GROUNDWATER
STATE OF THE ENVIRONMENT REPORT

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EXECUTIVE SUMMARY

This assessment carried out in this groundwater state of the environment report consisted of comprehensive analysis of West Coast Regional Council (WCRC) groundwater level (GWL) and quality (GWQ) databases. These databases were provided by WCRC staff. A limited data quality review was conducted of these databases prior to analysis. This resulted in identification of a number of data quality problems and deletion of clearly erroneous data. The remaining data were statistically analyzed. However, there were indications in the remaining data of data quality problems.

Substantial GWL data exist for 30 wells. Initial statistical analysis consisted of outlier identification, calculation of descriptive statistics, time series plots, and box and whiskers plots. It was found that about 3% of the data were outliers. The data were analyzed both including and excluding outliers. With the exception of mean and maximum values, there was minimal difference in results. Excluding outliers, 10 of the 30 wells were found to exhibit statistically significant seasonality, but only four had statistically significant trends. Three of these were decreasing depth to water (i.e., a rising water table) and one was increasing (i.e., a falling water table).

The most complete and longest term GWQ data was for the NGMP wells. Although there are only eight NGMP wells in service, there are nine datasets for NGMP wells because when one well was replaced in 2006 a new data set was started for its replacement well. This was not the case for another well where the replacement well was in very close proximity. Data for 20 variables were analysed for the nine NGMP wells. There are also more limited data for an additional 23 wider site wells. Data for 15 variables were analysed for these wells.

Results from analysis of the GWQ database indicate generally good quality water when compared with the commonly used criteria of New Zealand DWS. However, there were exceedances with regard to pH, E. Coli bacteria, iron, and manganese. GWQ data were statistically analysed in the same manner that GWL data were except that after outliers were identified all data (including outliers) they were still included in the data used for descriptive statistics, time series and box and whiskers plots, seasonality testing, and trend analysis. About 1.5% of the 7,098 data points were conservatively classified as outliers. Relatively little seasonality was found for GWQ variables, only 15 of 144 datasets of 10%. In contrast, 64 of the 144 datasets testing indicated statistically significant trend (64 of the 144 datasets or 44%). Most of these trends were increasing (45 or 70% of the statistically significant trends). Most of the statistically significant trends were for major ions. For example, all nine NGMP wells showed a statistically significant increasing trend for calcium. Where statistically significant trends were found for magnesium, bicarbonate, chloride, nitrate-nitrogen, and sulfate they also tended to be increasing while the trends for potassium and sodium tended to be decreasing. The cause of these trends is uncertain. Concentrations for major ions tend to be a function of natural weathering and there is no reason to suspect that natural weathering has increased. However, some variables (e.g., chloride, nitrate-nitrogen, and sulfate) can also be related to agricultural practices.

There is a lack of quality control/quality assurance (QC/QA) documentation for both field and laboratory work. This is not unusual in New Zealand. Nevertheless, adoption and implementation of a well-thought out QA plan would undoubtedly lead to improved data quality.

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1.0 INTRODUCTION

The West Coast Regional Council (WCRC) routinely monitors groundwater level and quality in a network of wells located throughout the region in all three of its districts. The location of the West Coast Region on New Zealand's South Island is shown in Figure 1. From north to south, the three districts that comprise the West Coast Region are Buller, Grey, and Westland. Additional detail for these districts are shown in Figures 2-5.

The WCRC requested that Prime Hydrogeology Ltd. (Prime) analyse the available data from its groundwater level (GWL) and quality (GWQ) databases and prepare a report on the state of the environment for groundwater in the West Coast Region. Groundwater level and quality data are maintained by WCRC staff in electronic form using Hilltop software. WCRC staff provided Prime with its complete GWL and GWQ databases in the form of Excel workbooks. The data provided for analysis span the period from September 1998 through January 2014. The processing and analysis of these level and quality data are discussed in Sections 2 and 3 of this report, respectively, with results for each also presented in those sections. Section 4 briefly presents a summary of pertinent historic information. Section 5 presents conclusions.

It is noteworthy that the wells used for groundwater monitoring in the West Coast Region, like most others used by regional councils in New Zealand, are water supply wells located on farms and other private properties rather than purpose-built for monitoring only. This circumstance adds additional complexity to the monitoring process in terms of the impact of pumping operations on both levels and quality and access to the well for measurements and sampling. However, it also assists the process as routinely pumped wells will be better developed than infrequently sampled purpose-built monitoring wells and in better communication with the aquifer involved. In addition to its routine monitoring program (nominally on a quarterly basis), the WCRC also has conducted irregular groundwater level measurement and water quality sampling events as well as special studies which have documented groundwater level and quality at selected well locations.

2.0 GROUNDWATER LEVEL DATA

2.1 Review and organization of data for analysis

The earliest data on record in the WCRC's GWL database are from September 1998 when monitoring began in seven wells as part of the National Groundwater Monitoring Programme (NGMP). The number of wells being monitored underwent major expansion in early-2000. There are now eight NGMP wells and up to an additional 21 wells in which groundwater levels are routinely measured. Two of the wells that were part of the NGMP were replaced by new nearby wells. These were the Coleman Farm (Fm) and Hunter Fm wells. The

Coleman Fm well was replaced by a new well installed in close proximity (i.e., within a few metres) to the original one in May 2006; however, it is still referred to by the same name. The dataset for this well is maintained as one continuous file for both the old and new well. The Hunter Fm well was replaced by a new well in a pasture about 98 m east of the old one in June 2006. The original well was labelled Hunter Fm and the new one Hunter Fm New. There are two data sets for these with those names. This makes 30 longer-term data sets for the GWL database.

In organising the GWL database for analysis, it was found necessary to first take various "cleanup" measures. These can be broadly classified as sorting and data quality checks. Some were of a general nature and some applied specifically to the data for individual wells. A summary of the cleanup measures taken is given in Appendix A1.

Review of the GWL database identified a total of 71 wells for which the WCRC has one or more groundwater level data points and information on the location (coordinates) and identity (e.g., a regional well identification number) of the well. These wells are listed in Tables 1 and 2. The locations of the wells listed in Table 1 are indicated in Figure 2. Figure 2 shows that although there is at least one well in each district, the distribution is not uniform throughout the West Coast Region. Table 1 has information on 30 wells (42% of the total), including NZTM coordinates, the date range (month and year) within which data are available, and the number of data points (count) for each well. With several exceptions and gaps that are evident in the record, the WCRC has measured water levels in these wells multiple times each year starting either in September 1998 or in the year 2000. One was apparently added to the network in September 2003, when data for it begins. Also, monitoring of three was apparently discontinued in 2009, as there are no further data for them after that year. There are GWL data included in the database for all other wells through to 2013 or January 2014. Although groundwater levels were reported in the GWL database for these wells on multiple occasions each year and there are 60 or more measurements for most of the wells over the approximately 15 year period involved (i.e., an average of four data points/year), the frequency of measurements is not necessarily consistent or on a quarterly basis. For example, monitoring dates in the GWL database for the Agnews Res well (the well with the most measurements) for the first and last two year periods of the 15 year monitoring period were:

1. First two years (eight values/two years) –
    a. 1 Mar 1999;
    b. 16 Jun 1999;
    c. 7 Jun 2000;
    d. 3 Jul 2000;
    e. 19 Sep 2000;
    f. 15 Nov 2000;
    g. 15 Dec 2000; and
    h. 22 Dec 2000.

2. Last two years (10 values/two years) –
    a. 16 Feb 2012;
    b. 29 Mar 2012;
    c. 3 Jul 2012;
    d. 24 Sep 2012;
    e. 19 Dec 2012;

f. 10 Jan 2013;
g. 27 Mar 2013;
h. 5 Apr 2013;
i. 21 May 2013; and
j. 12 Jul 2013.

Although the numbers are sufficient to have averaged a quarterly frequency or better, the actual frequency of monitoring is much different than quarterly for three of the four years shown.

Another 41 wells (58% of the total) are shown in Table 2. Table 2 includes NZTM coordinates and measurement count for each well. With one exception, the number of measurements in the GWL database for these wells is eight or less. The exception is the Bertacco Farm GW well for which there are 38 values in the GWL database. As discussed in Appendix A1, these are considered unreliable and were deleted for analysis. For these 41 wells, groundwater level monitoring has been irregular. The number of data points for each well are listed in Table 2. Although eight data points is approaching the minimum necessary for statistical analysis of such things as trends, it is deficient for that purpose because it has not been taken at a consistent frequency (e.g., quarterly or annually). For example, the GWL database shows monitoring data for the Rotomanu Station Rd. well on the following eight dates (eight values/seven years):

1. 23 Nov 2007;
2. 13 Aug 2010;
3. 19 May 2011;
4. 14 Nov 2011;
5. 6 Jul 2012;
6. 8 Feb 2013;
7. 19 Aug 2013; and
8. 13 Dec 2013.

The mean frequency is nearly annual, but the actual frequency of measurement is substantially different than annual with no values in some years and one, two, or three values in others.

The WCRC has no formal data quality programme in effect and, therefore, no documentation to support GWL database data quality. In New Zealand, it is unusual for field monitoring programmes such as this to have data quality plans. Such plans are commonly required by regulations in North American and European countries.

2.2 GWL data analysis

The computer programs used for statistical analysis of GWL data were Microsoft Excel 2013 and Version 9.4.40 of WQStat+ (Sanitas Technologies, 2014). The data for the 30 wells listed in Table 1 were statistically analysed as follows (specific details on methods are presented in Section 2.3):

1. Parametric and nonparametric outlier analysis;
2. Descriptive statistics - minimum, median, mean, maximum, median absolute deviation (MAD), and count (i.e., number of data points);
3. Time series plots;
4. Box and whiskers plots (showing median and 25th and 75th percentile values);

5. Seasonality plots (tested with Kruskal-Wallis H statistic at the 5% significance level); and
6. Trend plots (Mann-Kendall test with Sen's slope estimator unless seasonality present, seasonal Kendall test in that event with both at the 95% confidence level).

As the amount of data was insufficient (i.e., data counts of eight or less values), only mean GWL values were calculated for the 41 wells listed in Table 2. A more comprehensive statistical approach is unwarranted for the small amount of data involved.

Analysis was done twice for items 2-6 above. The first analysis was made using all data points. The second analysis was made with potential outliers removed. The use of nonparametric statistics is particularly important in environmental work where distributions tend to be positively skewed rather than normally distributed and the use of such normal statistics as means and standard deviation can be inordinately effected by extreme values.

2.3 Results of analysis of GWL data

2.3.1 Outliers

2.3.1.1 Background

Office of Environmental Information (2006) provides a good summary of the outlier situation:

> Potential outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected. Potential outliers may result from transcription errors, data-coding errors, or measurement system problems... (they) may also represent true extreme values... Failure to remove true outliers or the removal of false outliers both lead to a distortion of estimates of population parameters and it is recommended that the QA Project Plan or Sampling and Analysis Plan be reviewed for anomalies that could account for the potential outlier.
>
> Statistical outlier tests give the analyst probabilistic evidence that an extreme value does not "fit" with the distribution of the remainder of the data and is therefore a statistical outlier. These tests should only be used to identify data points that require further investigation... The tests alone cannot determine whether a statistical outlier should be discarded or corrected within a data set. This decision should be based on judgmental or scientific grounds...
>
> If an outlier is discarded from the data set, all statistical analysis of the data should be applied to both the full and truncated data set so that the effect of discarding observations may be assessed.

Identification of outliers is a relatively straightforward task. Potential outliers may first be determined by a simple time series plot of the data. There are also a variety of parametric and nonparametric statistical procedures available for determination of statistical outliers. However, judgment is required in applying them. The main uncertainty comes with regard to what action to take regarding outliers once they have been identified. The best approach to handling outliers is to prevent them and the best way of preventing them is through adherence to quality control (QC) procedures specified in a quality assurance (QA) plans. In the case of groundwater level data, this means following standard and appropriate field procedures in the measurement and recording of water levels as well as periodic routine checking of database quality. The latter is necessary to identify such things as data entry errors.

Errors in the entry of data collected on paper into electronic databases can be a “nontrivial source of error” (Wahi, et al., 2008) leading to outliers in the database. For example, studies on the entry of data from paper forms into medical research databases have reported single-entry data error rates in the range of 10.8 to 124 errors/10,000 fields (i.e., 0.1 to 1.2%). In one case, an error rate of 6.5% occurred. Database error rates may be reduced by adherence to protocols requiring consistency checks and, in cases of very large databases, using such procedures as double entry to identify errors (Wahi, et al., 2008).

2.3.1.2 Method used

Potential outliers were first identified by reviewing time series plots of the data. Next, two statistical tests were utilized: (1) the parametric USEPA 1989 outlier test as implemented by WQStat+; and (2) the nonparametric approach of plus or minus six times the MAD from the median value. The selection of plus or minus six MADs from the median as the nonparametric criteria for designating a value as an outlier is considered to be arbitrary, but conservative. Some statisticians recommend the use of three or four MADs (e.g., Dave and Varma, 2014). Therefore, any value identified as an outlier using plus or minus six MADs very likely represents some type of extreme anomaly that should not be in the database. It is possible that less extreme but nevertheless real outliers might not be detected by this approach. Finally, data were analyzed with and without outliers to see what impact removal of outliers had on the statistical results. Measurements identified as outliers by either parametric or nonparametric methods are referred to as statistical outliers.
Examples of application of this process are outlier Plots #1 and #2 of Appendix B1 for groundwater level data from the Agnews Res and Hunter Fm No. 2 wells. Review of the time series plot for these data sets indicated four potential outliers for the Agnews Res well (one low and three high) and three for the Hunter Fm No. 2 well (all high). The outliers for the Agnews Res well were identified by both parametric and nonparametric methods. However, the parametric method did not identify the three potential outliers for the Hunter Fm No. 2 well. Application of the nonparametric method of plus or minus six MADs from the median did identify all of these. With the exception of minimum and maximum values and seasonality and trend results for one well each, as is discussed further below with regard to those methods, results were similar for descriptive statistics, seasonality, and trend whether statistical outliers were included or excluded. Measurements judged to be outliers as a result of this process for the data from the 30 wells with data counts exceeding eight values/well are listed in Table 3. As shown in Table 3, there were 58 water level measurements identified as outliers or about 3% of the 1,825 total values in the GWL database. These are split nearly evenly between low and high outliers (low groundwater level values meaning shallower groundwater elevations and high ones deeper elevations).

2.3.1 <u>Descriptive statistics</u>

Results for descriptive statistics are presented in Tables 4 and 5 for the 30 wells with data counts exceeding eight values/well. Table 4 shows results for analysis using all data, including outliers, while Table 5 presents results from analysis of the data with outliers removed. Table 3 shows the dates and the values of the outliers that were removed before the analysis for which results are presented in Table 5. Of the 58 total outliers involved, 30 were for groundwater level data that were low (i.e., smaller values meaning shallower groundwater depths) and 28 were for groundwater level data which were high (i.e., larger values meaning deeper groundwater depths), as identified in Table 3.

Tables 4 and 5 indicate that, with the exception of minimum and maximum values, results were generally very similar whether the outliers involved were removed or not. Magnitudes of median, mean, and MAD values do not differ greatly and wells with seasonality and those showing trend were, with one exception each, also similar.

2.3.2 Time series plots

Time series plots #1 through #5 in Appendix B2 were prepared using WQStat+ with six or five wells per page. They indicate that for most of the wells the data plots are as expected, relatively flat with only marginal variation. Data for five of the six wells in Plot #1 of Appendix B2 show this. However, major variation is evident for the Becker, Bray, Lindell, and Van der Geest farm wells and, to a somewhat lessor degree for the original Hunter farm well. This is evident in Plot #1 of Appendix B2 for the Becker Farm well where the amplitude of the variation appears to be roughly 8 m (bottom peak to top peak). For the Bray well, variation the amplitude appears to be roughly 6 m. Such large variation with sharp peaks and valleys is not characteristic of natural groundwater levels, but could be a function of readings made both when the well is being pumped (i.e., larger depth values due to drawdown) and under natural conditions. There is also the possibility that high groundwater levels (i.e., lower depth values) may have been caused by flooding events for wells in close proximity to streams. Alternatively, well operation may be impacting water level measurements.

A time series plot for data from the Coleman Fm well, which includes data for both nearby wells before and after May 2006, is presented as Plot #6 of Appendix B2. It shows no noticeable effect attributable to the change in the well being monitored.

Data for the Hunter Fm #2 and Hunter Fm New wells show a different pattern. Their plots are similar in magnitude and depth to each other and show much less variation than is the case for the Hunter Fm well prior to 2006. The general depth of the plots for those two wells is roughly near the bottom values for the original Hunter Fm well having highly variable water level values (i.e., shallower depths). This pattern would be consistent with what is known of the locations of these wells and their likely responses to pumping (i.e., pumping of the original well could have been responsible for the variability prior to the new well being put into service, but if the original well was no longer used when the new well was commissioned that could explain the sudden change in variability). Assuming that the variation in the data for the Hunter Fm well is due a combination of measurements made when the well was being pumped and when it was not, there is no noticeable change in water levels over the full period of record attributable when the well was being monitored.

Substantial data gaps can also be highlighted by time series plots. This is, for example, the case for the Bray Farm well. Plot #2 of Appendix B2 shows major data gaps in the 2010 through 2013 time frame. Instead of quarterly monitoring, there are only four data points for that period, two for the year 2013, one each in the years 2010 and 2012, and none during 2011.

2.3.3 Box and whiskers plots

Box and whisker plots provide a way to visualise the distribution of data and to readily compare the magnitude and distribution of data for multiple sites at the same time. Box and whiskers plots #1 through #3 in Appendix B3 were prepared using WQStat+ with nine or 10 wells per page. They indicate major variation for the Becker, original Hunter, and Van der Geest farm wells with a lesser degree of variation for the Bray, Linell, Milnes, O'Reilly, and Sweeney farm wells. There was relatively minor variation for the other 20 wells and this variation appeared to be more consistent with the type expected under natural groundwater circumstances.

2.3.4 Seasonality and Trend

As was the case for descriptive statistics, with the exception of one well each, similar results were obtained for seasonality and trend (sometimes with marginally different slopes) regardless of using or excluding outliers. It was necessary to analyze for seasonality first. If there was significant indication of seasonality, trend analysis was conducted using the seasonal Kendall method instead of Mann-Kendall.

Results indicated seasonality for data from nine wells when all data were used, but this increased to 10 when outliers were excluded. The additional well was the Milne Fm well. There were no changes in status with regard to the other 29 wells.

Results for trend when outliers were included in the analysis were that data for five of the 30 wells had statistically significant trends, three decreasing and two increasing. When outliers were excluded, one of the wells with an apparently increasing trend fell out, leaving four (three decreasing and one increasing). The extra increasing result for trend when outliers were included was for the Knight Fm well, which with 15 values over a two year period had a smaller data set than was the case for any other well. Monitoring of water levels in the Knight Fm well ceased in February 2002. The outlier in this case was a low value early in the period of record. Therefore, it is mathematically evident why the increasing trend disappeared when this single data point was excluded. There were no changes in status for the other 29 wells which all had much longer periods of record (generally from between nine and 15 years). The three wells with decreasing trends were the Baker Res, Hunter Farm No. 2, and Stet Farm sites. The trend of a decreasing depth value means the water levels in these wells were increasing in elevation. Decreasing trend slopes tended to be small, varying from about 2 to 4 cm/year. Data for the well with an increasing trend (i.e., the groundwater level declining in elevation) with outliers excluded shows a larger slope at nearly 8 cm/year.

Seasonality plots from WQStat+ for the four wells with data showing statistically significant trends (outliers excluded) and trend analysis plots for these wells are presented in Appendices B4 and B5, respectively. Two of the seasonality plots showed statistically significant seasonality (Hunter Farm No. 2 and Sweeney Farm) and two did not (Baker Farm and Stet Farm). The closer the data lines in the plots are for original and deseasonalised data the less chance of seasonality.

Because seasonality plots indicated that data from the Hunter Farm No. 2 and Sweeny Farm wells were affected by seasonality, the data for these two wells were analyzed for trend using the seasonal Kendall method. The Mann-Kendall method was used for the other two in which it was concluded that there was a statistically significant trend for the data (Baker res and Stet Farm wells).

3.0 GROUNDWATER QUALITY DATA

3.1 Review and organisation of data for analysis

Review of the electronic database for groundwater quality data (GWQ) provided by the WCRC found that the data could be classified into three categories:

1. NGMP wells – Wells are sampled by the WCRC as a part of the NGMP. There are eight wells currently involved in this programme. Information on these is presented in Table 6. Seven were first monitored in September 1998 when it started. An additional well was added in July 2000 (i.e., the Van der Geest well) and it has been monitored since then. However, one of the original seven wells (i.e., the Anderson Fm well) was suspended from the programme for the three year period from late-2001 through late-2004) and, as noted in Subsection 2.1 with regard to groundwater level monitoring, water quality monitoring at the Coleman and Hunter farms was shifted to newly installed wells. Data for the new nearby wells on the Coleman Fm is compiled with data for the older well as a single data set under the same name (i.e., Coleman Fm). In the case of the Hunter Fm New, the new well is located approximately 98 m east of the old one and water quality data for those two wells are split nearly evenly at this time between samples taken from both. They constitute two separate data sets under the names of Hunter Fm and Hunter Fm New.

   There have never been more than eight NGMP wells in service in the West Coast Region at any one time and eight are currently used today. However, because the Hunter Fm well was replaced by the Hunter Fm New well, there are data sets in the water quality database for nine NGMP wells. The available information about these wells is given in Table 6. Their locations are indicated in Figure 3. Figure 3 shows that although there is at least one well in each district, the distribution is not uniform throughout the West Coast Region. These wells are sampled quarterly and, therefore, provide the longest and most consistent record of groundwater quality available for the region. An important aspect of the consistency of this record is that all of these samples have been analyzed by the GNS Science water quality laboratory at Wairakei. However, there are gaps in the record. As indicated in Table 7, there are many years where data for one or more quarterly sampling events are missing for each well. Many of these occurred in the first five or six years of the programme. However, there are unexplained gaps through 2010. In 2010, it appears that no sampling occurred during one quarter as there are results for only three of the four quarters for all eight of the wells. Overall, results are missing for about 11% of the samples that would be expected to be in the database if all of the wells being used had been sampled quarterly.

   The data for DO are a special case. As is evident in the time series plot for data from 1998-2013 (Plot #1, Appendix C1), there are major gaps in DO data for the 2001 through late-2005 period. There is also a high level of variation evident in DO data for most of the wells. This is particularly evident for the data from late-2005 through mid-2013 for data sets from the Agnew Res, Milnes Fm, Van der Geest, and Westland wells in both the time series and box and whiskers plots (Plots #2 and #3, Appendix C1). These wells also have relatively high MAD values (around 1 mg/L or more with a high of 2.44 mg/L for the Van der Geest well). The variation for some of these wells covers much of the range of oxygen saturation in water (e.g., from near zero to almost 10 mg/L for the Van der Geest well). The substantial gap for the 2001-2005 period means that DO data sets are bifurcated and cannot be statistically analyzed as one continuous record over the entire 1998-2013 period. Therefore, it would only be statistically appropriate to analyse the DO data for these two time frames separately.

Since there was generally insufficient data for meaningful statistical analysis using just the data from 1998 to 2001, only DO data for the second period (i.e., late 2005 through mid-2013) were statistically analysed for this report. However, analysis of data for this time frame was handicapped by the fact that the available data have not been uniformly collected on a quarterly basis and even for years where there may be some data it often did not provide the desired coverage of all four quarters. The following list for a six year time frame shows available quarters of data for three example wells with regard to this point:

a. Agnews Res well –

1) Year 2005 - 1 quarter;
2) Year 2006 - 3 quarters;
3) Year 2007 - 1 quarter;
4) Year 2008 - 2 quarters;
5) Year 2009 - 4 quarters; and
6) Year 2010 - 3 quarters.

b. Coleman Fm well –

1) Year 2005 - 0 data;
2) Year 2006 - 1 quarter;
3) Year 2007 - 2 quarters;
4) Year 2008 - 3 quarters (4 data points of which 2 are in 1 month);
5) Year 2009 - 4 quarters; and
6) Year 2010 - 3 quarters.

c. Van der Geest well

1) Year 2005 - 1 quarter;
2) Year 2006 - 2 quarters;
3) Year 2007 - 1 quarter;
4) Year 2008 - 3 quarters (4 data points of which 2 are in 1 month);
5) Year 2009 - 4 quarters; and
6) Year 2010 - 3 quarters.

In only one of the six years involved (i.e., year 2009) did any of the wells have four quarters of DO data. For two of the wells there were actually four data points for the year 2008 but two of them were obtained in the mid to late-January time frame (i.e., during the same month instead of during different quarters). Other wells could have also been listed to illustrate this point.

2. Wells occasionally sampled – In addition to the eight NGMP wells currently in service, there are an additional 23 wells throughout the region which have been

sampled more than five times. Most of these have been sampled occasionally on a more or less annual basis starting in 2007. Coordinates for these wells and the date range of their sampling are listed in Table 8. Their locations are indicated in Figure 4. Figure 4 shows that although there is at least one well in each district, the distribution is not uniform throughout the West Coast Region. At least 181 samples have been taken from these wells. The WCRC sends these samples to Hill Laboratories.

3. Infrequently sampled wells – There are an additional 42 wells in the WCRC GWQ database. In most cases, these have been sampled only once or twice. However, a handful have been sampled four or five times. These wells, coordinates for them, and the number of times sampled are listed in Table 9. Their locations are indicated in Figure 5. There are wells located in each district of the West Coast Region; however, most of the wells are located in the Westland District and the largest number are in the Kowhitirangi-Kokatahi Plains area of that District. Instead of labelling the wells on Figure 5, Table 7 is presented as two tables: (1) Table 7a lists the wells alphabetically; and (2) Table 7b lists them by from south to north by their northing coordinate. This makes it possible to identify locations for all of the wells, with the exception of the large number of wells in the Kowhitirangi-Kokatahi Plains area (with symbols for some overlapping others). One-hundred and seven samples have been taken from these wells. There are three wells with the same WCRC "Well #" of 170 (two at "Baird" farms in the Kowhitirangi Plains area and one "Harris" in the Inchbonnie catchment).

There is also water quality data for wells in two areas that have been the focus of special studies oriented towards nutrients. These are the Inchbonnie catchment south of Lake Brunner and the Kowhitirangi and Kokatahi plains south of Hokitika. Selected wells in those locations were sampled in the 2006-2007 time frame. Details about these studies are provided in Zemansky and Horrox (2007a) and Zemansky and Horrox (2007b).

Data for the nine NGMP wells and the additional 23 wells monitored irregularly were reviewed, organized, and formatted appropriately for the software to be used for statistical analysis. There were a number of apparent inconsistencies in the database requiring consultation with WCRC staff to ensure the best understanding possible of the available data in the record for analysis. In some cases, where it was not possible to otherwise resolve questions about the data, it was necessary to use professional judgment. As is discussed in further detail below, this was the case with regard to apparent data outliers.

In organising the GWQ database for analysis, it was found necessary to first take various "cleanup" measures. These can be broadly classified as sorting and data quality checks. Some were of a general nature and some applied specifically to the data for individual wells. A summary of the cleanup measures taken for NGMP well data is given in Appendix A2. A summary of the cleanup measures taken for the 23 wider site wells with more than five sample results is given in Appendix A3.

The WCRC has no formal data quality programme in effect covering either its field work or as a requirement for the laboratories analysing its water quality samples and, therefore, no formal documentation to support GWQ database data quality. GNS Science may conduct informal data quality checks such as calculation of major ion charge balance errors (CBEs) in support of the NGMP. If so, neither the criteria used nor the results are routinely reported to the WCRC. In New Zealand, it is unusual for water quality monitoring programmes to have data quality plans.

3.2 GWQ data analysis

Thirty-six water quality variables were identified in the GWQ database. 30 of these were for the nine NGMP wells and an additional six elements for the 23 wider sites wells. These and abbreviations and units for them are listed in Table 10. As noted in Appendices A2 and A3, there were good reasons for not analyzing the data for some of these. The 20 variables assessed for the NGMP wells listed in Table 6 are indicated in Table 10. For the 23 wider sites listed in Table 8, data for 15 variables were assessed. Five variables assessed for NGMP wells were dropped. These were: bromide, fluoride, ammonia-nitrogen, phosphate, and silica.

The computer programs used for statistical analysis of GWL data were Microsoft Excel 2013 and Version 9.4.40 of WQStat+ (Sanitas Technologies, 2014). The data for the nine NGMP wells listed in Table 6 were statistically analysed as follows (specific details on methods are presented in Section 3.3):

1. Parametric and nonparametric outliers analysis;
2. Descriptive statistics - minimum, median, mean, maximum, median absolute deviation (MAD), and count (i.e., number of data points);
3. Time series plots;
4. Box and whiskers plots (showing median and 25th and 75th percentile values);
5. Seasonality plots (tested with Kruskal-Wallis H statistic at the 5% significance level); and
6. Trend plots (Mann-Kendall test with Sen's slope estimator unless seasonality present, seasonal Kendall test in that event with both at the 95% confidence level).

Although outliers were identified, they were not removed from the database used for other statistical procedures. Due to the relatively small amount of available data, outliers were not identified for the 23 wider site wells having less than five sampling events, as per Table 8, and only descriptive statistics were calculated for those. The volume of data was considered insufficient to support a more comprehensive statistical approach. The data for the 42 wider site wells with five or less sampling events in the record were not statistically analysed at all. While these data can be considered suggestive for the areas where the wells are located, in the absence of other data, they are too limited to support meaningful statistical analysis.

As with water level data, the use of nonparametric statistics is particularly important in environmental work where distributions tend to be positively skewed rather than normally distributed and the use of such normal statistics as means and standard deviation can be inordinately impacted by extreme values.

3.3 Results of analysis of NGMP GWQ data

3.3.1 Outliers

The discussion about outliers in Section 2.3.1 regarding groundwater level data is also pertinent with regard to groundwater quality data. With regard to analysis of the water quality data, it was decided to identify outliers but to include them in the statistical analysis of data. Based on experience with water level data it was judged that this would not cause substantial problems for the classes of analysis conducted as follows:

1. Descriptive statistics – Since outliers were predominantly high values instead of low, including them only effects minimum values marginally and would not be expected to mean any substantial change in median values. However, when considering mean and maximum values it must be understood that they will be biased high.
2. Time series plots and box and whiskers plots will still provide useful visualisations of the data.
3. Seasonality and trend – It is unlikely that including outliers in the analysis will produce any meaningful difference in the number of wells identified as having statistically significant seasonality or trend. However, it is possible that there could be a marginal impact.

When water quality variables are involved, the analyst has an additional tool to assist in making judgments that is not available in analysis of water level data. That is, general knowledge about groundwater quality and how it changes and the chemical relationships between different water quality variables. For example, the oxidation state of groundwater will have a bearing on the concentrations of some water quality variables and, therefore, knowing that there is substantial dissolved oxygen (DO) present in groundwater is a relevant factor in evaluation of the data. With regard to dissolved iron, as an example, iron concentrations are unlikely to exceed the ferric iron solubility of 0.05 mg/L under oxidized conditions but may be much larger in the reduced ferrous form and reach levels as high as on the order of 50 mg/L. Similarly, it is common to have elevated concentrations of both dissolved iron and dissolved manganese when groundwater is reduced.

The pH for the Agnews Res well data set provides another case example with regard to identification of statistical outliers. Review of the time series and box and whiskers plots shows two sample results that are potential outliers. These are the values of 7.6 and 8.49 units reported for the sampling events on 18 December 2001 and 17 December 2003. Applying a factor of six times the MAD of 0.21 to the median pH of 5.92 for the data set, would result in both being identified as statistical outliers. The pH of 7.17 units from the 10 October 2011 sample would also be a statistical outlier using that criterion. Additionally, the USEPA 1989 outlier test shows three statistical outliers. These are the two highest ones already mentioned and a low one of 4.69 units on 17 September 2002. These are shown in the Plot #1 of Appendix C2. Based on general geochemistry, a pH as high as 8.49 units in groundwater with a median for the data set of 5.92 units would be highly unlikely. On this basis, the 8.49 value was classified as a confirmed outlier.

Other examples of water quality variable statistical outliers which were classified as confirmed outliers include the following:

1. Chloride in the Coleman Fm well – A high value of 12.7 mg/L was reported for 16 June 1999 for a data set of 56 samples having a median value of 3.0 and a MAD of 0.3 mg/L. The next highest value in the data set is 4.2 mg/L and the lowest value was 2.1 mg/L (this range is plus four MADs and negative three MADs). A value of 12.7 mg/L amounts to over 32 MADs above the median. This high data point is also identified by the EPA 1989 outlier test as an outlier (see Plot #2 in Appendix C2) and, in this case, this parametric test is appropriate as the data set is normally distributed with the outlier removed. Sample results in the quarterly events before and after the outlier (i.e., March and September, respectively) were 2.2 and 2.6 mg/L chloride. The nature of groundwater is that it moves relatively slowly and, short of flooding, quality does not change rapidly. It

is against such general principles that chloride within the aquifer in proximity to the well could have spiked from a value of 2.2 mg/L to 12.7 mg/L in three months and then have returned to 2.6 mg/L after another three months. This outlier could have been a result of contamination during the taking of the sample or transport to the laboratory, error in analysis by the laboratory, or even a data transcription error but it is highly unlikely that this value represented actual aquifer quality.

2. NO3-N in Agnew Res well – A high value of 3.7 mg/L was reported for 21 June 2013 for a data set of 53 samples having a median value of 1.2 and a MAD of 0.2 mg/L. The next highest value in the data set is 1.6 mg/L and the lowest value was 0.75 mg/L (this range is plus two MADs and negative 2.25 MADs. A value of 3.7 mg/L amounts to plus 12.5 MADs. The high data point was also identified by the EPA 1989 outlier test (see Plot #3 in Appendix C2) and, in this case, this parametric test is appropriate as the data set is normally distributed with the outlier removed. The value preceding the outlier was 0.94 mg/L five months earlier (apparently sampling for the intervening quarter was not conducted). As this outlier is the last value in the data set, we do not yet know what value was reported for the next sampling event; however, the same general principles of groundwater quality discussed above with regard to chloride in the Coleman Fm well apply here. The outlier could have been a result of contamination during taking of the sample or transport to the laboratory, error in analysis by the laboratory, or even a transcription error, but short of a major contamination event, such a radical change in groundwater quality for this variable is highly unlikely.

3. Two situations in the NGMP data sets are striking. These are outliers for multiple wells involving field measured variables; conductivity during the March 2003 sampling event and pH during the December 2003 sampling event as follows:

    a. Values reported for conductivity in six of the seven NGMP wells that existed in 2003 (i.e., the Agnews Res, Bertacco Fm, Coleman Fm, Hunter Fm, Milnes Fm, and Westland WW wells) were all outliers (i.e., predominantly greater than 150 uS/cm in comparison to median values of 100 uS/cm or less with MADs in the 3 to 13.5 uS/cm range. The EPA 1989 outlier test also identified these outliers. Plots #4 and #5 of Appendix C2 show EPA 1989 outlier plots for the Bertacco Fm and Westland wells, respectively, as examples.

    b. Values for pH in six of the seven NGMP wells (i.e., the Agnews Res, Bertacco Fm, Coleman Fm, Hunter Fm, Van der Geese, and Westland WW wells) that existed in 2003 (the Anderson Fm well was not in the programme that year) were all outliers and nearly the same number (i.e., pH for four of the wells was reported as 8.49 units while the remaining two were reported as 8.50 and 8.51 units in comparison to median values that were all less than 6.0 units and as low as 5.2 units with MADs in the 0.02 to 0.3 units range. The EPA 1989 outlier test also identified these outliers. This would mean that the outliers were greater than eight MADs above the median values. Furthermore, it is not credible that there would be such a small range in reported pH values for this sampling event (i.e., 0.02 units), that four of the six wells would have the same value to two decimal points, or that the pH would be as high as 8.5 units in these aquifers having median values between 5 and 6 units and maximum values otherwise on the order of 7 units or less. Plots #1 and #6 of Appendix C2 show EPA 1989 outlier plots for the Agnews Res and Westland wells, respectively, as examples.

Because the seven wells were not sampled for the quarterly event involved (Van der Geese for conductivity and Milnes for pH), values for these variables were not a factor. Values for these variables in all of the other wells which were sampled during the March 2003 and December 2003 quarterly sampling events, respectively, were outliers. This could have been caused by improper calibration or some other type of field error.

Measurements judged to be outliers as a result of this process for the data from the nine NGMP wells are listed in Table 11. As shown in Table 11, there were 109 water quality values in the database identified as outliers or about 1.5% out of 7,098 total values in the GWQ NGMP database used. The outliers were predominantly high values. Of the 109 outliers, 101 or 93% were high. Of the 180 data sets that were analyzed (20 variables in nine wells), there were 84 that contained outliers (47%). In 58 of these there was only one outlier, but in the other 25 there were two or more outliers. Of these, there were four or more outliers in seven cases. Two of these involved bromide (Coleman and Milnes farm wells). This may indicate an analytical problem for that variable at the concentrations involved. Outliers were disproportionately identified for the field measured variables conductivity, DO, and pH. These accounted for 23 or 21% of the 108 outliers (not taking into account concerns about DO measurements in general).

The limited data available precluded testing of the data from wells of the 23 wider sites for outliers. However, outliers were evident for manganese and DRP as noted in Section 3.4.

3.3.2 Descriptive statistics

Results for descriptive statistics are presented in Table 12 for the 9 NGMP wells (including both wells sequentially in service at the Hunter Farm). The data count column in Table 12 includes outliers. The outliers, identified in Table 11 are also quantified in the far right column of Table 12. With the exception of three variables, the data generally indicate good quality water in comparison with New Zealand drinking water standards. The exceptions are: (1) iron; (2) manganese; and (3) E. Coli bacteria. Values for iron and manganese were generally low (near the saturation level for iron and manganese in oxidized fresh water). However, values of maximum levels of these two variables were high in comparison with drinking water standards (Department of Health, 2008). E. Coli bacteria values were predominantly less than the standard detection limit of 1 MPN (which was the median level for most of the NGMP wells). In fact, it appears that one-half that detection limit was entered into the database (i.e.., 0.5 MPN) instead of <1 MPN notation. Therefore, minimum and median values were often 0.5 MPN when they are actually reported to be <1 MPN.

3.3.3 Time series plots

Time series plots were prepared for the 20 variables analyzed. All of the nine NGMP wells were graphed on the same plot for each variable. The plots for DO are Plots #1 and #2 in Appendix C1. Plots for 17 other variables are labelled Plots #1 through #17 in Appendix C3.

Due to limited and irregular data, time series plots were not made for the two other variables (PO_4 and DRP).

Concentrations in the time series for calcium in all nine wells appear to be increasing over the time period (1998 through 2013). Substantial increasing trends are also evident for nitrate-nitrogen in three of the wells (Bertacco Fm, Hunter Fm New, and Van der Geest) and sulfate for several wells.

As with water level data, time series plots for the two NGMP wells that were replaced in 2006 (i.e., at the Coleman and Hunter farms) provide an opportunity to check for continuity and any noticeable impact attributable to the change. No differences in variables as a function of the well change was noticeable for the Coleman wells and neither was there a change that could be attributed to the replacement of the Hunter Fm well by the Hunter Fm New well with regard to most of the 12 variables analyzed. However, a step change was evident in the data for four variables in the case of the Hunter wells. These were decreases in chloride, bicarbonate, and silica and an increase in nitrate-nitrogen for the samples from the Hunter Fm New well compared to what had been the case for the Hunter Fm well. Time series plots for these variables are presented as Plots #12, #13, #14, and #15, respectively, in Appendix C3.

Substantial data gaps were also highlighted by time series plots. This is, for example, the case for DO in all of the wells (see Plot #1 of Appendix C1), conductivity in all of the wells (see Plot #3 in Appendix C3), pH in all of the wells (see Plot #9 of Appendix C3), all variables for the Anderson well in the 2001-2004 time frame, all variables for the Van der Geest well in 2002, and data for other missing sampling events in various wells.

3.3.4 Box and whiskers plots

Box and whisker plots provide a way to visualise the distribution of data and to readily compare the magnitude and distribution of data for multiple sites at the same time. Box and whiskers plots were prepared for each of the 12 variables analyzed. All of the nine NGMP wells were graphed on the same plot for each variable. The plot for DO is in Appendix C1. Plots for 17 other variables are labelled Plots #1 through #17 in Appendix C4 (as for time series, box and whiskers plots were not made for PO_4 and DRP). These plots indicate a high degree of variability for DO in most of the wells (particularly for the Milnes Fm, Van der Geest, and Westland wells), chloride for the Van der Geest well, potassium for the Van der Geest well, and nitrate-nitrogen for the Milnes Fm and Van der Geest wells.

3.3.5 Seasonality and Trend

3.3.5.1 Seasonality

Data sets for 16 of the 20 variables analyzed in the nine NGMP wells (a total of 144 data sets) were first tested for seasonality before conducting trend analysis. The data were not sufficient to consider seasonality or trend for NH3-N, phosphate, DRP, or E. Coli bacteria. Where there was statistically significant seasonality, trend analysis was conducted using the seasonal Kendall method instead of Mann-Kendall.

In most cases, the data did not exhibit seasonality. As indicated in Table 12, there was indication of statistically significant seasonality in only 15 of the 144 cases. There was no indication of seasonality for any variable in data from four of the wells (the Anderson Fm, Bertacco Fm, Milnes Fm, and Westland WW wells). For the wells in which there was an indication of statistically significant seasonality, there were a mean of three variables involved for each, but the three variables were not the same in different wells. The closest they came to that were that chloride and bicarbonate were the variables in two of the five wells involved. For variables where there was seasonality, there tended to be a statistically significant trend (10 of 15 or 67%), and primarily an increasing trend (in nine of 10 cases showing trend or 90%), but not always. For example, there was an increasing trend for chloride in the data sets for the Coleman Fm and Van der Geest wells, but a decreasing trend for chloride for the Agnew Res well and while there was an increasing trend in bicarbonate for the data set from the Agnew Res wells, there was no statistically significant trend in bicarbonate for the Hunter Fm New well.

Plots #1 through #3 in Appendix C5 provide examples of seasonality for water quality data. They are, respectively, for chloride in the Agnews Res well, sulfate in the Coleman Fm well, and sodium in the Van der Geest well. As noted in Section 2.3.4 with respect to groundwater level data, the closer the data lines are in the seasonality plots shown for original and deseasonalised data, the less chance there is of seasonality.

3.3.5.2 Trend

Results from analysis for trend are summarized in Table 13. Out of 144 cases analyzed (16 variables in each of nine wells), there were statistically significant trends for 63 (44%). Most of these trends, 44 out of 63 (70%), were increasing and most were for the eight major ions The following discussion considers trends by one of four water quality variable categories: (1) major cations; (2) major anions; (3) silica and field variables; and (4) minor cations/anions.

Typical trend analytical plots from WQStat+ are provided as examples in plots #1 - #6, respectively, of Appendix C6 showing:

1. Calcium increasing Mann-Kendal (M-K) trend for Agnews Res well;
2. Calcium increasing M-K trend for Coleman Fm well;
3. Calcium increasing M-K trend for Van der Geest Fm well;
4. Chloride increasing seasonal Kendall trend for Van der Geest well;
5. NO_3-N increasing M-K trend for Bertacco Fm well; and
6. SO_4 decreasing M-K trend for Westland WW well.

3.3.5.2.1 Major cations

Results for calcium were a statistically significant increasing trend in all nine of the wells at a median annual rate of 0.19 mg/L. Magnesium also showed predominantly increasing trends (four of the nine wells with at least one well in each of the three districts); however, data for one well showed a decreasing trend (Westland WW in the Westland District). The median annual rate of this trend was 0.011 mg/L; a little over half of the rate for calcium. In contrast, where there were statistically significant trends for potassium and sodium they were predominantly decreasing (four or five of the nine wells with only one well with an increasing trend for each of these two major ions) with relatively low median annual rates of – 0.015 and – 0.063 mg/L, respectively. Decreasing potassium trends were predominantly found in wells in the Westland District; however, the Milne well in the Buller District also had a decreasing trend.

With regard to the example trend plots shown in Appendix C6, the following points are notable:

1. Plot #1 – A relatively small amount of variation with a clear increasing trend. There is an indication of a small amount of a cyclical nature to the data as it increases.

2. Plot #2 – Similar to Plot #1, but with a greater degree of variation and an apparent outlier of 10.5 mg/L on 30 January 2008. This was not identified as a statistically significant outlier by either of the two tests used for that purpose. The cyclical nature of the data is more evident with higher levels around 2007 and lower around 2010.

3. Plot #3 – Similar to Plots #1 and #2, but with a greater degree of variation. The cyclical nature of the data is evident with higher levels around 2007 and lower around 2010.
4. Plot #4 - Similar to Plots #1 - #3, but with a greater degree of variation. The cyclical nature of the data is evident with higher levels around 2007 and lower around 2010.
5. Plot #5 – Like Plot #1, there is less variation for each line segment, but the cyclical nature of the data is evident with higher levels around 2004 and 2010 and lower levels around 2007.
6. Plot #6 – Similar to Plot #1 in terms of variation and a small amount of cyclical nature to the data.

3.3.5.2.2 Major anions

The situation was more uniform for the major anions. Results for trend were statistically significant for around half of the wells for each of the major anions, predominantly increasing at median annual rates of 0.36, 0.132, and 0.13 mg/L, respectively, for bicarbonate, chloride, and sulfate. But there were decreasing trends for one well each in the cases of chloride and sulfate. Trends in the five wells with a statistically significant results for nitrate-nitrogen also, notably, were increasing. The median annual rate for this trend was 0.04 mg/L. It is interesting to note that the same three wells with statistically significant decreasing potassium trends (Agnew Res Fm, Anderson Fm, and Coleman Fm) also had statistically significant increasing trends for bicarbonate.

3.3.5.2.3 Silica and field variables

In the cases of silica and conductivity, there were three and four wells, respectively, with statistically significant increasing trends and no decreasing trends. The median annual rates of these trends were 0.088 mg/L and 2 uS/cm, respectively. Trend results for DO and pH were split with no significant trend for most of the wells but one well with an increasing trend each for DO and pH and one or two with decreasing trends.

3.3.5.2.4 Minor cations/anions

Minor cations/anions includes iron, manganese, bromide, and fluoride. Concentrations of these variables are generally low; less than or close to their detection limits for iron and manganese. With the exception of an average of two out of the nine wells for each variable there were no statistically significant trends. The statistically significant trends that were found were split evenly between increasing and decreasing trends and were small in magnitude. For example, results indicated decreasing trends for bromide in two wells at rates of 0.002 mg/L annually.

3.3.5.2.5 Nutrients and E. Coli (not including nitrate-nitrogen)

Trend analysis was inappropriate for the nature of the data in the cases of these four variables. The numbers of samples were too low for meaningful trend analysis for phosphate and DRP. Concentrations reported were also very low; less than or close to their detection limits. Although the numbers of samples for ammonia-nitrogen and E. Coli bacteria were sufficient, concentrations were generally less than or close to the detection limit. In the case of E. Coli, the only bacterial indicator of the three available in the database, most values were less than the detection limit with occasional relatively large concentrations being reported and the data distribution did not warrant trend analysis.

3.4 Results of analysis of 23 wider sites GWQ data

Due to the limited number of samples involved, only descriptive statistics were run on the data from the 23 wider sites wells. As shown in Table 10, variables analysed in wider sites samples were also analyzed in NGMP well samples. In addition, there were five other variables not analysed for in wider site samples that were analyzed for in NGMP well samples. These were: (1) bromide; (2) fluoride; (3) ammonia-nitrogen; (4) phosphate; and (5) silica.

In reviewing the data for these wells as a whole, quality issues were apparent that were not evident previously with regard to results for manganese and DRP. These affected the following sample results:

1. Manganese – In most cases, there were only one or two samples analysed for manganese in each of the wells. At most three. Generally more samples were analyzed for iron from each well than manganese. For three of the 23 wells, samples were not analyzed for iron or manganese. In all but the case of one well (Karamea-Baker) reported iron levels were at or near 0.01 mg/L. Such a low level is consistent with oxidized conditions, as was also indicated by DO concentrations ranging from 2.4 to 11.35 mg/L. Similarly, most manganese concentrations were also low (on the order of 0.008 mg/L or less). However, high results were also reported for manganese in samples from 10 wells. All of these were for the January 2014 sampling event. In all of these wells, the high results for manganese were inconsistent with the reported oxidized conditions (judging from DO levels) and, with one exception, inconsistent with the low levels of iron (also inferring oxidized conditions). In three of these cases, there were also substantial levels reported for manganese in samples from at least one earlier year, but only one of these was consistent with elevated iron (i.e., Karamea-Baker). The wells involved and the reported DO, iron, and manganese concentrations were:

		January 2014 Sample		
	Well	DO (mg/L)	Iron (mg/L)	Manganese (mg/L)
1)	Becker	9.32	0.01	2.30
2)	Begg	8.54	0.01	1.91
3)	Brookshaw	5.89	0.01	1.39
4)	Havill	11.35	0.01	2.90
5)	Karamea-Baker	3.19	NA+	2.00
6)	Karamea-BW	9.16	NA-	6.00

7)	Karamea-Kong	9.92	NA-	2.90
8)	Karamea-Umere	6.53	NA-	2.50
9)	Maimai	3.43	0.01	2.20
10)	Mills	2.40	0.01	3.00

Where "NA" means not analyzed in January 2014 sample. Suffix "+" means samples in earlier years for iron were elevated. Suffix "-" means samples in earlier years for iron were low (on the order of 0.01 mg/L). Therefore, it was judged that levels of manganese in nine of these wells, excluding Karamea-Baker, likely were actually low and that the high levels reported for January 2014 were confirmed outliers. Although the weight of evidence is that both iron and manganese concentrations in samples from the Karamea-Baker well are elevated, the level reported for the January 2014 sample was also judged quantitatively inaccurate.

2. DRP – Sample results for DRP were generally very low, often close to the apparent analytical detection limit of 0.004 mg/L. However, two anomalously high results were reported. One was for 0.25 mg/L in a sample from the Karamea-BW well in 2012. This value is suspect because the only other two values in the database for this well are 0.007 and 0.014 mg/L in subsequent years. The other was for 4.0 mg/L in a sample from the Rooney Old well on 12 April 2007. This value is bracketed by samples taken on 15 February 2007 and on the same 12 April 2007 day reported to have been at levels of 0.002 and 0.001 mg/L, respectively. There are results for 12 samples in the database from this well. The next highest value was 0.006 mg/L and the median value was 0.003 mg/L. It was judged that the 4.0 mg/L value was a confirmed outlier.

   Descriptive statistics for the wider sites wells are presented in Table 14. Table 14 shows all data as obtained from the GWQ database including the anomalously high manganese and DRP values that were discarded for statistical purposes.

   Reported concentrations were generally consistent with those from NGMP wells. Values for iron and manganese were generally low (near the saturation level for iron and manganese in oxidized fresh water). However, values of maximum levels were high in comparison with drinking water standards (Department of Health, 2008).

3.5 Type category of West Coast groundwater

Water is sometimes classified by it's major ion composition (not in this instance including nitrate-nitrogen). There are various ways this can be done. Plotting the major ion data on a Piper diagram is one. A Piper diagram is a presentation of major ion data (with the exception of nitrate-nitrogen) as ratios of the ions rather than concentrations. Median concentrations of the seven major ions plotted on a Piper diagram and the other 13 variables involved in this project are listed in Table 15. Using median concentrations of the seven major ions for each of the nine NGMP wells, a piper diagram was prepared. This is presented as Figure 6. It can be seen from Figure 6 that the major ion pattern for all nine wells is similar. The data cluster toward the lower left corners of the cations and anions triangles at the bottom of the diagram. This indicates a calcium-bicarbonate type water. Data for the Van der Geest and Westland WW wells deviate slightly from the general pattern due to a lower relative amount of bicarbonate ion in the water samples from Van der Geest well and a lower relative amount of calcium in the water samples from the Westland WW well.

3.6 Major ion charge balance error (CBE)

The ions in a water sample must be electrically balanced so that the sample as a whole is neutral. Therefore, a common method of assessing, if analytical results for groundwater samples in which all major ions have been analyzed are reliable, is to calculate the sums of equivalent concentrations of cations and anions. They should be approximately equal. When this is done, the CBE may be determined from these calculations as follows:

$$CBE = \frac{(\Sigma \text{ mequivalents of cations} - \Sigma \text{ mequivalents of anions})}{(\Sigma \text{ mequivalents of cations} + \Sigma \text{ mequivalents of anions})} * 100\%$$

Some professional judgment is appropriate in reviewing such calculations, but a widely used criterion for assessing if analytical results for major ions are acceptable is if the CBE is within the range of from - 5% to + 5% (Freeze and Cherry, 1979). Analytical results may be impacted by both field and laboratory procedures that introduce error producing a result deviating from actual groundwater quality at the time of sampling. However, the sample should still be electrically neutral even if field procedures altered it in some way. Therefore, calculation of the CBE reflects on the quality of laboratory analysis. Errors in analytical procedures may be random or systematic. When there are a disproportionate number of CBEs that are either positive or negative, it "points suspiciously to the presence of systematic errors" (Fritz, 1994).

CBEs were calculated for all samples from all NGMP wells for which there were sufficient data to do so. The results are summarized in Table 16. Results for most samples were judged acceptable. Of the 393 samples for which there was complete data for major ions (four each for cations and anions), 379 (96% of the CBEs calculated) met the + or – 5% CBE criterion. Of the 14 that failed that criterion, most failed in the negative direction (12 of the samples) and two failed in the positive direction. These samples were all analyzed by the GNS water quality laboratory at Wairakei.

CBEs were also calculated for the samples from 23 wider site wells. There were complete major ion data from 115 samples in this case. The results are summarized in Table 18. Of the 115 samples, most met the + or – 5% CBE criterion (95 of the 115 CBEs calculated or 83%. For the 20 not meeting the CBE criterion, 15 failed in the negative direction while 5 failed in the positive direction. These samples were all analyzed by the Hill Laboratories.

4.0 HISTORIC INFORMATION

4.1 Groundwater state of the environment (SOE) reports

Four groundwater SOE reports have been prepared since monitoring under the NGMP commenced in 1998. These and a summary of pertinent conclusions from them were as follows:

1. Rosen (2001) -

   a. "The chemical groundwater quality of the seven West Coast wells monitored... is excellent for the chemical(s) analysed."

   b. "The monitoring shows slowly increasing trends in nitrate-nitrogen concentrations in five of the seven wells monitored (i.e., Agnew Res, Bertacco Fm, Coleman Fm, Hunter Fm, and Milnes Fm)... (and) the wells with the most significant increases are associated with dairy farms... (This includes a) well that is located in a rural-residential setting... but the house is surrounded by dairy farms."

   d. "Sulphate concentrations are increasing in the two wells that show the greatest increase in nitrate-nitrogen (i.e., Coleman Fm and Hunter Fm), suggesting that fertiliser use is also impacting the shallow groundwater in some areas."

   e. "Three of the wells monitored (i.e., Agnews Res, Hunter Fm, and Milne Fm) have iron and manganese concentrations that are higher than the guideline values for New Zealand drinking-water standards on some occasions."

2. Daughney (2004) as reported by Zemansky, et al. (2005) -

   a. At present, the groundwater quality at the NGMP sites in the West Coast Region is quite good. This is evidenced by such things as nitrate-nitrogen concentration typically less than ca. 2 mg/L, which is low in comparison to other regions of New Zealand. This conclusion is qualified by the fact that concentrations of nitrate-nitrogen at some sites are approaching the level indicative of marginal but detectable agricultural impact (ca. 3 mg/L).

   b. Bacterial indicators exceed the health-related MAV for roughly one third of samples from all bores. This contamination probably results from leaching of effluent or manure associated with agricultural land use. High rainfall, shallow water tables, and porous aquifers accentuate the potential for this problem. It is also often a function of inappropriate well construction.

   c. Concentrations of iron and manganese exceed the aesthetic-based guideline at three sites on some occasions. These are probably the result of naturally low levels of oxygen in the aquifers.

   d. There is evidence of deterioration in groundwater quality in the West Coast Region. Concentrations of chloride, nitrate-nitrogen, and sulfate increased significantly in at least half of the NGMP wells since 1998. This is likely the result of increased leaching from manure, sewage effluent or fertilizer and appropriate management strategies should be adopted as soon as possible.

e. The distribution of NGMP wells in the West Coast Region is too sparse to identify relationships between hydrochemistry and surrounding land use, or to provide a reliable estimate of baseline hydrochemistry. There are too few sites for such a large region, the majority of the sites fall into the dairy land use category, and the likely capture zones are small.

3. Zemansky, et al. (2005) –

   a. "There is little indication of seasonality or trend in West Coast Region groundwater level data. However, there is an indication of one or more outliers in the data sets for most of the wells. Most of the outliers are in the high direction (i.e., indicating a shallower depth to water)."

   b. "There are substantial gaps in the water level and quality data base where data of one kind or another are missing."

   c. "There is an apparent lack of field and laboratory quality control and quality assurance measures, or at least a lack of documentation of them."

3. Raiber, M. and C. Daughney. (2009) –

   a. "Groundwater quality in the West Coast region is... good at present... However, during the most recent years (2005-2008), groundwater NO_3-N concentrations at two NGMP monitoring sites (... Hunter Fm New and Van der Geest) have approached or were in excess of the guideline value set for ecosystem protection (7.2 mg/L). In addition, bacterial indicator parameters exceeded the health-related guideline value of 1 cfu/100 ml on several occasions at all but one monitoring site between 2005-2008 (no bacterial counts were detected at the ... Westland WW well... during this period)" and "Mn concentrations at the... Van der Geest) site exceeded the health-related guideline value (0.5 mg/L). The co-occurring high concentrations of NO_3-N with high Mn concentrations at this site suggest that the elevated concentrations of Mn may be associated with corrosion of metal pipes and cylinders that are in contact with the water before it is sampled. Alternatively, inadequate purging time prior to sampling could be responsible for the high Mn concentrations in this bore and further clarification with regards to the well construction is required."

   b. "All NGMP sites in the West Coast region are shallow wells with shallow water tables, and the aquifers are composed of porous and highly permeable materials. This configuration makes groundwaters collected from these wells susceptible to bacterial and NO_3-N contamination from the immediate surroundings of the bore. Age determinations on groundwaters from the NGMP sites in the West Coast region had mean groundwater residence times as short as 1.5 years for some bores, suggesting that their capture zones are small and limited to the immediate surroundings of the sites. For those NGMP sites where young groundwater ages were observed, no significant future increase in nitrogen mass loading is to be expected unless further land use intensification occurs (e.g. increased leaching from manure, sewage effluent or fertiliser). By contrast,

> the recent trends of increasing NO_3-N concentrations of some groundwaters with comparatively long mean residence times of up to 45 years in the West Coast region suggest that even if the present level of land use is maintained in the capture zones of these sites, groundwater nitrate concentrations may continue to increase in the future due to the delayed arrival of land use-impacted water."

4.2 Special studies

Two groundwater special studies were conducted in the 2006-2007 time frame. These and a summary of pertinent conclusions from them were as follows:

1. Zemansky and Horrox (2007a) – This research project quantified the forms and concentrations of nitrogen and phosphorus species in both surface waters and groundwaters of the Inchbonnie dairy farm catchment and the load from this catchment of these nutrients into Lake Brunner. The dominant species of nitrogen in groundwater was nitrate-nitrogen and groundwater concentrations of this nutrient exceeded those in associated surface waters. Concentrations of nitrate-nitrogen in both surface waters and groundwater increased in the downgradient direction toward Lake Brunner. Concentrations of phosphorus species were all less than or only marginally above their respective detection limits.

2. Zemansky and Horrox (2007b) – This research project provided data to characterise the groundwater system underlying the Kowhitirangi and Kokatahi Plains and its relationship with associated surface waters. It was found that the direction of groundwater flow was to the north from the Hokitika River across the Kowhitirangi Plains and then to the northwest under the Kokatahi Plains after crossing under the Kokatahi River at a hydraulic gradient of about 0.003 m/m. With the exception of nitrate-nitrogen and sulfate, groundwater samples analyzed for major ions indicated good quality water at near natural conditions. In contrast, concentrations of nitrate nitrogen and sulfate appear to be elevated above natural levels for this area. A seasonal pattern was also noted for these two variables with marginally higher concentrations during the wet season compared to the dry. These two variables are likely contributed by farming operations. The overall pattern of nitrate-nitrogen levels found was higher concentrations in the centre of both plains and lower concentrations around the edges where mixing with lower concentration surface waters may occur and dilute levels.

4.3 Groundwater age

A table with the latest groundwater age determinations was provided by Morgenstern (2014). These are listed in Table 18. Results for two wells were classified as ambiguous; meaning another sample will be necessary to obtain a more reliable estimate of mean residence time (MRT). Groundwater ages were very short for four of the wells (i.e., from 1 to 4.5 years MRT) or relatively long for the remaining three (i.e., from 40 to 47 years MRT). No distinction is made in Table 18 between the old and new Coleman Fm wells. Both are listed by Morgenstern as ambiguous with the estimated age range for one including the estimated age for the other.

5.0 CONCLUSIONS

5.1 Groundwater level data

The assessment of groundwater level data is relatively straight forward. Substantial data exist for 30 wells located in each West Coast district. Data for these wells were analyzed to identify outliers, document descriptive statistics, and wells having seasonality or trends.

The distribution of data showed some substantial gaps in the record and that about 3% of the available measurements in the database were unreliable and apparent outliers. Excluding outliers, the data indicate that all of the 30 wells in the database are located in shallow groundwater with median depths ranging between 1.28 and 15 m BGL. The minimum depth measured was actually – 0.1 m *above* ground level (AGL) while the maximum was 21.90 m BGL.

Only 10 of the 30 wells were found to exhibit statistically significant seasonality and only four were found to have small statistically significant trends. Three of these were decreasing depth to water (i.e., the water table was rising) and one was increasing (i.e., the water table was falling. The slopes of these trends ranged from -0.017 to 0.077 m/year. Explanations for these trends are not obvious. In one case, two of three wells are located about 100 m and 1,500 m from the third, but only one of these wells has a statistically significant trend.

No formal QA plan exists for field procedures to measure groundwater levels or maintenance of the database for groundwater level data. The database as provided by WCRC was found to include a number of gaps, errors, and outliers. The existence of substantial data gaps can handicap the ability of the database to serve its intended function. The rate of errors and outliers could be reduced if a QA plan was implemented.

5.2 Groundwater quality data

5.2.1 Summary conclusions

The results for assessment of groundwater quality data are more complex and voluminous than is the case for groundwater level data. With regard to complexity, groundwater levels are relatively simple to measure but water quality variables involve the use of both proper field sampling and laboratory analytical methods (which have varying detection limits). With regard to the volume of data, instead of only one variable (i.e., groundwater level) there are 20 that were assessed for the NGMP monitoring wells. For groundwater levels, for example, one variable for 30 wells makes 30 possible data sets to assess. In the case of groundwater quality though, there could potentially be 20 variables in each of 9 NGMP wells or 180 possible data sets to assess. There were also an additional 23 “wider sites” wells for which 15 variables were analyzed (another 345 sets of results). However, for the NGMP wells, there were an insufficient number of data points to analyze for trend or seasonality in left cases of four of the variables (these were ammonia-nitrogen, phosphate, DRP, and E. Coli bacteria). This left 144 possible data sets for those variables and 180 for descriptive statistics). In the case of the 23 “wider sites” wells, only descriptive statistics were calculated because the number of samples for each well was too small to support analysis for such things as seasonality or trend.

As with previous groundwater SOE reports, the water quality data for the nine NGMP wells and 23 “wider sites” wells generally indicate good water quality with relatively low concentrations of water quality variables. In part, this is a function of the relatively large rainfall characteristic of the West Coast Region that tends to dilute the natural mineral content of both streams and groundwater or contaminant levels produced by anthropogenic activities. Although drinking water standards (DWS) for New Zealand (Ministry of Health, 2008) were developed to apply to drinking water in municipal systems and do not apply to ambient groundwater per se, they are commonly used as criteria by which to assess groundwater quality. Table 18 provides a listing of DWS for variables included in the analytical suite for NGMP wells and Table 19 provides a summary of the maximum concentration reported in the database for each NGMP well (minimum and median values for pH are also listed in view of the guideline range involved) while Table 20 the maximum values in Table 19 with New Zealand DWS. The following exceedances of either mandatory (for drinking water) acceptable values (MAVs) or advisory guideline (GL) values were evident from the data:

1. Nearly all pH data in all nine wells were lower than the GL of 7.0 units.
2. Although most samples were less than 1 MPN for E. Coli bacteria (which is also the MAV), there were several samples in each of the nine wells in which E. Coli bacteria exceeded the MAV. Results as high as 920 MPN were reported in the Hunter Fm New well which is located in a pasture.
3. Three of the nine wells had iron levels exceeding the GL for that element with a maximum reported concentration of 4.2 mg/L.
4. Three of the nine wells had manganese levels exceeding the GL of 0.04 mg/L and, in addition, two had concentrations exceeding the GL of 0.1 mg/L and one exceeded the MAV of 0.4 mg/L.

There were no other exceedances of criteria found in New Zealand DWS. However, there are several other GL values that are relevant. These are for hardness (primarily the sum of calcium and magnesium concentrations as equivalent $CaCO_3$) and TDS. It is evident from the data that all samples in all wells were well within their respective criteria for these variables.

With respect to seasonality and trend, of the 16 variables in nine NGMP wells analyzed for seasonality (144 possible data sets), there were 15 or 11% in which there was a statistically significant finding of seasonality. However, in the case of trend, there were 64 or 44% in which a statistically significant trend (either increasing or decreasing) was determined. Most of these were increasing trends (45 or 70%). There was a statistically significant increasing trend for calcium, for example, in samples from all NGMP wells. However, there were also primarily decreasing trends found for several elements (e.g., potassium and sodium. The large number of statistically significant trends was unexpected and, with the exception of chloride, nitrate-nitrogen, and sulfate, there is no obvious explanation for it. Most of the variables involved were major ions. There were also a few trace elements (Fe, Mn, Br, and F) for which statistically significant trends were found as well as silica and all three field-measured variables (conductivity, DO, and pH). With the exception of the field variables and nitrate-nitrogen, all of these could be considered to be derived from natural weathering. However, review of rainfall data does not indicate any substantial increasing trend that could be responsible for increased rates of weathering. Additionally, it must be considered that several are commonly a result of pollution from anthropogenic sources (e.g., dairy farms). These include the anions chloride, nitrate-nitrogen, and sulfate, all of which had predominantly statistically increasing trends.

No formal QA plan exists for field procedures for sampling groundwater, sample handling procedures, or maintenance of the database for groundwater quality data. Additionally, it is unknown what laboratory QC procedures are used and none have been documented from by laboratory used. Laboratory quality assurance reports should accompany results from each sampling event and be reviewed for support of data quality when results are received. The fact that CBEs for major ions generally met criteria is encouraging but not sufficient. CBEs identify whether or not reported ion concentrations balance or are nearly balancing electrically. The data may still be inaccurate. The database as provided by WCRC was found to include a number of gaps, errors, and outliers. The existence of substantial data gaps can handicap the ability of the database to serve its intended function. The rate of errors and outliers could be reduced if a QA plan was implemented.

5.2.2 Comparison with historic reports

Results for this assessment are generally comparable with the historic groundwater SOE reports. With regard to findings for specific wells, the following are noteworthy:

1. Rosen (2001) found that five of the seven wells being monitored at that time had increasing nitrate-nitrogen trends (Agnew Res, Bertacco Fm, Coleman Fm, Hunter Fm, and Milnes Fm). It is not stated how this conclusion was reached and there is no evidence it was determined by statistical analysis. Therefore, it may have been a simple observation of time series plots. Raiber and Daughney (2009) reported that two of the eight wells being monitored at that time had relatively high nitrate-nitrogen levels on the order of 8 mg/L (Hunter Fm New and Van der Geest). Daughney (2004) pointed out that nitrate-nitrogen levels were generally less than 2 mg/L, but that some sites where approaching the level of 3 mg/L which he characterised as the threshold for "detectable agricultural impact." In this assessment, it was found that five of the eight wells in operation at this time had statistically significant increasing trends for nitrate-nitrogen (Anderson Fm, Bertacco Fm, Coleman Fm, Milnes Fm, and Van der Geest. In addition, the levels at the Hunter Fm New and Van der Geest sites still have the highest nitrate-nitrogen concentrations of any of the nine NGMP wells.

2. Rosen (2001) found that sulfate concentrations were increasing in two wells (Coleman Fm and Hunter Fm) and noted that these were two of the wells that also had "the greatest increase in nitrate-nitrogen." Rosen (2001) suggested that these circumstances indicated impact from agricultural operations and that the source of the sulfate could be fertilizer. Daughney (2004) noted that chloride, nitrate-nitrogen, and sulfate concentrations were increasing and characterised this circumstance as "evidence of deterioration in water quality in the West Coast Region" that was "likely" related to agricultural practices or sewage effluents. He suggested institution of appropriate management practices to address it. In this assessment, it was also found that there was a statistically significant increasing trend for sulfate in the Coleman Fm and Hunter Fm wells, but the data for the Hunter Fm well ceased in June 2006 and there was no statistically significant trend for sulfate in the Hunter Fm New well. It is notable that the two wells with the highest median nitrate-nitrogen concentrations in this assessment also had high median sulfate concentrations (Hunter Fm New and Van der Geest. The Van der Geest well also had the highest median chloride concentration.

3. Rosen (2001) found that three of the seven wells being monitored at that time had concentrations of both iron and manganese that exceeded GL values (Agnes Res, Hunter Fm, and Milnes Fm). Daughney (2004) opined that the substantial levels of iron and manganese in several wells was probably a function of naturally reduced conditions in the aquifers involved. In this assessment, it was also found that those same three wells exceeded the GL value for iron and that two of them (Hunter Fm and Milne) exceeded the GL(s) for manganese. However, monitoring of the Hunter Fm well ceased in June 2006 and these exceedances were not found for the Hunter Fm New well. Exceedance of the GL for manganese was found for the Van der Geest well. Raiber and Daughney (2009) found that manganese in the Van der Geest well exceeded the MAV for it and that relatively high nitrate-nitrogen concentrations also co-occurred at this well. They suggested this could be from corrosion or inadequate purging prior to sampling. A review of the time series plot for manganese in the Van der Geest well in this assessment shows that the high manganese levels in excess of the MAV are restricted to a peak that occurred in the 2006-2008 time frame and that concentrations have since fallen to well below that standard. However, they remain within the range of 0.04 to 0.10 mg/L greater than one of the GL values but less than the other.

4. Daughney (2004) pointed out that about a third of the samples from all wells had detectable bacterial indicators and that this circumstance could be a function of several factors including agricultural practices, high rainfall, shallow water tables, porous aquifers, and poor well construction practices. Raiber and Daughney (2009) found that bacteria were reported in one or more samples from seven of the NGMP wells (all samples from the Westland WW well were less than the detection limit). In this assessment, although E. Coli bacteria were not detected in most samples, there were some samples in all wells with positive results for E. Coli bacteria.

5. Daughney (2004) noted that the eight NGMP wells makes for “sparse” coverage of a large region.

6. Raiber and Daughney (2009) reported that 98% of CBEs calculated for major ions in 207 samples were within the + or – 5% criteria and that CBEs were distributed uniformly around the mean of zero. In this assessment, 96% of 393 samples from NGMP wells analyzed by the GNS water quality laboratory at Wairakei were within CBE criteria. Additionally, for samples analyzed from the 23 wider site wells by Hill Laboratories, 83% of 115 samples were within CBE criteria.

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7.0 ACKNOWLEDGEMENTS

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TEXT FIGURES

Figure 1: South Island regional/district council boundaries (LGNZ, 2014).

Figure 2: 30 GWL well locations

Figure 3: 8 NGMP GWQ well locations

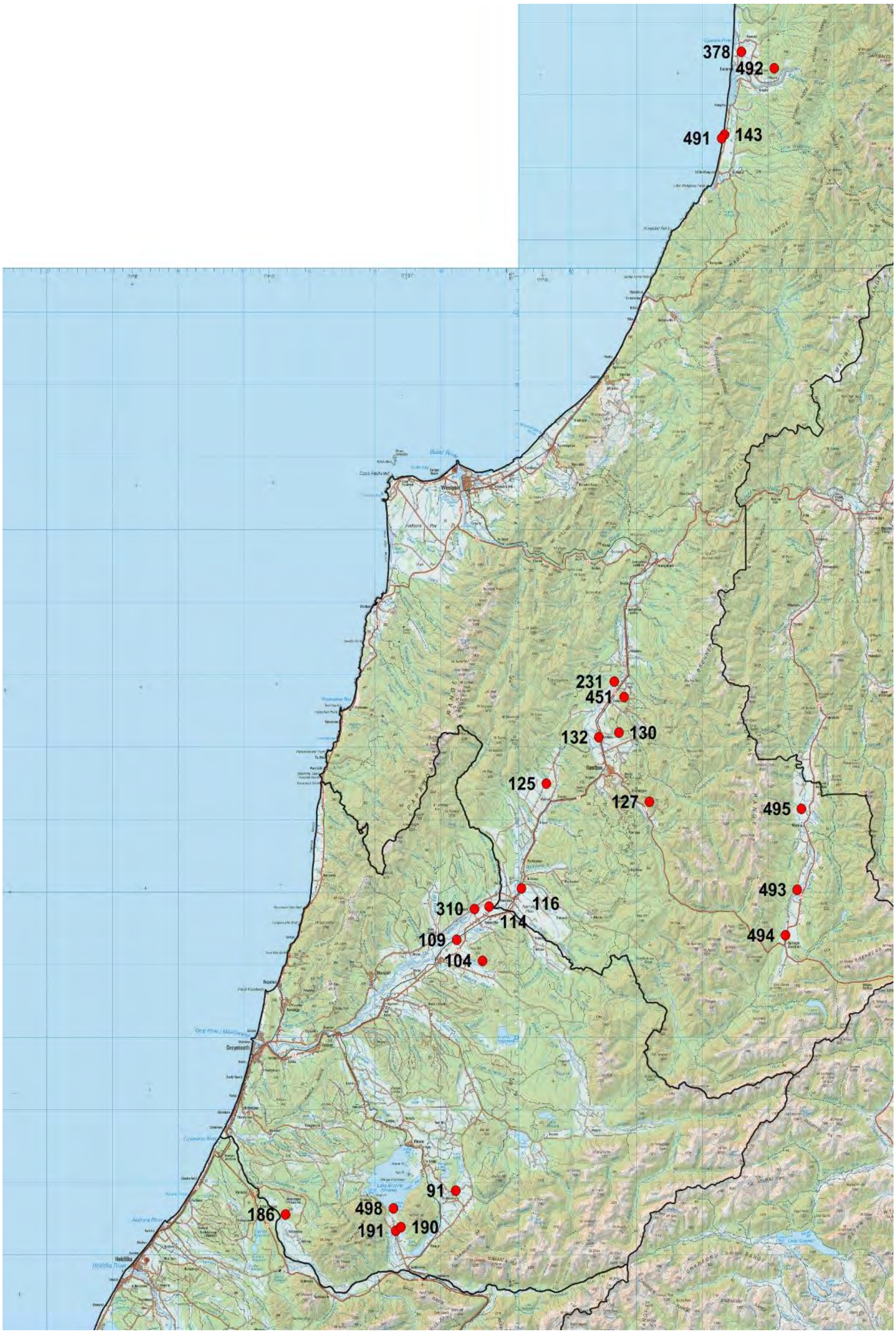


Figure 4: 23 wider sites GWQ well locations

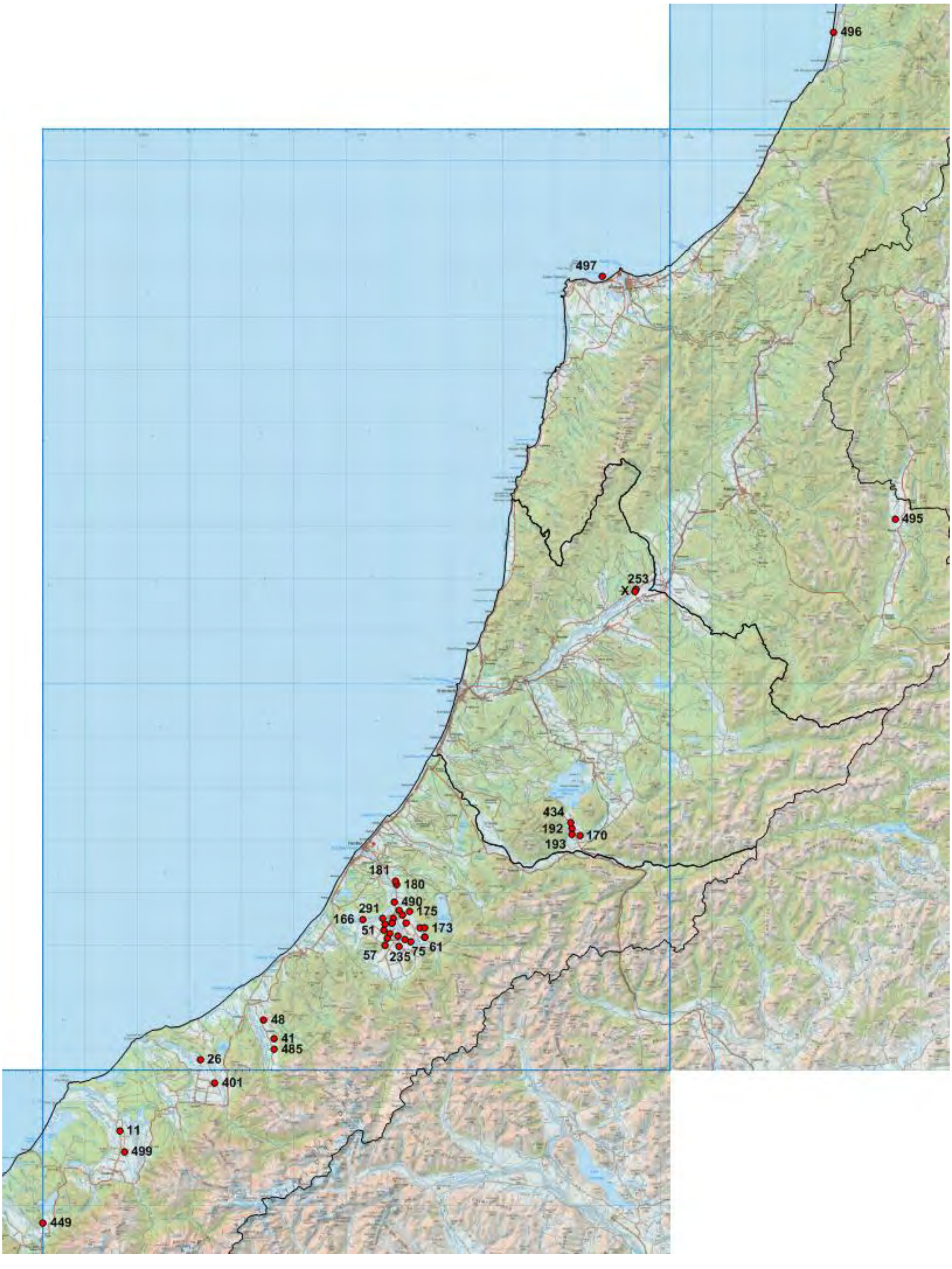


Figure 5: 42 additional GWQ well locations

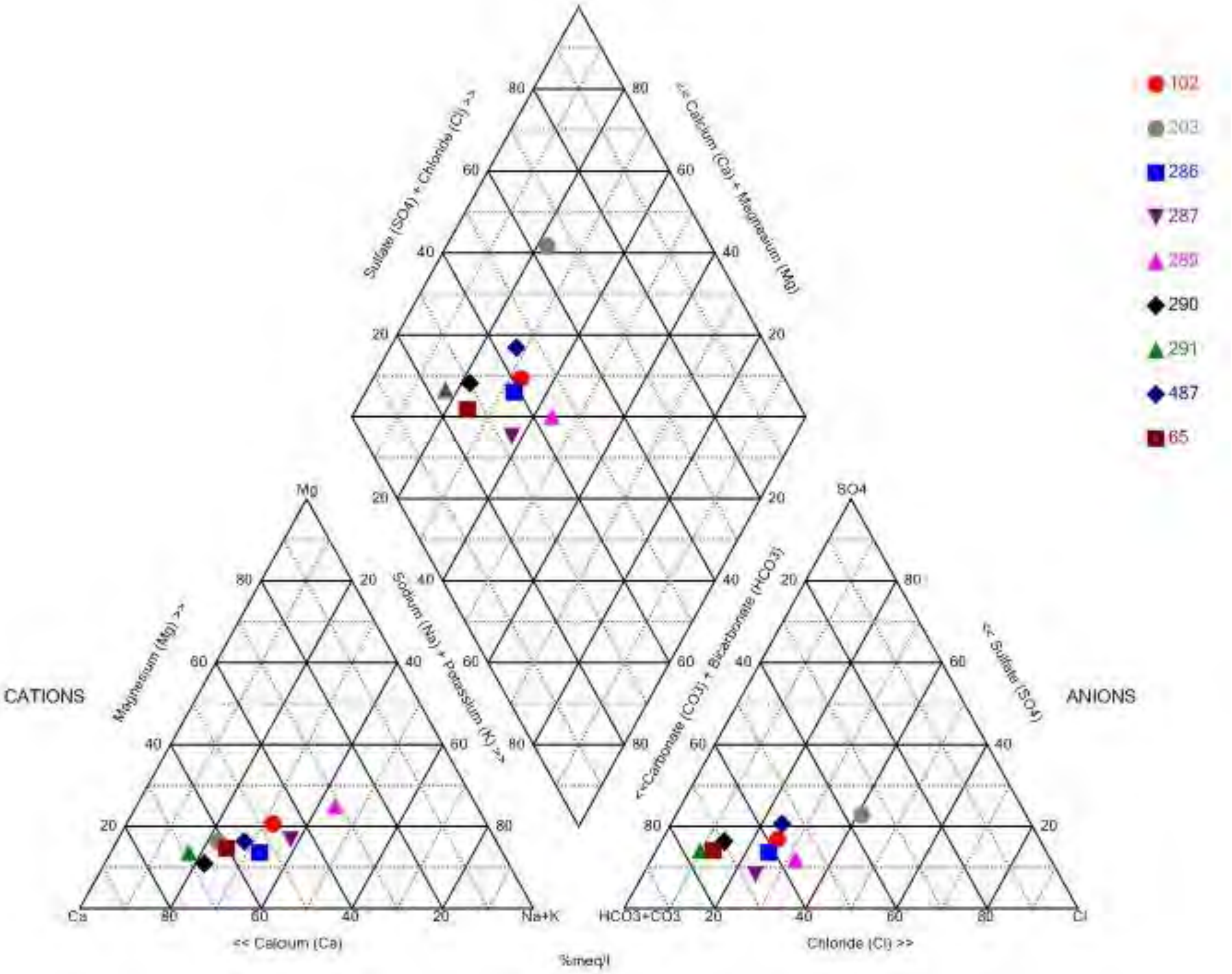


Figure 6: Piper diagram for median NGMP well major ion concentrations

TEXT TABLES

Table 1: 30 GWL wells

#	Full Site Name	Site Name	Well Name	Well ID	NZTM Coordinates		Date Range		Count[1]	Remarks
					Easting	Northing	Start	End		
1	Agnews Res GW @ Kokatahi	Agnews Res	HK31	290	1439978	5255423	Sep-98	Jan-14	104	NGMP well
2	Alison Farm GW @ Kowhitirangi Rd	Alison Fm	HK29	180	1439730	5259511	Feb-00	Jan-14	63	-
3	Anderson Farm GW @ Kowhitirangi	Anderson Fm	HK39	65	1439560	5246443	Sep-98	Jan-14	99	NGMP well
4	Baker Res GW @ Golf Links Rd Kaiata	Baker Res	GR45	255	1456440	5297266	Apr-00	Apr-09	48	No longer used (NLU)
5	Becker Farm GW @ Orwell Ck Rd	Becker Fm	GR21	104	1486424	5308665	Jun-00	Jan-14	68	-
6	Begg Farm GW @ Granville Rd Totara Flat	Begg Fm	GR09	114	1487439	5316136	Nov-00	Jan-14	54	-
7	Bertacco Farm No.2 GW @ Ahaura	Bertacco Fm #2	GR16	500	1482392	5311579	Apr-00	Jan-14	58	-
8	Bradley Farm GW @ 3km E Arahura SH6	Bradley Fm	HK24	275	1441037	5270974	Feb-00	Jul-09	50	NLU
9	Bray Farm GW @ Orwell Ck Rd	Bray Fm	GR19	105	1485036	5308990	Apr-00	Jan-14	57	-
10	Coleman Farm GW @ Kowhitirangi	Colemans Fm	HK34	291	1436947	5253002	Sep-98	Jan-14	100	NGMP well
11	Hunter Farms GW @ Atarau	Hunter Fm	GR04	287	1482688	5316128	Sep-99	Apr-09	60	Former NGMP well, NLU.
12	Hunter Farms No. 2 GW @ Atarau	Hunter Fm No. 2	GR05	454	1481547	5315352	Apr-00	Jan-14	24	-
13	Hunter Farms New GW @ Atarau	Hunter Fm New	GR24	487	1482786	5316122	Sep-06	Jun-13	63	NGMP well
14	Knight Farm GW @ Camptown Rd	Knight Fm	GR44	-	1470502	5304297	Apr-00	Feb-02	15	NLU
15	Lange Farm GW @ Kaniere Kowhitirangi Rd	Lange Fm	HK35	51	1437249	5250745	Feb-00	Jan-14	64	-
16	Lidell Farm GW @ Slatey Ck Rd	Lidell Fm	GR03	204	1478239	5317356	Apr-00	Jan-14	59	-
17	Marshall Farm GW @ Kaniere	Marshall Fm	HK27	262	1437337	5263675	Feb-00	Jan-14	61	-
18	Milnes Farm GW @ Orowaiti	Milnes Fm	BU01	286	1484550	5371338	Sep-98	Jul-13	44	NGMP well
19	Moynihan Farm GW @ Kowhitirangi Rd	Moynihan Fm	HK30	179	1438727	5252175	Feb-00	Jan-14	63	-
20	O_Reilly Farm GW @ Upper Kokatahi Rd	O'Reilly Fm	HK33	173	1445060	5251201	Apr-00	Jan-14	64	-
21	Parker Farm GW @ Municipal Rd	Parker Fm	HK36	79	1439900	5249808	Apr-00	Jan-14	62	-
22	Provis Farm GW @ Kowhitirangi Rd	Provis Fm	HK28	181	1439503	5260278	Feb-00	Jan-14	64	-
23	Robinson Farm GW @ Municipal Rd	Robinson Fm	HK37	78	1440134	5249577	Apr-00	Jan-14	60	-
24	South Side Nurseries GW @ Arthurstown Rd	S Side Nurseries	HK26	256	1432938	5266976	Feb-00	Apr-09	51	NLU
25	Stet Farm GW @ Upper Kokatahi Rd	Stet Fm	HK32	176	1441044	5255075	Feb-00	Jan-14	63	-
26	Sweeny Farm GW @ Whitcombe Terrace Rd	Sweeny Fm	HK40	61	1445183	5249531	Feb-00	Jan-14	65	-
27	Van Alphen Farm No.1 GW @ Nelson Ck Rd	Van Alphen Fm #1	-	268	1473538	5305061	Apr-00	Jan-14	60	-
28	Van Alphen Farm No.2 GW @ Nelson Ck Rd	Van Alphen Fm #2	GR23	268	1473538	5305061	Apr-00	Jan-14	60	-
29	Van der Geest GW @ Logburn Rd	Van der Geest	GR02	203	1479420	5320505	Sep-03	Jun-13	37	NGMP well
30	Westland Water World GW @ Hokitika	Westland WW	HK25	289	1433302	5268616	Sep-98	Jul-13	85	NGMP well
Column Total									1825	

1. Count means number of groundwater level measurements available for analysis.

Table 2: 41 additional GWL wells (insufficient data for analysis)

#	Site Name	Well ID	NZTM Coordinates Easting	Northing	Mean GWL	Count[1]
1	Anderson @ Karamea	496	1523333	5422896	5.07	3
2	Baird Bore	170	1440907	5253623	3.43	3
3	Baird Farm	171	1441547	5252152	3.63	2
4	Bertacco Farm (unreliable)	102	1481417	5311122	NA	38
5	Boatmans	451	1507985	5345072	4.83	8
6	Brookshaws Res	310	1485177	5315812	2.60	7
7	Burden Bore	166	1433236	5252862	3.36	1
8	Burden Bore Farm	175	1442126	5254347	2.51	2
9	Burke Ck	130	1507211	5340114	2.98	6
10	Burkes Ck @ Cape Foulwind	497	1479102	5376097	1.57	2
11	Cook Bore	81	1438346	5250073	1.71	2
12	Diedrichs	490	1439244	5256209	2.52	2
13	Elcock Bore	56	1437820	5249190	3.51	1
14	Garvey Ck @ Reefton	127	1511904	5330588	5.03	8
15	Godfrey Bore	57	1437584	5247951	2.81	2
16	Havill	162	1439092	5253025	1.92	1
17	Hyde-Ryder Bore	83	1437486	5251907	3.62	2
18	Karamea Well @ Blackwater	143	1523333	5423333	4.52	4
19	Karamea Well @ Baker Ck	378	1525893	5434050	2.69	6
20	Karamea @ Kongahu Bch	491	1522894	5422132	4.56	5
21	Karamea @ Umere	492	1530909	5431788	4.27	8
22	Linton Bore	176	1437249	5250745	3.74	2
23	Maimai Grey	125	1496138	5333101	2.71	8
24	Mills	109	1482457	5311527	6.80	5
25	Mitchell	231	1506512	5347160	2.44	7
26	Mitchell House	235	1440166	5247617	4.49	1
27	Monk Bore	172	1444286	5251220	7.34	2
28	Monk Farm	177	1440220	5254623	2.62	2
29	Morrison Bore	163	1438727	5252175	1.77	2
30	Newman Farm	495	1535105	5329624	4.58	3
31	Parkinson	132	1504177	5339516	2.74	4
32	Robertson @ Whanganui	26	1402085	5226052	2.62	1
33	Rotomanu Station Rd.	91	1482344	5276933	7.85	8
34	Springs Junction	494	1532622	5312168	2.27	7
35	Staples Bore	74	1445183	5249531	4.61	1
36	Tapp	48	1414314	5233650	2.55	1
37	Taramakau	186	1456366	5273648	5.15	7
38	Thomson	401	1404940	5221545	15.50	1
39	Upper Maruia River	495	1535085	5329624	4.99	7
40	Von Ah	75	1442376	5248687	1.92	2
41	Von Ah Bore No. 2	76	1441388	5249099	4.86	2
Column Total						186

1. Count means number of groundwater level measurements available for analysis.

Table 3: Outliers for 30 GWL wells

Site	Well	Total Measurements	# Results Used	Outliers	Min	Median	Max	MAD	Outliers	Lo	Hi
1	Agnews Res	104	100	4	1.36	1.82	2.20	0.08	7/12/04-2.72; 15/11/05-2.92; 15/12/05-2.72; 17/04/09-0.09	1	3
2	Alison Fm	63	61	2	2.20	3.13	3.96	0.19	25/06/02-1.62; 10/08/11-4.78	1	1
3	Anderson Fm	99	96	3	6.12	8.30	9.84	0.39	18/12/01-5.0; 19/02/02-1.71; 1/07/10-4.54	3	0
4	Baker Res	48	48	0	2.47	2.86	3.82	0.18	0	0	0
5	Becker Fm	68	68	0	4.68	12.70	19.90	2.30	0	0	0
6	Begg Fm	54	53	1	1.87	2.71	3.15	0.16	27/06/02-1.4	1	0
7	Bertacco Fm #2	58	47	11	4.92	6.26	6.78	0.17	17/12/01-4.4; 27/06/02-3.88; 30/09/03-4.63; 30/05/06-8.1; 7/11/07-8.38; 30/01/08-8.38; 6/05/08-4.6; 16/04/09-8.25; 15/10/09-7.85; 19/04/10-8.23; 10/02/12-8.4	4	7
8	Bradley Fm	50	50	0	2.47	3.51	4.08	0.29	0	0	0
9	Bray Fm	57	57	0	7.04	15.00	21.90	1.70	0	0	0
10	Coleman Fm	100	95	5	2.37	2.99	3.66	0.12	9/07/03-2.1; 28/10/05-3.78; 17/04/09-2.21; 16/02/12-3.85; 23/01/14-0.2	3	2
11	Hunter Fm	60	60	0	0.46	2.65	6.59	1.04	0	0	0
12	Hunter Fm No. 2	63	60	3	0.40	1.28	1.98	0.20	23/03/04-3.11; 10/06/04-2.87; 13/04/05-2.63	0	3
13	Hunter Fm New	24	24	0	0.10	1.37	1.98	0.26	0	0	0
14	Knight Fm	15	14	1	1.61	1.93	1.99	0.05	20/04/00-1.3	1	0
15	Lange Fm	64	64	0	2.30	3.51	4.27	0.26	0	0	0
16	Lidell Fm	59	55	4	1.78	3.74	6.35	0.42	15/11/00-6.91; 19/02/02-7.36; 25/10/05-6.7; 4/03/11-6.87	0	4
17	Marshall Fm	61	59	2	2.01	3.24	3.93	0.21	24/09/08-1.69; 17/04/09-1.39	2	0
18	Milnes Fm	44	43	1	6.29	7.71	8.65	0.39	14/03/02-2.97	1	0
19	Moynihan Fm	63	63	0	1.75	2.57	3.02	0.19	0	0	0
20	O'Reilly Fm	64	63	1	6.22	7.09	8.82	0.34	14/04/02-3.54	1	0
21	Parker Fm	62	57	5	1.78	2.07	2.41	0.09	3/07/00-2.75; 29/09/03-1.27; 28/07/04-2.87; 28/10/05-2.7; 17/04/09-1.47	2	3
22	Provis Fm	64	62	2	2.88	3.89	4.37	0.20	9/07/03-1.78; 17/04/09-2.33	2	0
23	Robinson Fm	60	59	1	1.56	1.87	2.20	0.11	17/04/09-1.22	1	0
24	S Side Nurseries	51	47	4	4.04	4.45	4.96	0.09	19/02/02-5.49; 4/03/03-3.5; 9/06/04-3.72; 10/09/05-5.42	2	2
25	Stet Fm	63	59	4	2.64	3.04	3.69	0.12	22/12/00-4.32; 22/03/04-1.95; 28/07/04-2.03; 1/08/07-3.79	2	2
26	Sweeny Fm	65	65	0	3.82	5.93	8.14	0.48	0	0	0
27	Van Alphen Fm #1	60	59	1	2.46	3.19	4.32	0.23	27/06/02-1.72	1	0
28	Van Alphen Fm #2	60	59	1	2.18	3.08	4.05	0.28	27/06/02-1.28	1	0
29	Van der Geest	37	37	0	3.94	5.35	9.95	0.85	0	0	0
30	Westland WW	85	83	2	1.79	2.45	2.95	0.12	9/06/04-3.39; 7/12/04-0.72	1	1
Column Totals		1825	1767	58						30	28

Table 4: Statistics for 30 GWL wells (outliers included)

Site	Well	Well ID #	Total Measurements	# Results Used	Min	Median	Mean	Max	MAD	Trend	Sen's Slope of Trend	Seasonality
1	Agnews Res	290	104	104	0.90	1.82	1.81	2.92	0.09	N	-	N
2	Alison Fm	180	63	63	1.62	3.13	3.10	4.78	0.19	N	-	N
3	Anderson Fm	65	99	99	1.71	8.25	8.07	9.84	0.41	N	-	N
4	Baker Res	255	48	48	2.47	2.86	2.88	3.82	0.18	DECR	-0.037	N
5	Becker Fm	104	68	68	4.68	12.70	12.60	19.90	2.30	N	-	Y
6	Begg Fm	114	54	54	1.41	2.71	2.63	3.15	0.17	N	-	Y
7	Bertacco Fm #2	500	58	58	3.88	6.27	6.26	8.40	0.24	N	-	Y
8	Bradley Fm	275	50	50	2.47	3.51	3.48	4.08	0.29	N	-	N
9	Bray Fm	105	57	57	7.04	15.00	14.04	21.90	1.70	N	-	N
10	Coleman Fm	291	100	100	0.20	2.99	2.96	3.85	0.12	N	-	N
11	Hunter Fm	287	60	60	0.46	2.62	2.65	6.59	1.04	N	-	Y
12	Hunter Fm No. 2	454	63	63	0.40	1.30	1.30	3.11	0.22	DECR	-0.028	Y
13	Hunter Fm New	487	24	24	0.10	1.37	1.30	1.98	0.26	N	-	N
14	Knight Fm	GR44	15	15	1.30	1.93	1.84	1.99	0.06	INCR	0.09	N
15	Lange Fm	51	64	64	2.30	3.51	3.45	4.27	0.26	N	-	N
16	Lidell Fm	204	59	59	1.78	3.77	4.01	7.36	0.45	N	-	N
17	Marshall Fm	262	61	61	1.39	3.24	3.13	3.93	0.23	N	-	N
18	Milnes Fm	286	44	44	2.97	7.71	7.53	8.65	0.40	N	-	N
19	Moynihan Fm	179	63	63	1.75	2.57	2.56	3.02	0.19	N	-	N
20	O'Reilly Fm	173	64	64	3.54	7.09	7.09	8.82	0.34	N	-	N
21	Parker Fm	79	62	62	1.27	2.08	2.07	2.87	0.10	N	-	N
22	Provis Fm	181	64	64	1.78	3.88	3.79	4.37	0.20	N	-	N
23	Robinson Fm	78	60	60	1.22	1.87	1.84	2.20	0.11	N	-	N
24	S Side Nurseries	256	51	51	3.50	4.45	4.44	5.49	0.11	N	-	N
25	Stet Fm	176	63	63	1.95	3.04	3.02	4.32	0.12	DECR	-0.019	N
26	Sweeny Fm	61	65	65	3.82	5.93	6.00	8.14	0.48	INCR	0.077	Y
27	Van Alphen Fm #1	268	60	60	1.72	3.19	3.22	4.32	0.23	N	-	Y
28	Van Alphen Fm #2	268	60	60	1.28	3.08	3.06	4.05	0.29	N	-	Y
29	Van der Geest	203	37	37	3.94	5.35	5.86	9.95	0.85	N	-	Y
30	Westland WW	289	85	85	0.72	2.45	2.43	3.39	0.12	N	-	N
Column Totals			1825	1825						5		9

Table 5: Statistics for 30 GWL wells (outliers excluded)

Site	Well	Well ID #	Total Measurements	# Results Used	Min	Median	Mean	Max	MAD	Trend	Trend Mag by Sen's	Seasonality	Outliers
1	Agnews Res	290	104	100	1.36	1.82	1.79	2.20	0.08	N	-	N	4
2	Alison Fm	180	63	61	2.20	3.13	3.09	3.96	0.19	N	-	N	2
3	Anderson Fm	65	99	96	6.12	8.30	8.20	9.84	0.39	N	-	N	3
4	Baker Res	255	48	48	2.47	2.86	2.88	3.82	0.18	DECR	-0.037	N	0
5	Becker Fm	104	68	68	4.68	12.70	12.60	19.90	2.30	N	-	Y	0
6	Begg Fm	114	54	53	1.87	2.71	2.66	3.15	0.16	N	-	Y	1
7	Bertacco Fm #2	500	58	47	4.92	6.26	6.13	6.78	0.17	N	-	Y	11
8	Bradley Fm	275	50	50	2.47	3.51	3.48	4.08	0.29	N	-	N	0
9	Bray Fm	105	57	57	7.04	15.00	14.04	21.90	1.70	N	-	N	0
10	Coleman Fm	291	100	95	2.37	2.99	2.99	3.66	0.12	N	-	N	5
11	Hunter Fm	287	60	60	0.46	2.62	2.65	6.59	1.04	N	-	Y	0
12	Hunter Fm No. 2	454	63	60	0.40	1.28	1.22	1.98	0.20	DECR	-0.029	Y	3
13	Hunter Fm New	487	24	24	0.10	1.37	1.30	1.98	0.26	N	-	N	0
14	Knight Fm	GR44	15	14	1.61	1.93	1.88	1.99	0.05	N	-	N	1
15	Lange Fm	51	64	64	2.30	3.51	3.45	4.27	0.26	N	-	N	0
16	Lidell Fm	204	59	55	1.78	3.74	3.80	6.35	0.42	N	-	N	4
17	Marshall Fm	262	61	59	2.01	3.24	3.18	3.93	0.21	N	-	N	2
18	Milnes Fm	286	44	43	6.29	7.71	7.63	8.65	0.39	N	-	Y	1
19	Moynihan Fm	179	63	63	1.75	2.57	2.56	3.02	0.19	N	-	N	0
20	O'Reilly Fm	173	64	63	6.22	7.09	7.15	8.82	0.34	N	-	N	1
21	Parker Fm	79	62	57	1.78	2.07	2.05	2.41	0.09	N	-	N	5
22	Provis Fm	181	64	62	2.88	3.89	3.84	4.37	0.20	N	-	N	2
23	Robinson Fm	78	60	59	1.56	1.87	1.85	2.20	0.11	N	-	N	1
24	S Side Nurseries	256	51	47	4.04	4.45	4.43	4.96	0.09	N	-	N	4
25	Stet Fm	176	63	59	2.64	3.04	3.02	3.69	0.12	DECR	-0.017	N	4
26	Sweeny Fm	61	65	65	3.82	5.93	6.00	8.14	0.48	INCR	0.077	Y	0
27	Van Alphen Fm #1	268	60	59	2.46	3.19	3.24	4.32	0.23	N	-	Y	1
28	Van Alphen Fm #2	268	60	59	2.18	3.08	3.09	4.05	0.28	N	-	Y	1
29	Van der Geest	203	37	37	3.94	5.35	5.86	9.95	0.85	N	-	Y	0
30	Westland WW	289	85	83	1.79	2.45	2.44	2.95	0.12	N	-	N	2
Column Totals			1825	1767						4		10	58

Table 6: NGMP well details

#	Site Name	Site Name	Well ID	NZTM		Contaminant Sources Near Well Location	Median GW Level	Screen Interval	Total Depth	Geology
				Easting	Northing					
1	Agnews Res	HK31	290	1439978	5255423	Dairy farm, septic tank	1.82	Unknown	3	Unknown
2	Anderson Fm	HK39	65	1439560	5246443	Dairy farm	8.30	Unknown	~ 7-10	Unknown
3	Bertacco Fm	GR17	102	1481417	5311122	Dairy farm	6.26	35-37 m	37	0-37: Sandy gravel (some clay 21-22.2)
4	Coleman Fm	HK34	291	1436947	5253002	Dairy farm	2.99	Last 2 m	~ 7-10	Unknown
5a	Hunter Fm GW	GR04	287	1482688	5316128	Dairy farm, septic tank	2.62	Unknown	5	0-5: Gravel
5b	Hunter Fm New	GR24	487	1482786	5316122	Dairy farm, septic tank	1.37	Unknown	Unknown	Unknown
6	Milnes Fm	BU-01	286	1484550	5371338	Dairy farm	7.71	16-18 m (< Jun 99) 22-24 m (> Jun 99)	18 24	0-18: Gravel 18-20: Sand
7	Van der Geest	GR02	203	1479420	5320505	Dairy farm	5.35	Unknown	Unkown	Unknown
8	Westland WW	HK25	289	1433302	5268616	Urban salmon pond	2.45	11-13 m	13	0-7: Beach sand, mud, gravel 7-12: Gravel 12-13: Sand

1. Rosen, M.R. 2001. Assessment of groundwater quality in the West Coast Regional Council state of the environment monitoring programme. GNS Science, Wairakei, 35 pages.
2. Zemansky, G.M., S. Bowis, and J. Horrox. 2005.
3. Median groundwater levels from this report.

Table 7: Missing GWQ data for NGMP wells

#	Site Name	Well #	Missing Samples	# Missing	#/Period	% Missing
1	Agnew Res	290	Only 3 samples in 1999	5	60	8.3
			Only 1 sample in 2004		Sep 98-Jul 13	
			Only 3 samples in 2010			
2	Anderson Fm	65	Only 3 samples in 1999	5	48	10.4
			Only 3 samples in 2001		Sep 98-Jul 13 (except as noted)	
			No samples in 2002		This site was out of the programme for the 2001-2004 period. It has been assumed that the 12 samples missing in this time frame are for that reason.	
			No samples in 2003			
			Only 1 sample in 2004			
			Only 1 sample in 2005			
			Only 3 samples in 2010			
3	Bertacco Fm	102	Only 3 samples in 1999	6	60	10.0
			Only 2 samples in 2004		Sep 98-Jul 13	
			Only 3 samples in 2005			
			Only 3 samples in 2007			
			Only 3 samples in 2010			
4	Coleman	291	Only 3 samples in 1999	5	60	8.3
			Only 2 samples in 2004		Sep 98-Jul 13	
			Only 3 samples in 2005			
			Only 3 samples in 2010			
5a	Hunter Fm	287	Only 3 samples in 1999	4	32	12.5
			Only 2 samples in 2004		Sep 98-Jun 06	
			Only 3 samples in 2005			
5b	Hunter Fm New	487	Only 3 samples in 2010	1	28	3.6
					Jun 06-Jul 13	
6	Milnes	286	Only 2 samples in 1999	8	60	13.3
			Only 3 samples in 2000			
			Only 2 samples in 2003			
			Only 2 samples in 2004			
			Only 3 samples in 2010			
7	Van der Geest	203	Only 1 sample in 2000	11	52	21.2
			No samples in 2002		Jul 00-Jul 13	
			Only 3 samples in 2003			
			Only 2 samples in 2004			
			Only 3 samples in 2010			
8	Westerland WW	289	Only 2 samples in 1999	6	60	10.0
			Only 2 samples in 2004		Sep 98-Jun 06	
			Only 3 samples in 2005			
			Only 3 samples in 2010			
Column Totals				51	460	11.1

Table 8: 23 wider sites GWQ wells[1]

#	Site Name	Well #	NZTM Coordinates		# Samples in Database
			Easting	Northing	
1	Becker @ Ahaura	104	1486424	5308665	7
2	Begg @ Totara Flat	114	1487439	5316136	7
3	Boatmans @ Reefton	451	1507985	5345072	7
4	Brookshaws Res GW @ Totara Flat	310	1485177	5315812	8
5	Burke Ck @ Reefton	130	1507211	5340114	8
6	Garvey Ck @ Reefton	127	1511904	5330588	7
7	Gault Bore @ Bottom	498	1472837	5274508	8
8	Havill @ Ikamatua	116	1492352	5318672	8
9	Karamea Well @ Baker Ck	378	1525893	5434050	8
10	Karamea Well @ Blackwater	143	1523333	5422642	8
11	Karamea @ Kongahu Beach	491	1522894	5422132	7
12	Karamea Well @ Umere	492	1530909	5431788	9
13	Kowhai Downs @ Maruia	493	1534429	5318461	8
14	Maimai (Grey)	125	1496138	5333101	8
15	Mills Farm GW @ Ahaura	109	1482457	5311527	8
16	Mitchell @ Reefton	231	1506512	5347160	6
17	Parrkinson @ Reefton	132	1504177	5339516	7
18	Rooney Old @ Inchbonnie	191	1473145	5271414	12
19	Rotomanu Station Rd @ Rotomanu	91	1482344	5276933	7
20	Shaffery Bore @ Inchbonnie	190	1473954	5271902	11
21	Springs Junction @ 500m s SJ	494	1532622	5312168	7
22	Taramakau @ Taramakau settlement	186	1456366	5273648	7
23	Upper Maruia River @ Dunsinane Hill	495	1535085	5329624	8
Column Total					181

1. The "# samples in Database" indicates the number for the water quality variable with the most samples for each well. Since not all variables were reported for each sampling event, the number of sampling events may be marginally greater than this number. In most cases, there were about eight or more sampling events.

Table 9a: 42 Additional sites GWQ wells (alphabetical order)

#	Site Name	Well #	NZTM Coordinates		# Samples in Database
			Easting	Northing	
1	Alison Fm @ Kowhitirangi	180	1439729	5259510	2
2	Anderson @ Karamea	496	1523333	5422896	4
3	Baird Bore @ Hokitika	170	1440907	5253623	2
4	Baird Fm_274 @ Hokitika	170	1441547	5252152	3
5	Burden Bore @ Hokitika	166	1433236	5252862	4
6	Burden Bore Fm_283 @ Hokitika	175	1442126	5254347	2
7	Burkes Ck @ Cape Foulwind	497	1479102	5376097	2
8	Coleman Old Well @ Kowhitirangi	291	1436945	5252984	1
9	Cook Bore @ Hokitika	81	1438346	5250073	2
10	Diedrichs @ Hokitika	490	1439244	5256209	3
11	Elcock Bore @ Hokitika	56	1437820	5249190	2
12	Fergussen @ Waitaha Mid	41	1416252	5230031	1
13	Franz Dairies @ Franz	449	1372058	5194788	3
14	Godfrey Bore @ Hokitika	57	1437584	5247951	3
15	Harding @ Whataroa	499	1387548	5208434	1
16	Harris Bore @ Inchbonnie	170	1474931	5268908	4
17	Harvey Bore @ Inchbonnie	192	1473171	5270187	5
18	Havill Bore @ Hokitika	162	1439092	5253025	3
19	Holland @ Waitaha	485	1416264	5227991	1
20	Hyde-Ryder Bore @ Hokitika	83	1437486	5251907	2
21	Parker Farm @ Municipal Rd	79	1439900	5249808	2
22	Keeney Bore @ Inchbonnie	193	1473170	5269169	4
23	Lange Bore @ Hokitika	51	1437249	5250745	5
24	Mitchell House Bore @ Hokitika	235	1440166	5247617	2
25	Monk Bore @ Hokitika	172	1444286	5251220	3
26	Monk Fm_288 @ Hokitika	177	1440220	5254623	3
27	Morrison Bore @ Hokitika	163	1438727	5252175	2
28	Moynihan Bore @ Hokitika	179	1438727	5252175	4
29	Newman Fm @ Maruia	495	1535105	5329624	5
30	O_Reilly Bore @ Hokitika	173	1445060	5251201	3
31	Provis Fm @ Kowhitirangi Rd	181	1439503	5260278	2
32	Robertson @ Whanganui	26	1402085	5226052	1
33	Rooney New @ Inchbonnie	434	1473145	5271414	3
34	Staples Bore @ Hokitika	74	1445183	5249531	3
35	Sweeny Bore @ Hokitika	61	1445183	5249531	2
36	Tapp @ Waitaha bottom	48	1414314	5233650	1
37	Thomson @ Whanganui	401	1404940	5221545	1
38	Totara Flat GW @ 100 m from Sch	253	1485536	5316054	3
39	Totara Flat Hotel GW @ Totara Flat	-	1485280	5315772	2
40	Van der Poel @ Whataroa	11	1386669	5212414	1
41	Von Ah @ Hokitika	75	1442376	5248687	2
42	Von Ah Bore 2 @ Hokitika	76	1441388	5249099	3
Column Total					107

Table 9b: 42 Additional sites GWQ wells (ordered S to N)

#	Site Name	Well #	NZTM Coordinates		# Samples in Database
			Easting	Northing	
13	Franz Dairies @ Franz	449	1372058	5194788	3
15	Harding @ Whataroa	499	1387548	5208434	1
40	Van der Poel @ Whataroa	11	1386669	5212414	1
37	Thomson @ Whanganui	401	1404940	5221545	1
32	Robertson @ Whanganui	26	1402085	5226052	1
19	Holland @ Waitaha	485	1416264	5227991	1
12	Fergussen @ Waitaha Mid	41	1416252	5230031	1
36	Tapp @ Waitaha bottom	48	1414314	5233650	1
24	Mitchell House Bore @ Hokitika	235	1440166	5247617	2
14	Godfrey Bore @ Hokitika	57	1437584	5247951	3
41	Von Ah @ Hokitika	75	1442376	5248687	2
42	Von Ah Bore 2 @ Hokitika	76	1441388	5249099	3
11	Elcock Bore @ Hokitika	56	1437820	5249190	2
34	Staples Bore @ Hokitika	74	1445183	5249531	3
35	Sweeny Bore @ Hokitika	61	1445183	5249531	2
21	Parker Farm @ Municipal Rd	79	1439900	5249808	2
9	Cook Bore @ Hokitika	81	1438346	5250073	2
23	Lange Bore @ Hokitika	51	1437249	5250745	5
30	O_Reilly Bore @ Hokitika	173	1445060	5251201	3
25	Monk Bore @ Hokitika	172	1444286	5251220	3
20	Hyde-Ryder Bore @ Hokitika	83	1437486	5251907	2
4	Baird Fm_274 @ Hokitika	170	1441547	5252152	3
27	Morrison Bore @ Hokitika	163	1438727	5252175	2
28	Moynihan Bore @ Hokitika	179	1438727	5252175	4
5	Burden Bore @ Hokitika	166	1433236	5252862	4
8	Coleman Old Well @ Kowhitirangi	291	1436945	5252984	1
18	Havill Bore @ Hokitika	162	1439092	5253025	3
3	Baird Bore @ Hokitika	170	1440907	5253623	2
6	Burden Bore Fm_283 @ Hokitika	175	1442126	5254347	2
26	Monk Fm_288 @ Hokitika	177	1440220	5254623	3
10	Diedrichs @ Hokitika	490	1439244	5256209	3
1	Alison Fm @ Kowhitirangi	180	1439729	5259510	2
31	Provis Fm @ Kowhitirangi Rd	181	1439503	5260278	2
16	Harris Bore @ Inchbonnie	170	1474931	5268908	4
22	Keeney Bore @ Inchbonnie	193	1473170	5269169	4
17	Harvey Bore @ Inchbonnie	192	1473171	5270187	5
33	Rooney New @ Inchbonnie	434	1473145	5271414	3
39	Totara Flat Hotel GW @ Totara Flat	-	1485280	5315772	2
38	Totara Flat GW @ 100 m from Sch	253	1485536	5316054	3
29	Newman Fm @ Maruia	495	1535105	5329624	5
7	Burkes Ck @ Cape Foulwind	497	1479102	5376097	2
2	Anderson @ Karamea	496	1523333	5422896	4
Column Total					107

Table 10: GWQ database water quality variables

#	Category	Variable	Abbrev.	Units	Assessed	
					NGMP	Wider
		Results in NGMP Well Database				
1	General	Conductivity	Cond	uS/cm	Cond	Cond
2		Specific conductance	Cond-Sp	uS/cm	DO	DO
3		Dissolved oxygen	DO	mg/L or % saturation	pH	pH
4		pH	pH	standard units	Ca	Ca
5		Temperature	T	°C	Fe	Fe
6		Turbidity	Turb	NTUs	Mg	Mg
7	Cations	Calcium	Ca	mg/L	Mn	Mn
8		Iron	Fe	mg/L	K	K
9		Magnesium	Mg	mg/L	Na	Na
10		Manganese	Mn	mg/L	HCO3	HCO3
11		Potassium	K	mg/L	Br	Cl
12		Sodium	Na	mg/L	Cl	SO4
13	Anions	Total alkalinity	Alk	mg/L as CaCO3	F	NO3-N
14		Bicarbonate	HCO3	mg/L	SO4	DRP
15		Bromide	CO3	mg/L as CaCO3	NH3-N	E-Coli
16		Fluoride	F	mg/L	NO3-N	
17		Chloride	Cl	mg/l	PO4	
18		Sulfate	SO4	mg/L	DRP	
19	Nutrients	Ammonia-N	NH3-N	mg/L	Silica	
20		Ammonium-N	NH4-N	mg/L	E-Coli	
21		Nitrite as nitrogen	NO2-N	mg/L		
22		Nitrate-N	NO3-N	mg/L		
23		Total oxidized nitrogen	TON	mg/L		
24		Total nitrogen	TN	mg/L		
25		Nitrite as nitrogen	NO2-N	mg/L		
26		Phosphate	PO4	mg/L		
27		Dissolved reactive phosphorus	DRP	mg/L		
28	Bacteria	Total coliforms	T Coli	#/100 mL		
29		Fecal coliforms	F. Coli	#/100 mL		
30		Escherichia coli	E. Coli	#/100 mL		
		Additional Results in Wider Wells Database				
31	Elements	Aluminum	Al	mg/L		
32		Arsenic	As	mg/L		
33		Boron	B	mg/L		
34		Cadmium	Cd	mg/L		
35		Lead	Pb	mg/L		
36		Zinc	Zn	mg/L		

Table 11a: Outliers for NGMP GWQ wells (Agnes Res-Coleman Fm)

Well	Variable	Outliers (Date-Value)	Hi	Lo
Agnews Res	Cond	4/3/03-141	1	
	pH	18/12/01-7.6; 17/12/03-8.49	2	
	Fe	7/8/98-0.68	1	
	F	29/9/03-2.6; 21/5/13-3.7	2	
	NO3-N	21/6/13-3.7	1	
	NH3-N	11/9/01-0.04; 18/12/01-0.05; 20/4/05-0.09; 12/7/05-0.07	4	
Anderson Fm	DO	1/3/99-10.2; 15/3/11-9.67	2	
	pH	15/9/98-8.9	1	
	Ca	26/10/04-13.7	1	
	Fe	7/6/00-0.03; 15/11/05-0.04; 1/24/06-0.04; 14/9/06-0.08; 15/3/11-0.06; 8/12/11-0.07; 29/3/12-0.04	7	
	Mn	16/6/99-0.025	1	
	HCO3	26/10/04-46	1	
	NH3-N	5/4/13-0.03	1	
	Silica	26/12/08-7.9		1
Bertacco Fm	Cond	3/3/03-176	1	
	DO	19/4/10-4.05		1
	pH	17/12/03-8.5	1	
	Fe	13/4/05-0.16	1	
	Mn	22/9/09-0.3	1	
	K	14/3/01-1.6; 3/3/03-1.8; 10/26/04-1.6; 4/13/04-2.1	4	
	Cl	13/4/05-10.3	1	
	F	22/9/09-0.09	1	
	NH3-N	14/3/01-5.4	1	
Coleman Fm	Cond	4/3/03-164	1	
	DO	15/3/11-9.29	1	
	pH	17/12/03-8.51	1	
	Fe	7/12/98-0.05; 2/3/99-0.07; 16/6/99-0.06; 8/9/99-0.07; 8/12/11-0.11	5	
	Mn	3/2/99-0.01	1	
	Br	12/15/00-0.12; 3/14/02-0.1; 25/6/02-0.1; 17/9/02-0.1; 4/12/02-0.1; 4/3/03-0.1; 10/6/03-0.1; 29/9/03-0.1; 17/12/03-0.1; 2/3/04-0.1; 26/10/04-0.1	11	
	HCO3	30/1/08-22		1
	Cl	16/6/99-12.7	1	
	NH3-N	4/20/05-0.11	1	
	Silica	12/7/13-14.6	1	

Table 11b: Outliers for NGMP GWQ wells (Hunter Fm – Westland WW)

Well	Variable	Outliers (Date-Value)	Hi	Lo
Hunter Fm	Cond	3/3/03-174	1	
	pH	17/12/03-8.49	1	
	Fe	3/14/01-0.89; 13/4/05-2.9	1	
	Mn	13/4/05-0.13	1	
	NH3-N	7/6/01-0.16	1	
Hunter Fm New	Cond	9/8/11-11		1
	DO	6/4/11-1.86		1
	Fe	18/6/07-0.001; 15/7/08-0.04	2	
	NH3-N	9/9/10-0.05	1	
Milnes	Cond	16/9/98-100; 26/3/01-109; 18/9/03-168; 24/3/03-149	4	
	Fe	6/6/00-4.0; 26/3/01-4.2	2	
	Mg	26/3/01-2.0	1	
	Mn	15/3/00-0.2; 26/3/01-0.18	2	
	K	31/1/13-1.9	1	
	Br	14/3/02-0.1; 26/6-02-0.1; 11/9/02-0.1; 18/12/02-0.1; 24/3/03-0.1; 18/9/03-0.1; 21/01/04-0.1; 3/3/04-0.1; 8/10/04-0.1	9	
	Cl	26//3/01-9.5	1	
	NO3-N	14/10/05-0.69	1	
Van der Geest	pH	17/12/03-8.49	1	
	Ca	19/7/05-20	1	
	Mn	11/5/07-0.79; 18/6/07-0.63	2	
	NH3-N	19/10/05-0.04; 28/7/08-0.05	2	
Westland WW	Cond	4/3/03-169	1	
	pH	17/12/03-8.47	1	
	Fe	1/5/09-0.09	1	
	Mn	16/6/99-0.025; 1/5/09-0.03	2	
	HCO3	7/12/98-6.1; 16/6/99-5.8		2
	F	1/5/09-0.17		1
	NH3-N	11/6/01-0.04; 24/1/06-0.04	2	
Column Totals			101	8

Table 12a: Statistics for NGMP GWQ wells (outliers included)

Site #	Variable	Units	Data Count	Minimum	Median	Mean	Maximum	MAD	Median + 6 * MAD	Trend	Trend Rate	Seasonality	Outliers
	AGNEWS RES												
1	Ca	mg/L	54	8.800	10.400	10.478	13.500	0.600	14.000	INCR	0.15	N	0
1	Mg	mg/L	54	0.830	1.000	1.004	1.200	0.055	1.330	INCR	0.0008	N	0
1	K	mg/L	54	1.800	2.150	2.181	2.800	0.150	3.050	DECR	-0.029	Y	0
1	Na	mg/L	54	2.000	2.750	2.794	3.700	0.250	4.250	DECR	-0.063	N	0
1	HCO3	mg/L	53	27.000	31.000	31.400	37.000	2.000	43.000	INCR	0.246	Y	0
1	Cl	mg/L	54	2.400	3.400	3.535	5.300	0.400	5.800	DECR	-0.046	Y	0
1	NO3-N	mg/L	54	0.430	1.150	1.208	3.700	0.170	2.170	N	-	Y	2
1	SO4	mg/L	54	3.600	5.600	5.615	7.700	0.500	8.600	INCR	0.089	N	0
1	Silica	mg/L	54	6.800	8.000	8.119	9.700	0.450	10.700	INCR	0.059	N	0
1	Cond	µS/cm	49	51.000	68.000	71.931	141.000	5.000	98.000	N	-	N	1
1	DO	mg/L	30	3.210	6.195	6.539	10.100	1.880	17.475	N	-	ID	0
1	pH	Units	50	4.690	5.925	6.008	8.490	0.250	7.425	N	-	N	2
1	Fe	mg/L	54	0.030	0.090	0.111	0.680	0.030	0.270	N	-	N	1
1	Mn	mg/L	54	0.003	0.005	0.005	0.010	0.003	0.020	N	-	N	0
1	Br	mg/L	52	0.010	0.030	0.043	0.100	0.010	0.090	N	-	N	0
1	F	mg/L	52	0.005	0.040	0.043	0.090	0.010	0.100	INCR	0.0015	N	0
1	NH3-N	mg/L	57	0.004	0.010	0.012	0.090	0.005	0.040	NA	-	NA	4
1	PO4	mg/L	16	0.020	0.040	0.051	0.100	NA	NA	NA	-	NA	NA
1	DRP	mg/L	7	0.002	0.006	0.006	0.015	NA	NA	NA	-	NA	NA
1	E-Coli	MPN	45	0.000	0.500	2.178	23.000	NA	NA	NA	-	NA	NA
	ANDERSON FM												
2	Ca	mg/L	42	7.700	9.650	9.476	13.700	0.600	13.250	INCR	0.13	N	1
2	Fe	mg/L	42	0.005	0.010	0.020	0.080	0.003	0.025	N	-	N	7
2	Mg	mg/L	42	1.100	1.400	1.342	1.600	0.100	2.000	BD	-	N	0
2	Mn	mg/L	42	0.002	0.003	0.004	0.025	0.000	0.003	N	-	N	1
2	K	mg/L	42	2.400	2.700	2.725	3.050	0.100	3.300	DECR	-0.012	N	0
2	Na	mg/L	42	2.300	3.040	3.064	4.000	0.260	4.600	N	-	N	0
2	HCO3	mg/L	42	31.000	33.000	33.300	37.000	1.500	42.000	INCR	0.162	N	1
2	Cl	mg/L	41	1.700	3.100	3.002	3.700	0.200	4.300	N	-	N	0
2	NO3-N	mg/L	42	0.750	1.200	1.187	1.600	0.200	2.400	INCR	0.04	N	0
2	SO4	mg/L	42	2.600	4.850	4.745	6.400	0.450	7.550	BD	-	N	0
2	Silica	mg/L	42	7.900	12.900	12.836	14.600	0.400	15.300	N	-	N	1
2	Cond	µS/cm	42	52.000	68.000	66.343	80.000	3.000	86.000	INCR	0.54	N	0
2	DO	mg/L	36	2.930	5.115	5.486	10.200	0.260	6.675	N	-	ID	2
2	pH	Units	39	5.150	5.650	5.814	8.900	0.150	6.550	N	-	N	1
2	Br	mg/L	41	0.005	0.030	0.031	0.070	0.010	0.090	N	-	N	0
2	F	mg/L	41	0.010	0.045	0.047	0.090	0.020	0.165	INCR	0.002	N	0
2	NH3-N	mg/L	44	0.003	0.005	0.008	0.030	0.000	0.005	NA	-	NA	1
2	PO4	mg/L	9	0.020	0.040	0.033	0.040	NA	NA	NA	-	NA	NA
2	DRP	mg/L	7	0.004	0.006	0.012	0.033	NA	NA	NA	-	NA	NA
2	E-Coli	MPN	33	0.000	0.500	2.424	48.000	NA	NA	NA	-	NA	NA

Table 12b: Statistics for NGMP GWQ wells (outliers included)

Site #	Variable	Units	Data Points	Minimum	Median	Mean	Maximum	MAD		Trend	Trend Rate	Seasonality	Outliers
	BERTACCO FM												
3	Ca	mg/L	53	8.100	9.900	9.783	11.400	0.800	14.700	INCR	0.19	N	0
3	Mg	mg/L	53	2.000	2.600	2.526	3.000	0.200	3.800	INCR	0.046	N	0
3	K	mg/L	53	0.350	0.720	0.778	2.100	0.080	1.200	N	-	N	4
3	Na	mg/L	53	6.600	7.600	7.672	9.700	0.300	9.400	N	-	N	0
3	HCO3	mg/L	52	26.000	29.000	30.300	37.000	1.500	38.000	DNM	N/A	N	0
3	Cl	mg/L	53	5.000	7.200	6.966	10.300	0.500	10.200	DNM	N/A	N	1
3	NO3-N	mg/L	53	1.500	3.400	3.283	4.700	0.600	7.000	INCR	0.17	N	0
3	SO4	mg/L	53	4.700	6.300	6.630	8.600	0.600	9.900	INCR	0.17	N	0
3	Silica	mg/L	53	17.500	20.000	20.175	24.000	0.600	23.600	INCR	0.088	N	0
3	Cond	µS/cm	48	65.000	95.000	94.990	176.000	9.000	149.000	N	-	N	1
3	DO	mg/L	36	4.050	7.820	7.783	11.400	1.115	14.510	N	-	N	1
3	pH	Units	48	5.340	5.865	5.962	8.500	0.210	7.125	DECR	-0.028	N	1
3	Fe	mg/L	53	0.010	0.020	0.026	0.160	0.010	0.080	N	-	N	1
3	Mn	mg/L	53	0.003	0.005	0.007	0.030	0.003	0.020	N	-	N	1
3	Br	mg/L	51	0.010	0.050	0.053	0.150	0.020	0.170	DECR	-0.0018	N	0
3	F	mg/L	52	0.010	0.043	0.044	0.090	0.007	0.085	N	-	N	1
3	NH3-N	mg/L	54	0.004	0.010	0.117	5.400	0.005	0.040	NA	-	NA	1
3	PO4	mg/L	17	0.020	0.040	0.050	0.100	NA	NA	NA	-	NA	NA
3	DRP	mg/L	7	0.012	0.021	0.023	0.033	NA	NA	NA	-	NA	NA
3	E-Coli	MPN	44	0.000	0.500	1.136	5.000	NA	NA	NA	-	NA	NA
	COLEMAN FM												
4	Ca	mg/L	57	10.500	13.800	13.874	16.500	1.000	19.800	INCR	0.19	N	0
4	Mg	mg/L	57	1.300	1.600	1.595	1.900	0.100	2.200	DNM	N/A	N	0
4	K	mg/L	57	1.600	2.300	2.321	2.900	0.100	2.900	DECR	-0.0105	N	0
4	Na	mg/L	57	1.900	2.700	2.754	6.200	0.200	3.900	DECR	-0.024	N	0
4	HCO3	mg/L	56	22.000	44.000	43.800	51.000	2.000	56.000	INCR	0.351	N	1
4	Cl	mg/L	56	2.100	3.000	3.223	12.700	0.300	4.800	INCR	0.033	Y	1
4	NO3-N	mg/L	57	0.480	1.200	1.231	5.100	0.260	2.760	INCR	0.038	N	0
4	SO4	mg/L	57	3.400	6.200	6.360	10.300	0.500	9.200	INCR	0.086	Y	0
4	Silica	mg/L	58	7.600	9.200	9.321	14.600	0.500	12.200	N	-	N	1
4	Cond	µS/cm	47	64.000	87.000	88.570	164.000	6.800	127.800	N	-	N	1
4	DO	mg/L	31	2.940	4.070	4.373	9.290	0.710	8.330	N	-	ID	1
4	pH	Units	50	4.960	5.955	6.080	8.510	0.220	7.275	N	-	N	1
4	Fe	mg/L	57	0.010	0.020	0.023	0.110	0.006	0.056	N	-	N	5
4	Mn	mg/L	57	0.003	0.005	0.004	0.010	0.000	0.005	N	-	N	1
4	Br	mg/L	54	0.010	0.030	0.045	0.120	0.010	0.090	N	-	N	11
4	F	mg/L	54	0.008	0.030	0.035	0.080	0.010	0.090	N	-	N	0
4	NH3-N	mg/L	57	0.002	0.010	0.010	0.110	0.005	0.040	NA	-	NA	1
4	PO4	mg/L	17	0.010	0.040	0.049	0.100	NA	NA	NA	-	NA	NA
4	DRP	mg/L	8	0.002	0.007	0.013	0.040	NA	NA	NA	-	NA	NA
4	E-Coli	MPN	45	0.000	0.500	6.567	210.000	0.500	3.500	NA	-	NA	NA

Table 12c: Statistics for NGMP GWQ wells (outliers included)

Site #	Variable	Units	Data Points	Minimum	Median	Mean	Maximum	MAD	Median + 6 * MAD	Trend	Trend Rate	Seasonality	Outliers
	HUNTER FM												
5	Ca	mg/L	27	7.500	8.900	8.874	10.500	0.400	11.300	INCR	0.23	N	0
5	Mg	mg/L	27	1.700	2.000	2.019	2.400	0.100	2.600	N	-	N	0
5	K	mg/L	27	1.100	1.400	1.407	1.700	0.100	2.000	N	-	N	0
5	Na	mg/L	27	6.600	7.900	8.081	10.100	0.700	12.100	DECR	-0.23	N	0
5	HCO3	mg/L	26	33.000	37.000	37.500	44.000	1.000	43.000	N	-	N	0
5	Cl	mg/L	27	5.700	7.600	7.333	8.200	0.400	10.000	INCR	0.23	N	0
5	NO3-N	mg/L	27	0.690	2.000	1.894	3.700	0.400	4.400	N	-	Y	0
5	SO4	mg/L	27	2.200	3.400	3.348	4.400	0.500	6.400	INCR	0.22	N	0
5	Silica	mg/L	26	11.900	14.800	14.612	19.400	1.050	21.100	N	-	N	0
5	Cond	µS/cm	21	60.000	90.000	97.429	174.000	13.000	168.000	N	-	N	1
5	DO	mg/L	13	0.380	7.300	6.375	13.100	2.900	24.700	ID	-	ID	0
5	pH	Units	18	5.320	5.860	6.075	8.490	0.305	7.690	DECR	-0.1	N	1
5	Fe	mg/L	27	0.040	0.140	0.312	2.900	0.090	0.680	N	-	N	2
5	Mn	mg/L	27	0.020	0.040	0.043	0.130	0.010	0.100	DECR	-0.0037	N	1
5	Br	mg/L	24	0.015	0.060	0.067	0.100	0.025	0.210	N	-	N	0
5	F	mg/L	25	0.024	0.060	0.053	0.070	0.006	0.096	N	-	N	0
5	NH3-N	mg/L	27	0.005	0.030	0.045	0.160	0.020	0.150	NA	-	NA	1
5	PO4	mg/L	16	0.020	0.040	0.050	0.100	NA	NA	NA	-	NA	NA
5	DRP	mg/L	1	0.002	0.002	0.002	0.002	NA	NA	NA	-	NA	NA
5	E-Coli	MPN	18	0.000	2.500	3.472	16.000	NA	NA	NA	-	NA	NA
	HUNTER FM NEW												
6	Ca	mg/L	26	9.700	11.500	11.635	14.800	0.900	16.900	INCR	0.38	N	0
6	Mg	mg/L	26	1.600	2.000	2.000	2.600	0.150	2.900	N	-	N	0
6	K	mg/L	26	1.200	1.600	1.612	2.100	0.100	2.200	N	-	N	0
6	Na	mg/L	26	4.600	5.800	5.838	7.000	0.400	8.200	N	-	N	0
6	HCO3	mg/L	26	19.200	23.000	23.500	29.000	1.500	32.000	N	-	Y	0
6	Cl	mg/L	26	4.100	5.700	5.927	7.800	0.500	8.700	N	-	N	0
6	NO3-N	mg/L	26	3.100	4.800	5.038	8.900	0.950	10.500	N	-	N	0
6	SO4	mg/L	26	4.700	6.600	6.619	9.100	0.850	11.700	N	-	N	0
6	Silica	mg/L	26	9.400	12.200	12.185	14.600	0.850	17.300	N	-	Y	0
6	Cond	µS/cm	30	11.000	89.000	90.513	144.000	12.000	161.000	INCR	3.4	Y	1
6	DO	mg/L	27	1.860	5.110	5.087	6.770	0.590	8.650	N	-	N	1
6	pH	Units	29	4.710	5.480	5.515	6.300	0.100	6.080	N	-	N	0
6	Fe	mg/L	26	0.001	0.010	0.014	0.040	0.000	0.010	N	-	N	2
6	Mn	mg/L	26	0.003	0.005	0.005	0.010	0.003	0.020	N	-	N	0
6	Br	mg/L	26	0.015	0.035	0.033	0.050	0.015	0.125	N	-	N	0
6	F	mg/L	26	0.029	0.059	0.059	0.090	0.012	0.128	INCR	0.0039	N	0
6	NH3-N	mg/L	28	0.005	0.005	0.009	0.050	0.000	0.005	NA	-	NA	1
6	PO4	mg/L	1	0.020	0.020	0.020	0.020	NA	NA	NA	-	NA	NA
6	DRP	mg/L	6	0.005	0.007	0.009	0.020	NA	NA	NA	-	NA	NA
6	E Coli	MPN	28	0.000	1.000	35.946	920.000	NA	NA	NA	-	NA	NA

Table 12d: Statistics for NGMP GWQ wells (outliers included)

Site #	Variable	Units	Data Points	Minimum	Median	Mean	Maximum	MAD	Median + 6 * MAD	Trend	Trend Rate	Seasonality	Outliers
	MILNES												
7	Ca	mg/L	51	4.300	8.700	8.420	9.400	0.500	11.700	INCR	0.094	N	0
7	Mg	mg/L	51	1.000	1.300	1.280	2.000	0.100	1.900	INCR	0.011	N	1
7	K	mg/L	51	0.740	1.100	1.110	1.900	0.100	1.700	DECR	-0.018	N	1
7	Na	mg/L	51	4.700	5.600	5.563	6.800	0.200	6.800	N	-	N	0
7	HCO3	mg/L	50	25.000	31.000	31.200	39.000	2.000	43.000	INCR	0.345	N	0
7	Cl	mg/L	51	6.000	7.200	7.284	9.500	0.300	9.000	N	-	N	1
7	NO3-N	mg/L	51	0.050	0.110	0.138	0.690	0.020	0.230	INCR	0.0049	N	1
7	SO4	mg/L	51	3.900	5.100	5.225	6.900	0.500	8.100	DNM	N/A	N	0
7	Silica	mg/L	51	9.000	11.700	11.745	13.300	0.500	14.700	INCR	0.11	N	0
7	Cond	µS/cm	40	58.000	69.500	75.005	168.000	3.500	90.500	INCR	0.61	N	4
7	DO	mg/L	27	0.310	1.420	2.943	9.950	0.930	7.000	DNM	N/A	N	0
7	pH	Units	45	4.700	5.940	5.980	7.300	0.240	7.380	N	-	N	0
7	Fe	mg/L	50	0.010	0.125	0.446	4.200	0.099	0.719	DECR	-0.0249	N	2
7	Mn	mg/L	51	0.010	0.030	0.038	0.200	0.006	0.066	INCR	0.0015	N	2
7	Br	mg/L	51	0.010	0.040	0.044	0.100	0.020	0.160	N	-	N	9
7	F	mg/L	51	0.010	0.033	0.038	0.090	0.007	0.075	N	-	N	0
7	NH3-N	mg/L	53	0.002	0.005	0.008	0.020	0.004	0.026	NA	-	N	0
7	PO4	mg/L	15	0.020	0.040	0.050	0.100	NA	NA	NA	-	NA	NA
7	DRP	mg/L	6	0.002	0.005	0.006	0.017	NA	NA	NA	-	NA	NA
7	E-Coli	MPN	38	0.000	0.500	0.658	5.000	NA	NA	NA	-	NA	NA
	VAN DER GEEST												
8	Ca	mg/L	38	7.100	12.600	12.645	20.000	1.100	19.200	INCR	0.46	N	1
8	Mg	mg/L	38	0.810	1.950	1.889	3.000	0.250	3.450	INCR	0.13	Y	0
8	K	mg/L	38	0.840	2.550	2.566	4.700	0.650	6.450	INCR	0.25	N	0
8	Na	mg/L	38	2.900	3.850	3.858	5.100	0.500	6.850	INCR	0.098	Y	0
8	HCO3	mg/L	37	13.300	16.000	15.700	19.700	1.000	22.000	N	-	N	0
8	Cl	mg/L	38	5.800	10.250	10.811	15.800	1.400	18.650	INCR	0.27	Y	0
8	NO3-N	mg/L	38	1.700	4.400	4.418	7.700	0.800	9.200	INCR	0.34	N	0
8	SO4	mg/L	38	4.400	7.750	7.861	11.100	1.550	17.050	INCR	0.41	N	0
8	Silica	mg/L	38	3.400	4.600	4.624	6.800	0.450	7.300	N	-	N	0
8	Cond	µS/cm	36	63.000	98.500	100.139	162.000	13.500	179.500	INCR	4.5	Y	0
8	DO	mg/L	30	0.230	3.350	4.068	9.870	2.441	17.996	INCR	0.568	N	0
8	pH	Units	38	4.740	5.170	5.313	8.490	0.140	6.010	INCR	0.034	N	1
8	Fe	mg/L	38	0.010	0.040	0.042	0.110	0.020	0.160	N	-	N	0
8	Mn	mg/L	38	0.003	0.150	0.190	0.790	0.057	0.492	N	-	Y	2
8	Br	mg/L	38	0.020	0.140	0.150	0.380	0.040	0.380	N	-	N	0
8	F	mg/L	38	0.003	0.015	0.015	0.030	0.007	0.057	N	-	N	0
8	NH3-N	mg/L	40	0.005	0.005	0.010	0.050	0.000	0.005	NA	-	NA	2
8	PO4	mg/L	3	0.002	0.025	0.017	0.025	NA	NA	NA	-	NA	NA
8	DRP	mg/L	7	0.002	0.002	0.002	0.004	NA	NA	NA	-	NA	NA
8	E Coli	MPN	39	0.000	1.000	3.192	49.000	NA	NA	NA	-	NA	NA

Table 12e: Statistics for NGMP GWQ wells (outliers included)

Site #	Variable	Units	Data Count	Minimum	Median	Mean	Maximum	MAD	Median + 6 * MAD	Trend	Trend Rate	Seasonality	Outliers
	WESTLAND WW												
9	Ca	mg/L	54	5.300	5.900	5.981	6.800	0.200	7.100	INCR	0.035	N	0
9	Mg	mg/L	54	2.400	2.800	2.807	3.200	0.100	3.400	DECR	-0.014	N	0
9	K	mg/L	54	1.400	1.800	1.826	2.400	0.200	3.000	DECR	-0.033	N	0
9	Na	mg/L	54	7.400	8.500	8.574	10.400	0.400	10.900	DECR	-0.078	N	0
9	HCO3	mg/L	53	5.800	32.000	30.800	37.000	1.000	38.000	N	-	N	2
9	Cl	mg/L	54	9.300	10.100	10.135	11.400	0.300	11.900	N	-	N	0
9	NO3-N	mg/L	54	0.610	0.780	0.795	1.100	0.075	1.230	N	-	N	0
9	SO4	mg/L	54	4.300	5.100	5.144	6.100	0.250	6.600	DECR	-0.068	N	0
9	Silica	mg/L	54	15.000	16.650	17.041	21.000	0.550	19.950	N	-	N	0
9	Cond	µS/cm	47	65.000	82.000	87.038	169.000	4.000	106.000	N	-	N	1
9	DO	mg/L	32	1.940	4.515	5.052	11.300	1.650	14.415	DECR	-0.73	N	0
9	pH	Units	48	4.800	5.815	5.898	8.470	0.195	6.985	N	-	N	1
9	Fe	mg/L	54	0.005	0.020	0.018	0.090	0.000	0.020	N	-	N	1
9	Mn	mg/L	54	0.003	0.005	0.005	0.030	0.001	0.011	N	-	N	2
9	Br	mg/L	53	0.002	0.044	0.049	0.100	0.014	0.128	DECR	-0.002	N	0
9	F	mg/L	53	0.017	0.090	0.093	0.140	0.011	0.156	N	-	N	1
9	NH3-N	mg/L	54	0.003	0.010	0.009	0.040	0.005	0.040	NA	-	NA	2
9	PO4	mg/L	17	0.020	0.040	0.050	0.100	NA	NA	NA	-	NA	NA
9	DRP	mg/L	8	0.011	0.025	0.026	0.048	NA	NA	NA	-	NA	NA
9	E Coli	MPN	45	0.000	0.500	0.644	5.000	NA	NA	NA	-	NA	NA
Column Totals (all nine wells)										63		15	109

Footnotes:

ID=Insufficient Data
BD=Bifurcated Data
DNM=Data Not Monotonic
1=Significant trend at 95% confidence level.
N=No significant trend.
INCR=Increasing trend
DECR=decreasing trend
No analysis for trend for NH3-N, PO4, DRP, or E Coli.

Table 13: NGMP GWQ well trends

#	NGMP Well	Ca			Mg			K			Na		
#	NGMP Well	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m
1	Agnew Res	1		0.15	1		0.001		1	-0.029		1	-0.063
2	Anderson Fm	1		0.13	BD		-		1	-0.012	N		-
3	Bertacco Fm	1		0.19	1		0.046	N		-	N		-
4	Coleman Fm	1		0.19	DNM		-		1	-0.01		1	-0.024
5	Hunter Fm	1		0.23	N		-	N		-		1	-0.23
6	Hunter Fm New	1		0.33	N		-	N		-	N		-
7	Milnes	1		0.094	1		0.011		1	-0.018	N		-
8	Van der Geest	1		0.46	1		0.13	1		0.25	1		0.098
9	Westland WW	1		0.035		1	-0.033		1	-0.033		1	-0.078
Column Total		9	0	-	4	1	-	1	5	-	1	4	-1.
Annual median slope		mg/L		0.19	mg/L		0.029	mg/L		-0.018	mg/L		-0.071

#	NGMP Well	HCO3			Cl			NO3-N			SO4		
#	NGMP Well	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m
1	Agnew Res	1		0.3		1	-0.048	N		-	1		0.089
2	Anderson Fm	1		0.21	N		-	1		0.04	BD		-
3	Bertacco Fm	DNM		-	DNM		-	1		0.17	1		0.17
4	Coleman Fm	1		0.48	1		0.033	1		0.038	1		0.086
5	Hunter Fm	N		-	1		0.23	N		-	1		0.22
6	Hunter Fm New	N		-	N		-	N		-	N		-
7	Milnes	1		0.42	N		-	1		0.005	DNM		-
8	Van der Geest	N		-	1		0.27	1		0.34	1		0.41
9	Westland WW	N		-	N		-	N		-		1	-0.068
Column Total		4	0	-	3	1	-	5	0	-	5	1	-
Annual median slope		mg/L		0.36	mg/L		0.23	mg/L		0.04	mg/L		0.17

#	NGMP Well	Silica			Cond			DO			pH		
#	NGMP Well	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m
1	Agnew Res	1		0.059	N		-	N		-	N		-
2	Anderson Fm	N		-	1		0.54	N		-	N		-
3	Bertacco Fm	1		0.088	N		-	N		-		1	-0.028
4	Coleman Fm	N		-	N		-	N		-	N		-
5	Hunter Fm	N		-	N		-	ID		-		1	-0.1
6	Hunter Fm New	N		-	1		3.4	N		-	N		-
7	Milnes	1		0.11	1		0.61	DNM		-	N		-
8	Van der Geest	N		-	1		4.3	1		0.568	1		0.034
9	Westland WW	N		-	N				1	-0.73	N		-
Column Total		3	0	-	4	0	-	1	1	-	1	2	-
Annual median slope		mg/L		0.088	uS/cm		2.005	mg/L		-	Units		-

#	NGMP Well	Fe			Mn			Br			F		
#	NGMP Well	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m	INCR	DECR	m
1	Agnew Res	N		-	N		-	N		-	1		0.002
2	Anderson Fm	N		-	N		-	N		-	1		0.002
3	Bertacco Fm	N		-	N		-		1	-0.002	N		-
4	Coleman Fm	N		-	N		-	N		-	N		-
5	Hunter Fm	N		-		1	-0.004	N		-	N		-
6	Hunter Fm New	N		-	N		-	N		-	1		0.004
7	Milnes		1	-0.025	1		0.002	N		-	N		-
8	Van der Geest	N		-	N		-	N		-	N		-
9	Westland WW	N		-	N				1	-0.002	N		-
Column Total		0	1	-	1	1	-	0	2	-	3	0	-
Annual median slope		mg/L		-0.025	uS/cm		-0.001	mg/L		-	Units		-

	INCR	DECR		Total
Table Total	45	19		64

Footnotes:

ID=Insufficient Data
BD=Bifurcated Data
DNM=Data Not Monotonic
1=Significant trend at 95% confidence level.
N=No significant trend.
INCR=Increasing trend
DECR=decreasing trend
m=slope of trend. Median slope calculated using predominant trend direction only.
No analysis for trend for NH3-N, PO4, DRP, or E Coli.

Table 14a: Descriptive statistics for 23 wider site wells

Variable	Min	Mdn	Mean	Max	Count	Min	Mdn	Mean	Max	Count
	Becker Well: Nov 07-Jan 14					**Brookshaws Well: Nov 07-Jan 14**				
Cond	70.	82.	83.33	98.	3	96.	99.	103.75	121.	4
DO	4.77	5.99	6.38	9.32	7	5.79	7.82	7.73	10.75	8
pH	4.12	6.	5.66	6.4	5	5.38	5.95	5.96	6.5	6
Ca	5.9	7.25	7.32	9.1	6	11.	11.1	11.86	13.7	7
Fe	0.01	0.01	0.01	0.01	4	0.01	0.01	0.01	0.01	4
Mg	1.8	2.2	2.24	2.8	5	1.1	1.13	1.18	1.43	6
Mn	0.003	1.152	1.152	2.300	2	0.004	0.697	0.697	1.390	1
K	0.68	0.75	0.75	0.82	6	1.54	1.69	1.73	1.95	6
Na	6.1	6.3	6.3	6.5	5	3.5	3.8	3.8	4.1	6
HCO3	23.	24.	26.29	34.16	4	0.53	23.5	24.06	48.8	6
Cl	6.1	6.7	6.68	7.3	6	0.85	5.5	5.06	6.9	7
SO4	4.5	6.15	6.18	7.9	6	5.4	6.6	19.97	101.	7
NO3-N	1.5	2.	2.19	3.3	7	2.3	3.	3.35	5.2	8
DRP	0.019	0.023	0.043	0.109	4	0.002	0.003	0.004	0.007	4
E-Coli	0.1	0.5	1.09	5.	7	0.5	1.	3.36	15.	7
	Begg Well: Nov 07-Jan 14					**Burke Ck Well: Nov 07-Jan 14**				
Cond	11.2	107.5	89.05	130.	4	13.	106.	72.	118.	5
DO	5.35	7.02	7.24	8.94	7	5.85	8.	15.12	68.	8
pH	5.1	6.2	6.13	6.8	6	5.7	5.8	5.83	5.9	7
Ca	10.2	13.	12.87	14.8	7	12.	13.9	13.74	15.	7
Fe	0.01	0.01	0.01	0.01	5	0.01	0.01	0.01	0.01	3
Mg	1.54	1.95	1.95	2.4	6	1.34	2.5	2.24	2.6	4
Mn	0.001	0.956	0.956	1.910	2	0.005	0.005	0.005	0.005	1
K	2.2	2.4	2.38	2.6	6	1.	1.12	1.12	1.21	6
Na	4.6	4.9	5.02	5.7	6	4.1	4.35	4.35	4.6	6
HCO3	26.	36.	35.69	52.46	5	15.2	15.55	15.87	17.	6
Cl	5.6	6.8	7.	9.6	7	2.8	4.1	3.75	4.3	6
SO4	5.3	8.1	8.03	9.5	7	13.	16.35	16.08	18.1	6
NO3-N	1.7	3.1	3.43	5.1	7	5.	6.4	6.4	7.5	7
DRP	0.002	0.002	0.002	0.003	4	0.006	0.007	0.007	0.009	3
E-Coli	0.5	0.5	1.79	5.	7	0.5	0.5	1.25	5.	6
	Boatmans: Nov 07-Jan 14					**Garvey Ck: Nov 07-Jan 14**				
Cond	6.1	65.	54.02	70.	5	13.4	14.	58.08	128.	5
DO	1.74	4.95	5.	8.37	7	2.59	4.4	4.38	6.06	7
pH	5.68	6.4	6.4	7.3	7	5.6	5.9	5.81	6.	7
Ca	4.1	4.4	4.87	7.4	6	13.8	15.7	15.94	19.1	7
Fe	0.01	0.01	0.01	0.01	3	0.01	0.01	0.01	0.01	3
Mg	2.5	2.6	2.58	2.7	5	1.6	1.87	1.86	2.1	6
Mn	0.01	0.01	0.01	0.01	1	0.01	0.01	0.01	0.01	1
K	0.68	0.7	0.74	0.84	5	1.67	2.3	2.21	2.7	6
Na	3.2	3.5	3.52	3.8	5	3.4	4.05	4.02	4.6	6
HCO3	27.	29.	40.	98.	6	21.	23.	23.71	26.	7
Cl	2.3	2.8	2.82	3.3	5	7.5	8.25	8.35	9.2	6
SO4	2.2	3.1	3.66	6.9	5	5.4	8.75	8.42	10.3	6
NO3-N	0.13	0.21	0.23	0.36	6	4.8	6.1	6.26	8.7	7
DRP	0.001	0.013	0.011	0.019	3	0.002	0.002	0.002	0.002	3
E-Coli	0.5	0.5	25.5	150.	6	0.5	0.5	1.5	5.	6

Table 14b: Descriptive statistics for 23 wider site wells

Variable	Min	Mdn	Mean	Max	Count	Min	Mdn	Mean	Max	Count
	Gault Well: Jul 00-Jun 08					**Karamea-BW: Nov 07-Jan 14**				
Cond	84.	85.5	85.75	88.	4	46.5	498.	399.38	555.	4
DO	2.27	5.	4.35	5.58	8	3.16	9.16	8.29	10.6	5
pH	6.4	6.6	6.58	6.7	4	5.7	6.4	6.43	7.3	7
Ca	11.	12.2	11.98	12.5	4	14.8	22.35	21.96	30.	8
Fe	-	-	-	-	-	0.01	0.01	0.02	0.03	3
Mg	0.77	0.89	0.87	0.93	4	2.5	7.7	7.45	14.	8
Mn	-	-	-	-	-	0.017	0.294	0.294	0.570	3
K	0.63	0.84	0.81	0.91	4	3.9	24.65	23.66	46.	8
Na	3.18	3.33	3.35	3.57	4	13.7	24.	23.14	32.	8
HCO3	37.82	39.	38.98	41.	7	30.	58.	63.84	129.32	7
Cl	2.8	3.4	3.35	3.8	4	28.	48.	51.	85.	8
SO4	3.7	4.15	4.18	4.7	4	11.6	22.95	23.2	37.	8
NO3-N	0.32	0.5	0.57	0.89	13	3.	7.35	7.1	11.	8
DRP	0.001	0.005	0.004	0.009	12	0.007	0.014	0.090	0.250	3
E-Coli	-	-	-	-	-	0.	0.5	3.92	17.	6
	Havill Well: Nov 07-Jan 14					**Karamea-Kong Bch: Jul 10-Jan 14**				
Cond	11.8	110.	82.22	147.	5	20.1	26.15	88.03	229.	6
DO	5.69	9.17	8.7	11.33	8	8.7	9.87	9.94	10.79	6
pH	5.17	5.95	6.	7.	6	6.3	6.8	6.74	7.3	5
Ca	9.9	11.1	11.2	13.2	7	14.8	16.8	17.31	19.7	7
Fe	0.01	0.01	0.01	0.01	4	0.01	0.01	0.01	0.01	3
Mg	2.4	2.55	2.6	3.	6	2.5	3.2	3.14	3.7	7
Mn	0.005	1.453	1.453	2.900	2	0.017	1.458	1.458	2.900	2
K	0.93	1.4	1.55	3.	7	3.9	4.8	4.81	5.5	7
Na	6.1	6.7	6.71	7.2	7	13.7	18.6	18.31	22.	7
HCO3	25.	26.	30.82	54.9	6	30.	36.	41.02	67.1	5
Cl	8.1	8.3	8.87	11.1	7	28.	31.	32.43	44.	7
SO4	6.1	7.2	7.27	9.9	7	11.6	13.6	15.27	22.	7
NO3-N	4.1	4.4	4.6	5.6	7	3.	3.5	3.93	5.6	7
DRP	0.009	0.010	0.012	0.017	3	0.002	0.003	0.003	0.004	3
E-Coli	0.5	0.5	1.14	5.	7	0.5	0.5	1.14	5.	7
	Karamea-Baker: Nov 07-Jan 14					**Karamea-Umere: Nov 07-Jan 14**				
Cond	16.9	210.	199.23	360.	4	17.3	86.6	90.13	170.	4
DO	3.	4.97	5.96	10.2	5	3.6	5.9	6.19	9.45	6
pH	5.7	6.2	6.17	6.6	7	5.04	5.8	5.78	6.3	8
Ca	5.6	8.55	9.51	18.4	8	11.1	16.	17.57	33.	9
Fe	0.480	0.695	0.695	0.910	2	0.01	0.01	0.01	0.01	5
Mg	1.87	2.75	3.1	6.4	8	1.56	2.2	3.02	9.	9
Mn	0.167	0.198	0.198	0.230	2	0.021	0.320	0.320	0.620	2
K	2.3	3.3	3.29	5.5	8	3.2	5.2	6.66	19.7	9
Na	17.	23.5	28.63	50.	8	6.9	8.6	9.64	18.	9
HCO3	15.2	46.	42.99	60.	7	19.1	21.	38.01	110.	7
Cl	19.1	38.5	50.26	120.	8	12.9	17.	19.28	45.	9
SO4	0.25	0.38	1.09	5.5	8	11.	14.4	14.08	20.	9
NO3-N	0.	0.01	0.02	0.05	7	2.5	6.4	6.97	13.4	9
DRP	0.002	0.071	0.076	0.156	3	0.001	0.002	0.003	0.005	3
E-Coli	0.5	0.5	1.25	5.	6	0.5	0.5	1.06	5.	8

Table 14c: Descriptive statistics for 23 wider site wells

Variable	Min	Mdn	Mean	Max	Count	Min	Mdn	Mean	Max	Count
	Kowhai Downs: Nov 07-Dec 13					**Mitchell: Nov 07-Jan 14**				
Cond	9.1	99.	79.42	110.	5	56.	74.	70.4	76.	5
DO	4.67	7.65	7.46	9.88	4	2.36	4.2	3.94	5.51	6
pH	6.2	6.5	6.79	7.9	7	5.08	6.15	6.	6.5	6
Ca	13.9	14.9	17.07	30.	7	7.2	7.7	7.84	8.8	5
Fe	0.01	0.01	0.01	0.01	4	0.01	0.03	0.03	0.04	3
Mg	1.16	1.24	1.35	2.	7	0.86	0.91	0.92	1.	4
Mn	0.	0.	0.	0.	1	0.02	0.02	0.02	0.02	1
K	1.19	1.24	1.25	1.34	7	2.1	2.1	2.2	2.5	4
Na	2.	2.4	2.34	2.5	7	3.4	3.75	3.68	3.8	4
HCO3	39.	42.	50.4	96.	7	22.	22.	24.2	29.	5
Cl	1.7	1.9	2.21	3.7	7	3.	4.35	4.15	4.9	4
SO4	4.9	5.7	5.93	8.2	7	0.	4.5	3.66	4.9	5
NO3-N	0.48	1.57	1.53	2.1	8	0.53	1.1	1.15	1.87	4
DRP	0.003	0.004	0.006	0.012	4	<0.004	0.002	0.002	0.004	3
E-Coli	0.5	0.5	1.21	5.	7	0.5	0.5	0.5	0.5	5
	Maimai: Nov 07-Jan 14					**Parrkinson: Nov 07-Jan 14**				
Cond	16.	136.	116.44	263.	8	9.8	93.	76.96	102.	5
DO	2.98	5.74	5.28	8.1	7	3.99	5.6	5.56	7.33	7
pH	5.8	5.95	6.02	6.3	6	5.9	6.3	6.19	6.5	7
Ca	16.	19.5	21.45	30.	8	6.	8.8	8.34	9.1	7
Fe	0.01	0.01	0.01	0.01	5	0.01	0.01	0.01	0.01	3
Mg	1.8	2.3	2.59	3.8	7	2.3	2.35	2.4	2.6	6
Mn	0.005	1.103	1.103	2.200	2	0.002	0.002	0.002	0.002	1
K	2.1	4.05	4.34	6.5	8	0.87	0.94	0.93	1.	6
Na	4.6	5.5	5.39	6.1	8	5.2	5.6	5.58	5.9	6
HCO3	19.5	28.	30.44	58.56	7	25.	26.	26.	27.	7
Cl	4.5	9.4	9.08	11.7	8	4.5	4.75	4.8	5.2	6
SO4	10.9	13.15	13.23	16.5	8	5.2	5.85	5.85	6.5	6
NO3-N	3.8	7.35	10.09	21.	8	2.6	3.2	3.11	3.6	7
DRP	0.002	0.002	0.002	0.003	4	0.010	0.010	0.011	0.014	3
E-Coli	0.5	1.	2.64	10.	7	0.5	0.5	1.33	5.	6
	Mills Fm: Nov 07-Jan 14					**Rooney Old: Feb 07-Jun 08**				
Cond	14.	127.5	103.52	170.	6	80.	83.	83.33	87.	3
DO	2.4	6.56	6.63	9.86	7	3.	7.03	6.07	7.83	10
pH	3.99	5.75	5.6	6.3	6	6.8	7.1	7.	7.1	3
Ca	8.8	14.	13.29	16.1	7	10.8	12.2	11.83	12.5	3
Fe	0.01	0.01	0.01	0.01	5	-	-	-	-	-
Mg	1.8	2.9	2.78	3.5	6	0.81	0.85	0.84	0.87	3
Mn	0.008	1.504	1.504	3.000	2	-	-	-	-	-
K	5.5	9.2	8.81	12.5	7	0.51	0.56	0.61	0.77	3
Na	4.8	5.7	5.68	6.5	6	3.33	3.62	3.57	3.76	3
HCO3	18.3	19.	26.76	56.12	5	39.	40.13	40.87	43.92	6
Cl	10.	11.9	11.87	14.5	7	2.6	3.1	3.	3.3	3
SO4	9.1	9.5	9.66	10.4	7	3.6	3.8	3.83	4.1	3
NO3-N	2.8	8.7	7.2	9.5	7	0.26	0.65	0.6	0.79	11
DRP	0.001	0.001	0.001	0.002	3	0.001	0.003	0.336	4.000	12
E-Coli	0.5	3.	8.56	23.	8	-	-	-	-	-

Table 14d: Descriptive statistics for 23 wider site wells

Variable	Min	Mdn	Mean	Max	Count	Min	Mdn	Mean	Max	Count
	Rotomanu Station: Nov 07-Dec 13					**Taramakau: Nov 07-Dec 13**				
Cond	84.	101.5	105.5	135.	4	7.7	69.	64.14	97.	5
DO	7.69	10.2	9.83	11.5	7	6.04	6.66	7.34	9.54	7
pH	5.32	6.95	6.72	7.4	6	5.79	6.8	6.67	7.2	6
Ca	12.3	13.1	13.64	14.9	5	9.5	9.9	10.22	12.2	5
Fe	0.01	0.01	0.01	0.01	2	0.01	0.01	0.01	0.01	3
Mg	0.64	0.69	0.73	0.84	5	0.73	0.8	0.96	1.65	5
Mn	0.000	0.000	0.000	0.000	1	0.003	0.003	0.003	0.003	1
K	1.36	1.41	1.42	1.53	5	1.09	1.11	1.15	1.22	5
Na	1.79	2.1	2.03	2.2	5	2.2	2.5	2.9	4.5	5
HCO3	41.	45.	45.	49.	4	31.	32.5	34.75	43.	4
Cl	1.6	1.7	1.88	2.2	5	1.9	2.1	3.02	4.9	5
SO4	4.2	4.9	4.74	5.1	5	3.7	4.	3.98	4.4	5
NO3-N	0.1	0.3	0.53	1.65	7	0.41	0.49	0.6	0.94	7
DRP	0.004	0.004	0.005	0.008	3	0.007	0.008	0.010	0.015	3
E-Coli	0.5	3.5	3.08	5.	6	0.5	3.	2.83	5.	6
	Shaffery Well: Feb 07-Jun 08					**Upper Maruia R: Nov 07-Dec 13**				
Cond	89.	90.	90.67	93.	3	16.7	93.	95.14	180.	8
DO	5.3	5.63	6.07	7.3	6	7.9	9.	8.95	10.31	7
pH	6.6	6.7	6.67	6.7	3	7.4	7.9	7.82	8.1	6
Ca	11.9	12.8	12.67	13.3	3	28.	30.5	30.83	33.	6
Fe	-	-	-	-	-	0.01	0.01	0.01	0.01	3
Mg	0.87	1.01	0.97	1.03	3	1.97	2.05	2.06	2.2	6
Mn	-	-	-	-	-	0.000	0.000	0.000	0.000	1
K	0.79	0.88	0.86	0.9	3	1.18	1.3	1.28	1.35	6
Na	3.47	3.9	3.81	4.05	3	1.88	2.25	2.18	2.3	6
HCO3	44.	44.	44.	44.	3	94.	95.	97.67	110.	6
Cl	3.2	3.3	3.43	3.8	3	1.5	1.9	1.82	2.	6
SO4	3.4	3.7	3.77	4.2	3	4.6	5.65	5.45	5.9	6
NO3-N	0.32	0.5	0.54	1.33	11	0.25	0.47	0.5	0.89	7
DRP	0.001	0.005	0.005	0.006	8	0.001	0.002	0.004	0.010	3
E-Coli	-	-	-	-	-	0.5	0.5	0.83	2.5	6
	Springs Junction: Nov 07-Dec 13									
Cond	7.7	82.	67.34	92.	5					
DO	5.79	8.31	8.28	11.5	7					
pH	6.	6.2	6.37	7.2	6					
Ca	10.8	12.15	12.23	14.	6					
Fe	0.01	0.01	0.02	0.04	3					
Mg	0.93	1.03	1.03	1.18	6					
Mn	0.001	0.001	0.001	0.001	1					
K	1.	1.14	1.16	1.45	6					
Na	2.3	2.65	2.6	2.8	6					
HCO3	26.	29.5	30.	34.	6					
Cl	2.2	2.6	2.7	3.4	6					
SO4	2.4	3.8	3.58	4.3	6					
NO3-N	1.5	2.2	2.68	4.7	7					
DRP	0.002	0.006	0.007	0.014	3					
E-Coli	0.5	1.75	5.58	23.	6					

Table 15: Median levels for NGMP GWQ wells

Variable		Median Levels								
ID	Units	Agnew	Anderson	Bertacco	Coleman	Hunter	Hunter New	Milnes	VdG[1]	Westland
Cond	µS/cm	68.000	68.000	95.000	87.000	90.000	89.000	69.500	98.500	82.000
DO	mg/L	6.195	5.115	7.820	4.070	7.300	5.110	1.420	3.350	4.515
pH	Units	5.925	5.650	5.865	5.955	5.860	5.480	5.940	5.170	5.815
Ca	mg/L	10.400	9.650	9.900	13.800	8.900	11.500	8.700	12.600	5.900
Fe	mg/L	0.090	0.010	0.020	0.020	0.140	0.010	0.125	0.040	0.020
Mg	mg/L	1.000	1.400	2.600	1.600	2.000	2.000	1.300	1.950	2.800
Mn	mg/L	0.005	0.003	0.005	0.005	0.040	0.005	0.030	0.150	0.005
K	mg/L	2.150	2.700	0.720	2.300	1.400	1.600	1.100	2.550	1.800
Na	mg/L	2.750	3.040	7.600	2.700	7.900	5.800	5.600	3.850	8.500
HCO3	mg/L	31.000	33.000	29.000	44.000	37.000	23.000	31.000	16.000	32.000
Br	mg/L	0.030	0.030	0.050	0.030	0.060	0.035	0.040	0.140	0.044
Cl	mg/L	3.400	3.100	7.200	3.000	7.600	5.700	7.200	10.250	10.100
F	mg/L	0.040	0.045	0.043	0.030	0.060	0.059	0.033	0.015	0.090
SO4	mg/L	5.600	4.850	6.300	6.200	3.400	6.600	5.100	7.750	5.100
NH3-N	mg/L	0.010	0.005	0.010	0.010	0.030	0.005	0.005	0.005	0.010
NO3-N	mg/L	1.150	1.200	3.400	1.200	2.000	4.800	0.110	4.400	0.780
PO4	mg/L	0.040	0.040	0.040	0.040	0.040	0.020	0.040	0.025	0.040
DRP	mg/L	0.006	0.006	0.021	0.007	0.002	0.007	0.005	0.002	0.025
Silica	mg/L	8.000	12.900	20.000	9.200	14.800	12.200	11.700	4.600	16.650
E Coli	MPN	0.500	0.500	0.500	0.500	2.500	1.000	0.500	1.000	0.500

1. Van der Geest.

Table 16a: CBE fpr NGMP GWQ well data

NGMP Wells	Sample Count	Charge Balance Error			Remarks
		<-5%	-5% to 5%	>5%	
Agnews Res	53	1	52	0	HCO3 relatively high in many samples
Anderson Fm	41	0	41	0	HCO3 relatively high in many samples
Bertacco Fm	52	1	51	0	Mg and Na relatively high in many samples
Coleman Fm	55	0	55	0	HCO3 relatively high in many samples
Hunter Fm	26	3	23	0	-
Hunter Fm New	26	0	26	0	Na relatively high and HCO3 relatively low in many samples
Milnes	50	4	46	0	Ca relatively low and Cl relatively high in many samples
Van der Geest	37	2	35	0	Ca relatively high and HCO3 relatively low in many samples
Westland WW	53	1	50	2	Ca relatively low and Cl relatively high in many samples
Column Totals	393	12	379	2	

Table 16b: CBE fpr 23 wider sites well data

Wider Sites Wells	Sample Count	Charge Balance Error			Remarks
		<-5%	-5% to 5%	>5%	
All 23 wells	115	15	95	5	
Minimum	-49.4				
Median	-1.87				
Mean	-3.20				
Maximum	5.76				

Table 17: NGMP well groundwater age

#	Site Name	Site Name	Well ID	NZTM		Median GW Level	Screen Interval	Total Depth	Groundwater MRT
				Easting	Northing				
1	Agnews Res	HK31	290	1439978	5255423	1.82	Unknown	3	1 year
2	Anderson Fm	HK39	65	1439560	5246443	8.30	Unknown	~ 7-10	47 years
3	Bertacco Fm	GR17	102	1481417	5311122	6.26	35-37 m	37	1.5 years
4	Coleman Fm	HK34	291	1436947	5253002	2.99	Last 2 m	~ 7-10	Ambiguous
5a	Hunter Fm GW	GR04	287	1482688	5316128	2.62	Unknown	5	40 years
5b	Hunter Fm New	GR24	487	1482786	5316122	1.37	Unknown	Unknown	Ambiguous
6	Milnes Fm	BU-01	286	1484550	5371338	7.71	16-18 m (< Jun 99) 22-24 m (> Jun 99)	18 24	4 years
7	Van der Geest	GR02	203	1479420	5320505	5.35	Unknown	Unknown	45 years
8	Westland WW	HK25	289	1433302	5268616	2.45	11-13 m	13	5 years

Table 18: Selected New Zealand drinking water standards

Variable	Full Name	NZDWS-2008		Units	Objective/Remarks
		MAV	GL		
General:					
Cond	Conductivity			µS/cm	No criterion
DO	Dissolved oxygen			mg/L	No criterion
pH	-		7.0-8.5	Units	Taste/disinfection
E-Coli	Escherichia coli	<1		#/100 mL	Health
Hardness	-		200	mg/L	Scale/scum
Silica	-				No criterion
TDS	Total dissolved solids		1,000	mg/L	Taste
Cations:					
Ca	Calcium		See hardness		-
Fe	Iron		0.2	mg/L	Staining
Mg	Magnesium		See hardness		-
Mn	Manganese	0.4	0.04	mg/L	Health/Staining
			0.1	mg/L	Taste
K	Potassium				No criterion
Na	Sodium		200	mg/L	Taste
Anions:					
HCO3	Bicarbonate				No criterion
Br	Bromide				No criterion
Cl	Chloride		250	mg/L	Taste/corrosion
F	Fluoride	1.5		mg/L	Health
SO4	Sulfate		250	mg/L	Taste
Nutrients:					
NH3-N	Ammonia-nitrogen		1.5	mg/L	Odor
NO3-N	Nitrate-nitrogen	11.3		mg/L	Health
PO4	Phosphate				No criterion
DRP	Dissolved reactive phosphorus				No criterion

1. Ministry of Health. 2008. Drinking-water standards for New Zealand 2005 (revised 2008). Wellington, 163 pages.

Table 19: Maximum levels for NGMP wells[1]

Variable		Maximum Levels								
ID	Units	Agnew	Anderson	Bertacco	Coleman	Hunter	Hunter New	Milnes	VdG[2]	Westland
Cond	µS/cm	141.000	80.000	176.000	164.000	174.000	144.000	168.000	162.000	169.000
DO	mg/L	10.100	10.200	11.400	9.290	13.100	6.770	9.950	9.870	11.300
pH	Units-Min	4.69	5.15	5.34	4.96	5.32	4.71	4.70	4.74	4.80
pH	Units-Mdn	5.93	5.65	5.87	5.96	5.86	5.48	5.94	5.17	5.82
pH	Units-Max	8.49	8.90	8.50	8.51	8.49	6.08	7.30	8.49	8.47
Ca	mg/L	13.500	13.700	11.400	16.500	10.500	14.800	9.400	20.000	6.800
Fe	mg/L	0.680	0.080	0.160	0.110	2.900	0.040	4.200	0.110	0.090
Mg	mg/L	1.200	1.600	3.000	1.900	2.400	2.600	0.000	3.000	3.200
Mn	mg/L	0.010	0.025	0.030	0.010	0.130	0.010	0.200	0.790	0.030
K	mg/L	2.800	3.050	2.100	2.900	1.700	2.100	1.900	4.700	2.400
Na	mg/L	3.700	4.000	9.700	6.200	10.100	7.000	6.800	5.100	10.400
HCO3	mg/L	37.000	46.000	37.000	51.000	44.000	29.000	39.000	19.700	37.000
Br	mg/L	0.100	0.070	0.150	0.120	0.100	0.050	0.100	0.380	0.100
Cl	mg/L	5.300	3.700	10.300	12.700	8.200	7.800	9.500	15.800	11.400
F	mg/L	0.090	0.090	0.090	0.080	0.070	0.090	0.090	0.030	0.140
SO4	mg/L	7.700	6.400	8.600	10.300	4.400	9.100	6.900	11.100	6.100
NH3-N	mg/L	0.090	0.030	5.400	0.110	0.160	0.050	0.020	0.050	0.040
NO3-N	mg/L	3.700	1.600	4.700	5.100	3.700	8.900	0.690	7.700	1.100
PO4	mg/L	0.100	0.040	0.100	0.100	0.100	0.020	0.100	0.025	0.100
DRP	mg/L	0.015	0.033	0.033	0.040	0.002	0.020	0.017	0.004	0.048
Silica	mg/L	9.700	14.600	24.000	14.600	19.400	14.600	13.300	6.800	21.000
E Coli	MPN	23.000	48.000	5.000	210.000	16.000	920.000	5.000	49.000	5.000

1. Includes outliers. Minimum, median, and maximum for pH.
2. Van der Geest.

Table 20: NGMP maximum levels compared to drinking water standards[1,2]

	NZDWS-2008		NGMP Well								
Variable	MAV	GL	Agnews	Anderson	Bertacco	Coleman	Hunter	Hunter New	Milnes	VdG[3]	Westland
pH-Min		7.0-8.5	4.69	5.15	5.34	4.96	5.32	4.71	4.70	4.74	4.80
pH-Mdn			5.93	5.65	5.87	5.96	5.86	5.48	5.94	5.17	5.82
pH-Max			8.49	8.90	8.50	8.51	8.49	6.30	7.30	8.49	8.47
E Coli	<1.		23	48	5	210	16	920	5	49	5
Hardness		200.	Data for combined Ca and Mg indicates less than 200mg/L								
TDS		1,000.	Data for major ions indicates less than 1,000 mg/L								
Fe		0.2	0.68	0.08	0.16	0.11	2.90	0.04	4.20	0.11	0.09
Mn	0.4	0.04	0.01	0.03	0.03	0.01	0.13	0.01	0.20	0.79	0.03
Na		200.	3.7	4.0	9.7	6.2	10.1	7.0	6.8	5.1	10.4
Cl		250.	5.3	3.7	10.3	12.7	8.2	7.8	9.5	15.8	11.4
F	1.5		0.09	0.09	0.09	0.08	0.07	0.09	0.09	0.03	0.14
SO4		250.	7.7	6.4	8.6	10.3	4.4	9.1	6.9	11.1	6.1
NH3-N		1.5	0.09	0.03	5.40	0.11	0.16	0.05	0.02	0.05	0.04
NO3-N	11.3		3.7	1.6	4.7	5.1	3.7	8.9	0.7	7.7	1.1

1. Maximum values except for pH. pH values are minimums, medians, and maximums.
2. Yellow highlight indicates MAV or GL, as appropriate, exceeded.
3. Van der Geest.

APPENDICES

APPENDIX A: Database Cleanup Measures

APPENDIX A1: Summary of GWL database cleanup measures for analysis

APPENDIX A2: Review and organization of NGMP GWQ database for analysis

APPENDIX A3: Review and organization of wider sites GWQ database for analysis

APPENDIX A1: Summary of GWL database cleanup measures for analysis

1. Only wells with more than 8 data points were used for statistical analysis.

2. A column in the GWL database for groundwater level during pumping was removed. It contained only one value out of 441 reported values.

3. When duplicate water level measurements were listed in the database for the same well on the same date, the measurement most consistent with historic values in the database was retained and the odd value deleted. Odd values generally appeared to be larger in magnitude (i.e., deeper depth) and were judged to likely reflect pumping influence.

4. There are water level data for three Bertacco Farm (Fm) wells. These are identified as "Bertacco Farm GW" (well ID #102), "Bertacco Farm No. 1 GW" (no well ID # listed), and "Bertacco Farm No. 2 GW" (well ID #500). The first of these is the well sampled for the NGMP. Values for this well exist for the June 1999-April 2005 period which are apparently erroneous. Many of these were listed as 15 m, the maximum length of the water level indicator used at that time rather than actual water level depth. Additionally, there are three values of 80 m listed for the 2004-2005 period and three values below 15 m listed for later dates, one each in the years 2007, 2008, and 2009. These have a wide range (i.e., between 18.50 and 28.20 m, which is not probable for ambient groundwater, and too few for trend analysis. Furthermore, the water level in this well is reportedly on the order of 20 m. All values in the database for this well have been rejected as unsuitable for analysis. With regard to "Bertacco Farm No. 1 GW," there was only one value in the database. It was 28.2 m. No further analysis is possible for this well. With regard to "Bertacco Farm No. 2 GW," data exist for the April 2000-January 2014 period. There are three values during 2004 of 80 m. They have been rejected as clearly erroneous. The remaining data for this well have been analysed. They fall with the range of 3.88 to 8.40 m. A value of 26.4 m was listed in the database for the Bertacco Fm No. 2 GW well on 23 March 2004. The well is reported to have a total depth of 9.2 m. This value was deleted as likely erroneous.

5. There are water level data for two wells at the Hunter Farms. One well was initially used for the NGMP. It is identified as "Hunter Farms GW" (well ID #287). The other replaced that well in June 2006 for NGMP purposes. It is identified as "Hunter Farms New GW" (well ID #454). Groundwater level data for both wells were analyzed separately and in combination.

6. Hunter Fm New well on the 9 Sep 10 measurement event. The water level is listed as -1 m. Reportedly, this should be -0.1 m. The actual measurement indicated a water level of 0.1 m AGL. For statistical purposes, this was treated as +0.1 m because of limitations in the WQStat+2 software for handling negative water level numbers. This adjustment would have negligible effect on the overall statistical analysis.

7. Two years of results were reported in the database for a well identified only as the "Knight Farm well at Campdown Road" (15 values). These were for the period April 2000 through February 2002. No well identification number or coordinates were provided about these data and current WCRC staff has no knowledge of this well or where it might actually have been located. Therefore, this well was deleted from this report.

8. Based on information provided by WCRC staff, well ID numbers and coordinates were corrected for the following wells:

a. Karamea River @ Blackwater Creek; and
b. Linton Bore @ Hokitika.

9. Based on information provided by WCRC staff, the following well listings in the database were deleted as duplicative:

a. Fowlie Farm @ Hokitika (part of Alison Farm);
b. Provis Bore @ Hokitika (part of Provis Farm @ Kowhitirangi);
c. Porter @ Maimai (part of Maimai Grey); and
d. Parker @ Hokitika (part of Parker @ Municipal Rd.).
e. The two entries in the database for Johnson Bore @ Hokitika are the same and were added. This well was also renamed Parker Farm @ Municipal Rd.

10. The Van Alphen Farm No. 1 and No. 2 wells are two separate wells but are located very close to each other and were assigned the same coordinates in the database.

APPENDIX A2: Review and organization of NGMP GWQ database for analysis

1. The "Agnews Res" well had two lines of data for 20 Apr 07 sampling event. There was a field result of 89 uS/cm on the first line with data for other analytes and a laboratory value of 57 uS/cm on a second line by itself from a sample taken a half hour earlier. The field value on the first line was used.

2. Anderson Fm well had two lines of data for 20 Apr 07 sampling event. There were a large number of analytes on the first line and only six on second. Analytes on the second line were major cations, sulfate, and nitrate-nitrogen. These values appear to be similar to those in the first line for the same six analytes. The reason for the second line was unknown, but if may have been a split for those analytes only. However, the similar values make it possible to use either line without causing a substantial difference. The first line was used and the second discarded.

3. Columns for total cations and anions were removed. These columns contained only scattered results for five sampling locations or dates out of 449 and in only two cases were results for both on the same date. These were reasonably close.

4. Column for hardness was removed. This column contained only three values reported out of 447 total samples taken. Hardness is generally a result of calcium and magnesium ion concentrations. Results for these major ions are in the database.

5. Column for combined nitrate-nitrite nitrogen was removed. This column contained only three values reported out of 449. For two of these, the value matched that of nitrate-nitrogen, for one there was a major difference. Nitrite-nitrogen is a transient species that is generally negligible compared to the concentration of nitrate-nitrogen in a sample.

6. Column for bicarbonate was removed. This column contained only five values reported out of 441 total samples. Of the five values, two were the same or close to that for reported

alkalinity, one was substantially less, and for the other two there was no reported alkalinity. For the two which were the same or close, it was assumed the value for alkalinity had been entered for bicarbonate. For the substantially smaller value, it was lower than reported alkalinity, which cannot be correct. Reported alkalinity appeared to be consistent with other values for the well involved. Therefore the lower bicarbonate value was removed as likely erroneous. For the other two with no comparable alkalinity values, the bicarbonate values were similar to other alkalinity values in the database. It was assumed that these were actually alkalinity values that had been misplaced in the bicarbonate column. Alkalinity by standard terminology means total alkalinity in mg/L equivalent $CaCO_3$. However, judging by ion balances, it appears that these values are actually bicarbonate in units of mg/L. Therefore, they were treated in that manner.

7. Column for nitrite-nitrogen removed. This column contained only three reported values out of 441 samples. All three were at a value of 0.001 mg/L. That use of the same low value could mean it was the detection limit rather than a detected concentration.

8. There were two columns for ammonia-nitrogen. One had only values for the 2007-2008 time frame. It was merged into the other column not having values for that time frame. All values were similar (i.e., in the 0.005-0.05 mg/L range and most were around 0.01 mg/l or less.

9. There are two columns for conductivity. These were labelled "Conductivity" and "Specific Conductance." There are fewer values in the specific conductance column (i.e., 273 reported of 441 total compared to 360 for conductivity). Values in the specific conductance column were generally marginally higher with median and mean levels of 101 and 103 uS/cm compared to 82 and 84 uS/cm for the conductivity column. However, the distributions had similar standard deviations (i.e., 21.1 for conductivity compared to 21.5 for specific conductance). Conductivity is the standard term for this water quality variable.

10. There were a few values for variables which were listed as less than (<) detection limits. These were replaced by a value of one-half of the detection limit. This is an commonly-used convention for which there are conflicting opinions in the literature. However, in this case, because of the few values involved and their magnitudes (i.e., generally substantially greater than detection limits), it is deemed acceptable. Since a number of values for the analytes involved were also listed at levels of one-half the detection limit, this convention may have already been implemented to some degree without notation in the database. The variables involved and number of cases for each in which this convention was implemented out of 441 total samples taken were:

Analyte	Number of Cases
a. Fe	5
b. Mn	10
c. Br	2
d. F	6
e. NH3-N	15
f. PO4	7

11. Hunter Farms had two lines of data for the 6 May 2008 sampling event. There were only values for chloride and ammonia-nitrogen on the second line and these were essentially the same on both lines. Therefore, the second line was deleted.

13. There were six lines of sampling dates for various wells for which there were no data after water level values were removed, only dates. These six lines were deleted.

14. Since the drinking water standard for bacteria in water in New Zealand is framed in terms of E. coli, columns for total coliform and fecal coliform were dropped. There were 194 samples for which total coliform values were available out of 441 samples. The median and mean values for total coliform were 1 and 9 cfu/100 mL, respectively, and the maximum 310 cfu/100 mL. There were 311 samples for which fecal coliform values were available out of 441 samples. The median and mean values for fecal coliform were 1 and 8 cfu/100 mL, respectively, and the maximum 1,600 cfu/100 ml. Similar data was listed for E. coli. For that variable, there were 335 values out of 441 samples. Median and mean values for E. coli were 1 and 5 cfu/100 mL, respectively, and the maximum was 920 cfu/100 mL. The minimum for all three variables was listed as zero (i.e., <1 cfu/100 mL).

APPENDIX A3: Review and organization of 23 wider sites GWQ database for analysis

1. "Dissolved phosphorus (total)" and "Dissolved Reactive Phosphorus" (DRP) columns were merged. These values generally appeared to be of similar magnitude. Where there was a difference, the DRP value was retained and the other deleted.

2. Particulate N and particulate P values were deleted. There were only 25 of these values out of 328 samples.

3. Clancy and Jackson's bores at Inchbonnie were deleted. There was no WCRC well ID or coordinates available for these wells. These are NIWA wells and there is only one reported sample for each in the database.

4. Columns for ionized ammonia and unionized ammonia were deleted with values for unionized ammonia transferred to the column for ammonia-nitrogen. Values for unionized ammonia and ammonia-nitrogen were similar and would be expected to be the same.

5. Values for dissolved Ca and total Ca, dissolved Mg and total Mg, were similar in magnitude and would be expected to be roughly the same. These columns were merged.

6. The column for dissolved "TN" (total nitrogen) was deleted.

7. There were only about four values each for total B, dissolved Cu, and total Mn. Total B and dissolved Cu columns were deleted while the values for total Mn were similar to those in the dissolved Mn column and were merged into it.

8. Columns for alkalinity and bicarbonate were largely redundant given the pH of samples involved . For the 15 values of alkalinity for which there was no bicarbonate value, a bicarbonate value was calculated using the atomic mass ratio.

9. There were no Br or F values. Therefore, those columns were deleted.

10. There was only one total As value. Therefore, that column was deleted.

11. All Cd values were listed as either zero or less than the detection limit of 0.0005 mg/L. Therefore that column was deleted.

12. All values for Pb were zero except three very low values near the detection limit. Therefore, the Pb column was deleted.

13. Non-detects changed to one-half the detection limit (DL). DLs varied for the same parameter, particularly in the case of microorganisms. DLs of 1, 2, and 10 were reported. For iron, DLs of 0.02 and 0.021 were reported. These were both replaced with 0.01. This precludes rigorous quantitative analysis. It appears that this had already been done in some cases with the less than sign dropped from the database. There were a number of values for microorganisms listed as >23 MPN. These were replaced by the value 23 MPN. There were values of 0 for bacterial concentrations. These were assumed to actually be <1 cfu/100 mL.

14. Values for alkalinity without corresponding values listed for bicarbonate or values for bicarbonate without corresponding values listed for alkalinity were calculated, assuming pH <8.3 units. All pH values in the database were <8.3 units. Values of <2 and <1, respectively, were listed for alkalinity and bicarbonate for a sample from the Burke Well @ Reefton on 7 August 2012. These were deleted as obviously erroneous.

15. Some sites listed two or three entries for the same sampling date or a date plus or minus one day of the sampling date. In these cases, there were generally a larger number of values on one date than the other(s) and where there were values for the same variables they were generally very similar. These dates were considered as one and combined for analytical purposes.

16. There were 273 values under the "specific conductance" column and 360 under the field conductivity column out of 441 samples. The field conductivity values were retained for analysis and the "specific conductance" values dropped.

17. There were 281 values under the DO as % saturation column and 262 under the DO in units of mg/L column out of 441 samples. Median and mean DO as % saturation were both 47%. DO values in units of mg/L were retained for analysis and DO as % saturation values were dropped.

18. Median and mean temperature values were 13.4 and 13.5 ºC, respectively. The range of temperatures was from a minimum of 8.3 ºC to a maximum of 17.9 ºC. There were 385 values for temperature out of 441 samples. These values were not analyzed further. Temperature measurements are useful for well purging but have limited utility otherwise.

19. Median and mean turbidity were 0.1 and 1.2 NTUs, respectively. The range of reported turbidity values was from a minimum of 0 to a maximum of 16.8 NTUs. There were 215 values out of 441 samples. These values were not analyzed further.

20. Alkalinity values were used to calculate bicarbonate values using atomic mass ratios and subsequently deleted. There were 395 alkalinity values out of 441 samples.

21. Median and mean values of dissolved reactive phosphorus (DRP) were 0.007 and 0.013 mg/L, respectively, for 57 reported values out of 441 samples. These were left in the data base for calculation of descriptive statistics.

22. Median and mean values of phosphate were 0.040 and 0.046 mg/L, respectively with a range from the minimum of 0.002 to the maximum of 0.100 mg/L. There were 118 reported values out of 441 samples. DRP is considered a more useful measure of potentially mobile

phophorus in groundwater. Phosphate generally has very limited mobility in groundwater systems. Therefore, phosphate was dropped and DRP retained.

23. Assumed that the value of 7.2 uS/cm in the database for the Mitchell @ Reefton well (#231) on 14 Feb 13 was actually 72 uS/cm, consistent with the levels on other sampling dates and made that change.

24. Assumed that the values for E-coli of <2 and <10 on 26 Jul 12 and 8 Jan 14, respectively for the Mitchell @ Reefton well were actually <1 cfu/100 mL, the standard DL. Also assumed that values of 0.5 on 19 Aug 10 and 29 Nov 11 had replaced the standard DL.

APPENDIX B: GWL Statistical Plots

APPENDIX B1: Outlier plots

APPENDIX B2: Time series plots

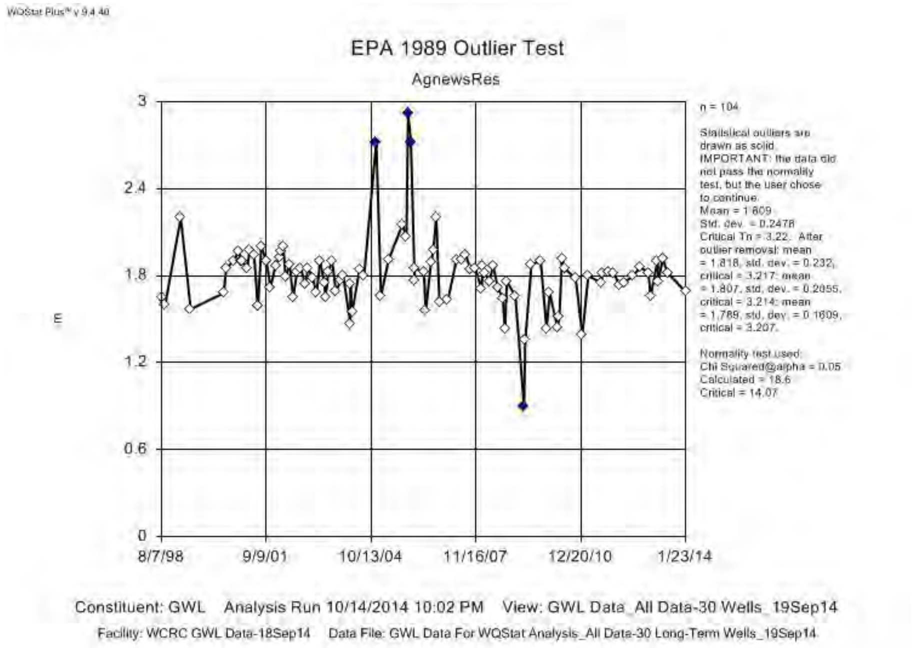
APPENDIX B3: Box and whiskers plots

APPENDIX B4: Seasonality plots

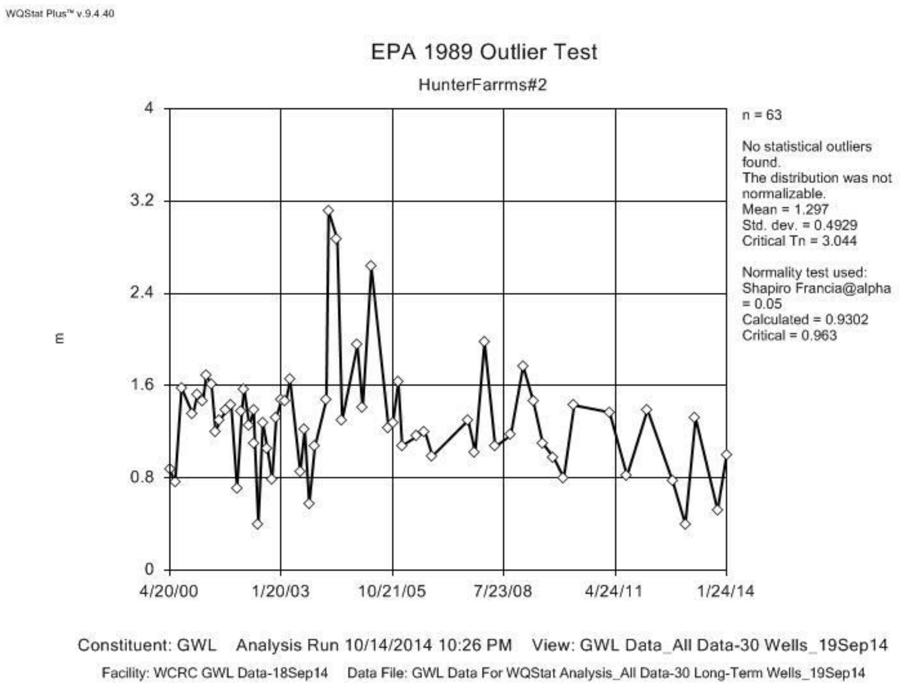
APPENDIX B5: Trend plots

APPENDIX B: Groundwater level (GWL) statistical plots

B1: Outlier plots

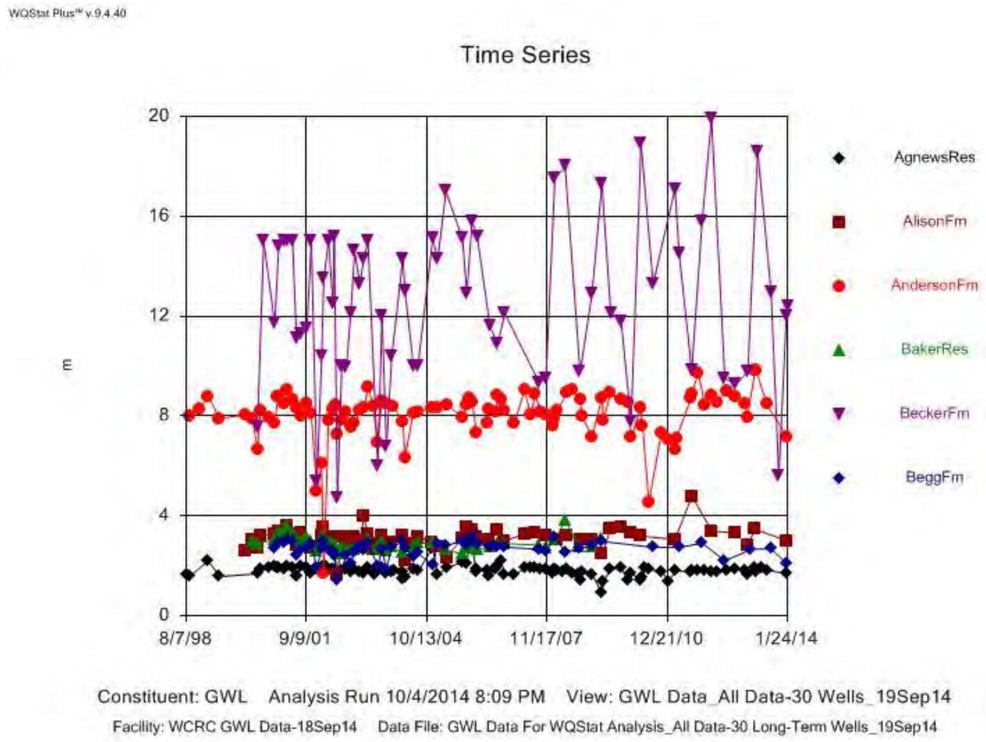


Plot #1 – Agnew Res well parametric statistical WL outliers

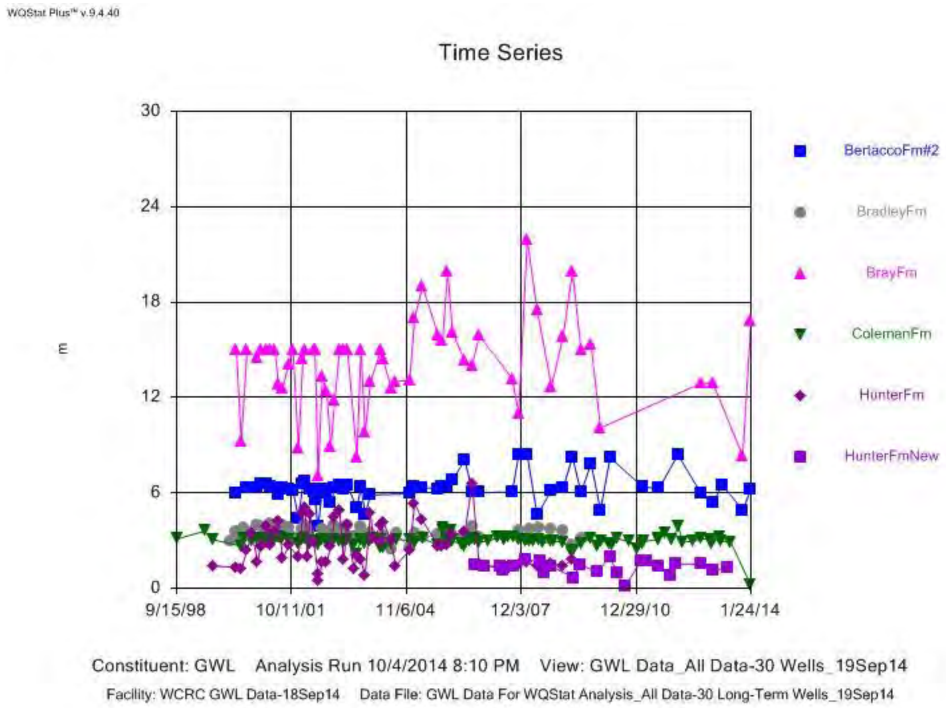


Plot #2 – Hunter #2 well nonparametric statistical WL outliers

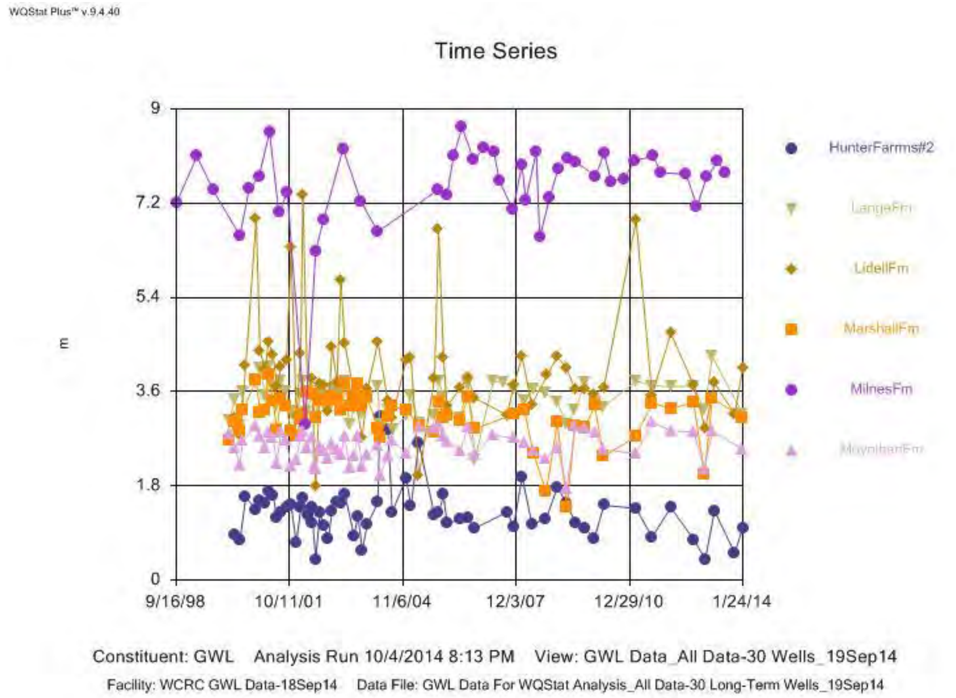
B2: Time series plots



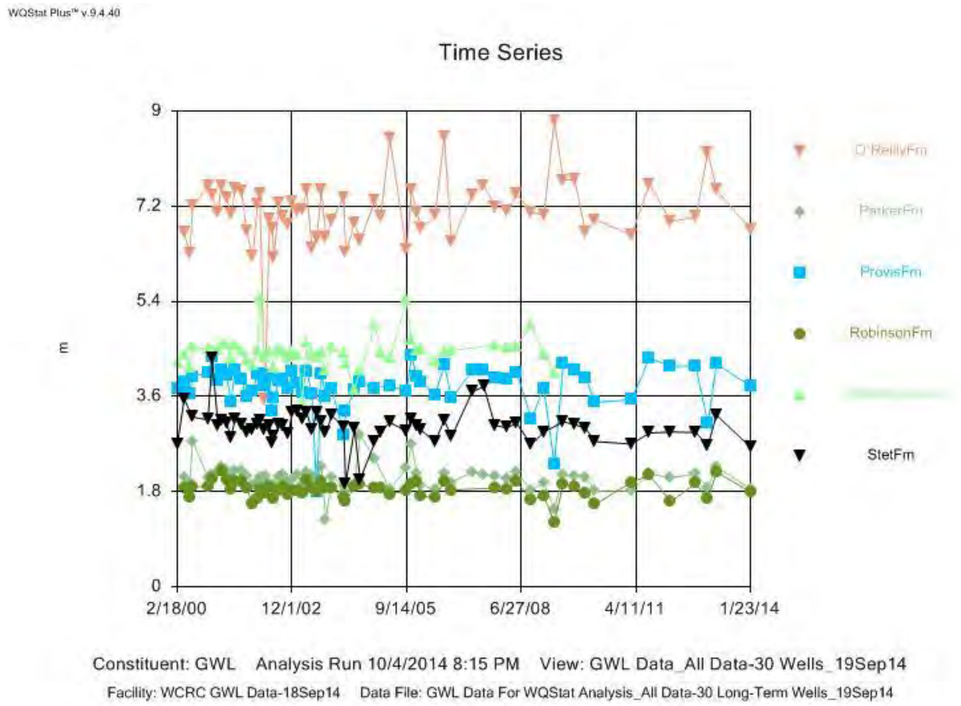
Plot #1: Wells Agnew Res through Begg Farm



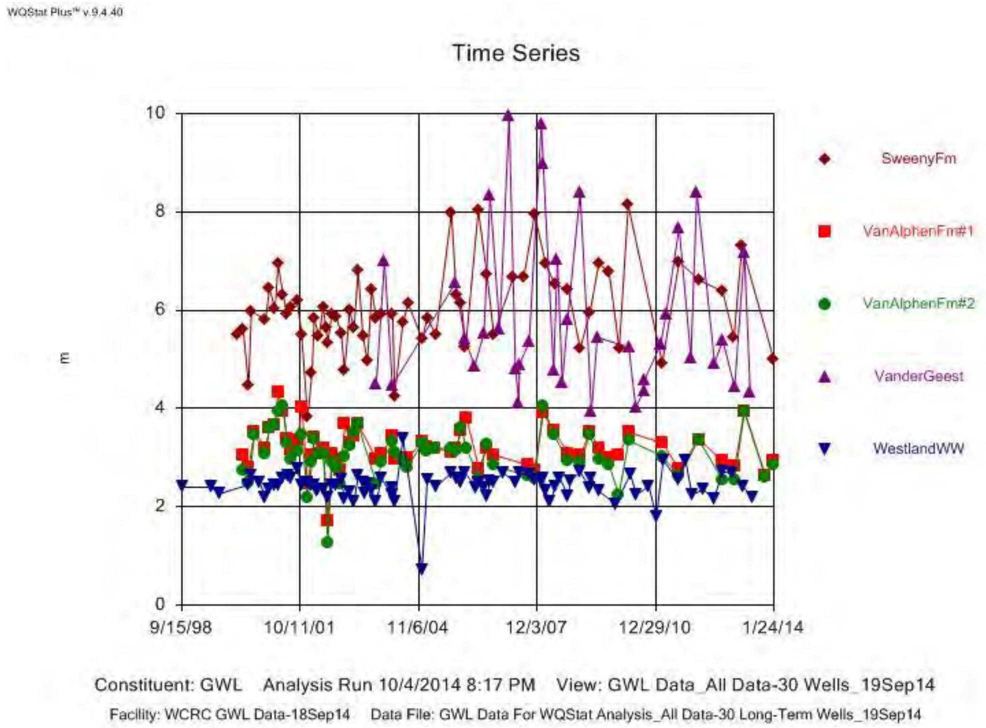
Plot #2: Wells Bertacco Farm through Hunter Farm New



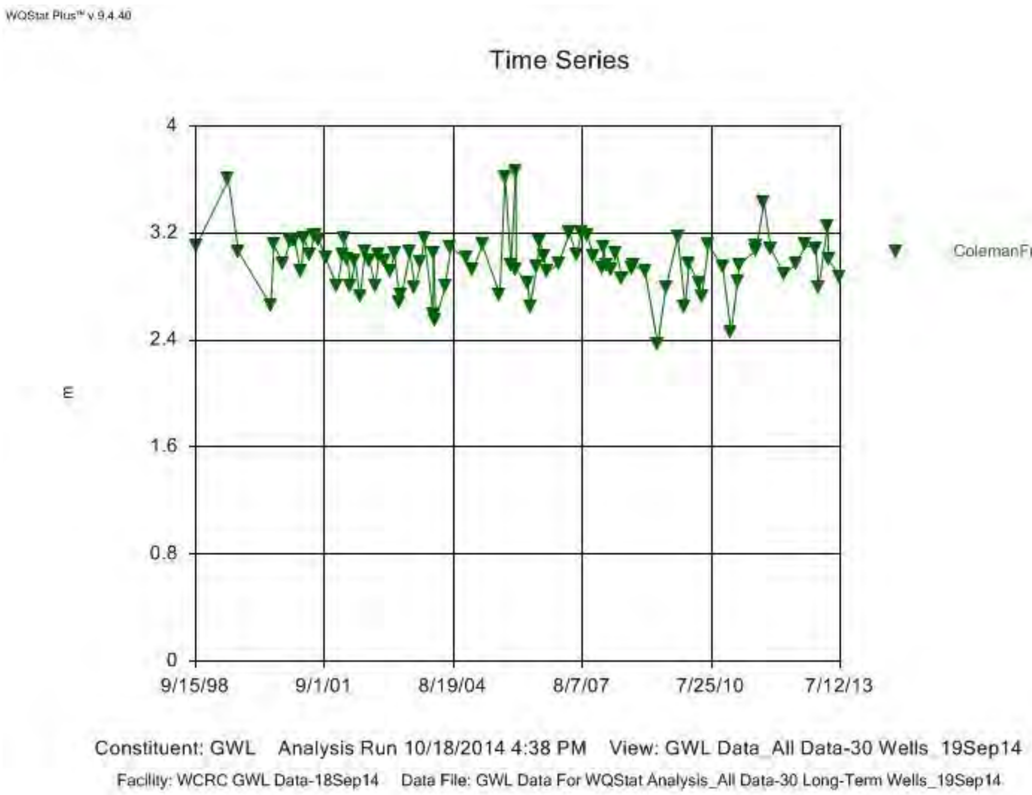
Plot #3: Wells Hunter Farm #2 through Moynihan Farm



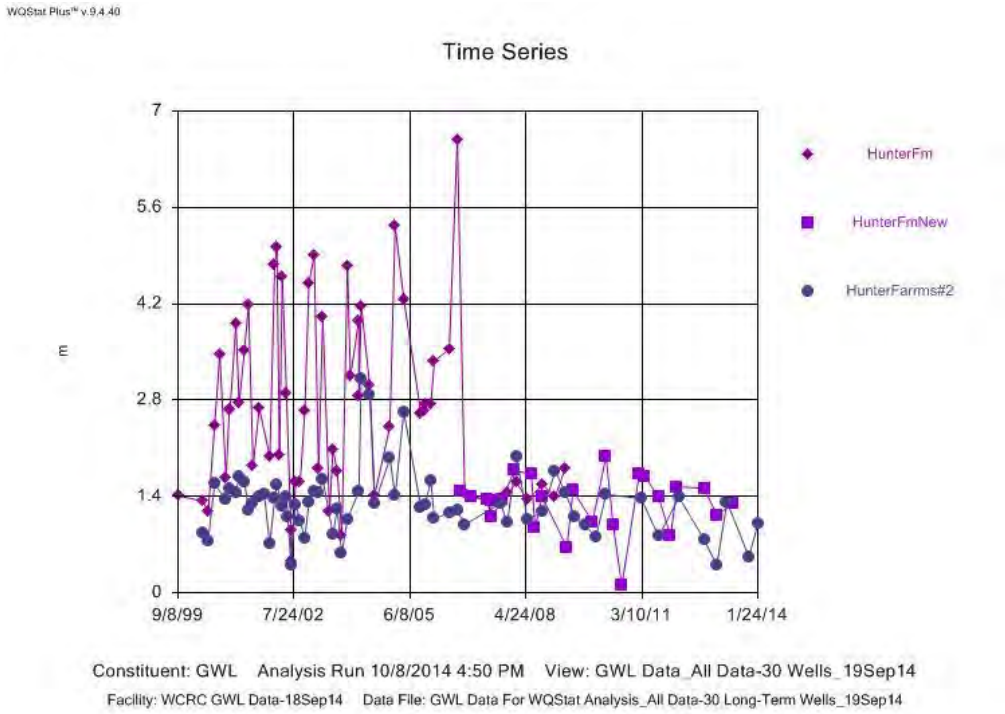
Plot #3 – Wells O'Reilly Farm through Stet Farm



Plot #5: Wells Sweeny Farm through Westland WW

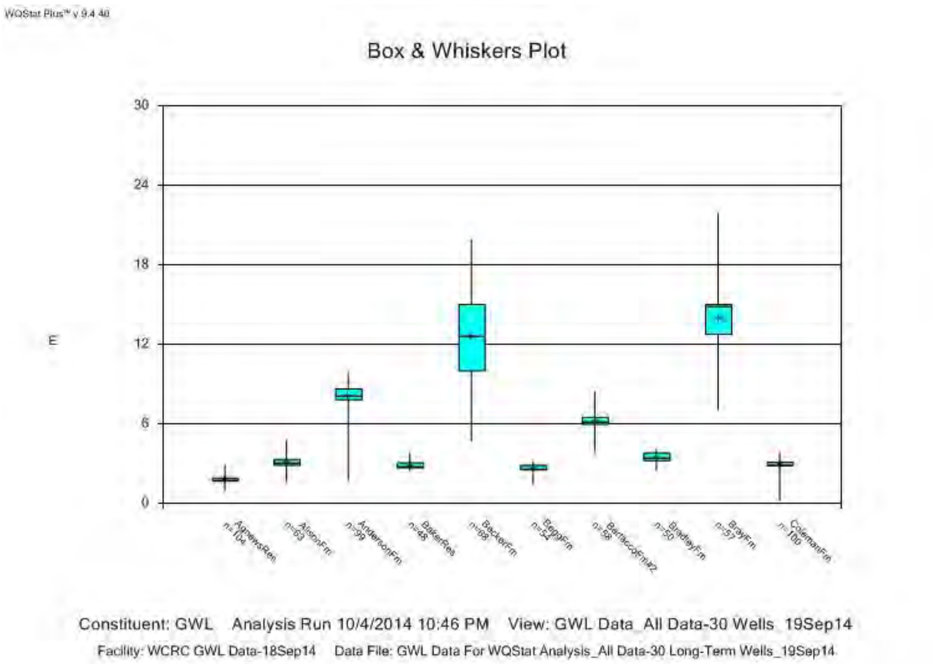


Plot #6: Coleman Fm Well

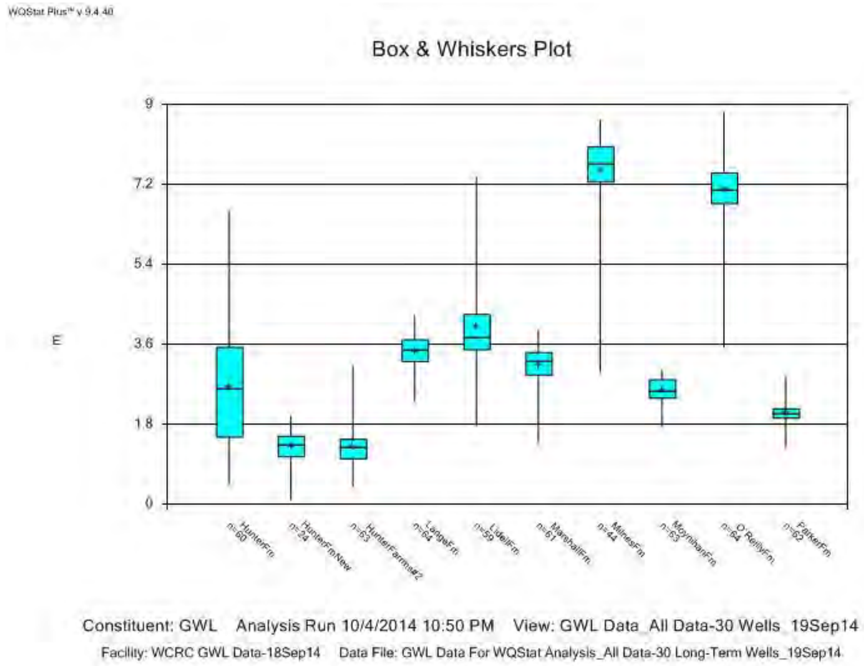


Plot #7: All Three Hunter Farm Wells

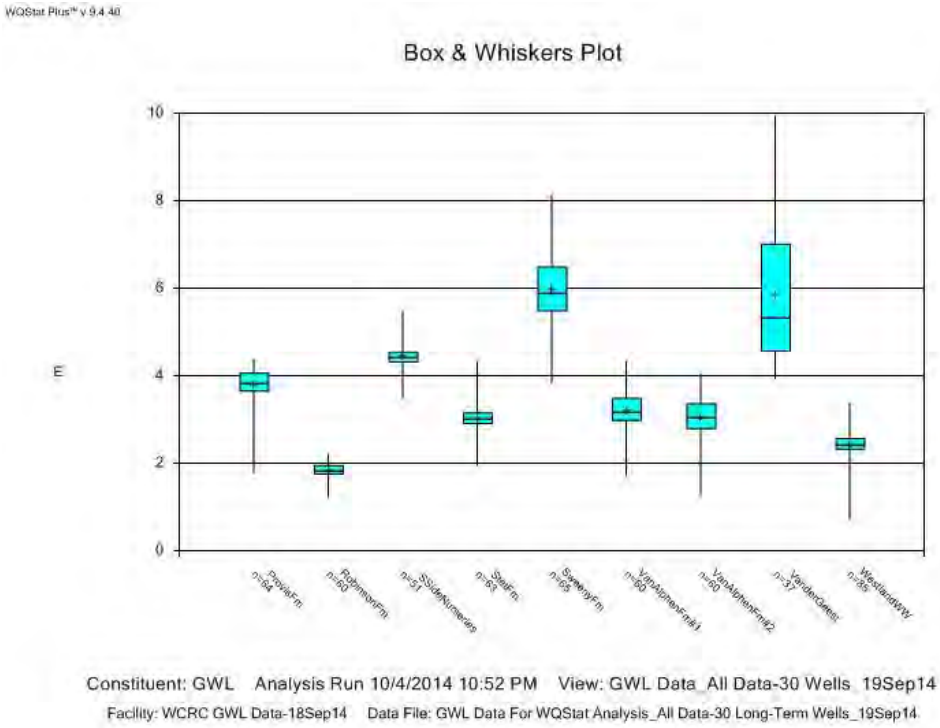
B3: Box and whiskers plots



Plot #1 – Wells Agnew Res through Coleman Fm



Plot #2 – Wells Hunter Fm through Parker Fm



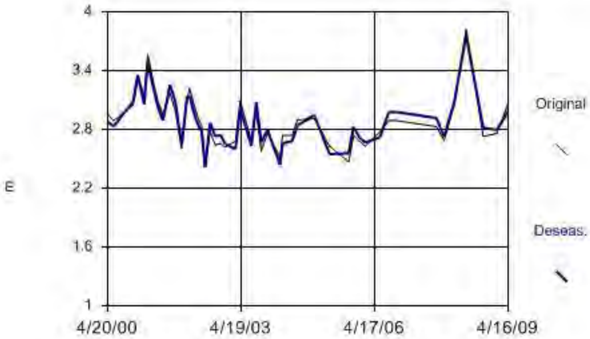
Plot #3 – Wells Provis Fm through Westland WW

B4: Seasonality plots

WQStat Plus™ v.9.4.40

Seasonality: BakerRes

For the selected data, the Kruskal-Wallis test indicates NO SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is less than or equal to the Chi-squared value, we conclude that no season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 2.69
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 11 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 2.688
Adjusted Kruskal-Wallis statistic (H') = 2.69



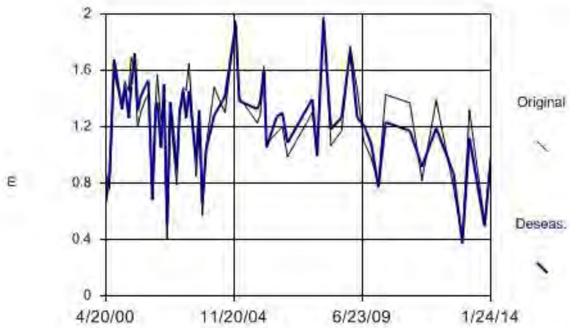
Constituent: GWL Analysis Run 10/6/2014 9:39 PM View: GWL Data_All Data-30 Wells_19Sep14
Facility: WCRC GWL Data-18Sep14 Data File: GWL Data For WQStat Analysis_All Data-30 Long-Term Wells_19Sep14

Plot #1 – Baker Res well

WQStat Plus™ v.9.4.40

Seasonality: HunterFarrms#2

For the selected data, the Kruskal-Wallis test indicates SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is greater than the Chi-squared value, we conclude that at least one season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 10.37
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 11 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 10.37
Adjusted Kruskal-Wallis statistic (H') = 10.37



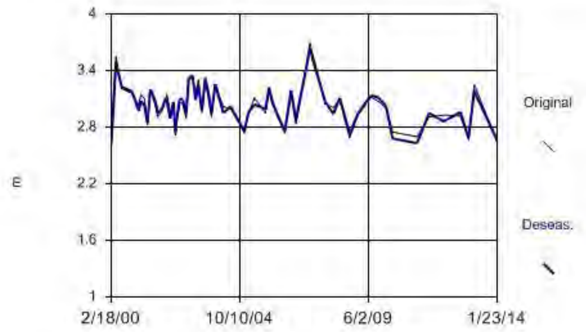
Constituent: GWL Analysis Run 10/6/2014 9:46 PM View: GWL Data_All Data-30 Wells_19Sep14
Facility: WCRC GWL Data-18Sep14 Data File: GWL Data For WQStat Analysis_All Data-30 Long-Term Wells_19Sep14

Plot #2 – Hunter Fm #2 well

WQStat Plus™ v.9.4.40

Seasonality: StetFm

For the selected data, the Kruskal-Wallis test indicates NO SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is less than or equal to the Chi-squared value, we conclude that no season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 2.176
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 14 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 2.174
Adjusted Kruskal-Wallis statistic (H') = 2.176



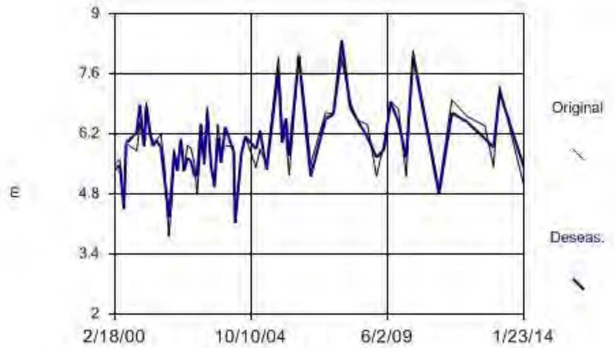
Constituent: GWL Analysis Run 10/6/2014 9:50 PM View: GWL Data All Data-30 Wells 19Sep14
Facility: WCRC GWL Data-18Sep14 Data File: GWL Data For WQStat Analysis_All Data-30 Long-Term Wells_19Sep14

Plot #3 – Stet Fm well

WQStat Plus™ v.9.4.40

Seasonality: SweenyFm

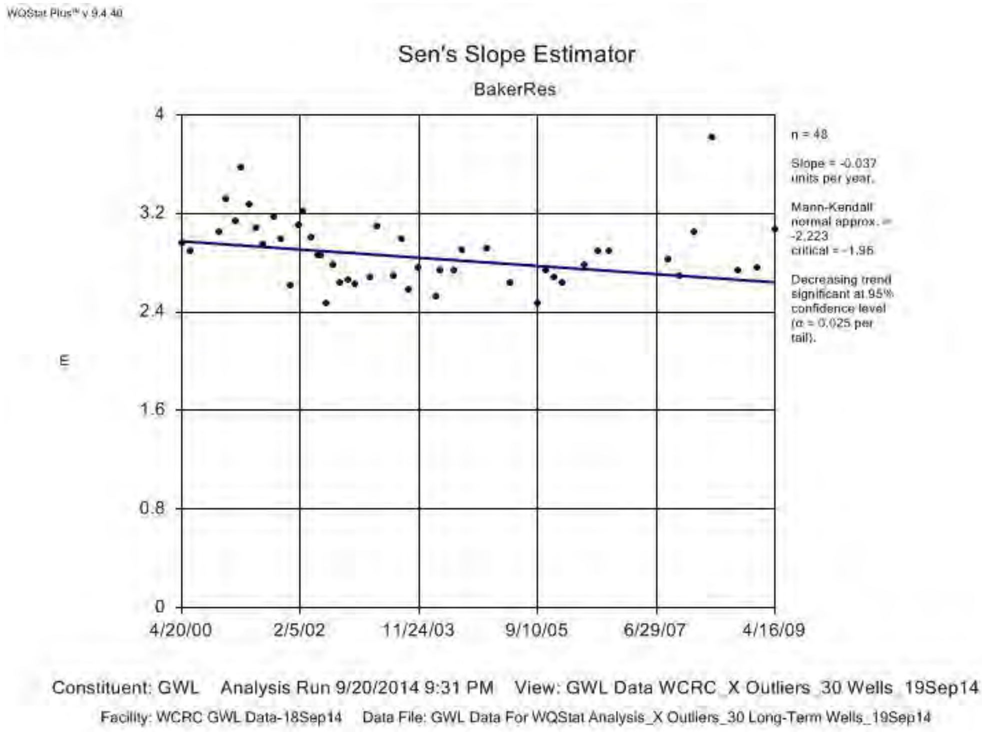
For the selected data, the Kruskal-Wallis test indicates SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is greater than the Chi-squared value, we conclude that at least one season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 8.369
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 9 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 8.367
Adjusted Kruskal-Wallis statistic (H') = 8.369



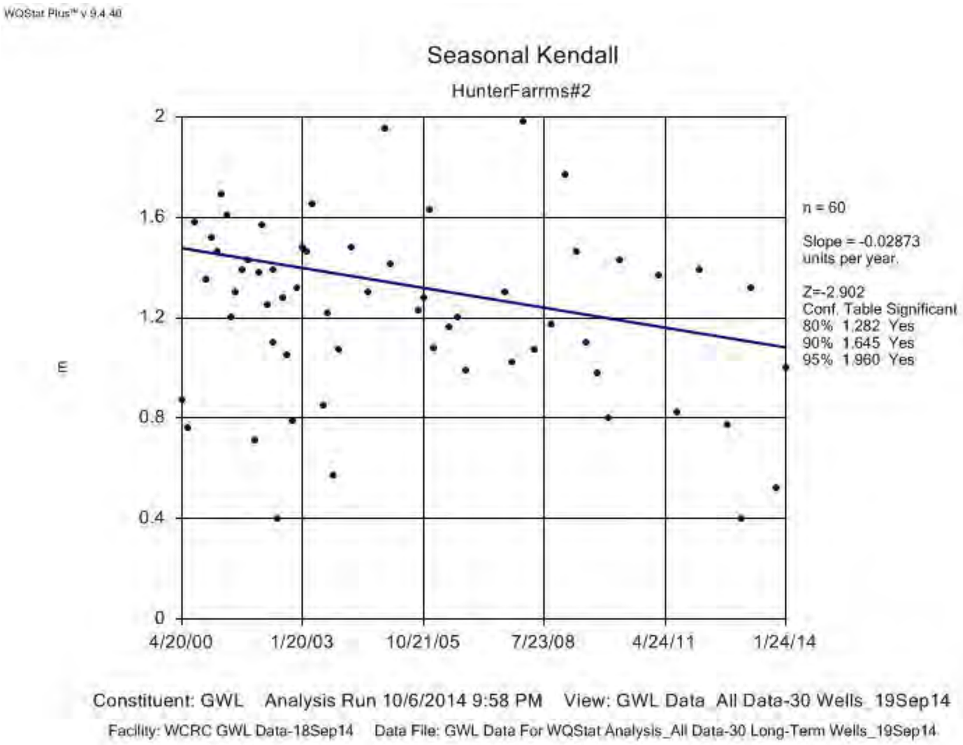
Constituent: GWL Analysis Run 10/6/2014 9:52 PM View: GWL Data All Data-30 Wells 19Sep14
Facility: WCRC GWL Data-18Sep14 Data File: GWL Data For WQStat Analysis_All Data-30 Long-Term Wells_19Sep14

Plot #4 – Sweeny Fm well

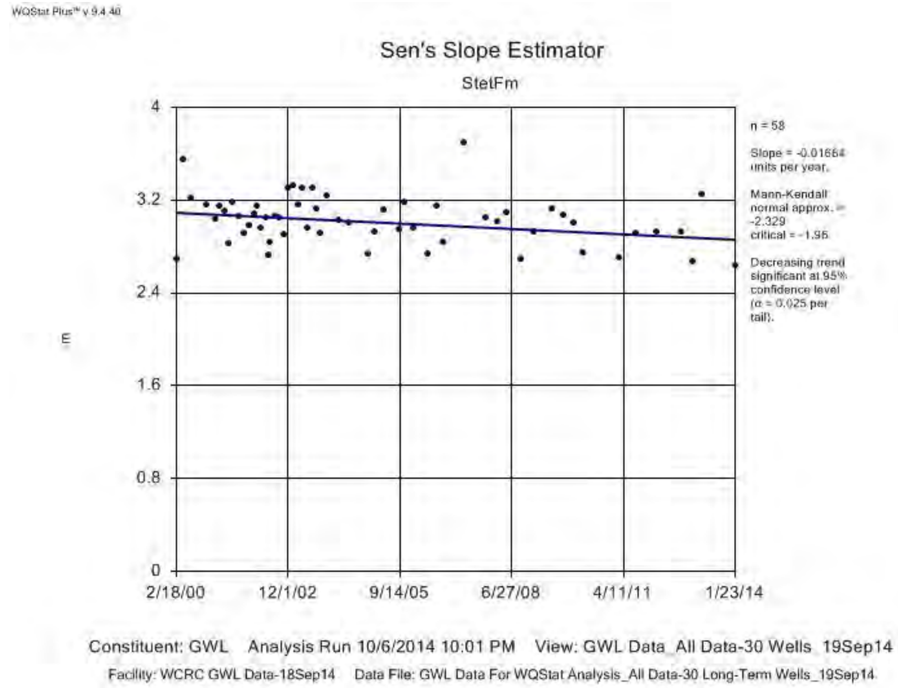
B5: Trend plots



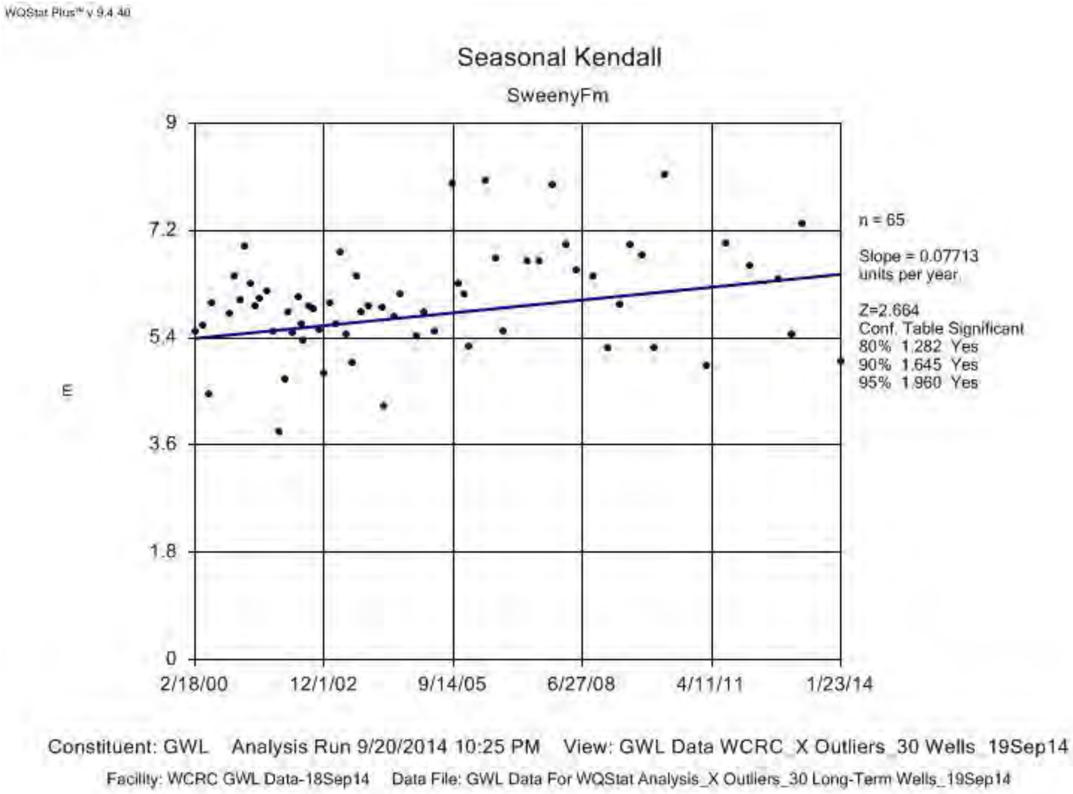
Plot #1 – Baker Res well



Plot #2 – Baker Res well



Plot #3 – Stet Fm well



Plot #4 – Sweeny Fm well

APPENDIX C: GWQ Statistical Plots

APPENDIX C1: DO time series and box and whiskers plots

APPENDIX C2: Outlier plots

APPENDIX C3: Time series plots

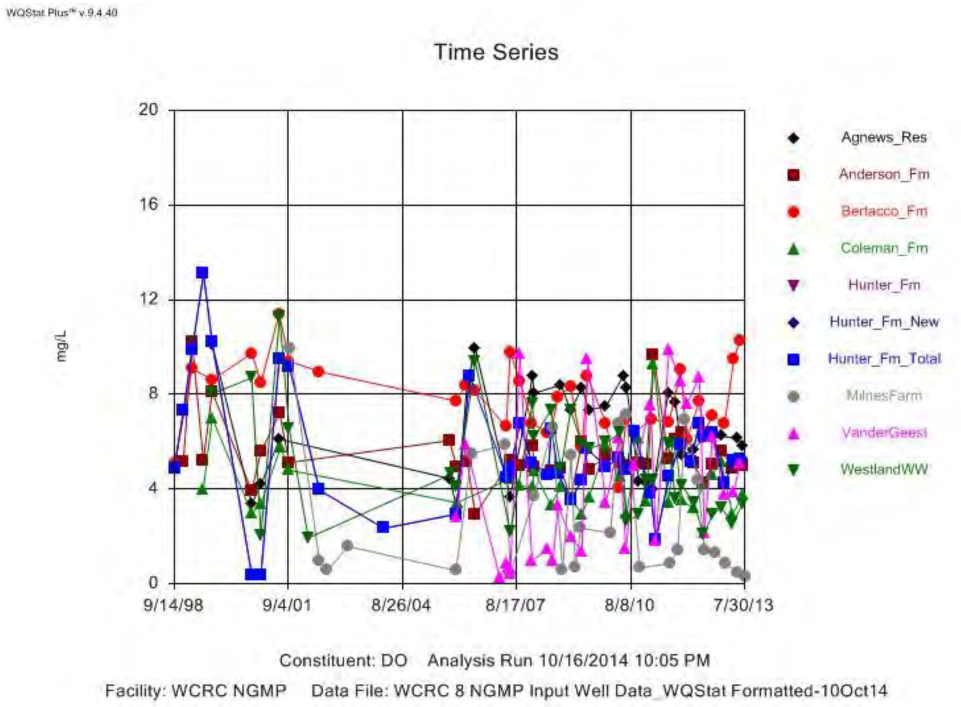
APPENDIX C4: Box and whiskers plots

APPENDIX C5: Seasonality plots

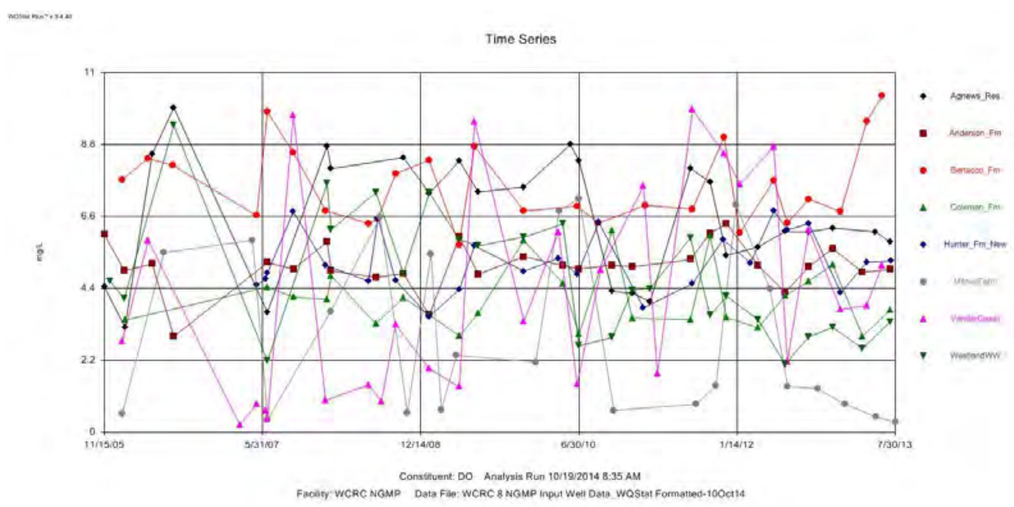
APPENDIX C6: Trend plots

APPENDIX C: Groundwater quality (GWQ) statistical plots

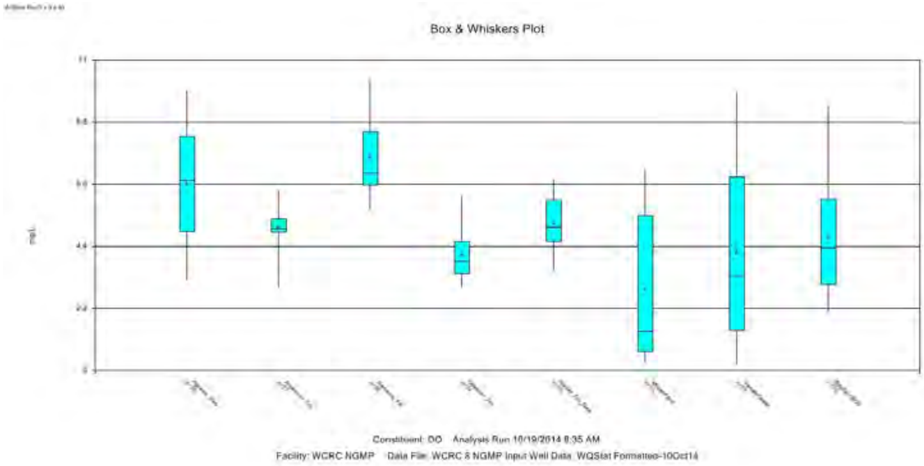
C1: DO time series and box and whiskers plots



Plot #1 – Time series for all NGMP wells

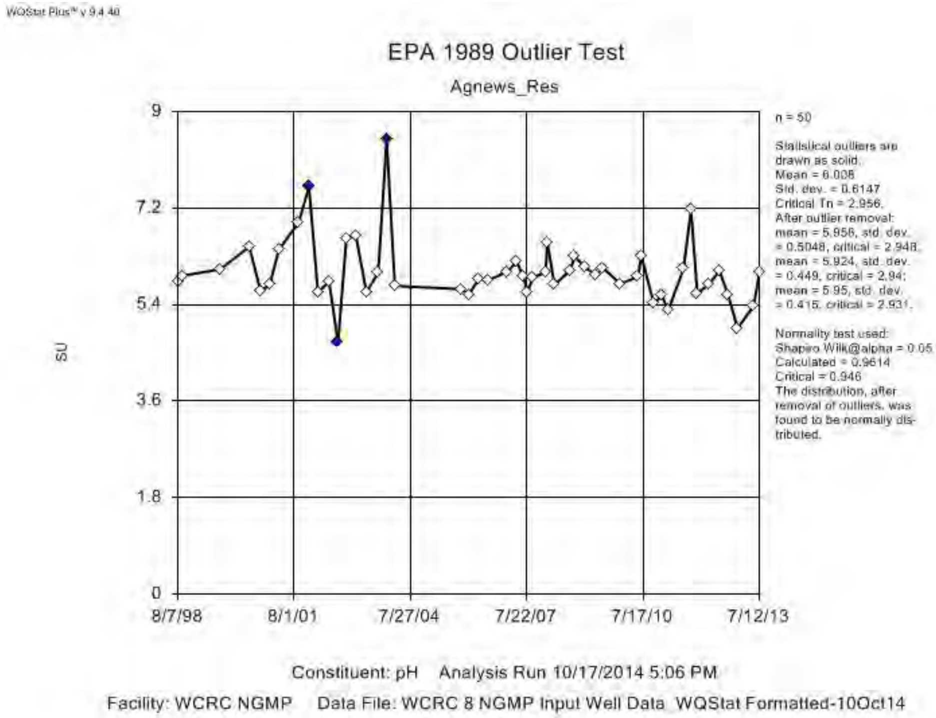


Plot #2: Time series for NGMP wells from late-2005 to mid-2013

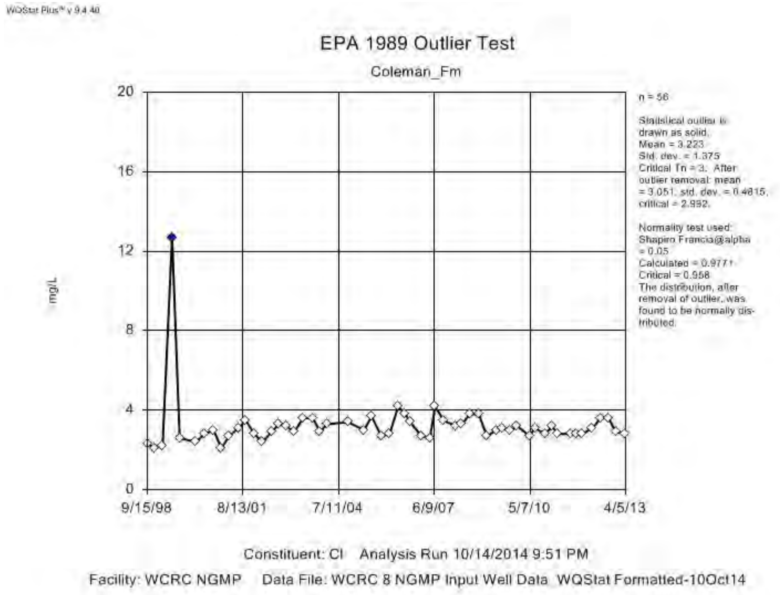


Plot #3 – Box and whiskers for NGMP wells from late-2005 to mid-2013

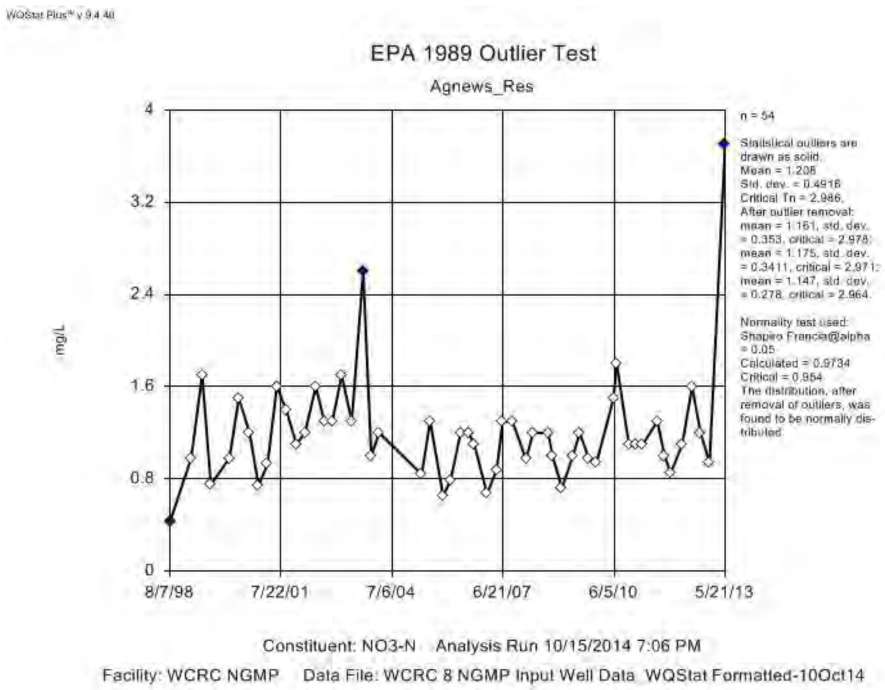
C2: Outlier plots



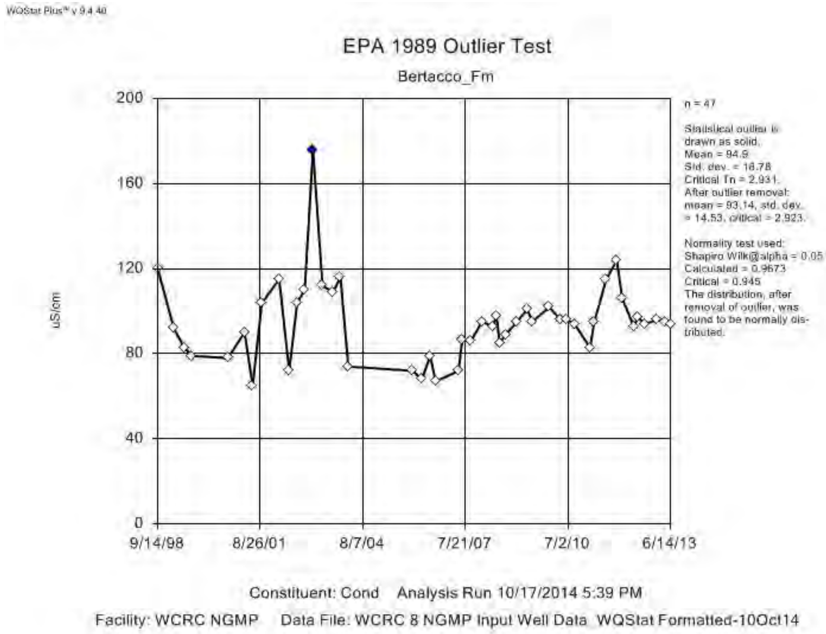
Plot #1 – Agnews Res well pH statistical outliers



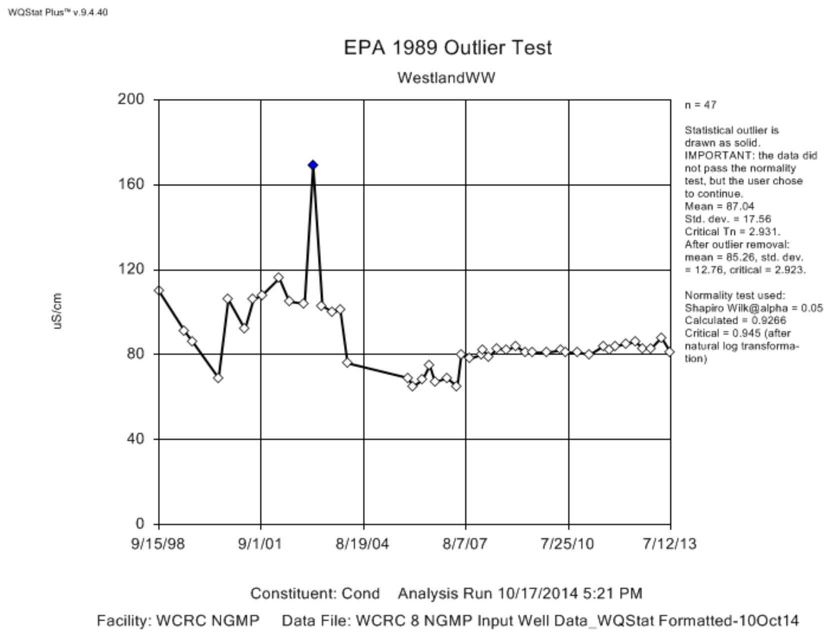
Plot #2 – Coleman Fm well chloride statistical outlier



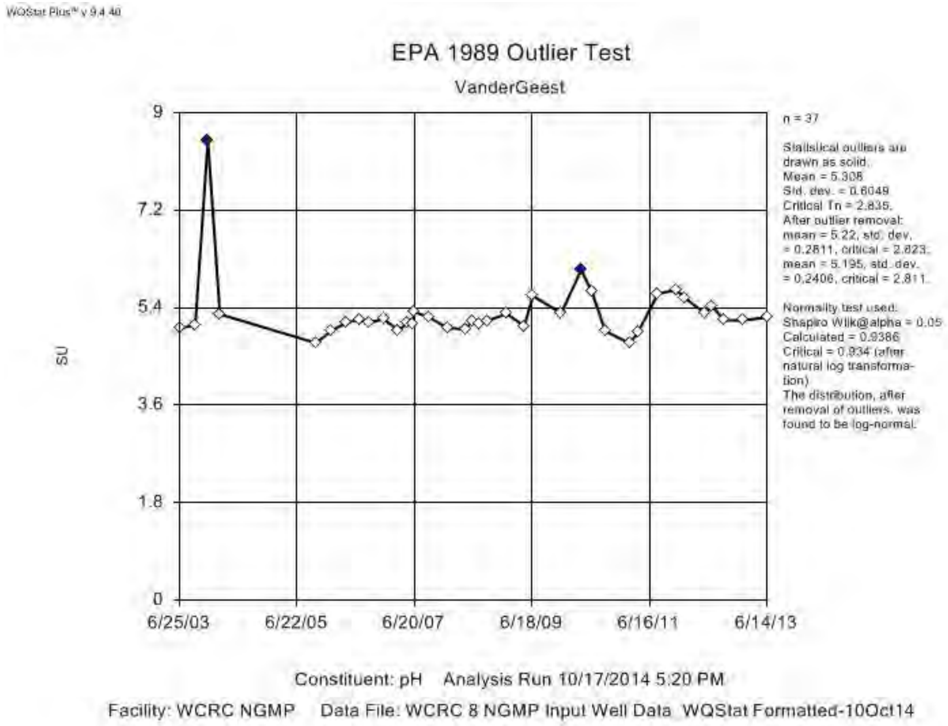
Plot #3 –Agnews Res well nitrate-nitrogen statistical outlier



Plot #4 – Bertacco well conductivity statistical outlier

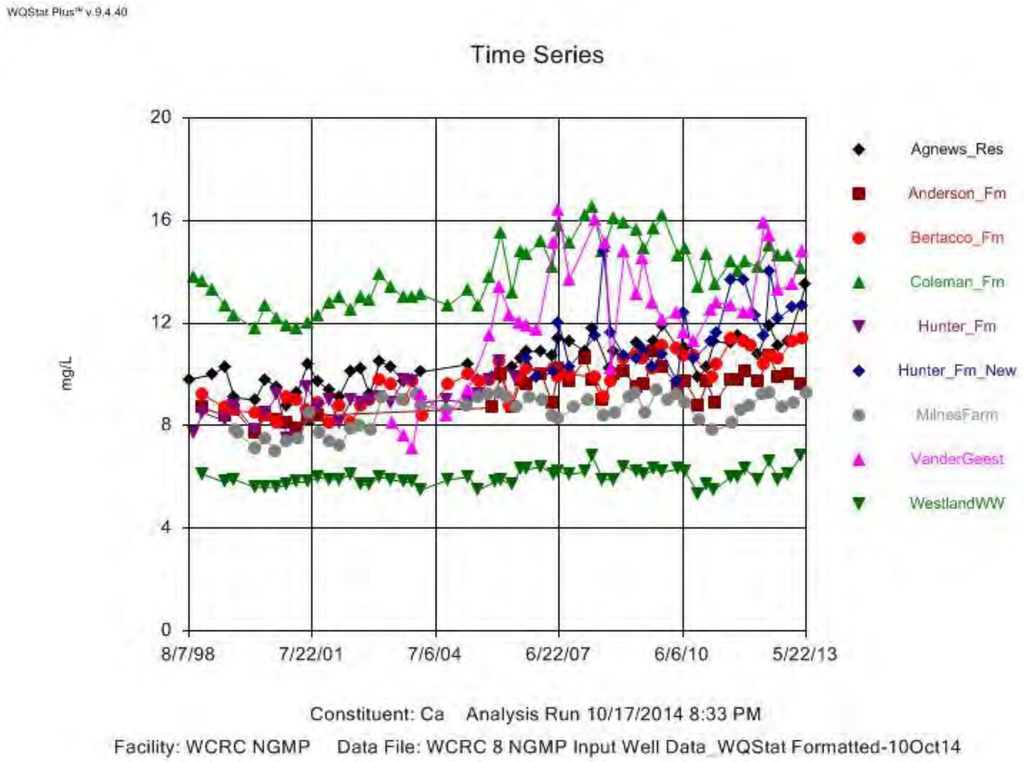


Plot #5 – Westland well conductivity statistical outlier

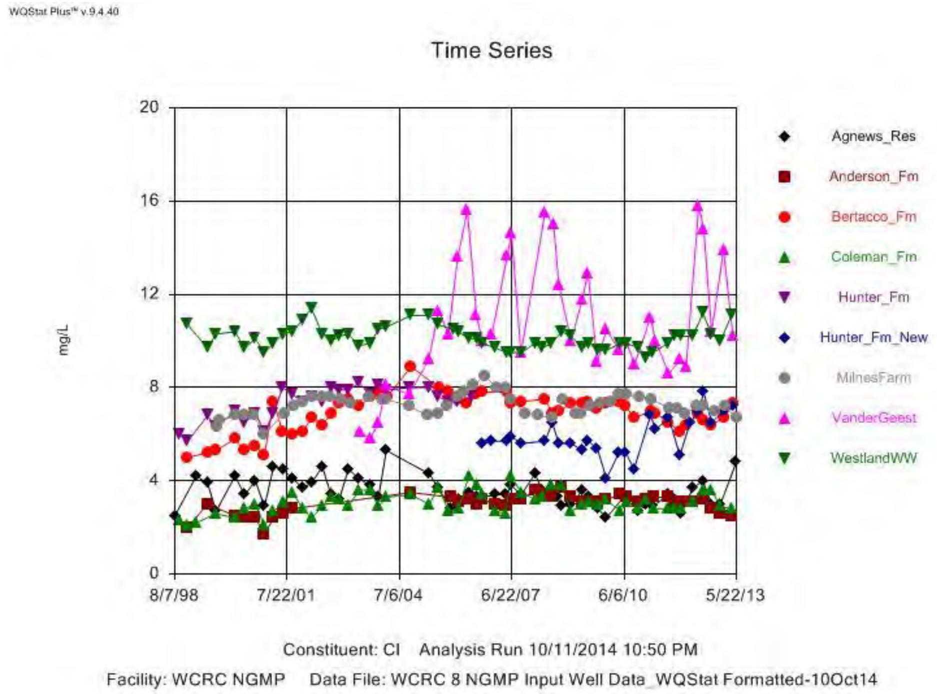


Plot #6 – Van der Geest well pH statistical outlier

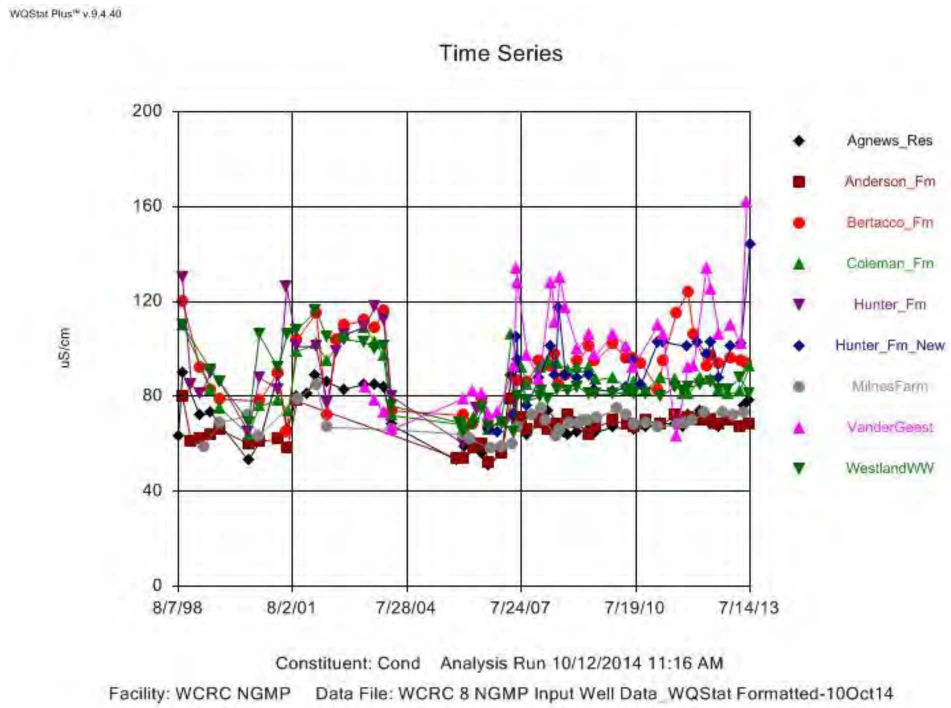
C3: Time series plots



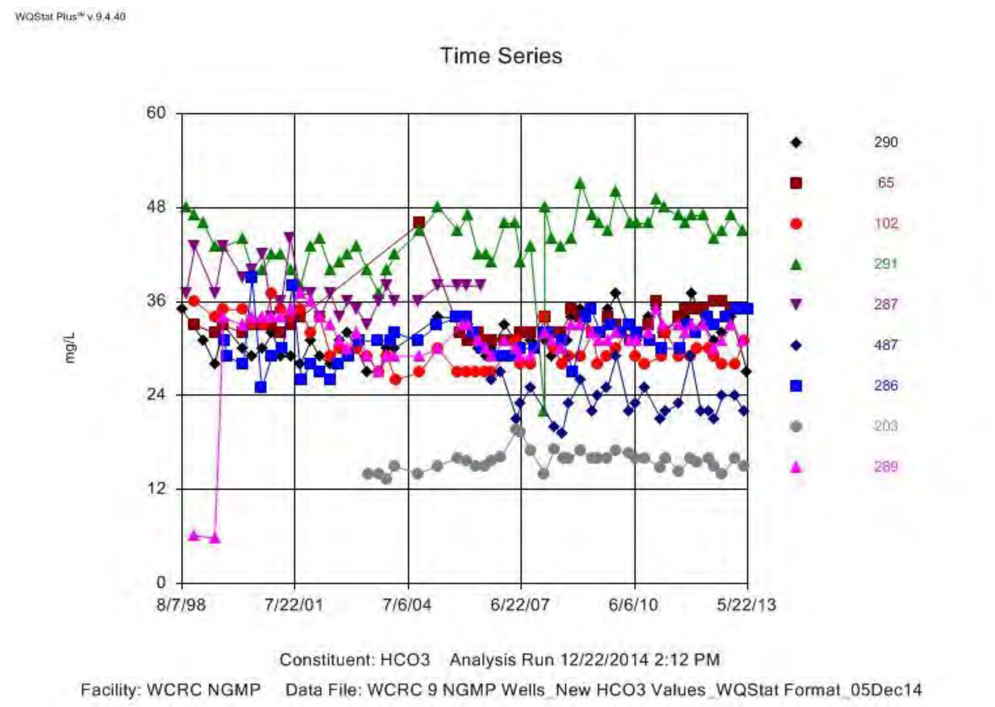
Plot #1 – Calcium for all NGMP wells



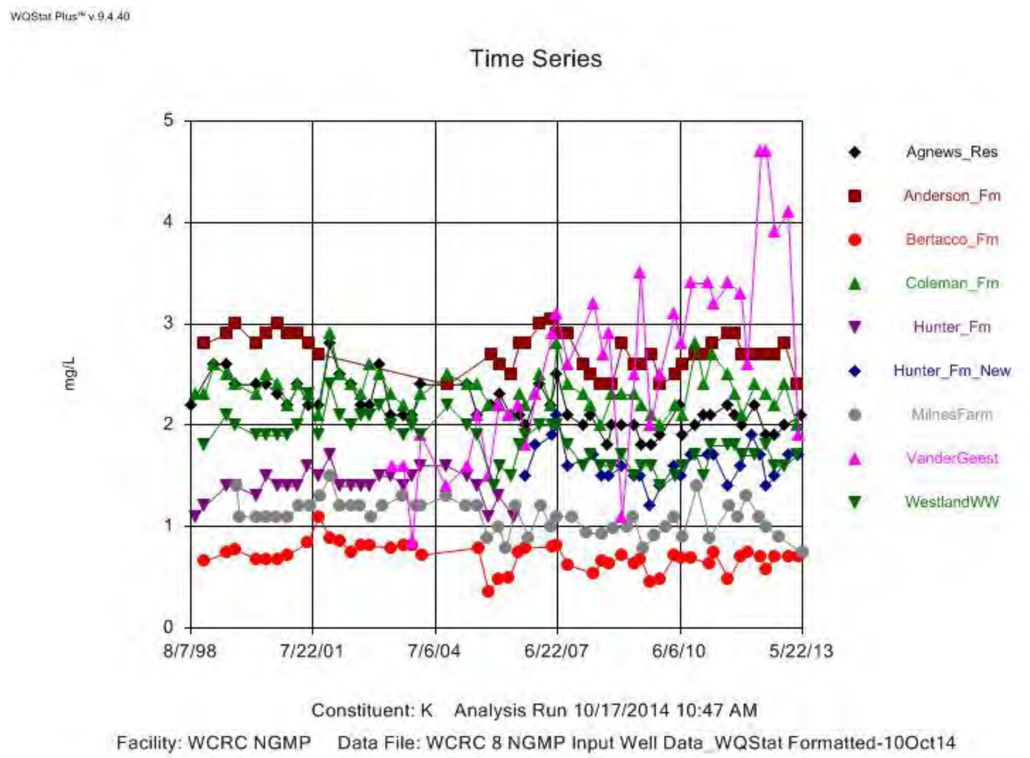
Plot #2 – Chloride for all NGMP wells



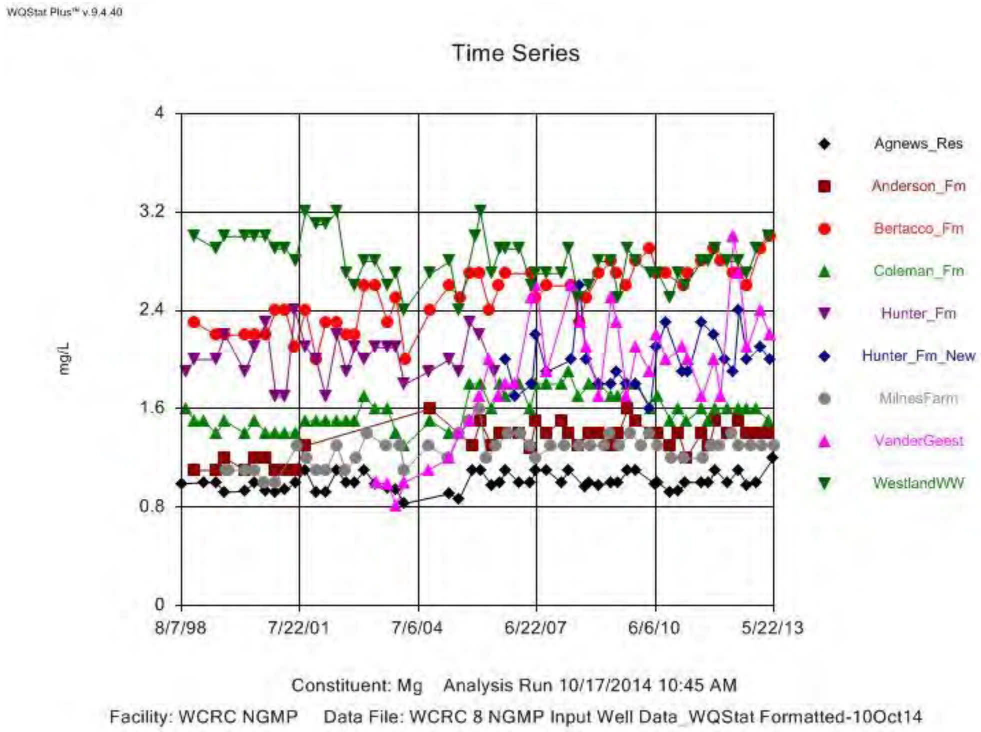
Plot #3 – Conductivity for all NGMP wells



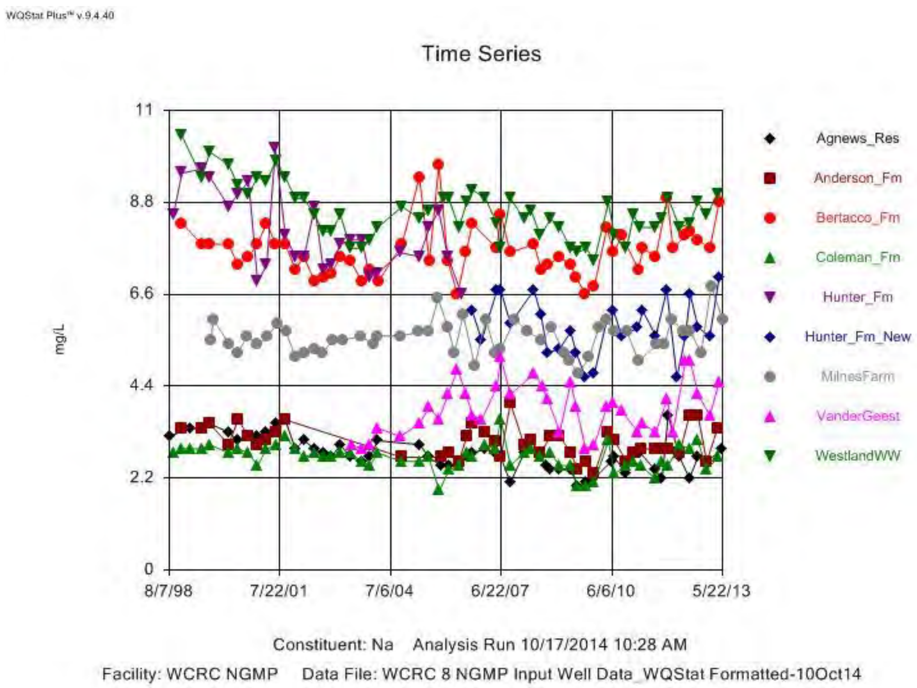
Plot #4 – Bicarbonate for all NGMP wells



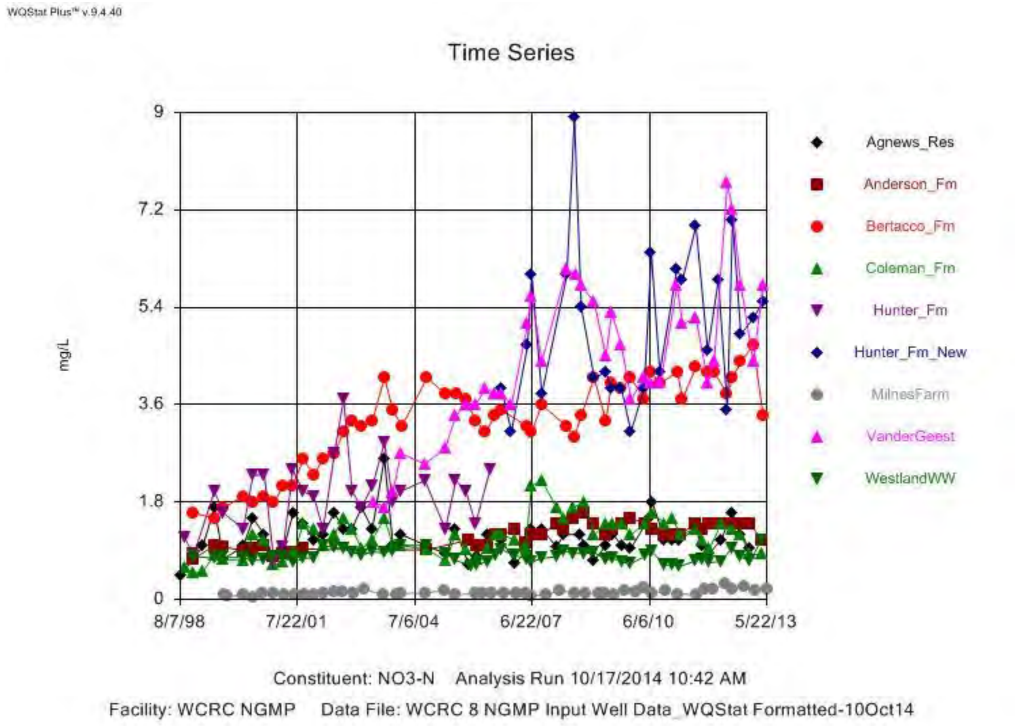
Plot #5 – Potassium for all NGMP wells



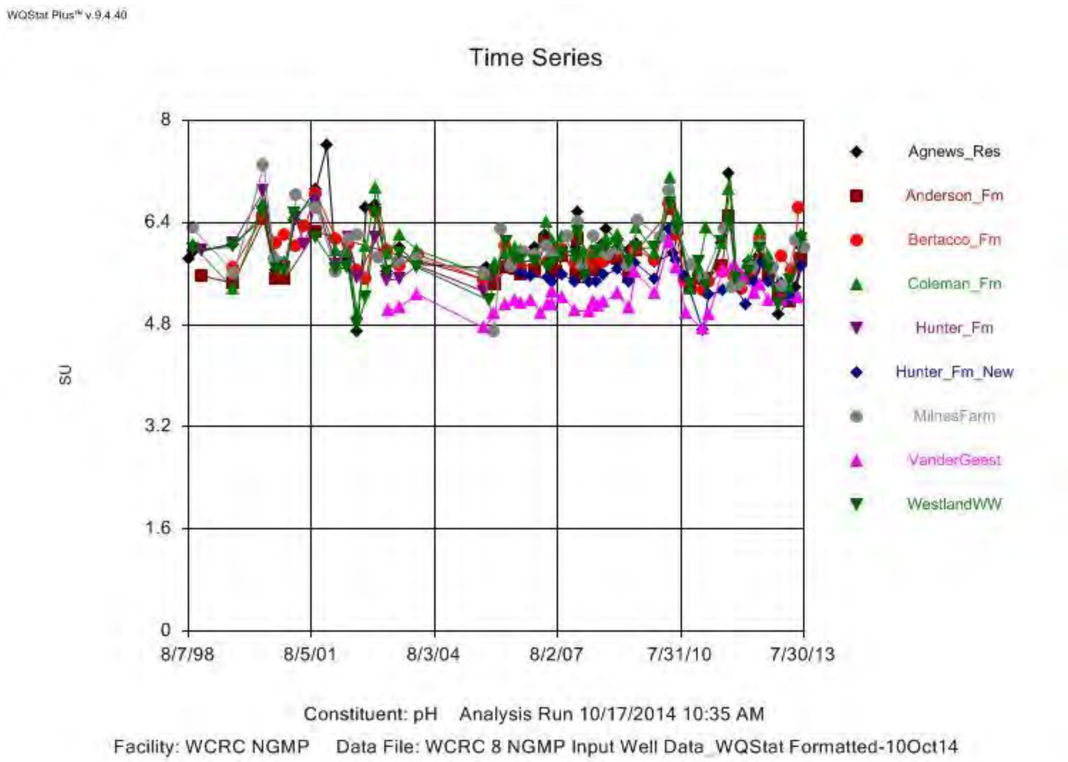
Plot #6 – Magnesium for all NGMP wells



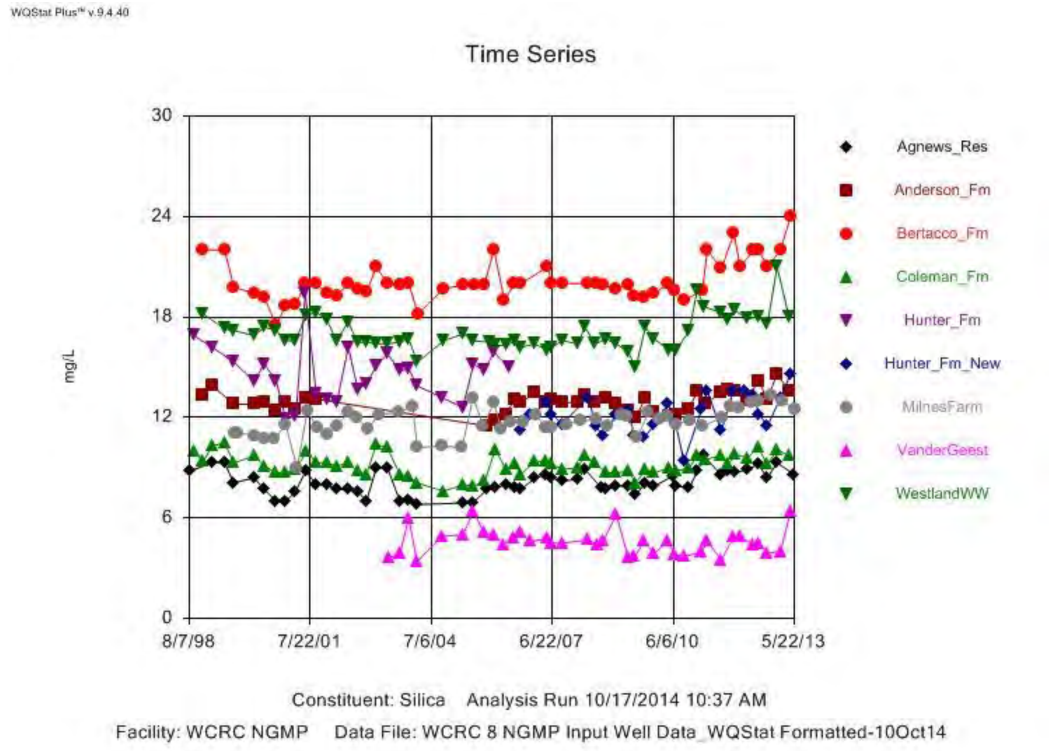
Plot #7 – Sodium for all NGMP wells



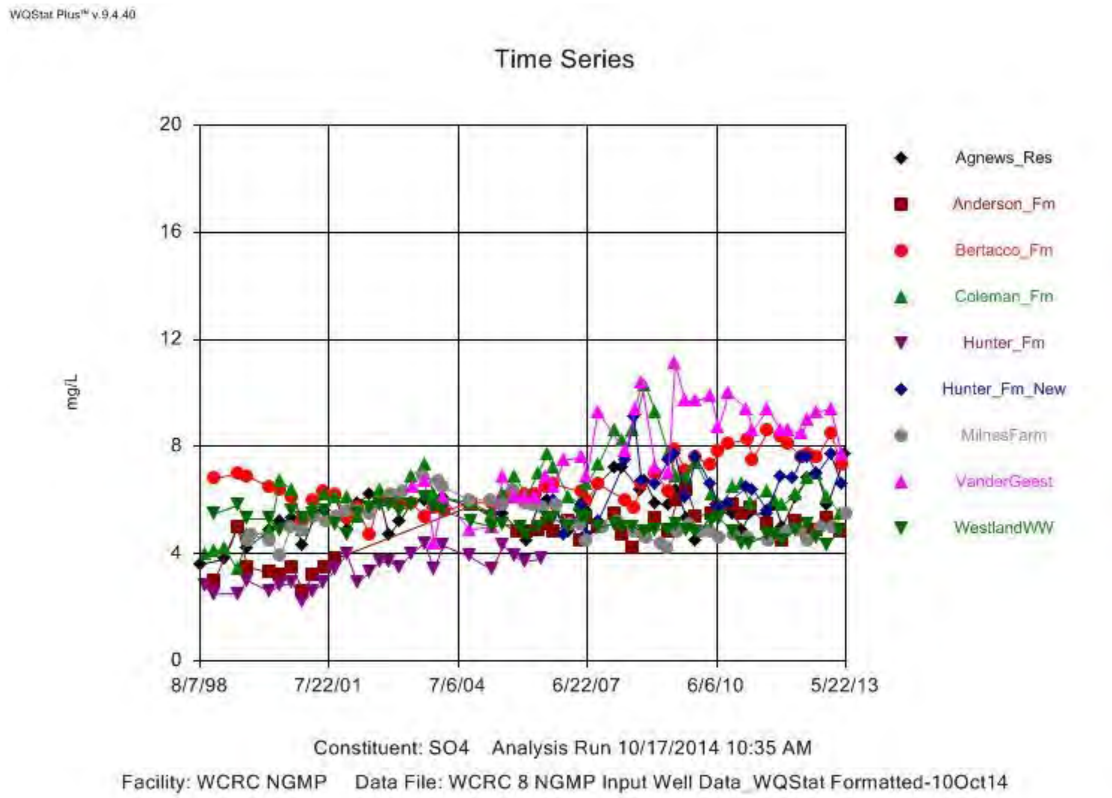
Plot #8 – Nitrate-nitrogen for all NGMP wells



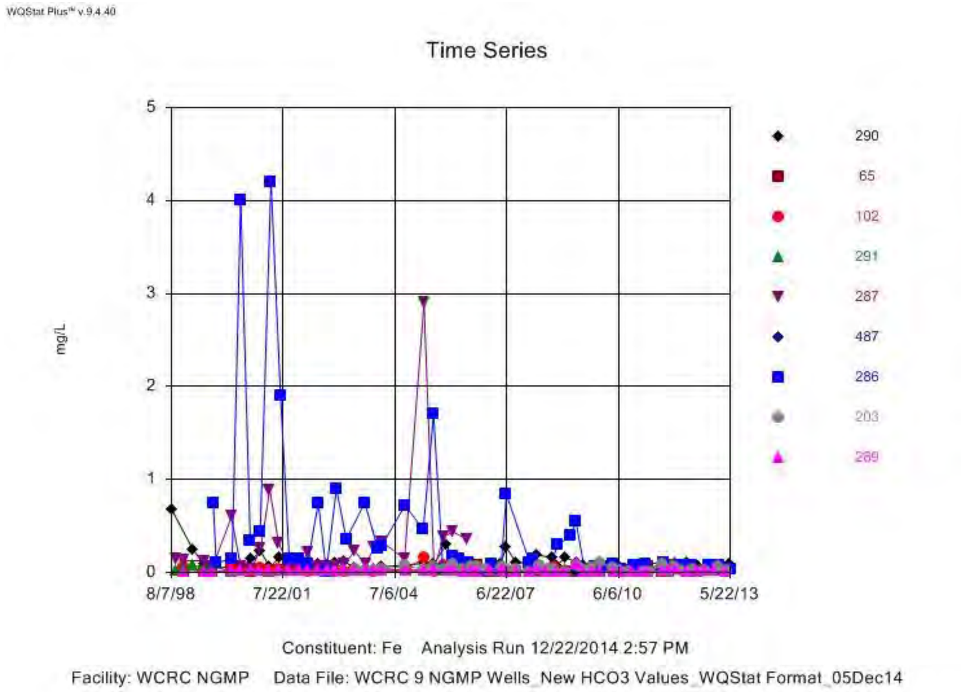
Plot #9 – pH for all NGMP wells



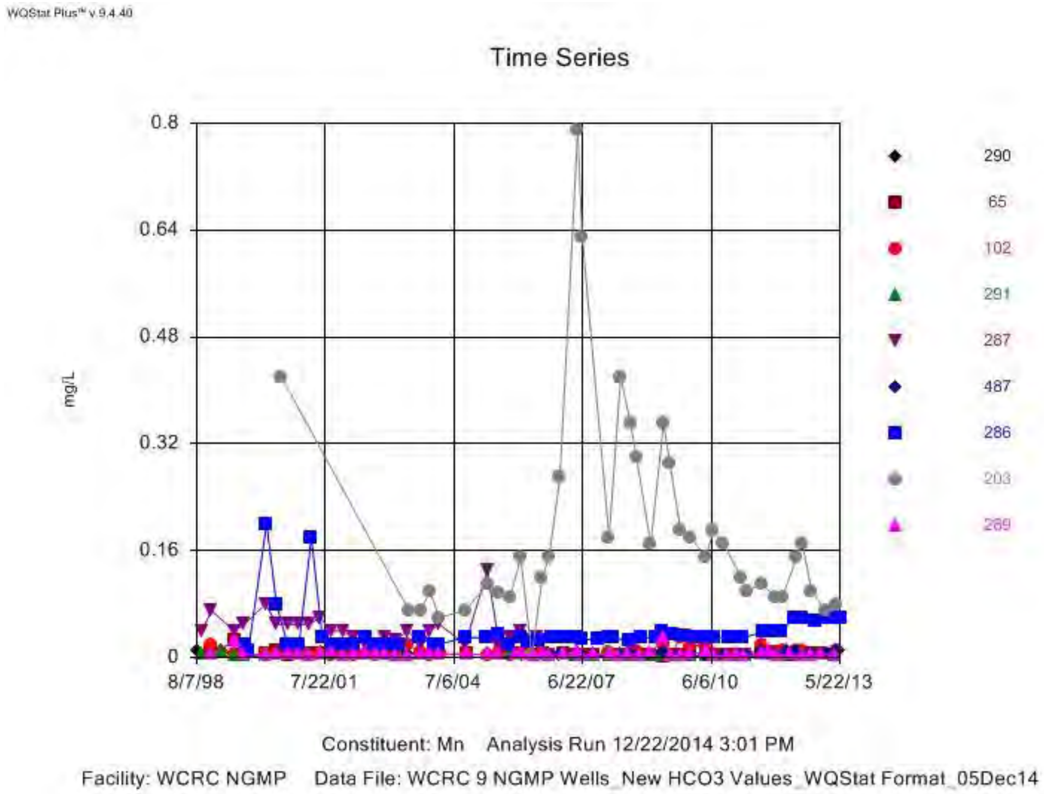
Plot #10 – Silica for all NGMP wells



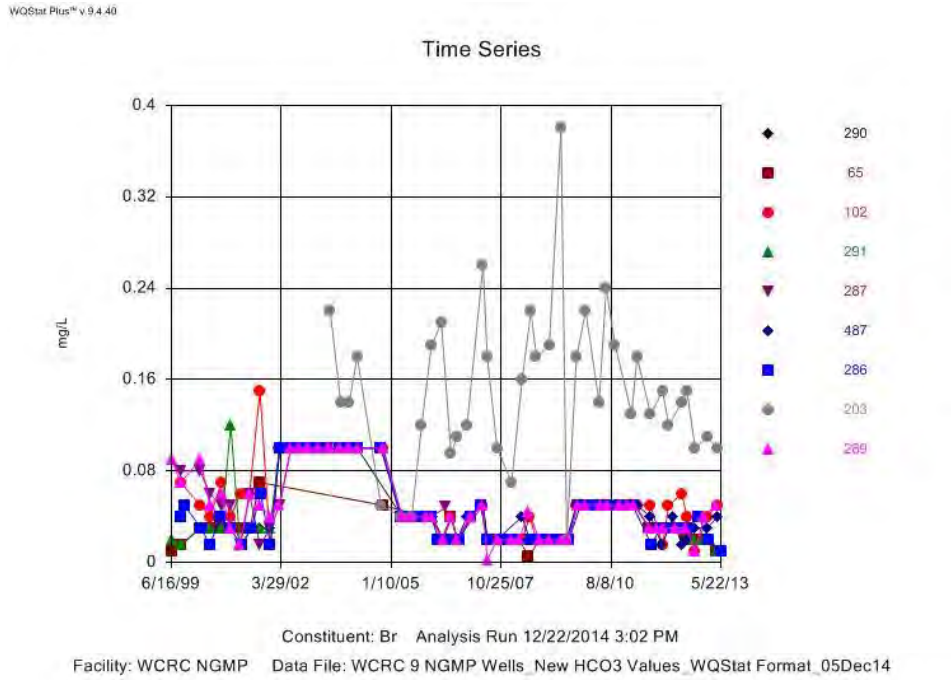
Plot #11 – Sulfate for all NGMP wells



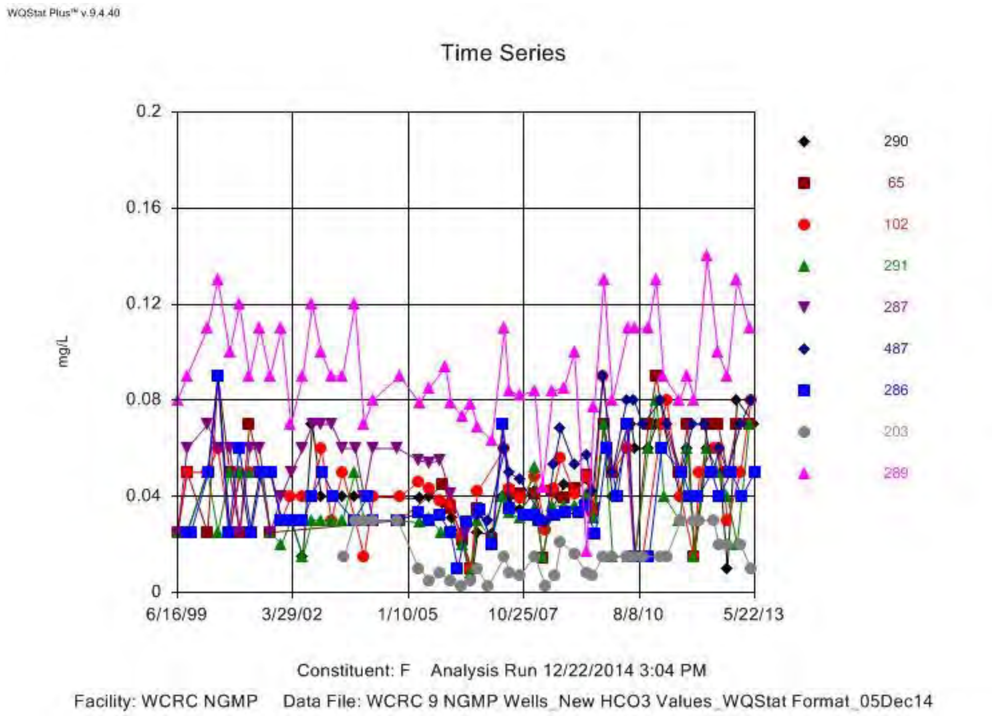
Plot #12 – Iron for all NGMP wells



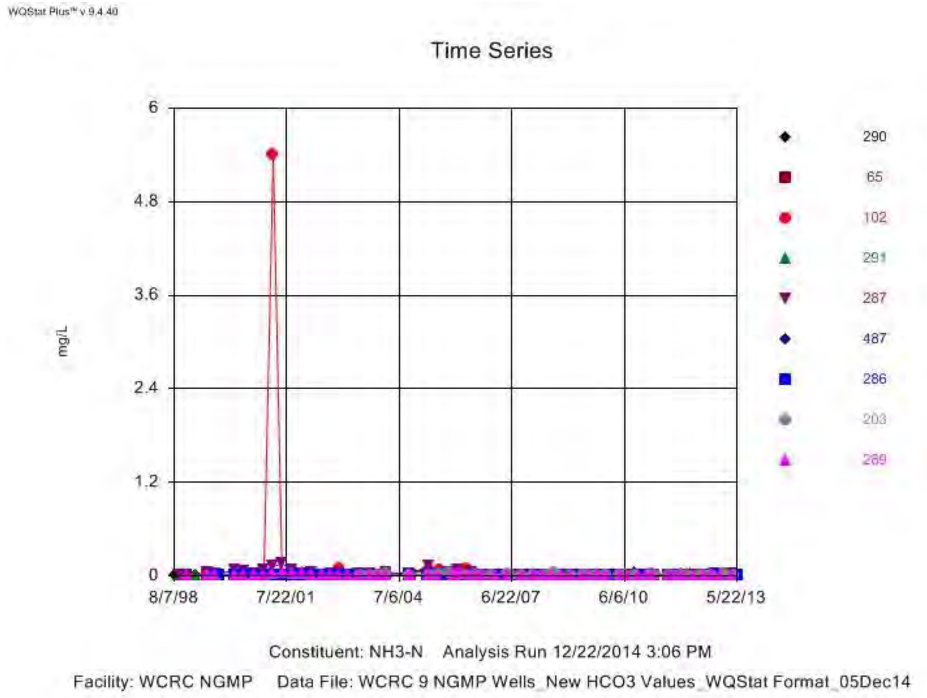
Ploy #13 – Manganese for all NGMP wells



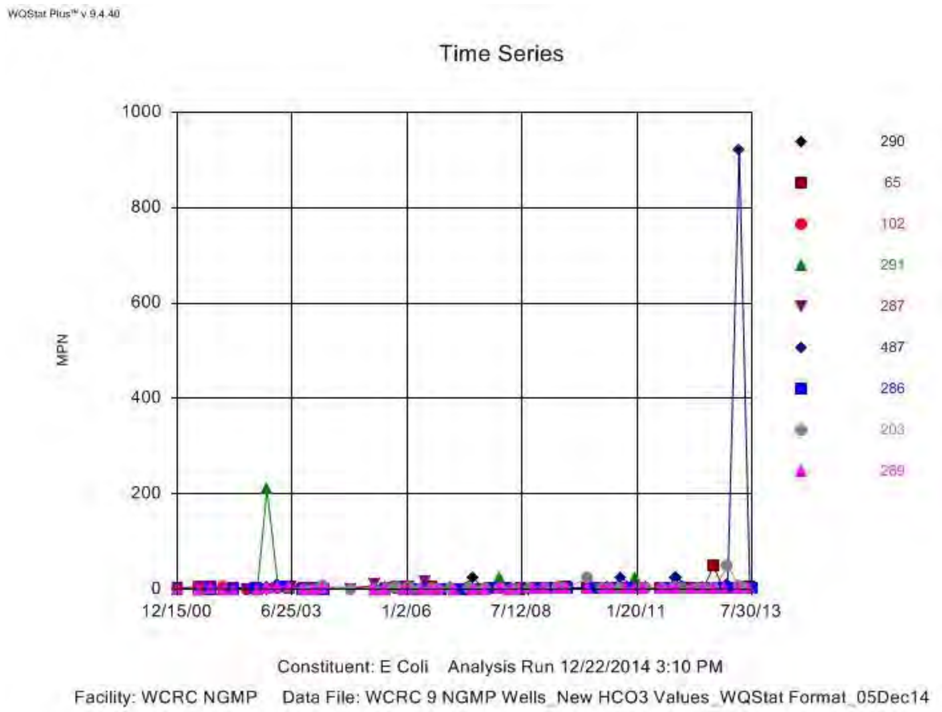
Plot #14 – Bromide for all NGMP wells



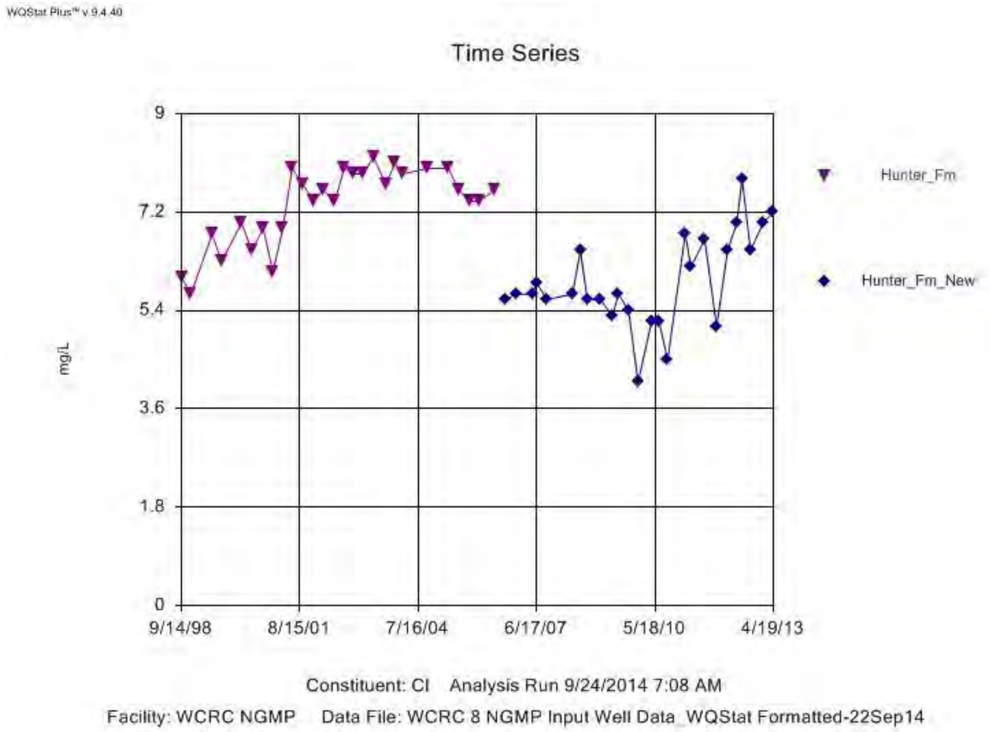
Plot #15 – Fluoride for all NGMP wells



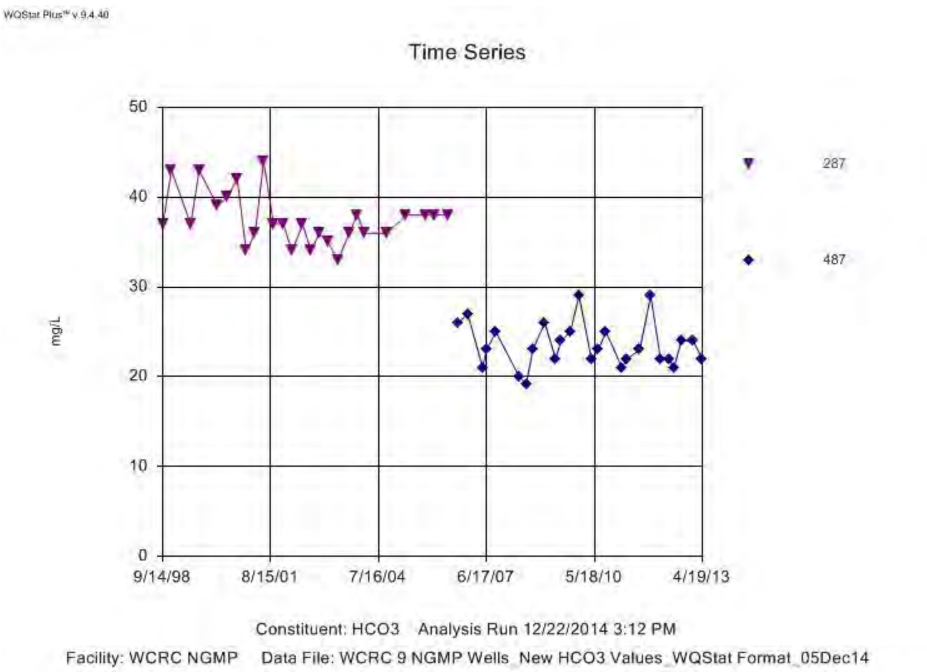
Plot #16 – Ammonia-nitrogen for all NGMP wells



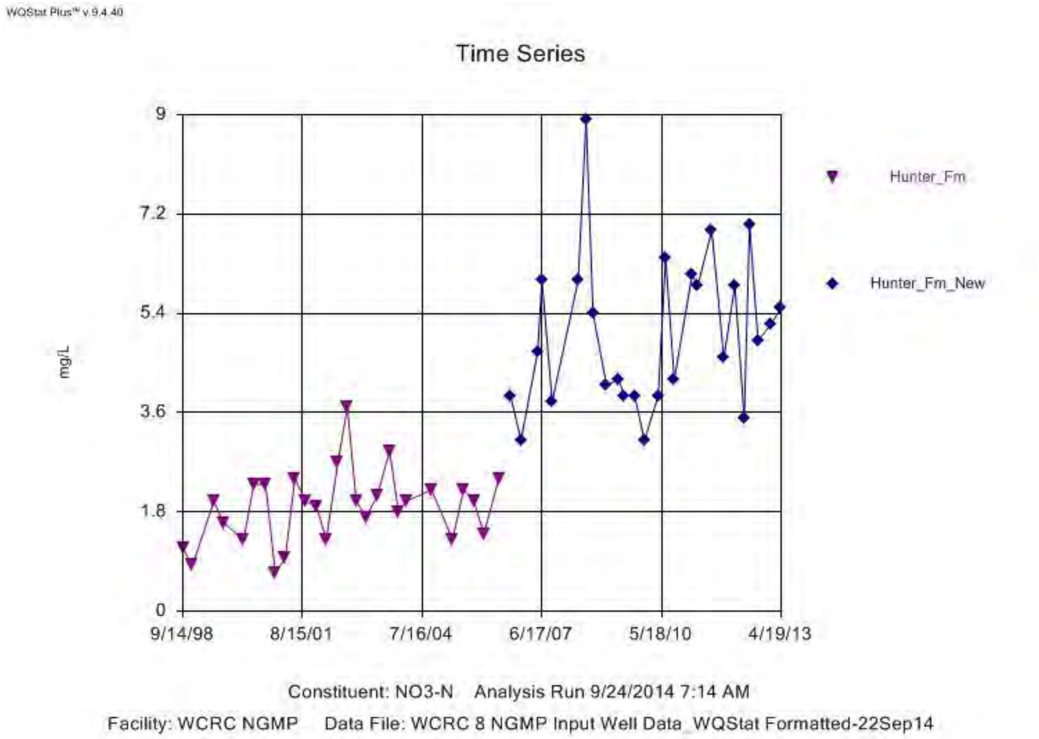
Ploy #17 – E. Coli bacteria for all NGMP wells



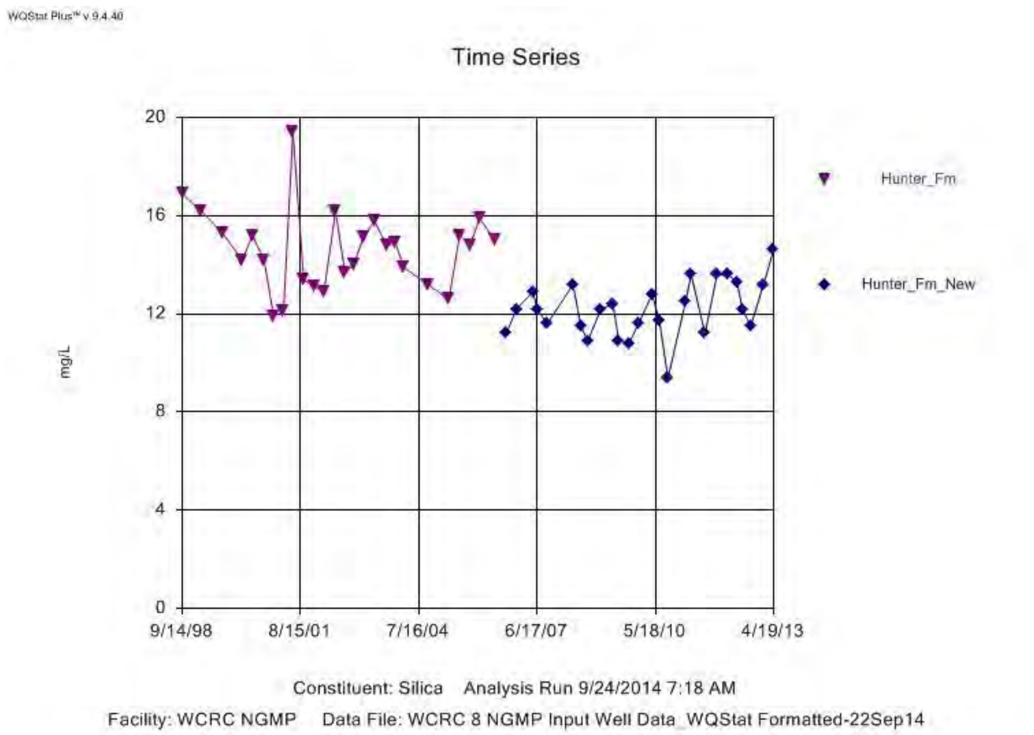
Plot #18: Chloride time series for Hunter Fm and Hunter Fm New wells



Plot #19: Bicarbonate time series for Hunter Fm and Hunter Fm New wells

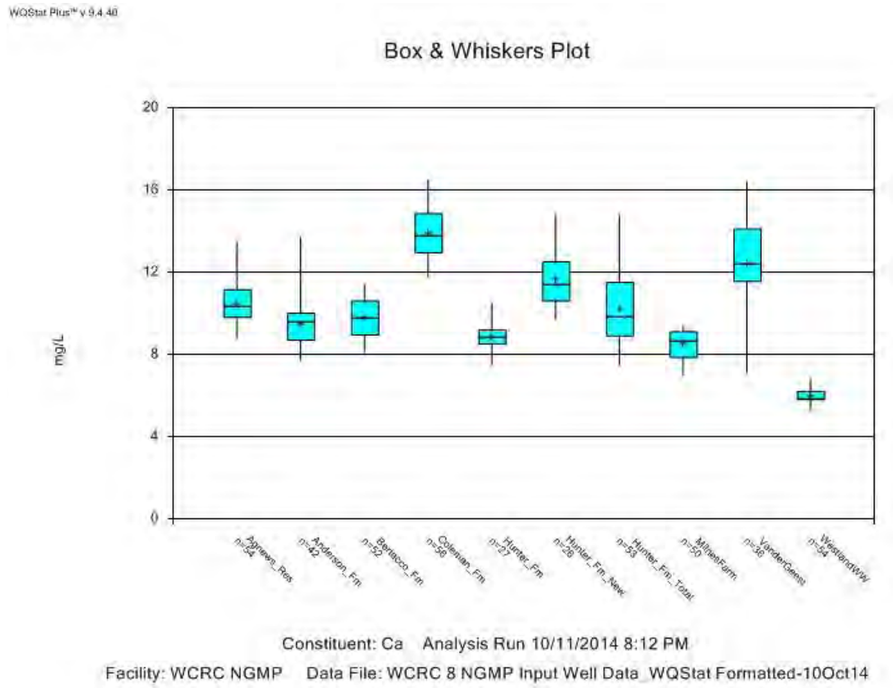


Plot #20: Nitrate-nitrogen time series for Hunter Fm and Hunter Fm New wells

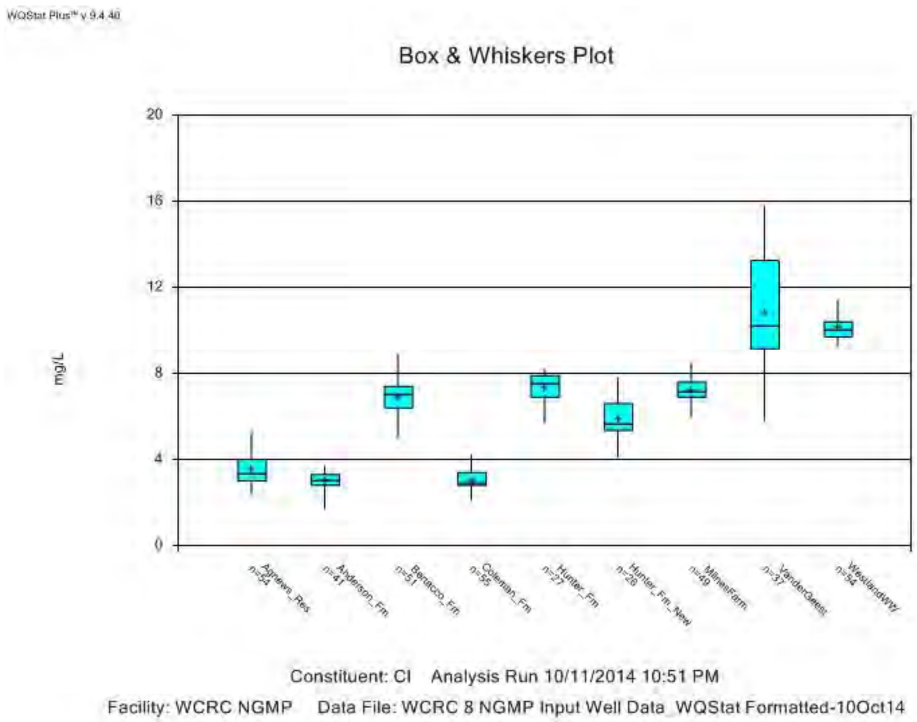


Plot #21: Silica time series for Hunter Fm and Hunter Fm New wells

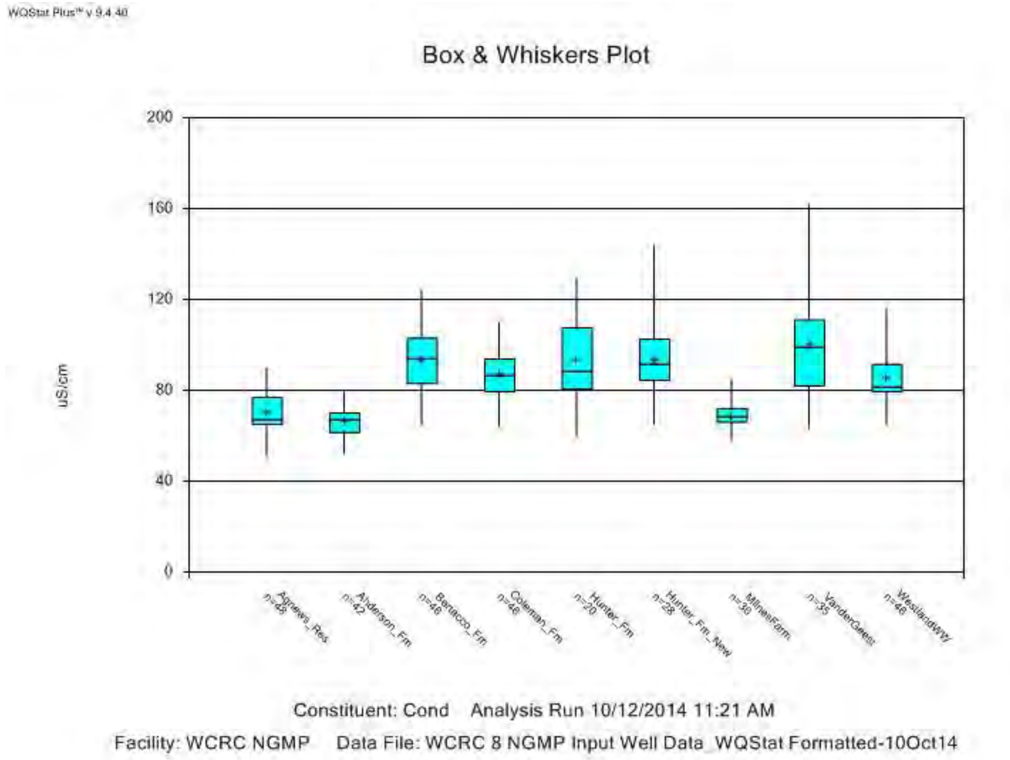
C4: Box and Whiskers



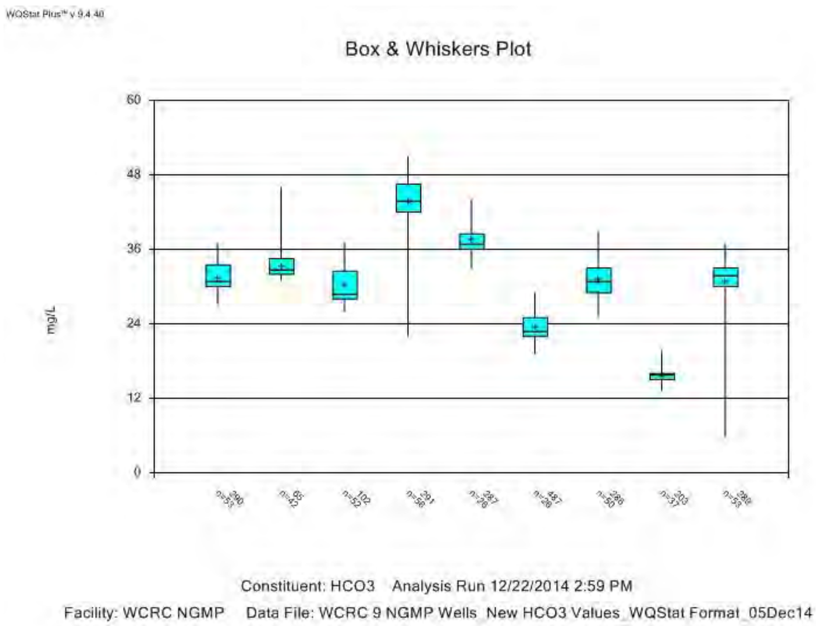
Plot #1 – Calcium for all NGMP wells



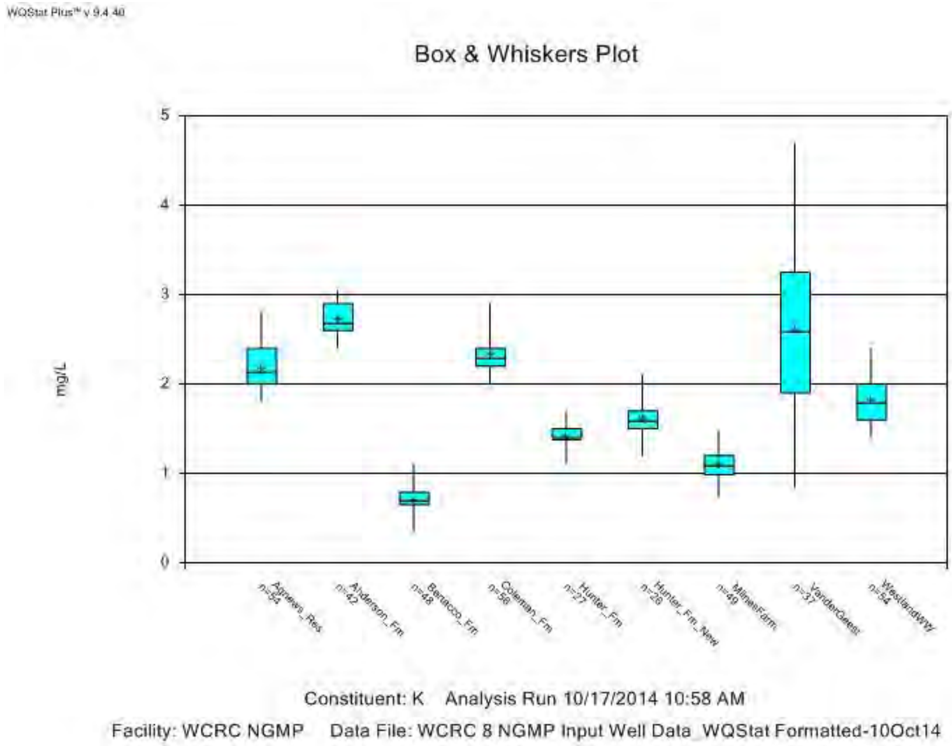
Plot #2 – Chloride for all NGMP wells



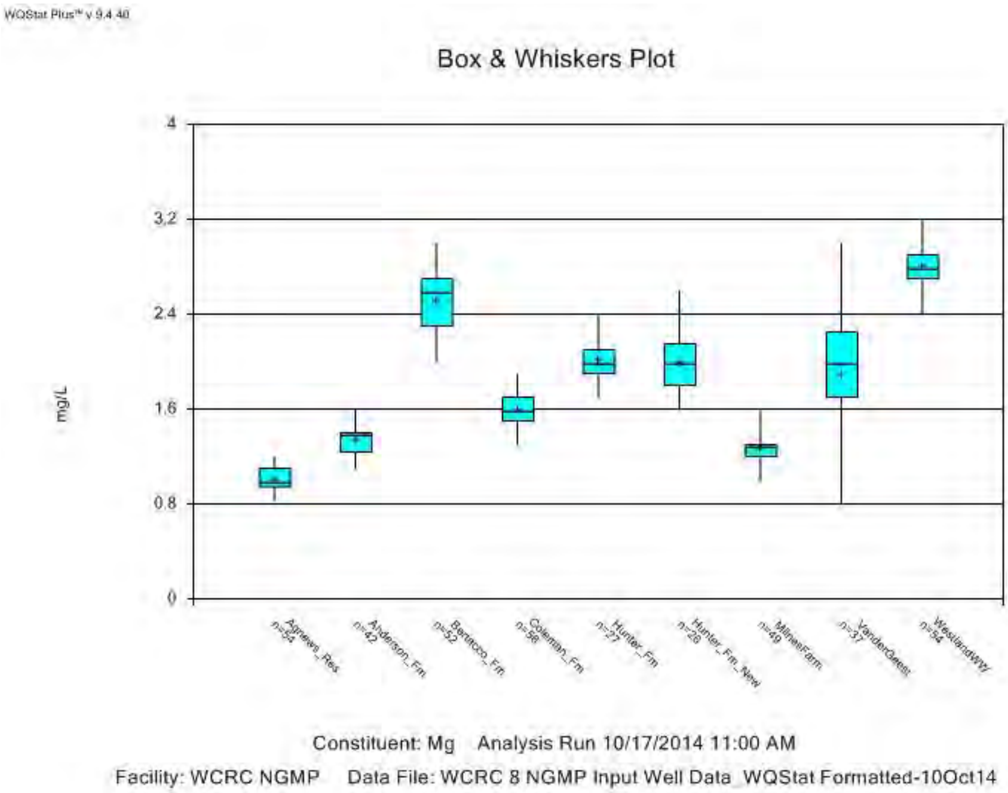
Plot #3 – Conductivity for all NGMP wells



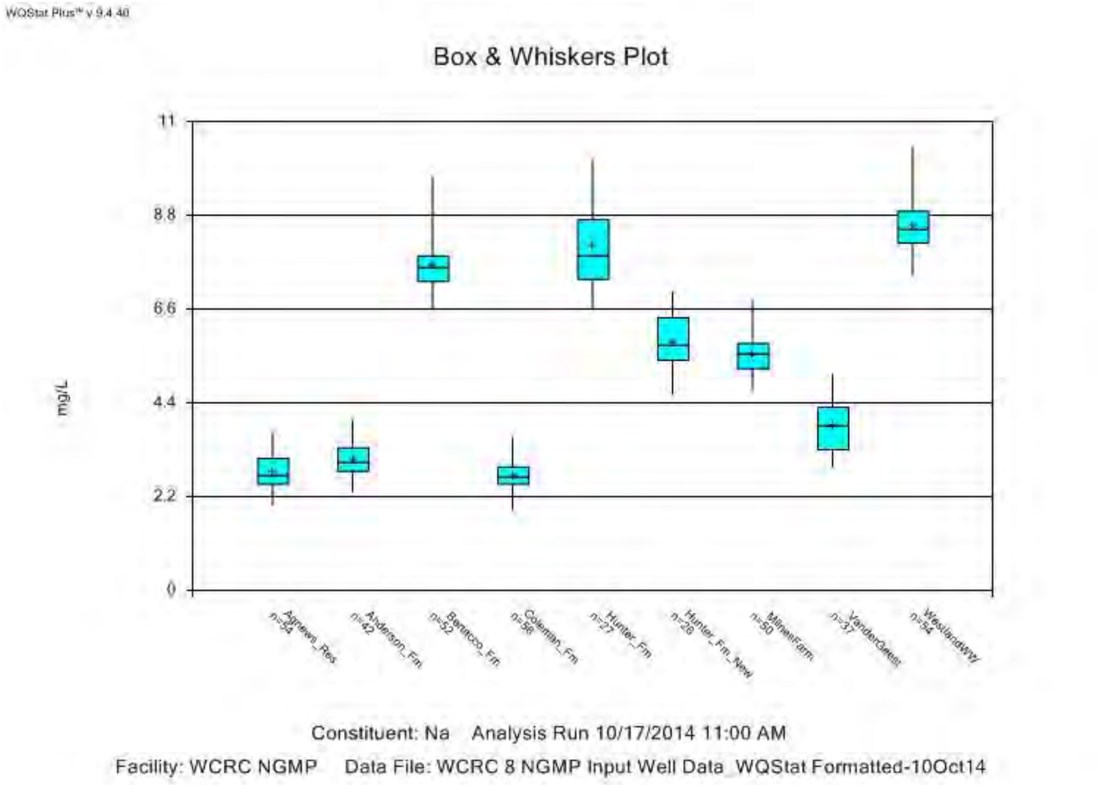
Plot #4 – Bicarbonate for all NGMP wells



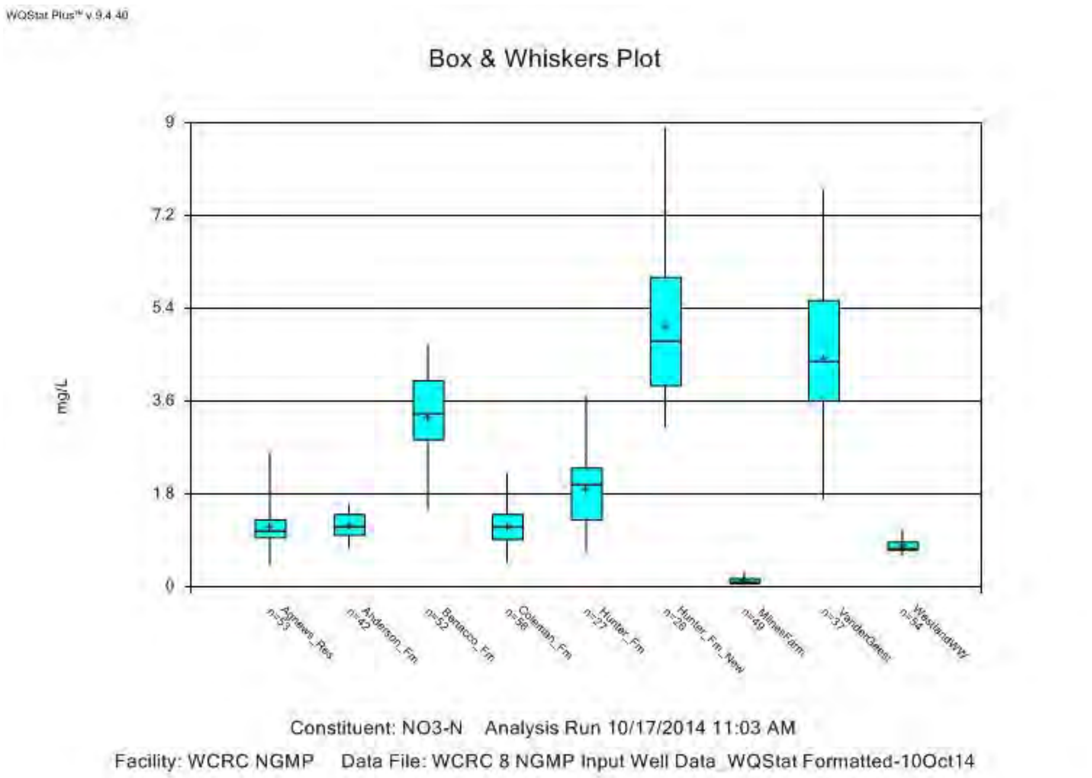
Plot #5 – Potassium for all NGMP wells



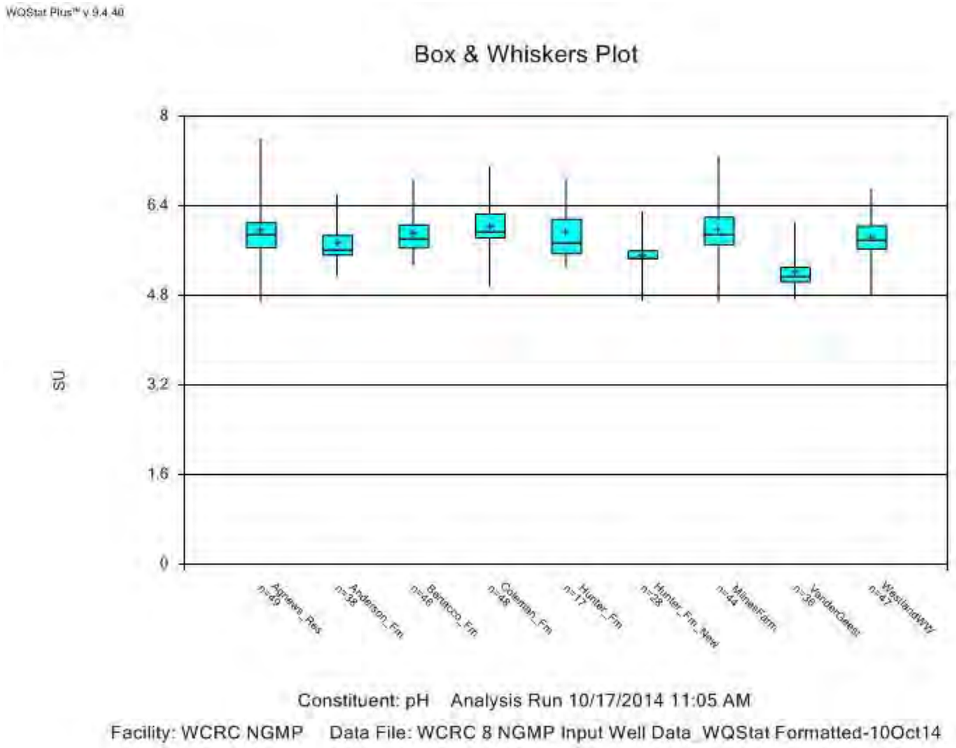
Plot #6 – Magnesium for all NGMP wells



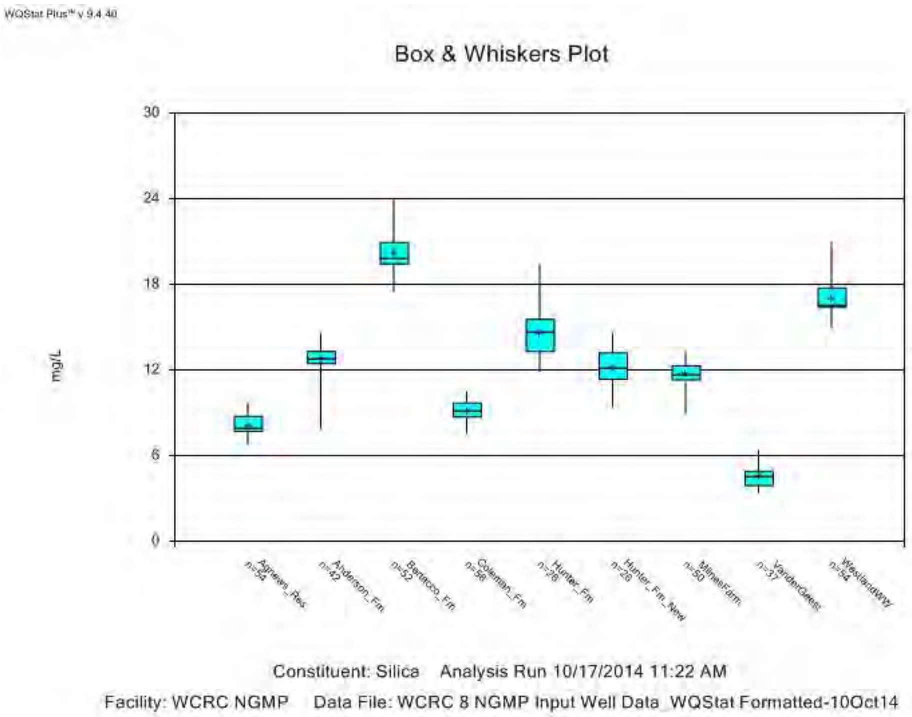
Plot #7 – Sodium for all NGMP wells



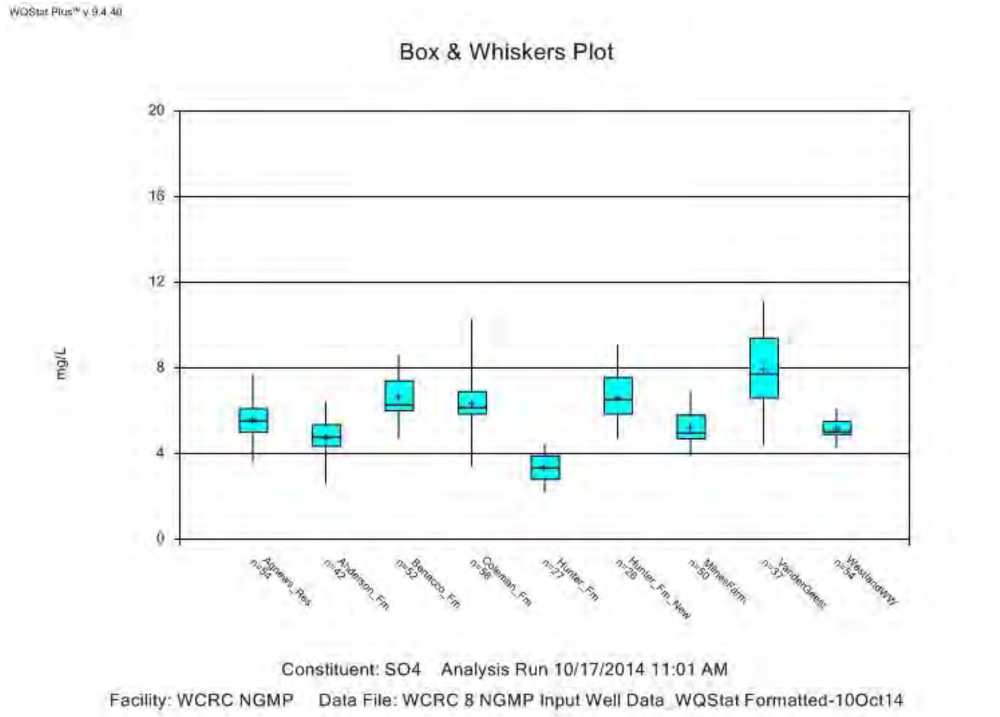
Plot #8 – Nitrate-nitrogen for all NGMP wells



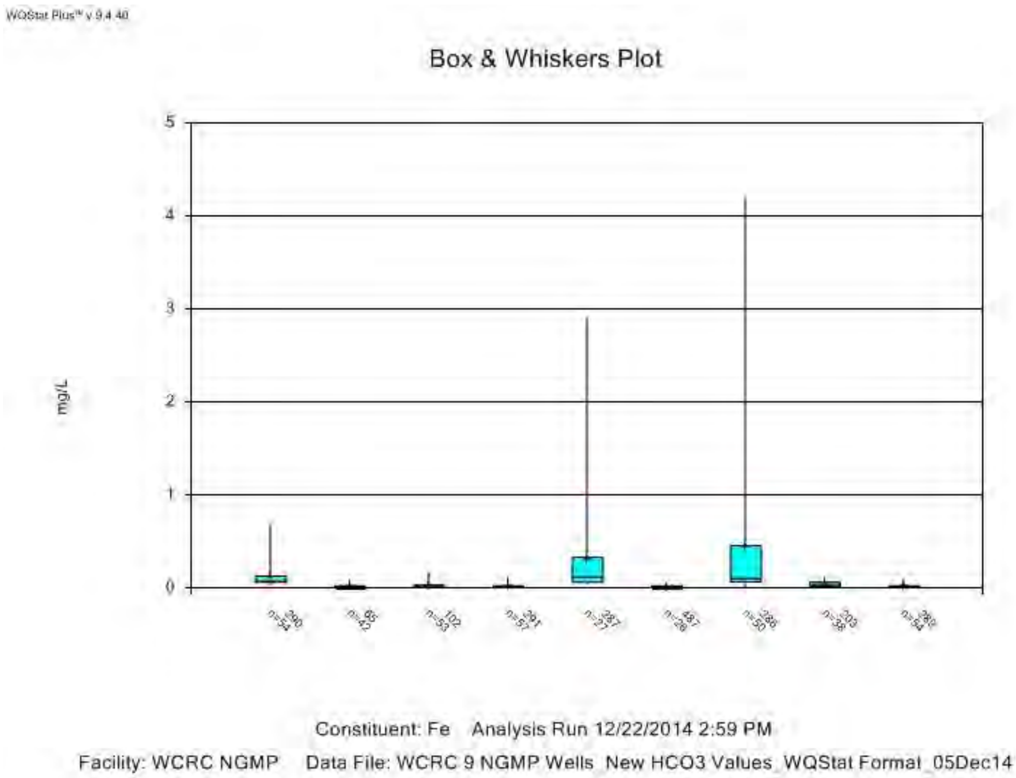
Plot #9 – pH for all NGMP wells



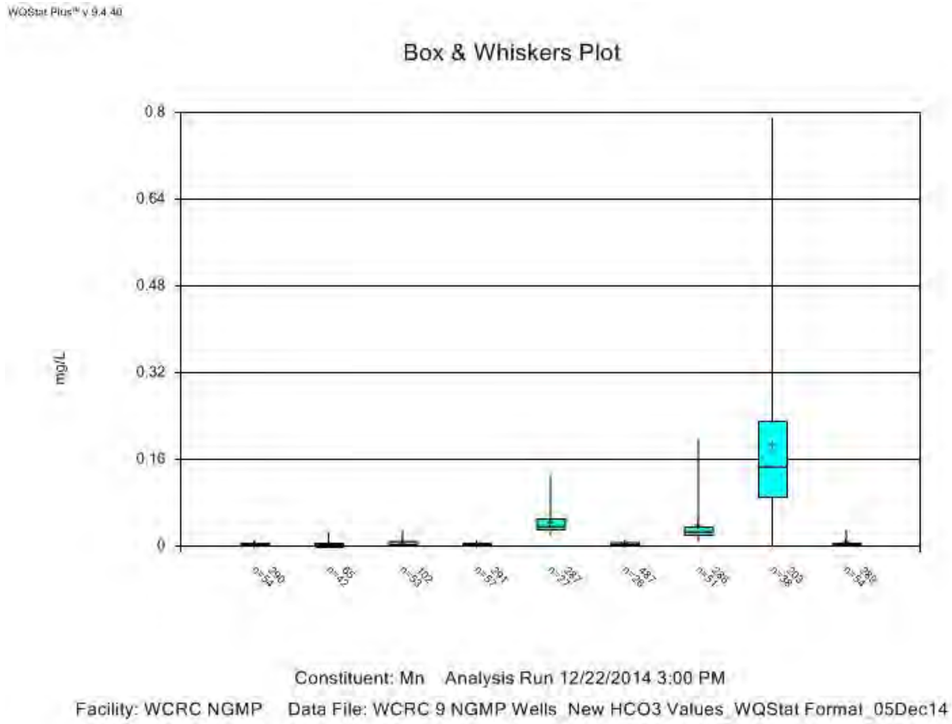
Plot #10 – Silica for all NGMP wells



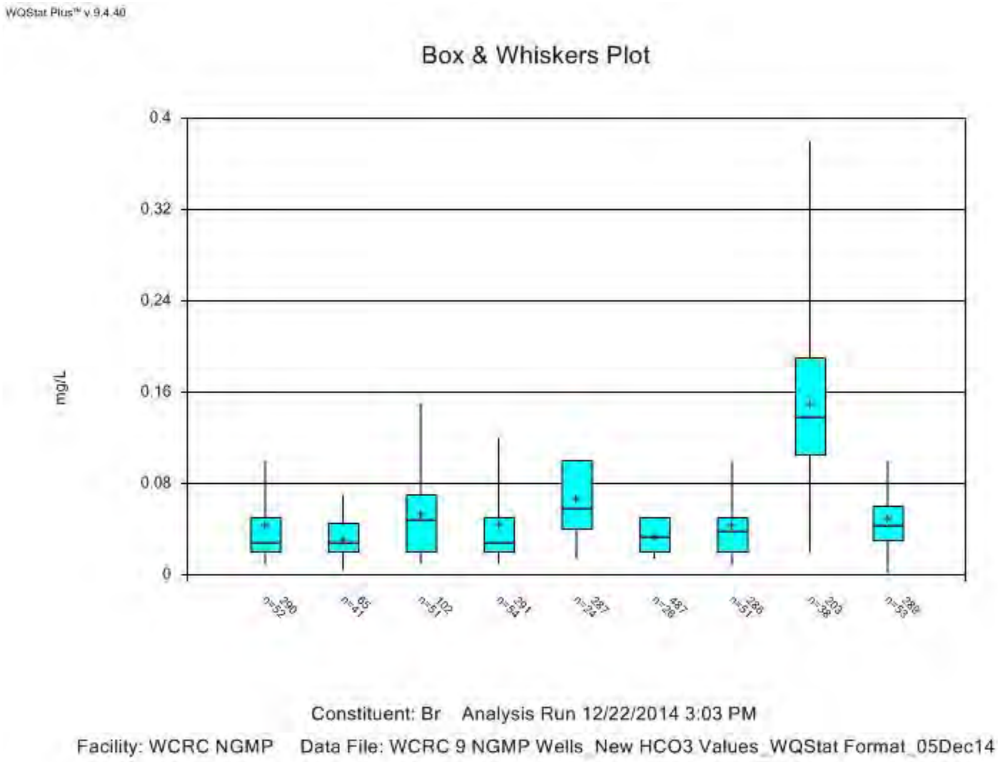
Plot #11 – Sulfate for all NGMP wells



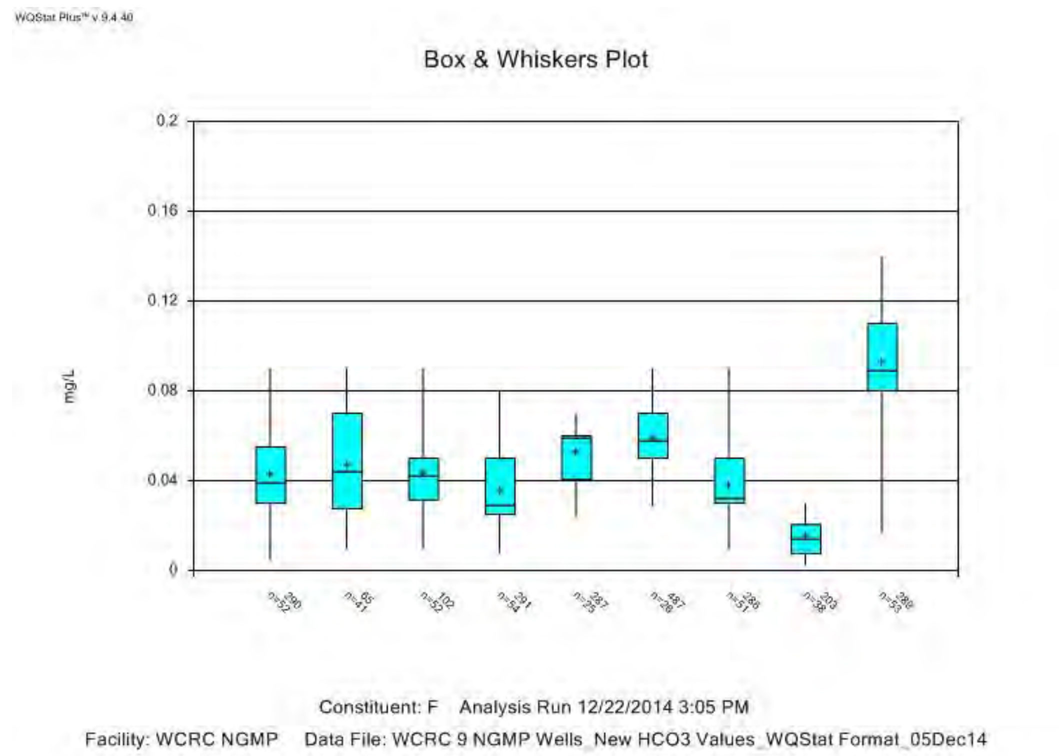
Plot #12 – Iron for all NGMP wells



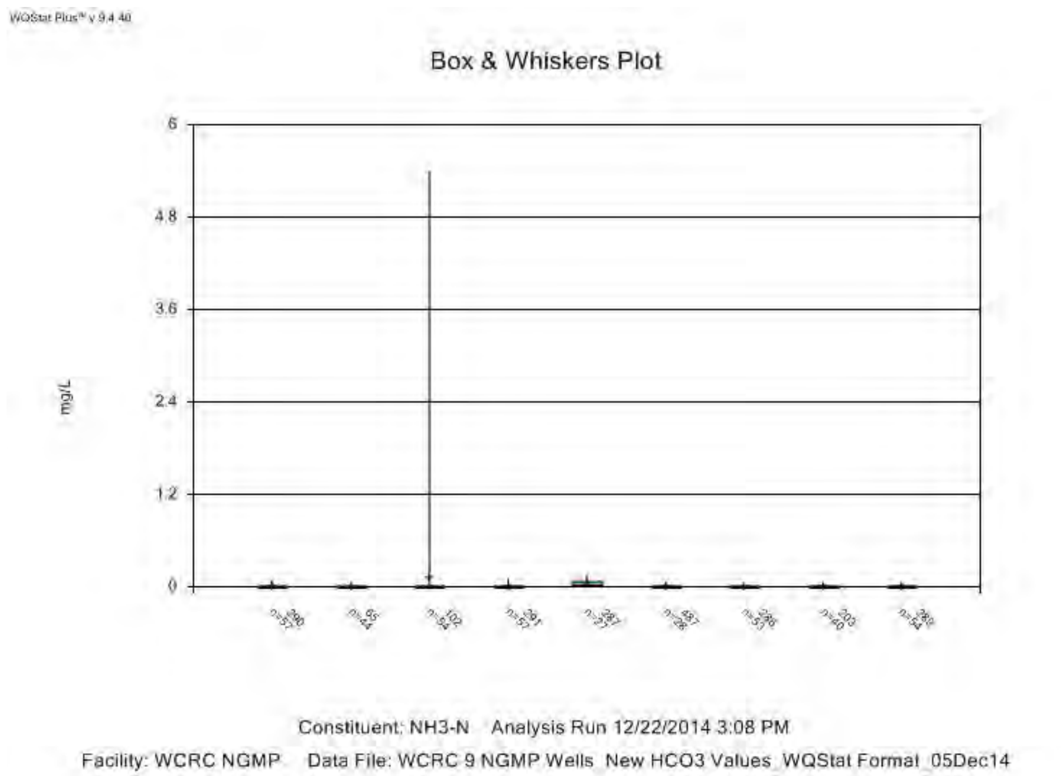
Plot #13 – Manganese for all NGMP wells



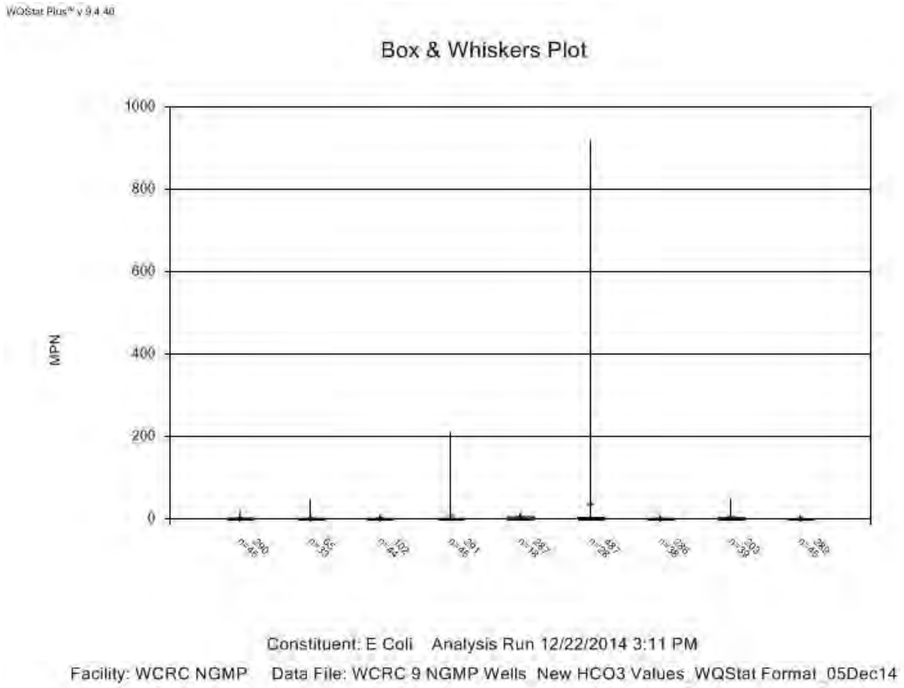
Plot #14 – Bromide for all NGMP wells



Plot #15 – Fluoride for all NGMP wells

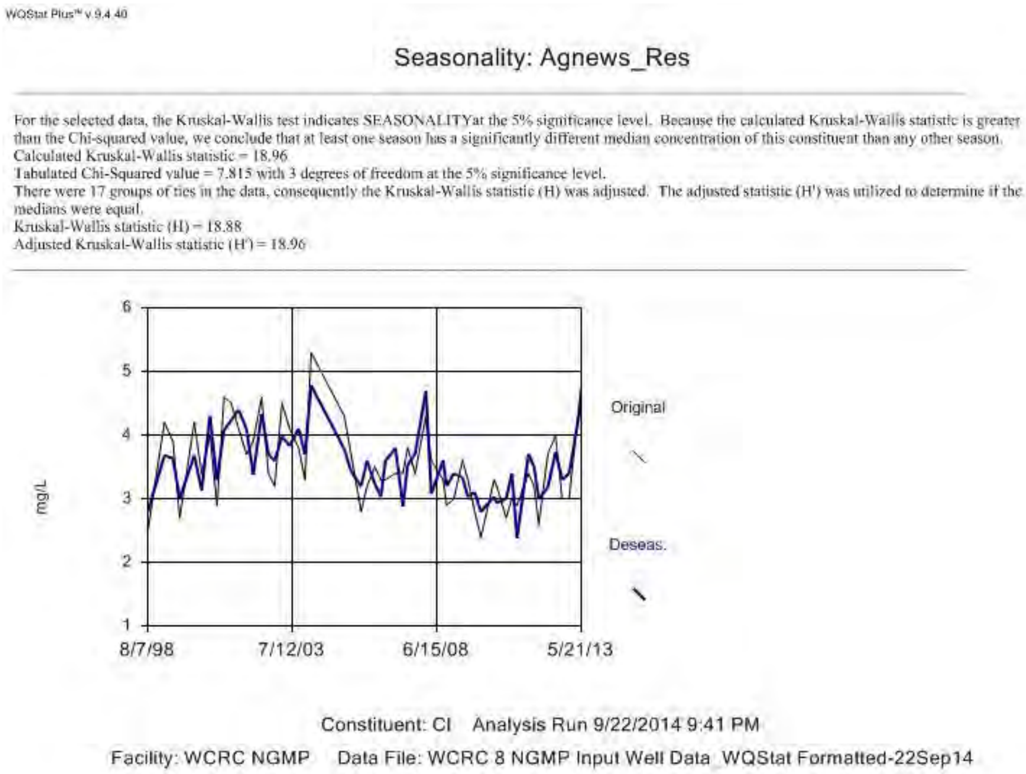


Plot #16 – Ammonia-nitrogen for all NGMP wells



Plot #17 – E. Coli bacteria for all NGMP wells

C5: Seasonality

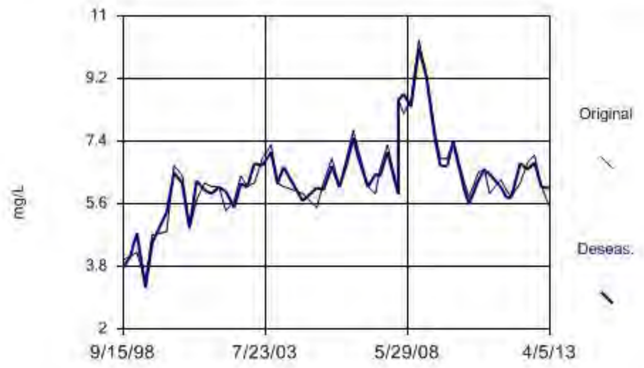


Plot #1 – Chloride for Agnews Res well

WQStat Plus™ v 9.4.40

Seasonality: 291

For the selected data, the Kruskal-Wallis test indicates SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is greater than the Chi-squared value, we conclude that at least one season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 8.257
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 13 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 8.225
Adjusted Kruskal-Wallis statistic (H') = 8.257



Constituent: SO4 Analysis Run 12/22/2014 9:26 PM

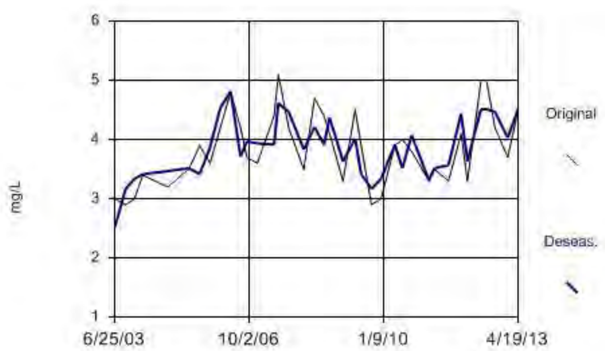
Facility: WCRC NGMP Data File: WCRC 9 NGMP Wells_New HCO3 Values_WQStat Format_05Dec14

Plot #2 – Sulfate for Coleman Fm well

WQStat Plus™ v 9.4.40

Seasonality: VanderGeest

For the selected data, the Kruskal-Wallis test indicates SEASONALITYat the 5% significance level. Because the calculated Kruskal-Wallis statistic is greater than the Chi-squared value, we conclude that at least one season has a significantly different median concentration of this constituent than any other season.
Calculated Kruskal-Wallis statistic = 11.13
Tabulated Chi-Squared value = 7.815 with 3 degrees of freedom at the 5% significance level.
There were 12 groups of ties in the data, consequently the Kruskal-Wallis statistic (H) was adjusted. The adjusted statistic (H') was utilized to determine if the medians were equal.
Kruskal-Wallis statistic (H) = 11.08
Adjusted Kruskal-Wallis statistic (H') = 11.13

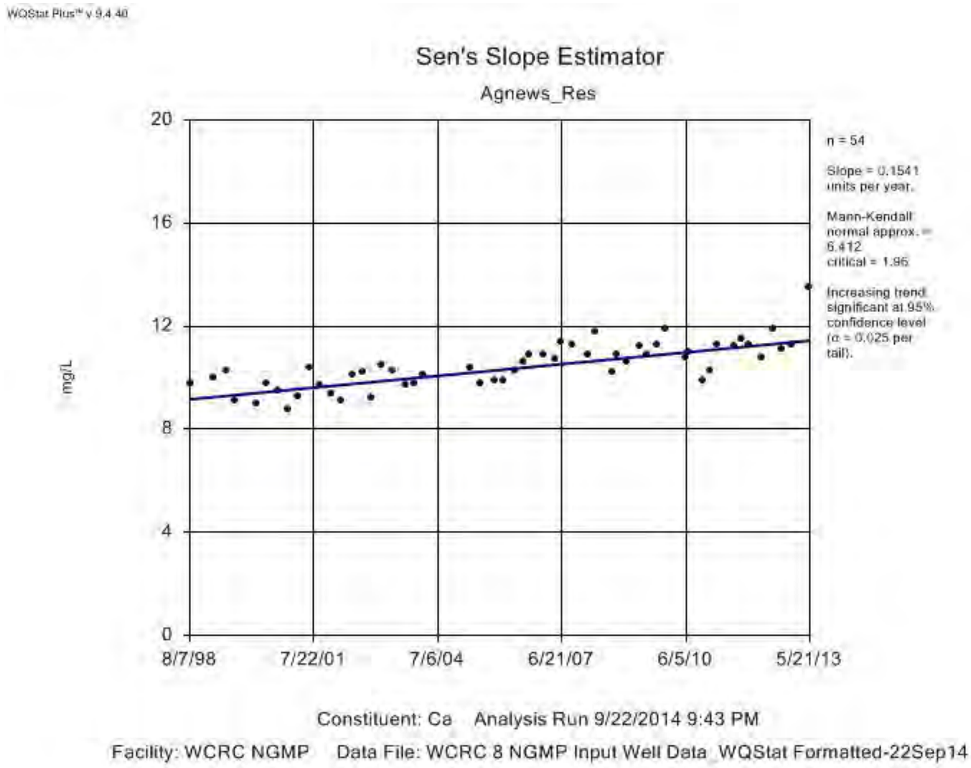


Constituent: Na Analysis Run 9/24/2014 11:18 AM

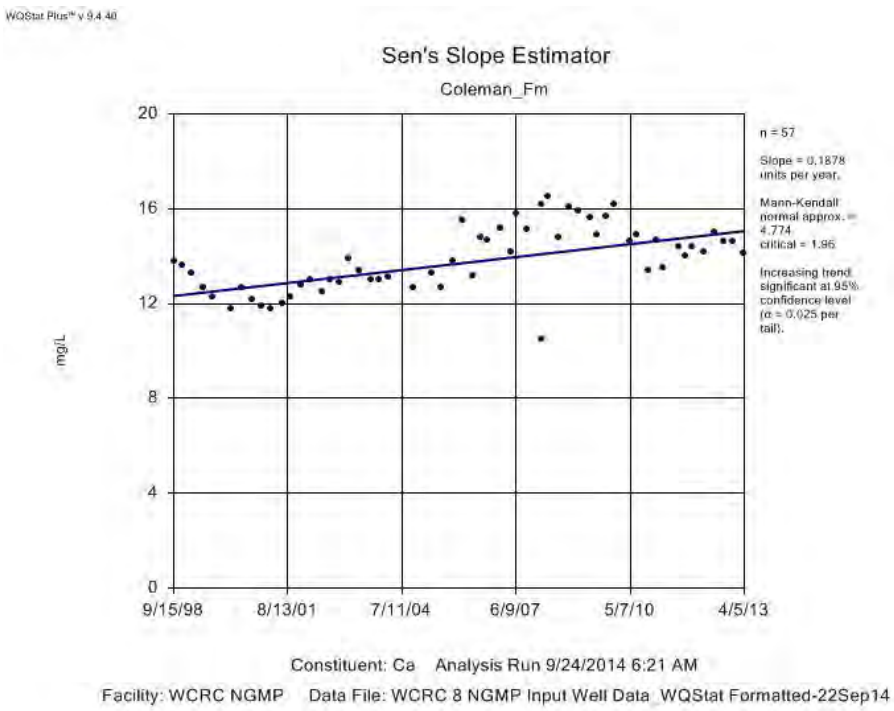
Facility: WCRC NGMP Data File: WCRC 8 NGMP Input Well Data_WQStat Formatted-22Sep14

Plot #3 – Sodium for Van der Geest well

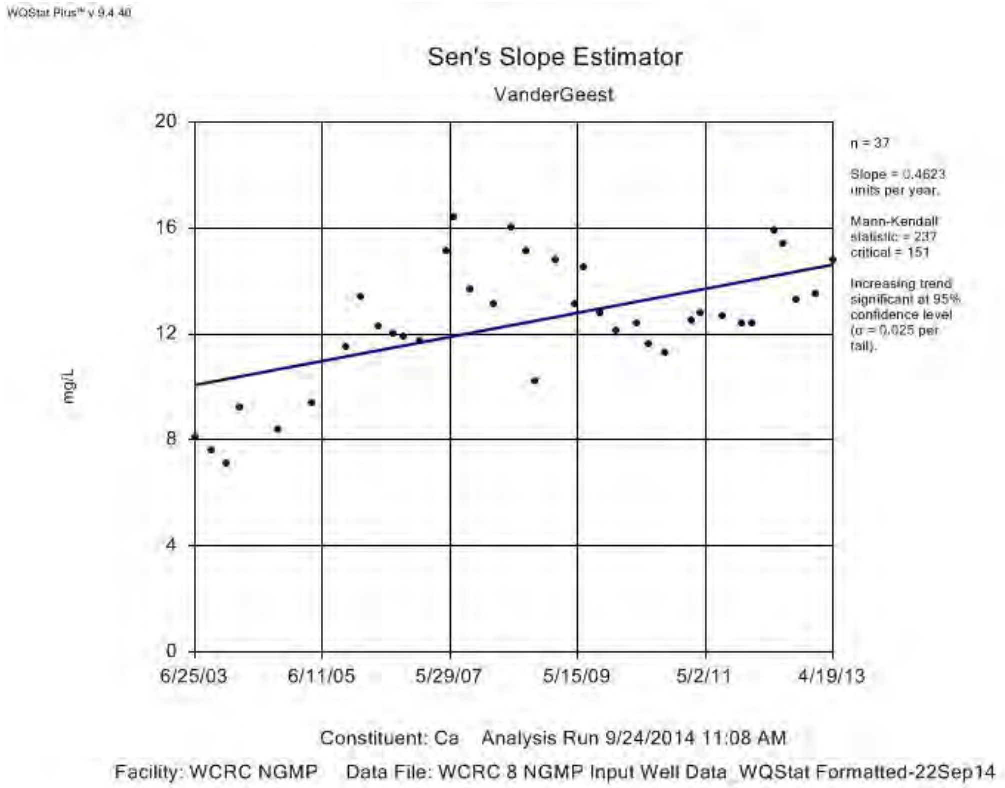
C6: Trend



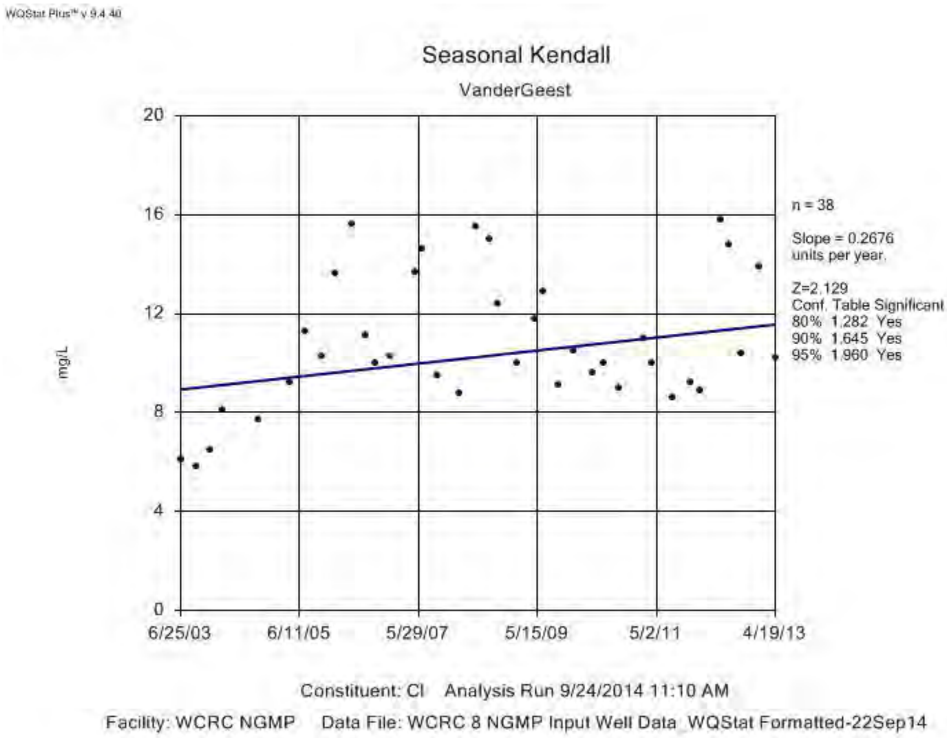
Plot #1 – Calcium M-K trend for Agnews Res well



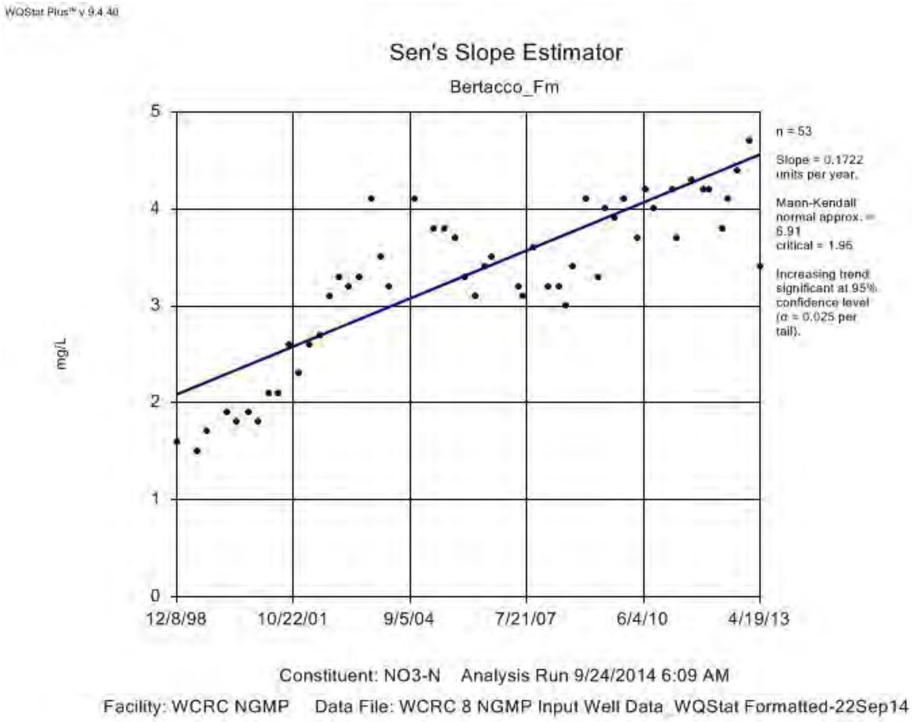
Plot #2 – Calcium M-K trend for Coleman Fm well



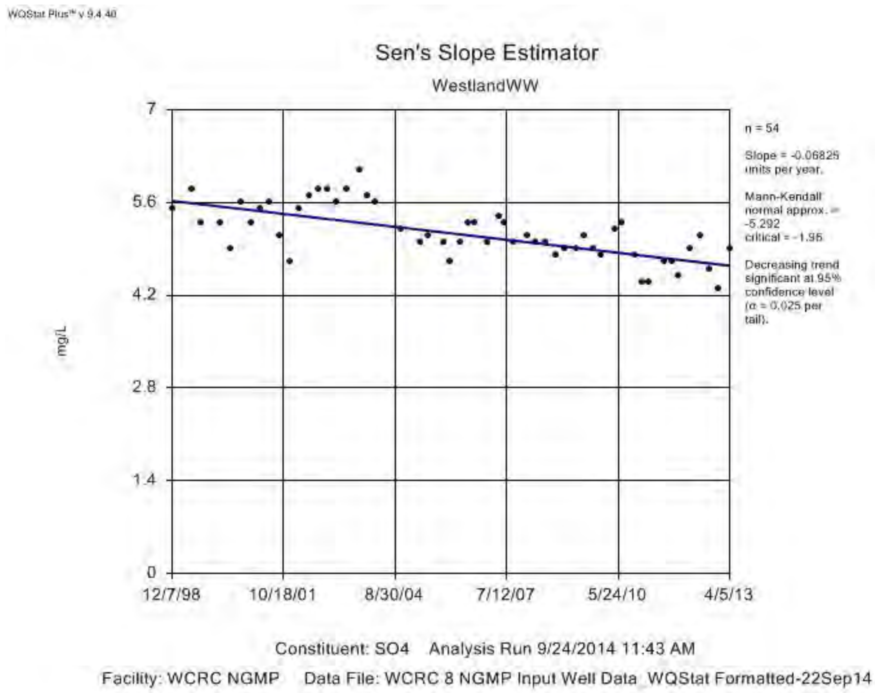
Plot #3 – Calcium M-K trend for Van der Geest Fm well



Plot #4 – Chloride seasonal Kendall trend for Van der Geest Fm well



Plot #5 – NO_3-N M-K trend for Bertacco Fm well



Plot #6 – SO_4 M-K trend for Westland WW well