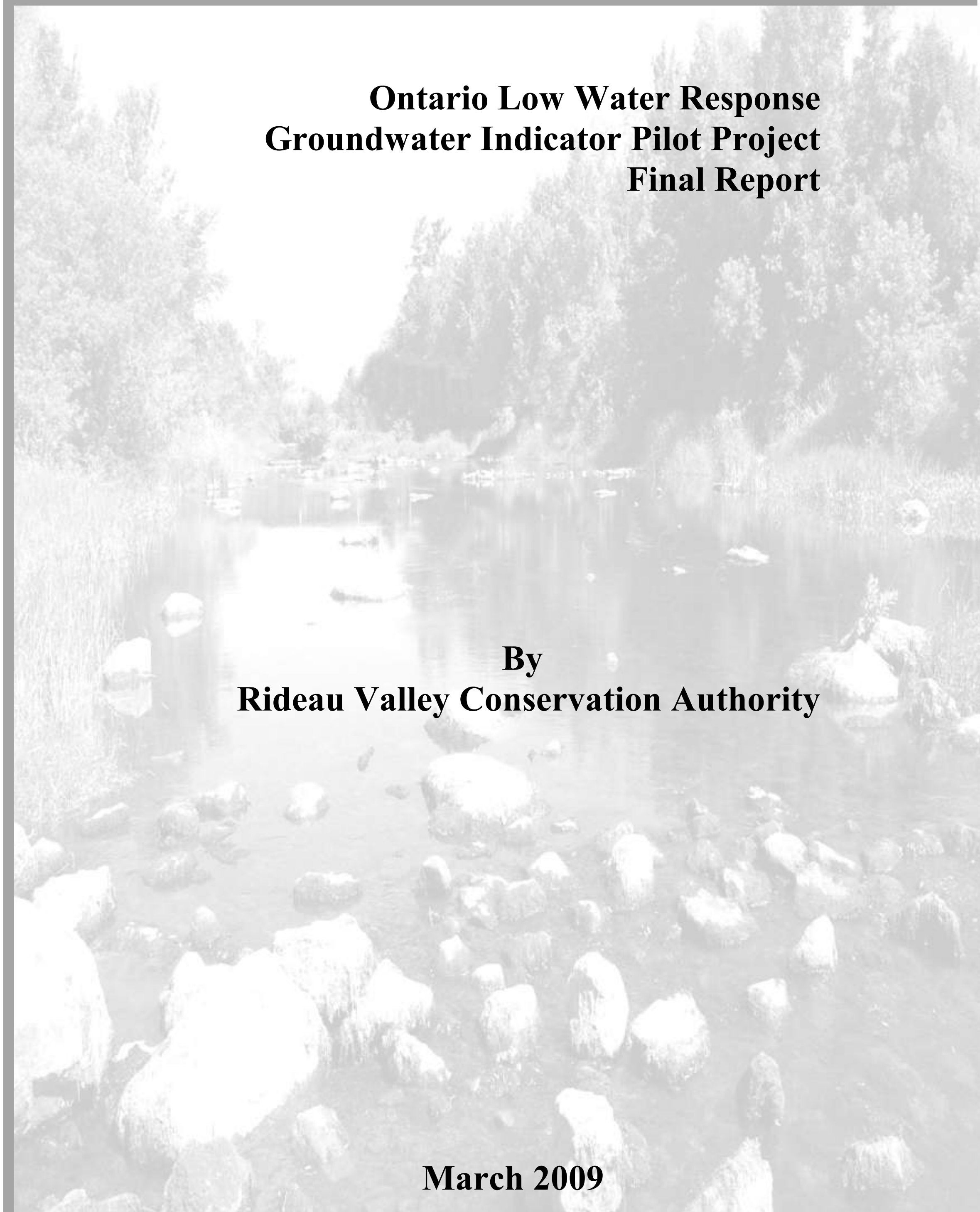
RIDEAU VALLEY CONSERVATION AUTHORITY



Ontario Low Water Response Groundwater Indicator Pilot Project Final Report

By

Rideau Valley Conservation Authority

March 2009

Ontario

Acknowledgements

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1. Introduction

This report presents the results of a study for the use of Provincial Groundwater Monitoring Network (PGMN) wells as indicators of climate change and low water conditions (Level I, II and III indictors) for applicability to the Ontario Low Water Response (OLWR) program. The report also presents an overview of the information that has been collected and used by Rideau Valley Conservation Authority (RVCA) in assessing the utility of the indicators such as water levels, description and characteristics of the selected wells, methods used to determine the groundwater indicators and issues associated with the groundwater data used in the project. The report also presents a comparison of the groundwater triggers based on two methodologies, namely the Jacques Whitford methodology described in their report titled "Groundwater Indicator Study" and the percentile based methodology proposed by the Ministry of Environment (MOE).

This study, which tests the use of wells and groundwater levels as potential indicators of low water conditions, has been funded by the Ontario Ministry of Natural Resources (MNR). A project budget and expense report is attached in Appendix C.

1.1. Background

Changing weather patterns associated with climate change can result in periods of drought, heat waves, and more frequent storm events. Both drought and storm events can be fairly localized, resulting in local impacts on water supplies, agriculture, wetlands etc. Extremely dry conditions in 1998 and 1999 in Ontario resulted in the development of the OLWR- Ontario Low Water Response Plan (revised July 2003). OLWR is intended to ensure provincial preparedness, to assist in coordination and to support local response in the event of drought. The advisories issued under the OLWR protocols also keep the public informed of the developing drought conditions within a watershed. Currently OLWR uses precipitation and flow as indicators for drought events. However, the need for baseflow, groundwater and aquifer level indicators have also been identified in OLWR Program (revised July 2003).

Since groundwater is impacted by changes in the weather conditions to varying degrees, it can be a useful indicator in addition to precipitation and stream flow. The MNR commissioned Jacques Whitford to conduct a study for the use of groundwater as an indicator and to develop a methodology for determining groundwater trigger levels at PGMN wells for potential use as Level I, II and III indicators for OLWR. This study resulted in a report, the Jacques Whitford Groundwater Indicator Report (2008), which defined two trigger levels and described how to use these to determine when a watershed is at a Level I, II or III condition. A number of conservation authorities were involved in the Groundwater Indicator study, supplying data and information. One of the outcomes of the project was the development of a spreadsheet tool used to calculate the groundwater indicator values at groundwater well sites. The tool was used to calculate the indicator values for five specific sites. These sites are located in the Ganaraska, Long Point, Rideau, South Nation, and Upper Thames conservation authorities.

The Jacques Whitford method is based on statistical diagnostics (mean and standard deviation) of the groundwater levels collected from the PGMN monitoring wells. The Ministry of Environment has developed another method for calculating groundwater indicators using the percentile methodology. Applying this method to groundwater levels, triggers or conditions for low water response is based on setting the triggers at specified percentiles (e.g. 5th, 10th or 50th percentiles). In general, the 25th to 75th percentile range is considered as normal to above normal, the 10^{th} to 25^{th} percentile range is considered dry (or drought watch), and below the 10th or 5th percentile is considered extremely dry conditions in a water well.

In the current study, the approaches for developing groundwater indicators and triggers are not a focus of discussion. Rather, the direct application of the noted approaches has been undertaken to determine the indicators for selected wells. Further details on the two methods can be found in the following two reports:

1. Guidance Document for Using the Percentile Method for Calculating Trigger Levels for Groundwater for the Ontario Low Water Response Plan., Ministry of Environment, March 2008 (MOE 2008).

2. FINAL REPORT: Develop a Groundwater Indicator for Ontario Low Water Response, Ontario Ministry of Natural Resources, 2008 (JW 2008).

The above mentioned documents are also used in the preparation of this report to provide conceptual background for the methods used.

The source of the groundwater level data used for calculating groundwater indicators and triggers (based on the two methodologies mentioned above) in the study were the groundwater monitoring wells that form the Provincial Groundwater Monitoring Network (PGMN) in Ontario. In the Rideau Valley Conservation Authority, there are 15 groundwater monitoring stations (Figure 3-1) and five of these stations were selected for the purpose of this study.

1.2. Study Objectives

The purpose of the study is to evaluate the utility of the groundwater indicators for the Ontario Low Water Response Program and to assess whether these can be used to report on developing low water conditions in an area represented by water well or an aquifer in Rideau Valley Watershed.

1.3. Scope of the Study

The study will determine groundwater triggers and indicators using two approaches and apply the results to establish if low level water conditions are developing in the monitoring wells. More specifically the study will:

1. Present an overview of the two approaches used for developing the groundwater triggers.
2. Identify the PGMN wells for use in the study.
3. Discuss the characteristics of the selected well sites.
4. Analyze the groundwater level data and calculate the triggers based on the JW approach and the Percentile approach.
5. Collect the water levels from the selected wells between July-October 2008.
6. Compare the collected water levels to the indicators and triggers to establish whether low water conditions are developing in selected wells. If the observed water levels in 2008 are representative of normal aquifer conditions, then historical water levels observed in a

low rainfall year (2001, 2003 or 2007) will be used to establish whether low water level conditions are developing based on groundwater indicators inferred by the two approaches.

7. Evaluate the utility of the groundwater indicators to the Ontario Low Water Response Program, and whether these can be used to report on the developing low water conditions in areas represented by water wells or aquifers (as per Ontario Low Water Response (OLWR) Level I, II and III indicators for groundwater).
8. Compare the two approaches in terms of ease of use, data requirements, level of effort required and requirements of expertise for undertaking the analysis.
9. Identify the limitations in implementing the approaches, if any.
10. Document the data gaps, issues, etc. with groundwater data.

Following completion of the above mentioned tasks, study findings and recommendations will be presented.

2. Groundwater Triggers and Calculation Approaches

This section briefly discusses the groundwater triggers and associated conditions based on the Jacques Whitford approach and the Percentile approach. The groundwater levels from the monitoring wells were compared with the triggers developed through the two approaches to assess the development of low water conditions in aquifers or in areas represented by monitoring wells.

2.1. Jacques Whitford (JW) Method

The proposed groundwater low water indicator is based on the recognition that groundwater levels fluctuate on a seasonal cycle under normal conditions. Triggers are specific groundwater indicator values (i.e., monthly average groundwater levels) for activating the Ontario Low Water Response Program (OLWR) condition levels (i.e., Level I, Level II, and Level III). Two Trigger values have been developed for this method, which act as specific groundwater indicator values for activating the OLWR levels. The Triggers (i.e. Trigger 1 and 2) are based on monthly average groundwater levels. The JW approach assumes that groundwater levels follow a seasonal pattern that occurs every 12 months and that variation in daily groundwater levels are symmetrically distributed about the mean value, i.e. in a distribution that resembles the normal distribution. The triggers are described below.

The Trigger 1 value for a well is defined as the mean groundwater level in a month minus the standard deviation of daily-average water levels for that month. The Trigger 2 value for a well is defined as the extreme low groundwater level below which environmental, social and economic impacts are expected to occur. This value must be selected for each monitoring well based on the terminating depth of the well, properties of the aquifer, and characteristics of the groundwater users that depend on the resources monitored by the well. If this information is unavailable, a default value for the Trigger 2 level can be taken as the value of the lowest daily average level that has been observed in the well.

The Table 2-1 shown below highlights the application of Trigger levels, and demonstrates the circumstances that must take place in order to activate a Level I, Level II or Level III Low Water Condition, and also the circumstances for recovery from Low Water Conditions. In all cases, the term "30-day average" refers to the 30-day average groundwater level for a particular well, and the term "Daily average" refers to the daily average groundwater level for all measurements recorded on the same day, for a particular well.

The indicators and triggers calculated using the JW methodology are discussed in Section 5 of this report.

Table 2-1: On-Set and Recovery of Low Water Conditions.

OLWR Level	Conditions for On-Set	Conditions for Recovery
"No Advisory"	30-day average remains above Trigger 1	30-day average remains above Trigger 1
Level I – the first indication of a potential water supply problem.	30-day average falls below Trigger 1	30-day average rises above Trigger 1 for three months in a row (and) Daily average rises above Trigger 2 for all of the days in the previous month
Level II – indicates a potentially serious problem.	30-day average falls below Trigger 1 for three months in a row (or) Daily average falls below Trigger 2 for at least one day in the previous month	30-day average rises above Trigger 1 (and) Daily average rises above Trigger 2 for all of the days in the previous month
Level III – indicates the failure of the water supply to meet the demand, resulting in progressively more severe and widespread socioeconomic effects.	30-day average falls below Trigger 2	30-day average rises above Trigger 2

2.2. Percentile Method

The percentile approach for establishing groundwater triggers is consistent with the kind of approach taken to establish other OLWR triggers based on precipitation and streamflow indicators. A percentile is a value on a scale of 0 to 100 that indicates the percent of the number of observations that is equal to or below it. For example, the 50^{th} percentile is the value (or score) below which 50 percent of the observations may be found. The groundwater triggers and associated conditions based on this approach are given in the following table:

Table 2-2: Percentiles Based Triggers and associated groundwater Conditions (MOE 2008).

Percentile (percentage of values below)	**Trigger or Condition**	**Description**
100	Maximum	Maximum water level
75	Above normal	Above normal or wet conditions
50	Normal or median	Normal conditions
25	Trigger 1	Below normal or drought watch
10	Trigger 2	Dry conditions or drought warning
5	Trigger 3	Very dry
0	Minimum	Minimum water level

The measured water levels are compared to the 25th percentile to determine Trigger 1 (**OLWR Level I)**, 10th percentile to determine Trigger 2 (**OLWR Level II)** and 5th percentile to determine Trigger 3 (**OLWR Level III)**. A well will be considered normal if the measured water levels are between 25th to 75th percentile range, in Level I or under drought watch if the levels are between 10th to 25th percentile range, in Level II or in dry conditions if levels are between 5th to 10th percentile, and in level III or very dry conditions if the levels fall below the 5th percentile.

As an example, if the measured water levels for a particular period are above the 25th percentile, the comparison with percentile and trigger levels (Table 2-2) will indicate that normal groundwater conditions exist within the well during the period under consideration and the aquifer is not suffering from low water conditions as a result of climate change or other factors. The indicators and triggers calculated using the percentile approach are discussed in Section 5 of this report.

3. Groundwater Monitoring Stations

In the Rideau Valley Conservation Authority, there are 15 wells (Figure 3-1) being monitored (for groundwater levels and water quality) as part of the Provincial Groundwater Monitoring Network (PGMN) in Ontario. Five of these stations have been selected for testing the Jacques Whitford (JW) approach and the Percentile approach, for applicability to the Ontario Low Water Response program. A brief description of each monitoring well, site characteristics and rationale for their selection has been discussed in this section. The well logs and photos for the selected wells are attached in Appendix A and B of the report.

3.1. Selection of Monitoring Wells

Out of fifteen (15) wells being monitored within the Rideau Watershed, only five (5) were selected for the purposes of this study. This selection was based on the following factors:

1. Length of the water level record available from the wells. Selected well should have continuous long term (3 to 5 years) water level measurements to better reflect the behavior of the aquifer in response to the changing weather patterns (to establish normals and extremes).
2. Water levels during a reference dry year(s) or drought year(s) are available for comparison. It is critical that the available water level data be representative of a dry year(s) or a season(s) during which drought conditions were observed (and caused economical, environmental, social etc. impacts) in an aquifer (as shown by monitoring wells or area wells going dry, or exhibiting extremely low water levels etc.). This will ensure the correct interpretation of the triggers, and support the manipulation of the trigger values, if required.
3. Quality of collected data is good and gaps in the data records are minimal. There should be minimal gaps in the data record so that the seasonal water level fluctuations are accurately represented. Also, the water levels collected by the automatic data loggers such as those used in the PGMN may include some inaccuracies (outliers etc.). It is necessary that the manual water level measurements also be available (from the wells) in order to capture the inaccuracies and to ensure that the data is reliable. Also, any unexplainable water level fluctuations such as spikes etc. due to equipment malfunctions, equipment replacements should be explainable.
4. Well or water levels are responsive to the seasonal weather changes. There should be good correlation between the water level fluctuations in the well and the rainfall events in order to ensure that the well is suitable to register extreme climate change events such as drought etc. It is critical to understand the degree of “lag” between a rainfall event and corresponding water level fluctuation in a well to make an assessment of the groundwater conditions and the application of triggers.
5. Geology and hydrogeology of the well site is known. The selected well should at least have a well log, well record etc. This will ensure accurate understanding of the groundwater dynamics for interpreting the aquifer response and for application of the groundwater triggers.

6. Hydraulic interconnectivity and surface influences are understood. The influences on wells from rivers, streams, wetlands, etc. and recharge-discharge characteristics of the site need to be clearly understood so that well (aquifer) behavior is accurately interpreted. The comparison with stream flows records (from the gauge stations located nearby) could provide a useful insight into the potential of hydraulic interconnectivity with the surface influences. However, this analysis was not undertaken in the current study.
7. Type of the well is known. Deeper wells, such as those drilled into regional aquifers (Sandstone aquifer etc.), may not show any response to the changing weather patterns, or may show the impacts of climate change in terms of lower water levels but due to ample storage, they are able to better withstand the drought or low water conditions. On the other hand, shallower wells may be prune to more frequent water shortages due to even slight water level changes as they have far less borehole storage as compared to the deeper wells. Such wells (too deep or too shallow) were not considered suitable for this study since the water level changes in these well will not necessarily translate into the impacts (drought etc.) on the surroundings environment.
8. The well is representative of the aquifer in use in the area so that the well or aquifer users can be informed of the developing low water conditions.
9. Information on the surrounding land use is available. The inventory of the surrounding land use around the well site is necessary for understanding whether factors other than the weather changes (water takings, etc.) are impacting the water levels.
10. Well is accessible. The selected well should be readily accessible so that manual water level measurements etc. can be performed or other site investigations could be undertaken, if required, to better understand the local aquifer.

The characteristics of the selected wells are discussed individually in the following paragraphs along with additional details on the rationale for their selection (Table 3-1 and Table 3-2).

Table 3-1: Wells Characteristics and Rationale for Selection.

Well ID	New/ Existing	Geology	Owner-ship	Location		Rationale
				General	Municipality	
Well-81	Existing	Clay overlying dolostone (Oxford Formation)	RVCA	W.A. Taylor Park	Ottawa	This well is tapping a contact zone aquifer and is located between two branches of the Rideau River. By comparing the groundwater levels with the Rideau water levels/flows, recharge conditions between the shallow and deep aquifers and their interconnections with the Rideau could be deciphered, if any. If there is direct hydraulic interconnection, then this well will reflect the effects of climate change on river flows and recharge to the aquifers. This well is not considered to be under any water taking influences.
Well-83	Existing	Precambrian bedrock underlying sandstone (Nepean Formation)	RVCA	OMYA	Tay Valley	A substantial amount of groundwater is being extracted from wells at OMYA. Groundwater quantity is an issue in the surrounding area, which could be worsened by droughts and dry seasons. Therefore, information regarding impacts of weather changes on ambient groundwater levels would be valuable to determine whether drought conditions can develop in this well and the area represented by this well.
Well-86	Existing	Clay and gravel overlying dolostone (Oxford Formation)	RVCA	Long Island Park	Ottawa	The groundwater quantity of the private wells along Long Island is in question. Water levels from this well could help to detect potential groundwater shortages as a result of climate change.
Well-156-2	New	Champlain Sea deposits (marine clay and gravel layers) overlying dolostone (Oxford	RVCA	Twin Elm Bridge	Ottawa	During the dry season, the shallow groundwater from the agricultural area north of the Jock River contributes to the baseflow of the river. From the water level readings, it may be possible to forecast the effect of climate change on the shallow aquifer and

		Formation)				the river water level/discharge.
Well-252	New	Precambrian Granite	RVCA	Christie Lake Club	Tay valley	This well is located very close to a lake, where population is scattered along valleys between tectonic ridges. Water level observations will help to understand groundwater supply behavior as well as potential climate change impacts in low-yielding Precambrian rocks.

Table 3-2: Well Locations and Elevations.

Well ID	MOE Well ID	Location	Easting	Northing	Top of Casing Elevation (m.a.s.l)	Ownership (Well/ Land)	Lot	Conc.	Current (Former) Township
Well-81	W0000081	W.A. Taylor Park	450190	4998110	91	RVCA	28	Broken Front	City of Ottawa (Osgoode)
Well-83	W0000083	OMYA Industrial Plant Site	395523	4969770	146	Private	18	3	Tay Valley
Well-86	W0000086	Long Island Park	444923	5010463	93	RVCA			City of Ottawa
Well-156-2 (shallow)	W0000156-2	Twin Elm Bride	436497	5009067	107	RVCA/City of Ottawa	12	5	City of Ottawa
Well-252	W0000252	Christie Lake Camp Site	386698	4961094	180	RVCA/ Private	19	2	Tay Valley

3.2. Well-81 (W.A. Taylor Park)

3.2.1. Well Description

This well is located in the W.A. Taylor Conservation Area (owned by the RVCA) along the east bank of the Rideau River, approximately 1.5 km west of the community of Osgoode (Figure 3-2). The distance between the well and the river to the west is approximately 100 m. A park area surrounds the well, while the land use fewer than 100 m to the east is agricultural. The well was pre-existing when it was selected as a PGMN well. A well photo is provided in Appendix B.

This well was a part of the Jacques Whitford 2008 Groundwater Indicator Study. The groundwater triggers calculated by the mentioned study for this well have been updated based on the recently available water level data.

A summary of well characteristics and rationale for including this well in the groundwater indicator study has been provided in Table 3-1. Well location description has been summarized in Table 3-2.

3.2.2. Geology & Hydrogeology

The well (Log 1, Appendix A) was assumed to correspond to the MOE Well Record ID 1516562. The well record described Well-81 as having approximately 14 m of clay, underlain by 7 m of material ("hardpan") interpreted to be glacial till, all of which overlies the dolostone of the Oxford Formation. The fine-grained overburden materials are inconsistent with geology maps which suggest the presence of fine- to-medium-grained glaciomarine sand deposits; however, glaciomarine clay, silt and till deposits have been mapped nearby.

The well record indicates that the water-bearing zone of the bedrock aquifer was encountered at approximately 36 m below the top of the dolostone unit. The PGMN well reaches 54.3 m depth below ground surface (bgs) and well construction consists of a steel casing through the overburden to 21.6 m and an open hole in the bedrock.

3.3. Well-83 (OMYA Industrial Plant Site)

3.3.1. Well Description

This well is located 6 km southwest of the town of Perth near the fabrication plant of OMYA, a producer of calcium carbonate and talc (Figure 3-3). The OMYA plant is approximately 500 m northwest of the well; otherwise the surrounding land use is a combination of forest, agriculture and rural settlement. The Tay River passes approximately 800 m southeast of the well, while a tributary stream to the river flows 250 m north of it. The well was pre-existing when it was selected as a PGMN well and is located on land owned by OMYA. A well photo is provided in Appendix B.

A summary of well characteristics and rationale for including this well in the groundwater indicator study has been provided in Table 3-1. Well location description has been summarized in Table 3-2.

3.3.2. Geology & Hydrogeology

The well (Log 2, Appendix A) was assumed to correspond to MOE Well Record ID 3511815 since the original well record was not available. The stratigraphy described in that record consisted of approximately 1.2 m of topsoil underlain by 19.5 m of sandstone (Nepean Formation). Below the sandstone, the material was interpreted to be 25.0 m of Precambrian granite bedrock (described in the well record as black sandstone and grey-red sandstone).

The well was constructed with a steel casing to 6.7 m and an open hole to 45.7 m in the granite. According to the well record, water-bearing zones were encountered at around 21.9 m (near the interface of the sandstone and granite units) and 43.0 m. As a result, the groundwater in the well may represent the characteristics of both units.

3.4. Well-86 (Long Island Park)

3.4.1. Well Description

This well is located on Long Island in the community of Manotick, which is incorporated in the City of Ottawa. More specifically, the well is located in the 35-acre David Bartlett Park (Long Island Park) on the northern tip of the island, which is on the Rideau River (Figure 3-4). Beyond the limits of the park, the island is populated by suburban settlement. The west channel of the Rideau River is within 90 m of the well. The well is located on land owned by the City of Ottawa and was pre-existing when it was selected as a PGMN well. A well photo is provided in Appendix B.

A summary of well characteristics and rationale for including this well in the groundwater indicator study has been provided in Table 3-1. Well location description has been summarized in Table 3-2.

3.4.2. Geology & Hydrogeology

Since the log of the PGMN well was not available, its stratigraphy (Log 3, Appendix A) was assumed from the water well record for a nearby well (MOE Well Record ID 1505910). The nearby well's stratigraphy was described as approximately 17.7 m of clay underlain by gravel to 18.3 m. The well depth is 18.9 m, and the well construction consists of a steel casing through the overburden and an open hole in the bedrock below the gravel formation. Geological mapping shows that the local overburden consists of glaciomarine silt and clay deposits, and the bedrock is dolostone of the Oxford Formation.

3.5. Well-156-2 (Twin Elm Bridge)

3.5.1. Well Description

This well is located on the west bank of the Jock River approximately 900 m downstream of the Twin Elm bridge (Cambrian Road) and 5 km northeast of the community of Richmond (Figure 3-5). The well is located approximately 15 m from the river on land owned by the City of Ottawa, and was drilled in 2002 in conjunction with the PGMN program. The dominant land use in the area surrounding the well is agriculture. A well photo is provided in Appendix B.

A summary of well characteristics and rationale for including this well in the current study has been provided in Table 3-1. The well location description has been summarized in Table 3-2.

3.5.2. Geology & Hydrogeology

This is a multi-level monitoring well, however only the overburden level (shallow well) has been incorporated into this study. A borehole log (Log 4) is provided in Appendix A. The geologic materials recorded at the site consist of approximately 18.3 m of clay (described in geological maps as glaciomarine deposits), underlain by gravel with sand and boulders to 26.2 m bgs followed by dolostone bedrock of the Oxford Formation. The well record indicates that water was encountered during drilling at approximately 26 m bgs (at the overburden-bedrock interface) and 46 m bgs (in the bedrock). A metal casing was installed through clay, and a multi-level monitoring well was installed in the water-yielding units below, with screen of the shallow well (Well 156-2, shallow) from approximately 18.3 to 25.9 m bgs in the gravel and another from 33.5 m to 42.7 m bgs in the dolostone (Well 156-3, deep). Most wells in the area tap either the overburden/contact aquifer or the dolostone aquifer, both of which are represented by this PGMN well.

3.6. Well-252 (Christie Lake Camp Site)

3.6.1. Well Description

This well is located on private land along the south shore of Christie Lake (Figure 3-6), 18 km southwest of Perth, and was drilled in 2002 in conjunction with the PGMN program. The lake is approximately 300 m from the well. The dominant land cover in the area is forest, although there is a concentration of permanent or seasonal residences along the lakeshore. A well photo is provided in Appendix B.

A summary of well characteristics and rationale for including this well in the groundwater indicator study has been provided in Table 3-1. Well location description has been summarized in Table 3-2.

3.6.2. Geology & Hydrogeology

The well (Log 5, Appendix A) corresponds to MOE Well Record ID 3513962 which describes a thin layer (1 m) of topsoil overlying Precambrian granite bedrock to 31 m. Well construction consisted of a steel casing to 6.7 m, below which was an open hole in the bedrock. The well record indicates that water was encountered during drilling at approximately 23 and 26 m bgs, suggesting that the fractured, water-yielding portion of the bedrock aquifer is confined by the less-fractured material above.

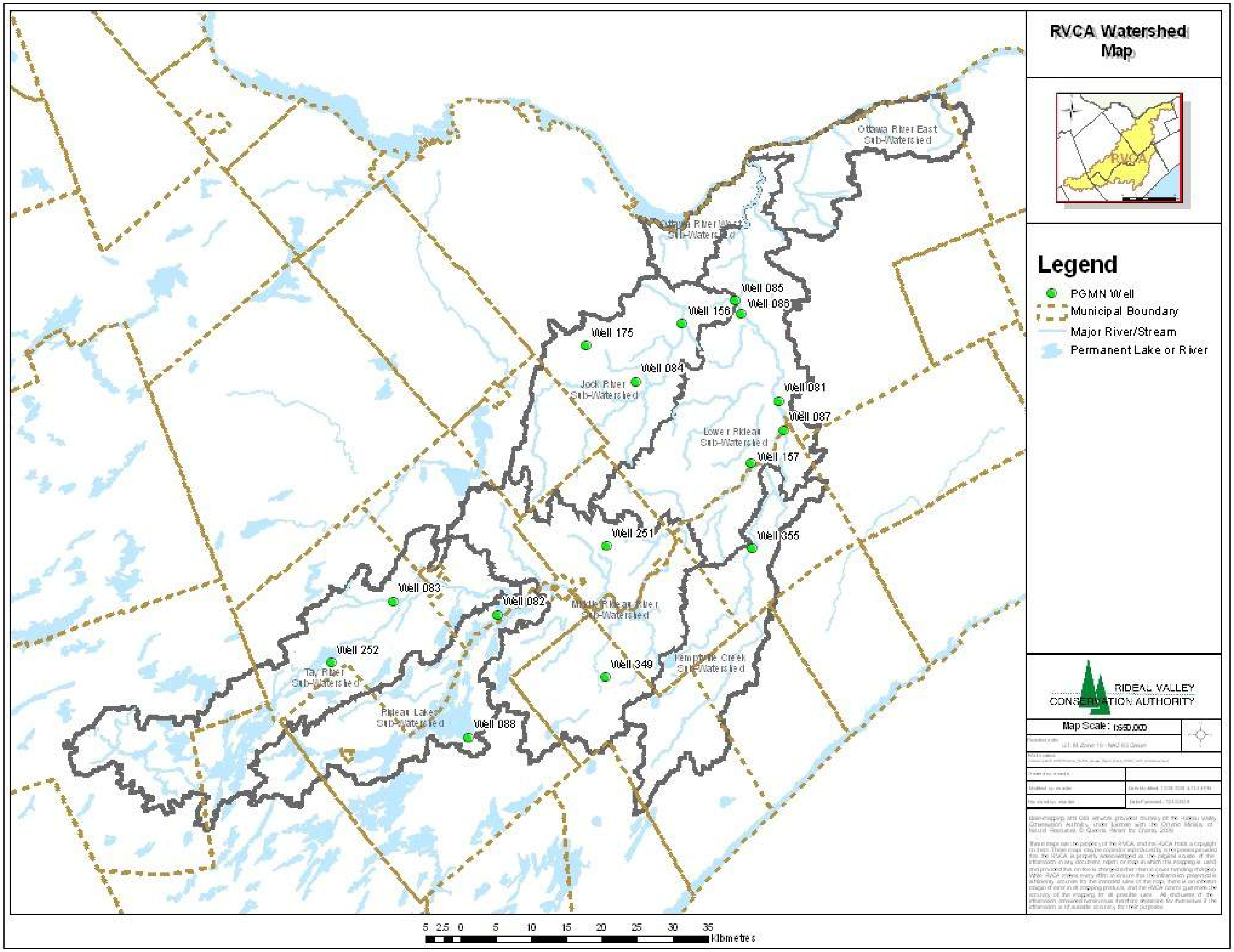


Figure 3-1: Rideau Valley Watershed and locations of PGMN Stations.

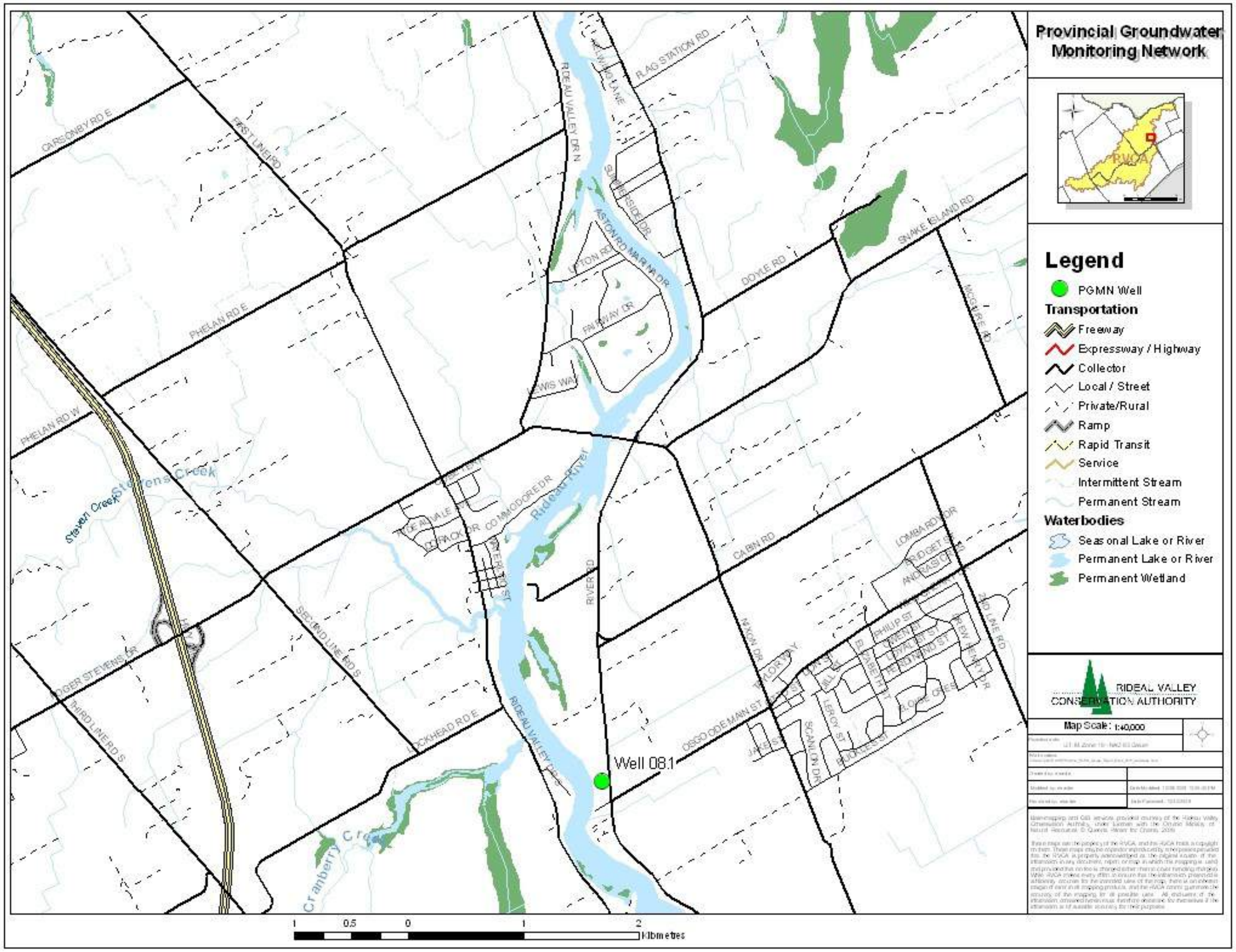


Figure 3-2: Location of Well-81 close to Rideau River at W.A.Taylor Park.

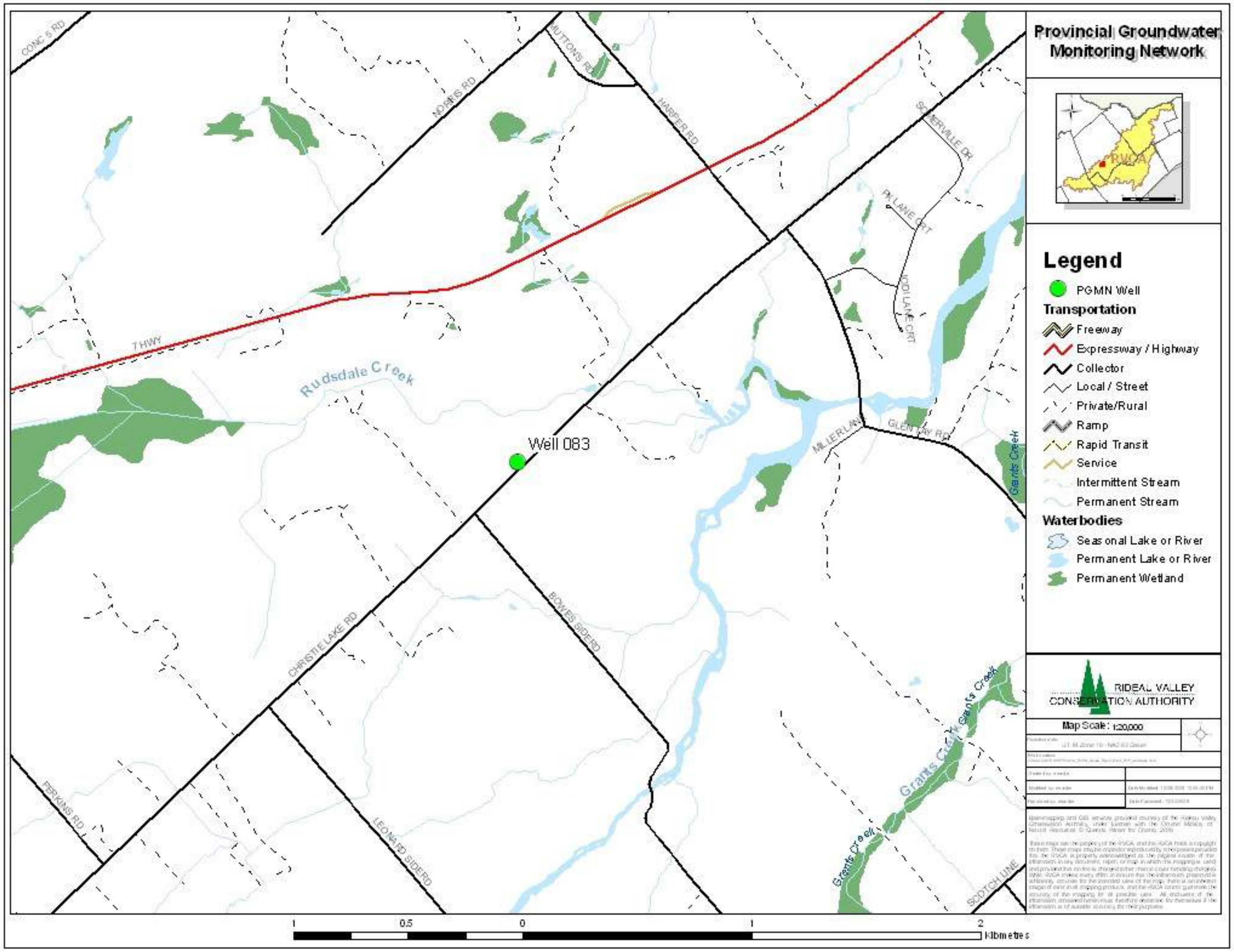


Figure 3-3: Location of Well-83 close to Tay River at OMYA site.

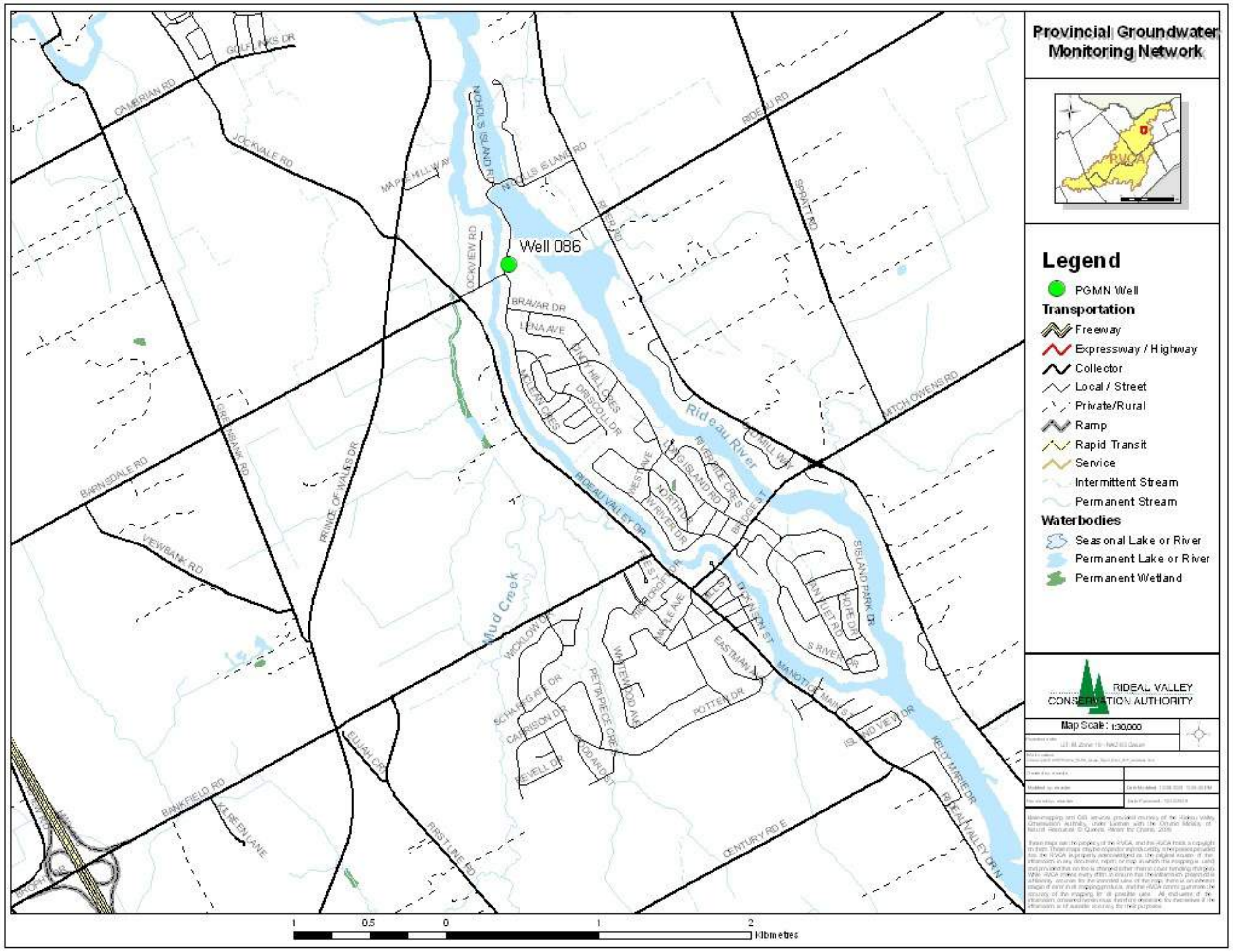


Figure 3-4: Location of Well-86 on Rideau River at Long Island Park.

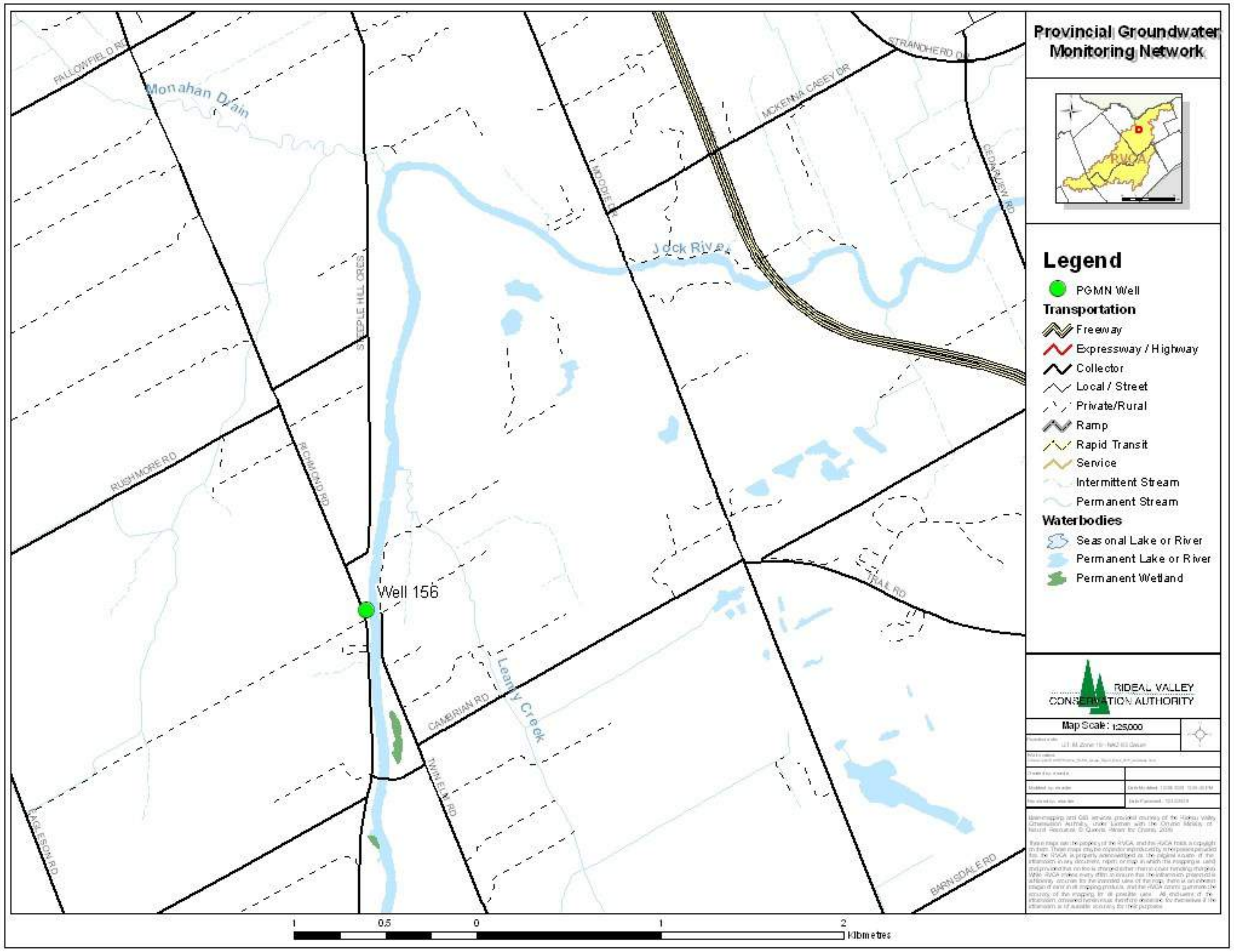


Figure 3-5: Location of Well-156 on Jock River at Twin Elm Bridge.

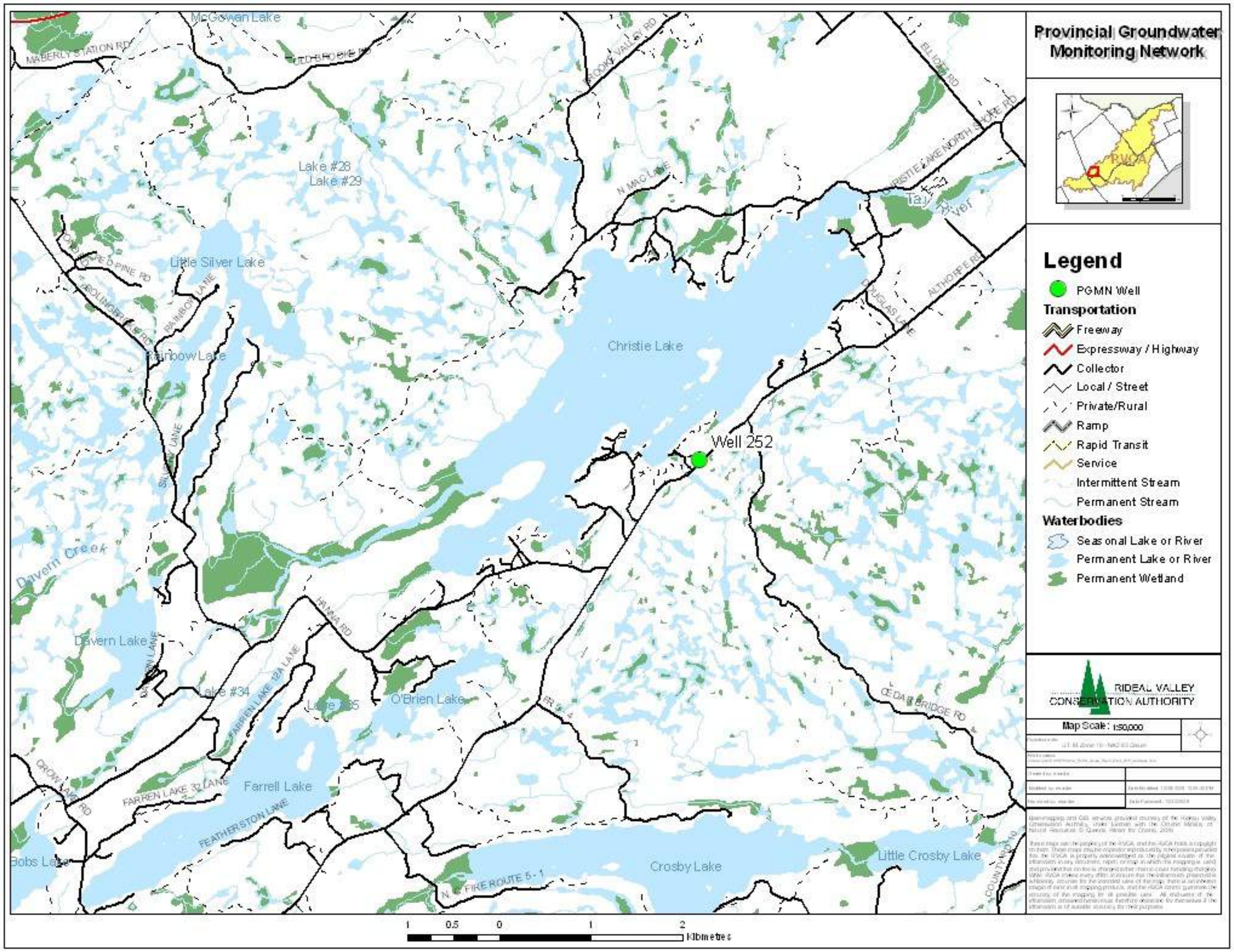


Figure 3-6: Location of Well-252 on Christy Lake at Christy Lake Camp site.

4. Groundwater Levels and Weather Trends

The water level data from five groundwater monitoring wells that are a part of the Provincial Groundwater Monitoring Network (PGMN) in Ontario has been used for testing the Jacques Whitford approach and the Percentile approach, for applicability to the Ontario Low Water Response program. This section discusses the water level data collected from the selected wells, data issues, and rainfall trends.

4.1. Well-81 (W.A. Taylor Park)

This well is located approximately 100 m from Rideau River. The well encountered 14 m of clay and 7 m of glacial till overlying dolostone bedrock of the Oxford Formation. The well is about 57 m deep and terminates in the bedrock. The well steel casing extends into the bedrock therefore this well is considered a bedrock monitoring well. A borehole log (Log 1) is provided in Appendix A of the report.

4.1.1. Historical Water Levels and Rainfall Trends

This station became operational in 2001. Water level data from Nov. 2001 to Mar. 2008 (Figure 4-3) collected from this well was used to determine the indicators and triggers as per the two approaches discussed in section 2 of the report. Seasonal water level trends are consistent with weather related events, and generally include a marked increase in mid-March to early April, followed by a slow but progressive decline from mid-June to September/October, moderate increases in the autumn, and another slow decline from January to March.

Accounting for the historical rainfalls for years 2001 to 2008, lower than average rainfall conditions for the months of April to October were observed in 2001 and to some degree in 2003 and 2007. The water level trend observed during these years especially for months of April to October is considered to be reflective of the dry weather conditions or low water conditions in the aquifer. Monthly rainfalls for the years 2001-2008 are shown in Table 4-1. A graphic comparison of the rainfall data is shown in Figure 4-1 and Figure 4-2.

As the Table 4-1 shows, the year 2001 was relatively drier than the years 2003 and 2007 (for April to October). However, water level data between April and October for the year 2001 was not available from this well as the monitoring station was not operational. Therefore, the water levels observed in year 2007 were considered to be reflective of the low water conditions (Table 4-2). The year 2003 water level data was not used in comparisons as the cumulative rainfall for the months of April to October was higher than the year 2007 rainfall for the same months.

4.1.2. Water Levels and Weather Conditions in 2008

The monthly averages of daily water level data from April 2008 to mid of August 2008 (Table 4-3) were used for comparison with the indicators and to determine if the well was developing dry or low water conditions. The level logger malfunctioned in August 2008 and therefore the daily water level data was not available. However, the manual water level data (bi-weekly manual measurement of water levels) collected between July and October 2008 was available. Therefore, the manual water levels for September and October were used in testing of triggers and indicators.

The water level trend between the months of April to October 2008 is consistent with the weather events and seasonal variations. Based on the monthly rainfalls noted in the months of April to October 2008 (Table 4-1) and comparing with the 2001 rainfalls for the same months, dry weather conditions or low water conditions in the aquifer were not encountered in 2008. The daily water levels (Table 4-3) also did not show any indication of stress or unusually low values, indicating that levels in the noted months are representative of a normal or above normal water level trend (i.e. water levels are not impacted by dry weather conditions such as those observed in 2001). In fact, the water levels observed in the month of April were the highest ever noted. Therefore, it was not possible to test the groundwater indicators and triggers determined for this well on the 2008 groundwater levels for use as the OLWR indicator. However, as discussed earlier, the water levels observed for the year 2007 for the April to October months (Table 4-2) from this well are considered to be representative of low water conditions in aquifers, and were used for testing the suitability of inferred groundwater triggers and indicators.

The comparison of 2008 and 2007 water levels with the indicators and triggers (based on two approaches) is presented in Section 5 of this report.

4.1.3. Water Level Data Issues

The following issues were noted in the water level data for this well:

1. Water level data between April and October 2001 is not available as the well was not in operation.
2. The water levels in 2006 and 2007 were affected by the barometric pressure-related error.
3. Missing water level data in June/July 2005 and Oct/Nov 2007 due to logger failure.
4. Unexplainable "spikes and lows" in the water levels which do not correspond to seasonal variations, maintenance activities, pumping events, instrument malfunctions etc.
5. Water levels between August and October 2008 are missing as the level logger malfunctioned in August 2008.

4.2. Well-83 (OMYA Industrial Plant Site)

This is a bedrock monitoring well. This well is 45.7 m deep and terminates in the Granite bedrock. About 1.2m of overburden and 19.5m of Sandstone bedrock overlies the Granite bedrock. A borehole log (Log 2) is provided in Appendix A of the report.

4.2.1. Historical Water Levels and Rainfall Trends

Water level measurement made during years 2001-2007 were used in the analysis. Water level trends are shown in Figure 4-4. The seasonal trends in water levels were relatively inconsistent from year to year. An offset of approximately 2.8 m in the 2005 and onwards water level data (relative to previous years' data) suggested that the depth of the water level datalogger in the monitoring well had been changed on January 17, 2005 without the appropriate adjustment to the raw data. As a result, a correction factor was estimated using available manual water level measurements from before and after the datalogger depth change. This factor was applied to all data collected after January 17, 2005. All water level data shown in Figure 4-4 has undergone this correction.

There were several instances in 2003 through early 2008 in which the water level readings in the well were beyond the range of the datalogger. The out-of-range data were omitted from the analysis.

Accounting for the historical rainfalls for years 2001 to 2008, lower than average rainfall conditions for the months of April to October were observed in 2001 and to some degree in 2003 and 2007. The water level trends observed during these years, especially for the months of April to October are considered to be reflective of dry weather conditions or low water conditions in the aquifer. Monthly rainfalls for the years 2001-2008 are shown in Table 4-1. A graphic comparison of the rainfall data is shown in Figure 4-1 and Figure 4-2. As Table 4-1 shows, the year 2001 was relatively drier than the years 2003 and 2007 (for April to October months). The cumulative rainfall for the months of April to October for year 2003 is slightly higher than the year 2007 rainfall for the same months. However, water level data between April and October for the year 2001 was not available as the well was not in operation. A large part of the water level data for the year for 2007 were missing due to equipment malfunctions. Therefore, year 2003 water levels (Table 4-2) are considered to be reflective of the low water conditions in the aquifer and are used in the comparisons.

4.2.2. Water Levels and Weather Conditions in 2008

The monthly averages of daily water level data from July 2008 to September 2008 (Table 4-3) were used for comparison with the indicators and to determine if the well was developing dry or low water conditions. A major portion of the 2008 water level data is missing from January to July due to "level logger out of range" error. The manual water level data (bi-weekly manual measurement of water levels) was also not available for this well. Therefore, the available data between July and September 2008 was used in the analysis.

The water level trends between the months of July and September 2008 (Table 4-3) did not show any indication of stress or unusually low values, indicating that levels in the noted months are representative of a normal or above normal water level trend (i.e. water levels are not impacted by low rainfall conditions such as those observed in 2001, 2003 or 2007). Based on the monthly rainfalls noted in the months of April to October 2008 (Table 4-1) and comparing with the 2001 rainfalls for the same months, dry weather conditions or low water conditions in the aquifer were not encountered. The daily water levels in 2008 (Table 4-3) are actually higher than those noted in 2003 for the same months. Therefore, it was not possible to test the groundwater indicators and triggers determined for this well on the 2008 groundwater levels for use as the OLWR indicator. However, as discussed earlier, the water levels observed in the year 2003 for the April to October months (Table 4-2) from this well are considered to be representative of low water conditions in the aquifer and were used for testing the suitability of inferred groundwater triggers and indicators.

The comparison of 2008 and 2003 water levels with the indicators and triggers (based on the two approaches) is presented in Section 5 of this report.

4.2.3. Water Level Data Issues

The following issues were noted in the water level data for this well:

1. Major portion of data missing due to “level logger out of range” error.
2. Missing water level data between Oct. 2006 and May 2007 due to logger failure.
3. Unexplainable “spikes and lows” in the water levels which do not correspond to seasonal variations, maintenance activities, pumping events, instrument malfunctions etc.

4.3. Well-86 (Long Island Park)

This well is 18.9 m deep, and terminates in dolostone bedrock of the Oxford Formation. A thick overburden of about 18.3 m overlies the bedrock. This well is considered to be a contact zone well as the well casing does not extend into the bedrock. A borehole log (Log 3) is provided in Appendix A of the report.

4.3.1. Historical Water Levels and Rainfall Trends

Water level trends in the well are shown in Figure 4-5 for years 2001-2008. Raw water level data from the well indicated four instances in 2004 to 2006 in which the water level datalogger depth appeared to change by more than one metre without a corresponding adjustment to the water level data. Manual water level readings recorded during that period were insufficient to be of use in the correction of the water level. As a result, data correction was conducted based on the magnitude of the water level change observed at each of the four instances described above. This method yielded sufficiently accurate water level data to observe general trends, but all the data should be considered with caution. Furthermore, a large portion of 2006 and some 2007 water level data was affected by a barometric pressure-related error, and was therefore not used in the calculations for groundwater triggers.

The resulting graph (Figure 4-5) shows that periods of relatively high water levels are observed annually from April to June, and from November to January, with the exception of the winter of 2002-03 during which water levels were consistently low.

Accounting for the historical rainfalls for years 2001 to 2008, lower than average rainfall conditions for the months of April to October were observed in 2001 and to some degree in 2003 and 2007. The water level trends observed during these years, especially for the months of April to October are considered to be reflective of the dry weather conditions or low water conditions in the aquifer. Monthly rainfalls for the years 2001-2008 are shown in Table 4-1. A graphic comparison of the rainfall data is shown in Figure 4-1 and Figure 4-2. As Table 4-1 shows, the year 2001 was relatively drier than the years 2003 and 2007 (for April to October months). However, water level data between April and October of the year 2001 is not available from this well as the monitoring station was not operational. Therefore, the water levels observed in year 2007 (Table 4-2) were considered to be reflective of the low water conditions. The year 2003 water level data was not used for comparisons, as the cumulative rainfall for the months of April to October is higher than the year 2007 rainfall for the same months.

4.3.2. Water Levels and Weather Conditions in 2008

The monthly averages of daily water level data from April 2008 to September 2008 (Table 4-3) were used for comparison with the indicators and to determine if the well is developing dry or low water conditions.

The water level trends between the months of April and September 2008 (Table 4-3) did not show any indication of stress or unusually low values indicating that levels in the noted months are representative of a normal or above normal water level trend (i.e. water levels are not impacted by low rainfall conditions such as those observed in 2001, 2003 or 2007). Based on the monthly rainfalls noted in the months of April to October 2008 (Table 4-1) and comparing with the 2001 rainfalls for the same months, dry weather conditions or low water conditions in aquifer were not encountered in 2008. The daily water levels in 2008 are actually higher than those noted in 2007 for the same months. Therefore, it was not possible to test the groundwater indicators and triggers determined for this well on the 2008 groundwater levels for potential use as the OLWR indicator. However, as discussed earlier, the water levels observed in the year 2007 (Table 4-2) for the April to October months from this well were considered to be representative of low water conditions in aquifer and were used for testing the suitability of inferred groundwater triggers and indicators.

The comparison of 2008 and 2007 water levels with the indicators and triggers (based on two approaches) is presented in Section 5 of this report.

4.3.3. Water Level Data Issues

The following issues were noted in the water level data for this well:

1. Large portion of 2006-2007 data not useable due to barometric pressure-related error in the water levels.
2. Unexplainable “spikes and lows” in the water levels which do not correspond to seasonal variations, maintenance activities, pumping events, instrument malfunctions etc.

4.4. Well-156-2 (Twin Elm Bridge)

This is a multi-level monitoring well, however only the overburden level (shallow well) has been incorporated into this study. The overburden material consists of clay followed by a gravel and sand layer. The overburden water bearing zone was encountered at bedrock and overburden interface around 26m which is being monitored by this level. The well is located approximately 15 m from the river. A borehole log (Log 4) is provided in Appendix A of the report.

4.4.1. Historical Water Levels and Rainfall Trends

Water level trends for this well are shown in Figure 4-6 for years 2005-2008. The analysis of automated water level readings from Well-156 was problematic due to frequent unexplained “highs and lows” and data jumps. Therefore, although the trends and relative changes in water level from 2005 to 2007 may be considered accurate, the absolute value of the water level is not. The seasonal trends in water levels were relatively inconsistent from year to year. Noticeable springtime increases in water levels were not seen in 2006 and 2007, perhaps due to higher winter temperatures which allowed gradual snow melt rather than a large spring melt. A steady decrease from May to September/October was observed every year.

Accounting for the historical rainfalls for years 2001 to 2008, lower than average rainfall conditions for the months of April to October were observed in 2001, and to some degree in 2003 and 2007. The water level trends observed during these years especially for the months of April to October are considered to be reflective of dry weather conditions or low water conditions in the aquifer. Monthly rainfalls for the years 2001-2008 are shown in Table 4-1. A graphic comparison of the rainfall data is shown in Figure 4-1 and Figure 4-2. As Table 4-1 shows, the year 2001 was relatively drier than the years 2003 and 2007 (for April to October months). However, water level data between April 2001 and July 2002 is not available from this well as the monitoring station was not operational. Therefore, the water levels observed in year 2007 (Table 4-2) are considered to be reflective of the low water conditions. The year 2003 water level data was not used for comparisons, as the cumulative rainfall for the months of April to October is higher than the year 2007 rainfall for the same months, and the water levels in this well showed inconsistent trends in comparison to water levels observed in other years.

4.4.2. Water Levels and Weather Conditions in 2008

The monthly averages of daily water level data from April 2008 to September 2008 (Table 4-3) were used for comparison with the indicators and to determine if the well is developing dry or low water conditions.

The water level trends between the months of April to September 2008 did not show any indication of stress or unusually low values, indicating that levels in the noted months are representative of a normal or above normal water level trend (i.e. water levels are not impacted by low rainfall conditions such as those observed in 2001, 2003 or 2007). Based on the monthly rainfalls (Table 4-1) noted in the months of April to October 2008, and comparing with the 2001 rainfalls for the same months, dry weather conditions or low water conditions in the aquifer were not encountered in 2008. The daily water levels in 2008 (Table 4-3) are actually higher than those noted in 2007 (Table 4-2) for the same months. Therefore, it was not possible to test the groundwater indicators and triggers determined for this well on the 2008 groundwater levels for potential use as the OLWR indicator. However, as discussed earlier, the water levels observed in the year 2007 (Table 4-2) for the April to October months from this well are considered to be representative of low water conditions in the aquifer and were used for testing the suitability of inferred groundwater triggers and indicators.

The comparison of 2008 and 2007 water levels with the indicators and triggers (based on the two approaches) is presented in Section 5 of this report.

4.4.3. Water Level Data Issues

The following issues were noted in the water level data for this well:

1. Some of the data from July 2002 to 2005 was not used in the study due to inconsistencies caused by logger being out of range, data spikes and missing data due to frequent logger malfunctions.
2. Unexplainable “spikes and lows” in the water levels which do not correlate to the seasonal fluctuations, pumping events or usual maintenance activities.
3. Inconsistencies between water level trends and seasonal events.

4.5. Well-252 (Christie Lake Camp Site)

This well is located on the south shore of a Lake. The well (Log 5, Appendix A) encountered a thin layer (1 m) of topsoil overlying Precambrian Granite bedrock. This is a bedrock monitoring well and is 31 m deep.

4.5.1. Historical Water Levels and Rainfall Trends

Water level trends in this well are shown in Figure 4-7 for year 2003-2008. Annual water level fluctuations in this well were relatively large, ranging from 2.07 m in 2004 to 3.37 m in 2005. There was generally a 1.1 to 2.3 m increase in water levels in March, followed by a gradual decrease until September. The well also exhibited greater daily water level fluctuations (average 0.09 m) than at most other PGMN wells in this study, which may reflect the effect of nearby supply wells. The average annual water level variations seem consistent with seasonal changes. Accounting for the historical rainfalls for years 2001 to 2008, lower than average rainfall conditions for the months of April to October were observed in 2001 and to some degree in 2003 and 2007. The water level trends observed during these years especially for the months of April to October are considered to be reflective of dry weather conditions or low water conditions in the aquifer. Monthly rainfalls for the years 2001-2008 are shown in Table 4-1. A graphic comparison of the rainfall data is shown in Figure 4-1 and Figure 4-2.

As the Table 4-1 shows, the year 2001 was relatively drier than the years 2003 and 2007 (for April to October months). The cumulative rainfall for the months of April to October for year 2003 is slightly higher than the year 2007 rainfall for the same months. The water level data starting from 2001 to February 2003 is not available as the well was not in operation. Despite higher rainfall in 2007 than 2003, the water levels for year 2003 (Table 4-2) are slightly lower than those observed in 2007 for the months of April to June. Therefore, year 2003 water levels are considered to be reflective of low water conditions in the aquifer and are used in the comparisons.

4.5.2. Water Levels and Weather Conditions in 2008

The monthly averages of daily water level data from April 2008 to September 2008 (Table 4-3) were used for comparison with the indicators and to determine if the well is developing dry or low water conditions.

The water level trends between the months of April and September 2008 (Table 4-3) did not show any indication of stress or unusually low values, indicating that levels in the noted months are representative of average or normal water level trend (i.e. water levels are not impacted by low rainfall conditions such as those observed in 2001, 2003 or 2007). Based on the monthly rainfalls noted in the months of April to October 2008 and comparing with the 2001 rainfalls for the same months, dry weather conditions or low water conditions in the aquifer were not encountered in 2008. The daily water levels in 2008 are actually higher than those noted in 2003(Table 4-2) for the same months. Therefore, it was not possible to test the groundwater indicators and triggers determined for this well on the 2008 groundwater levels for potential use as the Ontario Low Water Response (OLWR) indicator. However, as discussed earlier, the water levels observed in the year 2003 for the April to October months from this well are considered to be representative of low water conditions in aquifer and were used for testing the suitability of inferred groundwater triggers and indicators.

The comparison of 2008 and 2003 water levels with the indicators and triggers (based on two approaches) is presented in Section 5 of this report.

4.5.3. Water Level Data Issues

The following issues were noted in the water level data for this well:

1. Water levels showed a wide range of daily fluctuations which may be due to the use of nearby wells or effect of the lake water levels.
2. Water level data between April 2001 and January 2003 is not available as the well was not in operation.
3. Unexplainable "spikes and lows" in the water levels which do not correspond to seasonal variations, maintenance activities, pumping events, instrument malfunctions etc.

Table 4-1: Monthly rainfall for the years 2001 to 2008.

Monthly Rainfall (mm)								
Month	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Jan	0.6	3.8		1.8	19	52.2	27.2	36
Feb	31.6	20.3	9.8	0.6	10	36.2		11
Mar	9.1	28.2	39.6	51.8	8	25.4	30.2	35
Apr	11.2	61.3	32.6	62.8	143.8	63.8	78.6	68
May	81.1	91.5	129.4	72.2	48	114.6	50.8	91.8
Jun	98	224.8	57	76.4	125.4	112.6	49.2	106.6
Jul	38.6	47.8	93.6	65.2	106.2	100.8	138.6	64.8
Aug	68.6	39.4	63.6	111	82.2	72.2	107.4	74
Sep	78.4	71.6	65.2	142.8	104	154.8	40.8	79
Oct	95.2	77.8	148	60.4	100.4	125.1	86.6	74.8
Nov	77.6	28.8	95.8	87.4	92.2	99	33.2	
Dec	38.6	9.2	91	41.2	28.8	44	28.8	

Table 4-2: Monthly water level for low rainfall years.

Monthly Water Levels (masl)					
Month	**Well- 81**	**Well-83**	**Well-86**	**Well-152-2**	**Well-252**
Year	**2007**	**2003**	**2007**	**2007**	**2003**
Apr	87.67	142.44	86.80	103.39	175.64
May	87.67	142.41	86.42	103.06	175.64
Jun	87.56	142.41	86.18	102.94	175.66
Jul	87.48	141.72	86.09	102.71	174.92
Aug	87.35	141.23	85.88	102.54	175.09
Sep	87.30	141.29	85.87	102.24	174.70
Oct	87.536	141.99	86.12	102.12	175.67

Table 4-3: Monthly water levels for 2008.

Monthly Water Levels (masl) for 2008					
Month	**Well- 81**	**Well-83**	**Well-86**	**Well-152-2**	**Well-252**
Apr	88.08		86.71	103.53	176.63
May	87.72		86.48	103.26	175.72
Jun	87.70		86.43	103.09	175.94
Jul	87.64	142.25	86.41	103.08	175.88
Aug	87.45	142.15	86.31	102.92	175.57
Sep	87.46	141.84	86.15	102.68	175.18
Oct	87.4				

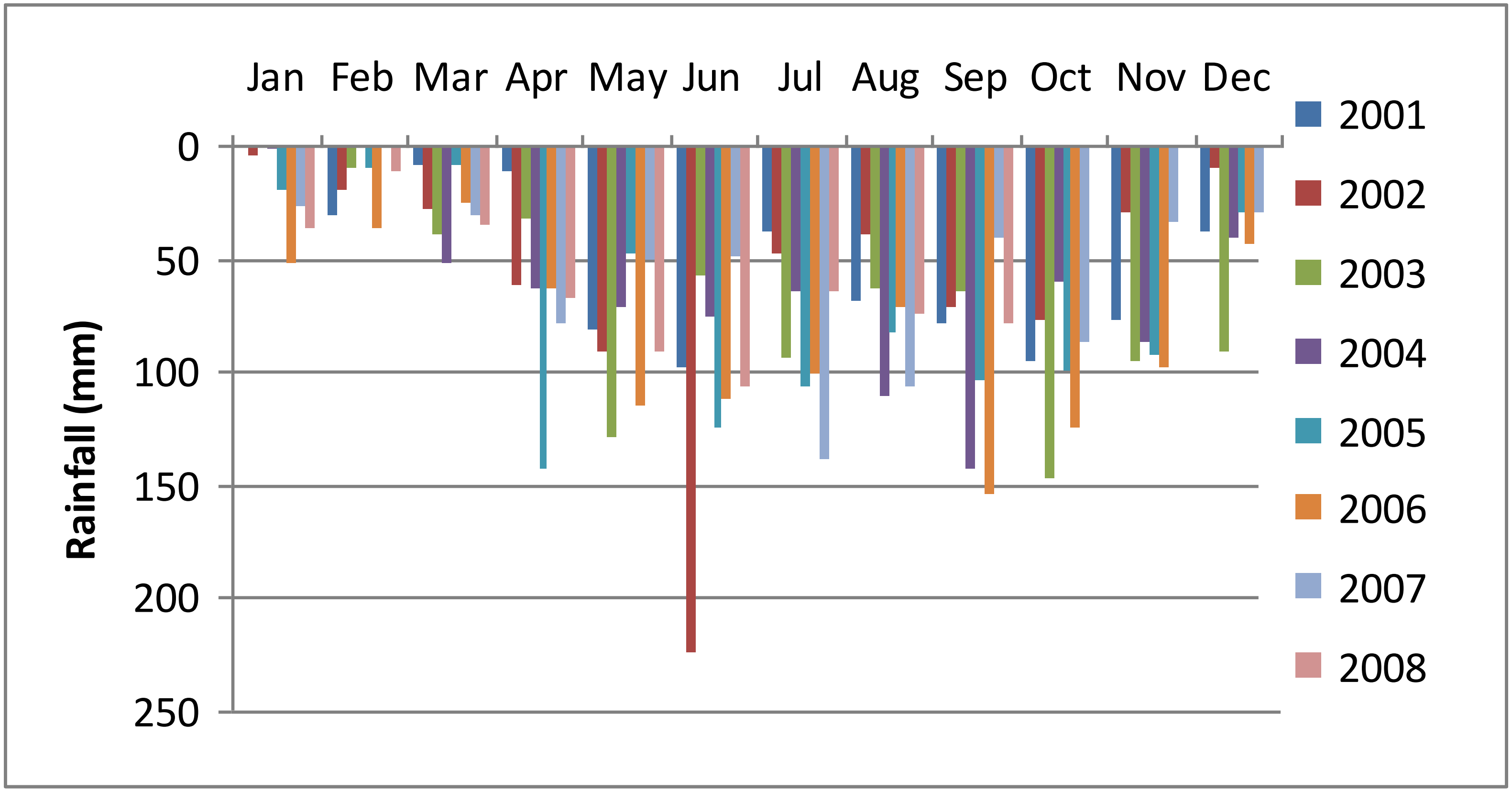


Figure 4-1: Yearly rainfall variations for 2001-2008.

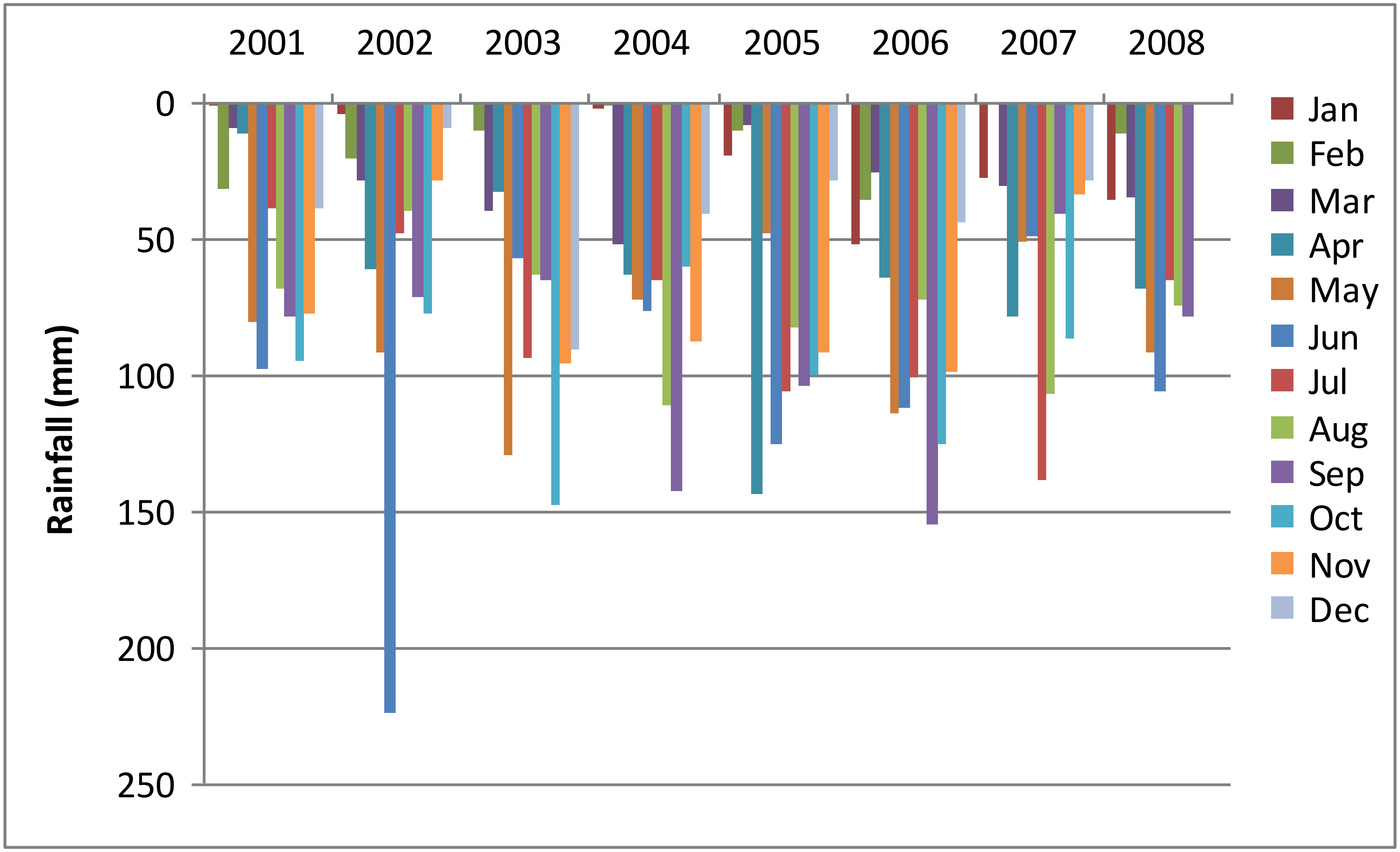


Figure 4-2: Comparison of monthly rainfall for the year 2001-2008

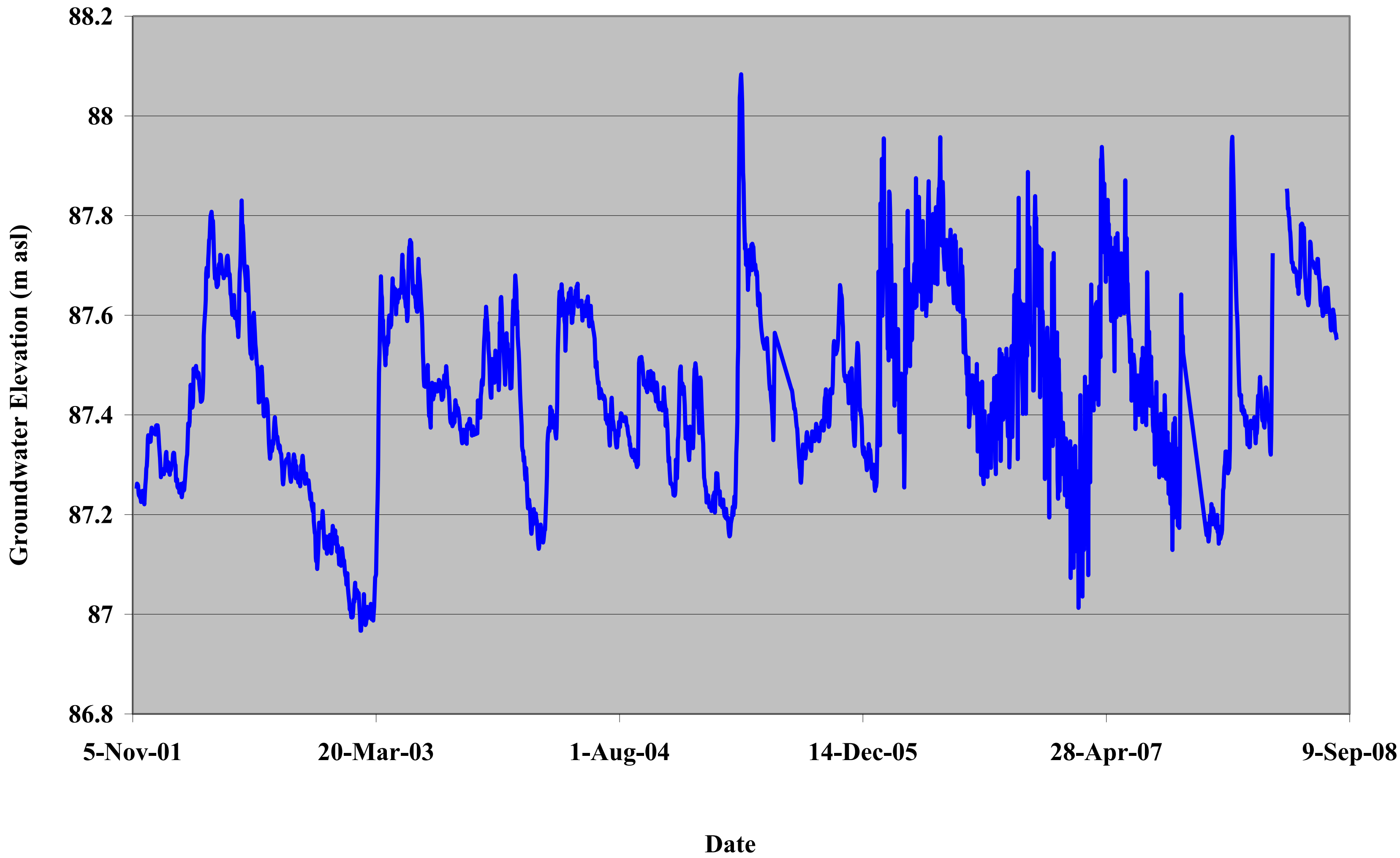


Figure 4-3: Water level trends in Well-81.

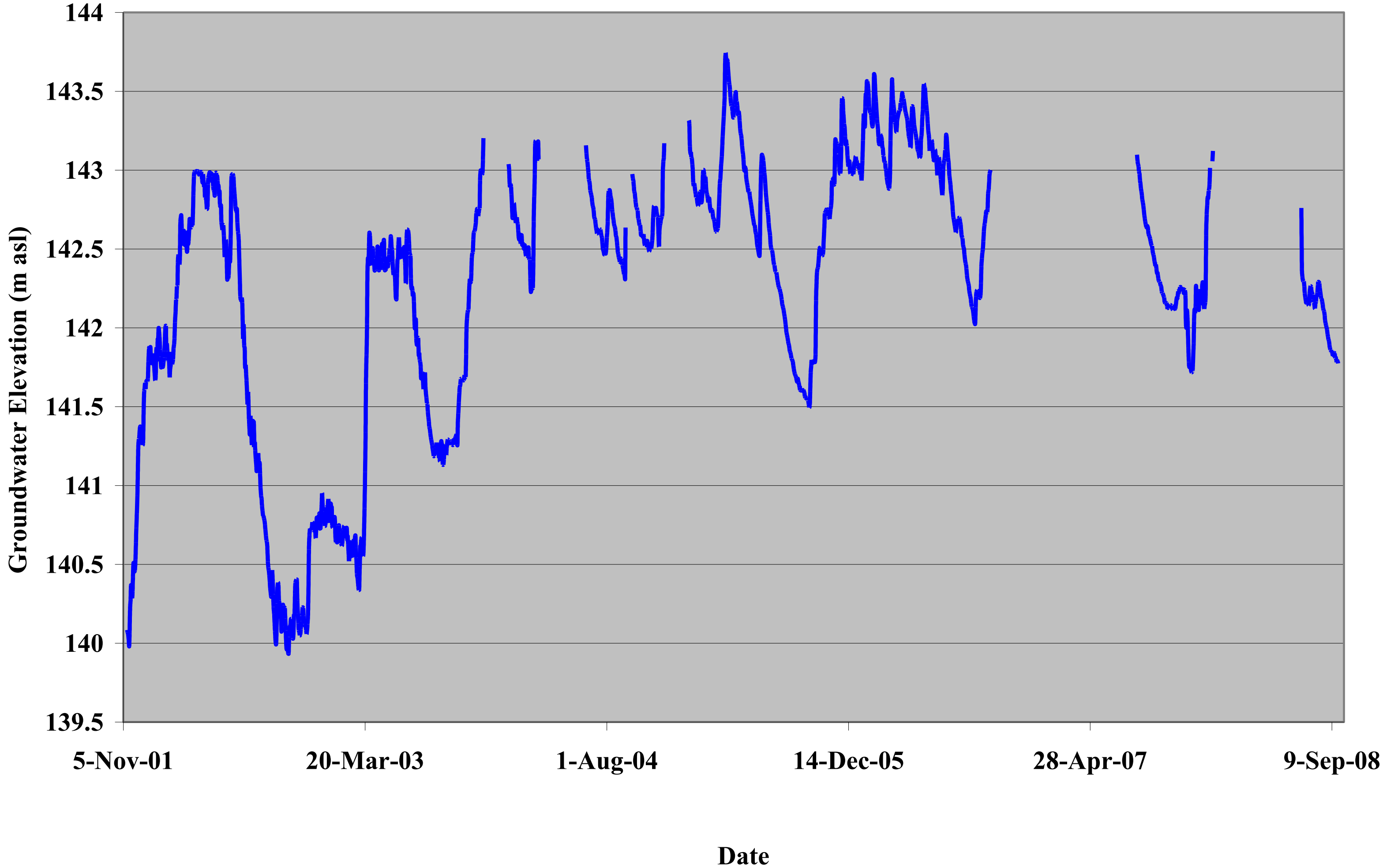


Figure 4-4: Water Level Trends in Well-83.

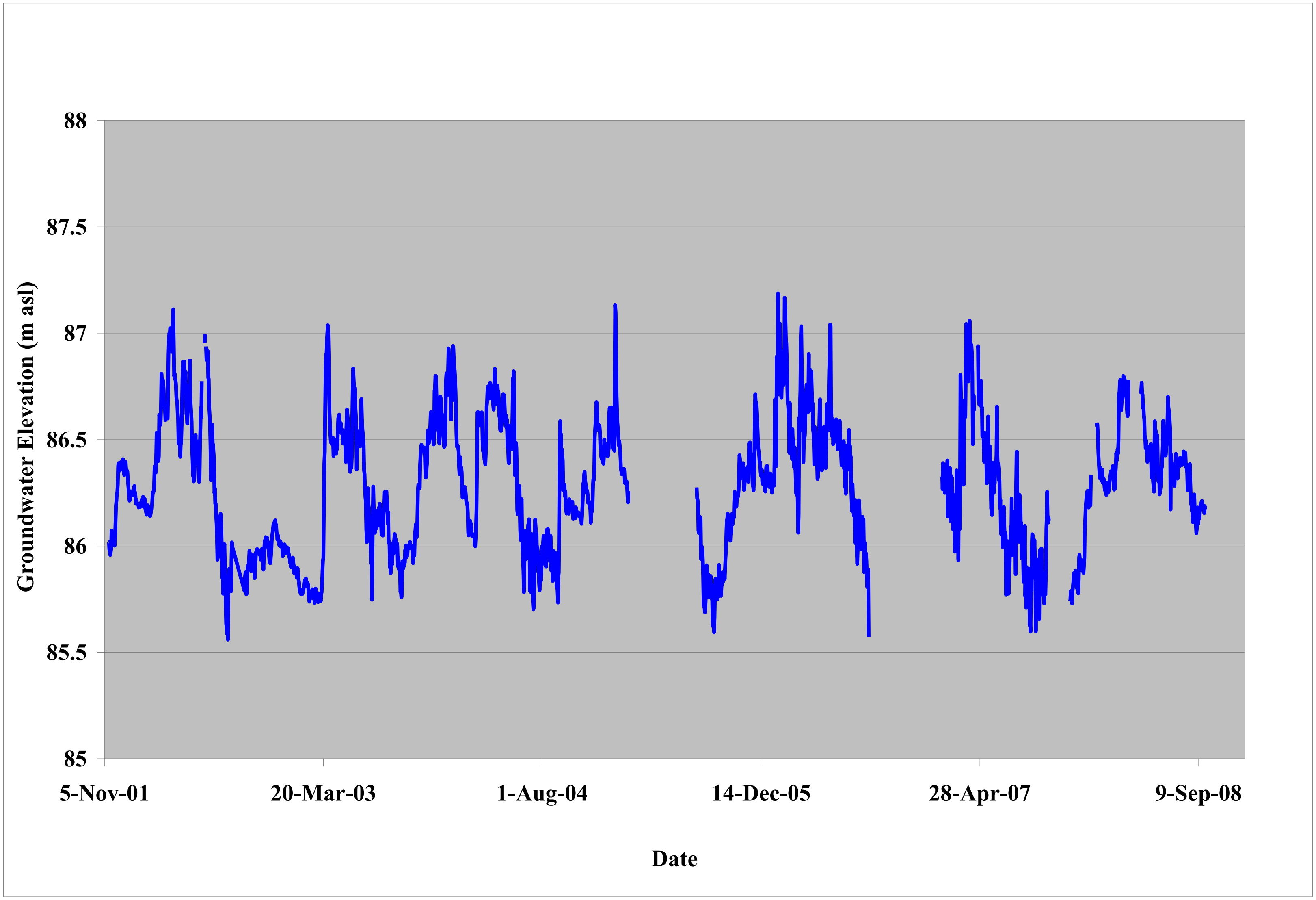


Figure 4-5: Water level trends in Well-86.

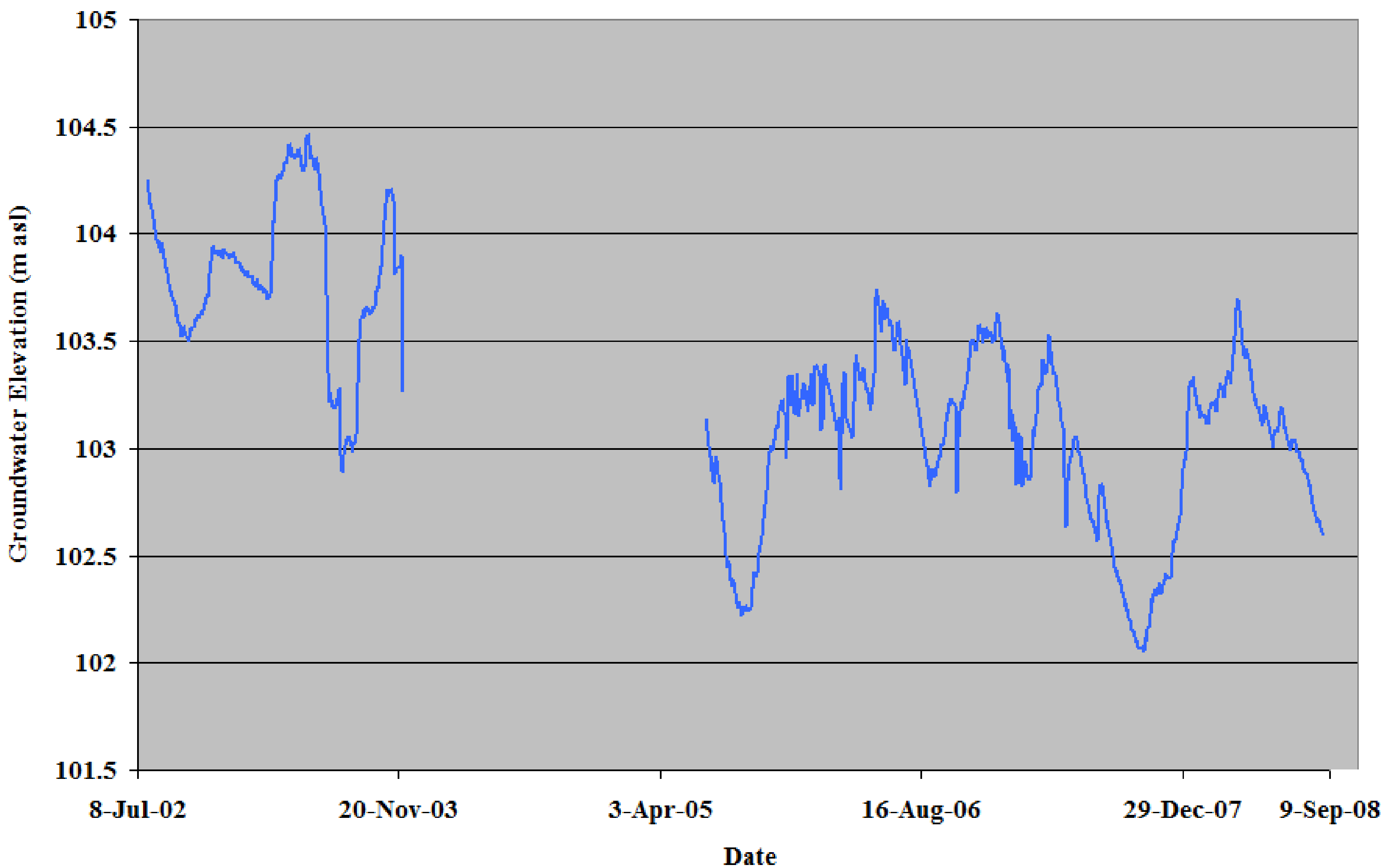


Figure 4-6: Water level trends in Well-156.

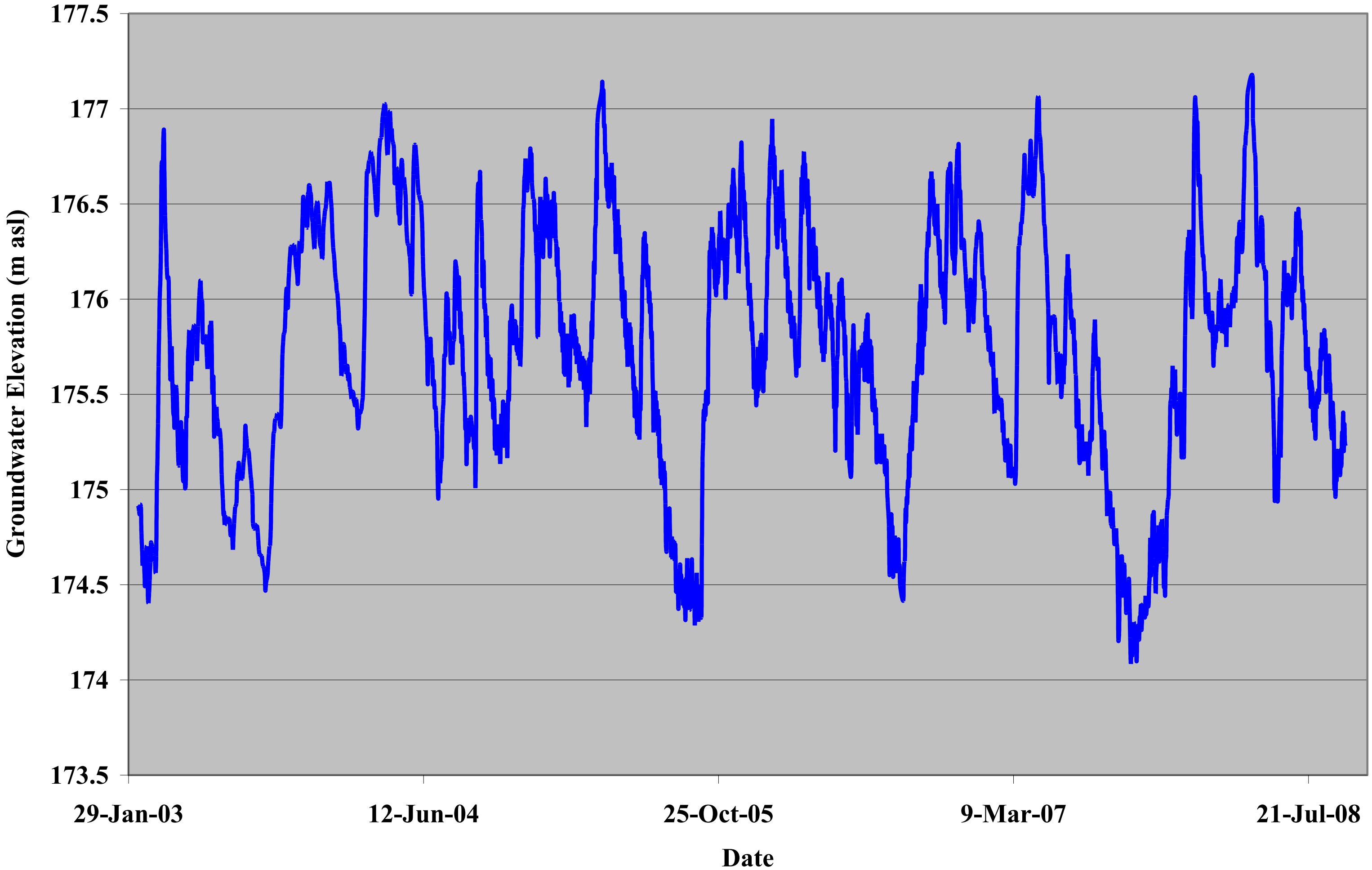


Figure 4-7: Water level trends in Well-252.

5. Determination and Comparison of Groundwater Triggers

This section presents the results of the groundwater indicators and triggers calculated from the water levels (Section 4) observed in the wells described in Section 3 of this report. The groundwater triggers have been calculated by both Percentile and Jacques Whitford (JW) approaches. The trigger values have been presented in tabular form in the following sections. A comparison of Percentile and JW groundwater triggers has been presented in graphic form (Figure 5-1to Figure 5-10) to illustrate the differences in trigger values as calculated by the two approaches. The comparison of triggers and indicators with the water levels observed in the monitoring wells between months of April and October 2008 is also shown in these charts.

Further application of triggers to evaluate their utility for the OLWR, and to determine whether low water conditions are developing in a monitoring well or in an aquifer, has been undertaken by comparing the water level data for the year 2003 or 2007 with the inferred indicators and triggers (Table 5-1 to Table 5-10). These two years were selected because the water levels observed in these years were lower as compared to the water levels from other years (2001 to 2008). This comparison is presented in Figure 5-1 to Figure 5-10 in this section. This section also presents comparison of two approaches, accounting for the ease of application, time spent on the analysis, level of expertise required to undertake the analysis, and which approach is better representative of the aquifer behavior (Level I, II or III) in terms of the indicators.

5.1. Well-81 (W.A. Taylor Park)

5.1.1. Indicators and Triggers

The historical water levels collected between November 2001 and March 2008 were used to determine indicators and triggers. The indicators determined by the JW and Percentile approaches are shown in the Table 5-1 and Table 5-2. A comparison of the indicator values calculated by the two approaches is shown in Figure 5-1 and Table 5-2.

Generally, the JW Trigger 1 (Level 1- First indication of a potential water supply problem) values are lower than the Percentile Trigger 1 (25^{th} Percentile-Below normal or drought watch) values in this well Table 5-1. This means that Percentile based Trigger 1 will always declare the below normal water level conditions in an aquifer or well before JW Trigger 1 can detect Level I conditions in the well (Figure 5-1, Table 2-1 and Table 2-2). This is expected when the water levels are declining. However, if the water levels are recovering after a period of low water conditions, then JW Trigger 1 conditions for Level I will be met first.

5.1.2. Application

The water level data collected between April and October 2008 was used to establish whether the indicators (JW and Percentile) are showing that low water level conditions are developing in this well. The indicators determined by the JW and Percentile approaches are shown in Table 5-2 along with the monthly water levels for 2008. A graphical comparison of the observed water levels with indicators is shown in Figure 5-2. Additional comparison undertaken for the year 2007 water levels, which were deemed to be representative of historical low water conditions in the aquifer, is also presented in the already mentioned figures and tables.

According to Figure 5-2, the observed water levels in 2008 did not reach the 25th Percentile (Trigger 1). As the figure shows, the water levels did not show that any low water conditions are developing in this well. Rather, the water levels rose in the month of April, which is more reflective of above normal conditions (Figure 5-2). The measured water levels were above the 50th Percentile or median (normal conditions) and as high as the maximum percentile indicator level (100th Percentile) except in the month of October 2008. Similarly, in comparison with JW indicators, the monthly water levels during 2008 did not drop below the JW Trigger 1 (Figure 5-2). All levels were higher than the JW Trigger 1 and Trigger 2 (Table 5-2).

As indicated above, the water levels in April 2008 were above the 100th Percentile. However, this is not considered to indicate that the current 100th Percentile (Table 5-1, Figure 5-2) is too conservative (stringent) or sensitive. Since the 2008 water levels were only used for comparison and not included in determination of the indicators values, the 100th Percentile value is estimated lower than it would have been if the 2008 water levels were included in determining the indicators. Since the 2008 water levels were higher than all the previous years, this trend would have been reflected in the higher value of this indicator if 2008 data was included in the analysis. Also, in the perspective of aquifers, it does not really matter whether the water levels are above normal (75th Percentile), at maximum levels (100th Percentile) or beyond maximum since the aquifer will be able to meet the demand in either case (unless the well is a shallow well and does not have sufficient borehole storage so even minor changes in water levels will have an impact). The impacts may only be experienced when the water levels start to drop below the 50th Percentile. Therefore, in terms of interpretation of indicators, the 75th and 100th Percentile are conveying the same indication i.e. water levels are in normal or above normal range. Even if the indicator values are refined, these indicators will interpret the aquifer behavior in the same way. However, these indicators are useful to establish whether the observed water levels are within the normal or above normal ranges of historical water levels.

A comparison of indicators with historical water levels for the year 2007 (same months as 2008), representing low water conditions, is shown in the Figure 5-2. According to this figure, the measured water levels were below the 50th Percentile or median (normal conditions) in June and August, and sometimes as low as the Percentile Trigger 1 level in the month of September. This represents above normal to below normal conditions in these months. In consideration of the September 2007 below normal conditions, as shown by the Percentile Trigger 1 (Table 2-2), potential water supply problems did develop in the aquifer in 2007, but did not reach the dry conditions indicator level (10th Percentile). The appropriate action plan under the OLWR Program for this indicator level (if developed in 2007) would have been implemented in this month. The water levels jumped to the 50th Percentile levels in the following month, indicating that normal conditions returned to the aquifer.

In comparison to the JW Triggers (Figure 5-2), the measured water levels in 2007 (April to October) remained above the Trigger 1 (Table 5-2). Therefore, according to JW criteria (Table 2-1), no action would have required in 2007 on part of the OLWR program.

For this well, the JW Trigger 1 seems less sensitive as compared to Percentile Trigger 1, since water levels in September 2007 did reach Level I (drought watch) according to the Percentile criteria but not as per JW approach.

Table 5-1: Percentile Method Results for Well-81.

Trigger or Condition	Minimum	Trigger 3	Trigger 2	Trigger 1	Normal	Above normal	Very wet
Percentile	**0th Percentile**	**5th Percentile**	**10th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**100th Percentile**
January	86.99	87.06	87.11	87.26	87.32	87.49	87.96
February	86.97	87.00	87.04	87.17	87.26	87.37	87.85
March	86.99	87.01	87.08	87.21	87.39	87.46	87.81
April	87.41	87.52	87.55	87.60	87.65	87.73	88.08
May	87.49	87.55	87.59	87.62	87.66	87.71	87.96
June	87.35	87.43	87.44	87.50	87.61	87.67	87.87
July	87.33	87.36	87.38	87.41	87.45	87.51	87.73
August	87.26	87.28	87.31	87.33	87.36	87.40	87.50
September	87.13	87.24	87.27	87.31	87.36	87.41	87.64
October	87.26	87.27	87.28	87.36	87.42	87.49	87.84
November	87.09	87.16	87.18	87.24	87.39	87.49	87.89
December	87.12	87.14	87.16	87.25	87.36	87.49	87.84

Table 5-2: Comparison of JW & Percentile Indicators with Water Levels from Well-81.

Trigger or Condition	Minimum 0 Percentile	Trigger 1 25th Percentile	JW Trigger 1	Normal 50th Percentile	Above Normal 75th Percentile	Very wet 100th Percentile	JW Trigger 2	Water Levels 2008	Water Levels 2007
January	86.99	87.26	87.16	87.32	87.49	87.96	86.97		
February	86.97	87.17	87.09	87.26	87.37	87.85			
March	86.99	87.21	87.15	87.39	87.46	87.81			
April	87.41	87.60	87.51	87.66	87.74	88.08		88.09	87.67
May	87.49	87.62	87.60	87.66	87.71	87.96		87.72	87.67
June	87.35	87.50	87.48	87.61	87.67	87.87		87.71	87.57
July	87.33	87.41	87.39	87.45	87.51	87.73		87.64	87.49
August	87.26	87.33	87.32	87.36	87.40	87.50		87.45	87.35
September	87.13	87.31	87.28	87.36	87.41	87.64		87.47	87.31
October	87.26	87.36	87.32	87.42	87.49	87.84		87.40	87.54
November	87.09	87.24	87.23	87.39	87.49	87.89			
December	87.12	87.25	87.20	87.36	87.49	87.84			

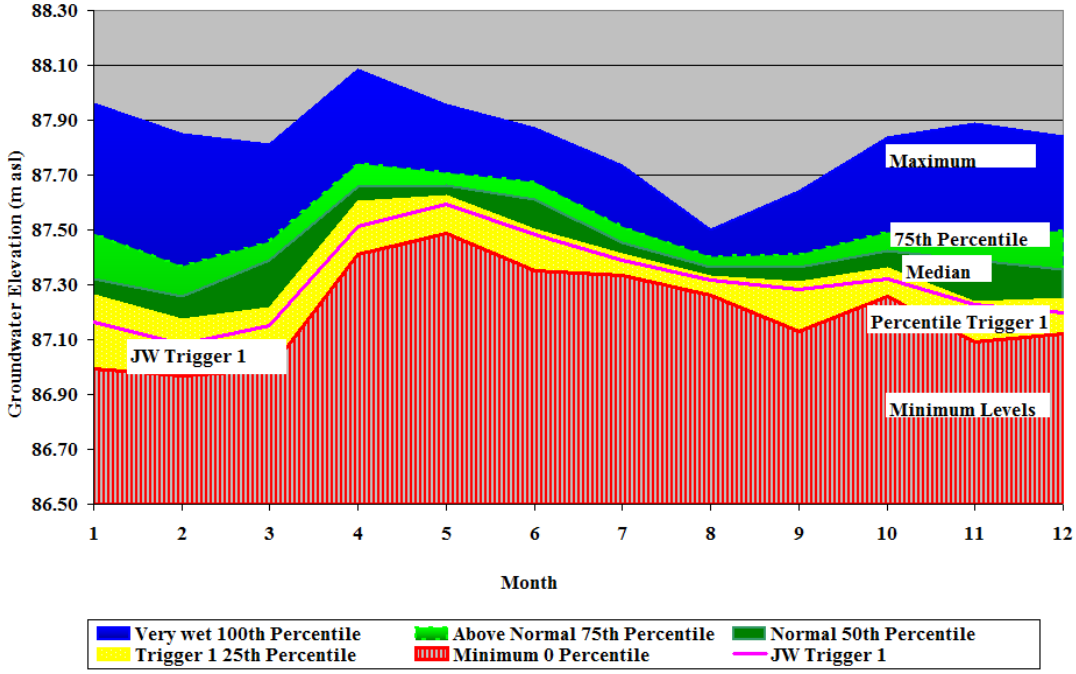


Figure 5-1: Comparison of groundwater indicators based on Jacques Whitford and Percentile methodologies for Well-81.

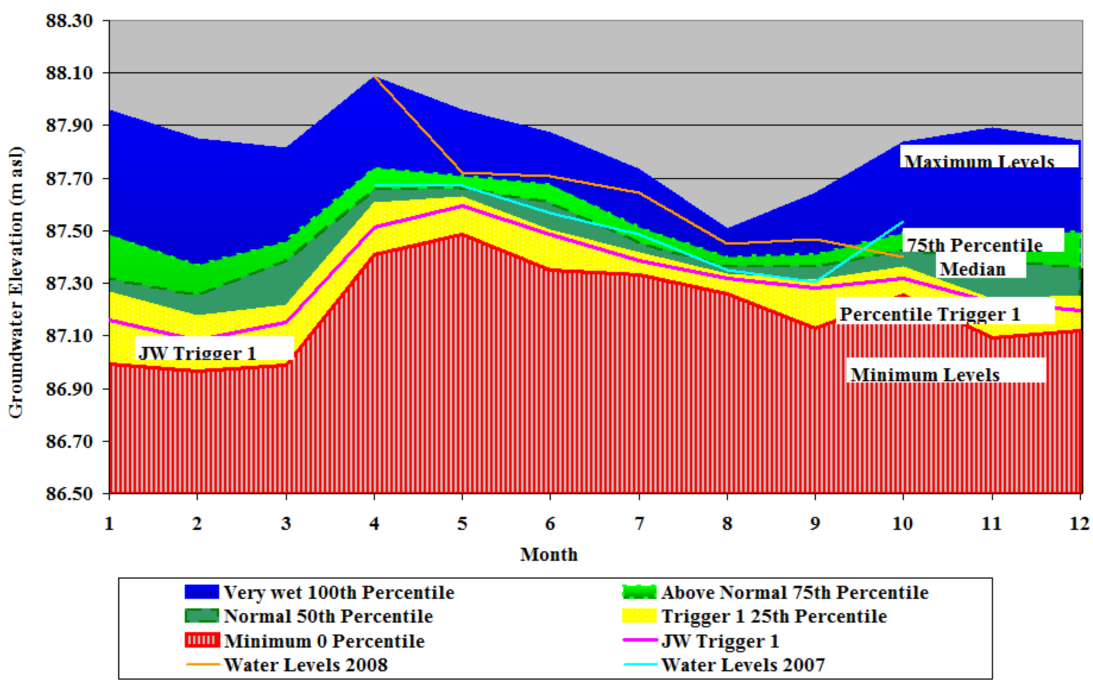


Figure 5-2: Comparison of groundwater Jacques Whitford & Percentile indicators with water levels form Well-81.

5.2. Well-83 (OMYA Industrial Plant Site)

5.2.1. Indicators and Triggers

The historical water levels collected between November 2001 and January 2008 were used to determine indicators and triggers. The indicators determined by the JW and Percentile approaches are shown in the Table 5-3 and Table 5-4. A comparison of the indicator values calculated by the two approaches is shown in the Figure 5-3, Figure 5-4 and Table 5-4.

Generally, the JW Trigger 1 (Level 1- First indication of a potential water supply problem) values are lower than the Percentile Trigger 1 (25th Percentile-Below normal or drought watch) values in this well for the months April to October, except in the month of August when they are higher (compared to Percentile Trigger 1). This means that Percentile based Trigger 1 (Figure 5-4) will always declare the below normal water level conditions in an aquifer or a well before the JW Trigger 1(Table 5-4) can detected if Level 1 conditions are developing. This is expected when the water levels are declining. However, if the water levels are recovering after a period of low water conditions, then JW Trigger 1 criteria for Level 1 will be satisfied first. This process will be reversed in the month of August.

In the months of November to December, the JW Indicator I value is higher than the 25th Percentile (Figure 5-3). This might be due to the fact that the JW trigger 1 calculation is based on the standard deviation of daily-average water levels for that month from the mean water level (assuming normal distribution of water levels), and in these months, the mean monthly levels were unusually high (the water levels in these months are not symmetrically distributed and have high standard deviation as the observed water levels are far from the mean water levels) or had far greater variations in water levels giving rise to higher trigger value. Greater than average water level variations or non-symmetrical distribution of water levels will skew the trigger values relative to percentile indicator which only accounts for the number of water level observation below a certain percentile. As can be seen from the water levels chart for well-83 (Table 4-2), the water levels in months of November to December for some years (2005, 2007) were consistently higher and this trend is reflected in the higher value of the JW Trigger 1.

5.2.2. Application

The water level data collected between July and September 2008 was used to establish whether the indicators (JW and Percentile) are showing that low water level conditions are developing in this well. The indicators determined by the JW and Percentile approaches are shown in Table 5-4 along with monthly water levels for 2008. A graphical comparison of the observed water levels with indicators is shown in Figure 5-4. Additional comparison undertaken with year 2003 water levels, which were deemed to be representative of historical low water conditions in the aquifer, is also presented in the mentioned figures and tables.

According to Figure 5-4, the observed water levels in 2008 did not drop below the 25th Percentile (Percentile Trigger 1). As the figure shows, the water levels did not show that any low water conditions are developing in this well. The measured water levels were within the 50th Percentile or median (normal conditions) in July and as high as the 75th Percentile or above normal percentile indicator level in the months of August and September. Similarly, in comparison with

JW indicators, the monthly water levels during 2008 did not drop below the JW Trigger 1 (Figure 5-4). All levels were higher than the JW Trigger 1 and Trigger 2 (Table 5-4).

A comparison of indicators with historical water levels for the year 2003 (same months as 2008) representing low water conditions is shown in the Figure 5-4. According to this figure, the measured water levels were below the 50th Percentile or median (normal conditions) and as low as the Trigger 1 level in the months of April to August. Although the water levels did not reach Trigger 2 (Level II), this represents below normal conditions in the well. In consideration of the 2003 below normal conditions in the noted months as shown by the Percentile Trigger 1 (Table 2-2), potential water supply problems did develop in the aquifer in 2007 in the mentioned months but did not reach the dry conditions indicator level (Level II, 10th Percentile). Therefore, the appropriate actions plans under the OLWR Program for this indicator level (if developed in 2007) would have been implemented in the noted months. The water levels jumped to normal levels in the month of September indicating that the aquifer returned to the normal conditions.

In comparison to the JW Triggers (Figure 5-4), the measured water levels in 2003 in the months of April to August remained below the JW Trigger 1 (Table 5-4). As the 30-day average fell below the Trigger 1 in the first month (April 2003), the well was in Level-1 which is the first indication of potential water supply problem as per JW criteria (Table 2-1). The well was in Level-II between May to July as the 30-day average water level remained below Trigger 1 in three months in a row (May to July 2003). Level-II indicates a potential serious problem in aquifer according to the JW criteria (Table 2-1).

It is to be noted that as per Percentile Triggers, this well did not reach Level II. Therefore, it seems that the JW Trigger 2 is more sensitive as compared to Percentile Trigger 2. This is because the declaration of Level II for JW criteria is dependent on how persistent the Level 1 condition in a well is over the months being monitored. On the other hand, if the JW Trigger 2 alternate criteria of historic lowest water level (daily average falls below the lowest noted water level in a well) is applied, then Level II will not be reached in this well. This well remained in Level-II in August as the 30-day average for this month did not fall below Trigger 2 (lowest daily average level observed in the well). The water levels in September rose above Trigger 1, indicating that recovery had started. The recovery in the well followed in the same manner as described above when low water conditions were developing (Table 2-1). The appropriate actions plan under the OLWR Program for indicator Level I and II (if developed in 2003) would have been implemented during both on-set of low water conditions and recovery.

As shown by the above discussion, the JW Trigger 2 is more sensitive as compared to the Percentile Trigger 2. However, this is dependent on how persistent the Level 1 condition is in a well over the period being monitored. Also, as per JW Triggers , the Level I or II conditions may be persistent over many months whereas in the case of Percentile Triggers, the well may be out of Level I or Level II as soon the water levels recover to their noted values for each percentile. On the other hand, if the JW Trigger 2 alternate criteria of historic lowest water level (daily average falls below the lowest noted water level in a well) is applied, then Level II will not be reached in this well. In fact, if historic lowest water level is used as Trigger 2 (or to declare Level II), then the JW Trigger becomes less sensitive than Percentile Trigger 2.

Table 5-3: Percentile Method Results for Well-83.

Trigger or Condition	**Minimum**	**Trigger 3**	**Trigger 2**	**Trigger 1**	**Normal**	**Above normal**	**Very wet**
Percentile	0th Percentile	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	100th Percentile
January	140.62	140.66	140.73	141.69	142.66	143.02	143.56
February	140.52	140.62	140.65	141.79	142.51	142.89	143.61
March	140.34	140.52	140.62	142.52	142.69	143.00	143.57
April	142.36	142.39	142.42	142.65	142.99	143.41	143.74
May	142.18	142.35	142.39	142.60	142.93	143.14	143.55
June	142.09	142.27	142.34	142.49	142.77	143.01	143.19
July	141.26	141.41	141.52	141.85	142.41	142.64	143.22
August	140.52	140.81	141.12	141.24	142.09	142.60	143.10
September	139.99	140.17	140.31	141.27	141.64	142.35	142.98
October	139.93	140.04	140.14	141.67	142.16	142.52	143.00
November	139.98	140.07	140.11	140.50	142.50	142.75	143.42
December	140.64	140.73	140.74	140.87	141.98	142.93	143.46

Table 5-4: Comparison of JW & Percentile Indicators with Water Levels from Well-83.

Trigger or Condition	**Minimum 0 Percentile**	**Trigger 1 25th Percentile**	**JW Trigger 1**	**Normal 50th Percentile**	**Above Normal 75th Percentile**	**Very wet 100th Percentile**	**JW Trigger 2**	**Water Levels 2008**	**Water Levels 2003**
January	140.62	141.69	141.21	142.66	143.02	143.56	139.93	143.06	
February	140.52	141.79	141.33	142.51	142.89	143.61			
March	140.34	142.52	141.61	142.69	143.00	143.57			
April	142.36	142.65	142.63	142.99	143.41	143.74			142.44
May	142.18	142.60	142.54	142.93	143.14	143.55			142.41
June	142.09	142.49	142.45	142.77	143.01	143.19			142.41
July	141.26	141.85	141.77	142.41	142.64	143.22		142.25	141.72
August	140.52	141.24	141.27	142.09	142.60	143.10		142.15	141.23
September	139.99	141.27	140.87	141.64	142.35	142.98		141.84	141.29
October	139.93	141.67	140.96	142.16	142.52	143.00			141.99
November	139.98	140.50	140.74	142.50	142.75	143.42			
December	140.64	140.87	140.99	141.98	142.93	143.46			

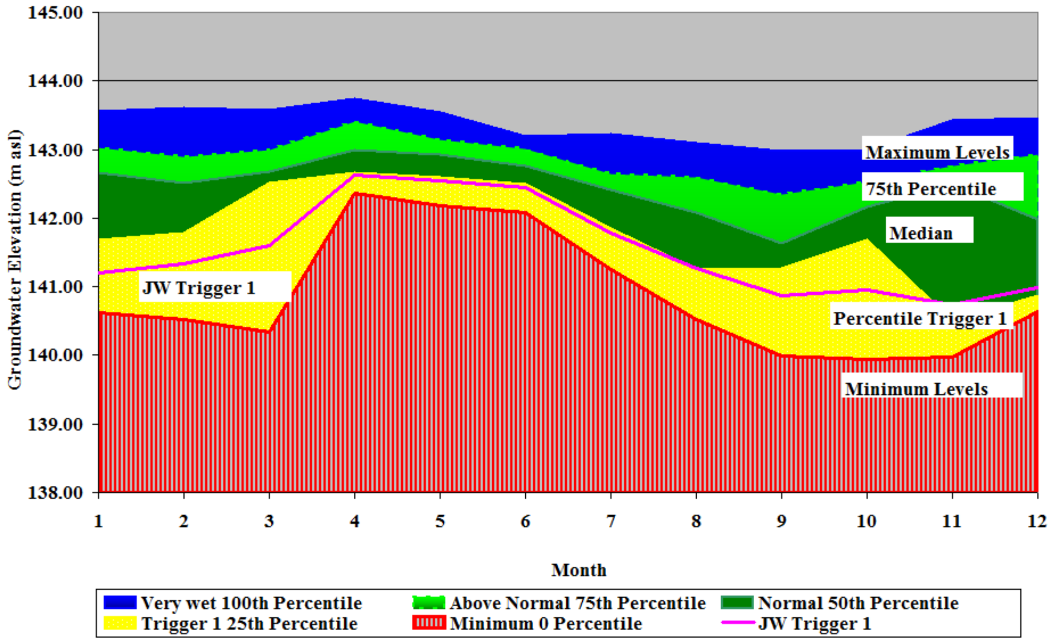


Figure 5-3: Comparison of groundwater indicators based on Jacques Whitford and Percentile methodologies for Well-83.

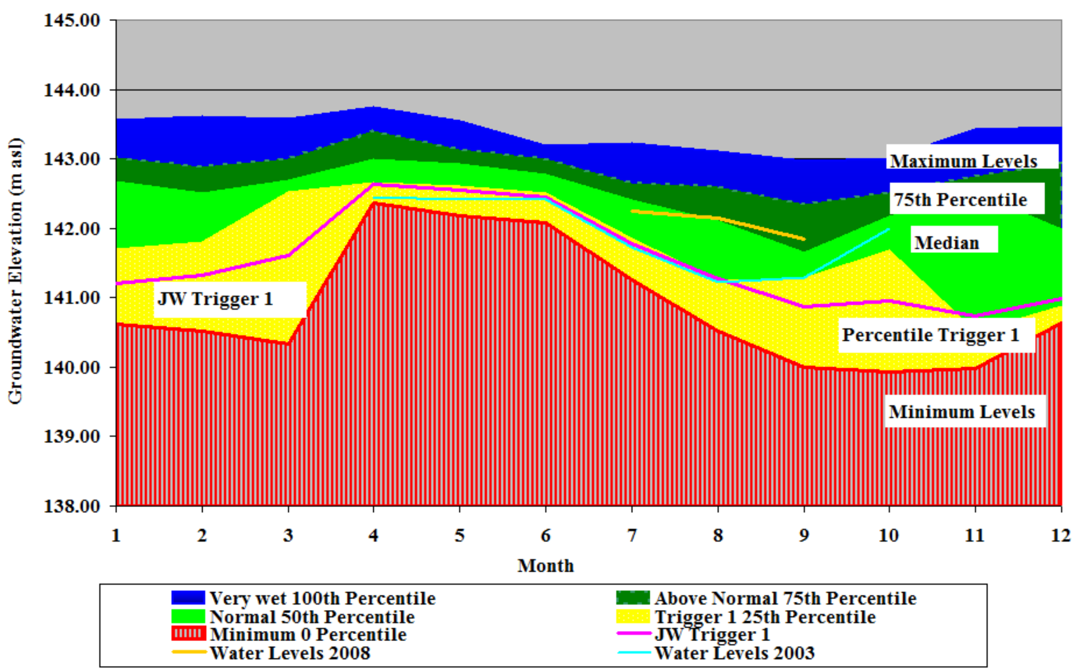


Figure 5-4: Comparison of groundwater Jacques Whitford & Percentile indicators with water levels form Well-83.

5.3. Well-86 (Long Island Park)

5.3.1. Indicators and Triggers

The historical water level data collected between November 2001and March 2008 was used to determine indicators and triggers. The indicators determined by the JW and Percentile approaches are shown in the Table 5-5 and Table 5-6. A comparison of the indicator values calculated by the two approaches is shown in the Figure 5-5, Figure 5-6 and Table 5-6.

For this well, JW Trigger 1 and Percentile Trigger 1 values are comparable (Table 5-5, Figure 5-5) for months of April to October. The JW Trigger 1 (Level 1- first indication of a potential water supply problem) values are slightly lower than the Percentile Trigger 1 (25^{th} Percentile- below normal or drought watch) values for the months of April to October. Due to the minor difference in trigger values of both approaches, it is expected that the Percentile based Trigger 1 and JW Trigger 1 will detect the below normal water level conditions in an aquifer at the same time.

5.3.2. Application

The water level data collected between April and September 2008 was used to establish whether the indicators (JW and Percentile) are showing that low water level conditions are developing in this well. The indicators determined by the JW and Percentile approaches are shown in Table 5-6 along with monthly water levels for 2008. A graphical comparison of the observed water levels with indicators is shown in Figure 5-6. Additional comparison undertaken with year 2007 water levels, which were deemed to be representative of historical low water conditions in the aquifer, is also presented in the already mentioned figures and tables.

According to Figure 5-6, the observed water levels in 2008 did not drop below the 25^{th} Percentile (Percentile Trigger 1). As the figure shows, the water levels did not show that any low water conditions are developing in this well. The measured water levels were above the 50^{th} Percentile or median (normal conditions) and as high as the maximum percentile indicator level (100^{th} Percentile). In the month of August 2008, water levels rose above the maximum percentile indicator level (Table 5-6). In comparison with JW indicators, the monthly water levels did not drop below the JW Trigger 1 (Figure 5-6). All levels were higher than the JW Trigger 1 and Trigger 2 (Table 5-6).

As indicated above, the water levels in August 2008 were above the 100^{th} Percentile. However, this is not considered to indicate that the current 100^{th} Percentile (Table 5-5,Figure 5-6) is too conservative (stringent) or sensitive. Since the 2008 water levels were only used for comparison and not included in determination of the indicators values, the 100^{th} Percentile value is estimated lower than would have been if the 2008 water levels were included in determining the indicators. Since the 2008 water levels were higher than all the previous years, this trend would have been reflected in the higher value of this indicator if 2008 data was included in the analysis. Also, in the perspective of aquifers, it does not really matter whether the water levels are above normal (75^{th} Percentile), at maximum levels (100^{th} Percentile) or beyond maximum since the aquifer will be able to meet the demand in either case (unless the well is a shallow well and does not have sufficient borehole storage so even minor changes in water levels will have an impact). The impacts may only be experienced when the water levels start to drop below the 50^{th} Percentile. Therefore, in terms of interpretation of indicators, the 75^{th} and 100^{th} Percentile are conveying the same indication i.e. water levels are in normal or above normal range. Even if the indicator values are refined, these indicators will interpret the aquifer behavior in the same way. However, these indicators are useful to establish whether the observed water levels are within the normal or above normal ranges of historical water levels.

A comparison of indicators with water levels for year 2007 (same months as 2008) representing low water conditions is shown in Figure 5-6. According to this figure, the measured water levels in the month of April were in the above normal range (100^{th} and 75^{th} percentiles). However, the water levels were below the 50^{th} Percentile or median (normal conditions) and as low as the Trigger 1 level in the month of May. This represents below normal conditions in this month. In consideration of the below normal conditions, as shown by the Percentile Trigger 1 (Table 2-2), water supply problems did develop in the aquifer in May 2007 but did not reach the dry conditions indicator level (10^{th} Percentile). Therefore, the appropriate actions plan under the OLWR Program for this indicator level (if developed in 2007) would have been implemented in this month. The water levels jumped above the 50^{th} Percentile level in the following month indicating that normal levels had returned to the aquifer.

In comparison to the JW Triggers (Figure 5-6) the measured water levels in 2007 (April to October) remained above the JW Trigger 1 (Table 5-6). Therefore, according to JW criteria (Table 2-1), no action would have required in 2007 on part of the OLWR program.

For this well, the JW Trigger 1 seems less sensitive as compared to Percentile Trigger 1, since water levels in May 2007 did reach Level I (drought watch) according to the Percentile criteria but not as per JW approach.

Table 5-5: Percentile Method Results for Well-86.

Trigger or Condition	Minimum	Trigger 3	Trigger 2	Trigger 1	Normal	Above normal	Very wet
Percentile	**0th Percentile**	**5th Percentile**	**10th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**100th Percentile**
January	85.77	85.84	85.90	86.20	86.34	86.59	87.19
February	85.73	85.77	85.81	86.14	86.25	86.35	87.17
March	85.74	85.77	85.93	86.30	86.57	86.70	87.04
April	86.31	86.41	86.45	86.51	86.67	86.77	87.11
May	86.15	86.30	86.34	86.43	86.53	86.65	87.04
June	85.77	85.94	86.02	86.16	86.38	86.50	86.99
July	85.70	85.82	85.90	86.00	86.10	86.20	86.79
August	85.56	85.64	85.71	85.82	85.92	86.01	86.26
September	85.60	85.74	85.76	85.83	85.90	86.01	86.59
October	85.85	85.92	85.95	85.98	86.12	86.18	86.48
November	85.89	85.95	85.98	86.04	86.28	86.41	86.73
December	85.87	85.93	85.97	86.11	86.36	86.50	86.93

Table 5-6: Jacques Whitford Method Results for Well-86.

Trigger or Condition	Minimum 0 Percentile	Trigger 1 25th Percentile	JW Trigger 1	Normal 50th Percentile	Above Normal 75th Percentile	Very wet 100th Percentile	JW Trigger 2	Water Levels 2008	Water Levels 2007
January	85.77	86.20	86.04	86.34	86.59	87.19	85.56		
February	85.73	86.14	85.96	86.25	86.35	87.17			
March	85.74	86.30	86.14	86.57	86.70	87.04			
April	86.31	86.51	86.49	86.67	86.77	87.11		86.71	86.80
May	86.15	86.43	86.38	86.53	86.65	87.04		86.48	86.42
June	85.77	86.16	86.09	86.38	86.50	86.99		86.43	86.18
July	85.70	86.00	85.93	86.10	86.20	86.79		86.41	86.09
August	85.56	85.82	85.77	85.92	86.01	86.26		86.31	85.88
September	85.60	85.83	85.76	85.90	86.01	86.59		86.15	85.87
October	85.85	85.98	85.96	86.12	86.18	86.48			86.12
November	85.89	86.04	85.98	86.28	86.41	86.73			
December	85.87	86.11	86.04	86.36	86.50	86.93			

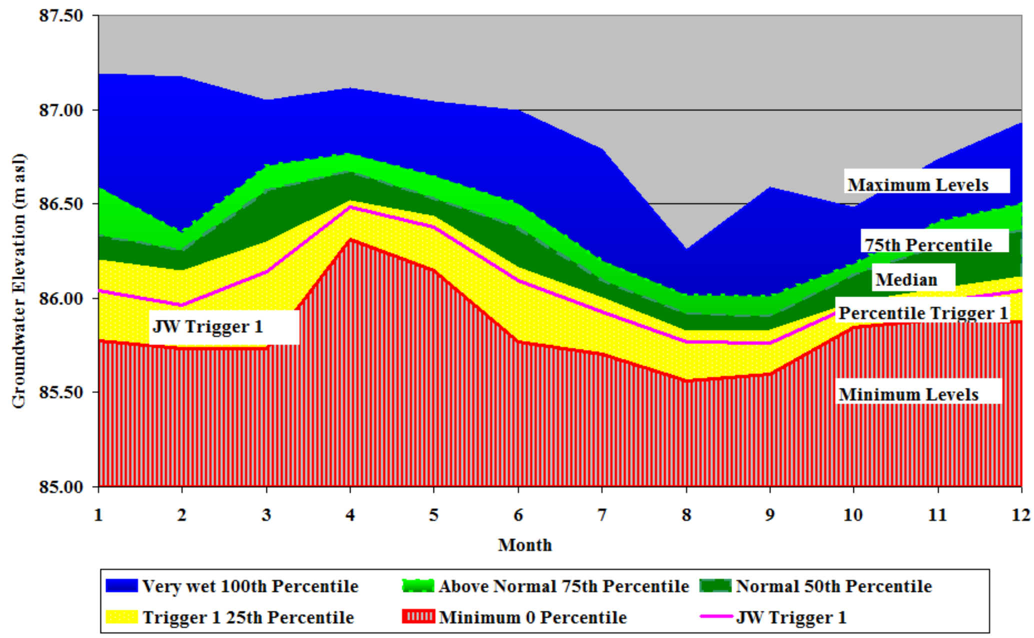


Figure 5-5: Comparison of groundwater indicators based on Jacques Whitford and Percentile methodologies for Well-86.

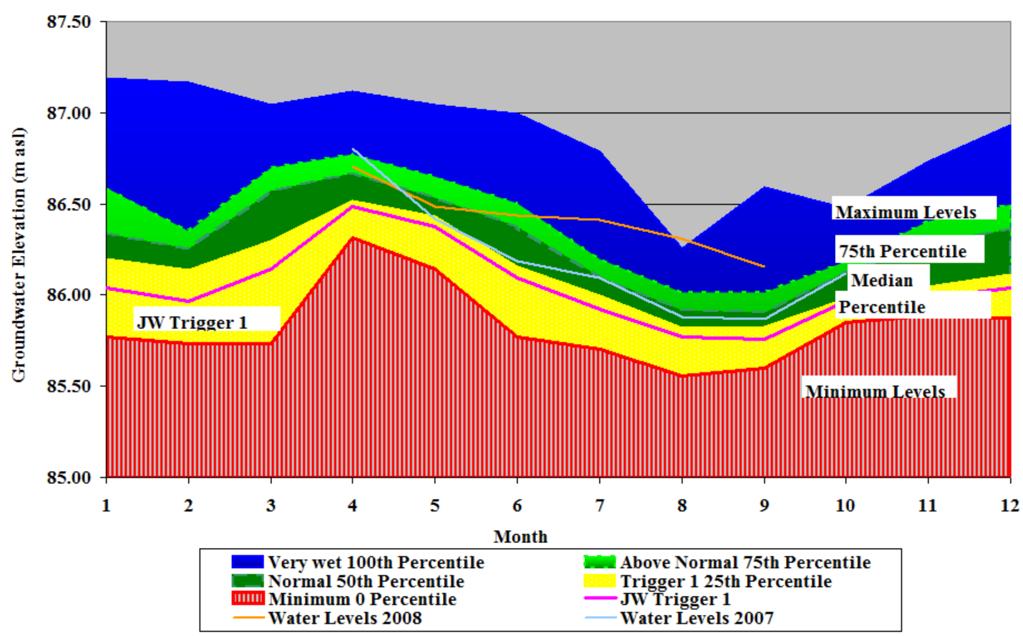


Figure 5-6: Comparison of groundwater Jacques Whitford & Percentile indicators with water levels form Well-86.

5.4. Well-156 (Twin Elm Bridge)

5.4.1. Indicators and Triggers

The historical water levels collected between August 2002 and March 2008 were used to determine indicators and triggers. The indicators determined by the JW and Percentile approaches are shown in the Table 5-7 and Table 5-8. A comparison of the indicator values calculated by the two approaches is shown in the Figure 5-7, Figure 5-8 and Table 5-8.

For this well, JW Trigger 1 and Percentile Trigger 1 values are shown in Table 5-8 and Figure 5-8. The JW Trigger 1 (Level 1- first indication of a potential water supply problem) values are slightly lower than the Percentile Trigger 1 (25^{th} Percentile-below normal or drought watch) values for the months of April, May and July while they are higher in the months of June, and September. Due to the mentioned variations in trigger values of both approaches, it is expected that the Percentile based Trigger 1 and JW Trigger 1 will detect the below normal water level conditions in an aquifer at different times depending on the month under consideration.

5.4.2. Application

The water level data collected between April and September 2008 was used to establish whether the indicators (JW and Percentile) are showing that low water level conditions are developing in this well. The indicators determined by the JW and Percentile approaches are shown in Table 5-8 along with monthly water levels for 2008. A graphical comparison of the observed water levels with indicators is shown in Figure 5-8. Additional comparison undertaken with year 2007 water levels, which were deemed to be representative of historical low water conditions in the aquifer, is also presented in the figures and tables already mentioned.

According to Figure 5-8, the observed water levels in 2008 did not drop below the 25^{th} Percentile (Percentile Trigger 1). As the figure shows, the water levels did not show that any low water conditions are developing in this well. The measured water levels remained within the 50^{th} Percentile or median (normal conditions) and as high as the above normal indicator level (75^{th} Percentile). Similarly, in comparison with JW indicators, the monthly water levels did not drop below the JW Trigger 1 (Figure 5-8). All levels were higher than the JW Trigger 1 and Trigger 2 (Table 5-8).

A comparison of indicators with historical water levels for year 2007 (same months as 2008) representing low water conditions is shown in the Figure 5-8. According to this figure, the measured water levels were below the 50^{th} Percentile or median (normal conditions) and as low as the Trigger 1 level in the months of May, June, August and September. However, they did not reach the Trigger 2 level (Table 2-2) between April and October. This represents below normal conditions in the months mentioned above. In consideration of the below normal conditions, as shown by the Percentile Trigger 1 (Table 2-2), potential water supply problems did develop in the aquifer in 2007 but did not reach the dry conditions indicator level (10^{th} Percentile). The appropriate actions plan under the OLWR Program for this indicator level (if developed in 2007) would have been implemented in these months. The water levels jumped to the 50^{th} Percentile levels in the month of November indicating that aquifer was in normal conditions.

In comparison to the JW Triggers (Figure 5-8), the measured water levels in 2007 remained below the JW Trigger 1 (Table 5-8) for most of the year excluding the months of January, March, April, and August. Since the 30-day water level average fell below Trigger 1 in the months of February, May, June, July, and September, this indicates that water supply problems were potentially developing (Table 2-1) in these months. The 30-day average fell below Trigger 1 level for three months in a row starting from November 2007. Therefore, according to JW criteria (Table 2-1), the well was in Level-II (potentially serious problems) condition. The well remained in Level-II (and did not reach Level-III) from November 2007 onwards as the 30-day average for any of the following months did not fall below Trigger 2 (lowest daily average level observed in the well). The well started to show recovery in February of 2008 as water levels rose above Trigger 1 level. The appropriate actions plan under the OLWR Program for indicator Level I and II (if developed in 2007) would have been implemented during both on-set of low water conditions and recovery starting from September 2007. However, once in the winter months, there might have been no need of water conservation measures due to decline in the groundwater.

As shown by the above discussion, the JW Trigger 2 is more sensitive as compared to Percentile Trigger 2 as it is dependent on how persistent the Level I condition is in a well over the period being monitored. Also, as per JW Triggers, the Level II conditions persisted over many months whereas in the case of Percentile Triggers, the well was in Level I in May, June, August and September and never reached Level II condition. However, in the case of Percentile approach, the cycle of shifting between recovery and low water conditions (Level I in one month and Level II in the next or vice versa) seems far more quick and frequent which means that rapidly changing weather conditions or water level changes in the aquifer will impact the Percentile Triggers more frequently and may result in far more frequent advisories etc.

Table 5-7: Percentile Method Results for Well-156-2.

Trigger or Condition	Minimum	Trigger 3	Trigger 2	Trigger 1	Normal	Above normal	Very wet
Percentile	**0th Percentile**	**5th Percentile**	**10th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**100th Percentile**
January	102.93	103.02	103.19	103.25	103.37	103.68	103.91
February	102.83	102.92	103.02	103.12	103.21	103.74	103.83
March	102.81	102.87	102.91	103.11	103.27	103.70	104.23
April	103.05	103.29	103.32	103.35	103.41	104.28	104.42
May	102.64	102.89	102.96	103.21	103.56	104.36	104.46
June	102.75	102.83	102.89	103.03	103.59	104.21	104.44
July	102.57	102.63	102.66	102.81	103.02	103.34	104.25
August	102.26	102.35	102.38	102.47	102.90	103.06	104.16
September	102.10	102.16	102.22	102.27	102.94	103.62	103.84
October	102.05	102.07	102.09	102.43	103.17	103.60	104.21
November	102.28	102.32	102.35	103.04	103.30	103.69	104.21
December	102.39	102.56	102.71	103.20	103.52	103.90	103.93

Table 5-8: Jacques Whitford Method Results for Well-156-2.

Trigger or Condition	Minimum 0 Percentile	Trigger 1 25th Percentile	JW Trigger 1	Normal 50th Percentile	Above Normal 75th Percentile	Very wet 100th Percentile	JW Trigger 2	Water Levels 2008	Water Levels 2007
January	102.93	103.25	103.18	103.37	103.68	103.91	102.05	103.18	103.4867
February	102.83	103.12	103.02	103.21	103.74	103.83		103.16	103.0194
March	102.81	103.11	102.99	103.27	103.70	104.23			103.026
April	103.05	103.35	103.25	103.41	104.28	104.42		103.53	103.39
May	102.64	103.21	103.08	103.56	104.36	104.46		103.26	103.06
June	102.75	103.03	103.04	103.59	104.21	104.44		103.09	102.94
July	102.57	102.81	102.72	103.02	103.34	104.25		103.08	102.71
August	102.26	102.47	102.38	102.90	103.06	104.16		102.92	102.54
September	102.10	102.27	102.34	102.94	103.62	103.84		102.68	102.24
October	102.05	102.43	102.40	103.17	103.60	104.21			102.12
November	102.28	103.04	102.72	103.30	103.69	104.21			102.35
December	102.39	103.20	102.99	103.52	103.90	103.93			102.63

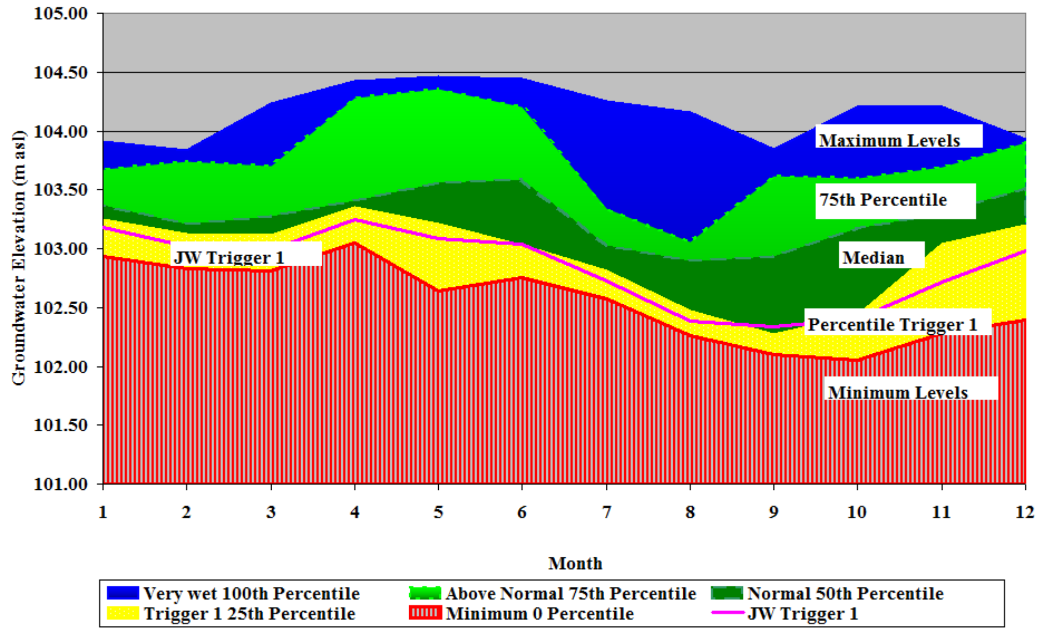


Figure 5-7: Comparison of groundwater indicators based on Jacques Whitford and Percentile methodologies for Well-156-2.

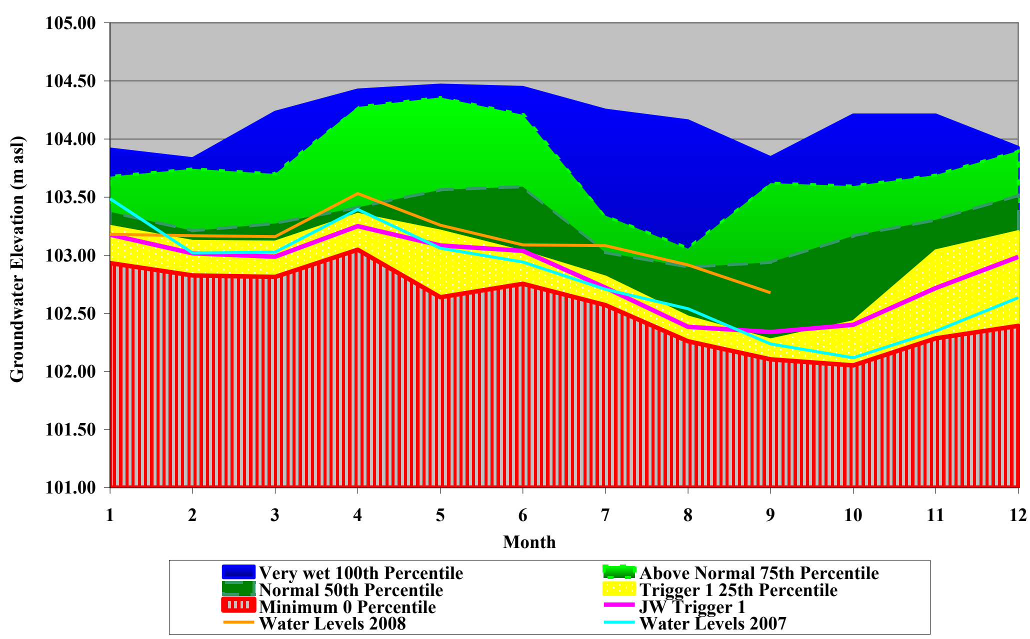


Figure 5-8: Comparison of groundwater Jacques Whitford & Percentile indicators with water levels form Well-156-2.

5.5. Well-252 (Christie Lake Camp Site)

5.5.1. Indicators and Triggers

The historical water levels collected between February 2003 and March 2008 were used to determine indicators and triggers. The indicators determined by the JW and Percentile approaches are shown in the Table 5-9 and Table 5-10. A comparison of the indicator values calculated by the two approaches is shown in the Figure 5-9, Figure 5-10 and Table 4-10.

Generally, the JW Trigger 1 (Level I- First indication of a potential water supply problem) values are lower than the Percentile Trigger 1 (25th Percentile-Below normal or drought watch) values in this well as shown in Table 5-9 and Figure 5-9. This means that Percentile based Trigger 1 will always declare the below normal water level conditions in an aquifer or well before JW Trigger 1 can detect Level 1(Table 2-1,Table 2-2). This is expected when the water levels are declining in the well. However, if the water levels are recovering after a period of low water conditions, then JW Trigger 1 conditions for Level I will be met first.

5.5.2. Application

The water level data collected between April and September 2008 was used to establish whether the indicators (JW and Percentile) are showing that low water level conditions are developing in this well. The indicators determined by the JW and Percentile approaches are shown in Table 5-10 along with monthly water levels for 2008. A graphical comparison of the observed water levels with indicators is shown in Figure 5-10. Additional comparison undertaken with year 2003 water levels, which were deemed to be representative of historical low water conditions in the aquifer, is also presented in the already mentioned figures and tables.

According to Figure 5-10, the observed water levels in 2008 did not drop below the 25th Percentile (Percentile Trigger 1) except in the month of May when water levels did fall below the Trigger 1 indicating that low water conditions developed in this well. However, the water levels rose in the month of June and were reflective of normal conditions. For remainder of the months, the water levels did not show that any low water conditions are developing in this well as the measured water levels were above the 50th Percentile or median (normal conditions) and as high as the maximum percentile indicator level (100th Percentile) in the months of July and August 2008. In comparison with JW indicators, the monthly water levels did not drop below the JW Trigger 1 (Figure 5-10). All levels were higher than the JW Trigger 1 and Trigger 2 (Table 5-10).

As indicated above, the water levels in July and August 2008 were above the 100th Percentile. However, this is not considered to indicate that the current 100th Percentile (Table 5-9,Figure 5-10) is too conservative (stringent) or sensitive. Since the 2008 water levels were only used for comparison and not included in determination of the indicators values, the 100th Percentile value is estimated lower than would have been if the 2008 water levels were included in determining the indicators. Since the 2008 water levels were higher than all the previous years, this trend would have been reflected in the higher value of this indicator if 2008 data was included in the analysis. Also, in the perspective of aquifers, it does not really matter whether the water levels are above normal (75th Percentile), at maximum levels (100th Percentile) or beyond maximum since the aquifer will be able to meet the demand in either case (unless the well is a shallow well and does not have sufficient borehole storage so even minor changes in water levels will have an impact). The impacts may only be experienced when the water levels start to drop below the 50th Percentile. Therefore, in terms of interpretation of indicators, the 75th and 100th Percentile are conveying the same indication i.e. water levels are in normal or above normal range. Even if the indicator values are refined, these indicators will interpret the aquifer behavior in the same way. However, these indicators are useful to establish whether the observed water levels are within the normal or above normal ranges of historical water levels.

A comparison of indicators with historical water levels for year 2003 (same months as 2008) representing low water is shown in the Figure 5-10. According to this figure, the measured water levels during the months of April, May and July were below the 50th Percentile or median (normal conditions) and as low as the Trigger 1 level but did not reach the Trigger 2 level (Table 5-10). This represents below normal conditions in the aquifer. For remainder of the months, the water levels were in the normal to above normal indicator levels. In consideration of the 2003 below normal conditions for some months, as shown by the Percentile Trigger 1 (Table 2-2), water supply problems did start to develop in the aquifer in the noted months but did not reach the dry conditions indicator level (10th Percentile). Therefore, the appropriate actions plan under the OLWR Program for this indicator level (if developed) would have been implemented in these months. The water levels jumped to above normal levels in the month of August indicating that aquifer had returned to normal conditions.

In comparison to the JW Triggers (Figure 5-10), the measured water levels in 2003 remained below the JW Trigger 1 (Table 5-10) for April and July while they were above the Trigger 1 levels in the remaining months. In April and July, the well was in Level I (the first indication of a potential water supply problem) according to the JW criteria (Table 2-1). However, the 30-day average did not fall below Trigger 1 for three months in a row. Therefore, according to JW criteria (Table 2-1), Level II was not reached. The appropriate actions plan under the OLWR Program for indicator Level I (if developed in 2007) would have been implemented in both months during on-set of low water conditions and recovery.

As shown by the above discussion, both Percentile and JW Trigger 1 found the water levels in April and July 2003 to be in Level I water conditions. However, in the case of Percentile approach, the cycle of shifting between normal and low water conditions seems far more frequent which means that rapidly changing weather conditions or water level changes in the aquifer will impact the Percentile Trigger 1 more frequently and may result in far more frequent advisories etc.

Table 5-9: Percentile method Results for Well-252.

Trigger or Condition	Minimum	Trigger 3	Trigger 2	Trigger 1	Normal	Above normal	Very wet
Percentile	**0th Percentile**	**5th Percentile**	**10th Percentile**	**25th Percentile**	**50th Percentile**	**75th Percentile**	**100th Percentile**
January	175.52	175.66	175.73	175.93	176.23	176.50	177.06
February	174.49	174.74	175.15	175.44	175.66	175.88	176.68
March	174.40	174.65	175.04	175.57	175.97	176.48	176.89
April	175.13	175.33	175.54	175.99	176.55	176.79	177.14
May	175.01	175.40	175.57	175.73	175.90	176.24	176.81
June	175.07	175.28	175.35	175.53	175.72	175.98	176.70
July	174.67	174.79	174.84	175.10	175.28	175.63	176.03
August	174.32	174.45	174.54	174.71	174.99	175.27	176.20
September	174.08	174.22	174.36	174.49	174.67	175.33	176.66
October	174.10	174.27	174.35	175.25	175.52	176.14	176.67
November	174.44	174.62	174.72	175.73	176.17	176.34	176.71
December	175.17	175.35	175.49	175.86	176.27	176.51	176.82

Table 5-10: Jacques Whitford Method Results for Well-252

Trigger or Condition	Minimum 0 Percentile	Trigger 1 25th Percentile	JW Trigger 1	Normal 50th Percentile	Above Normal 75th Percentile	Very wet 100th Percentile	JW Trigger 2	Water Levels 2008	Water Levels 2003
January	175.52	175.93	175.85	176.23	176.50	177.06	174.08		
February	174.49	175.44	175.22	175.66	175.88	176.68			
March	174.40	175.57	175.30	175.97	176.48	176.89			
April	175.13	175.99	175.83	176.55	176.79	177.14		176.63	175.64
May	175.01	175.73	175.56	175.90	176.24	176.81		175.72	175.64
June	175.07	175.53	175.42	175.72	175.98	176.70		175.94	175.66
July	174.67	175.10	174.97	175.28	175.63	176.03		175.88	174.92
August	174.32	174.71	174.60	174.99	175.27	176.20		175.57	175.09
September	174.08	174.49	174.32	174.67	175.33	176.66		175.18	174.70
October	174.10	175.25	174.85	175.52	176.14	176.67			175.67
November	174.44	175.73	175.27	176.17	176.34	176.71			
December	175.17	175.86	175.73	176.27	176.51	176.82			

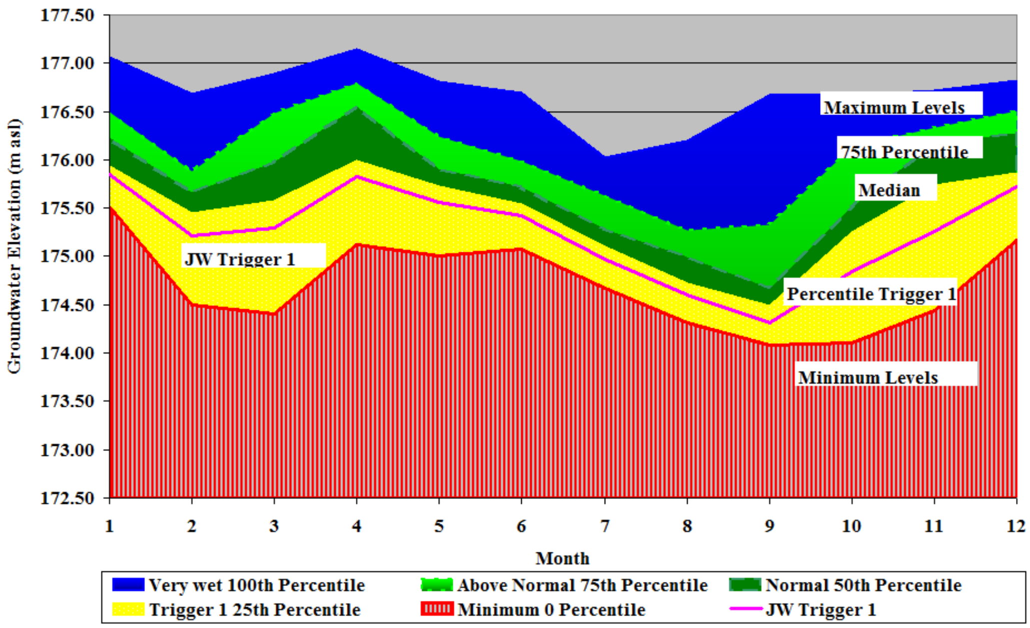


Figure 5-9: Comparison of groundwater indicators based on Jacques Whitford and Percentile methodologies for Well-252

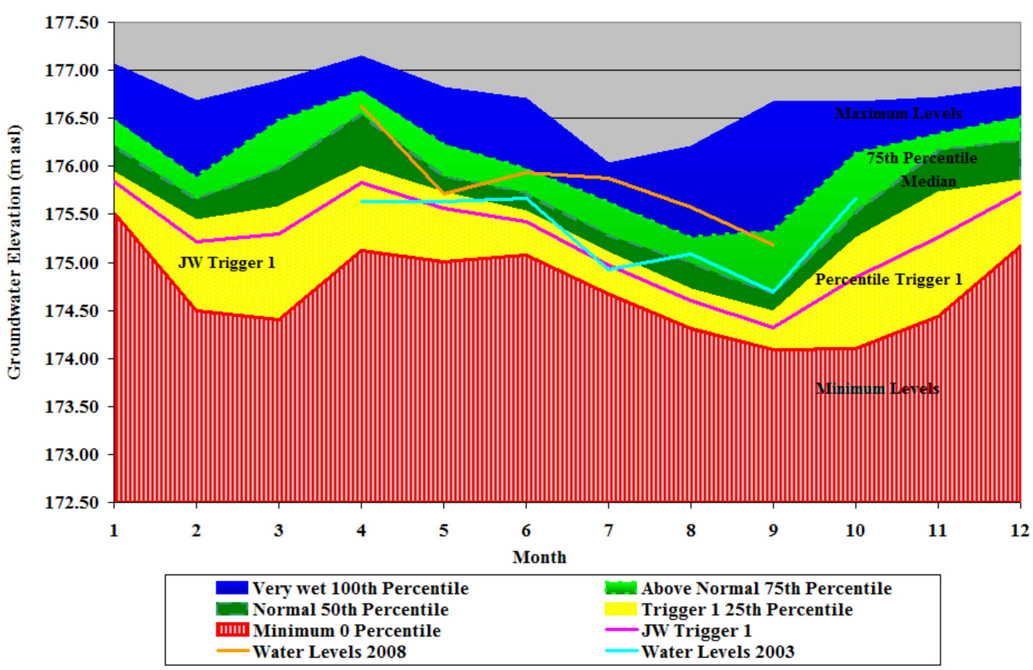


Figure 5-10: Comparison of groundwater Jacques Whitford & Percentile indicators with water levels form Well-252.

5.6. Comparison of Triggers, Indicators and Calculation Approaches

5.6.1. Triggers and Indicators

In terms of effectiveness of a particular method in detecting level I or level II conditions, since JW Trigger 1 value is generally lower than the Percentile Trigger 1, therefore it will always take longer to reach the Level I conditions as per JW Approach. Hence Level I condition will be declared first by the Percentile Trigger 1 during the on-set of the low water conditions in a well or in an aquifer. Therefore, during the on-set, the Percentile Trigger 1 is considered to be more sensitive as compared to JW Trigger 1. On the other hand during the recovery from the low water conditions, the JW Trigger 1 requirements may be met first in ending the Level I declaration while a well may still be in below normal or drought watch status as per Percentile Trigger 1.

It seems that the JW Trigger 2 is more sensitive as compared to Percentile Trigger 2 (Well-83, Well-156) since it is dependent on how persistent the Level I is in a well over the monitoring period. On the other hand, if the JW Trigger 2 alternate criteria of historic lowest water level (daily average falls below the lowest noted water level in a well) is applied, then Level II will be declared less frequently. In fact, if historic lowest water level is used as Trigger 2 (or to declare Level II), then JW Trigger 2 becomes less sensitive than Percentile Trigger 2.

It has to be recognized that as per the JW Triggers, the Level I and Level II conditions (both for on-set and recovery of the low water conditions) can persist for long periods of time whereas in the case of Percentile Triggers, the aquifer or well may be out of Level I or Level II conditions as soon the water levels recover to their noted values for each percentile (Well-83, Well-252). In other words, the JW Approach will result in Level I or II being declared for much longer durations once it is entered, as compared to the Percentile Method. However, the Percentile approach will result in frequent declaration of Level I or Level II especially if weather conditions are changing or water levels are cycling rapidly.

The persistence of Level I, II or III conditions in case of JW Approach may be problematic for watershed residents, especially if they have to implement groundwater conservation measures (lower domestic use, decrease water takings etc.) for long periods of time. Implementing the conservation measures for a long time as advised by JW triggers may not sit well with the well users. The Percentile approach on the other hand does not require the declaration of Levels (I, II or III) to continue for months during on-set or in recovery cycle. Although, this may result in groundwater conservation measures being implemented for shorter period of time, the declaration of Level I or II between on-set to recovery or recovery to on-set can vary from month to month (depending on the water levels encountered) and may become rather frequent especially if the weather conditions or water levels are cycling rapidly. In terms of advisories or implementation of conservation measures (as per each declared level), the communications on frequently changing conditions (as per Percentile approach) may become confusing or too strenuous for the watershed residents.

For the Percentile approach, the frequent shift between triggers or levels may be solved by refining the range of Triggers (increasing or perhaps eliminating/combining some of the Triggers) especially those above the 75th Percentile since it does not really matter whether aquifer is in normal or above normal conditions as sufficient water supply is available for use in either case. This will also further simplify the application of Percentile approach for declaring Level I or II.

In some wells (Well-81, Well-86, Well-252), the 2008 water levels rose above the 100th Percentile. However, this is not considered to indicate that the 100th Percentile is too conservative (stringent) or sensitive. Since the 2008 water levels were only used for comparison and not included in determination of the indicators values, the 100th Percentile value is estimated lower than would have been if the 2008 water levels were included in determining the indicators. Because the 2008 water levels were higher than all the previous years, this trend would have been reflected in the higher value of this indicator if 2008 data was included in the analysis. Also, in the perspective of aquifers, it does not really matter whether the water levels are above normal (75th Percentile), at maximum levels (100th Percentile) or beyond maximum since the aquifer will be able to meet the demand in either case (unless the well is a shallow well and does not have sufficient borehole storage so even minor changes in water levels will have an impact). The impacts may only be experienced when the water levels start to drop below the 50th Percentile. Therefore, in terms of interpretation of indicators, the 75th and 100th Percentile are conveying the same indication i.e. water levels are in normal or above normal range. Even if the indicator values are refined, these indicators will interpret the aquifer behavior in the same way. It may be worth decreasing the number of percentile indicators, especially 75th and 100th Percentiles (perhaps by eliminating and widening the range of percentiles that a Triggers represent or by combining some of the Triggers into one). However, these indicators are still useful to establish whether the observed water levels are within the normal or above normal ranges of historical water levels.

As already mentioned, the Percentile Trigger 1 (Well-81, Well-86) was found to be more sensitive because it meant that Level I low water conditions were met prior to the JW Trigger 1. However, this is not considered a disadvantage of the Percentile approach since the Trigger values can easily be manipulated to better reflect developing conditions in a well simply by setting a new percentile value for the trigger. Flexibility in manipulating the percentile values for triggers is an advantage of this approach as the JW trigger values are comparatively fixed (less flexible as calculated based on mean and standard deviation). However, comparison with more long term data and especially for those years when confirmed drought conditions developed in an aquifer (as shown by social, economic etc. impacts) are necessary to fine tune both Percentile and JW Triggers.

The JW approach defines triggers and indictors for both on-set and recovery of the low water conditions. However, the Percentile approach only relies on attaining a certain percentile value for each trigger. As in the case of Percentile approach, the cycle of shifting between recovery and low water conditions (Level I in one month and Level II in the next or vice versa) seems far quicker and frequent (as shown by Well-156), this means that rapidly changing weather conditions or water level changes in the aquifer will impact the Percentile Triggers more frequently. Therefore, it is necessary to clearly define how the recovery in a well after a period of low conditions is to be interpreted if utilizing the percentile triggers in order to avoid too frequent advisories etc. to the watershed residents.

Overall, both approaches proved to be useful tools for analyzing the water level trends. However, they must be applied with caution, especially when translating the indictors to represent the aquifer behavior. This is because the aquifer may be slow to respond to climate changes, or the aquifer response may be highly localized depending on the type of well, type of aquifer, recharge and other factors such as density of well users in an area, pumping effects etc. These factors will impact the water levels, which may not be reflected in the indicator value directly. If the indictors are to be used at local scale, then it is suggested that a suitable network of monitoring wells be established which properly represents the aquifer in the area, and the factors affecting the aquifer behavior must be clearly understood. Also, there should be very reliable baseline water level data available for an aquifer (or an area) when extreme water conditions (well doing dry, etc.) developed as this will help to confirm how the water levels behave drying extreme events and to set indicator values which are more reflective of the aquifer conditions.

The groundwater triggers as indicators for the Ontario Low Water Response Program have their utility, as these can be used to report on the developing low water conditions in an area represented by a water well or in an aquifer. Both the JW and Percentile indicators seem suitable, and the use of both can complement each other by fully capturing the water level trends and aquifer behavior in response to climate changes or anthropogenic activities. However, considering that Percentile Triggers are simpler to apply, do not require the Level I or Level II water conditions to be declared for a long period of time, and that the percentile triggers are relatively flexible (values can be easily redefined to better represent an aquifer behavior), the Percentile Approach has an advantage over the JW Approach.

5.6.2. Calculation Approaches

Calculation of both JW and Percentile triggers was done using the spreadsheets tools. Although the spreadsheets were automated for the most part, it still involved a lot of pasting and copying operations especially for raw water level data. In consideration of the huge amount of data used in the analysis, the percentiles approach proved to be more time consuming and cumbersome. However, JW indicator calculations were found to be more complicated (compared to percentile formulas) as they required more advanced understanding of worksheet functionality (complex macros etc.) to manipulate data and calculate means, standard deviation etc. However, both approaches were prone to errors during pasting, copying, etc. while the analysis was in progress. In terms of graphic representation (charts etc.), the JW indicators are simpler to display and visually interpret being fewer in number as compared to the five percentile indicators.

In terms of level of expertise required to undertake the analysis, neither approach seemed to be very demanding. Both methods were considered to be simple and did not require high levels of expertise or familiarization with complex mathematical and statistical methods. The actual difficulty lies in interpretation of the results and when a comparison is undertaken. The Percentile approach, with its five indicators, may be more confusing to interpret than the three indicators of the JW approach. On the other hand, the JW approach is at a disadvantage due to the use of standard deviations and mean water levels which are hard to explain conceptually or understand in terms of behavior of the actual water levels.

Both approaches required extensive QA/QC on the raw data prior to the actual analysis stage when indicators were calculated. The Percentile method seemed more sensitive to outlier data or spikes in water levels; therefore the data needed to be more intensively scrutinized. Depending on the length of the data record, the outliers, spikes etc. seem to impact the JW calculations as well (as standard deviation is miscalculated) to some degree. The most critical was the value of zero in the raw data which may significantly alter the outcome of the JW triggers.

The JW approach may introduce relatively higher degree of inaccuracy for interpreting aquifer conditions where the water levels are not following symmetrical seasonal variations (normal distribution of the data). This is because the greater the variations in water levels, which are far from the mean water levels, the higher the deviation from the actual water levels which will reflect on the indicator value and may not be representative of actual aquifer conditions.

Accounting for the simpler mathematical formulas for percentiles and easier understanding of the percentile concept, the Percentile Approach has an advantage over the JW Approach.

6. Conclusions and Recommendations

The groundwater trigger levels were calculated for selected wells. These wells were monitored during the summer of 2008 (April to October) to determine when water levels in a well fell below the JW triggers (Trigger 1 and II) and met the Level I (indication of potential water supply problems), Level II (potentially serious problems) and level III (failure of the water supply to meet the demand) thresholds as set out in the Jacques Whitford Groundwater Indicator Report (JW 2008). The collected water level data was also used to determine when the water levels in a well dropped below the 25th Percentile (Trigger 1 - below normal water levels), 10th Percentile (Trigger 2-dry conditions) or 5th Percentile (very dry conditions), to assess whether these wells would identify the state of an aquifer in response to climate change based on the Percentile methodology. The results of the analysis are presented and discussed in Section 5 of the report.

The water levels in 2008 remained consistently higher than the triggers and indicators of both approaches. Therefore, two years (2003 and 2007) which showed low water level trends were selected and used to test the utility of the indicators and triggers. The results of this exercise are documented in Section 5 of this report.

Based on the analysis and comparison undertaken, it is concluded that:

1. The accuracy of the indicators is greatly dependent on length of the available water level records and the number of wells being monitored. This accuracy can be greatly increased by incorporating more wells and collecting more water level data that captures a wider range of seasonal variations.
2. It is critical that there is very reliable water level data available from a well (an aquifer) when extreme conditions (well going dry, etc.) developed in an area and caused economical, environmental, social, etc. impacts. This will help to confirm how the water levels behave during extreme events and to identify the water levels where the impacts are anticipated. This reference dry year data will further help to refine indicator values which are more representative of the aquifer conditions.
3. Both approaches for calculating indicators apply simple statistical and mathematical techniques. Therefore, high levels of expertise and familiarization with complex mathematical or statistical methods is not required. Both approaches use spreadsheet tools and involve huge amounts of data which makes the analysis and calculations cumbersome and prone to mistakes. Both approaches require a high degree of QA/QC for proper analysis. However, because the mathematical formulas are easier for percentiles and the concept is simpler, the Percentile approach has an advantage.
4. In some wells, the JW Trigger 1 and Percentile Trigger 1 did not correlate very well. Those are the wells which showed water level variations which are inconsistent with seasonal changes, or where the water levels had wider variations. The JW triggers are calculated based on statistical analysis i.e. normal distribution and mean deviations. Therefore, it seems that the JW indicator may describe the groundwater levels in a reasonable degree for wells where the variations in groundwater levels follow a symmetric distribution about the mean. However, percentile indicators seem to better reflect the water levels in wells with wider variations since the percentile technique is based on accounting for the actual amount of variation in a well. However, these

differences are not considered to be critical and may not be significant if a lengthy data record is available. Both approaches need to be applied with caution accounting for the type of well, range of water level variations, amount of data available, factors affecting water level behavior and whether the basic assumptions of a technique (normal distribution of data as assumed for JW approach) being applied are met. It is recognized that the percentile indicators have advantage over the JW triggers in the sense that the percentile values can be easily manipulated so that the triggers are more or less sensitive to the developing conditions. This manipulation should be undertaken carefully and should be based on the water levels observed in dry years and especially those when the impacts on aquifers (wells going dry etc.) were evident.

5. The Percentile Trigger 1 is more sensitive than the JW Trigger 1. On the other hand, JW Trigger 2 was found to be more sensitive than the Percentile Trigger 2.
6. In case of JW Triggers, the Level I and Level II conditions (both for on-set and recovery of the low water conditions) can persist for long periods of time whereas with Percentile Triggers, the aquifer or well may be out of Level I or Level II conditions as soon as the water levels recover to their noted values for each percentile. In other words, the JW Approach will result in Level I or II being declared for much longer durations once it is entered, as compared to the Percentile Approach. However, the Percentile Approach will result in frequent declaration of Level I or Level II, if weather conditions are changing or water levels are cycling rapidly.
7. In the perspective of aquifers, it does not really matter whether the water levels are above normal (75^{th} Percentile), at maximum levels (100^{th} Percentile) or beyond maximum since aquifer will be able to meet the demand in either case (unless the well is a shallow well and does not have sufficient borehole storage so even minor changes in water levels will have an impact). The impacts may only be experienced when the water levels start to drop below 50^{th} Percentile. Therefore, in terms of interpretation of indicators, the 75^{th} and 100^{th} percentile are conveying the same indication i.e. water levels are in normal or above normal range. Even if the indicator values are refined, these indicators will interpret the aquifer behavior in the same way. It may be worth decreasing the number of percentile indicators, especially the 75^{th} and 100^{th} percentiles (perhaps by eliminating and widening the range of percentiles that a trigger represents or by combining some of the triggers into one). However, these indicators are still useful to establish whether the observed water levels are within the normal or above normal ranges of historical water levels.
8. The Percentile approach does not differentiate how the triggers and indicators are to be applied during the on-set of low conditions or in recovery cycle. Under certain conditions (rapidly fluctuating water levels), this may result in frequent advisories regarding the low water conditions in watershed.
9. Water level indicators are a useful tool to quickly establish whether the observed water levels are falling below the historical low water levels on record. This can be combined with further analysis (rainfall etc.) to determine whether the climate changes (low rainfall etc.) are causing these impacts on the aquifers. However, they must be applied with caution, especially when translating the indicators to represent or explain the aquifer behavior in an area. This is because the aquifer behavior is impacted by a whole range of

factors other than the weather events which may not be directly reflected by the indicators.

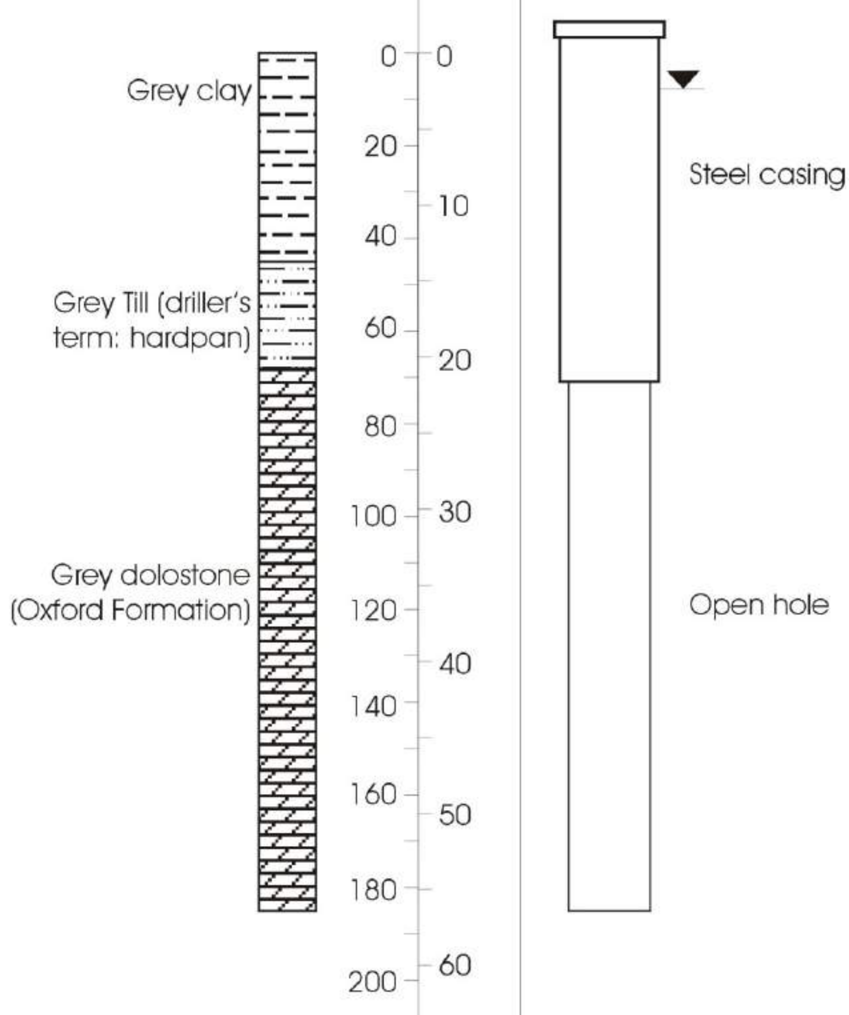
10. The groundwater triggers as indicators for the Ontario Low Water Response Program have their utility as these can be used to report on the developing low water conditions in an area represented by a water well or in an aquifer. Both the JW and Percentile indicators seem suitable, and the use of both can complement each other by fully capturing the water level trends and aquifer behavior in response to climate changes or anthropogenic activities. However, considering easier mathematical formulas for percentiles, simpler understanding of the percentile concept, and that the percentile triggers are flexible (values can be easily redefined to better represent aquifer response to the climate changes), Percentile approach is at an advantage.

7. REFERENCES

1. Guidance Document for Using the Percentile Method for Calculating Trigger Levels for Groundwater for the Ontario Low Water Response Plan., Ministry of Environment, March 2008 (MOE 2008).
2. Final Report: Develop a Groundwater Indicator for Ontario Low Water Response, Ontario Ministry of Natural Resources, 2008 (JW 2008).
3. Ontario Low Water Response Plan, revised July 2003 (OLWR).
4. Provincial Groundwater Monitoring Network Information System (PGMIS). Ministry of Environment.
5. MOU between Ministry of Natural Resources and Rideau Valley Conservation Authority for Ontario Low Water Response Groundwater Indicator Pilot Project, March 2008.

Appendix A
(Logs)

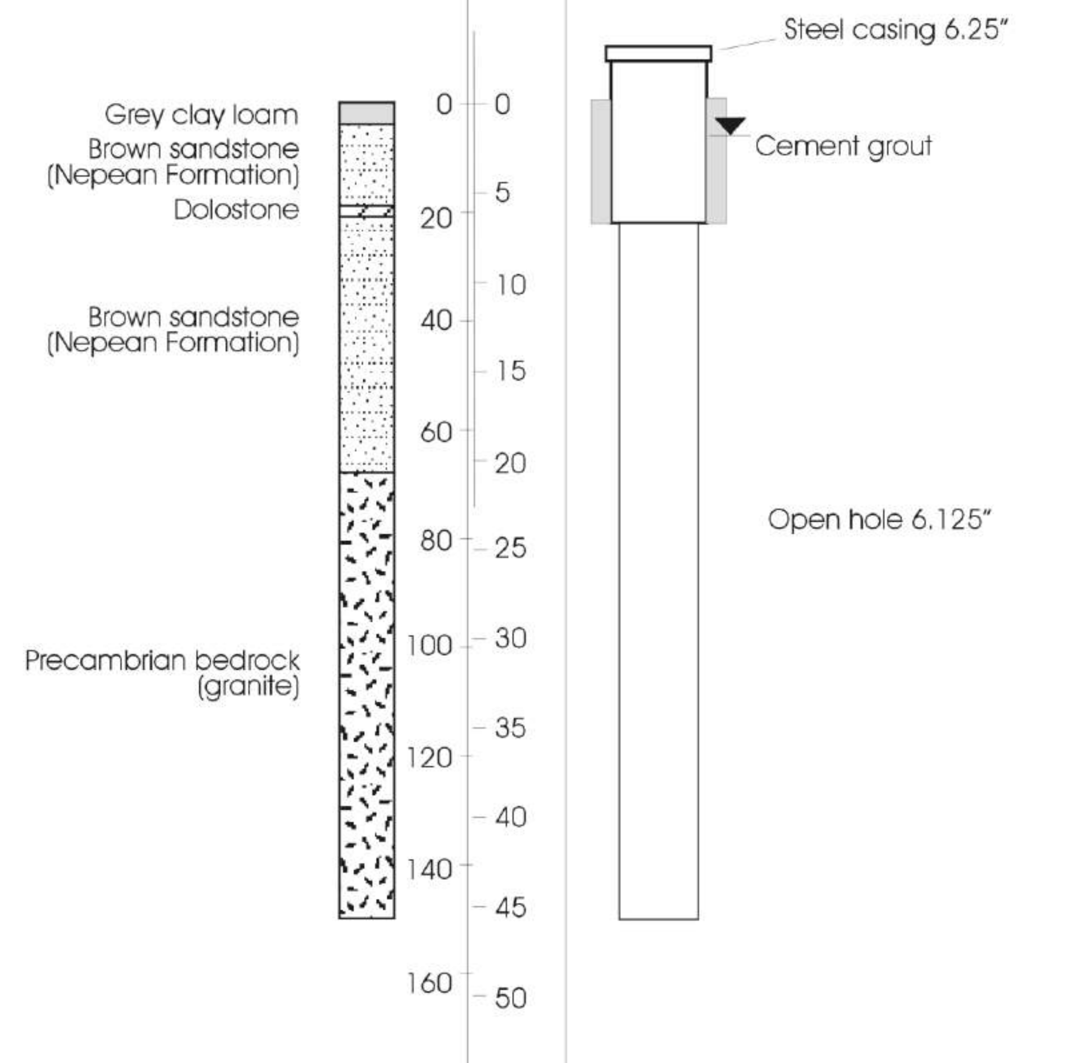
PIEZOMETER NUMBER: W000081		DESCRIPTION: W.A.TAYLOR PARK	LOG 1
SOIL DESCRIPTION / STRAT. / DEPTH (FT)	DEPTH (M)	PIEZOMETER INSTALLATION	



SOURCE: MOE WELL LOG 1516562

NOTES: WATER FOUND AT 56.4 m (185 FT)

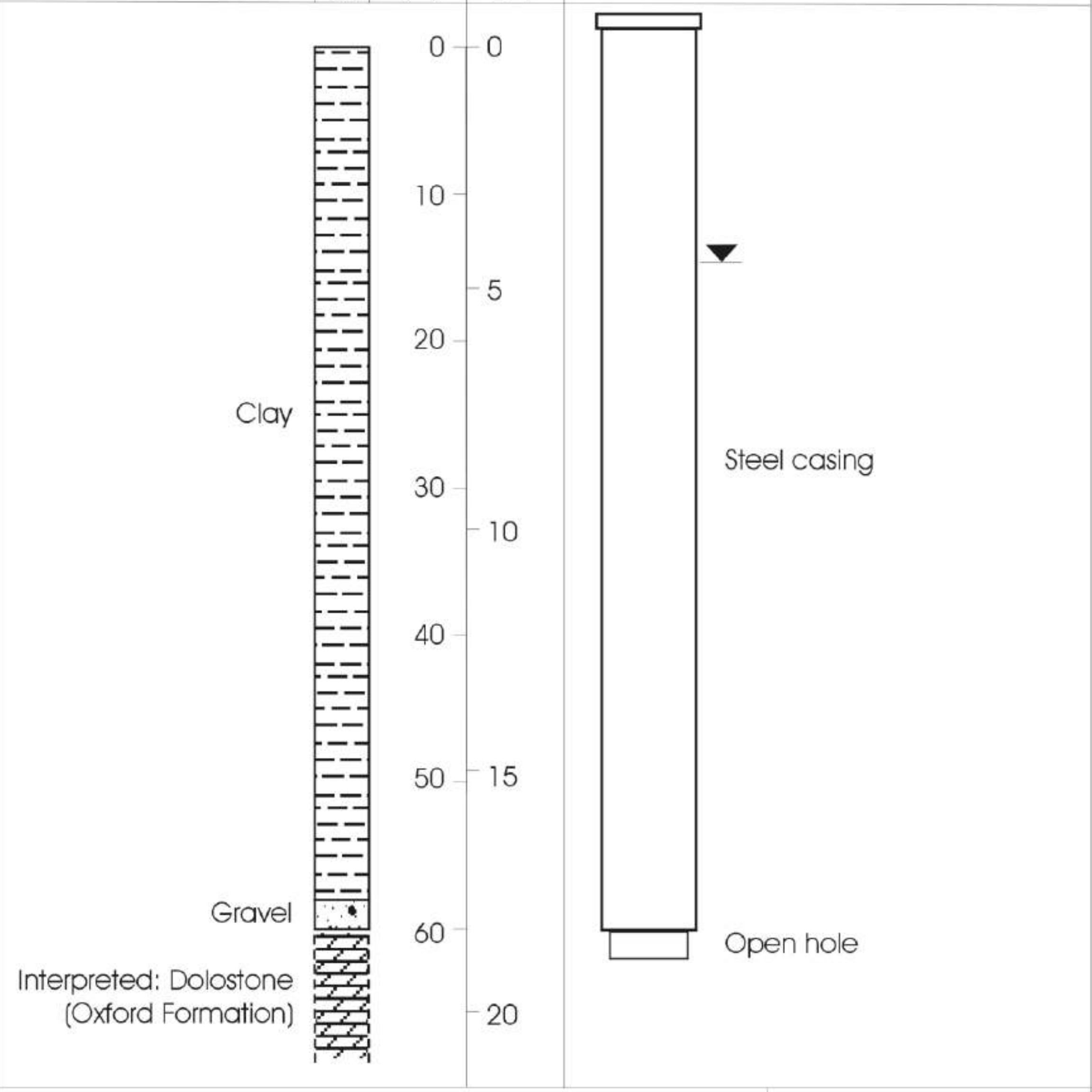
PIEZOMETER NUMBER: W0000083		DESCRIPTION: OMYA	LOG 2
SOIL DESCRIPTION / STRAT. / DEPTH (FT)	DEPTH (M)	PIEZOMETER INSTALLATION	



SOURCE: MOE WATER WELL RECORD 3511815

NOTES: WATER FOUND AT 21.9 m (72 FT) AND 43.0 m (141 FT)

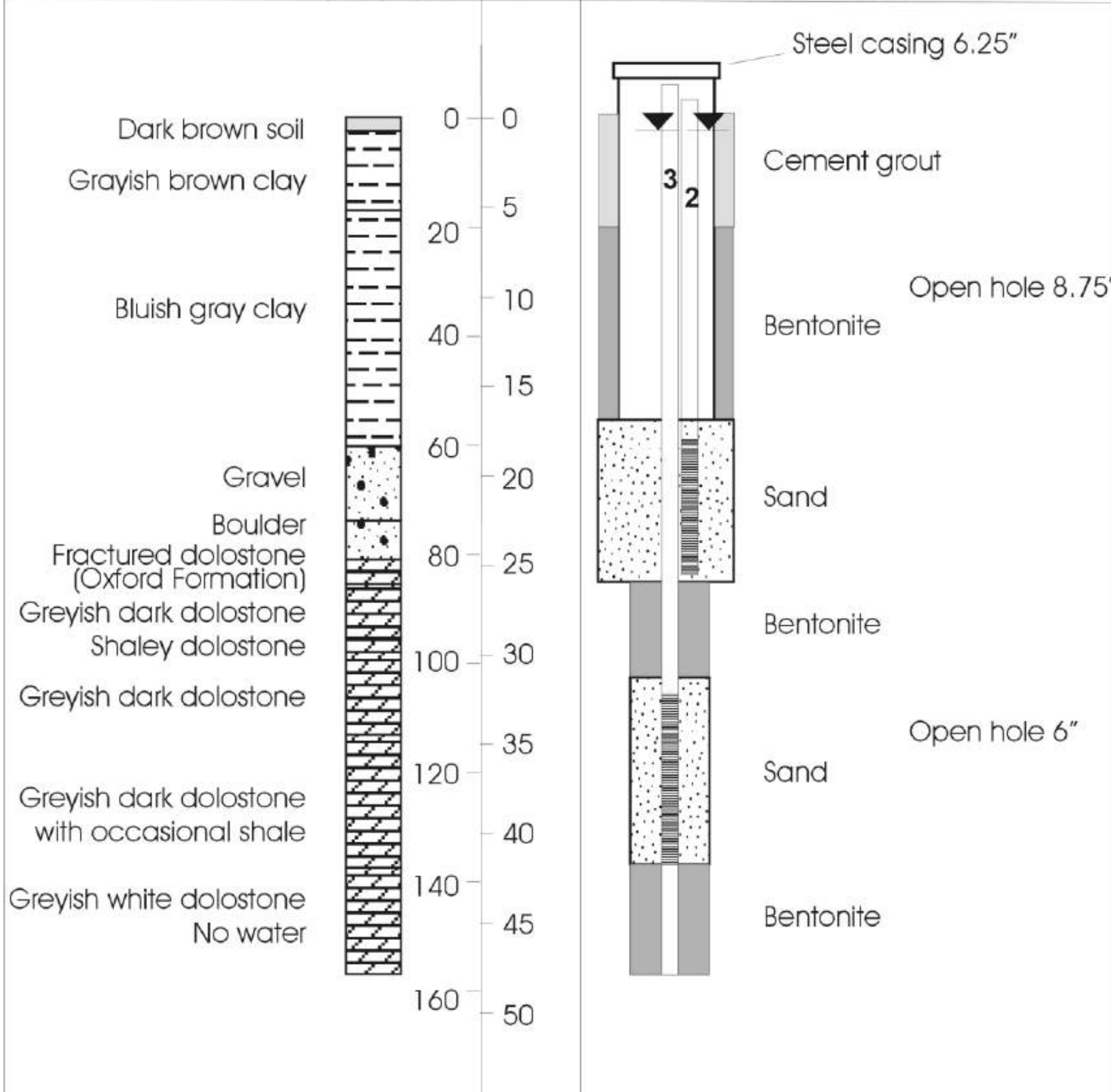
PIEZOMETER NUMBER: W000086		DESCRIPTION: LONG ISLAND	LOG 3
SOIL DESCRIPTION	STRAT.	DEPTH (FT)	DEPTH (M)	PIEZOMETER INSTALLATION



SOURCE: *ASSUMED* FROM NEARBY MOE WELL LOG 1505910

PIEZOMETER NUMBER: W0000156	DESCRIPTION: TWIN ELM	LOG 4

SOIL DESCRIPTION	STRAT.	DEPTH (FT)	DEPTH (M)	PIEZOMETER INSTALLATION



SOURCE: RVCA BOREHOLE RECORDS

NOTES: WATER FOUND AT 26.2 m (86 FT) AND 45.7 m (150 FT)

PIEZOMETER NUMBER: W0000252	DESCRIPTION: CHRISTIE LAKE	LOG 5

SOIL DESCRIPTION	STRAT.	DEPTH (FT)	DEPTH (M)	PIEZOMETER INSTALLATION

Sandy soil

Red and black granite

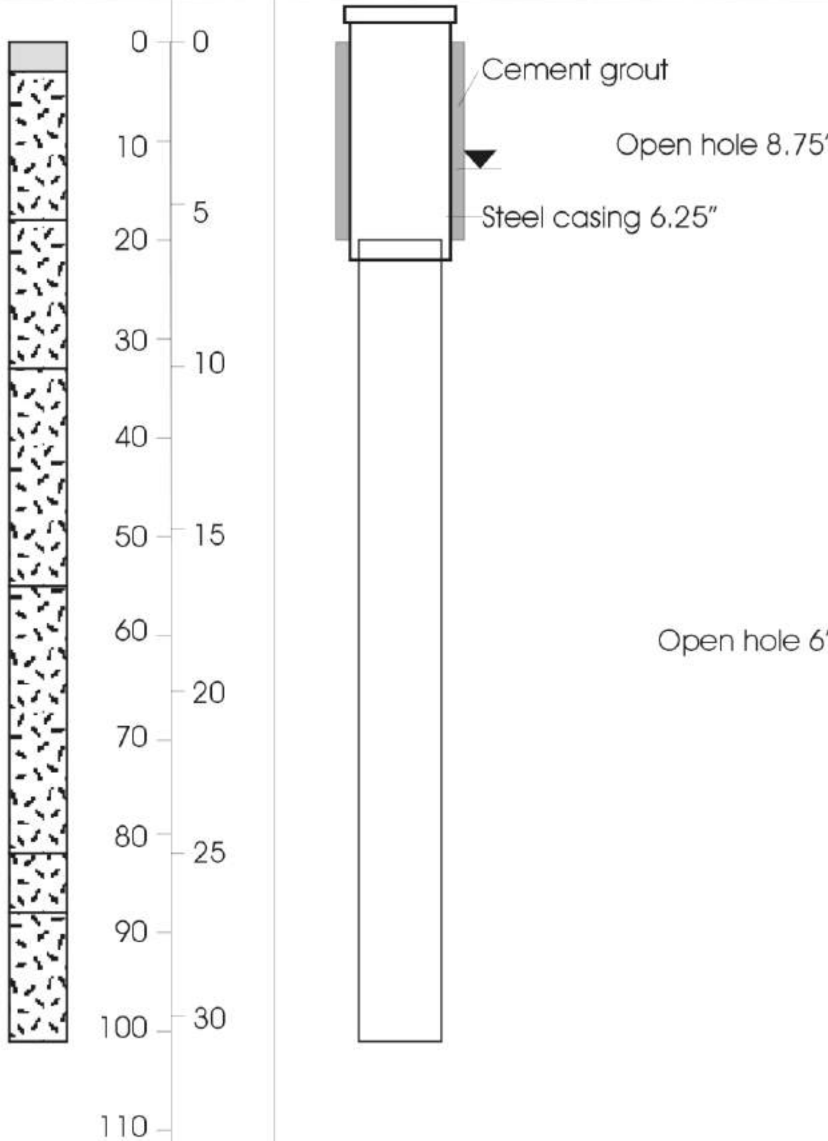
Black granite

Red and black granite

Red and black granite with quartz

Red granite

Red and black granite



SOURCE: MOE WELL RECORD

NOTES: WATER FOUND AT 22.9 m (75 FT) AND 25.9 m (85 FT)

Appendix B
(Well Photos)

Well 81- Located in the W.A.Taylor Park.

Well 83- Located in the OMYA Industrial Plant site.

Well 86- Located in the Long Island Park.

Well- 156-2- Located along the Twin Elm Bridge.

Well- 252- Located in the Christie Lake Camp site.

Appendix C
(Budget and Expenses)

Budget and Expense Report

Personnel Costs			
Person	Activity	Person days	Cost
Hydrogeologist	- Project supervision, coordination -Percentile analysis -QA/QC -Reporting	23	$9,935
Water Resources Technician	- Fieldwork - Data compilation -QA/QC	11	$3,528
Engineering Assistant	-JW analysis -QA/QC -Report review and editing	6	$1,809
		Total:	$15,272.00

Expenses	
Item	Cost
Vehicle use – 1600 km at $0.44/km	$704
Printing, information management etc.	$1,000
Equipment (computer etc.)	in-kind
Total Expenses:	$1,704

Total Costs:	$16,976.00
Grant Funding Allocation:	$10,606.38