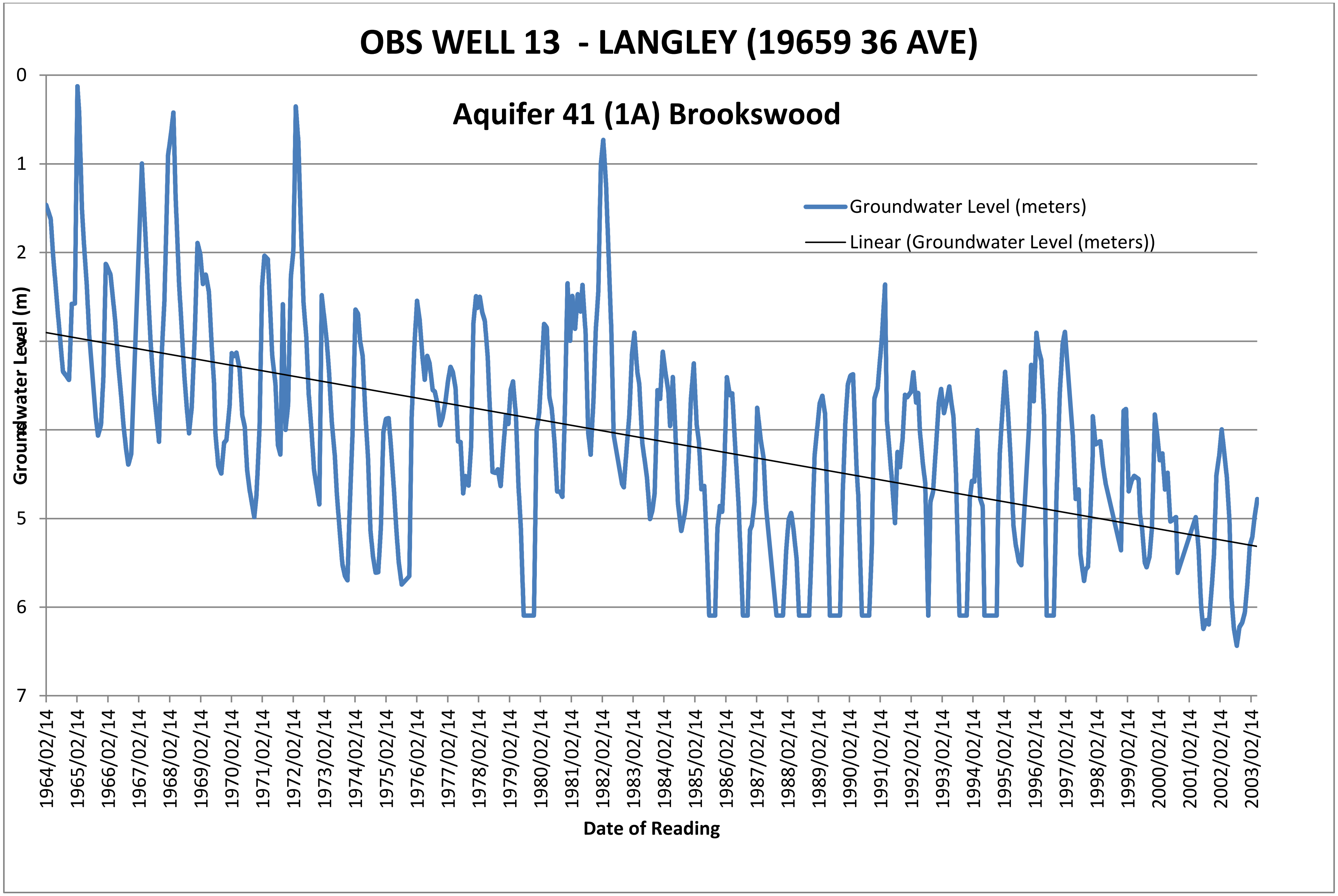
2009/06/23
2009/08/23


OBS WELL 13 - LANGLEY (19659 36 AVE)
Aquifer 41 (1A) Brookswood
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
0
1
2
3
4
5
6
7
1964/02/14
1965/02/14
1966/02/14
1967/02/14
1968/02/14
1969/02/14
1970/02/14
1971/02/14
1972/02/14
1973/02/14
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1995/02/14
1996/02/14
1997/02/14
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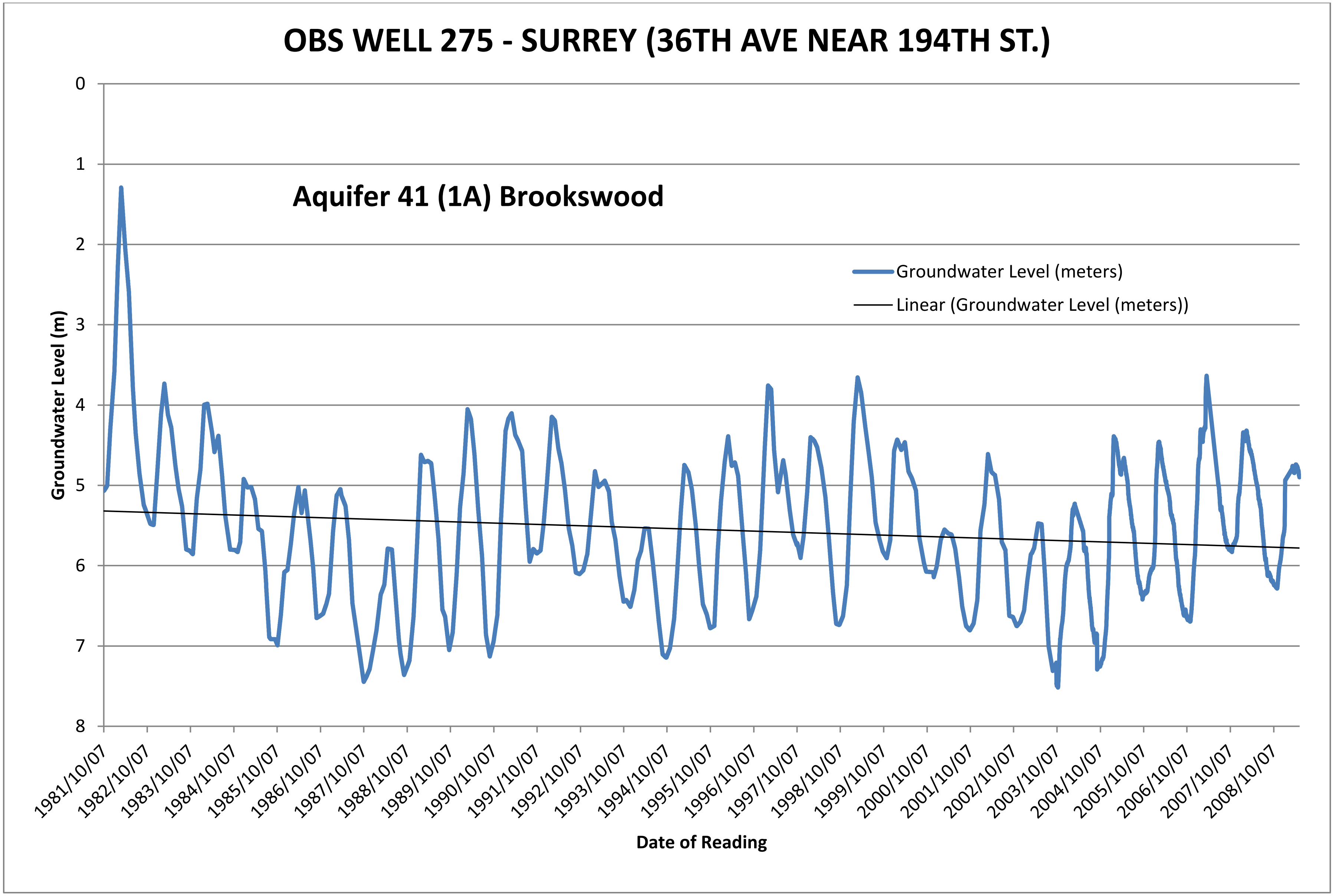
2000/02/14
2001/02/14
2002/02/14
2003/02/14
Date of Reading

 DRAFT



OBS WELL 275 - SURREY (36TH AVE NEAR 194TH ST.)
Aquifer 41 (1A) Brookswood
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
Date of Reading
0
1
2
3
4
5
6
7
8
1981/10/07
1982/10/07
1983/10/07
1984/10/07
1985/10/07
1986/10/07
1987/10/07
1988/10/07
1989/10/07
1990/10/07
1991/10/07
1992/10/07
1993/10/07
1994/10/07
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1999/10/07
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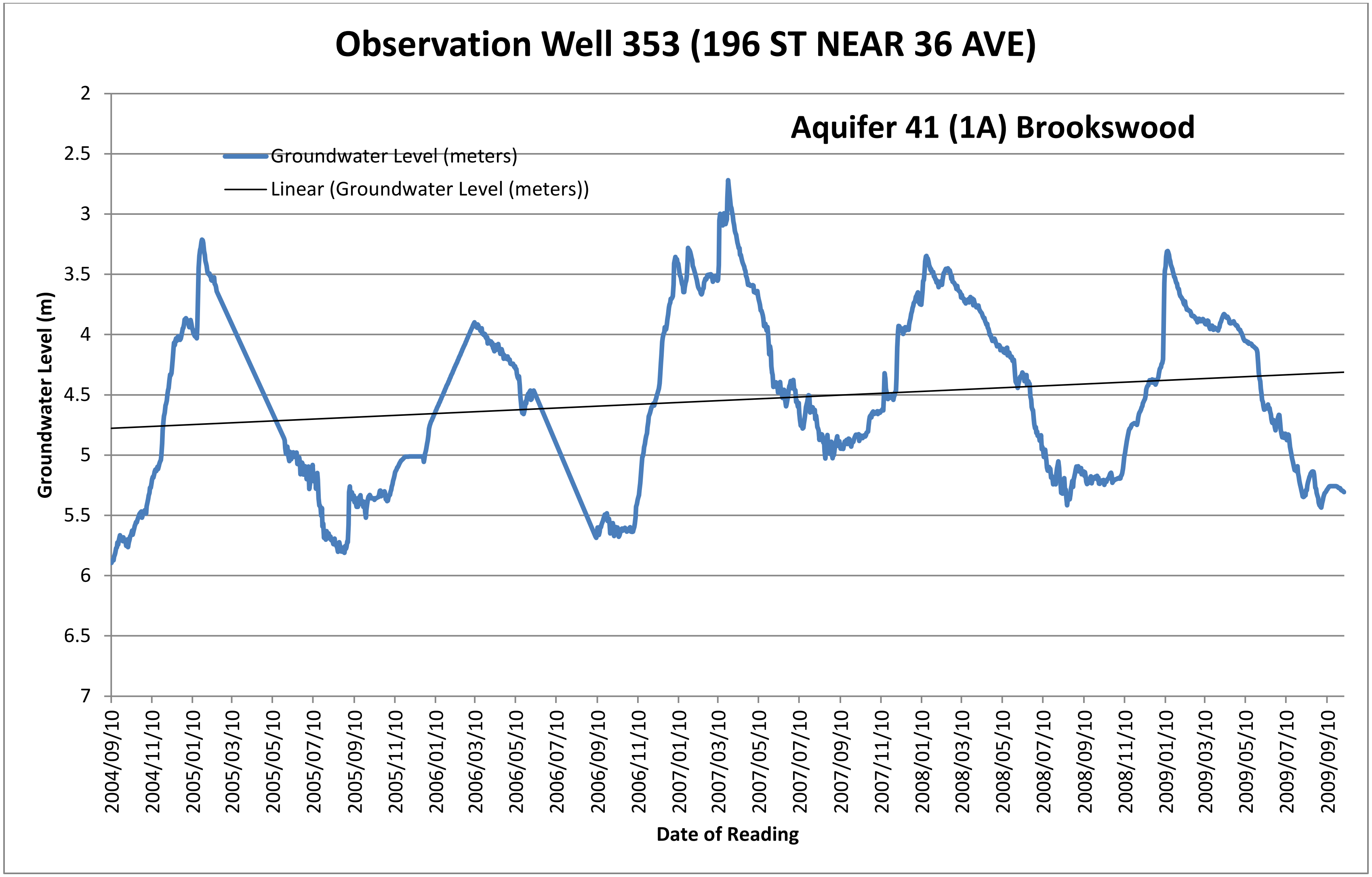
2007/10/07
2008/10/07


Observation Well 353 (196 ST NEAR 36 AVE)
Aquifer 41 (1A) Brookswood
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
2004/09/10
2004/11/10
2005/01/10
2005/03/10
2005/05/10
2005/07/10
2005/09/10
2005/11/10
2006/01/10
2006/03/10
2006/05/10
2006/07/10
2006/09/10
2006/11/10
2007/01/10
2007/03/10
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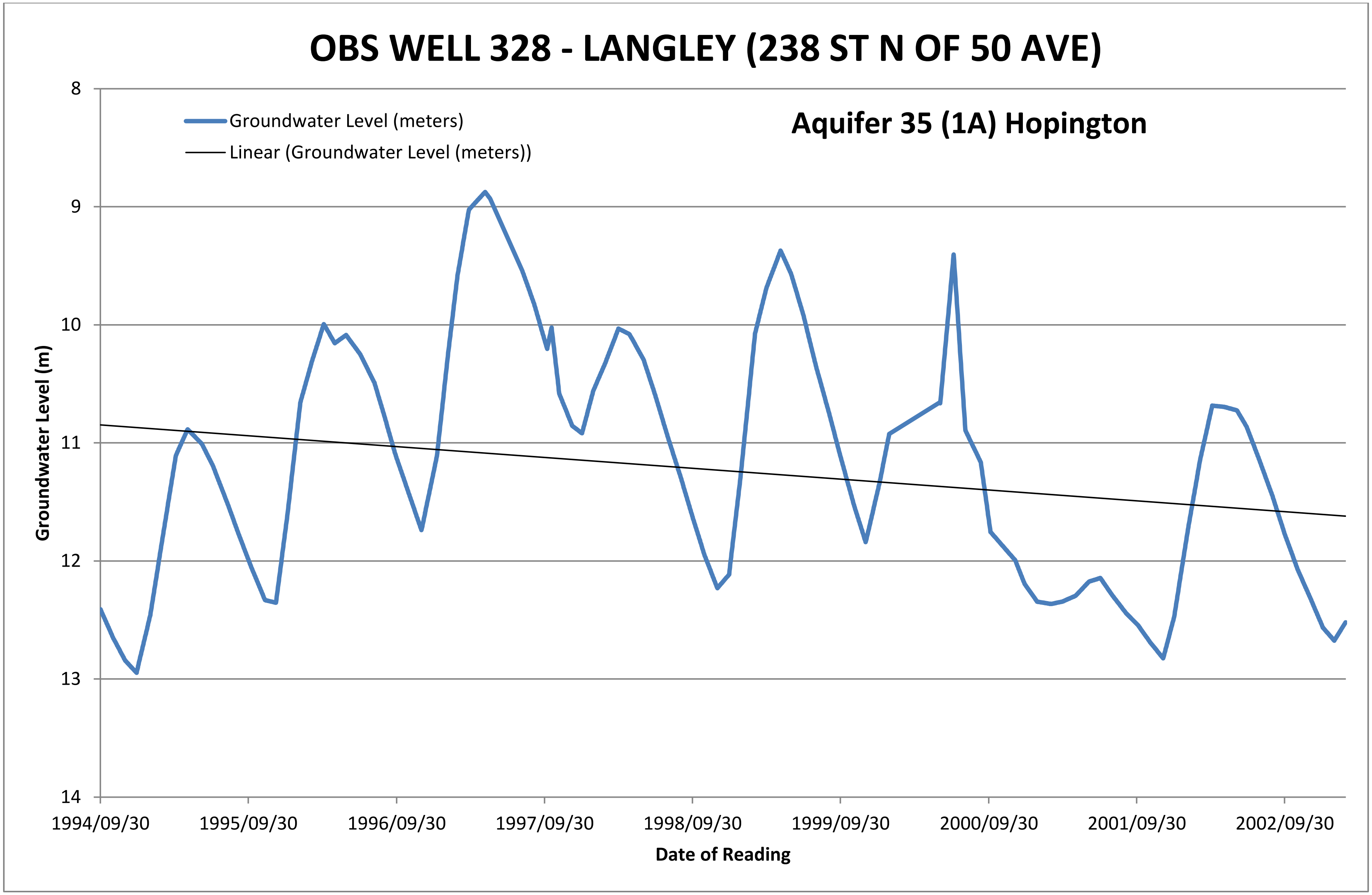
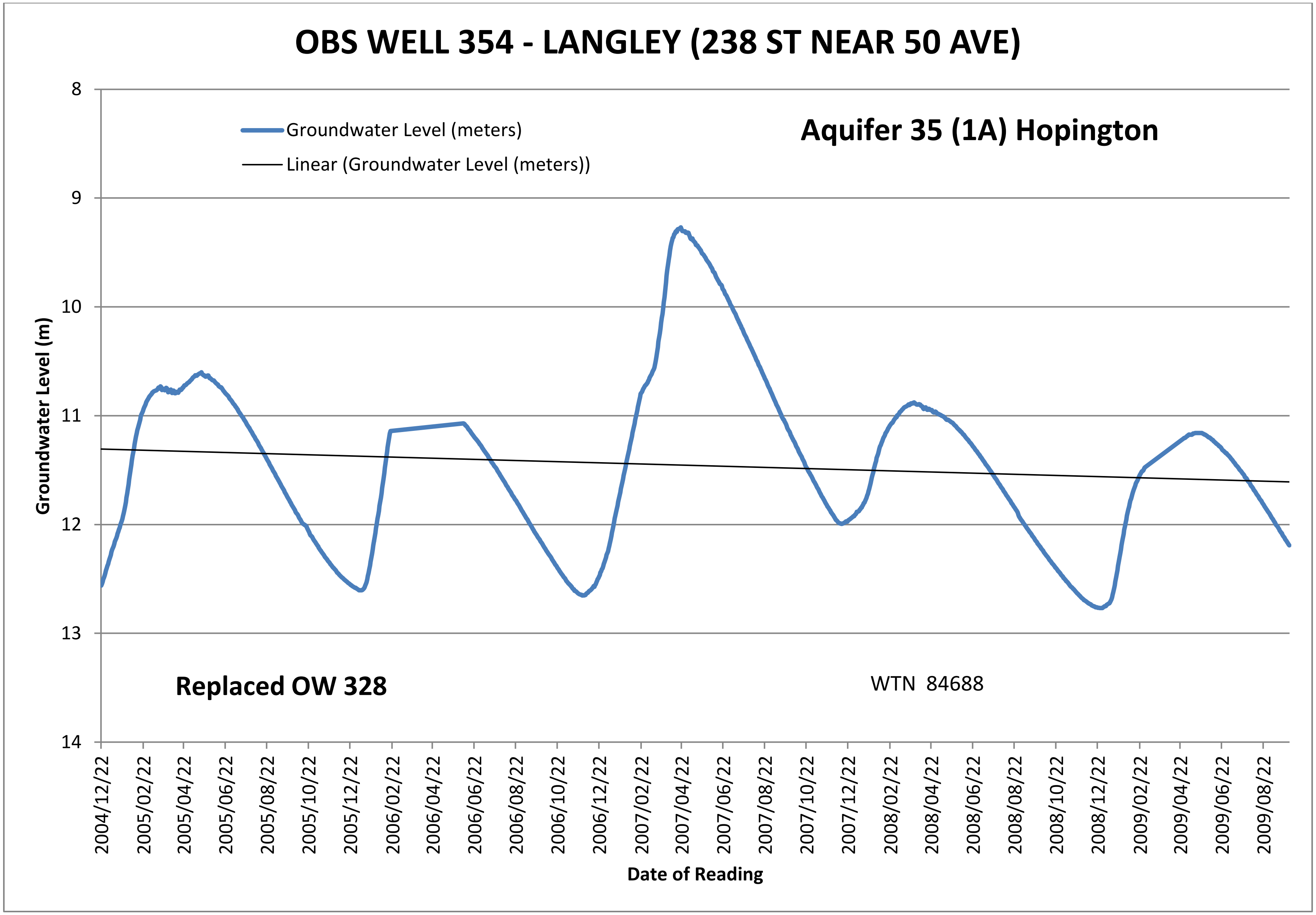
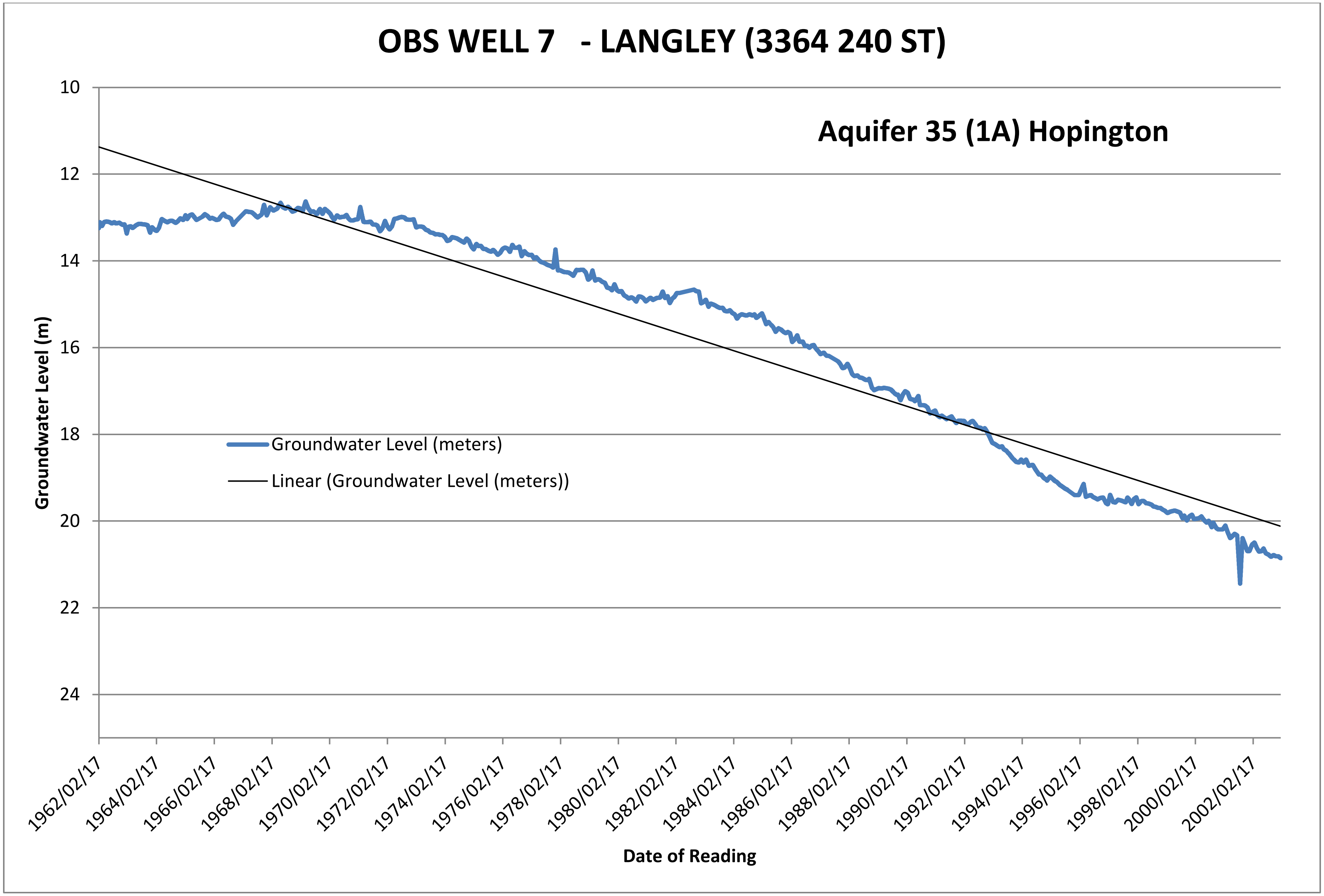
2009/09/10
Date of Reading

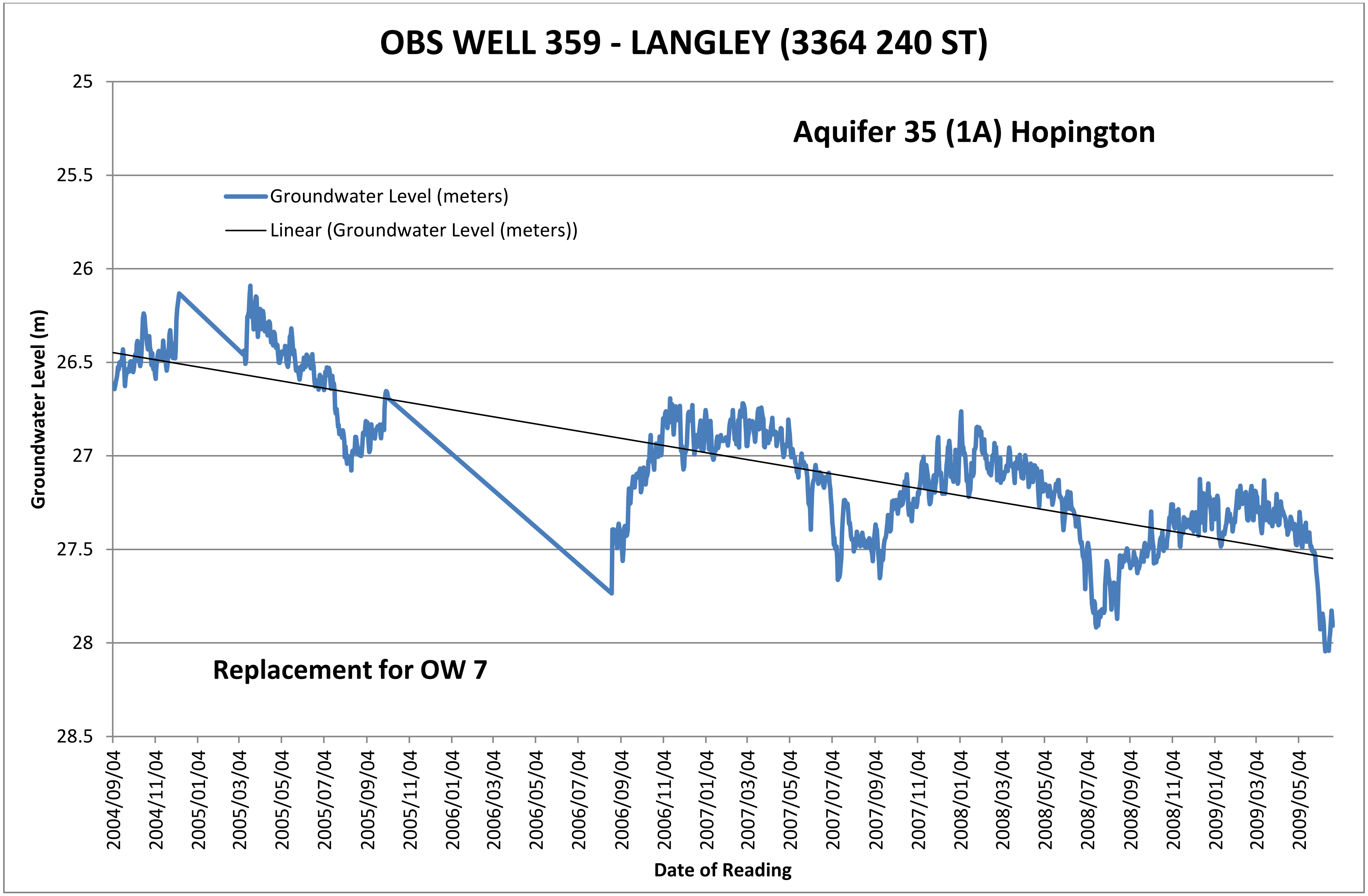


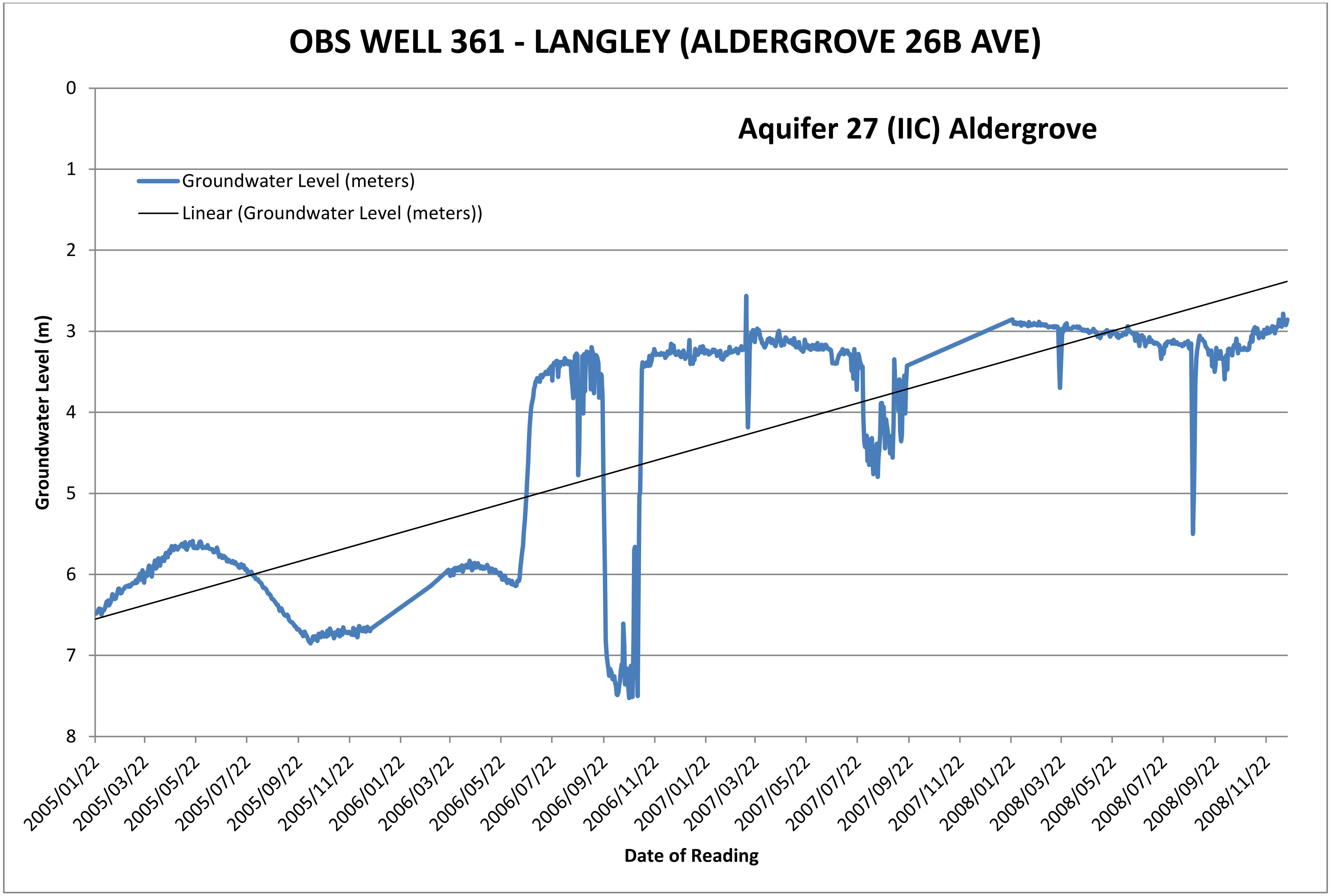
OBS WELL 328 - LANGLEY (238 ST N OF 50 AVE)
Aquifer 35 (1A) Hopington
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
8
9
10
11
12
13
14
1994/09/30
1995/09/30
1996/09/30
1997/09/30
1998/09/30
1999/09/30
2000/09/30
2001/09/30
2002/09/30
Date of Reading

DRAFT


OBS WELL 354 - LANGLEY (238 ST NEAR 50 AVE)
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Aquifer 35 (1A) Hopington
Groundwater Level (m)
8
9
10
11
12
13
14
Replaced OW 328
WTN 84688
2004/12/22
2005/02/22
2005/04/22
2005/06/22
2005/08/22
2005/10/22
2005/12/22
2006/02/22
2006/04/22
2006/06/22
2006/08/22
2006/10/22
2006/12/22
2007/02/22
2007/04/22
2007/06/22
2007/08/22
2007/10/22
2007/12/22
2008/02/22
2008/04/22
2008/06/22
2008/08/22
2008/10/22
2008/12/22
2009/02/22
2009/04/22
2009/06/22
2009/08/22
Date of Reading


OBS WELL 7 - LANGLEY (3364 240 ST)
Aquifer 35 (1A) Hopington
Groundwater Level (m)
10
12
14
16
18
20
22
24
Groundwater Level (meters)
Linear (Groundwater Level (meters))
1962/02/17
1964/02/17
1966/02/17
1968/02/17
1970/02/17
1972/02/17
1974/02/17
1976/02/17
1978/02/17
1980/02/17
1982/02/17
1984/02/17
1986/02/17
1988/02/17
1990/02/17
1992/02/17
1994/02/17
1996/02/17
1998/02/17
2000/02/17
2002/02/17
Date of Reading


OBS WELL 359 - LANGLEY (3364 240 ST)
Aquifer 35 (1A) Hopington
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Replacement for OW 7
Groundwater Level (m)
Date of Reading
25
25.5
26
26.5
27
27.5
28
28.5
2004/09/04
2004/11/04
2005/01/04
2005/03/04
2005/05/04
2005/07/04
2005/09/04
2005/11/04
2006/01/04
2006/03/04
2006/05/04
2006/07/04
2006/09/04
2006/11/04
2007/01/04
2007/03/04
2007/05/04
2007/07/04
2007/09/04
2007/11/04
2008/01/04
2008/03/04
2008/05/04
2008/07/04
2008/09/04
2008/11/04
2009/01/04
2009/03/04
2009/05/04



OBS WELL 361 - LANGLEY (ALDERGROVE 26B AVE)
Aquifer 27 (IIC) Aldergrove
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
Date of Reading
0
1
2
3
4
5
6
7
8
2005/01/22
2005/03/22
2005/05/22
2005/07/22
2005/09/22
2005/11/22
2006/01/22
2006/03/22
2006/05/22
2006/07/22
2006/09/22
2006/11/22
2007/01/22
2007/03/22
2007/05/22
2007/07/22
2007/09/22
2007/11/22
2008/01/22
2008/03/22
2008/05/22
2008/07/22
2008/09/22
2008/11/22

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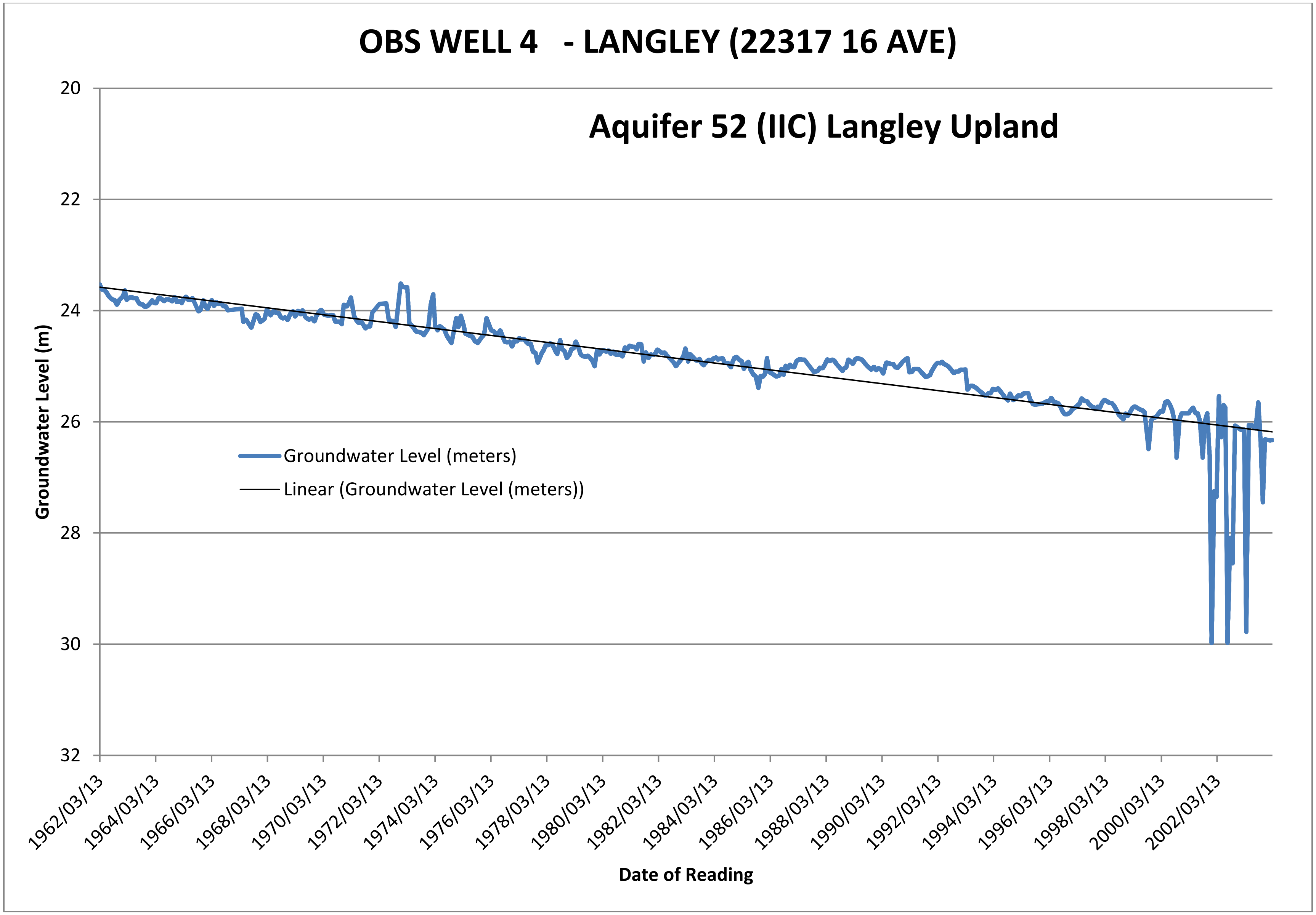
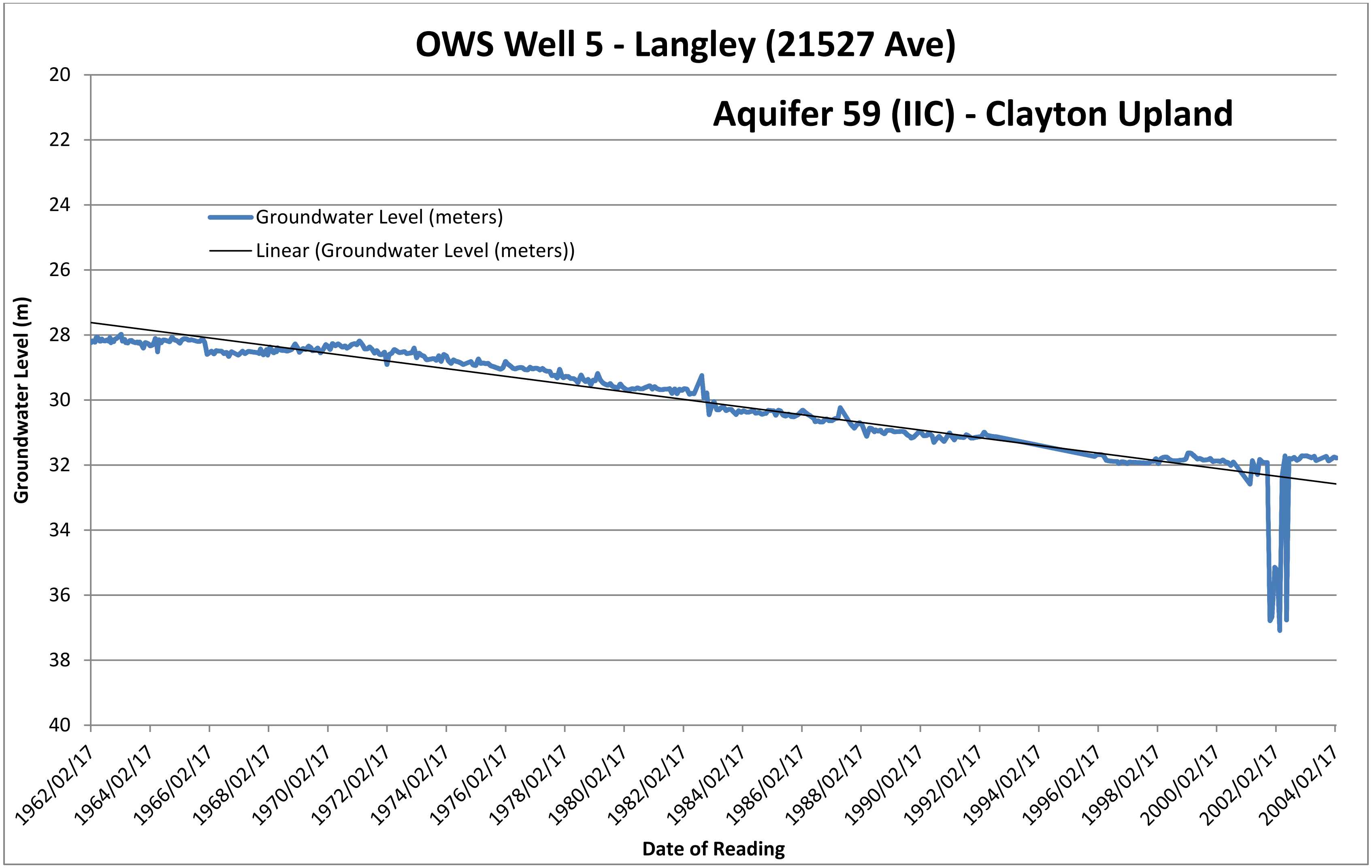


OBS WELL 4 - LANGLEY (22317 16 AVE)
Aquifer 52 (IIC) Langley Upland
Groundwater Level (m)
20
22
24
26
28
30
32
Groundwater Level (meters)
Linear (Groundwater Level (meters))
1962/03/13
1964/03/13
1966/03/13
1968/03/13
1970/03/13
1972/03/13
1974/03/13
1976/03/13
1978/03/13
1980/03/13
1982/03/13
1984/03/13
1986/03/13
1988/03/13
1990/03/13
1992/03/13
1994/03/13
1996/03/13
1998/03/13
2000/03/13
2002/03/13
Date of Reading


OWS Well 5 - Langley (21527 Ave)
Aquifer 59 (IIC) - Clayton Upland
Groundwater Level (meters)
Linear (Groundwater Level (meters))
Groundwater Level (m)
20
22
24
26
28
30
32
34
36
38
40
1962/02/17
1964/02/17
1966/02/17
1968/02/17
1970/02/17
1972/02/17
1974/02/17
1976/02/17
1978/02/17
1980/02/17
1982/02/17
1984/02/17
1986/02/17
1988/02/17
1990/02/17
1992/02/17
1994/02/17
1996/02/17
1998/02/17
2000/02/17
2002/02/17
2004/02/17
Date of Reading

