

Water Year 2014 Seawater Intrusion Analysis Report Seaside Basin, Monterey County California

*Prepared for:
Seaside Basin Watermaster*

December 2014



Prepared by:



TABLE OF CONTENTS

Table of Figures.....	iii
Tables	iv
Abbreviations	v
Conversions.....	v
Executive Summary	1
SECTION 1 Background and Introduction	3
SECTION 2 Overview of Seawater Intrusion.....	5
Groundwater Pumping and Seawater Intrusion.....	7
Indicators of Seawater Intrusion.....	8
Cation/Anion Ratios	9
Increasing Chloride Concentrations.....	14
Sodium/Chloride Molar Ratios	14
Chloride-Bicarbonate Ratios.....	17
Electric Induction Logs.....	17
Other Indicators	18
SECTION 3 Seawater Intrusion in the Seaside Groundwater Basin .	19
Analysis Approach	19
Cation/Anion Ratios	19
Second Quarter Water Year 2014 (January-March 2014).....	20
Fourth Quarter Water Year 2014 (July-September 2014).....	21
Chloride Concentrations	34
Trends	34
Chloride Concentration Maps.....	36
Sodium/Chloride Molar Ratios	39
Electric Induction Logs.....	40
Groundwater Levels	44
Trends	44
Groundwater Elevation Maps.....	45
Groundwater Production.....	52
Protective Groundwater Elevations	55

SECTION 4 Conclusions..... 59

SECTION 5 Recommendations..... 63

 Verification Water Quality Sampling and Analysis for Sentinel Well SBWM-1..... 63

 Continue to Analyze and Report on Water Quality Annually..... 63

SECTION 6 References..... 65

Appendix A: Piper Diagrams for Individual Wells

Appendix B: Chloride and Sodium/Chloride Ratio Graphs

TABLE OF FIGURES

Figure 1: Seawater Wedge in a Simple Coastal Aquifer (from Barlow, 2003).....	5
Figure 2: Seawater Wedge in a Layered Coastal Aquifer (from Barlow, 2003)	6
Figure 3: Interface Migration in Response to Groundwater Pumping (from Barlow, 2003)	8
Figure 4: Piper Diagram for Groundwater in Pajaro Valley (Data source: PVWMA).....	11
Figure 5: Piper Diagram for Groundwater in Salinas Valley (Source: MCWRA).....	12
Figure 6: Stiff Diagrams from Salinas Valley Wells without Seawater Intrusion (Source: MWCRA).....	13
Figure 7: Stiff Diagrams from Salinas Valley Wells with Seawater Intrusion (Source: MWCRA)	13
Figure 8: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Salinas Valley Showing Incipient Intrusion (Source: MCWRA).....	15
Figure 9: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Pajaro Valley Showing Incipient Intrusion (Data source: PVWMA).....	16
Figure 10: Wells Used for Seawater Intrusion Analyses	23
Figure 11: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 2 nd Quarter Water Year 2014 (January-March 2014).....	24
Figure 12: Stiff Diagrams for MSC, Fort Ord 9, and Fort Ord 10 Wells (Data source: Watermaster).....	25
Figure 13: Stiff Diagrams for PCA West, PCA East, and Ord Terrace Wells (Data source: Watermaster)	26
Figure 14: Stiff Diagrams for Watermaster Sentinel Wells 1 - 3 (Data source: Watermaster)	27
Figure 15: Stiff Diagrams for Watermaster Sentinel Wells 4 and 5, and Seaside Middle School Deep	28
Figure 16: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 4 th Quarter Water Year 2014 (July- September 2014)	29
Figure 17: Piper Diagram for Seaside Groundwater Basin Production Wells, 4 th Quarter Water Year 2014 (July-September 2014)	30
Figure 18: Stiff Diagrams for Southern Coastal and Inland Subarea Production Wells.....	31
Figure 19: Stiff Diagrams for Northern Coastal Subarea Production Wells #1	32
Figure 20: Stiff Diagrams for Northern Coastal Subarea Production Wells #2.....	33

Trends Figure 21: Historical Chloride and Sodium/Chloride Molar Ratios, Shallow PCA West Well.....	35
Figure 22: Shallow Zone Chloride Concentration Map – 4 th Quarter WY 2014....	37
Figure 23: Deep Zone Chloride Concentration Map – 4 th Quarter WY 2014.....	38
Figure 24: Sentinel Well Induction Logs by Welenco, Inc. through January 2014.....	42
Figure 25: Sentinel Well Induction Logs from August 2014 – New Baseline.....	43
Figure 26: Example Hydrographs (Source: Watermaster).....	47
Figure 27: Shallow Zone Water Elevation Map – 2 nd Quarter WY 2014 (January-March 2014)	48
Figure 28: Deep Zone Water Elevation Map – 2 nd Quarter WY 2014 (January- March 2014).....	49
Figure 29: Shallow Zone Water Elevation Map – 4 th Quarter WY 2014 (July/August 2014)	50
Figure 30: Deep Zone Water Elevation Map – 4 th Quarter WY 2014 (July/August 2014)	51
Figure 31: Annual Reported Groundwater Production and Operating Yield for Watermaster Producers.....	53
Figure 32: Watermaster Producers’ Pumping Distribution for Water Years 2013 and 2014.....	54
Figure 33: MSC Deep and Shallow Groundwater and Protective Elevations.....	56
Figure 34: PCA West Deep and Shallow Groundwater and Protective Elevations	57
Figure 35: CDM-MW4 Groundwater and Protective Elevations	58
Figure 36: Sentinel Well 3 Groundwater and Protective Elevations	58
Figure 37: Possible Processes Limiting Seawater Intrusion.....	61

TABLES

Table 1: Summary of Protective Elevation Monitoring Locations	55
---	----

ABBREVIATIONS

amsl	.....	above mean sea level
ASR	.....	aquifer storage and recovery
bgs	.....	below ground surface
Ca	.....	calcium
CAW	.....	California American Water
Cl	.....	chloride
CO ₃	.....	carbonate
FO	.....	Fort Ord
HCO ₃	.....	bicarbonate
K	.....	potassium
MCWRA	.....	Monterey County Water Resources Agency
meq/L	.....	milliequivalent per liter
Mg	.....	magnesium
mg/L	.....	milligrams per liter
MPWMD	.....	Monterey Peninsula Water Management District
MSC	.....	Monterey Sand Company
Na	.....	sodium
PCA	.....	Pacific Cement Aggregates
PVWMA	.....	Pajaro Valley Water Management Agency
SBMMP	.....	Seaside Groundwater Basin Monitoring and Management Program
SO ₄	.....	sulfate
TAC	.....	Technical Advisory Committee
WY	.....	Water Year

CONVERSIONS

1 acre-foot = 325,851 gallons

1 mg/L \approx 1 part per million

This page left
intentionally blank

EXECUTIVE SUMMARY

No seawater intrusion has historically been or is currently observed in existing monitoring and production wells in the Seaside Groundwater Basin, as demonstrated by the different tools and analyses that are used to investigate for evidence of seawater intrusion.

This annual report addresses the potential for, and extent of, seawater intrusion in the Seaside Groundwater Basin. Continued pumping in excess of recharge and fresh water inflows, pumping depressions near the coast, and ongoing seawater intrusion in the nearby Salinas Valley all suggest that seawater intrusion could occur in the Seaside Groundwater Basin.

- Piper diagrams for groundwater samples collected from depth-discreet monitoring wells during Water Year 2014 show no changes in water chemistry towards seawater.
- No groundwater samples collected in Water Year 2014 and plotted on Stiff diagrams, show chemistry indicative of incipient seawater intrusion.
- Overall, chloride concentration trends have been stable for most monitoring wells, with only two wells showing increasing trends over the past few years. These are sentinel well SBWM-1 and SBWM-2.
- Maps of chloride concentrations for the shallow aquifer do not show chlorides increasing towards the coast. The deep aquifer maps show that the highest chloride concentrations are limited to coastal monitoring wells PCA-West Deep and sentinel well SBWM-4. The chloride concentrations in these wells appears to be stable.
- Although production wells have a different water quality than the monitoring wells, this is probably as a result of them being screened across both shallow and deep zones. The production well water qualities are not indicative of seawater intrusion.
- Induction logging data at the coastal sentinel wells do not indicate changes indicative of seawater intrusion.

- Groundwater levels continue to be below protective elevations in the deep coastal target monitoring wells for which protective elevations were developed (MSC deep, PCA-West, and sentinel well SBWM-3). Two of the three shallow wells' groundwater levels are above protective elevations: PCA-W shallow and CDM-MW4. MSC shallow remains below protective elevations.

Based on the findings of this report, the following recommendations should be implemented to continue to monitor and track potential seawater intrusion.

1. Verification Water Quality Sampling and Analysis for Sentinel Well SBWM-1

Because of the 47 mg/L increase in chloride and 31 mg/L increase in sodium at sentinel well SBWM-1 since last year, it is recommended that this well be resampled in the next quarter to verify these increases at both sample depths.

2. Continue to Analyze and Report on Water Quality Annually

Seawater intrusion is a threat, and data must be analyzed regularly to identify incipient intrusion. Maps, graphs, and analyses similar to what are found in this report should continue to be developed every year.

SECTION 1

BACKGROUND AND INTRODUCTION

Historical and persistent low groundwater elevations caused by pumping in the Seaside Groundwater Basin have led to concerns that seawater intrusion may threaten the Basin's groundwater resources. This report addresses the potential for, and extent of, seawater intrusion in the Seaside Groundwater Basin. The report first reviews seawater intrusion mechanisms, analyzes historical water quality data for indications of seawater intrusion in the Seaside Groundwater Basin, and finally reaches conclusions on the extent of seawater intrusion and proposes recommendations for continued monitoring.

This report fulfills part of the annual reporting requirements contained in the Seaside Groundwater Basin Adjudication (California American Water v. City of Seaside, Monterey County Superior Court, Case Number M66343). The analyses in this report were developed by HydroMetrics Water Resources Inc. of Oakland, CA, in cooperation with members of the Watermaster Technical Advisory Committee (TAC). Staff from the Monterey County Water Resources Agency (MWCRA) and Monterey Peninsula Water Management District (MPWMD) provided invaluable assistance, data, and review during the preparation of this report.

This report is the seventh in a series of Seawater Intrusion Analysis Reports (SIAR) which are produced annually by the Watermaster. It builds on the work performed in the preceding SIARs.

This page left
intentionally blank

SECTION 2

OVERVIEW OF SEAWATER INTRUSION

Seawater intrusion is a threat to many coastal groundwater basins along the California Coast. It has been observed and documented in a number of groundwater basins in both southern and central California.

In general, groundwater in coastal basins flows from recharge areas in local highlands towards discharge areas along the coast. In most undeveloped coastal groundwater basins there is a net outflow of fresh water into the ocean. Seawater intrusion occurs when the outflow of freshwater ceases and seawater flows into the groundwater basin from the ocean.

In the simplest condition, seawater intrudes as a wedge beneath the fresh groundwater (Figure 1). This wedge shape is a result of seawater being denser than freshwater.

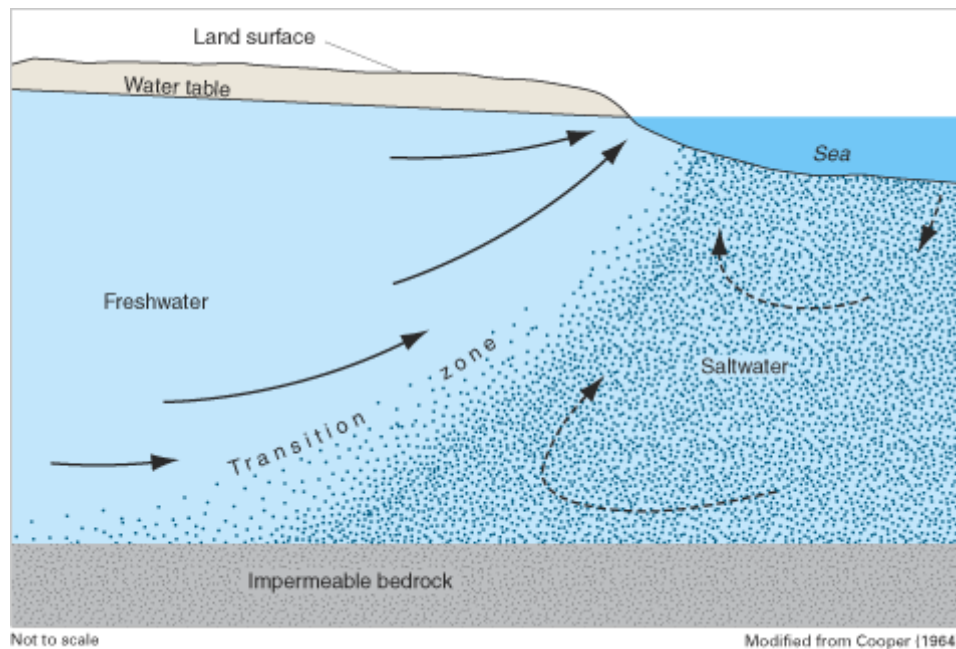
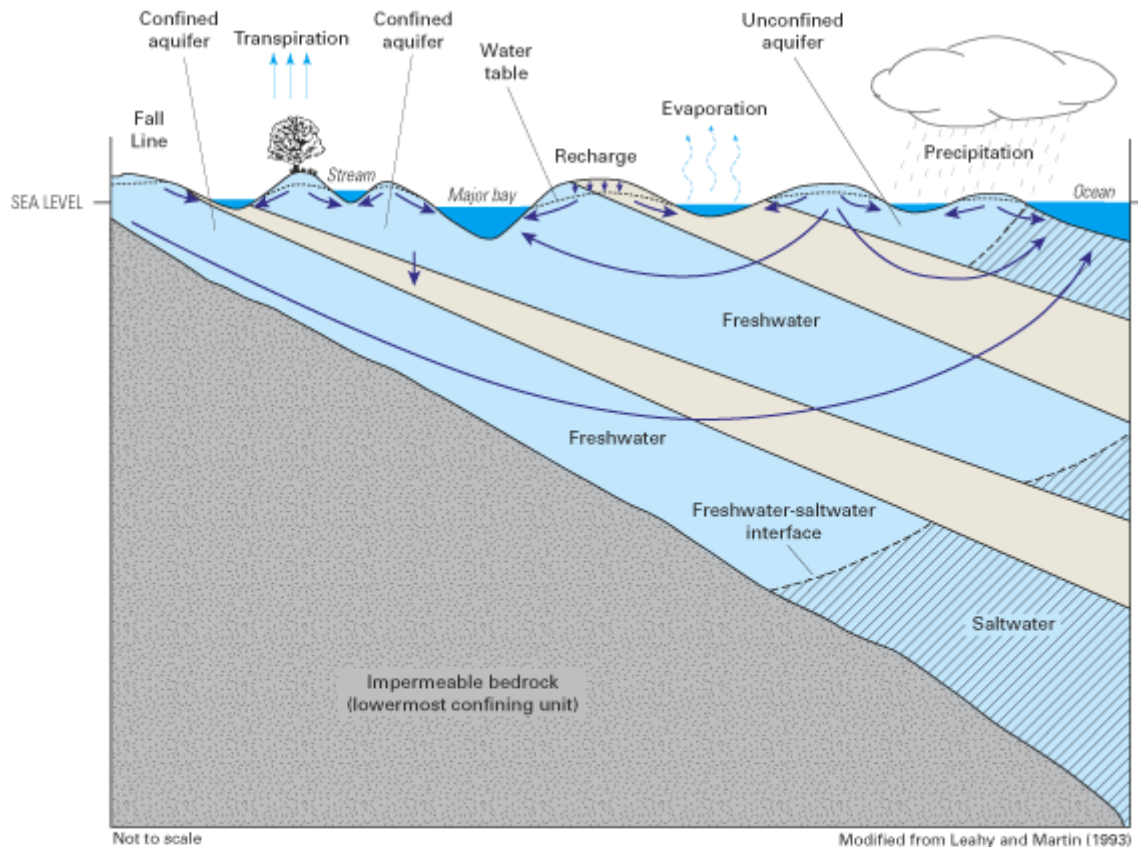


Figure 1: Seawater Wedge in a Simple Coastal Aquifer (from Barlow, 2003)

In more complex, layered groundwater systems, the location of the seawater/freshwater interface may vary among the different aquifers. Such a situation is illustrated on Figure 2. Figure 2 shows a series of aquifers in blue, which transmit water easily. The aquifers are separated by a series of tan

aquitards, which transmit water relatively slowly. Each aquifer has a unique rate of outflow to the ocean, and therefore a unique location of the seawater interface. In these more complex situations, the locations of the seawater/freshwater interfaces are a complex function of the horizontal groundwater gradient in each aquifer, the aquifer hydraulic conductivities, and the vertical conductivity of the inter-layer aquitards.



- EXPLANATION**
- Aquifer**
 - Confining unit**
 - Ground-water flow paths—**
Shows general direction of ground-water flow

Figure 2: Seawater Wedge in a Layered Coastal Aquifer (from Barlow, 2003)

Figure 2 shows that under non-pumping conditions, the seawater interface in confined units can be located farther offshore than in surficial unconfined aquifers. The fresh water in an unconfined aquifer can flow readily into the ocean, allowing the seawater interface to exist near shore. Fresh water in the

lower confined aquifers must seep out slowly through the overlying confining units. The slow seepage rates allow the fresh water to maintain pressure beneath the sea floor, pushing the seawater interface away from the coastline.

GROUNDWATER PUMPING AND SEAWATER INTRUSION

Pumping groundwater in a coastal aquifer reduces the amount of water discharging to the ocean. Sufficient pumping can eliminate ocean discharges, either locally or basin-wide, triggering seawater intrusion. The response of the seawater interface to groundwater pumping is manifested in two related ways: upconing and interface migration. Upconing refers to the ability of a pumping well to draw seawater up from below. Upconing only occurs if seawater exists directly below a pumping well. Because no seawater intrusion has been observed in the Seaside Groundwater Basin, upconing cannot occur, and only seawater interface migration will be further addressed in this report.

As mentioned earlier, groundwater pumping reduces the amount of fresh water outflow to the ocean. This allows the interface to migrate shoreward. Substantial pumping can allow the interface to move onshore, potentially impacting municipal wells, private wells, or agricultural wells. Figure 3 shows a two-dimensional cross section of how the fresh water/seawater interface may migrate in response to pumping.

As can be inferred from Figure 3, the degree of interface migration depends on the amount of water pumped from a particular aquifer, as well as the amount of leakage from overlying or underlying aquifers. Groundwater extracted from the lowest aquifer might be replaced by rainfall recharge, by seawater migrating shoreward, or by groundwater leaking from the overlying aquifer.

An additional issue that must be considered with seawater interface migration is the initial location of the seawater interface. An interface that starts far from the shore may take a considerable amount of time, often on the order of decades, to reach any production or monitoring well. Furthermore, the farther the interface is from the pumping well, the more area is available for fresh water to leak from overlying aquifers into the producing aquifer. This slows, or may completely stop, seawater intrusion in the pumped aquifer. Downward leakage, however, removes fresh water from overlying aquifers. This leakage may therefore exacerbate seawater intrusion in the overlying aquifer.

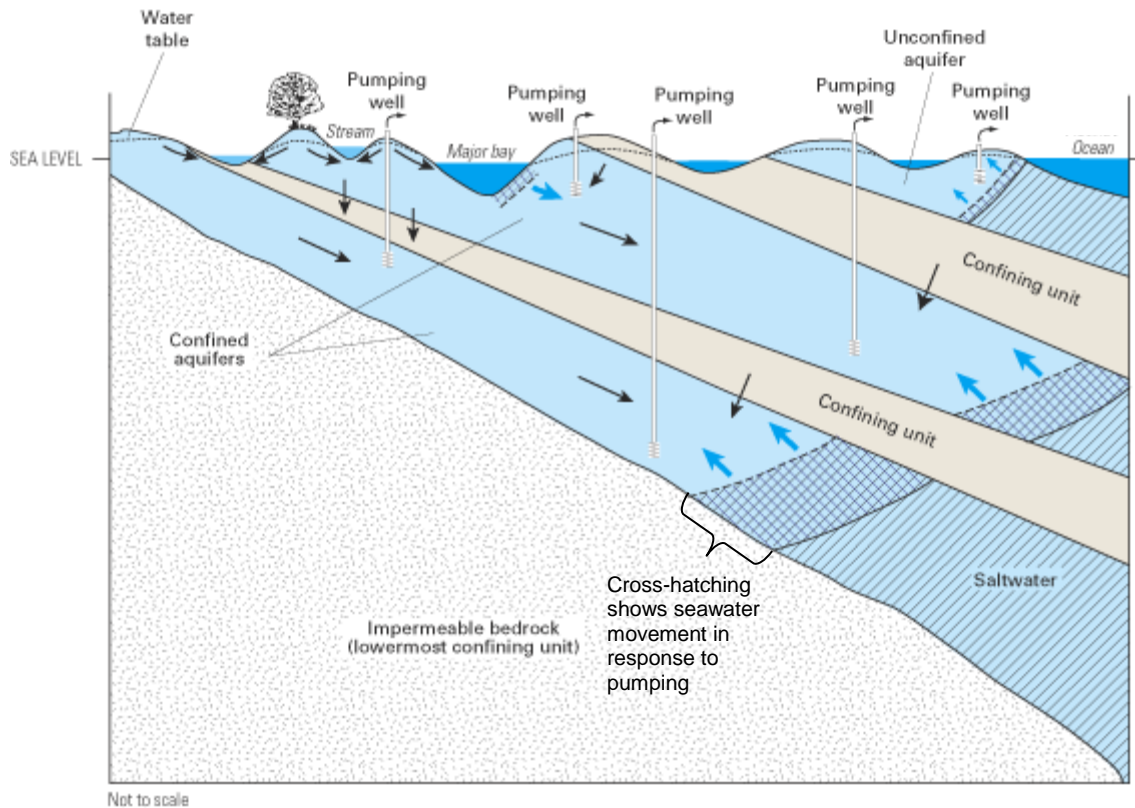


Figure 3: Interface Migration in Response to Groundwater Pumping
(from Barlow, 2003)

INDICATORS OF SEAWATER INTRUSION

Seawater intrusion is generally identified through chemical analyses of groundwater. Groundwater levels below or near sea level indicate an opportunity for seawater intrusion, but the actual seawater intrusion is indicated by various geochemical changes in groundwater.

No single analysis definitively identifies seawater intrusion, however by looking at various analyses we can ascertain when fresh groundwater mixes with seawater. At low chloride concentrations, it is often difficult to identify incipient seawater intrusion. This is due to the natural variation in fresh water chemistry at chloride concentrations below 1,000 milligrams per liter (mg/L) (Richter and Kreitler, 1993). Mixing trends between groundwater and seawater are more easily defined when chloride concentrations exceed 1,000 mg/L.

Common geochemical indicators of seawater intrusion are discussed, and example analyses are presented, in the following sections.

CATION/ANION RATIOS

Molar ratios of cations and anions can prove distinctive for various groundwater systems. Seawater intrusion is often indicated by graphically analyzing shifts in these molar ratios. Two common graphical techniques for these analyses are Piper diagrams and Stiff diagrams.

PIPER DIAGRAMS

Example Piper diagrams are shown for data from the Pajaro Valley and Salinas Valley on Figure 4 and Figure 5, respectively. These figures are included to demonstrate the utility of Piper diagrams, and show how they have been used in nearby basins. These figures are not provided for directly comparing data between basins; groundwater quality trends in one basin will not necessarily correlate with trends in other basins.

On these Piper diagrams, the relative abundances of individual cations and anions are plotted in the left and right triangles, respectively, and their combined distribution is plotted in the central diamond. Waters from similar or related sources will generally plot together. The mixture of two waters will generally plot along a straight line between the two end-member types within the central diamond. The trend towards seawater intrusion, however, often plots along a curved path as shown on Figure 4. The red arrows track the evolution of water chemistry from freshwater to seawater. Often only the first, upward leg of this curve is observed, because wells become too saline to use before reaching the downward leg, and sampling is usually discontinued.

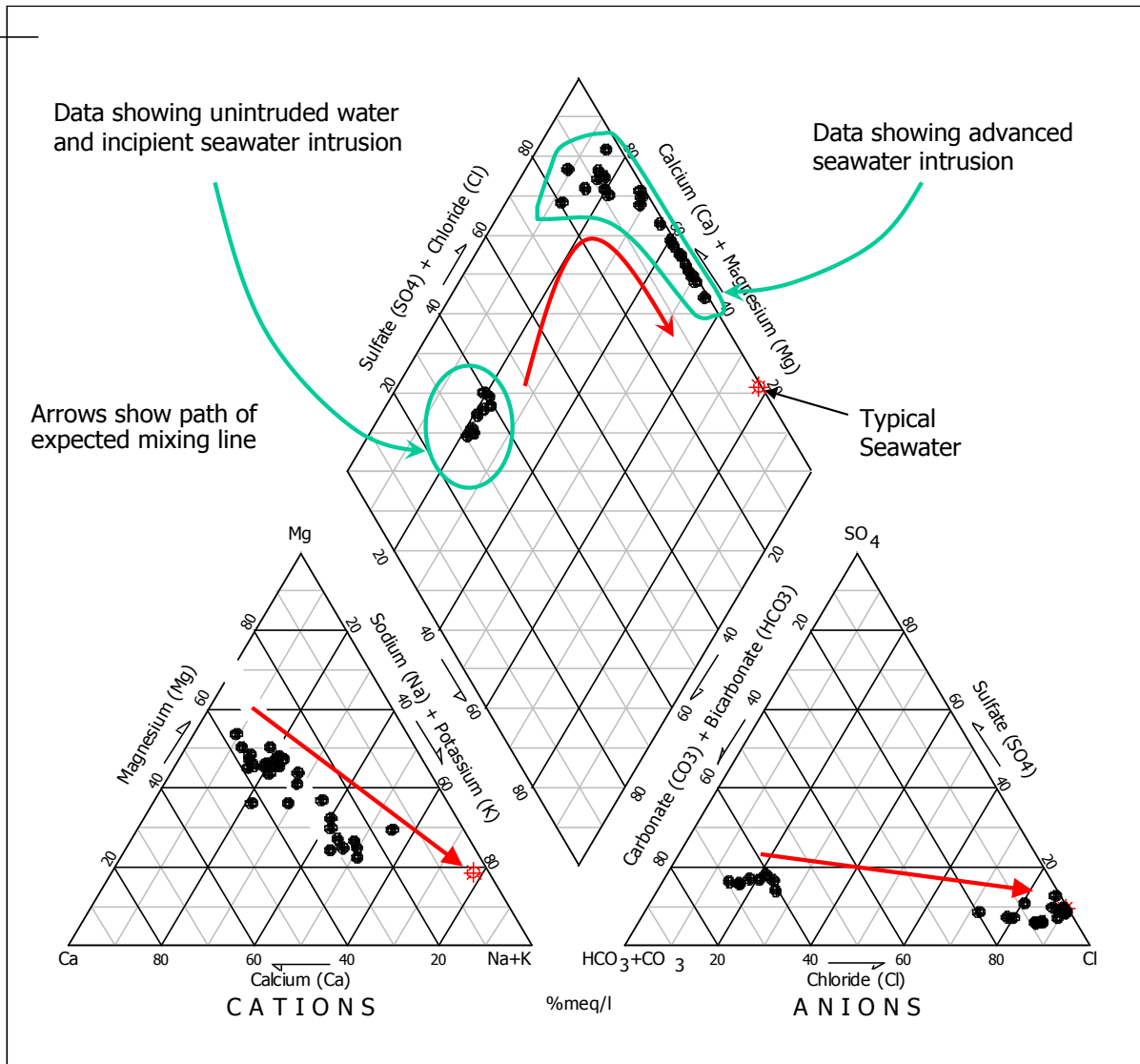
STIFF DIAGRAMS

Example Stiff diagrams from the Salinas Valley are shown on Figure 6 and Figure 7. These figures are included to demonstrate the utility of Stiff diagrams, and show how they have been used in nearby basins. On Stiff diagrams, the relative abundances of individual cations are plotted on the left side of the graph, and the relative abundances of anions are plotted on the right side of the graph. Waters with similar chemistries will have similarly shaped Stiff diagrams.

Figure 6 shows Stiff diagrams characteristic of the unintruded portions of the Salinas Valley Pressure 400-Foot Aquifer. By contrast, Figure 7 shows Stiff diagrams from the intruded portion of the Salinas Valley Pressure 400-Foot Aquifer. The significantly higher chloride levels in the intruded aquifer result in the noticeable spike at the upper right hand side of the Stiff diagrams on Figure 7. This spike is indicative of incipient seawater intrusion.

The Stiff diagrams shown on Figure 7 are from wells that have acknowledged seawater intrusion, based on multiple lines of evidence. The Stiff diagrams alone are often not sufficient to identify seawater intrusion because there is no standard for Stiff diagram shapes; the diagrams are most useful as a comparative tool, showing the evolution of water chemistry over time and space. The shape of these Stiff diagrams is considered indicative of seawater intrusion in Salinas Valley only because considerable data analyses have shown that locally, Stiff diagrams adopt this shape as seawater encroaches.

The Stiff diagrams of seawater intruded wells shown on Figure 7 show calcium concentrations greater than sodium concentrations, in spite of the fact that sodium is the dominant cation in seawater. Incipient seawater intrusion is often characterized by increasing calcium and decreasing sodium, due to cation exchange between sodium and calcium on the aquifer material. This concept is discussed further on page 14.



(Data source: PVWMA)

Seawater Intruded Wells (Pressure 400-Foot Aquifer)

2003 Water Quality Data

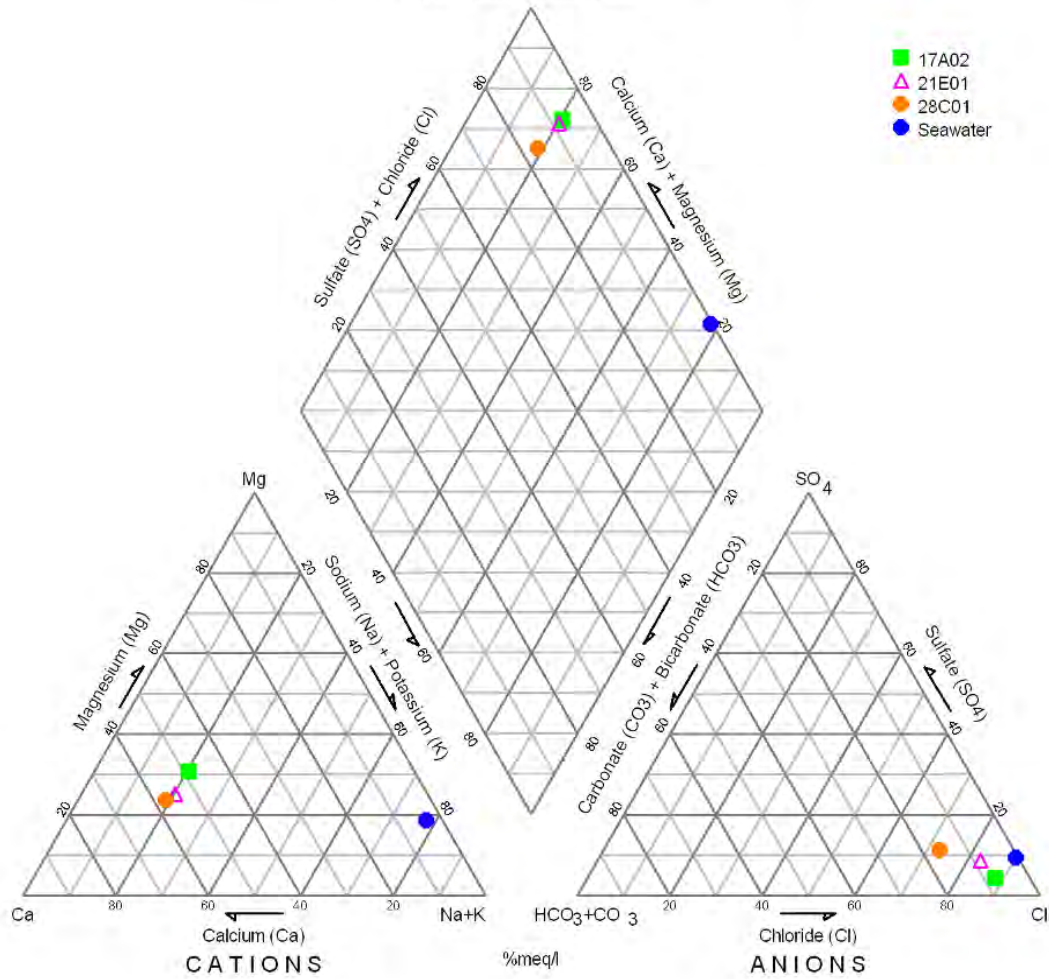


Figure 5: Piper Diagram for Groundwater in Salinas Valley
(Source: MCWRA)

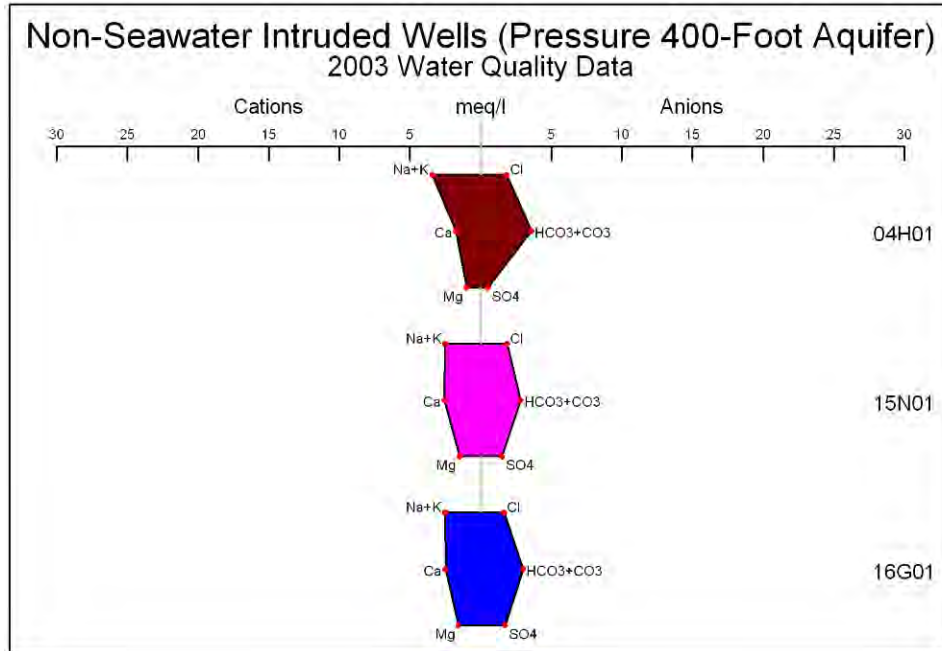


Figure 6: Stiff Diagrams from Salinas Valley Wells without Seawater Intrusion
(Source: MWCRA)

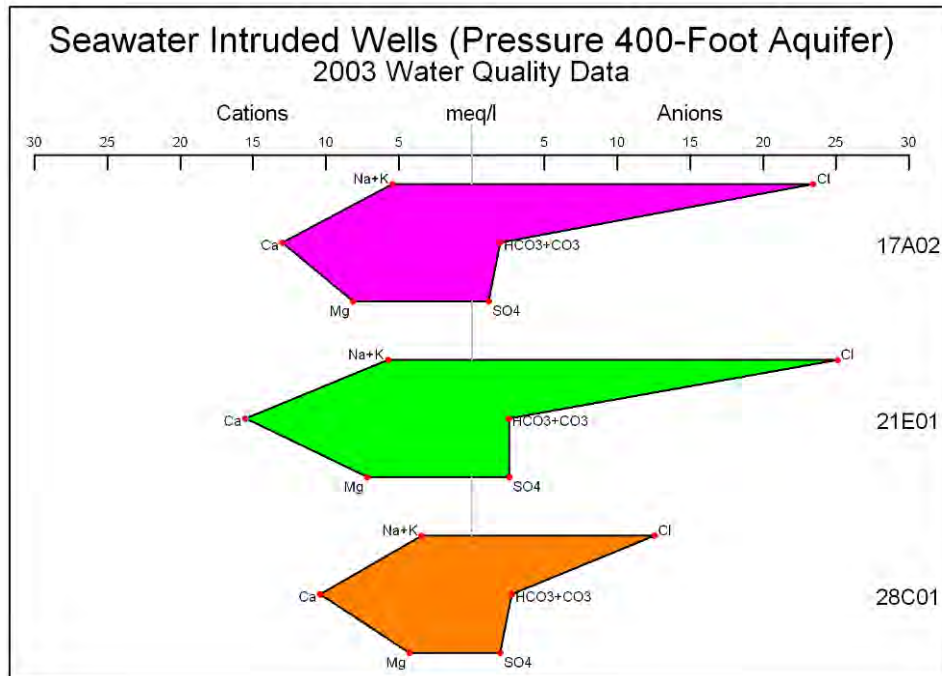


Figure 7: Stiff Diagrams from Salinas Valley Wells with Seawater Intrusion
(Source: MWCRA)

INCREASING CHLORIDE CONCENTRATIONS

Seawater is chloride rich, whereas bicarbonate or sulfate are the dominant anions in many groundwater systems. Steadily increasing chloride concentrations over time is the one of the most commonly used indicators of seawater intrusion. At low chloride concentrations, trends are often as important as absolute concentrations because of natural variations in groundwater chemistry. As an example, in 2004 the coastal shallow Pacific Cement Aggregates (PCA) West well had a chloride concentration of 46 mg/L, whereas the much more inland well 2701882-016, located in the Laguna Seca subarea, had a chloride concentration of 225 mg/L. The higher chloride concentration in well 2701882-016 is fairly consistent, showing no increasing trend, and is clearly not an indicator of seawater intrusion.

Example graphs showing historical chloride concentration increases indicative of seawater intrusion are shown on Figure 8 and Figure 9. Figure 8 graphs steadily increasing chloride concentrations in a shallow well in the Salinas Valley. Figure 9 graphs increasing chloride concentrations in a well in the Pajaro Valley. Both of these graphs show that the rise in chlorides is a lengthy and persistent process; chloride concentrations began to increase in the representative Salinas Valley well in 1982, and took six years before exceeding the Safe Drinking Water Act secondary drinking water standard of 250 mg/L. This long-term and relatively slow increase in chlorides suggests that while chloride concentrations are strongly indicative of seawater intrusion, it often takes time for the increasing chloride trend to be recognizable.

SODIUM/CHLORIDE MOLAR RATIOS

As mentioned earlier in this report, sodium often replaces calcium on the aquifer matrix through ion exchange in advance of the seawater front. This effectively removes sodium from the water, and sodium/chloride ratios drop in advance of the seawater front. This can sometimes be used as an early indicator of seawater intrusion. Sodium/Chloride ratios can also be used to differentiate between seawater intrusion and other sources of saltwater. Jones et al. (1999) suggest that sodium/chloride ratios in advance of a seawater intrusion front will be below 0.86 (molar ratio). This distinguishes seawater intrusion from domestic waste water, which typically has sodium/chloride ratios above 1.

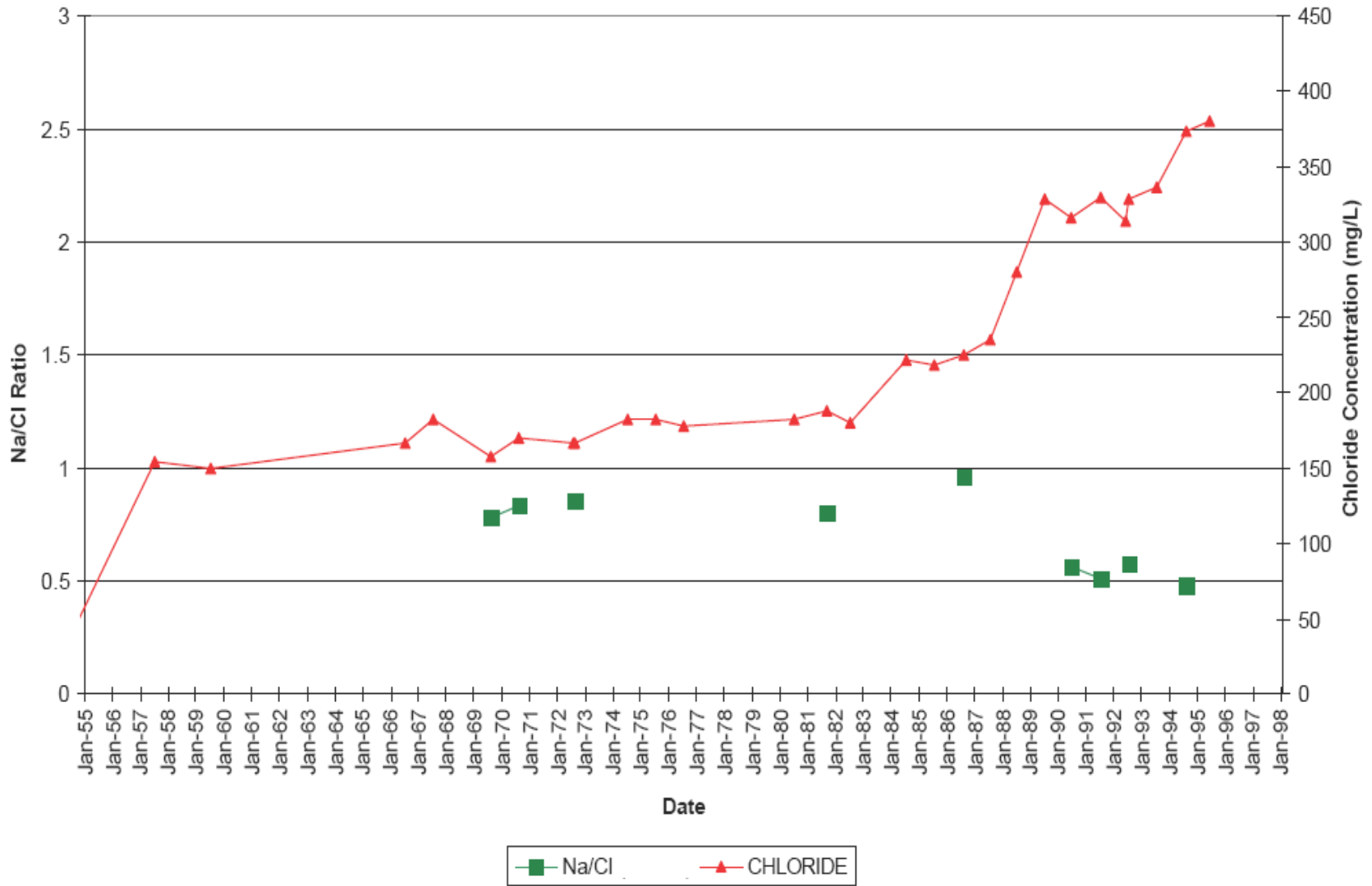


Figure 8: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Salinas Valley Showing Incipient Intrusion (Source: MCWRA)

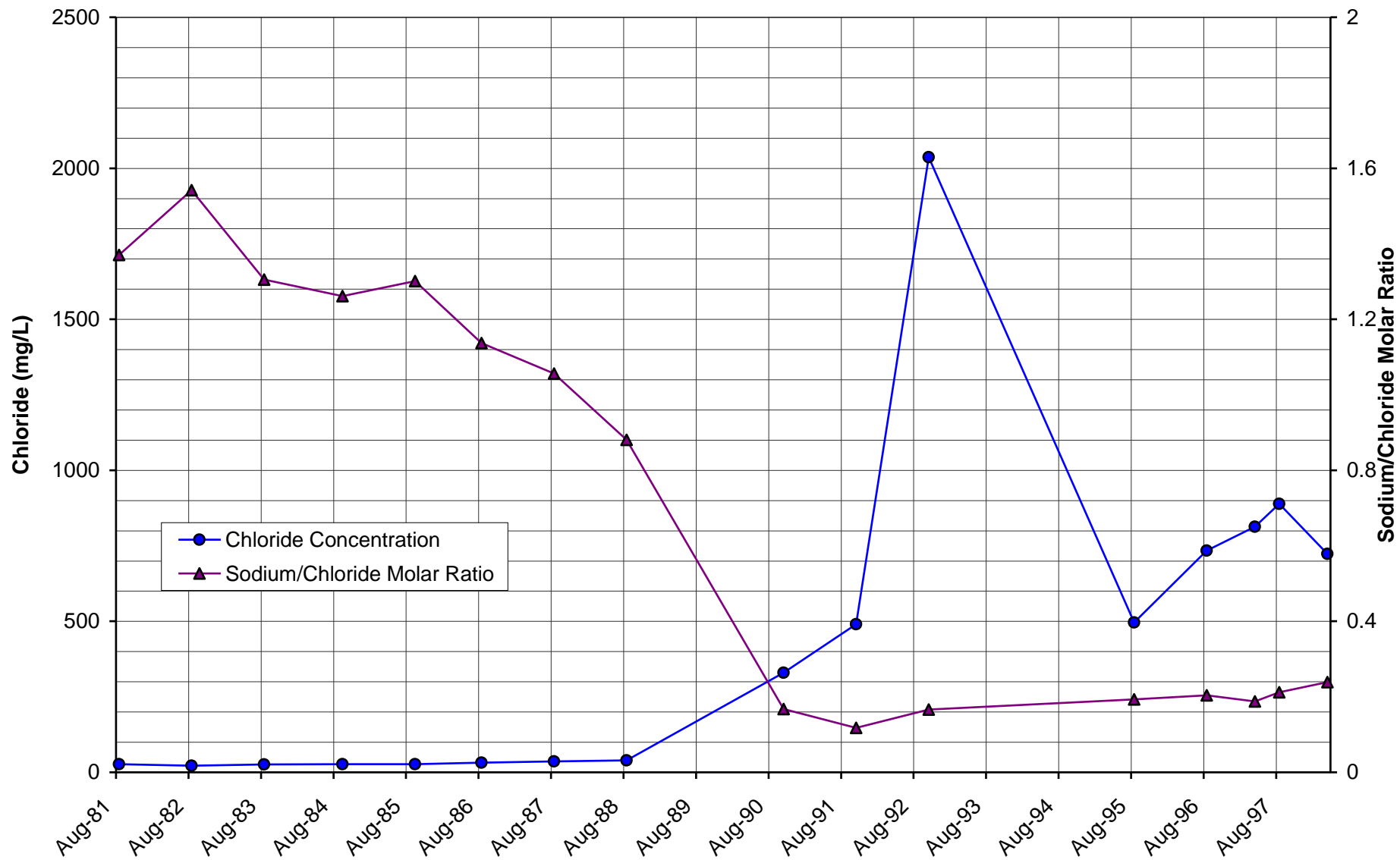


Figure 9: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Pajaro Valley Showing Incipient Intrusion (Data source: PVWMA)

In addition to plotting increasing chloride concentrations, decreasing sodium/chloride ratios are plotted on Figure 8 and Figure 9. The strong correlation between the two indicators of seawater intrusion can be observed on these two figures. The potential utility of sodium/chloride ratios as an early indicator of seawater intrusion is shown on Figure 9. This figure shows that by August 1988, chloride concentrations in the Pajaro Valley well had remained relatively constant, yet sodium/chloride ratios were beginning to drop, suggesting incipient seawater intrusion. By September 1990, the rising chloride levels can be clearly correlated to dropping sodium/chloride ratios; definitively associating the high chlorides with seawater intrusion.

CHLORIDE-BICARBONATE RATIOS

The ratio of chloride to bicarbonate-plus-carbonate contrasts the relative abundance of the dominant seawater and freshwater anions. As a ratio of concentrations expressed in mg/L, the ratio for seawater exceeds 100 and values for groundwater unaffected by seawater are generally less than 0.3. For groundwater with relatively low total dissolved solids, this ratio provides little benefit over evaluating chloride concentrations alone; and therefore is not used in the current analyses.

ELECTRIC INDUCTION LOGS

Changes in formation salinity can be measured from within a well using electric induction logging. Induction logging within the well measures the fluid conductivity within the adjacent formation up to a distance of three feet from the well casing. This technique can be used in wells that are completed with PVC casings and screens.

This method can be used as a cost-effective method of detecting seawater intrusion by measuring the electrical conductivity of the formation throughout the depth of the well. If over time, the conductivity increases relative to the baseline value, it could indicate seawater intrusion. One limitation of this method is that it does not provide concentrations of chloride or other ions that contribute to salinity. Therefore, the use of electric induction logs can only be used qualitatively.

Induction logging has been performed on the Watermaster's coastal sentinel wells since their completion in 2007.

OTHER INDICATORS

Hem (1989) suggested several other indicators for seawater intrusion, including the concentration ratio of calcium to magnesium (approximately 0.3 in seawater and greater in fresh water); the percentage of sulfate among all ions (approximately 8 percent in seawater and larger in fresh water); and the concentrations of minor constituents such as iodide, bromide, boron, and barium. These other indicators are not used in the current analyses for two reasons:

1. The analyses presented in the following sections overwhelmingly suggest that seawater intrusion has not advanced onshore in the Seaside Groundwater Basin.
2. No historical data exists for the minor constituents such as iodide and barium; and only limited historical data exist for bromide and boron. It should be noted that since 2012, the Watermaster has been analyzing samples from selected coastal monitoring and production wells for iodide, bromide, boron, and barium.

Using the other indicators mentioned above is not necessary in light of there being other methods available for indicating seawater intrusion, as discussed in the preceding sections. Should the other methods start showing seawater intrusion, the minor constituents of iodide, bromide, boron, and/or barium will be included in future water quality analyses so that they can be used as supplemental indicators.

SECTION 3

SEAWATER INTRUSION IN THE SEASIDE GROUNDWATER BASIN

The geochemical criteria discussed above, along with various maps, can be used to estimate the presence or lack of seawater intrusion in the Seaside Groundwater Basin. While no single analysis is a definitive indicator of seawater intrusion, the combined weight of all analyses may be instrumental in detecting seawater intrusion.

ANALYSIS APPROACH

As was used in previous Seawater Intrusion Analysis Reports (RBF, 2007; HydroMetrics LLC, 2008; HydroMetrics LLC, 2009a; HydroMetrics WRI, 2010; HydroMetrics WRI, 2011, HydroMetrics WRI, 2012a, HydroMetrics WRI, 2013a), this report includes a number of approaches to evaluate seawater intrusion. Data for the 2nd quarter of Water Year 2014 (sampled and measured January-March 2014) and 4th quarter of Water Year 2014 (sampled and measured July-September 2014) were analyzed and mapped to show the spatial distribution of groundwater quality and groundwater elevations. In addition to spatial mapping, historical data were graphed to assess geochemical trends. Data from the 2nd quarter represents conditions during the wet time of the year; data from the 4th quarter represents conditions during the dry time of the year.

Where possible, analyses are separated by depth zone. Two depth zones have been chosen, following the system of Yates et al. (2005). Wells assigned to the shallow depth zone generally correlate to the Paso Robles Formation where it exists. This shallow zone is roughly at the same depth as the Salinas Valley Pressure 400-Foot Aquifer. Wells assigned to the deep zone correlate with the Santa Margarita Sandstone where it exists in the Seaside Groundwater Basin. The deep zone is roughly at the same depth as the Salinas Valley Deep Aquifer.

CATION/ANION RATIOS

For Water Year 2014, 15 monitoring wells and 12 production wells were used for geochemical trend analyses. The location of all monitoring and production wells used in the SIAR analysis over the years are shown on Figure 10. Some of the production wells are not included in the analysis this year because they have not been pumped during the year. Of the 15 monitoring wells, four are the deep

sentinel wells installed by the Watermaster in 2007. Eleven monitoring wells used in this analysis represent one or both well pairs from the MPWMD monitoring well network (Figure 10). MPWMD uses the deep monitoring well at Seaside Middle School for ASR reporting purposes to the Regional Water Quality Control Board; if there has been no injection during the year, no water quality sample is collected.

A well pair comprises two wells drilled in close proximity to one another – one perforated in the shallow zone and the other perforated in the deep zone. Each well pair is represented with a unique color and symbol on Piper and Stiff diagrams. The shallow well of each pair is represented by a filled square on the Piper diagrams; the deep well of each pair is represented by a filled circle on the Piper diagrams.

The production wells included in the analysis are water purveyor wells that are sampled annually for general inorganic minerals per the Seaside Basin Monitoring and Management Program. The current schedule includes sampling selected coastal monitoring wells quarterly. All other monitoring and production wells are sampled annually during the 4th quarter. Where samples are not available for analysis, the text and figures indicate as such.

SECOND QUARTER WATER YEAR 2014 (JANUARY-MARCH 2014)

A Piper diagram displaying analyses from six monitoring wells in the Seaside Groundwater Basin for the 2nd quarter Water Year 2014 (January-March 2014) is shown on Figure 11. Analyses from only six wells are shown because most of the monitoring well pairs, and all but one production well, are not sampled during this quarter; they are only sampled annually in the 4th quarter. Appendix A includes individual Piper diagrams for each well to show their chemical nature over time.

The monitoring wells generally cluster in a single area on the Piper diagram that is consistent with previous data. The location on the Piper diagram indicates that the water from both the deep and shallow well pairs straddle the sodium-chloride and sodium-bicarbonate type water¹. The Piper diagrams in

¹ Where the data points fall in the Piper diagram triangle for anions and the triangle for cations determines the type of water. For example, if the points plot in the lower right corner of the anion triangle, the water is classed as chloride type water.

Appendix A show no trends over time towards typical seawater, indicating that there is currently no seawater intrusion at any of the analyzed wells.

Stiff diagrams for the monitoring wells sampled during the 2nd quarter of Water Year 2014 are shown in the left column on Figure 12 through Figure 15. The Stiff diagrams are coded to match the colors and symbols on the Piper diagram. None of the Stiff diagrams show the high chloride spike shown on Figure 7 that indicates seawater intrusion. The shapes of the Stiff diagrams for the paired monitoring wells in the Northern subarea are similar to the shapes of the 4th quarter 2013 and earlier data.

FOURTH QUARTER WATER YEAR 2014 (JULY-SEPTEMBER 2014)

Piper diagrams displaying groundwater quality data from 15 monitoring wells and 12 production wells in the Seaside Groundwater Basin for the 4th quarter of Water Year 2014 (July-September 2014) are shown on Figure 16 and Figure 17, respectively. Appendix A includes individual Piper diagrams for each well to show trends over time.

Except for sentinel wells SBWM-1 through SBWM-3, Figure 16 shows water quality data for the monitoring wells clustering in a single area on the Piper diagram. This pattern is similar to that observed during the 4th quarter Water Year 2013 and the 2nd quarter of Water Year 2014. Most of the groundwater is of sodium-chloride/sodium-bicarbonate type. The data points on the Piper diagram for the deep completion of sentinel well SBWM-2 at 1,470 feet (Appendix A: Figure A-16) were previously thought to be evolving towards being more chloride-rich over time, however, with seven years of data to evaluate, it appears that the relative percentage of chloride anions varies between fixed points and is not evolving in one direction only. The historical trend of cations and anions is not indicative of seawater intrusion as shown on Figure 4 or Figure 5.

Figure 17 shows some production wells plotting within the same area as the monitoring wells. The variation of the plot location on the Piper diagram for production wells is due to higher sulfate and chloride anions than in the monitoring wells. These wells can be characterized as sodium-sulfate-chloride type waters. The York School well plots closest to typical seawater on this diagram, however its inland location precludes seawater intrusion as the cause for the observed water chemistry at this well. Overall, the Piper diagrams show no indication of seawater intrusion at any of the analyzed wells.

The Sand City's Public Works Corp Yard production well Piper diagram shows that its cations, namely calcium, sodium, and potassium, vary while the anions remain more stable (Appendix A: Figure A-23). Initially, it was thought this well's chemistry was evolving over time, but now after six years of data to evaluate, it appears that the relative percentage of cations varies between fixed points and is not evolving in one direction only. The source of this variance is not seawater because it does not follow the pattern depicted on Figure 4 and Figure 5.

Stiff diagrams for the 15 monitoring wells sampled during the 4th quarter of Water Year 2014 are shown in the right column on Figure 12 through Figure 15. The shapes of the Stiff diagrams for the paired monitoring wells are similar to the shapes of the Stiff diagrams from previous years. Stiff diagrams for the 12 production wells sampled during the 4th quarter of Water Year 2014 are shown in the right column on Figure 18 through Figure 20. These production well Stiff diagrams show the same shapes as were observed in the 4th quarter of Water Year 2013 and previous years. The Pasadera Paddock production well has a stiff diagram shape that is different to the other wells' chemistry. The cause of this could be localized mineralization. The Laguna Sea subarea is known to have higher salts in groundwater than the rest of the basin due to the underlying Monterey shale which was deposited in a marine environment. None of the Stiff diagrams show the high chloride spike shown on Figure 7 that indicates seawater intrusion.

The York School production well, in the Laguna Seca subarea, and Sand City's Public Works Corp Yard production well, in the Southern Coastal subarea both have Stiff diagrams different from most other wells' water quality (Figure 18). Although the shapes are different, they do not display the large chloride spike associated with seawater intrusion as shown on Figure 7. None of the production wells analyzed using Stiff and Piper diagrams show an indication of seawater intrusion.

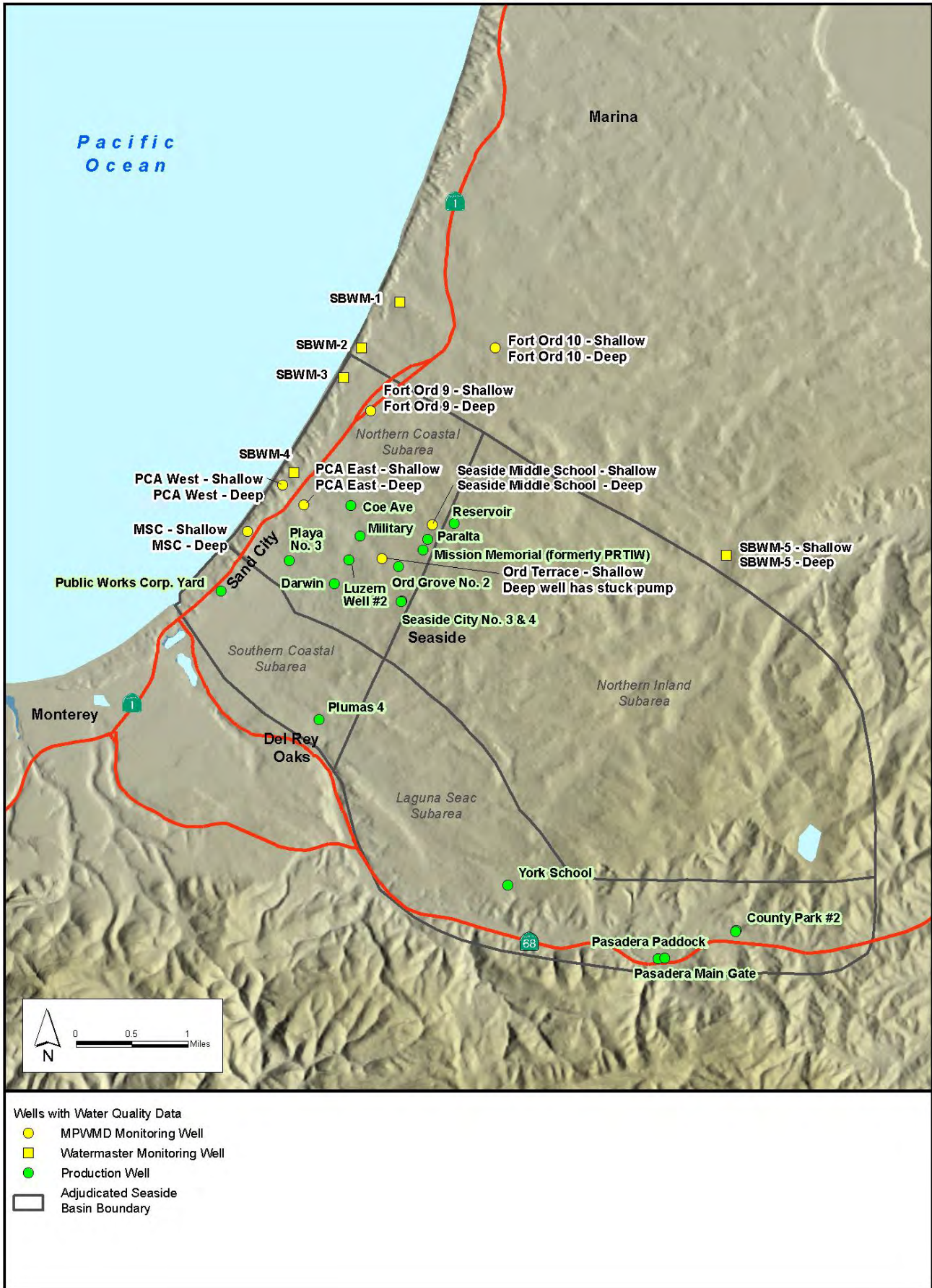


Figure 10: Wells Used for Seawater Intrusion Analyses

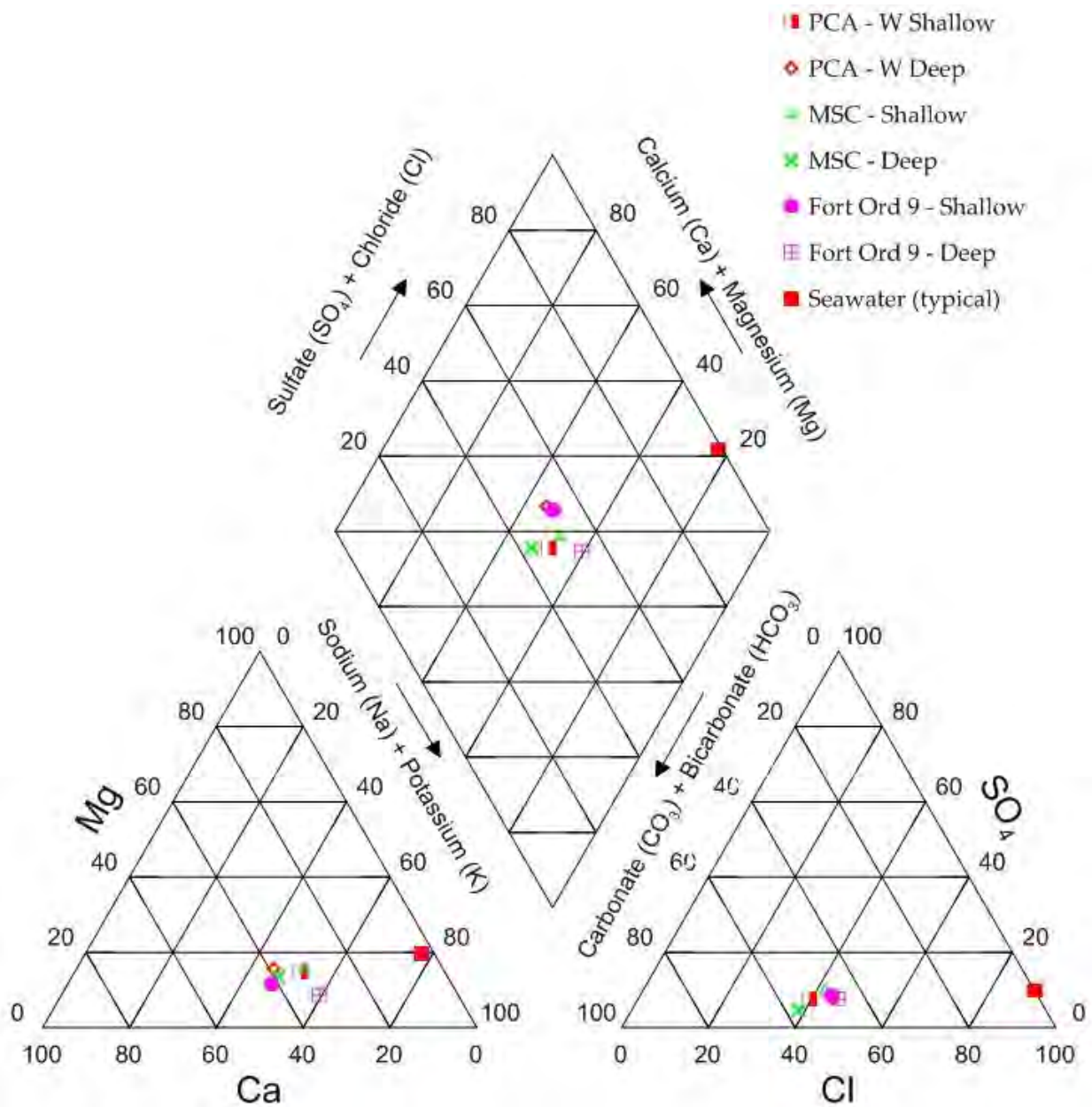


Figure 11: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 2nd Quarter Water Year 2014 (January-March 2014)
 (Data source: Watermaster)

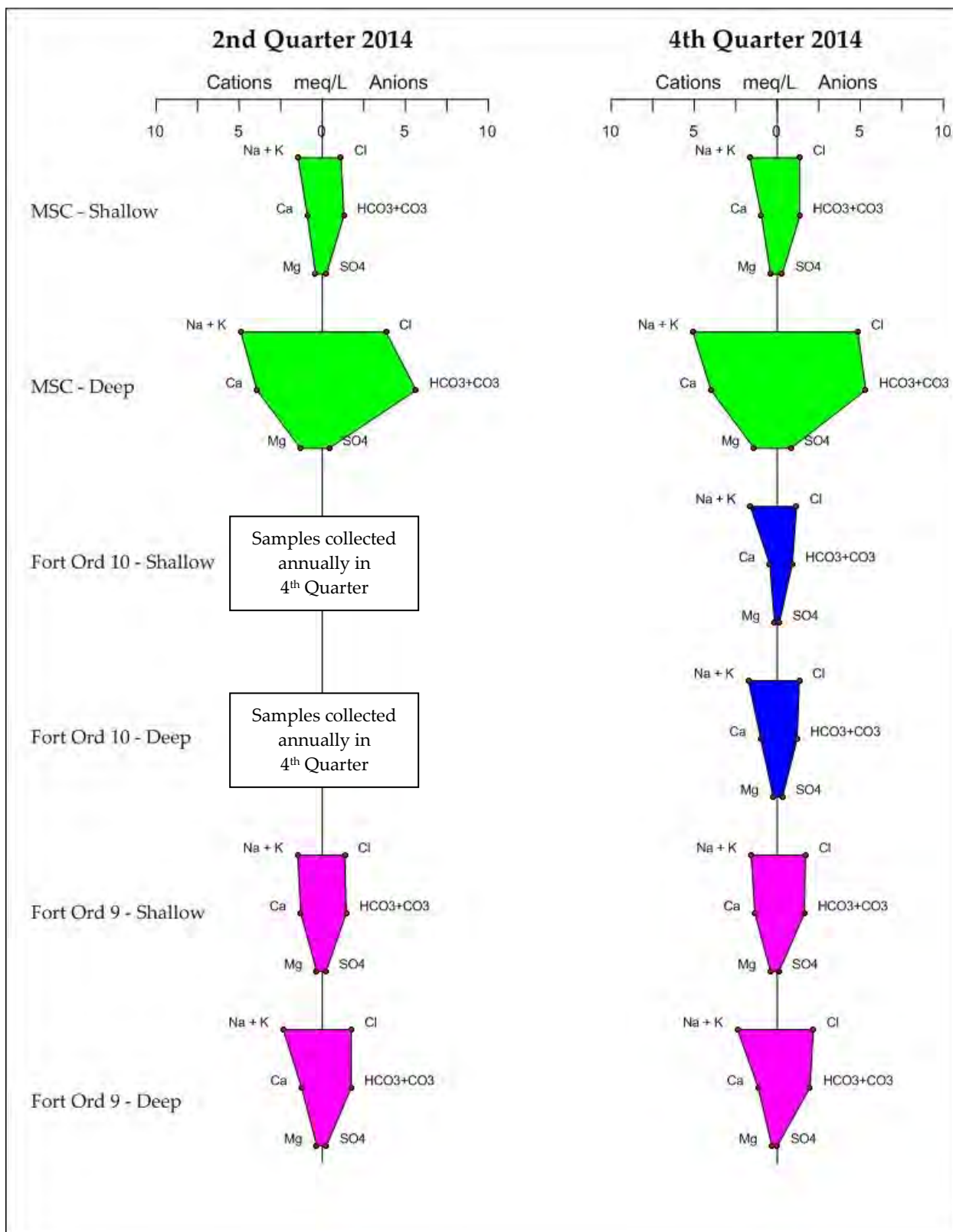


Figure 12: Stiff Diagrams for MSC, Fort Ord 9, and Fort Ord 10 Wells
(Data source: Watermaster)

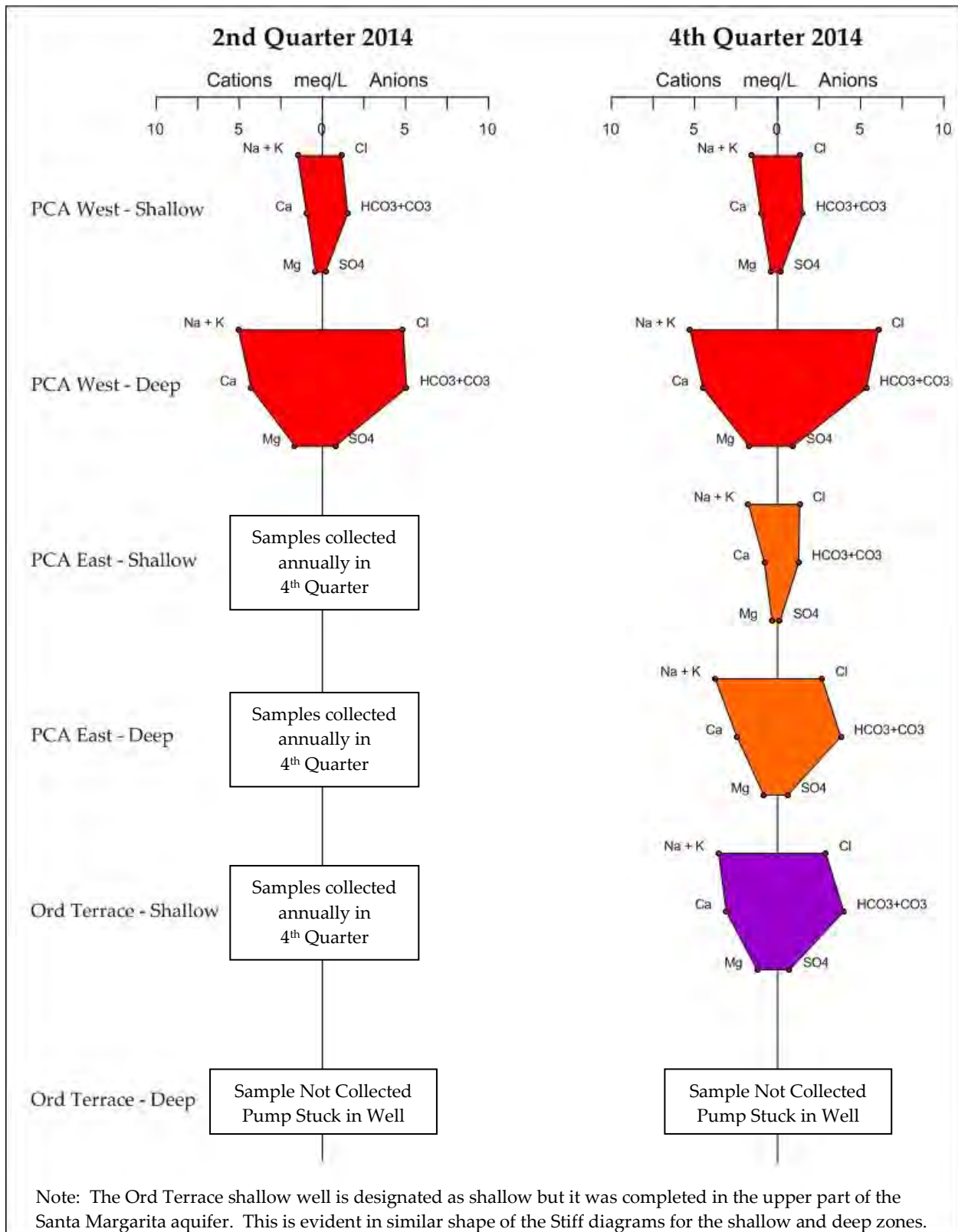


Figure 13: Stiff Diagrams for PCA West, PCA East, and Ord Terrace Wells
(Data source: Watermaster)

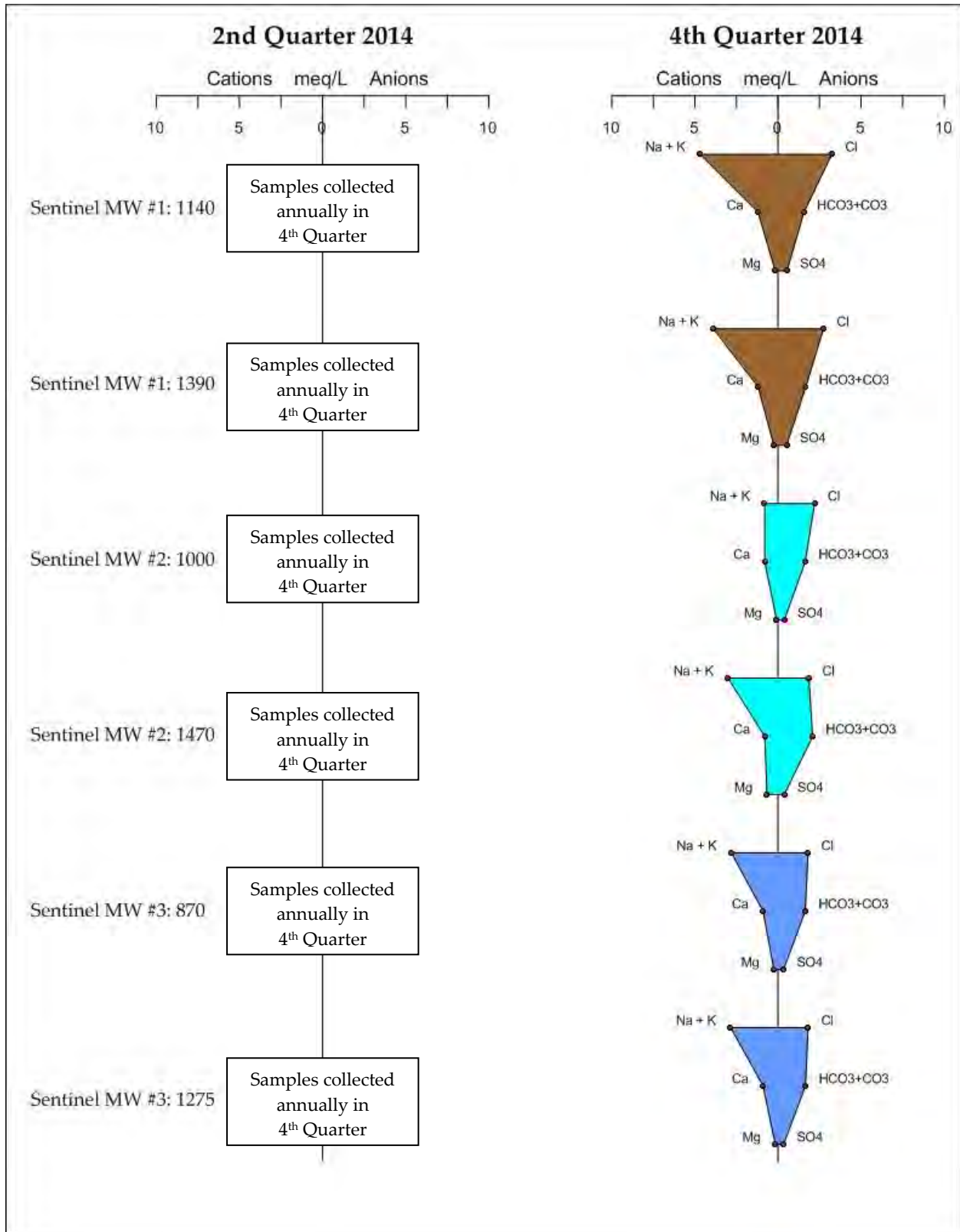


Figure 14: Stiff Diagrams for Watermaster Sentinel Wells 1 - 3
(Data source: Watermaster)

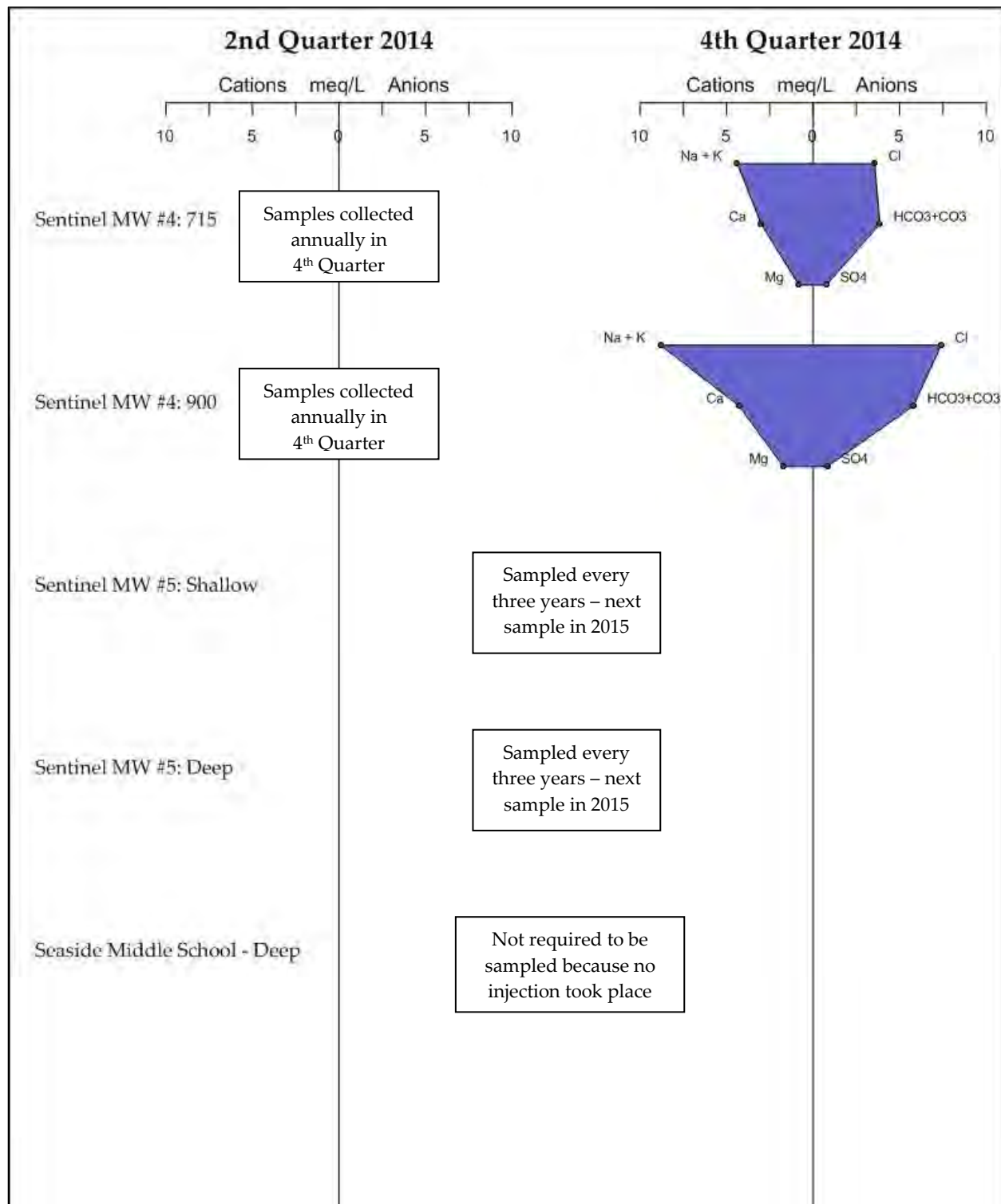


Figure 15: Stiff Diagrams for Watermaster Sentinel Wells 4 and 5, and Seaside Middle School Deep
(Data source: Watermaster and MPWMD)

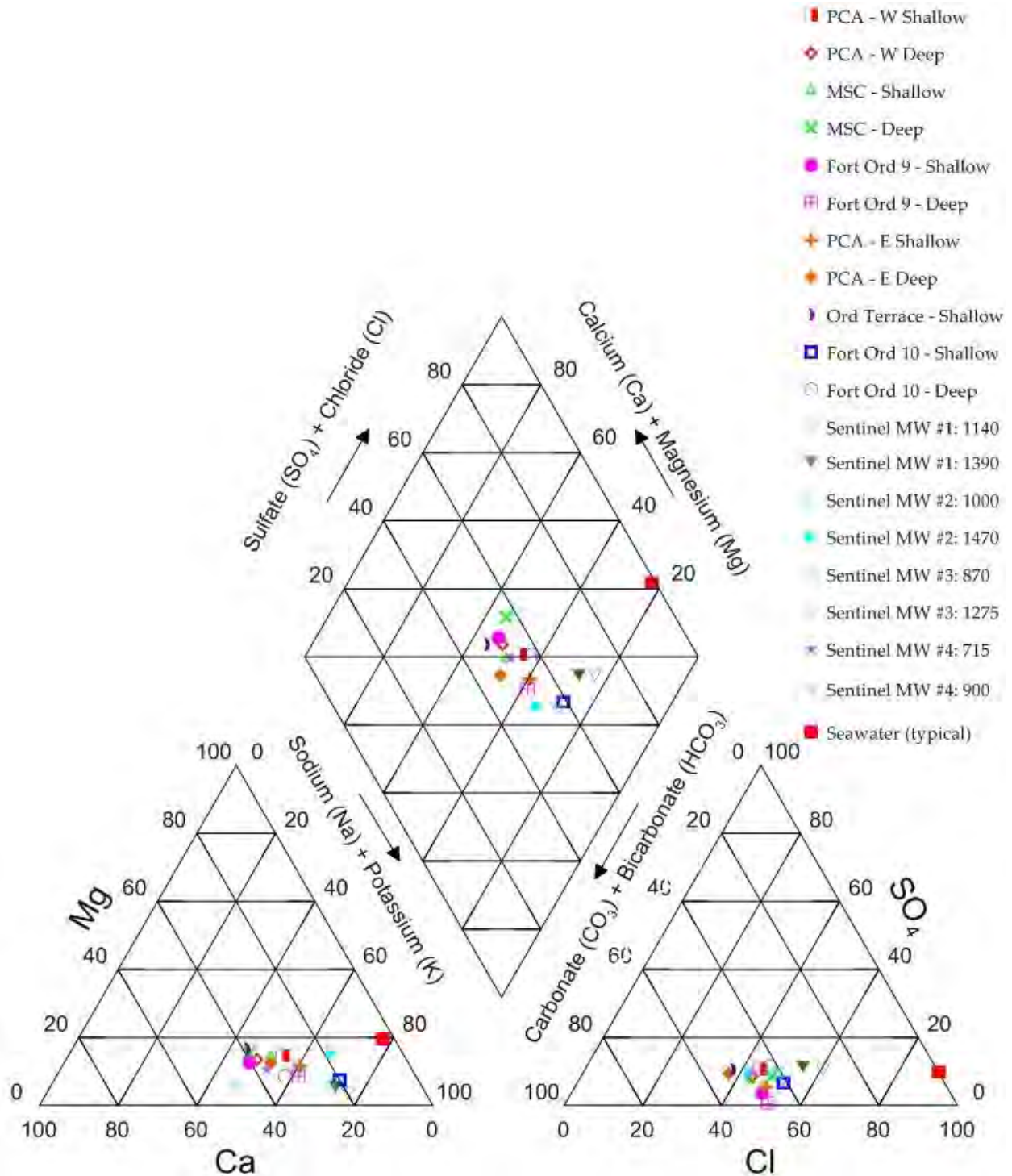


Figure 16: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 4th Quarter Water Year 2014 (July- September 2014)
 (Data source: Watermaster)

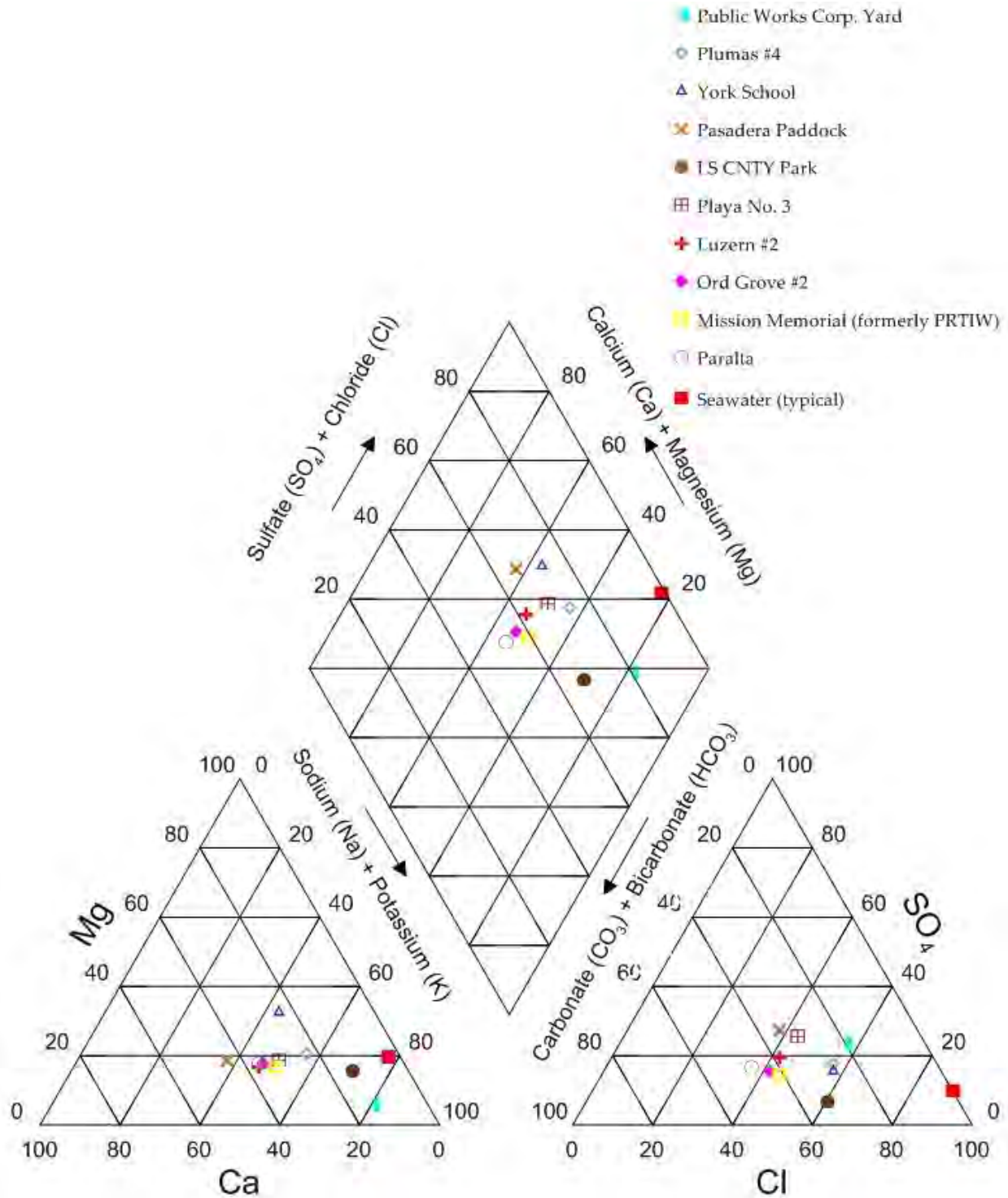


Figure 17: Piper Diagram for Seaside Groundwater Basin Production Wells, 4th Quarter Water Year 2014 (July-September 2014)
 (Data source: Watermaster)

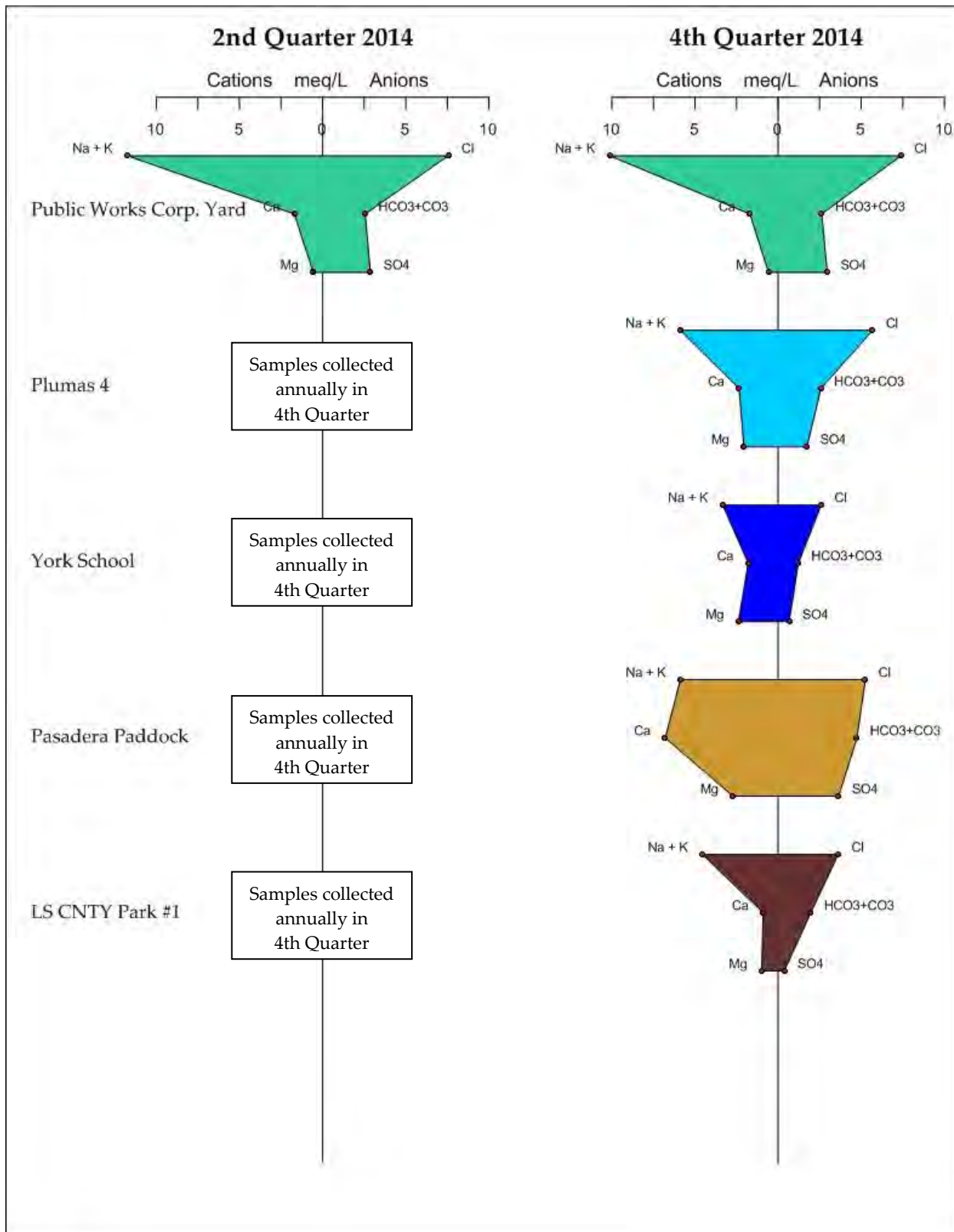


Figure 18: Stiff Diagrams for Southern Coastal and Inland Subarea Production Wells
(Data source: Watermaster)

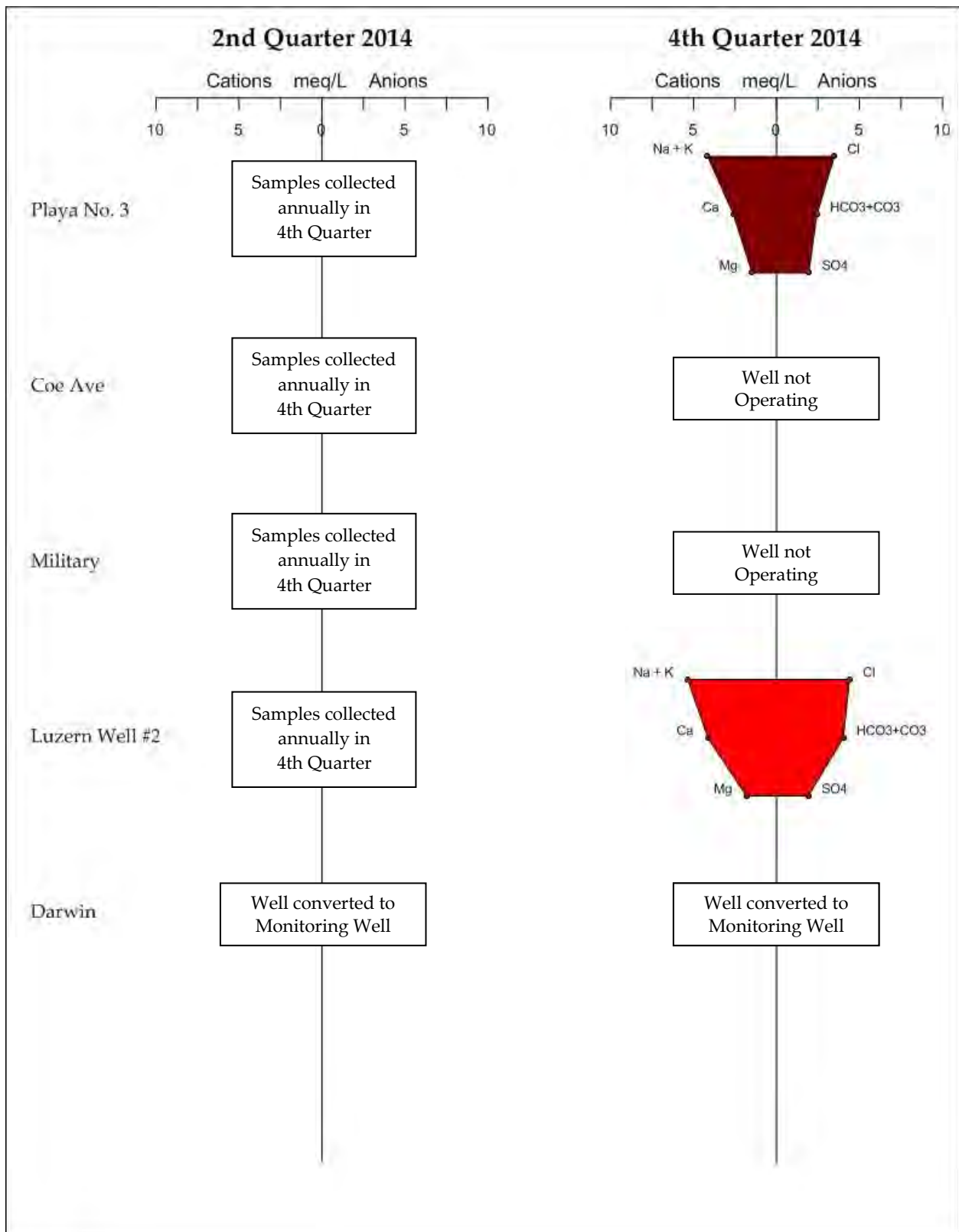


Figure 19: Stiff Diagrams for Northern Coastal Subarea Production Wells #1
(Data source: Watermaster)

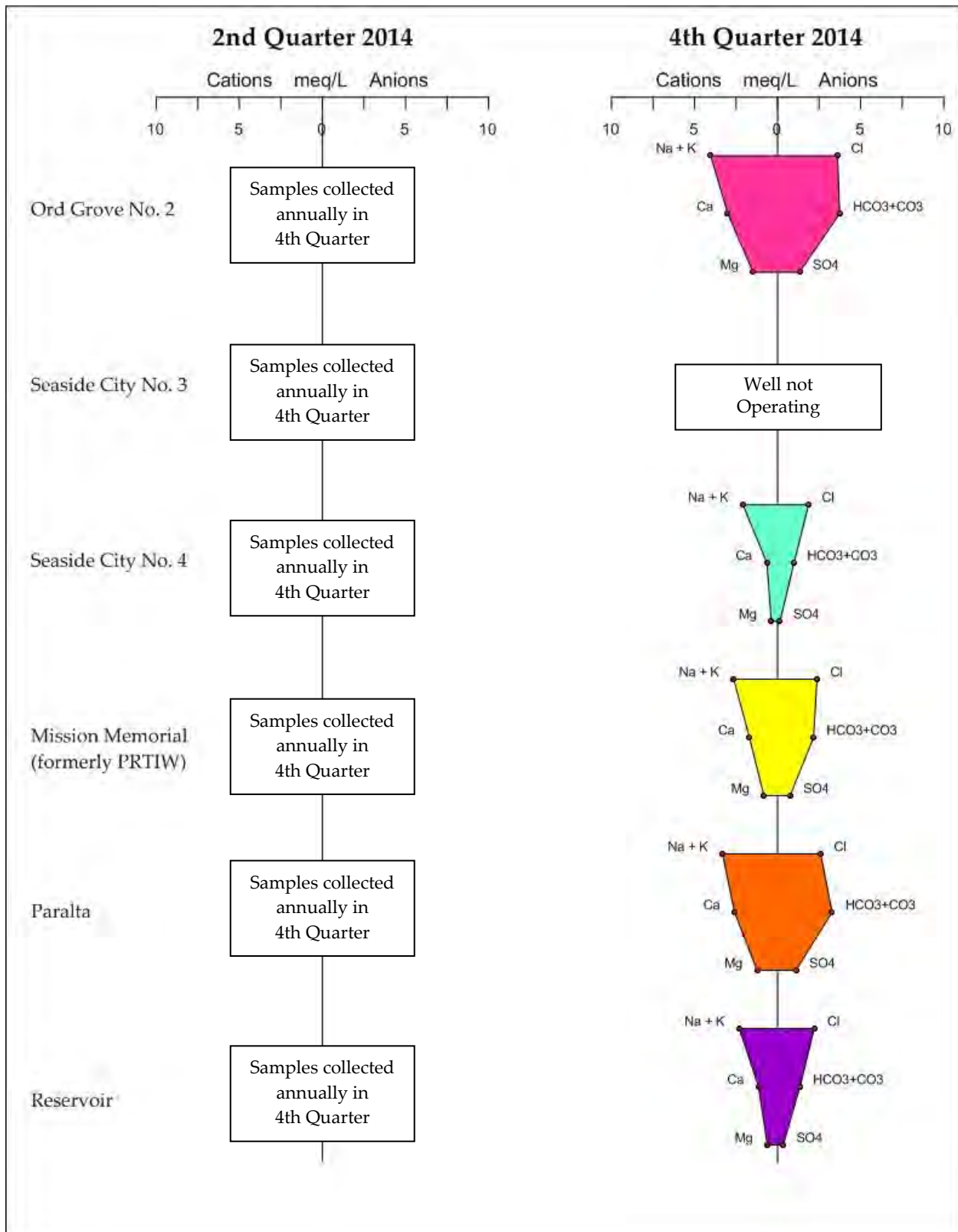


Figure 20: Stiff Diagrams for Northern Coastal Subarea Production Wells #2
(Data source: Watermaster)

CHLORIDE CONCENTRATIONS

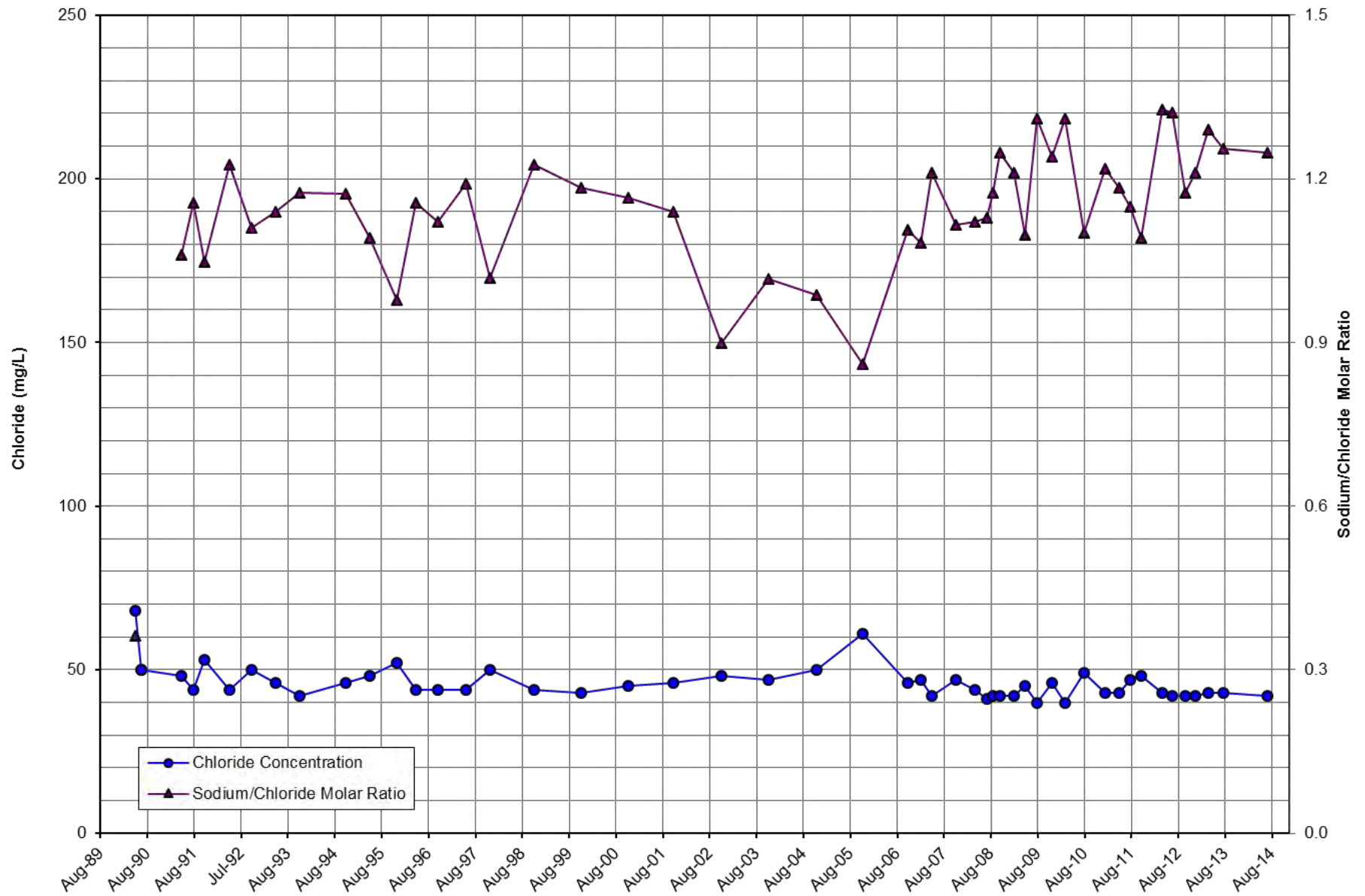
TRENDS

Chemographs showing chloride concentrations over time are plotted for each of the MPWMD and Watermaster monitoring wells plotted on the Piper and Stiff diagrams. An example plot displaying chloride concentrations for the shallow PCA West well is shown on Trends Figure 21. The complete set of chemographs is included in Appendix B.

Overall, chloride concentration trends have been stable for most coastal monitoring wells, with only two wells having increasing trends: sentinel wells SBWM-1 and SBWM-2. Chloride concentrations in the deep sentinel well SBWM-1 1,140 and 1,390 foot sample depths both increased by over 37 mg/L in Water Year 2014 (Figures B-13 and B-14 in Appendix B). The shallow 1,000 foot sample depth in sentinel well SBWM-2 had a greater increase than the deeper sample depth in the well, but both had a much smaller increases than SBWM-1 (less than 12 mg/L).

Seawater intrusion will be identified by a sustained chloride concentration increase over time along with other positive indicators. As seen in previous years, Stiff and Piper diagrams for wells with increasing chloride concentrations did not indicate seawater intrusion.

Chloride concentration trend graphs at this time do not indicate any seawater intrusion in the Seaside Groundwater Basin, based on the existing monitoring data.



Trends Figure 21: Historical Chloride and Sodium/Chloride Molar Ratios, Shallow PCA West Well

CHLORIDE CONCENTRATION MAPS

FOURTH QUARTER WATER YEAR 2014 (JULY-SEPTEMBER 2014)

Fourth quarter Water Year 2014 chloride concentrations were mapped using data from July through September 2014. The maps for the shallow and deep zones are included on Figure 22 and Figure 23 respectively.

The shallow zone 4th quarter Water Year 2014 chloride concentration map is shown on Figure 22. Chloride data from shallow wells are posted on this map, but do not show a spatial distribution that can be readily contoured because of large differences in concentrations in close proximity to each other. For the data available in the shallow zone, chloride concentrations near the coast average around 48 mg/L in the Northern Coastal subarea. More inland wells have consistently shown higher chloride concentrations than coastal wells. Based on existing data, there is no discernible spatial trend of higher coastal chloride concentrations, and therefore no indication of seawater intrusion. Sand City's Public Works Corp Yard well continues to be the only coastal well in the Southern Coastal subarea with measured chloride data, and has the highest concentration of all shallow wells (262 mg/L). The Piper and Stiff diagrams, and sodium/chloride molar ratio for the well suggest that the source of high chloride is not seawater.

The deep zone 4th quarter Water Year 2014 chloride concentration map is shown on Figure 23. Because the chloride data shows no discernible spatial distribution, with high concentrations in close proximity to low concentrations, the data cannot be readily contoured. Deep zone chloride concentrations near the coast range between 64 mg/L and 262 mg/L, which is the same as the previous water year. Because the chloride concentration in sentinel well SBWM-4 (262 mg/L) has not displayed an overall increasing trend since 2007, it is not needed to sample this well quarterly as recommended in previous years.

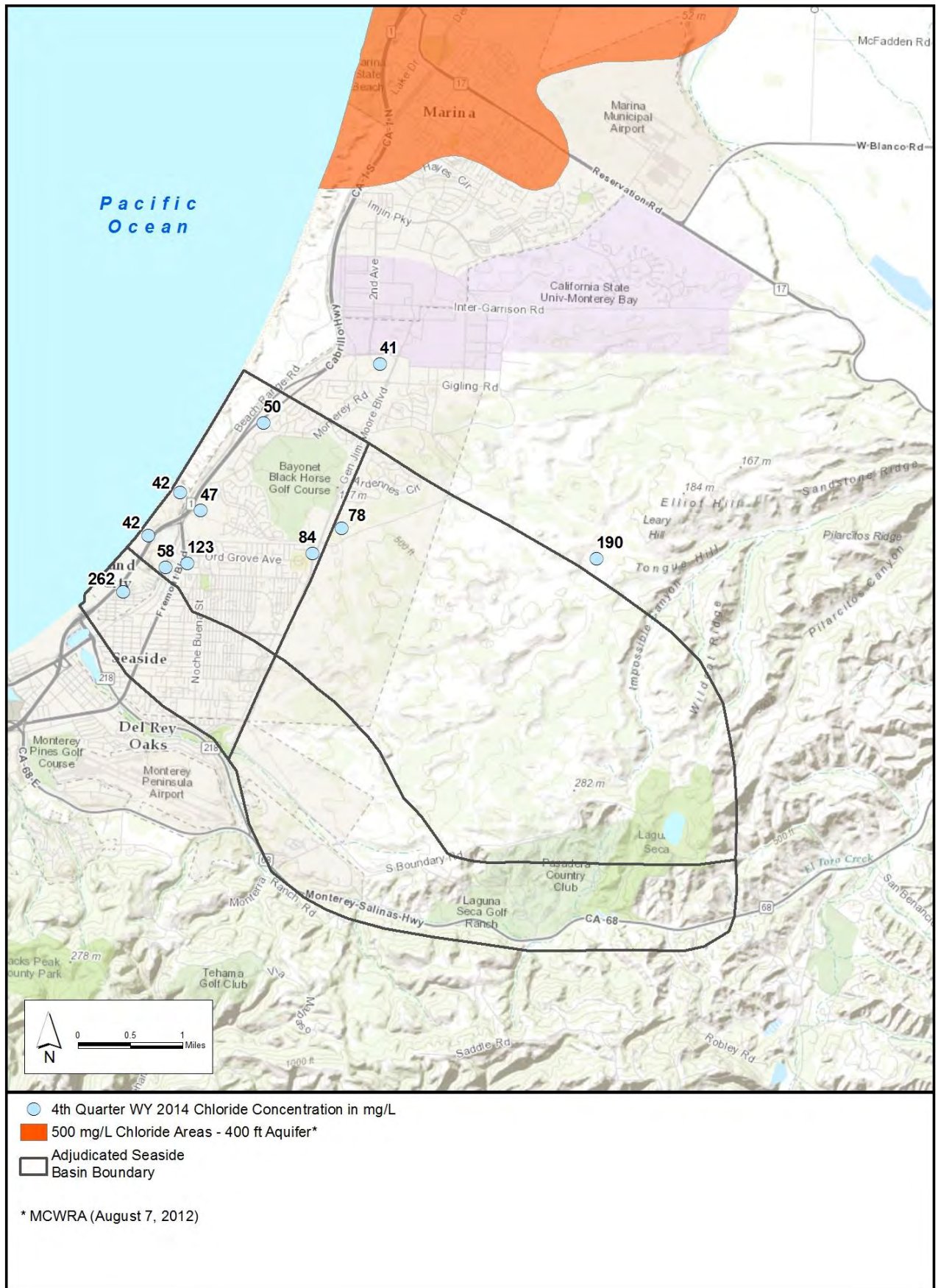


Figure 22: Shallow Zone Chloride Concentration Map – 4th Quarter WY 2014

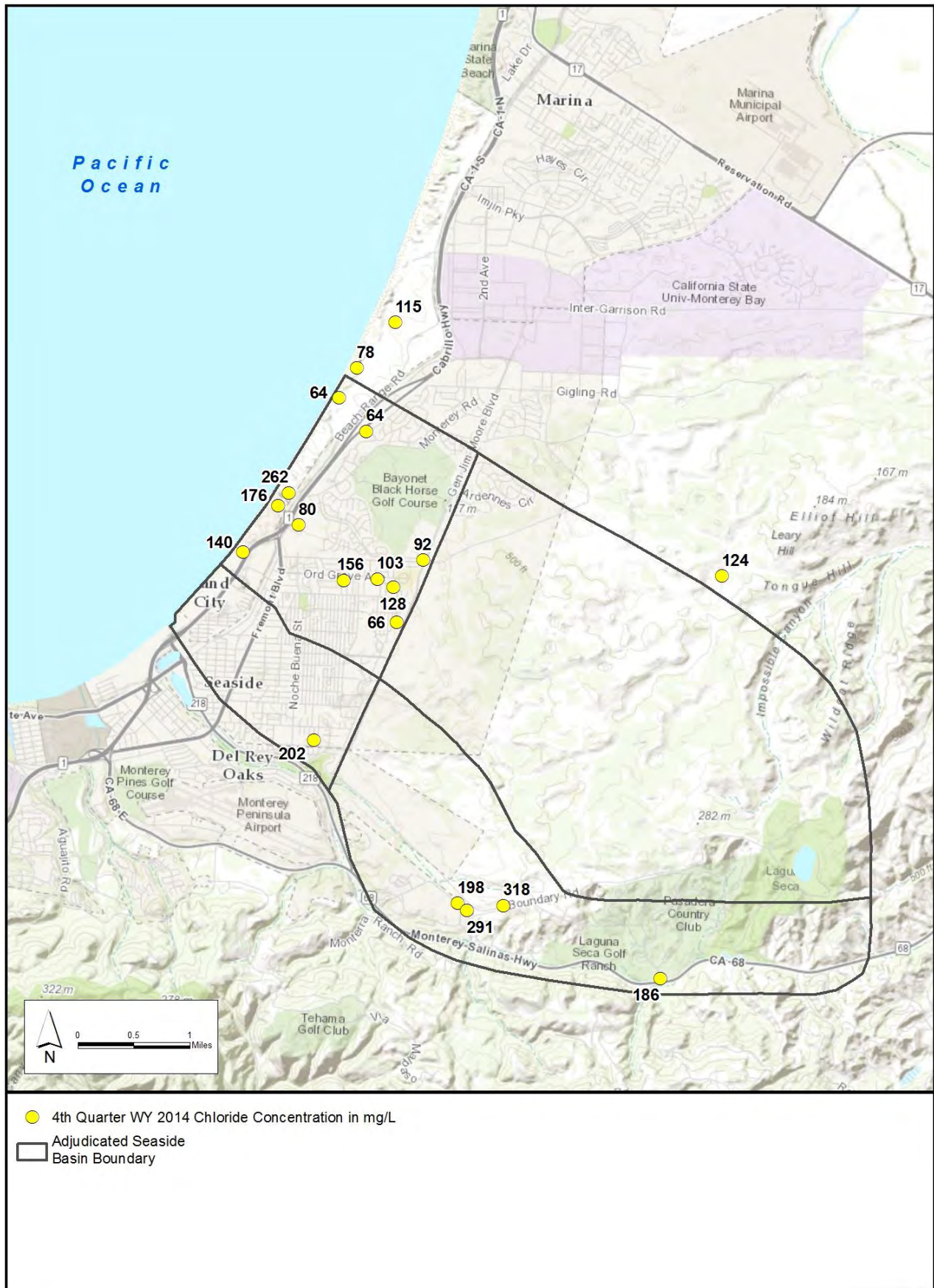


Figure 23: Deep Zone Chloride Concentration Map – 4th Quarter WY 2014

SODIUM/CHLORIDE MOLAR RATIOS

Chemographs showing sodium/chloride molar ratios over time are plotted for each of the 15 monitoring wells plotted on the Piper and Stiff diagrams. Historical chemographs for monitoring wells that are not on the Water Year 2014 Piper and Stiff diagrams, because data were not available, are also included for completeness. An example plot displaying ratios for the shallow PCA West well is shown on Trends Figure 21. The complete set of chemographs is included in Appendix B.

Most of the sodium/chloride molar ratios remained constant or increased. These monitoring wells have ratios consistently above 0.9, which indicates that there is no incipient or ongoing seawater intrusion in those wells. The sentinel well SBWM-1 1,140 and 1,390 foot sample depths both had increases in chloride and sodium over the past water year, which has resulted in declining sodium/chloride molar ratios. The sentinel well SBWM-1 1,140 foot sample depth has had a slightly declining sodium/chloride molar ratio since 2011, which declined further by almost 0.3 over the past year (Appendix B: Figure B-13). The sentinel well SBWM-1 1,390 foot sample depth also had a large decrease from last year but does not show a decline in prior years (Appendix B: Figure B-14). Neither sodium/chloride molar ratio is approaching the ratio of 0.9. However, it is recommended that this well be resampled in the next quarter to verify the increase in chloride and sodium in the well at both sample depths.

The sentinel well SBWM-2 1,000 foot sample and SBWM-3 870 foot sample depth both have a slight decrease in their sodium/chloride molar ratios (Appendix B: Figure B-15), but not enough to warrant verification sampling.

ELECTRIC INDUCTION LOGS

Two induction logging events took place in the sentinel wells during Water Year 2014. As in previous years, the first logging event was conducted in January, and the second event that usually takes place in July took place in August. A new service provider, Pacific Surveys, was used starting August 2014 to conduct the logging as the previous provider, Welenco, Inc., has undergone some corporate changes that prevented them from continuing this service. As a result of the different logging instrument, calibration, and interpretation software, the Pacific Survey electric induction logs do not overlay the previous data.

The purpose of the induction logging program was to collect qualitative data from the deep sentinel wells that could be used to compare relative changes in electrical conductivity every six months. The intent was not to collect quantitative data, and therefore it has been proposed to start a new baseline based on the August 2014 data from which to assess future changes. This is proposed because:

1. The overall shapes of the Welenco, Inc. and Pacific Survey logs are the same, with the Pacific Survey logs being universally lower. This indicates no relative change in pore water conductivity, i.e., no seawater intrusion since the last Welenco, Inc. log in January 2014.
2. The logs were becoming cluttered with multiple lines plotted over one another (Figure 24).

More details on the difference between the Welenco, Inc. and Pacific Survey logs, and the decision to start with a new baseline based on the Pacific Survey logs is provided in a Technical Memorandum by Martin Feeney to Joe Oliver of Monterey Peninsula Water Management District, dated November 5, 2014.

The Welenco, Inc. logs for January 2014 are provided on Figure 24, along with the average readings from 2007 through January 2014. The new baseline logs starting August 2014 are provided on Figure 25.

Feeney (2007) described the Welenco, Inc. baseline induction logs for each of the wells as follows:

“SBWM-1 — The upper 50 feet of this well shows very high conductivities. This signature is present in all of the wells and is the

result of the 50-foot steel conductor casing. However, because the water table is below the conductor casing at all locations, the steel casing does not interfere with data collection within the saturated sediments below. Below the conductor casing in SBWM-1, the sediment materials are dry to a depth of approximately 115 feet. Below this depth, there is approximately 10 feet of sand containing fresh water. Below 125 feet and extending to approximately 350 – 400 feet is sand containing saline water with conductivities measuring as high as 10,000 $\mu\text{mhos/cm}$. This saline water is contained within the Dune /Beach Sand Deposits and the Aromas Sand. Below this depth, conductivities are relatively low with the exception of the thick marine clay between approximately 600 -700 feet. The other conductive zones also correlate with clay zones.

SBWM-2 — As in SBWM-1 there is a thin layer of fresh water overlying a zone of saline water to approximately 130 feet within the Beach/Dune Sands and Aromas Sand. Below this depth, the materials become increasingly clayey, complicating the interpretation. Below this depth, there are no obvious zones of anomalous conductivity; that is, the zones that are more conductive correlate with clay zones.

SBWM-3 — In SBWM-3 saline water extends to a depth of approximately 100 feet within the Dune/Beach Sand and Aromas Deposits. Below 100 feet, the materials become clay and conductivities rapidly decline. Again, below the shallow saline water in the sand deposits, all zones of increased conductivity correlate with clay zones.

SBWM-4 — As with the other wells, the induction log reveals a thin layer of fresh water overlying saline water with the Dune Sands/Beach Deposits to a depth of approximately 100 feet. Below this depth the materials become clay and there are no additional zones of increased conductivity uncorrelated with clay zones.”

The salinity changes shown on Figure 24 and Figure 25 are only relative, and do not allow direct measurement of TDS or chloride concentrations in the aquifer. They do, however, provide a means to determine changes in salinity over time. It appears that the salinity in the Dune Sands and Aromas Formation overlying the main production aquifers fluctuates from year to year. As has been the case historically, none of the wells show detectable changes to the deeper aquifers where production wells extract groundwater. This indicates that there is currently no seawater intrusion into these deeper aquifers.

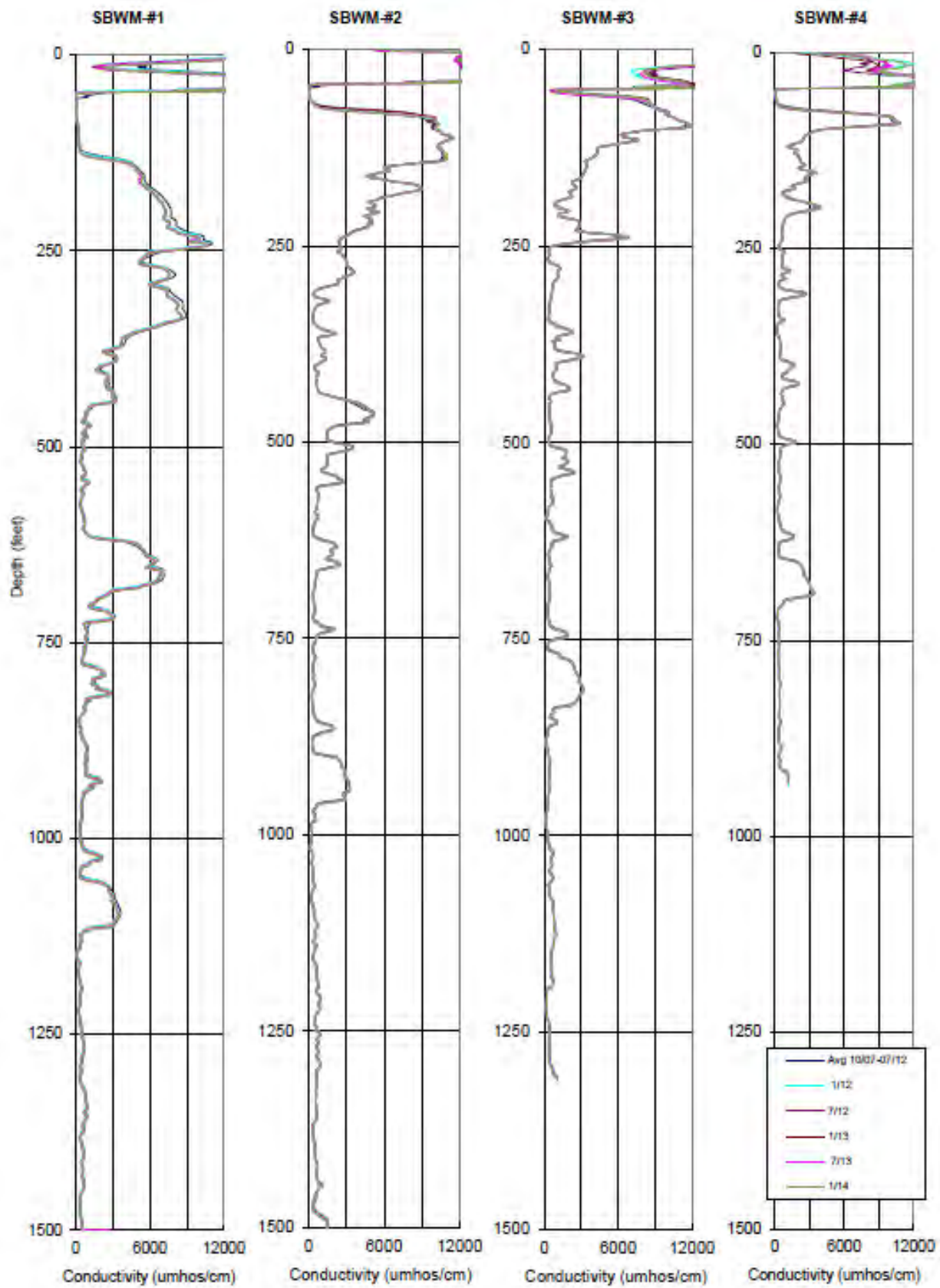


Figure 24: Sentinel Well Induction Logs by Welenco, Inc. through January 2014

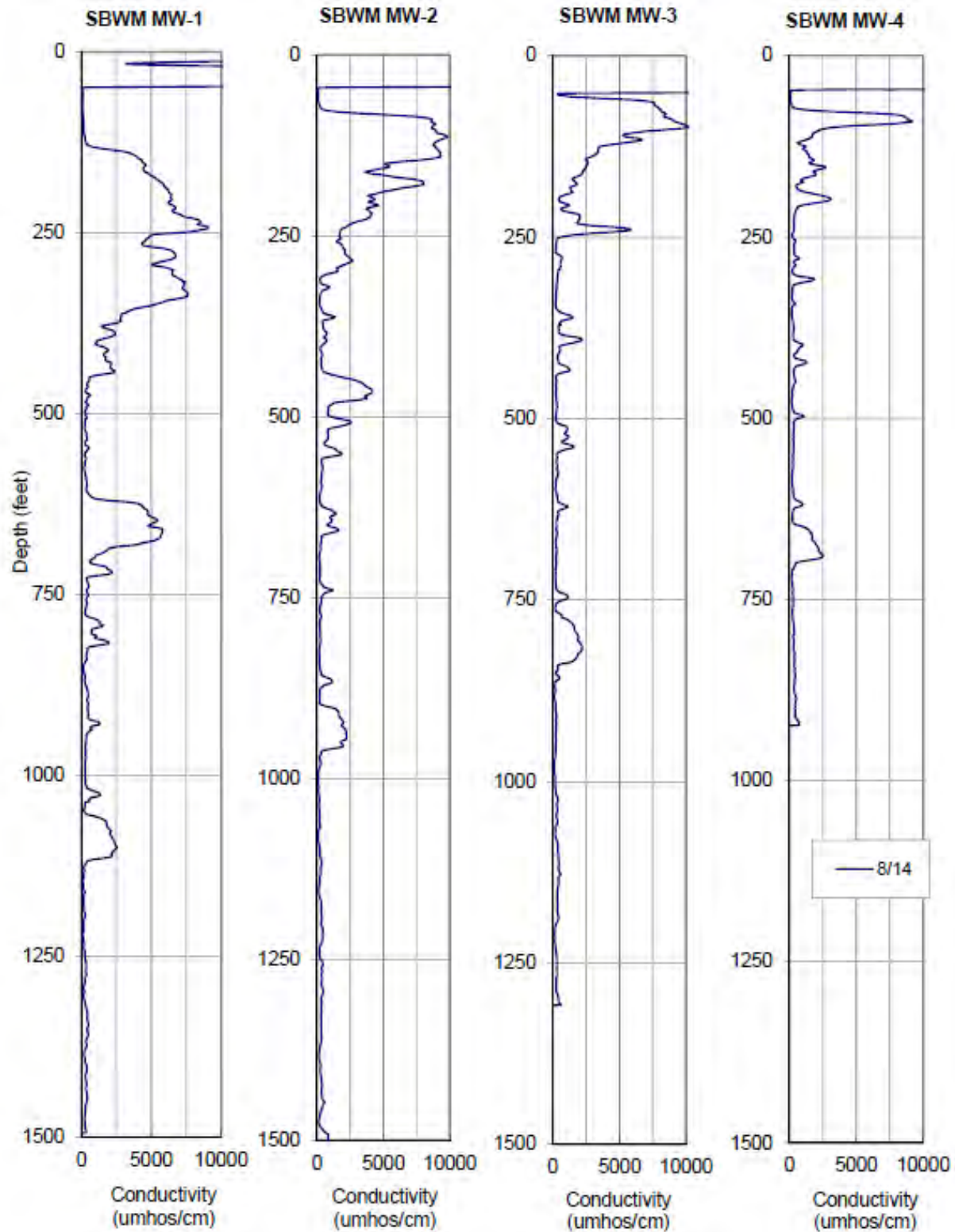


Figure 25: Sentinel Well Induction Logs from August 2014 – New Baseline

GROUNDWATER LEVELS

Groundwater levels are not direct indicators of seawater intrusion, but indirectly suggest opportunities for seawater intrusion. Coastal groundwater levels at or near sea level are not sufficient to repel seawater intrusion, and will likely allow some level of seawater intrusion unless groundwater levels increase.

TRENDS

Groundwater level hydrographs representative of well pairs in the Northern Coastal subarea and a shallow well in the Southern Coastal subarea are shown on Figure 26.

NORTHERN COASTAL SUBAREA

Groundwater level data from the PCA-East well are representative of groundwater levels in the Northern Coastal subarea, downgradient of nearby production wells. This hydrograph shows the effect of production from the nearby CAW production wells on groundwater levels in the deep zone. In the deep zone, groundwater levels continue to be well below sea level, with October 2014 groundwater elevations being the lowest on record for this well. The hydrograph peaks and lows are strongly influenced by pumping and/or injection occurring in the area upgradient of the monitoring well when the groundwater level measurements were taken. Other influences such as tides which can cause up to a one foot fluctuation in the deep completion of PCA-East also need to be recognized. Because of all the possible influences on groundwater levels, it is difficult to compare the present year to the previous year directly. What is more important is to look at the long-term trends. PCA-East deep on Figure 26 shows an overall decline in groundwater levels until 2009, levels more or less stabilize the next two years, and then over the past five years have shown a continual decline. The decline in groundwater levels in the deep completion of PCA-East corresponds with the shift in CAW's production from their shallow Paso Robles wells to deeper Santa Margarita wells.

Seasonal fluctuations are noticeable in the winter season when groundwater elevations are at their highest for the year. For Water Year 2014, the winter high was extremely muted to non-existent. This is probably due to the past three years of below average rainfall, which has limited groundwater recharge in the basin.

It is important to note that the Santa Margarita Sandstone has limited connection to the ocean and is highly confined by the layers above it. This means that the amount of recharge entering the Santa Margarita Sandstone is limited and is therefore always susceptible to depletion if more water is pumped than is being recharged.

No water was injected into the deep Santa Margarita aquifer as part of the aquifer storage and recovery program because no water was available from the Carmel River due to low flows.

In the shallow zone, recent groundwater levels have stabilized over the past several years (Figure 26). Seasonal level increases seen in the data are usually related to reduced wintertime production in the shallow aquifer, and increased pumping during summer. Although the shallow seasonal fluctuations correspond with deep zone fluctuations, it is because seasonal pumping occurs in both aquifers, and not because the aquifers are closely connected.

SOUTHERN COASTAL SUBAREA

In the Southern Coastal subarea, the KMART monitoring well is representative of groundwater levels near the coast (Figure 26). The hydrograph shows that groundwater elevations have always been above sea level and have continued to remain stable over time.

GROUNDWATER ELEVATION MAPS

SECOND QUARTER WATER YEAR 2014 (JANUARY-MARCH 2014)

Groundwater level maps for the shallow and deep aquifer zones for the 2nd quarter of Water Year 2014 are shown on Figure 27 and Figure 28 respectively.

The shallow aquifer does not show seasonal fluctuations to the same extent as the deep aquifer. The groundwater level contours for Water Year 2014 remains essentially the same along the coast in the Northern Coastal subarea. The Laguna Seca subarea pumping depression is slightly larger than the previous water year. In the eastern part of the Northern Inland subarea, an area of the shallow aquifer has been indicated to be potentially dry due to geologic structural control (Figure 27).

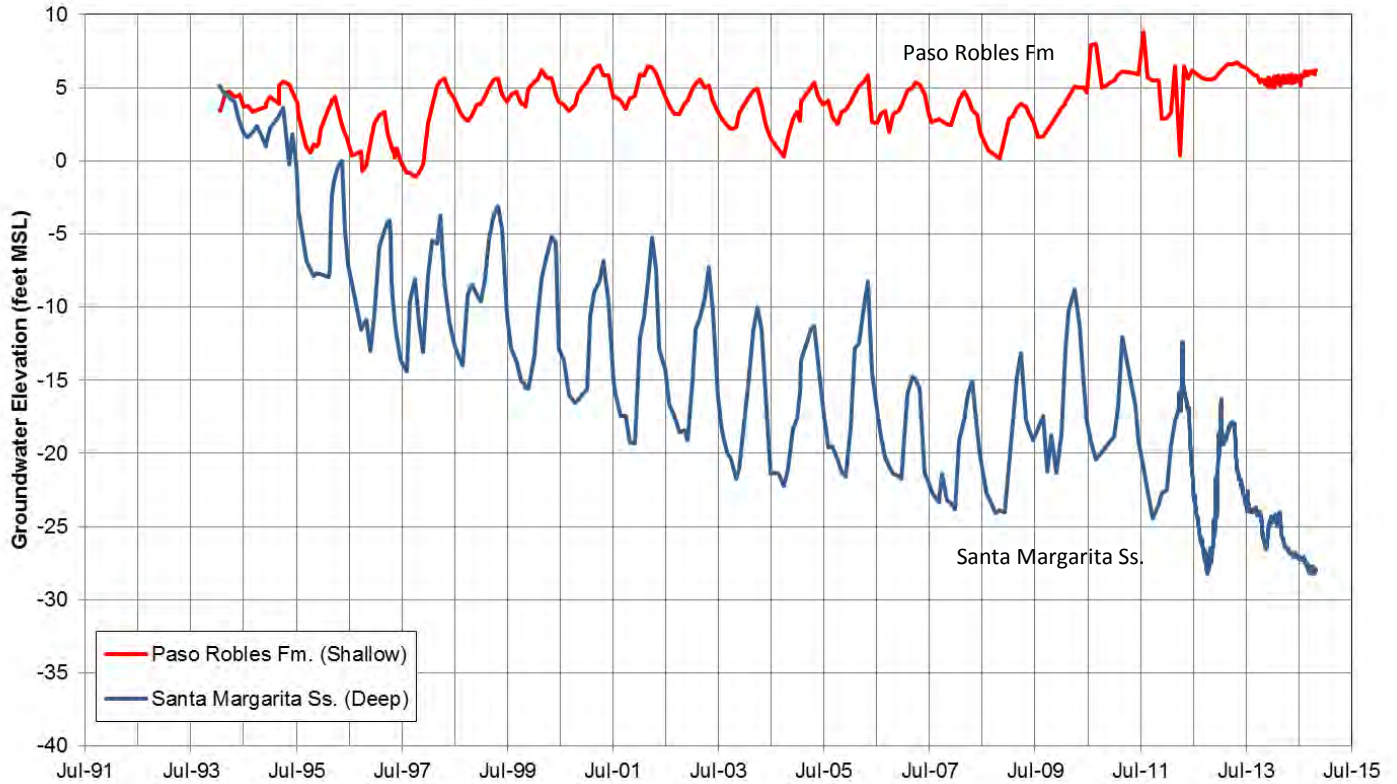
Second quarter groundwater levels in the deep aquifer, particularly along the coast, are usually higher than 4th quarter groundwater levels by up to six feet due to seasonal variations. However, for Water Year 2014, there was a much smaller seasonal fluctuation as seen on Figure 26. The pumping depression in the Northern Coastal subarea increased in size over last year (Figure 28). The interpretation of contours in the Laguna Seca area was adjusted from previous years to better depict the small pumping depression caused by the golf course wells (143 – 146 feet above mean sea level (amsl)) and the 165 foot amsl groundwater elevation measured in monitoring well FO-5 Deep at the very eastern edge of the subarea near CAW's Toro production wells. The adjustment involved the removal of some contours around the edges of the subarea and the addition of 160 foot amsl contours around the golf course wells, and the addition of a 180 foot amsl contour representing an area of relatively higher groundwater elevations between the golf course wells and the eastern edge of the subarea. Overall groundwater levels in the Laguna Seca subarea fell by a couple of feet over the last year.

FOURTH QUARTER WATER YEAR 2014 (JULY-SEPTEMBER 2014)

Groundwater elevation maps for the shallow and deep aquifer zones for the 4th quarter of Water Year 2014 are shown on Figure 29 and Figure 30, respectively. The contours for the shallow aquifer show that levels are stable since last water year in the Northern Coastal subarea, but the pumping depression in the Laguna Seca subarea shifted slightly to the east, which may be a result of production in CAW's Toro wells just outside of the subarea (Figure 29). The 4th quarter deep zone groundwater elevations (Figure 30) show a slightly increased pumping depression in the Northern Coastal subarea and the adjusted contours in the Laguna Seca subarea as described in the section above.

The pumping depression around CAW's main production wells in the Northern Coastal subarea continues to be deeper than 40 feet below sea level. Note that the elevation of the Ord Grove No. 2 production well on the contour map within the -40 foot contour, is a pumping groundwater elevation, which means the static level would be higher if the well was allowed to recover after pumping.

**GROUNDWATER ELEVATION
PCA-EAST MONITORING WELL - NORTHERN COASTAL SUBAREA**



**GROUNDWATER ELEVATION
KMART MONITORING WELL - SOUTHERN COASTAL SUBAREA**

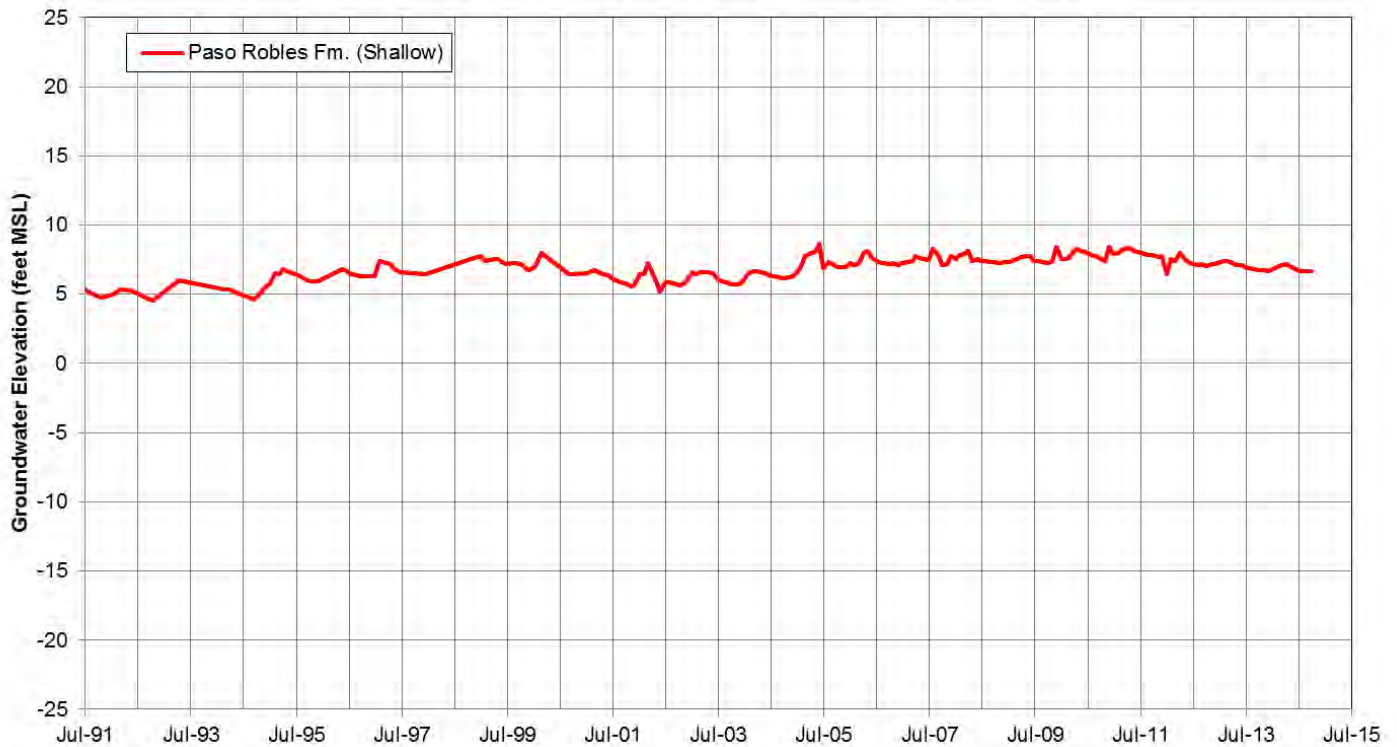


Figure 26: Example Hydrographs (Source: Watermaster)

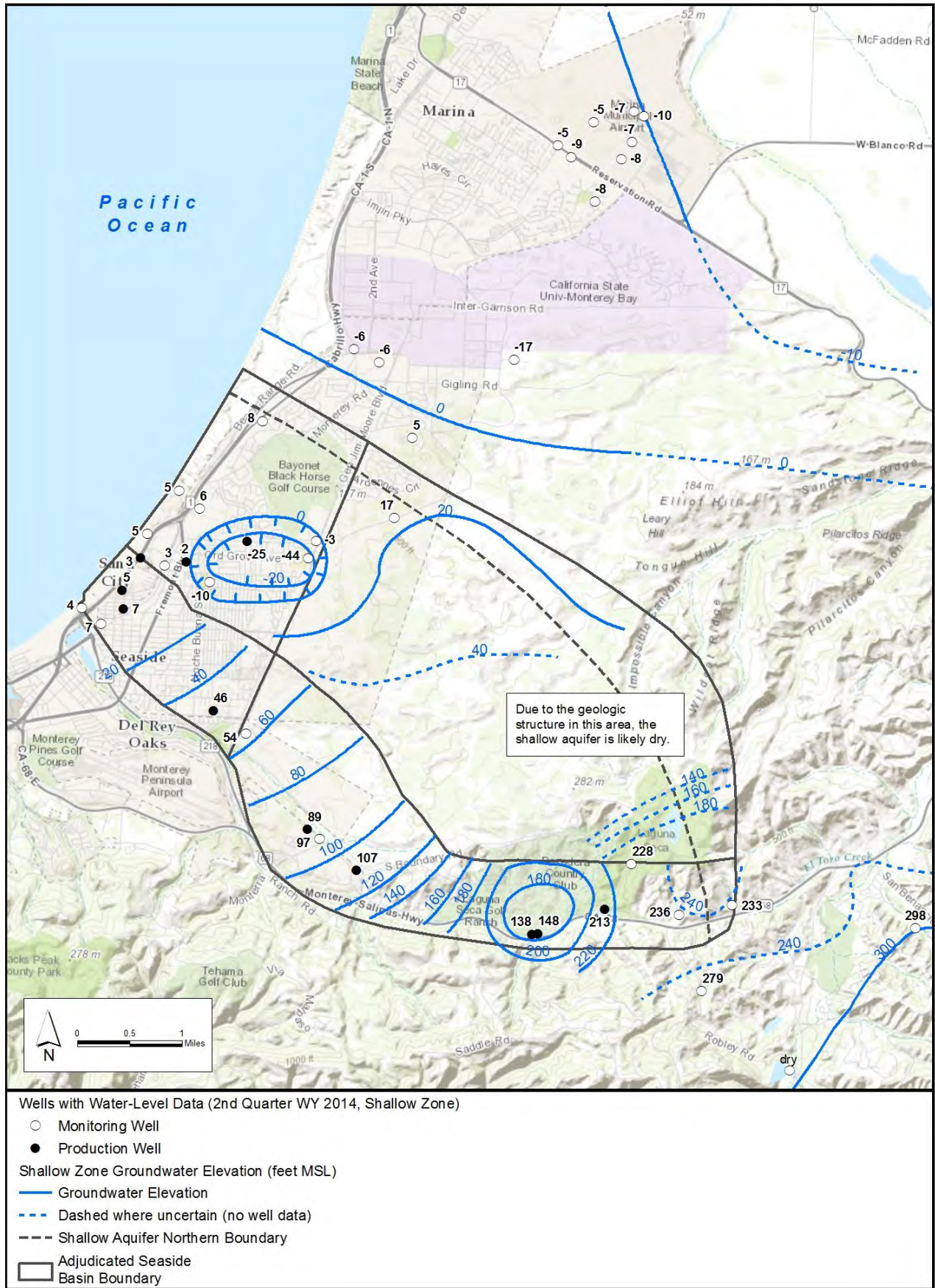
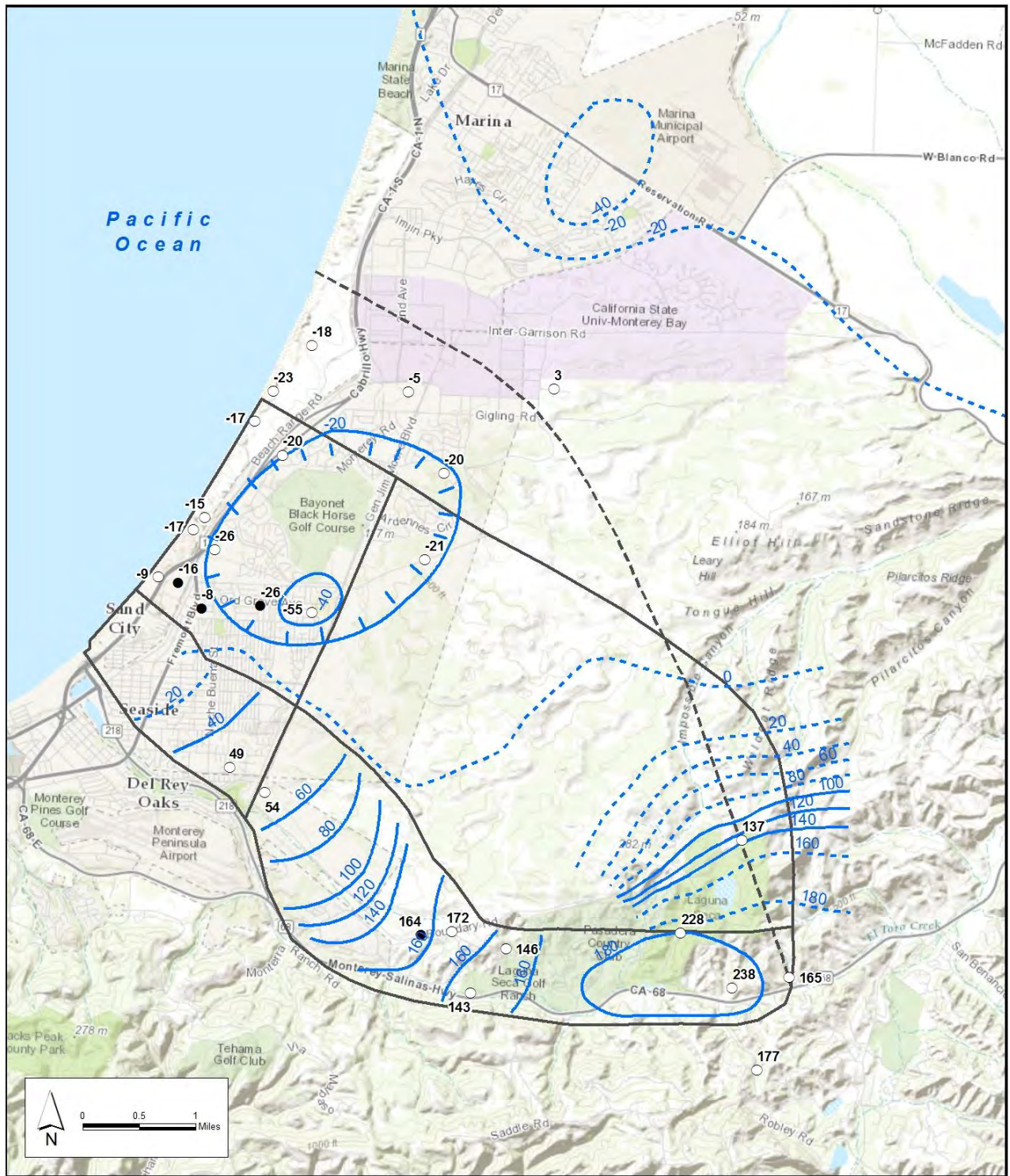


Figure 27: Shallow Zone Water Elevation Map – 2nd Quarter WY 2014 (January-March 2014)



Wells with Water-Level Data (2nd Quarter WY 2014, Deep Zone)

- Monitoring Well
 - Production Well
- Deep Zone Groundwater Elevation (feet MSL)
- Groundwater Elevation
 - - - Dashed where uncertain (no well data)
 - - - Deep Aquifer Northern Boundary
 - ▭ Adjudicated Seaside Basin Boundary

Figure 28: Deep Zone Water Elevation Map – 2nd Quarter WY 2014 (January-March 2014)

WY 2014 Seawater Intrusion Analysis Report

December 3, 2014

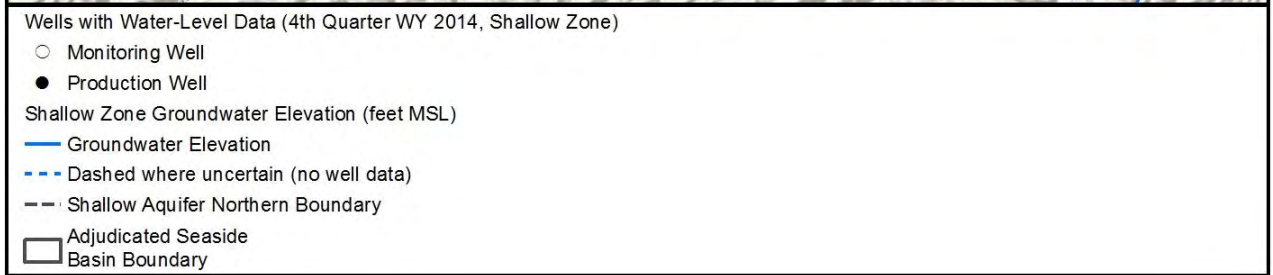
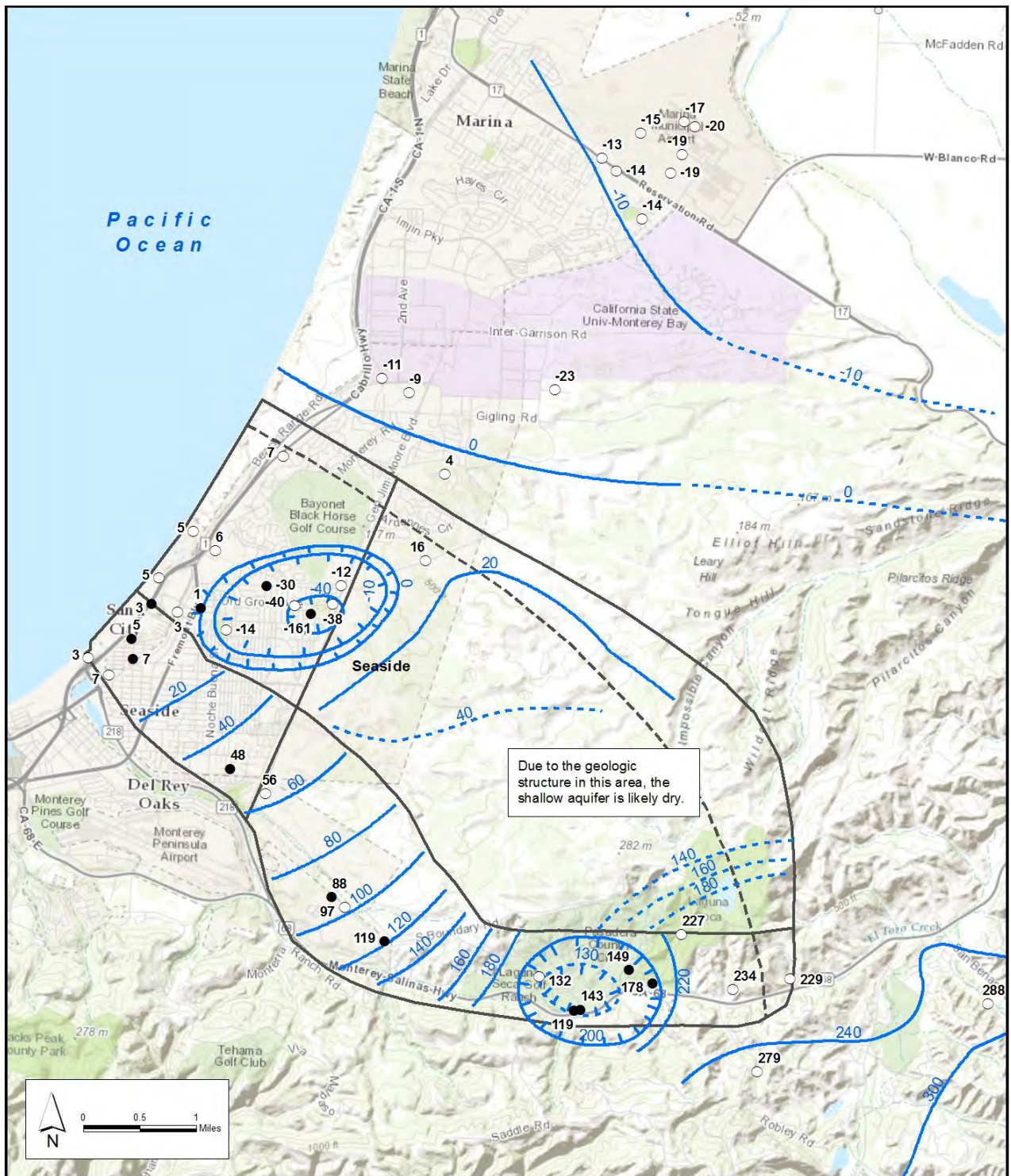
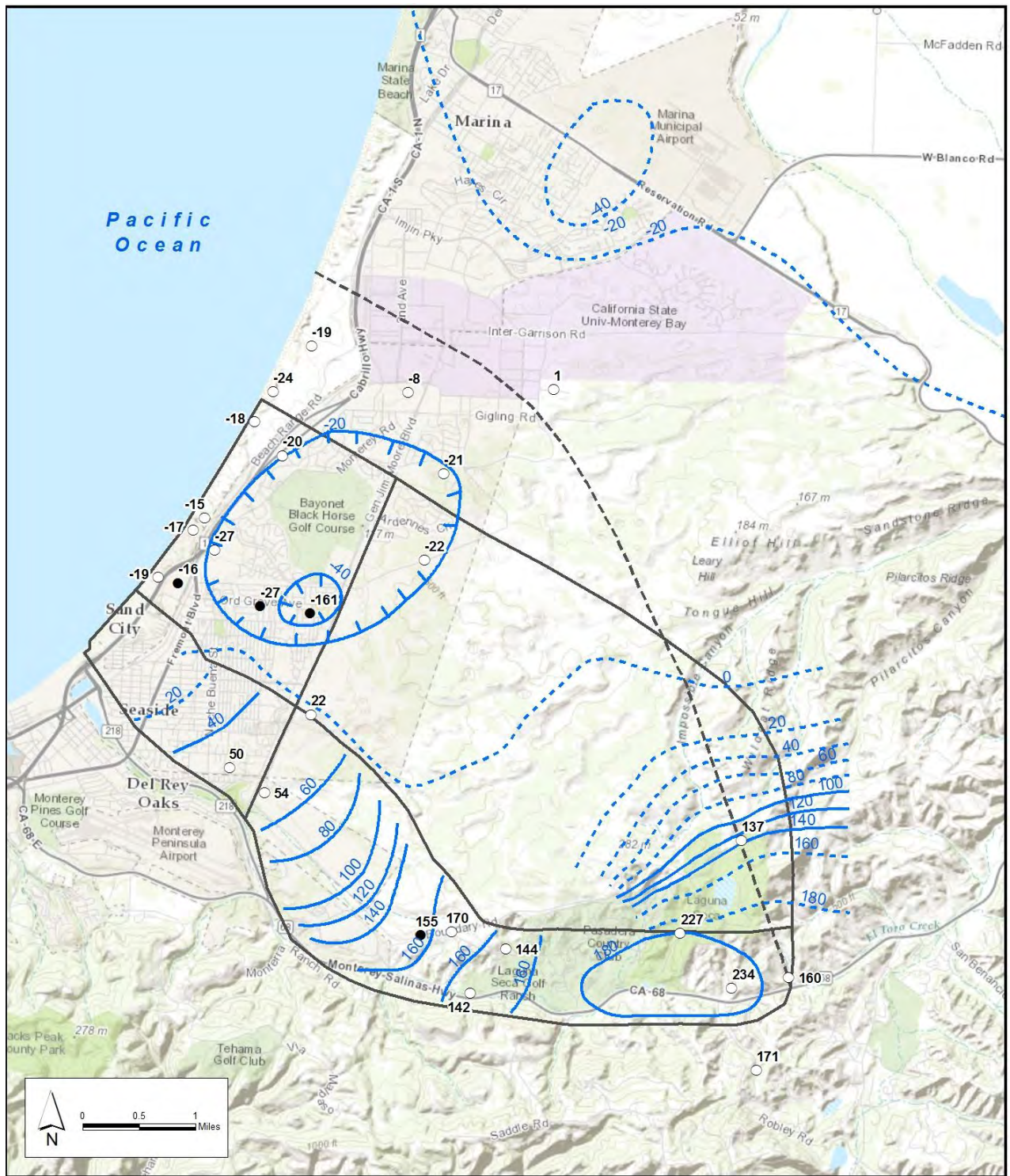


Figure 29: Shallow Zone Water Elevation Map – 4th Quarter WY 2014 (July/August 2014)



Wells with Water-Level Data (4th Quarter WY 2014, Deep Zone)

- Monitoring Well
- Production Well
- Deep Zone Groundwater Elevation (feet MSL)
 - Groundwater Elevation
 - - - Dashed where uncertain (no well data)
 - - - Deep Aquifer Northern Boundary
- ▭ Adjudicated Seaside Basin Boundary

Figure 30: Deep Zone Water Elevation Map – 4th Quarter WY 2014 (July/August 2014)

GROUNDWATER PRODUCTION

Groundwater pumping in excess of freshwater recharge and subsurface inflow from adjacent areas is the primary cause of seawater intrusion. Mapping pumping volumes gives an indirect indication of the threat of seawater intrusion. Ideally, pumping should be equally distributed throughout a basin, and occur relatively far inland.

Net or reported pumping by Watermaster producers in Water Year 2014 was 4,040.1 acre-feet, which is 144.3 acre-feet more than Water Year 2013. Net pumping is the amount pumped after the aquifer storage and recovery program is taken into account. This means that in years where there is water injected and recovered, more water is actually pumped from CAW's wells to recover water injected the previous operational year. No injection took place in Water Year 2014 because there was no Carmel River water available.

Annual reported production for Water Year 2014 was less than the Court-ordered operating yield of 4,480 acre-feet (Figure 31). Water Year 2015 will have a triennial reduction that decreases pumping in the basin to 3,920 acre-feet per year until the end of Water Year 2017.

The blue charts on Figure 32 reflect the actual or gross amounts pumped from each well, and the green chart reflects the amount of water injected. As with previous years, the majority of pumping occurs at CAW's Ord Grove No. 2 and Paralta wells.

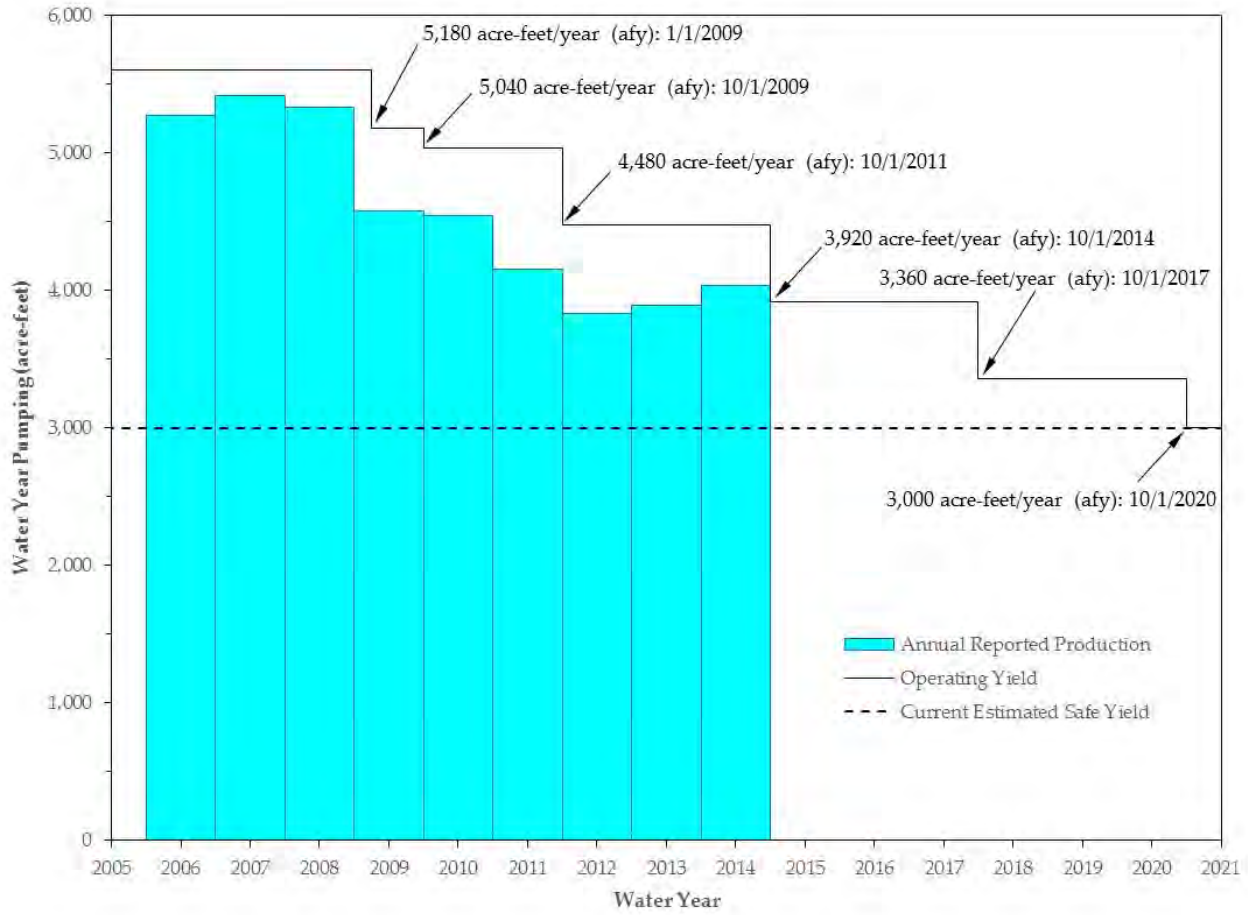


Figure 31: Annual Reported Groundwater Production and Operating Yield for Watermaster Producers

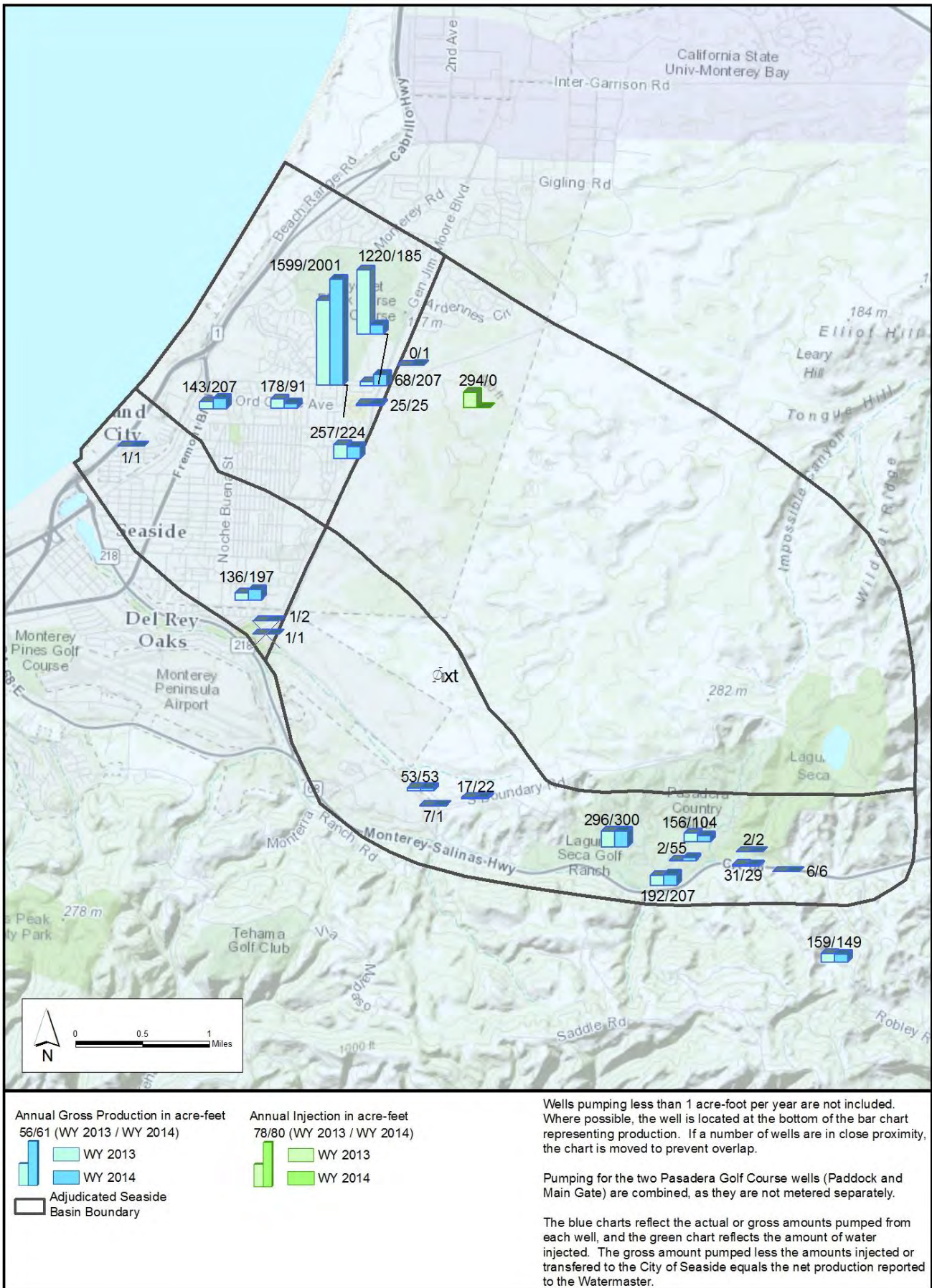


Figure 32: Watermaster Producers' Pumping Distribution for Water Years 2013 and 2014

PROTECTIVE GROUNDWATER ELEVATIONS

Protective groundwater elevations were determined in 2009 using the Seaside Groundwater Basin groundwater flow model and cross-sectional modeling (HydroMetrics LLC, 2009b). Protective elevations for both the deep and shallow aquifers were established for monitoring well pairs with both a shallow and deep completion. Protective elevations are shown in Table 1. A recent study to revisit and update the protective groundwater elevations concluded that the calibrated parameters in the basinwide model do not indicate that protective elevations should be lowered (HydroMetrics WRI, 2013b).

Table 1: Summary of Protective Elevation Monitoring Locations

Subarea	Well	Completion	Protective Elevation, Feet above sea level
Northern Coastal	MSC	Deep	17
		Shallow	11
	PCA-W	Deep	17
		Shallow	2
	Sentinel Well 3	Deep	4
Southern Coastal	CDM-MW4	Shallow	2

Figure 33 through Figure 36 show the historical groundwater elevations at each of the target protective elevation locations. Groundwater levels continue to be below protective elevations in all deep target monitoring wells (MSC deep, PCA-West Deep, and Sentinel Well 3). Two of the three shallow wells' groundwater levels are above protective elevations: PCA-W shallow and CDM-MW4. MSC shallow is the only shallow target well with levels below its protective elevation.

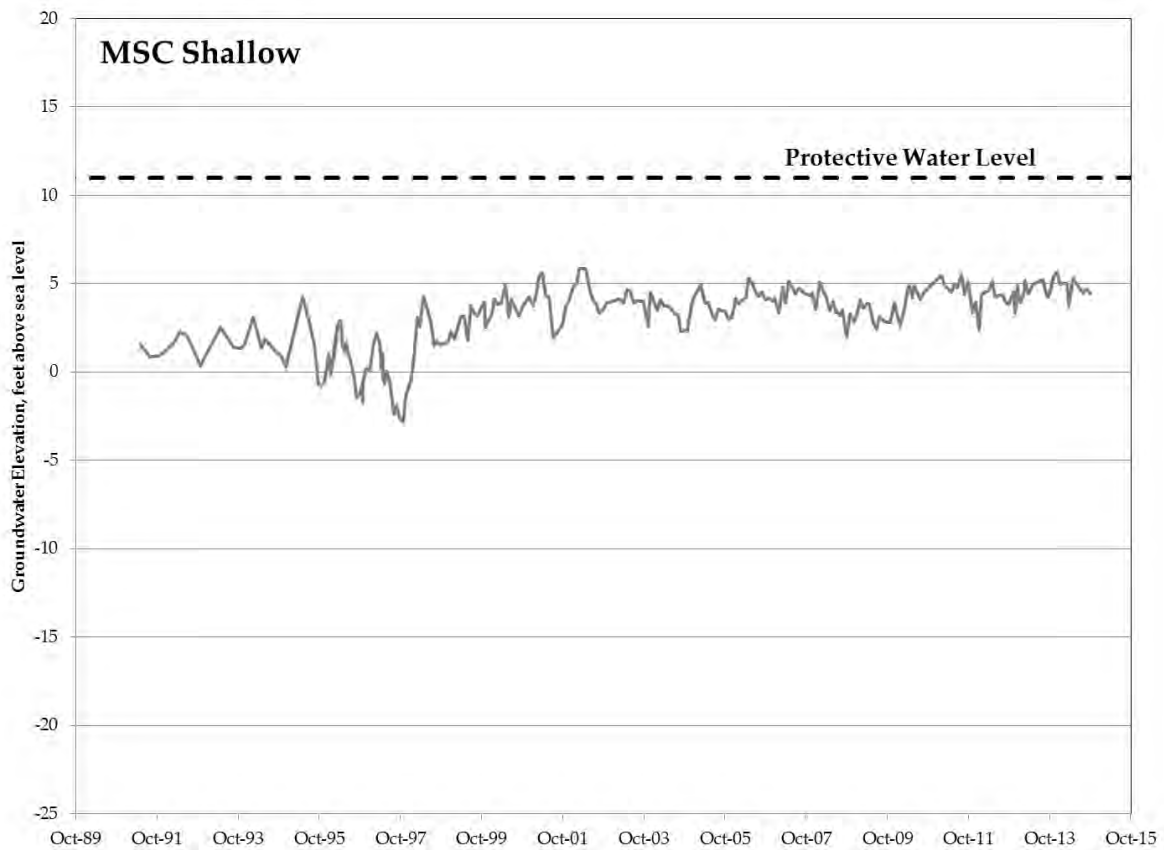
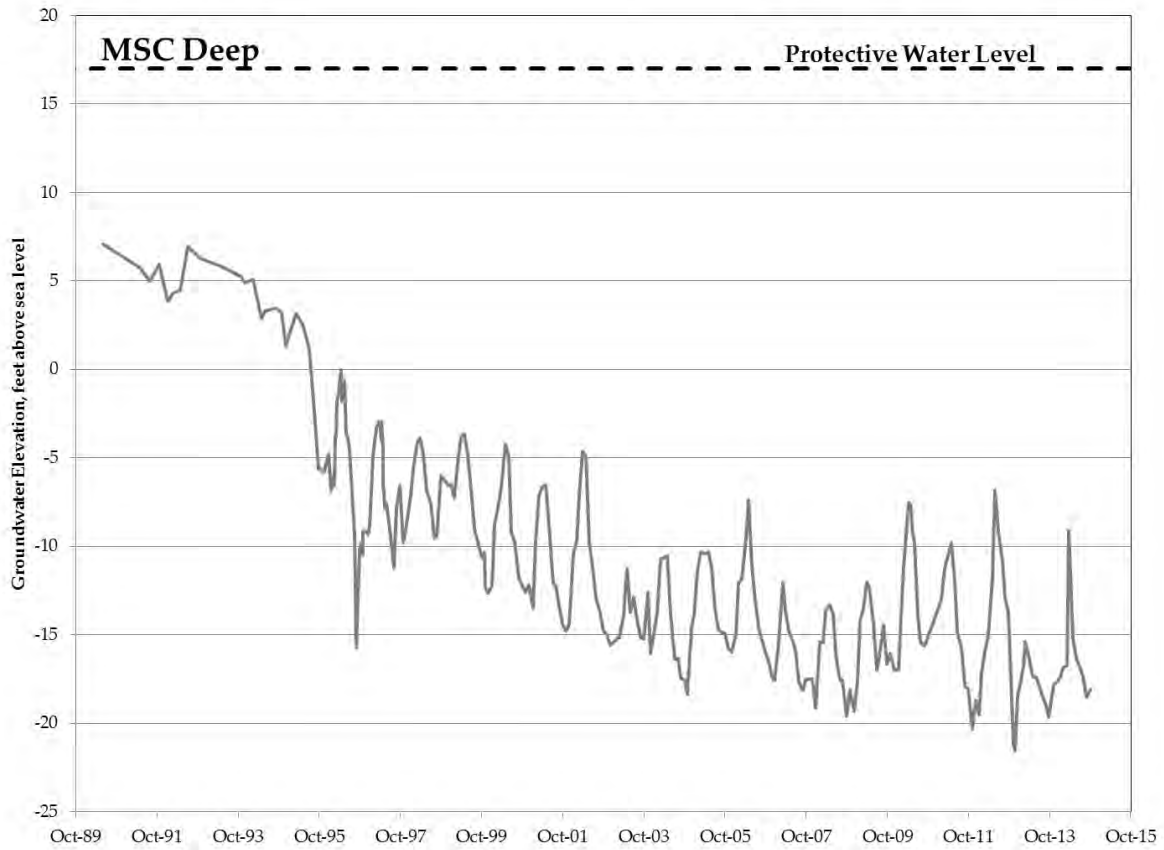


Figure 33: MSC Deep and Shallow Groundwater and Protective Elevations

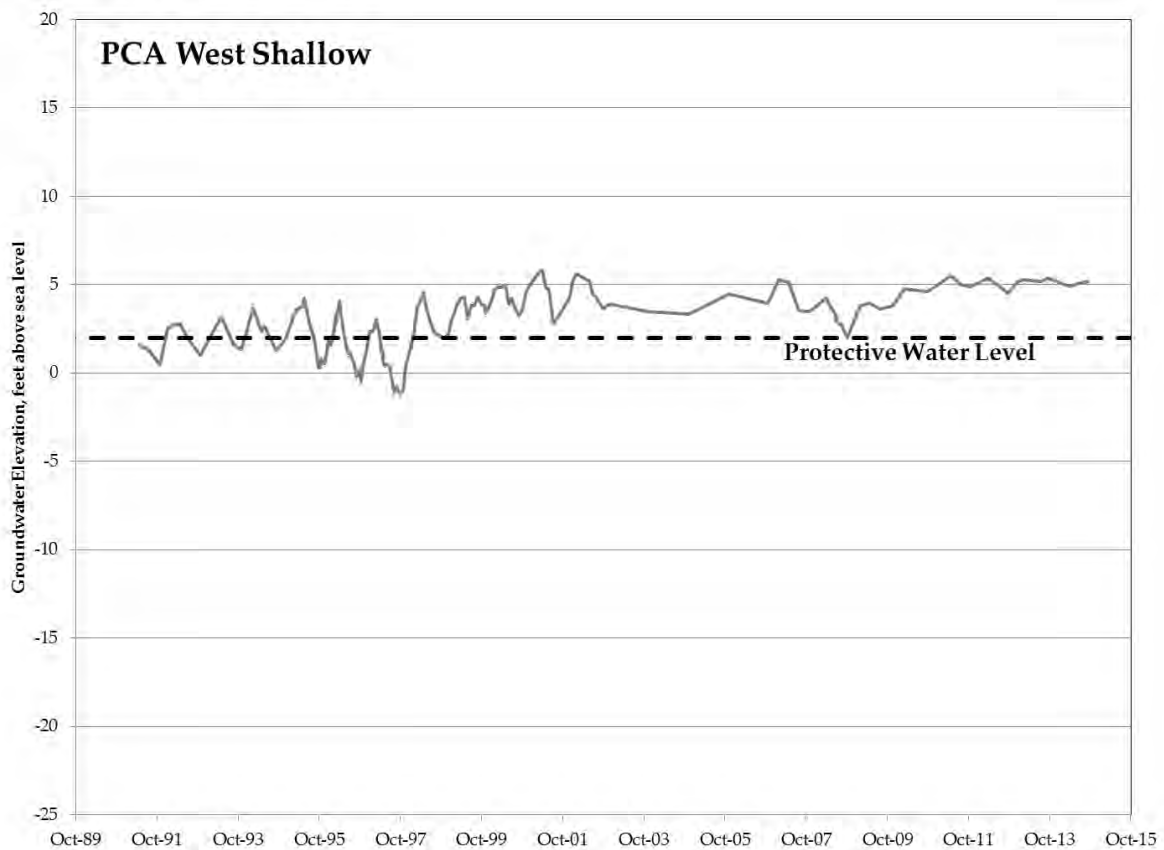
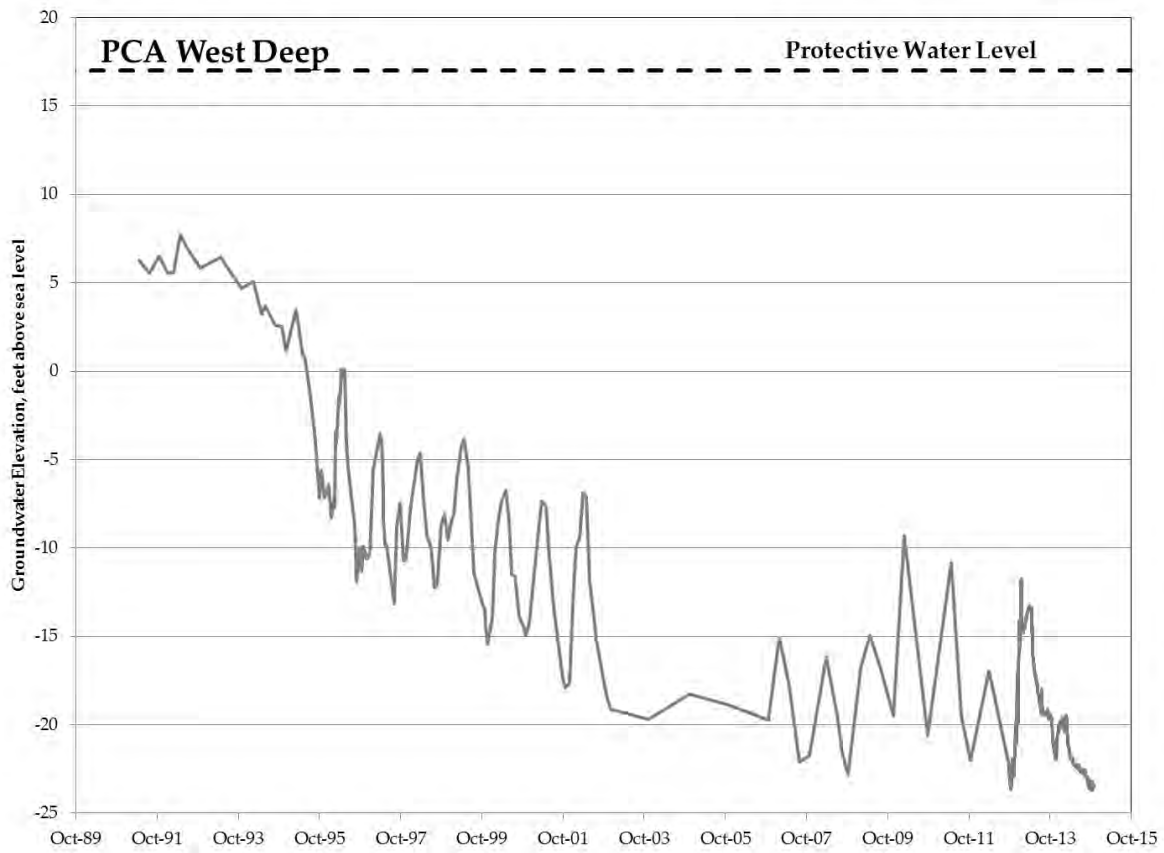


Figure 34: PCA West Deep and Shallow Groundwater and Protective Elevations

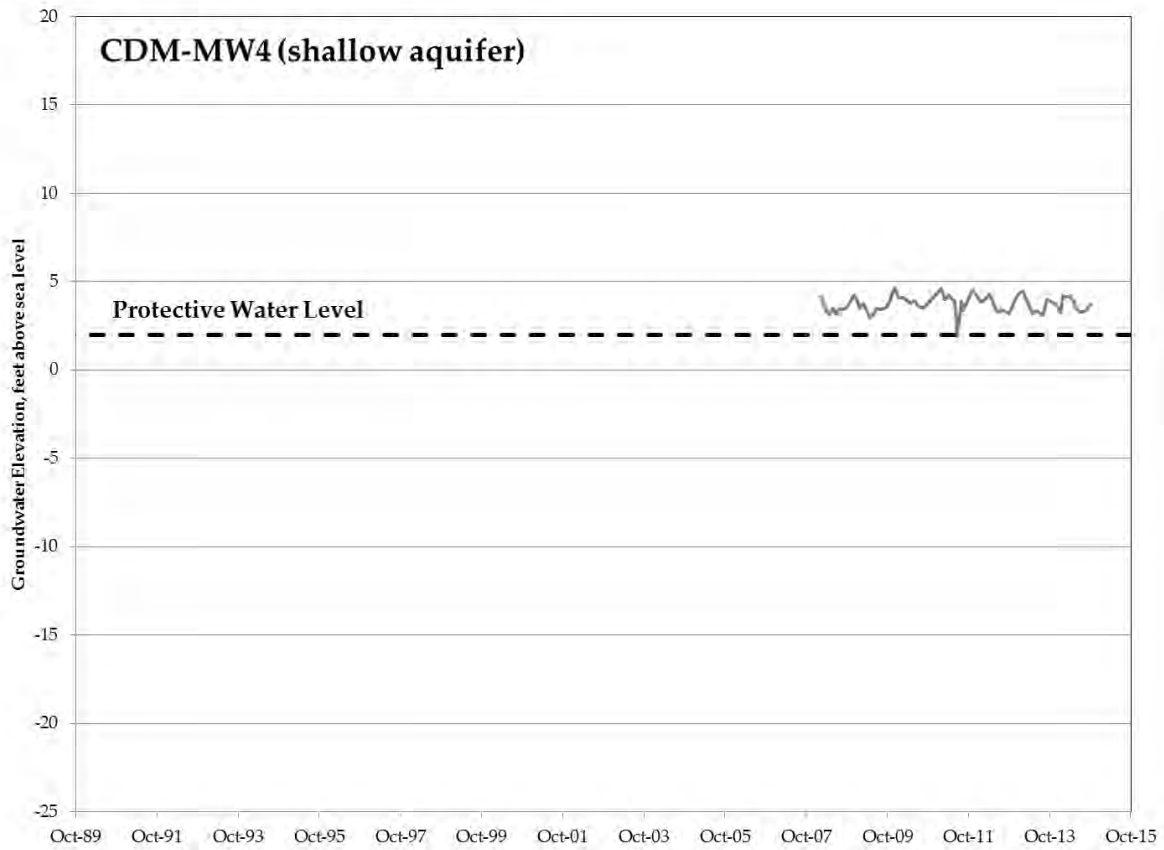


Figure 35: CDM-MW4 Groundwater and Protective Elevations

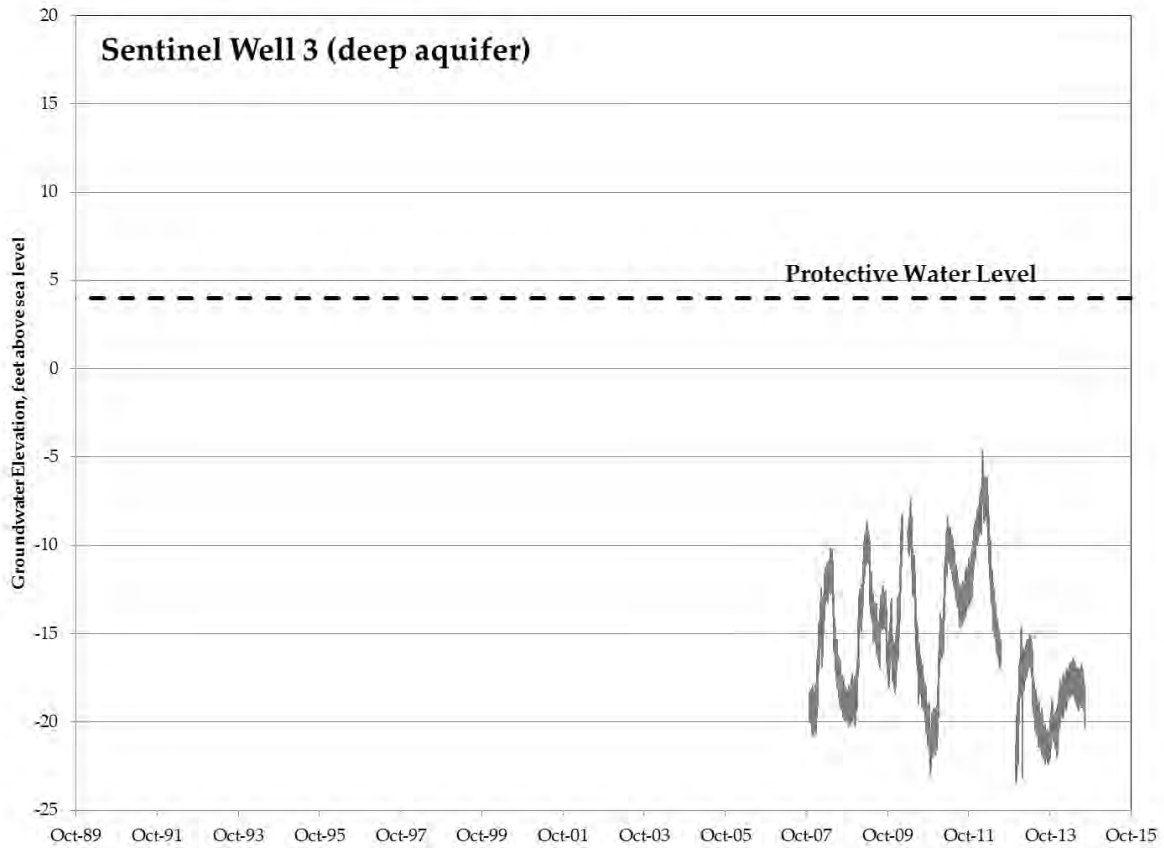


Figure 36: Sentinel Well 3 Groundwater and Protective Elevations

SECTION 4

CONCLUSIONS

Depressed groundwater levels below sea level, continued pumping in excess of recharge and fresh water inflows, and ongoing seawater intrusion in the nearby Salinas Valley all suggest that seawater intrusion could occur in the Seaside Groundwater Basin. In spite of these factors, no seawater intrusion has historically been or is currently observed in existing monitoring or production wells in the Seaside Groundwater Basin. Analyses which indicate that seawater intrusion is not occurring include:

- All water samples for Water Year 2014 from depth-discreet monitoring wells plot generally in a single cluster on Piper diagrams, with no water chemistry changes towards seawater.
- Water quality in some of the production wells is different than the water quality in the monitoring wells. This may be a result of mixed water quality from both shallow and deep zones in which these wells are perforated. The production wells' water qualities are not indicative of seawater intrusion.
- Stiff diagrams of production wells were not indicative of incipient seawater intrusion.
- Overall, chloride concentration trends have been stable for most monitoring wells, with two sentinel wells (SBWM-1 and SBWM-2) having increasing trends.
- Maps of chloride concentrations for the shallow aquifer do not show chlorides increasing towards the coast. The deep aquifer maps show that higher chloride concentrations are limited to coastal monitoring wells PCA-West Deep and sentinel well SBWM-4.
- Induction logging data at the coastal sentinel wells do not indicate changes indicative of seawater intrusion.
- Groundwater production in the Seaside Groundwater Basin for Water Year 2014 was 4,040.1 acre-feet, which is 144.3 acre-feet more than Water Year 2013. This amount is less than the Court-mandated operating yield

of 4,480 acre-feet per year that is required between October 1, 2011 and October 1, 2014.

- Groundwater levels remain below protective elevations in all deep target monitoring wells (MSC deep, PCA-W, and sentinel well SBWM-3). Two of the three shallow wells' groundwater levels are above protective elevations: PCA-W shallow and CDM-MW4. MSC shallow remains below protective elevations.

In spite of the definitive geochemical data, groundwater level and pumping data suggest that a potential for seawater intrusion exists. Northern Coastal subarea groundwater levels in the deep zone remain below sea level (Figure 28 and Figure 30). Two potential processes may explain why no seawater intrusion has not yet been observed in the deep coastal wells:

- The location of seawater/fresh water interface is currently unknown. It is, however, sufficiently far offshore in the deep zone that it has not reached the coastal monitoring wells. A seawater interface may be moving towards the coast, but may take some years to arrive. Before the interface arrives, pumping will mine much of the fresh water stored beneath the ocean in the lower aquifer.
- Overlying aquifers and aquitards limit or prevent seawater from percolating into the lower aquifer. Groundwater level data and results from groundwater modeling suggest that this condition is occurring. Coastal groundwater levels in aquifers that are in close hydraulic communication with the ocean remain near sea level because the ocean acts as a constant-pressure reservoir. Northern Coastal subarea groundwater levels in the deep aquifer are more than 20 feet below sea level (Figure 28 and Figure 30), suggesting that this aquifer is not in close communication with the ocean. This is further evidence that groundwater in the deep aquifer is currently being mined rather than replaced by seawater.

These two processes are displayed on Figure 37. The two processes are not independent, and it is likely that some combination of both factors is occurring.

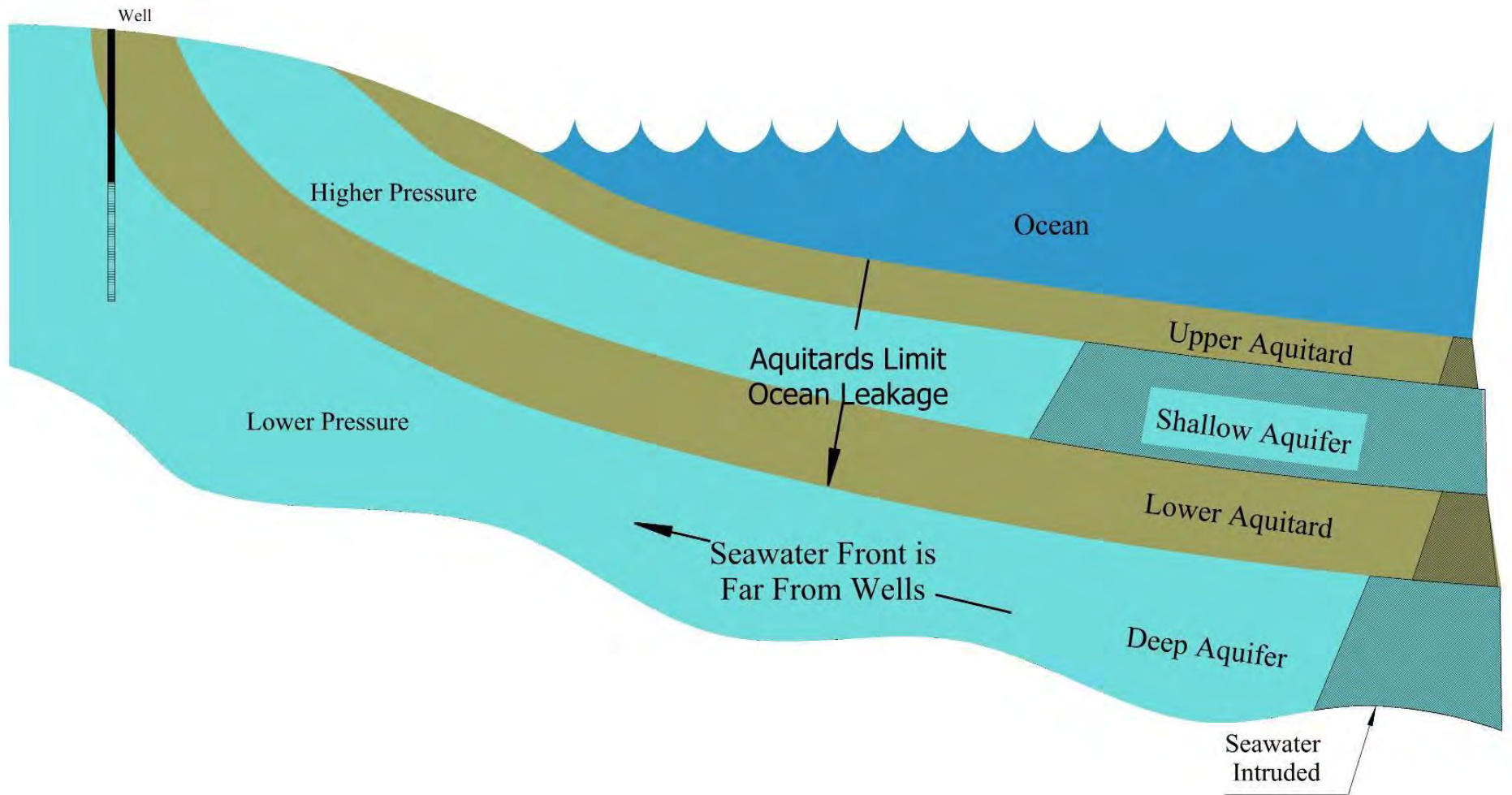


Figure 37: Possible Processes Limiting Seawater Intrusion

This page left
intentionally blank

SECTION 5 RECOMMENDATIONS

The analyses presented previously in this report are based on existing data. While informative, the data are spatially incomplete and temporally sporadic. The following recommendations should be implemented to monitor and track seawater intrusion. They are the same recommendations as were made last year.

VERIFICATION WATER QUALITY SAMPLING AND ANALYSIS FOR SENTINEL WELL SBWM-1

Because of the 47 mg/L increase in chloride and 31 mg/L increase in sodium at sentinel well SBWM-1 since last year, it is recommended that this well be resampled in the next quarter to verify the increase in chloride and sodium in the well at both sample depths.

CONTINUE TO ANALYZE AND REPORT ON WATER QUALITY ANNUALLY

Seawater intrusion is a threat, and data must be analyzed regularly to identify incipient intrusion. Maps, graphs, and analyses similar to what are found in this report should continue to be developed every year.

This page left
intentionally blank

SECTION 6

REFERENCES

- Barlow, P. M., 2003. *Ground Water in freshwater-saltwater environments of the Atlantic coast*, U.S. Geological Survey Circular 1262, 113 p.
- Feeney, M.B., 2007. *Seaside Groundwater Basin Watermaster seawater sentinel wells project - summary of operations*, prepared for Seaside Groundwater Basin Watermaster.
- Hem, J.D., 1989. *Study and interpretation of the chemical characteristics of natural water*, USGS water supply paper 2254, 3rd edition.
- HydroMetrics LLC, 2008. *Seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, October 2008.
- , 2009a. *Water year 2009 seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, October 2009.
- , 2009b. *Seaside groundwater basin modeling and protective groundwater elevations*, prepared for the Seaside Groundwater Basin Watermaster, October 2009.
- , 2009c. *Seawater intrusion response plan, Seaside basin, Monterey County, California*, prepared for the Seaside Groundwater Basin Watermaster, February 2009.
- , 2010. *Water year 2010 seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, October 2010.
- , 2011. *Water year 2011 seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, November 2011.
- , 2012a. *Water year 2012 seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, November 2012.
- , 2013a. *Water year 2013 seawater intrusion analysis report*, prepared for the Seaside Groundwater Basin Watermaster, December 2013.
- , 2013b. *Groundwater Modeling Results of Replenishment Repayment in the Seaside Basin*. Technical memorandum prepared for the Seaside Groundwater Basin Watermaster, April 4, 2013.
- RBF, 2007. *Seawater intrusion analysis report, Seaside Groundwater Basin, Monterey County, California*, prepared for Seaside Groundwater Basin Watermaster by RBF and HydroMetrics, LLC.

- Jones, B.F., A. Vengosh, E. Rosenthal, and Y. Yechieli, 1999. Geochemical investigations, in Bear, Jacob, and others, eds., *Seawater intrusion in coastal aquifers—Concepts, methods and practices*, Dordrecht, The Netherlands, Kluwer Academic Publishers, p. 51–71.
- Paillet, F.L., 2001. *Integrating surface and borehole geophysics in the characterization of salinity in a coastal aquifer*. Proceedings of the First International Conference on Saltwater Intrusion and Coastal Aquifers -- Monitoring, Modeling, and Management, Essaouira, Morocco, Workshops -- April 18-21, 2001, Conference -- April 23-25, 2001.
- Richter, B.C., and C.W. Kreitler, 1993. *Geochemical techniques for identifying sources of ground-water salinization*, Boca Raton, Fla., C.K. Smoley (CRC Press, Inc.), 258 p.
- Seaside Groundwater Basin Watermaster, 2006. *Seaside Basin Monitoring and Management Program*, May 17, 24 pp.
- Yates, E.B., M.B. Feeney, and L.I. Rosenberg, 2005. *Seaside groundwater basin: update on water resources conditions*, prepared for Monterey Peninsula Water Management District.

APPENDIX A: PIPER DIAGRAMS FOR INDIVIDUAL WELLS

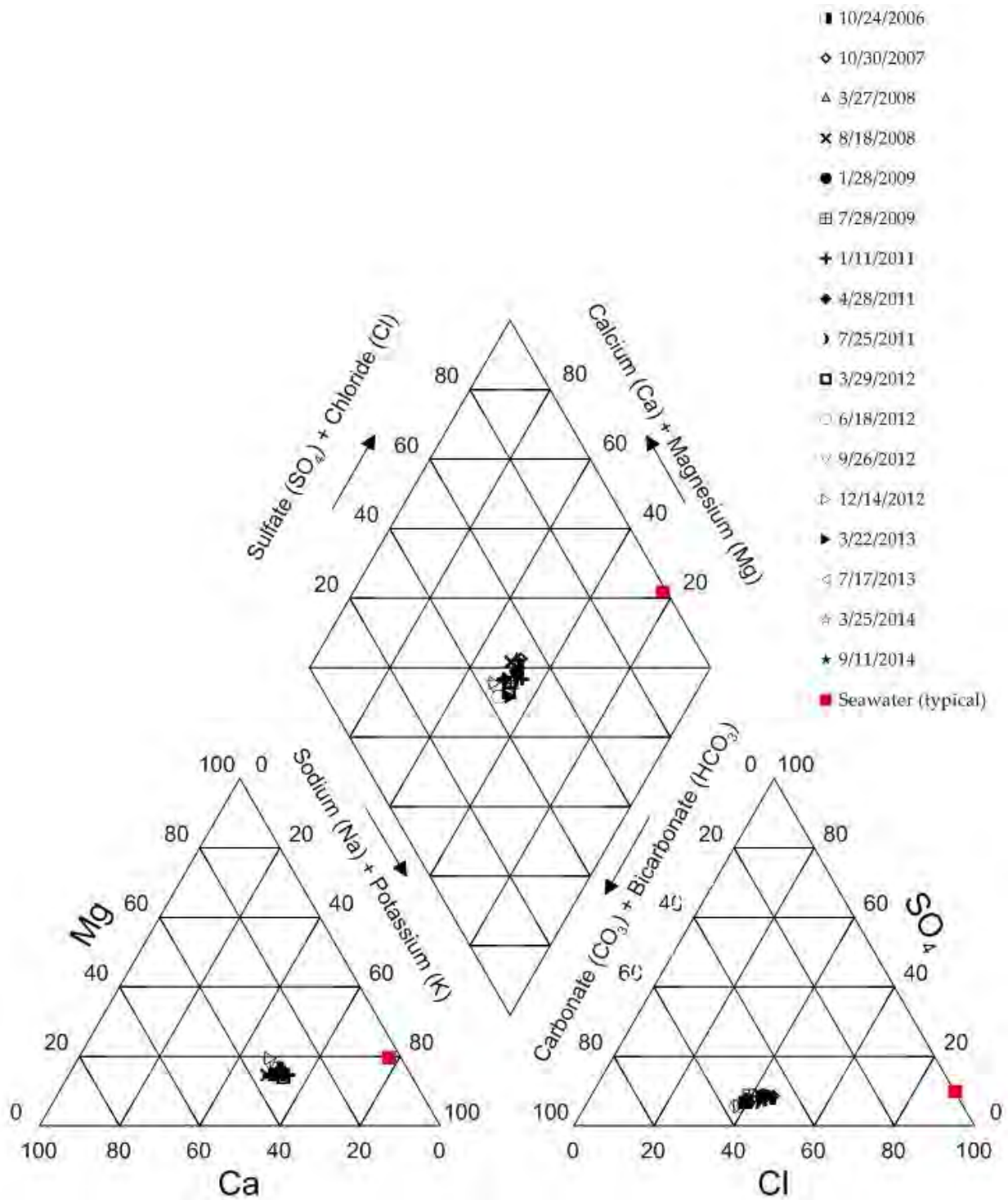


Figure A-1: Piper Diagram of PCA West Shallow

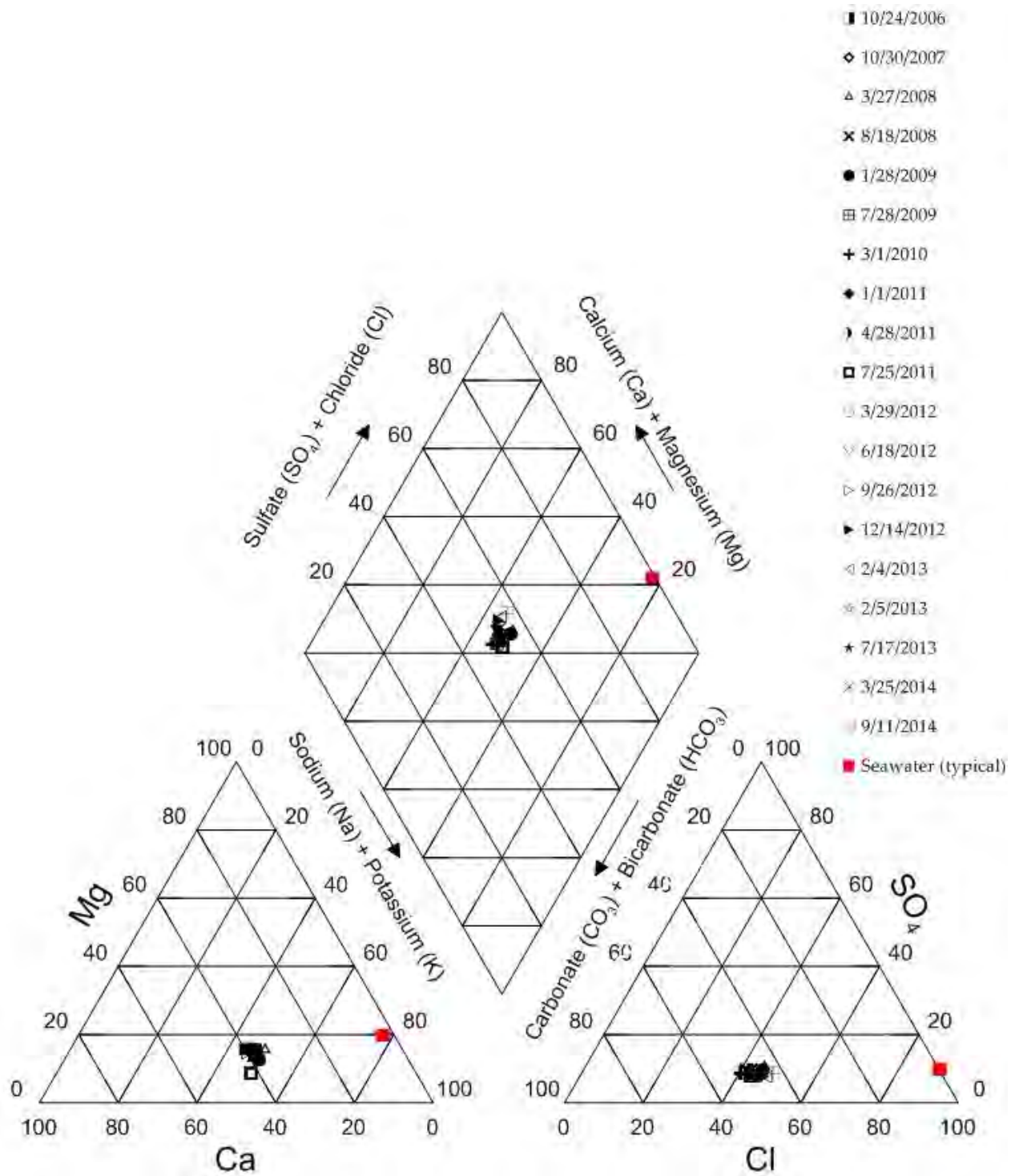


Figure A-2: Piper Diagram of PCA West Deep

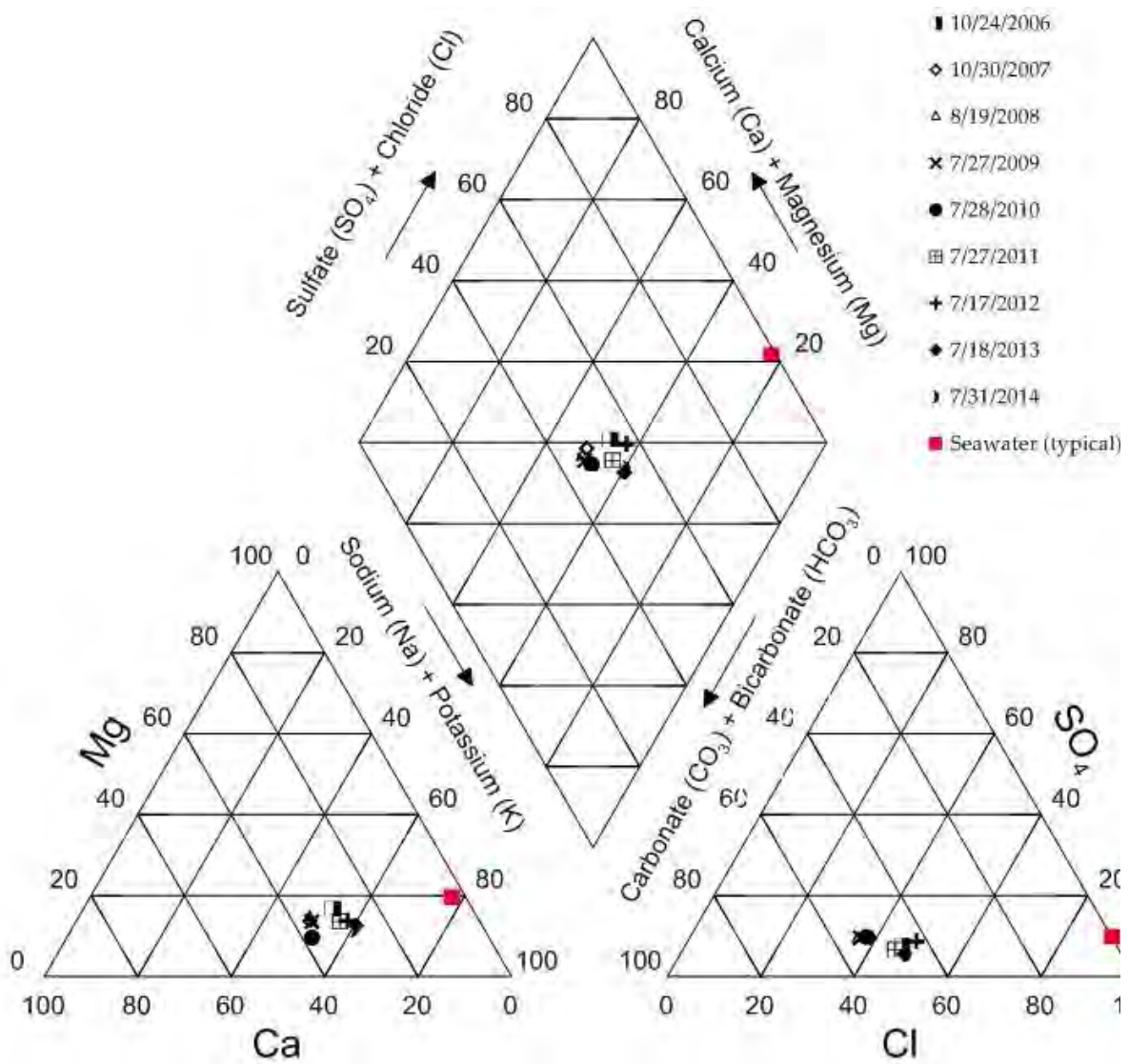


Figure A-3: Piper Diagram of PCA East Shallow

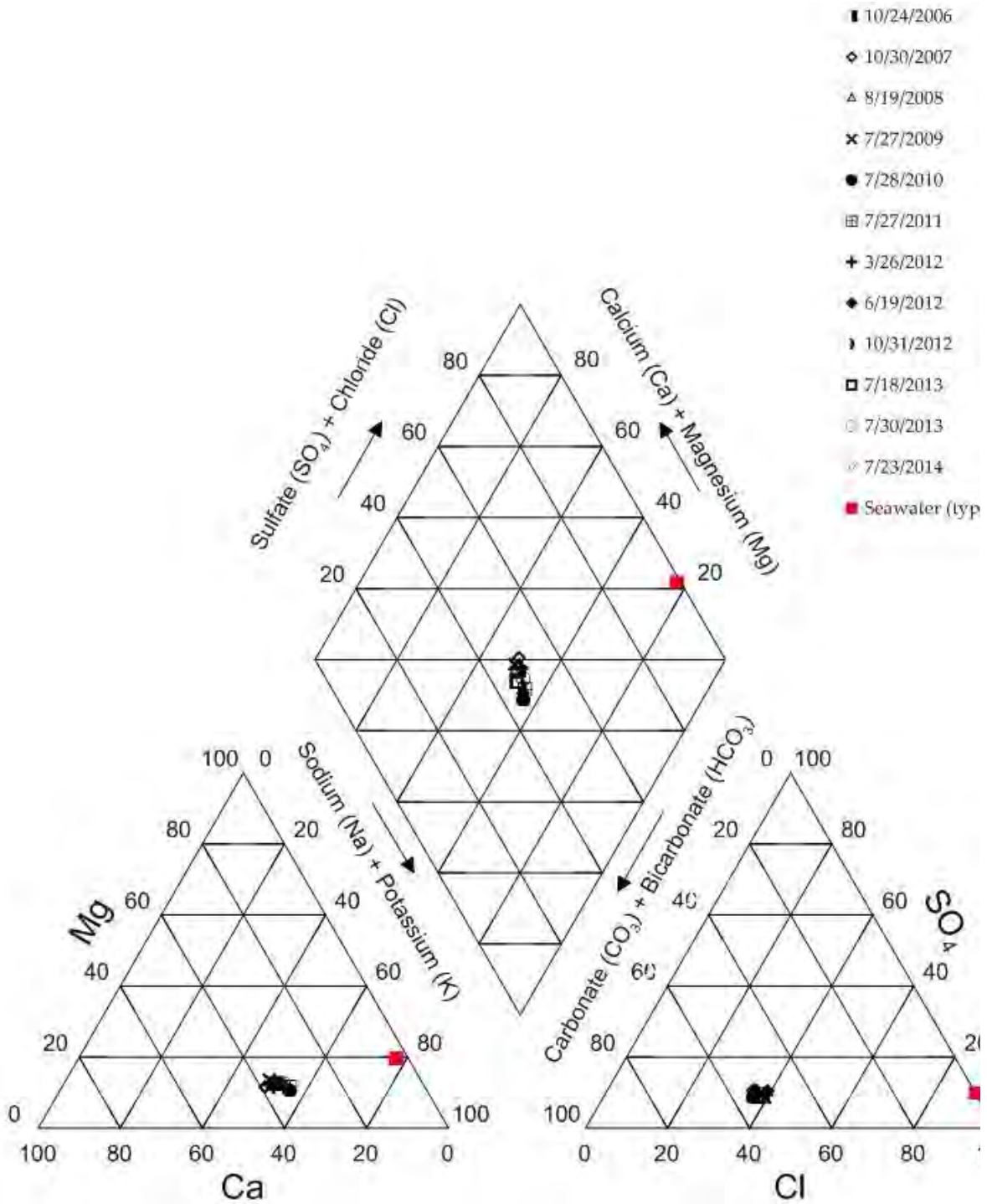


Figure A-4: Piper Diagram of PCA East Deep

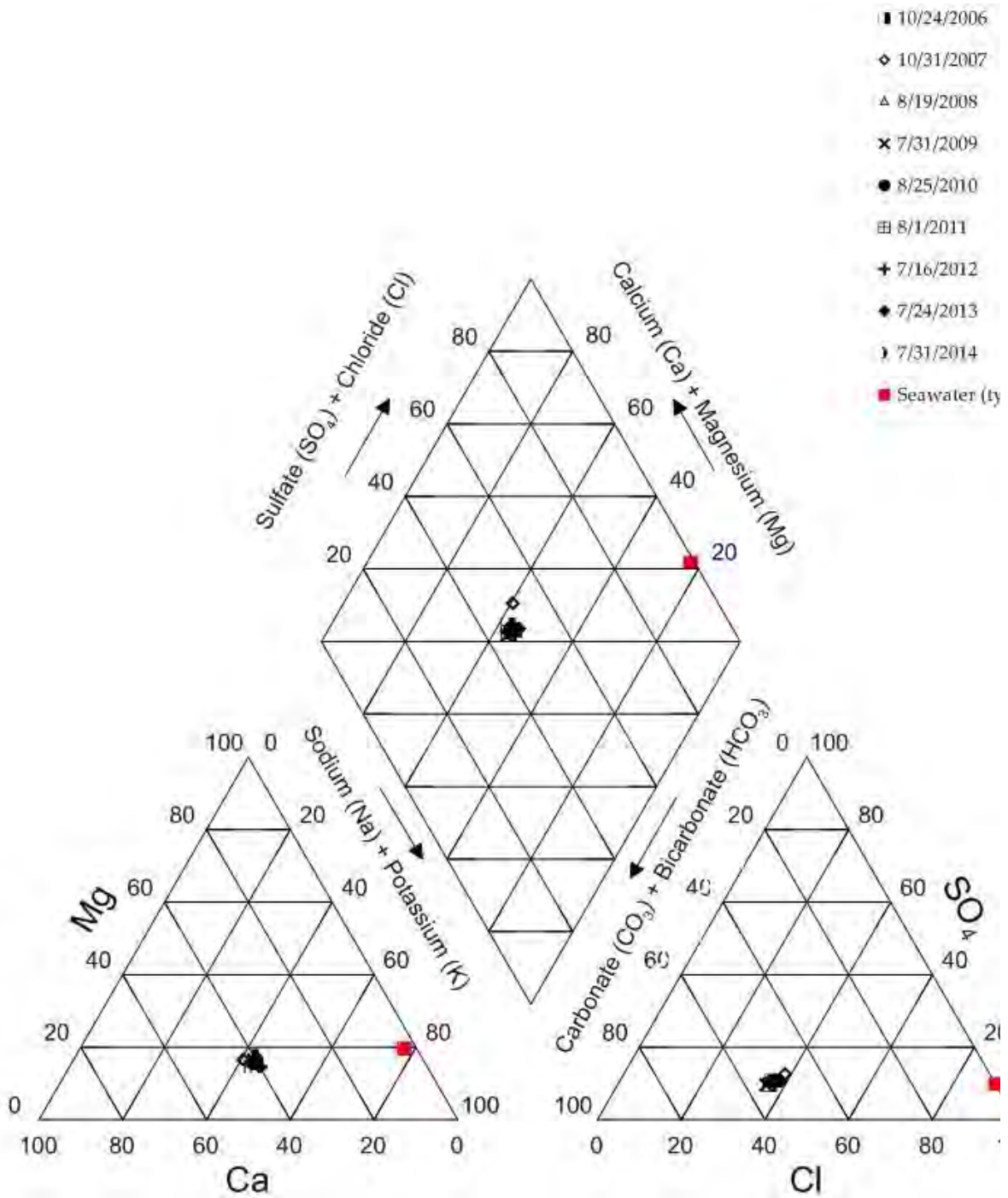


Figure A-5: Piper Diagram of Ord Terrace Shallow

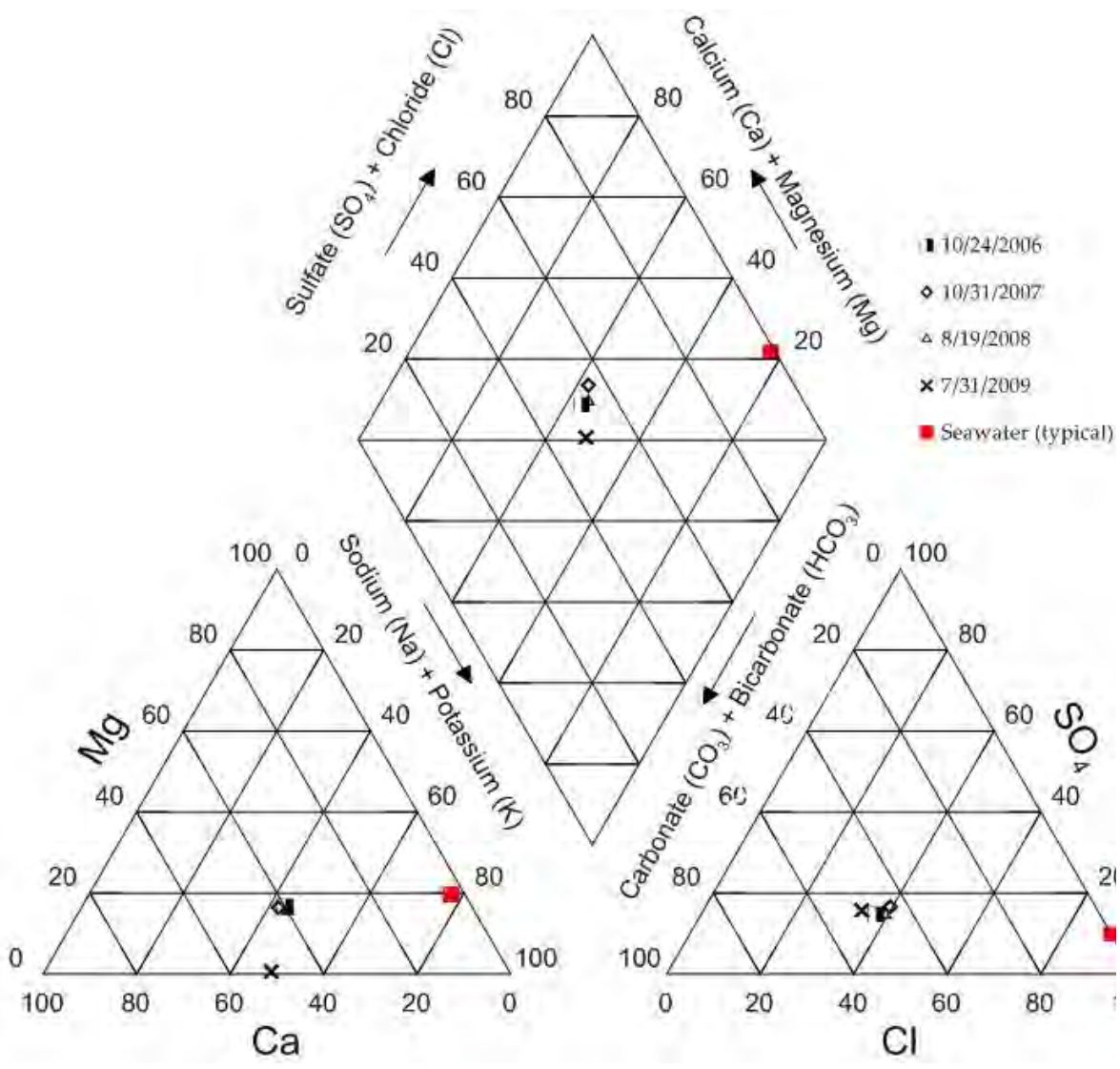


Figure A-6: Piper Diagram of Ord Terrace Deep

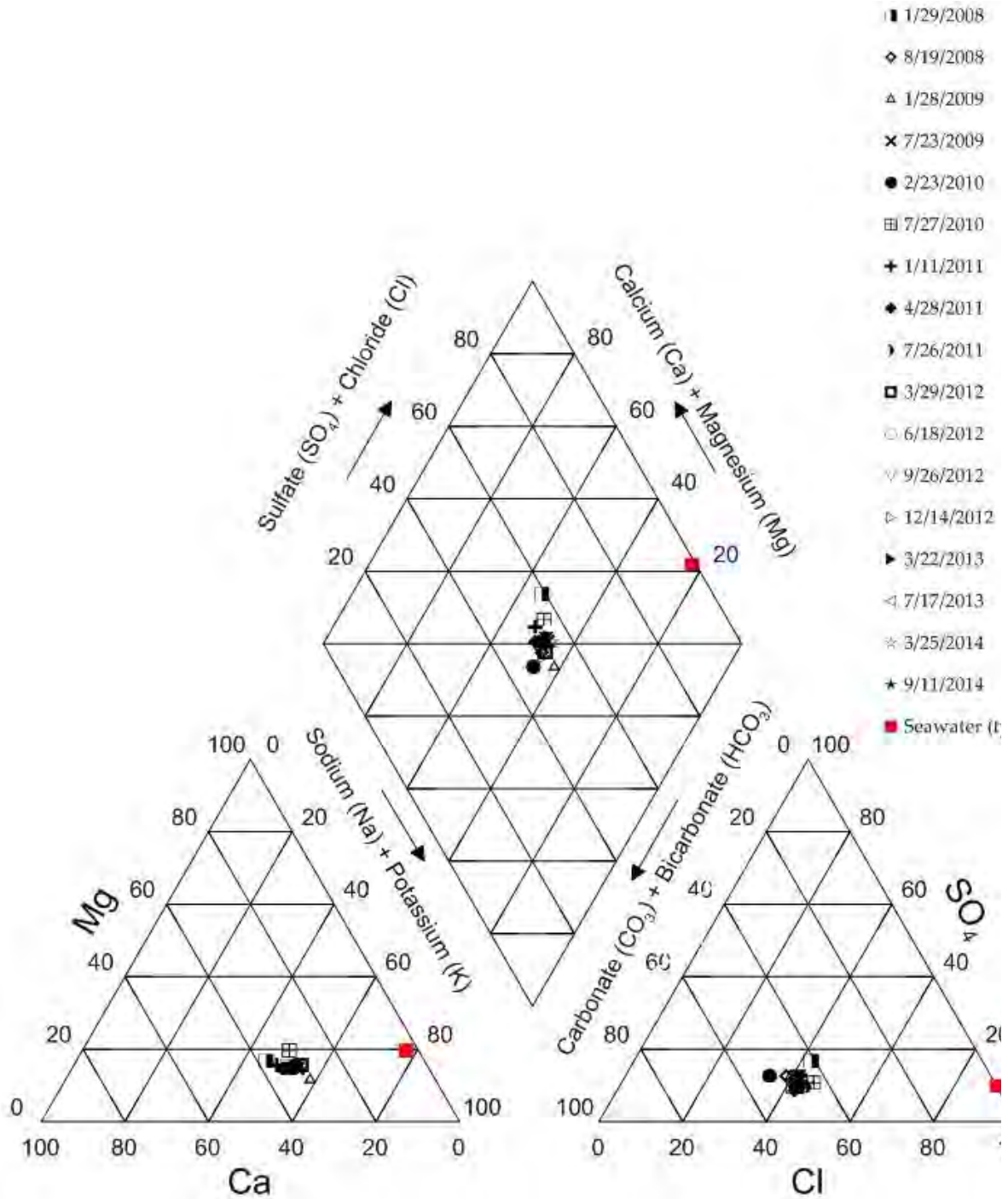


Figure A-7: Piper Diagram of MSC Shallow

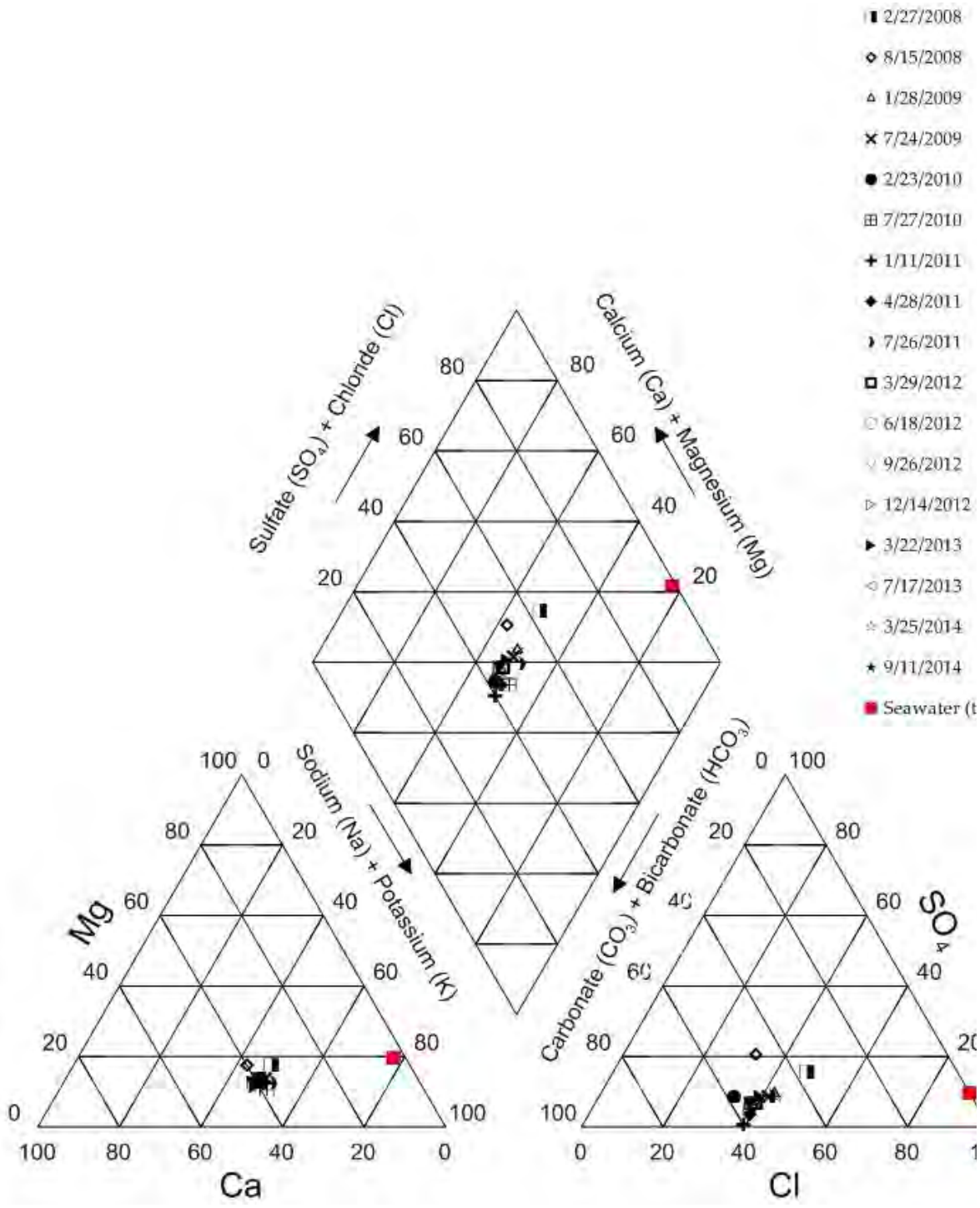


Figure A-8: Piper Diagram of MSC Deep

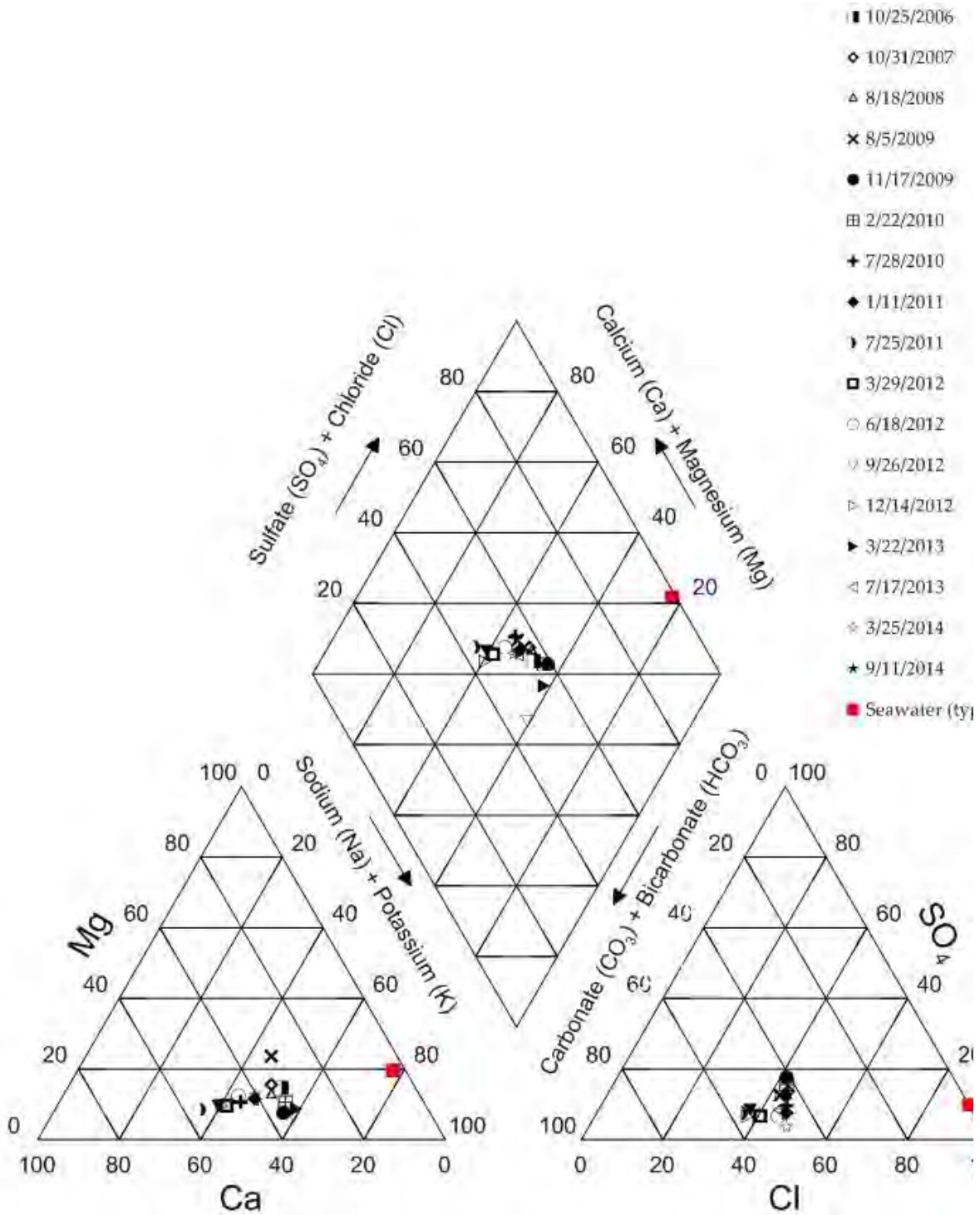


Figure A-9: Piper Diagram of Fort Ord 9 Shallow

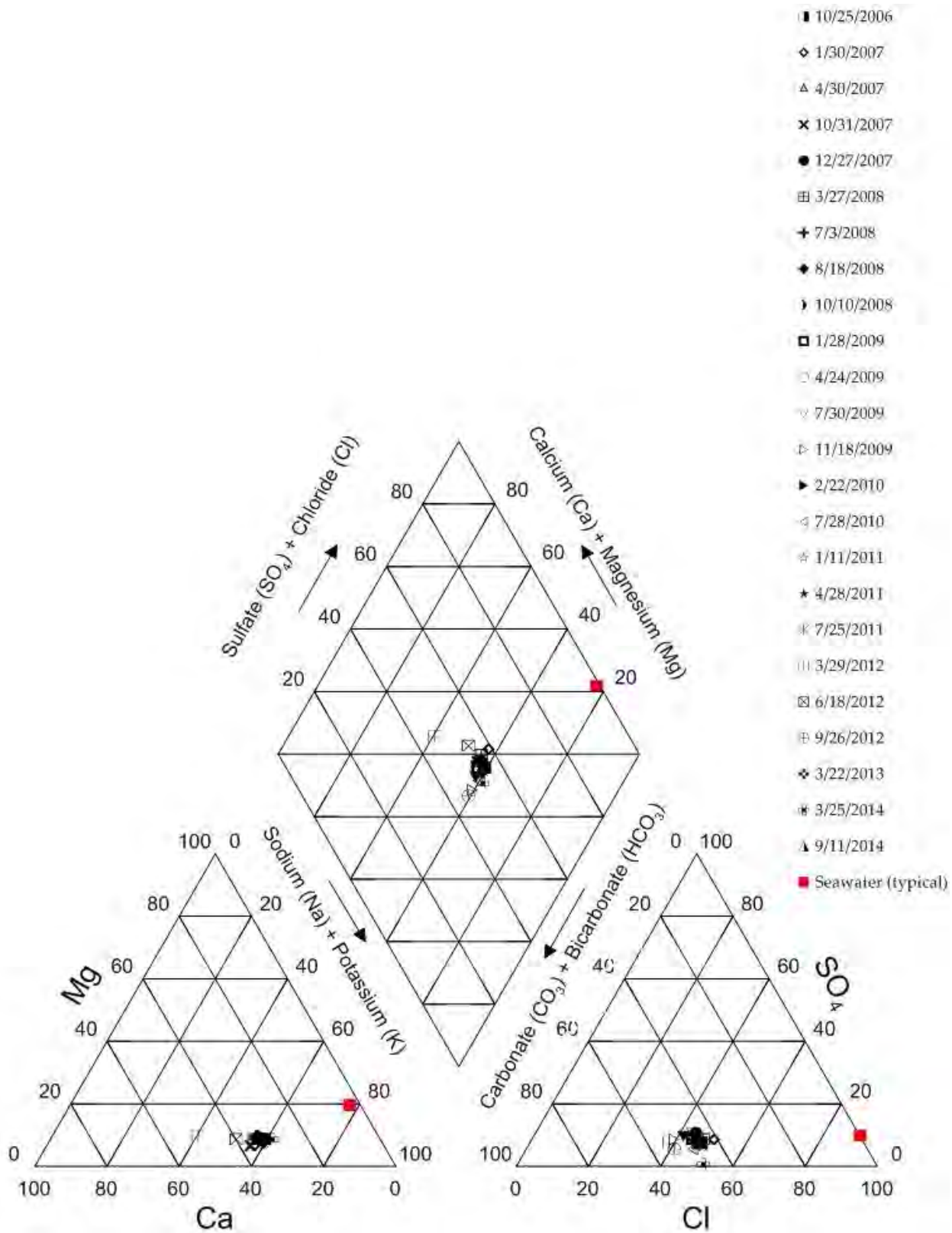


Figure A-10: Piper Diagram of Fort Ord 9 Deep

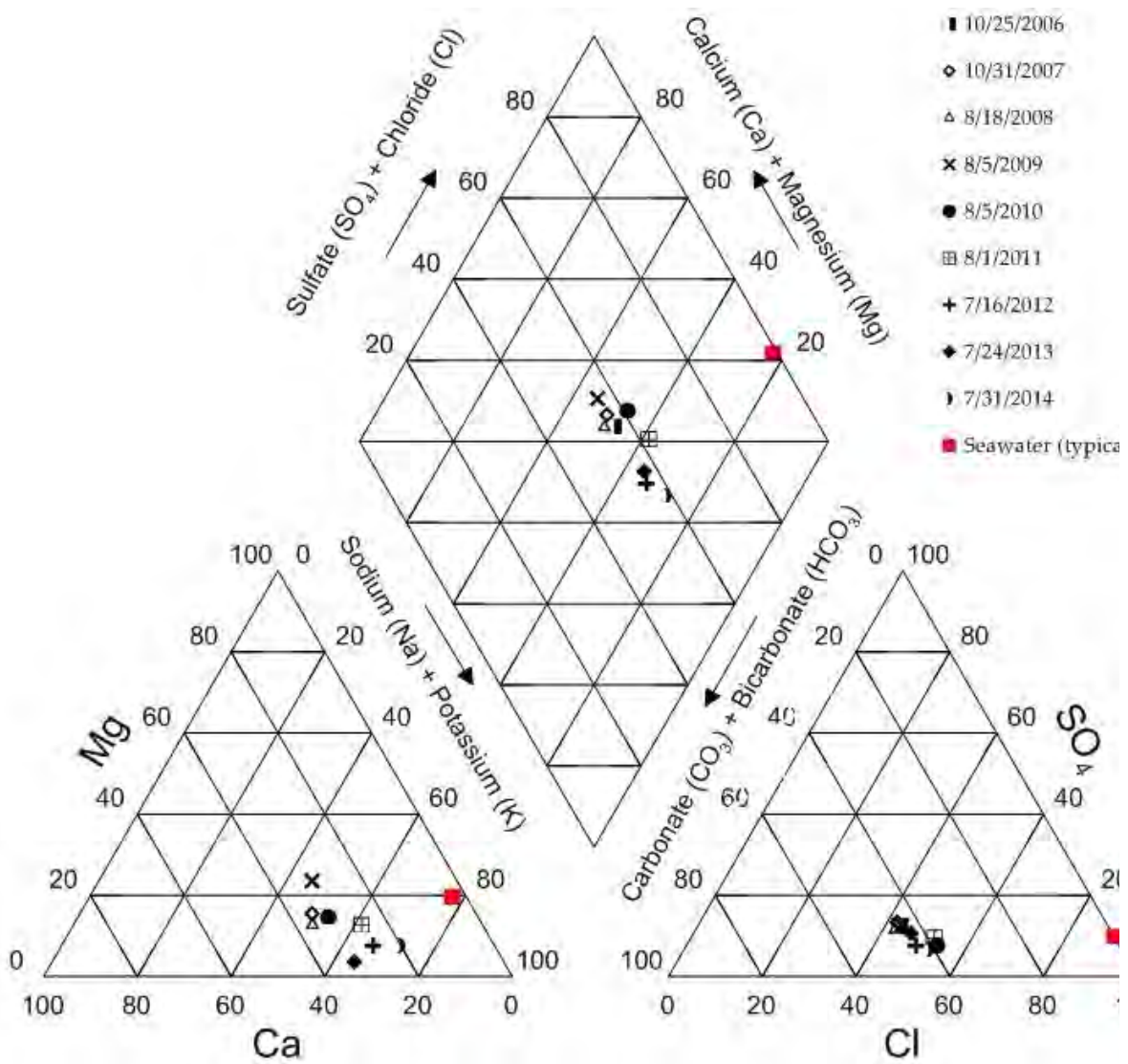


Figure A-11: Piper Diagram of Fort Ord 10 Shallow

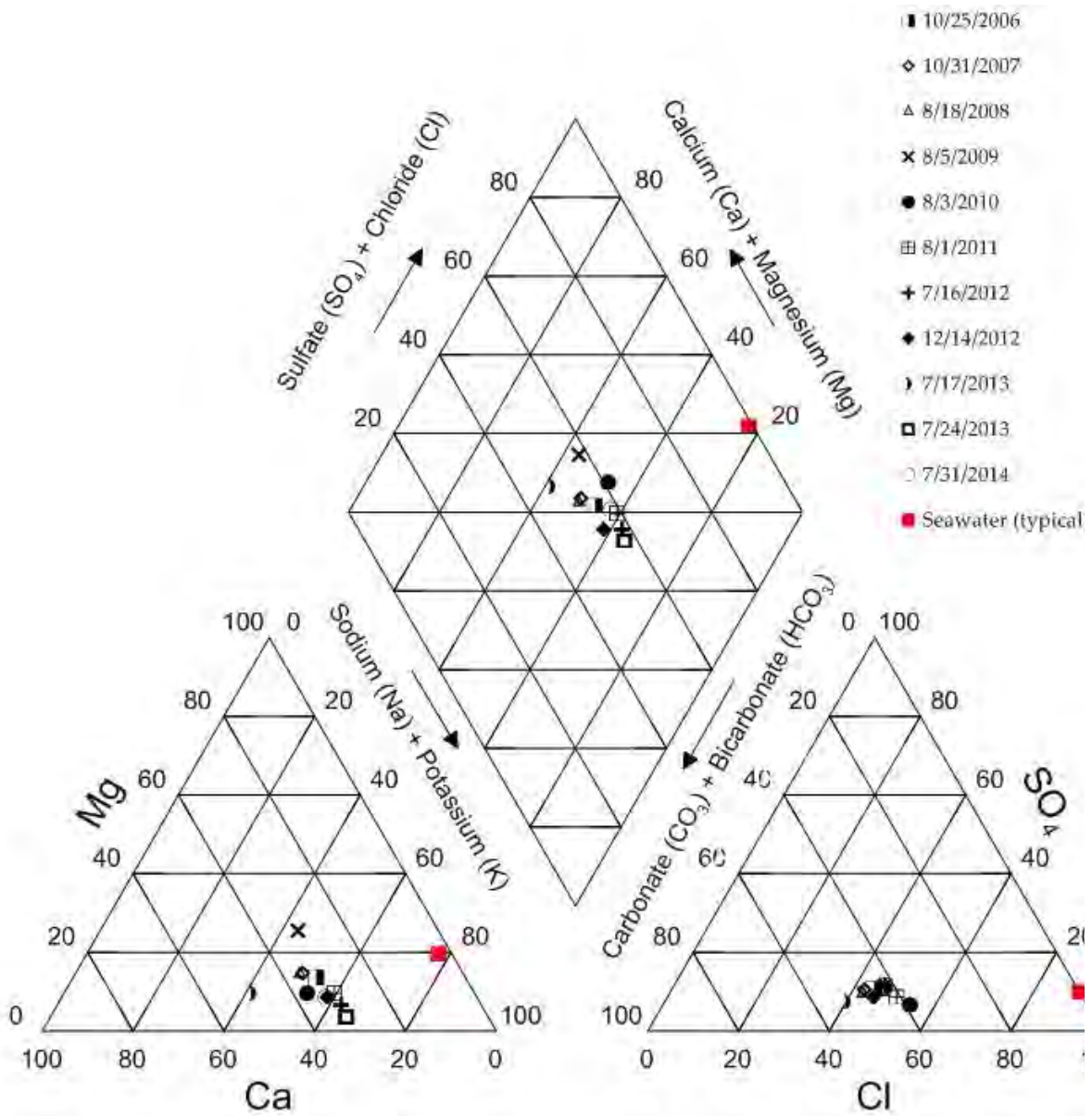


Figure A-12: Piper Diagram of Fort Ord 10 Deep

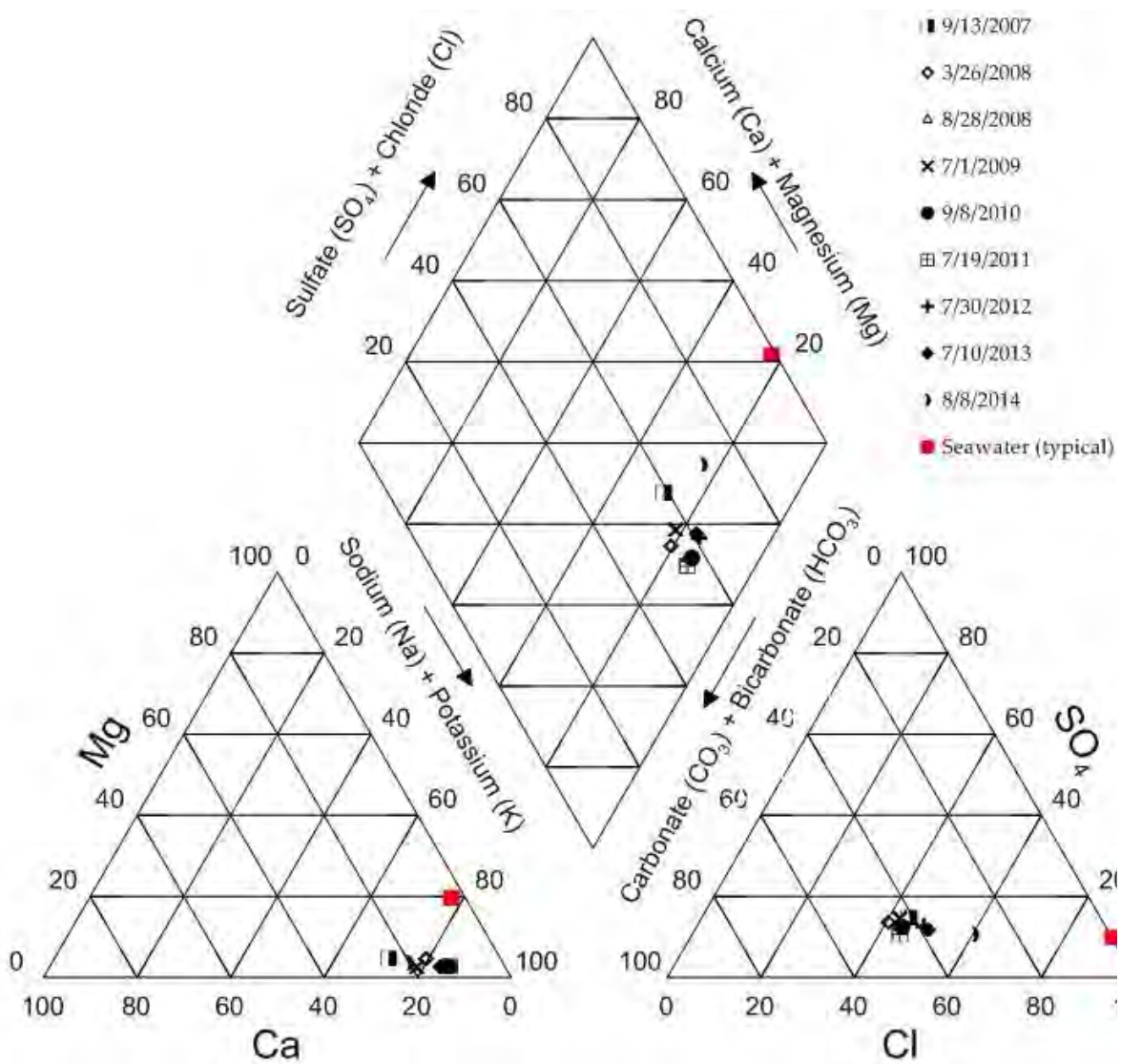


Figure A-13: Piper Diagram of SBWM-1 1,140 ft sample

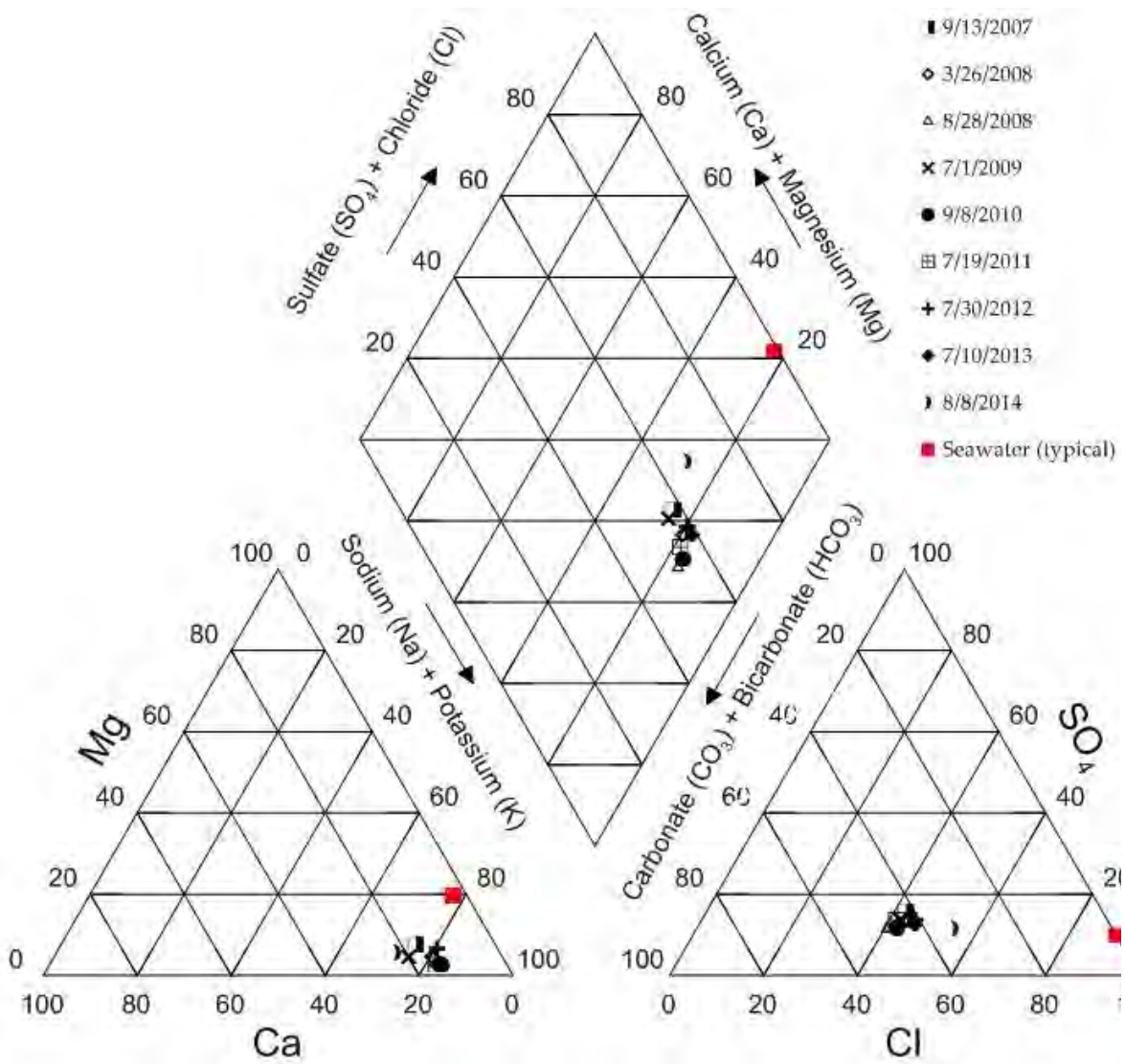


Figure A-14: Piper Diagram of SBWM-1 1,390 ft sample

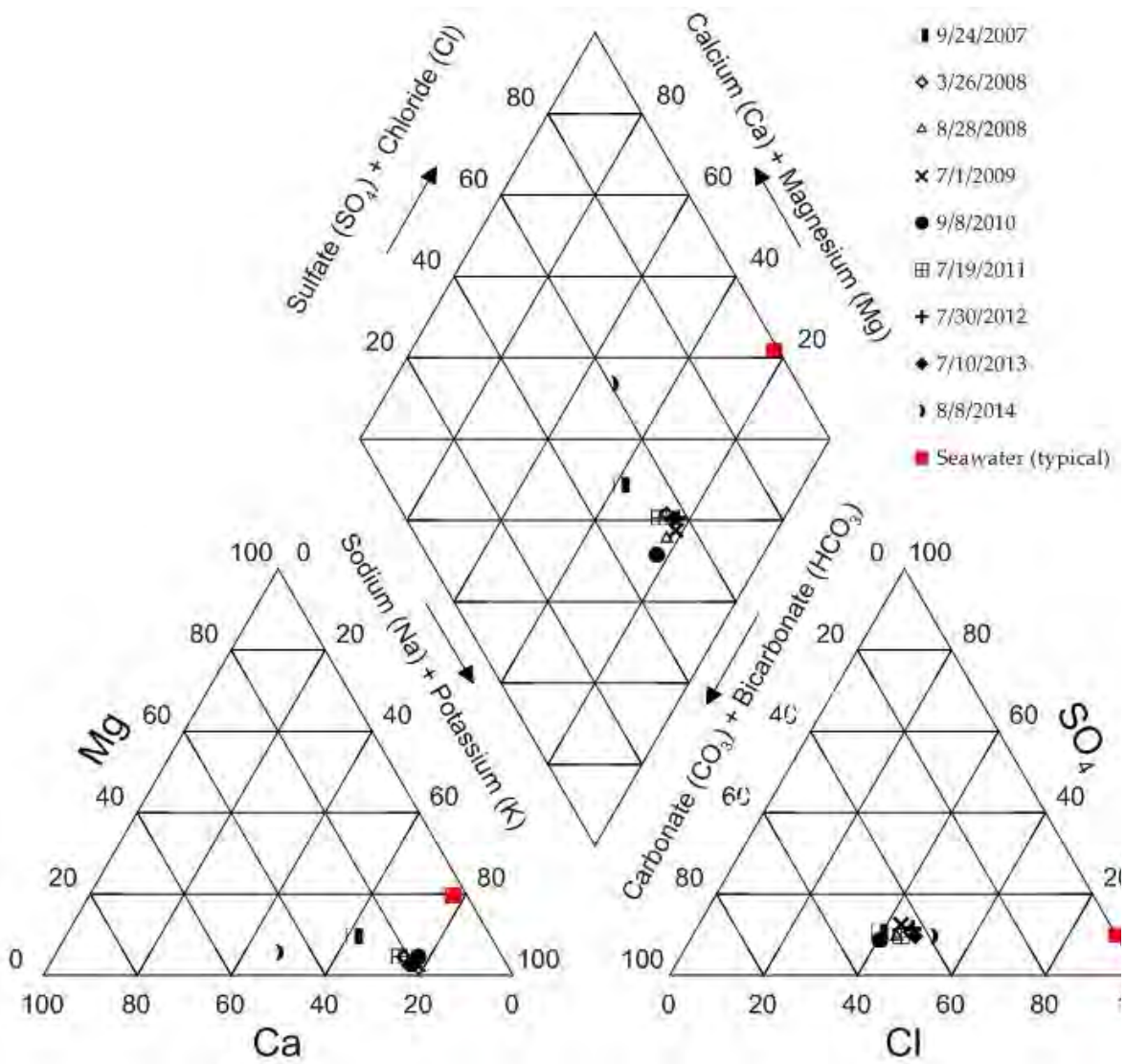


Figure A-15: Piper Diagram of SBWM-2 1,000 ft sample

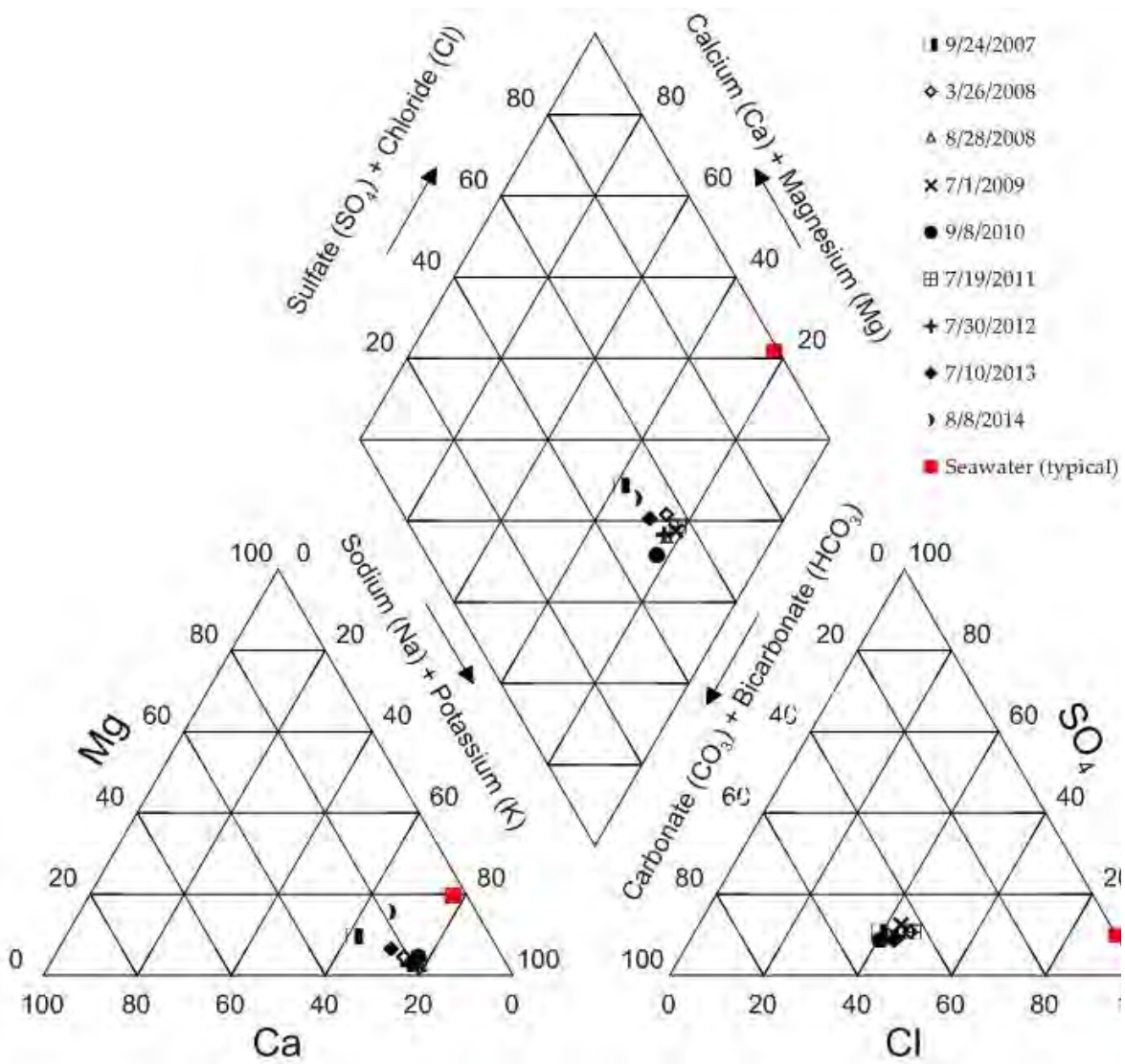


Figure A-16: Piper Diagram of SBWM-2 1,470 ft sample

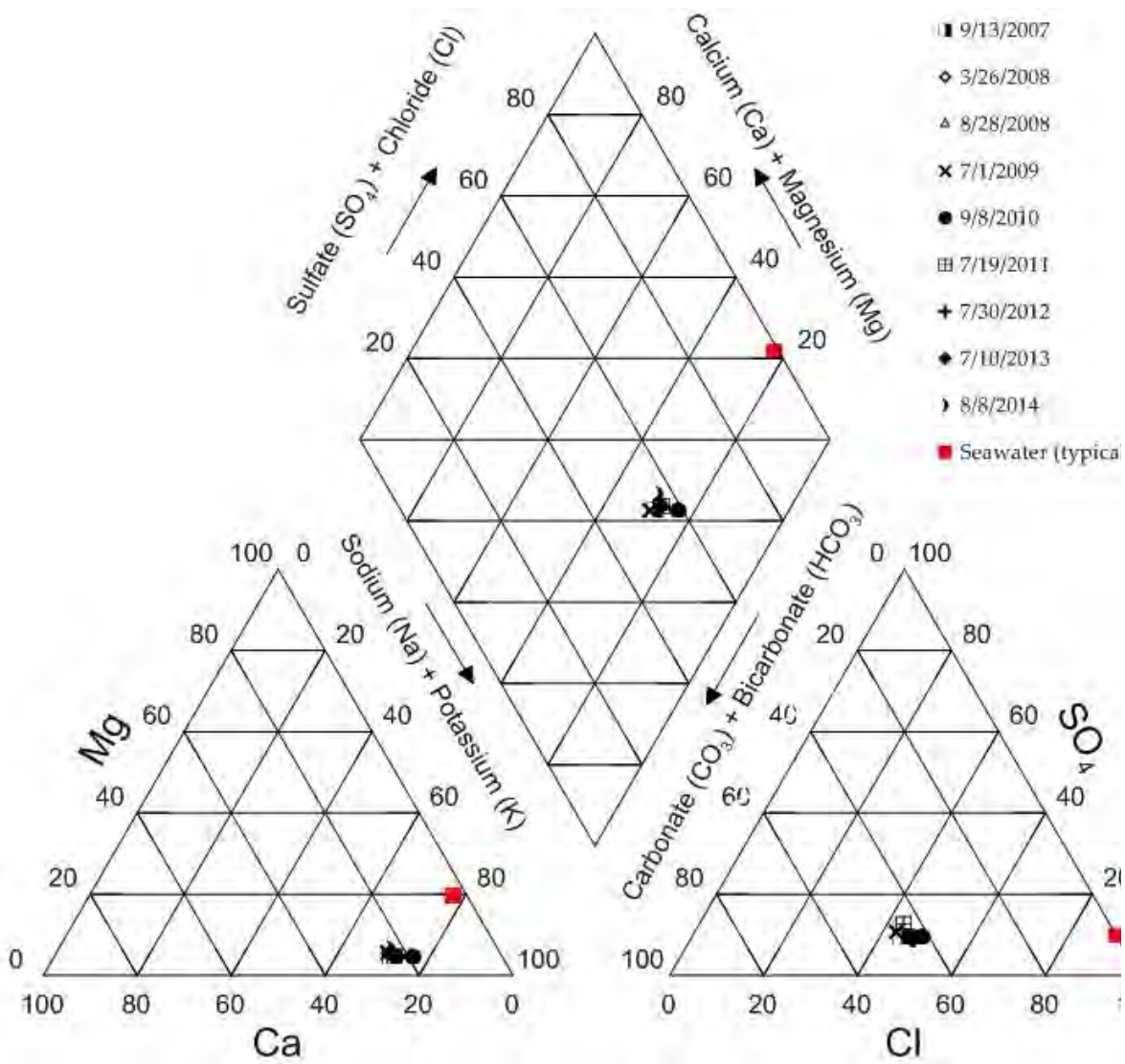


Figure A-17: Piper Diagram of SBWM-3 870 ft sample

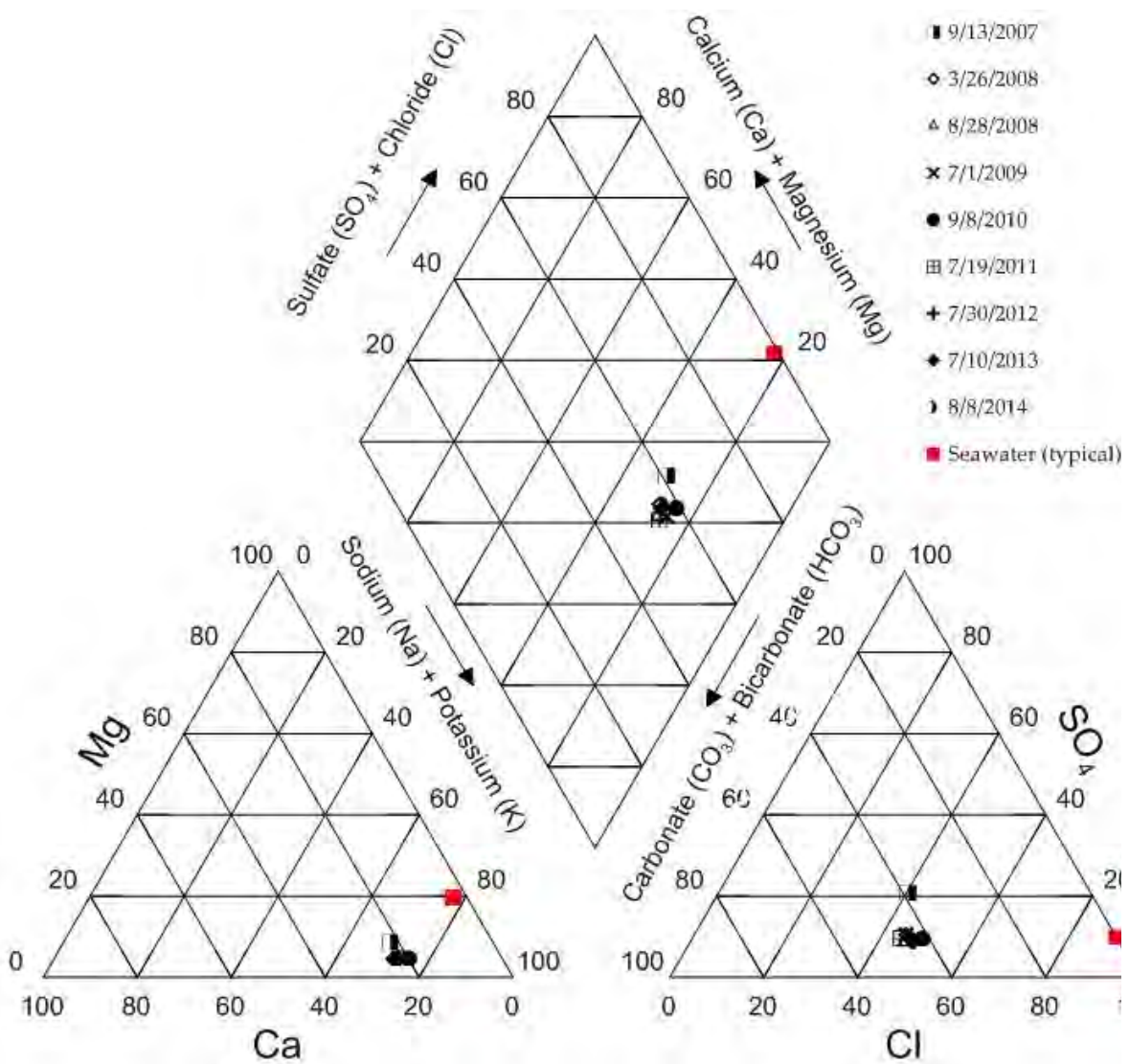


Figure A-18: Piper Diagram of SBWM-3 1,275 ft sample

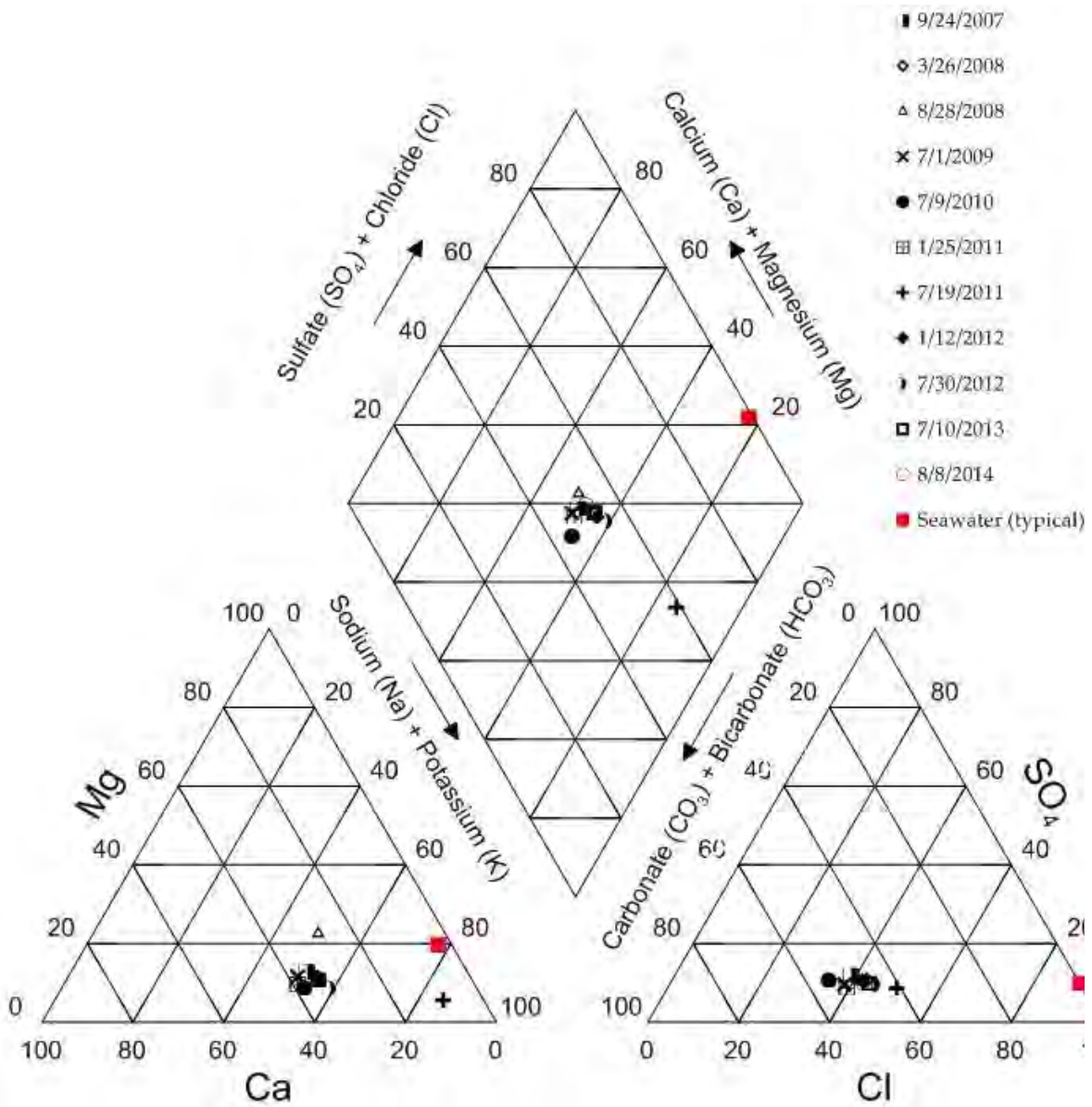


Figure A-19: Piper Diagram of SBWM-4 715 ft sample

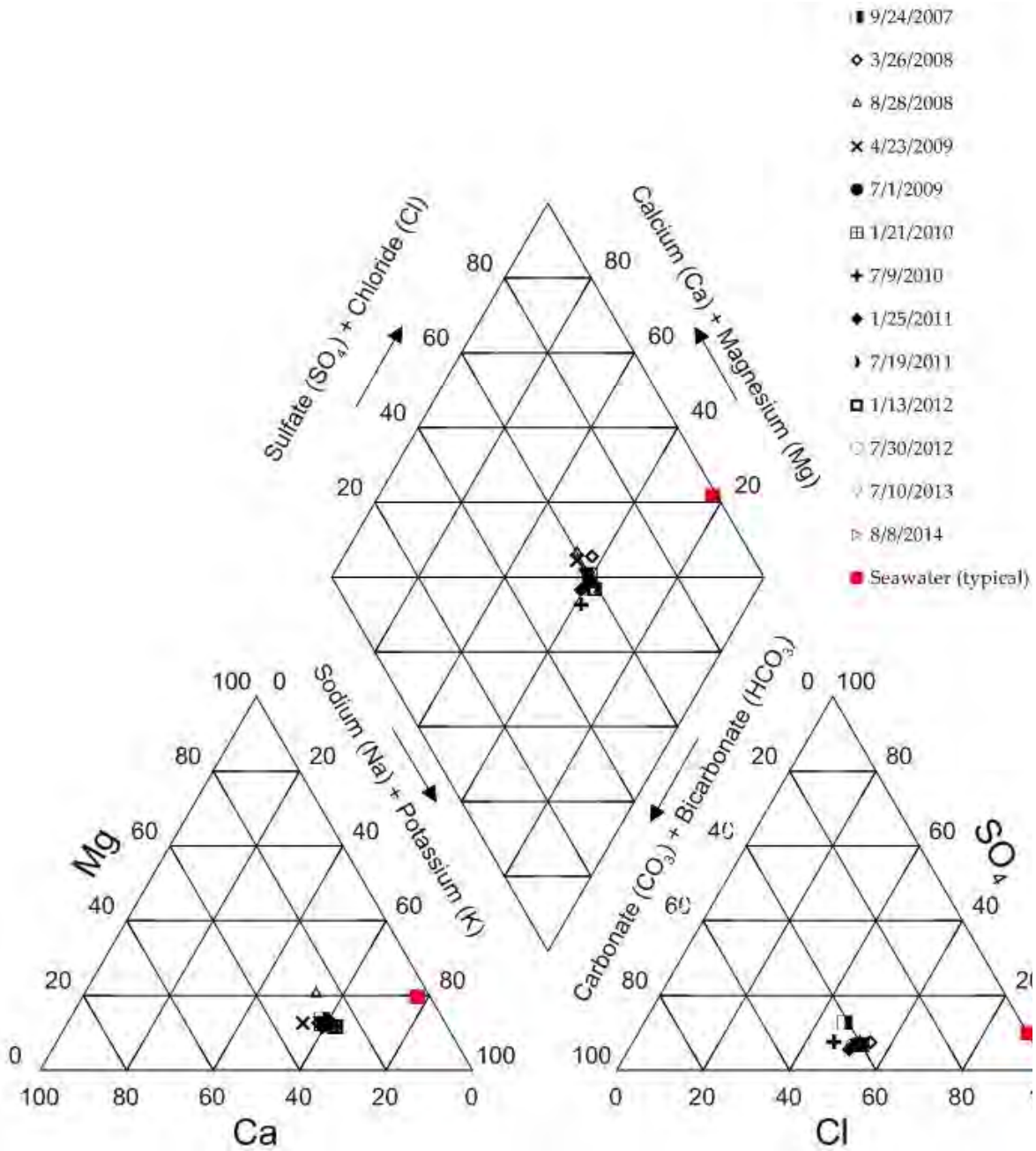


Figure A-20: Piper Diagram of SBWM-4 900 ft sample

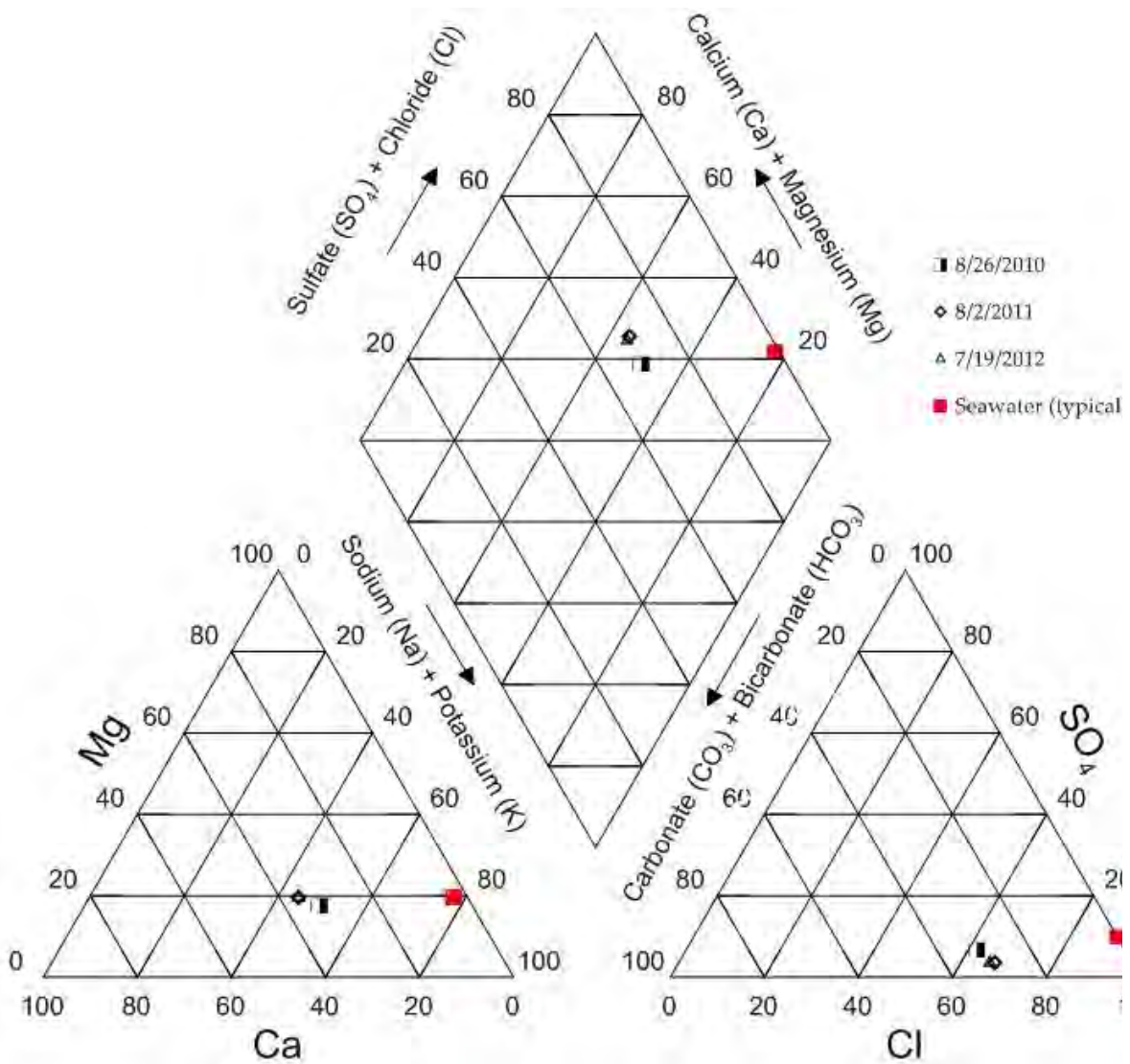


Figure A-21: Piper Diagram of SBMW-5 Shallow Well

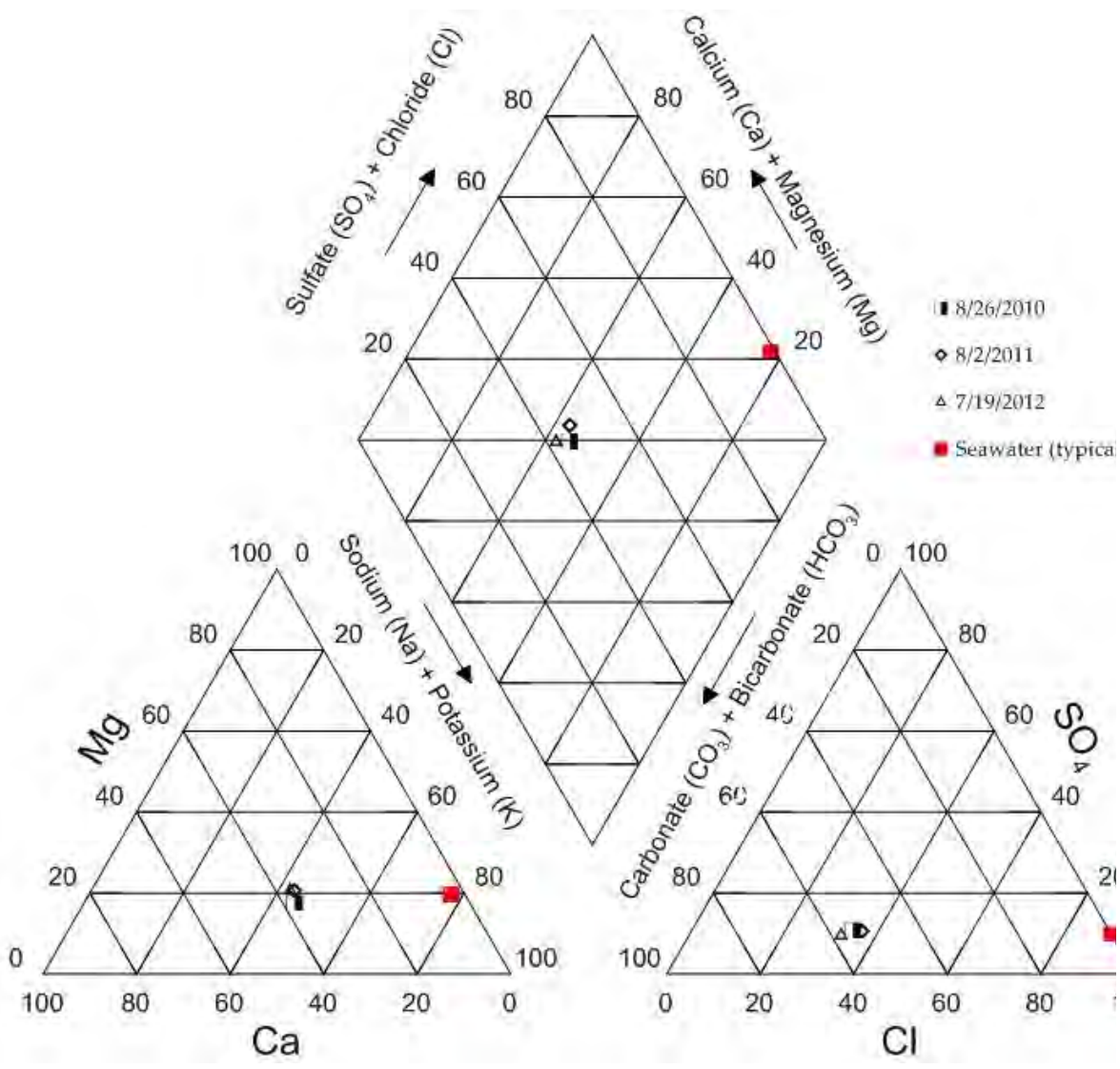


Figure A-22: Piper Diagram of SBMW-5 Deep Well

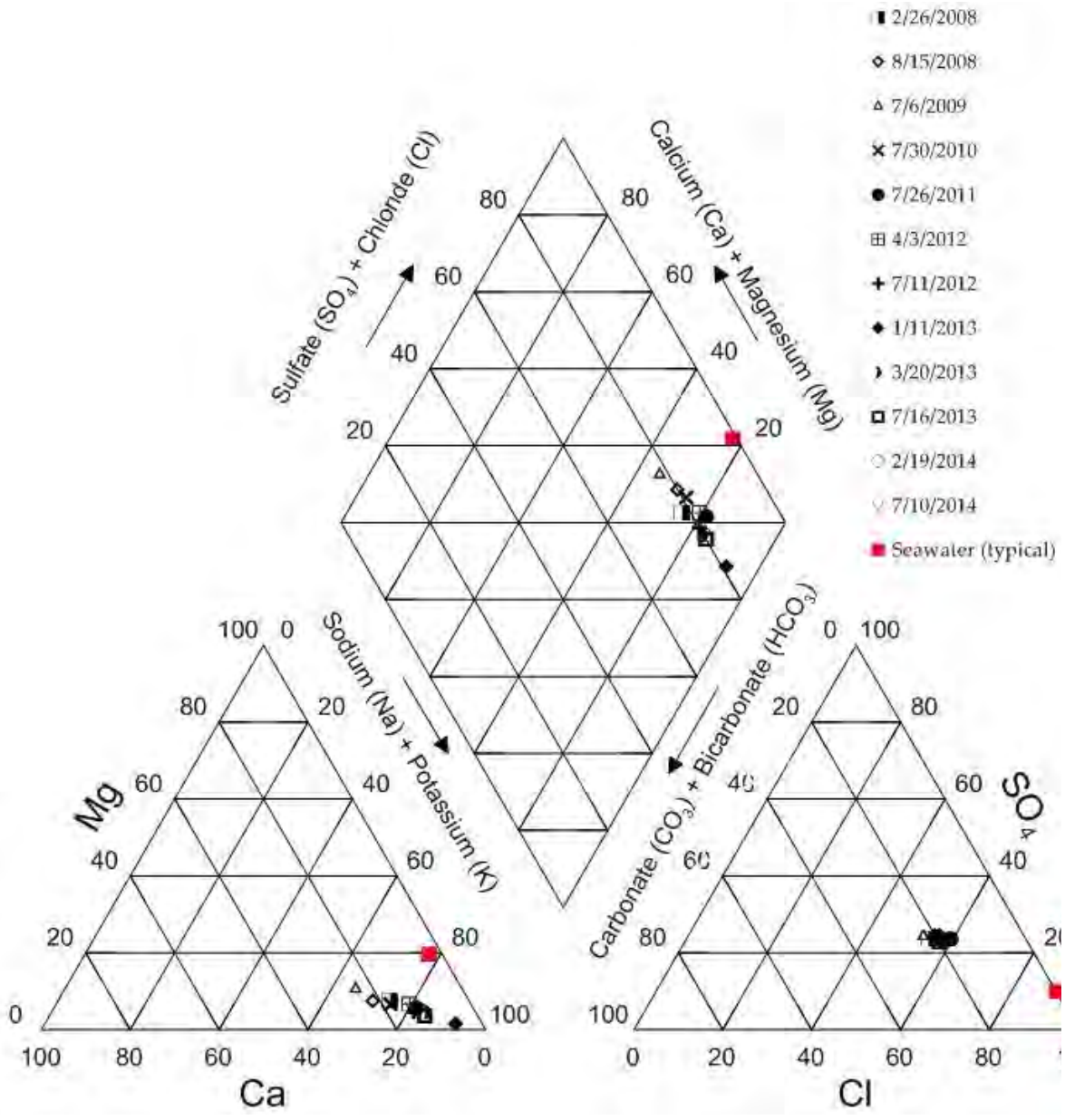


Figure A-23: Piper Diagram of Public Works Corp. Yard Production Well

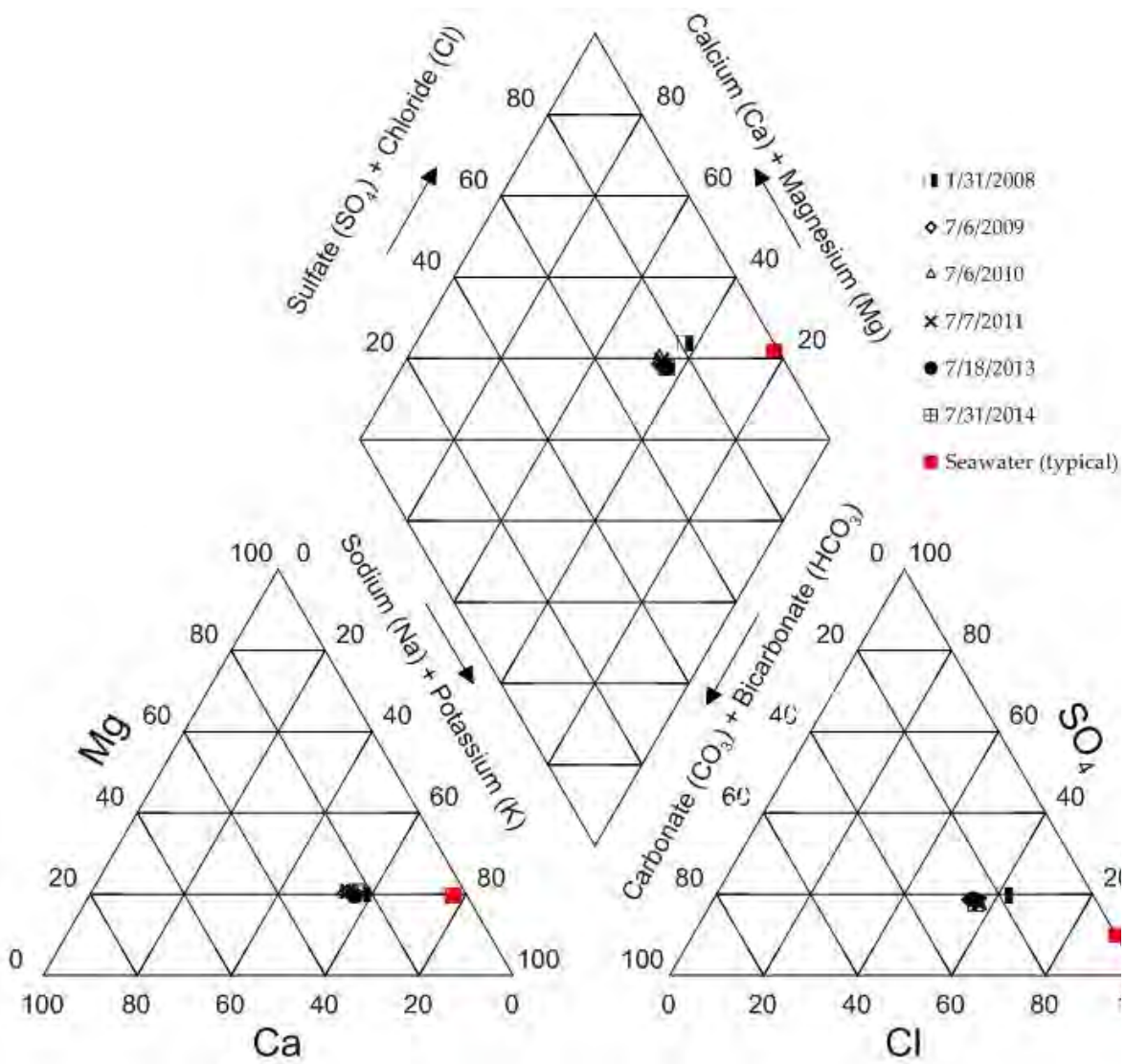


Figure A-24: Piper Diagram of Plumas 4 Production Well

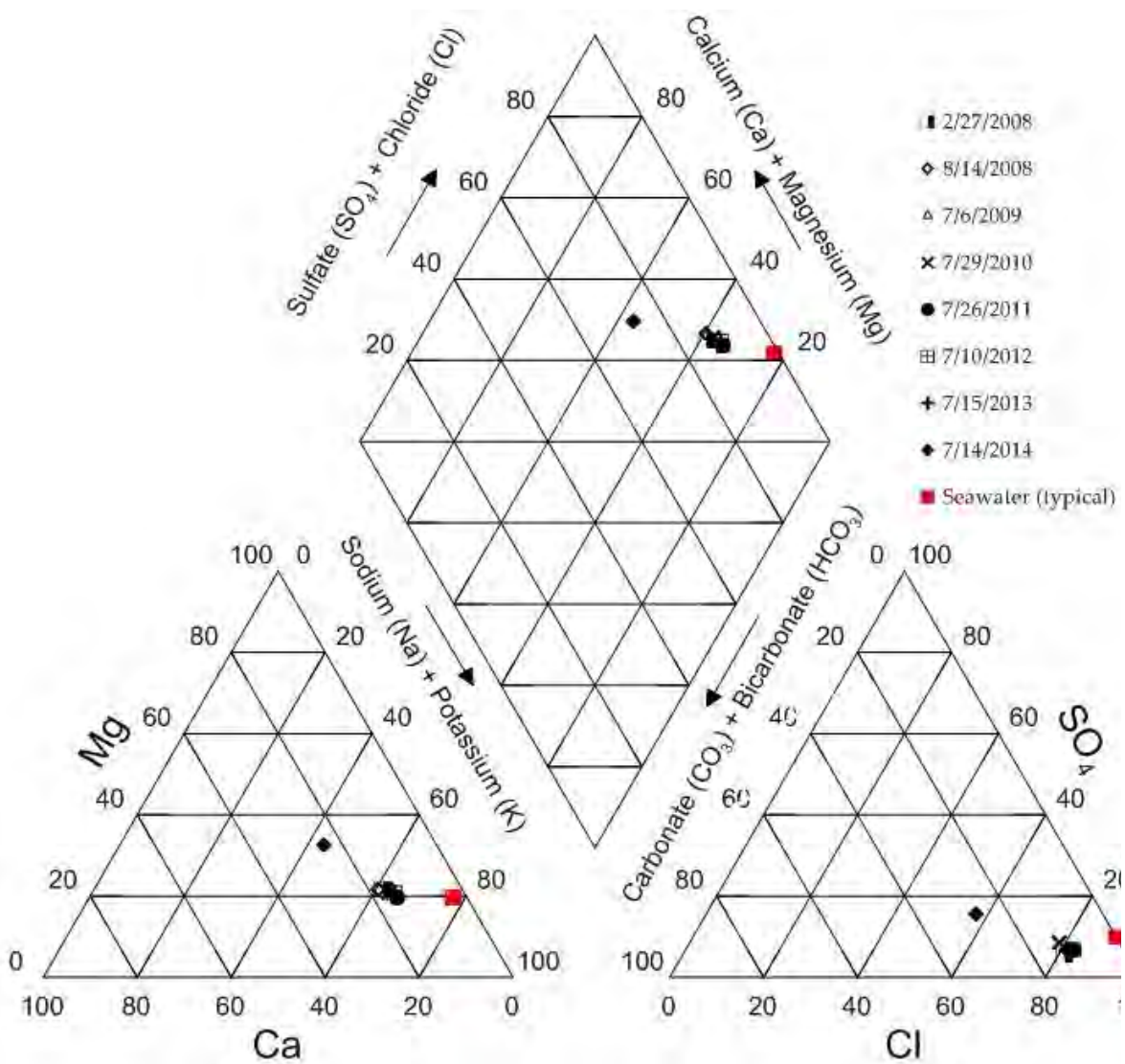


Figure A-25: Piper Diagram of York School Production Well

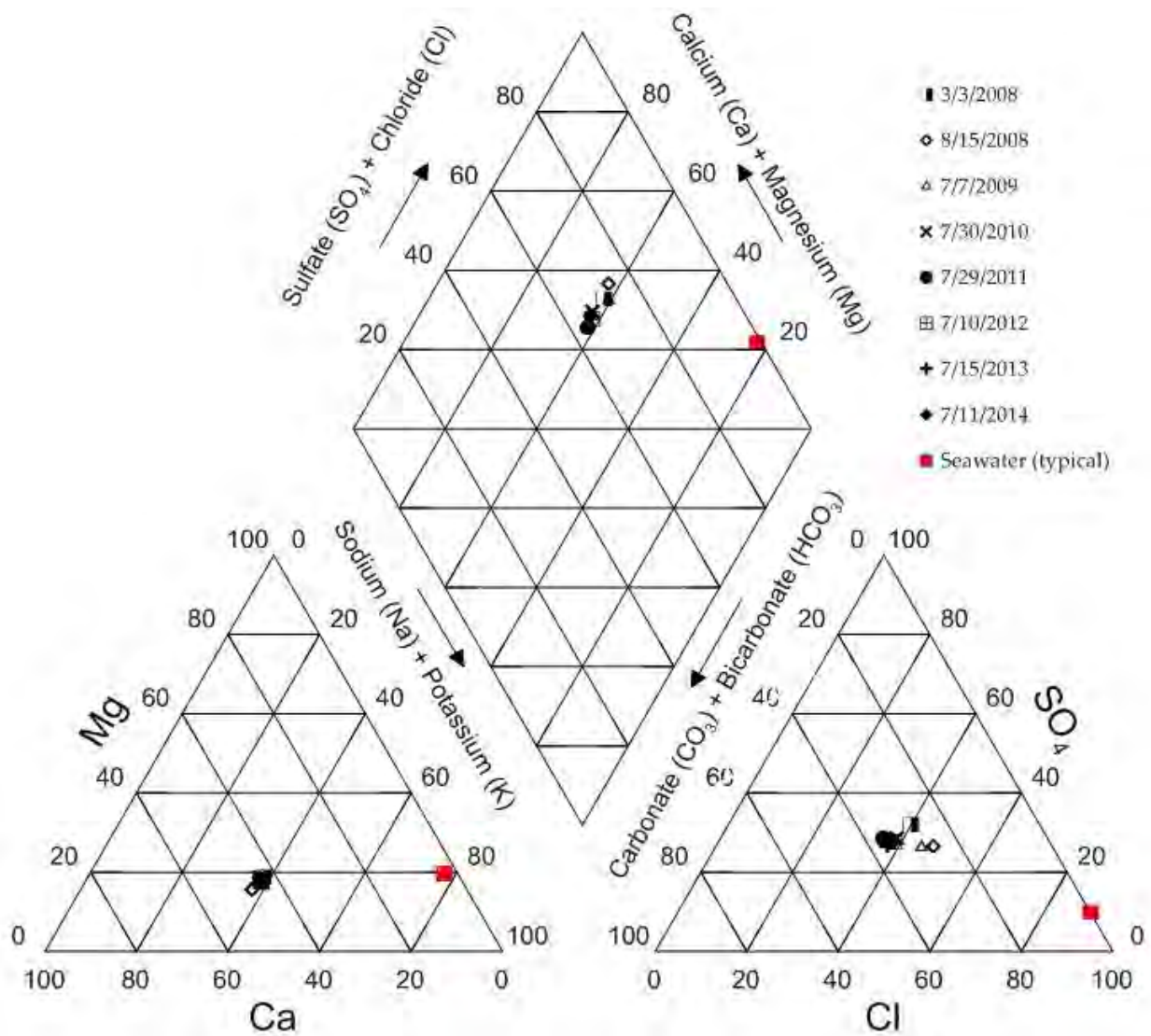


Figure A-26: Piper Diagram of Pasadera Main Gate Production Well

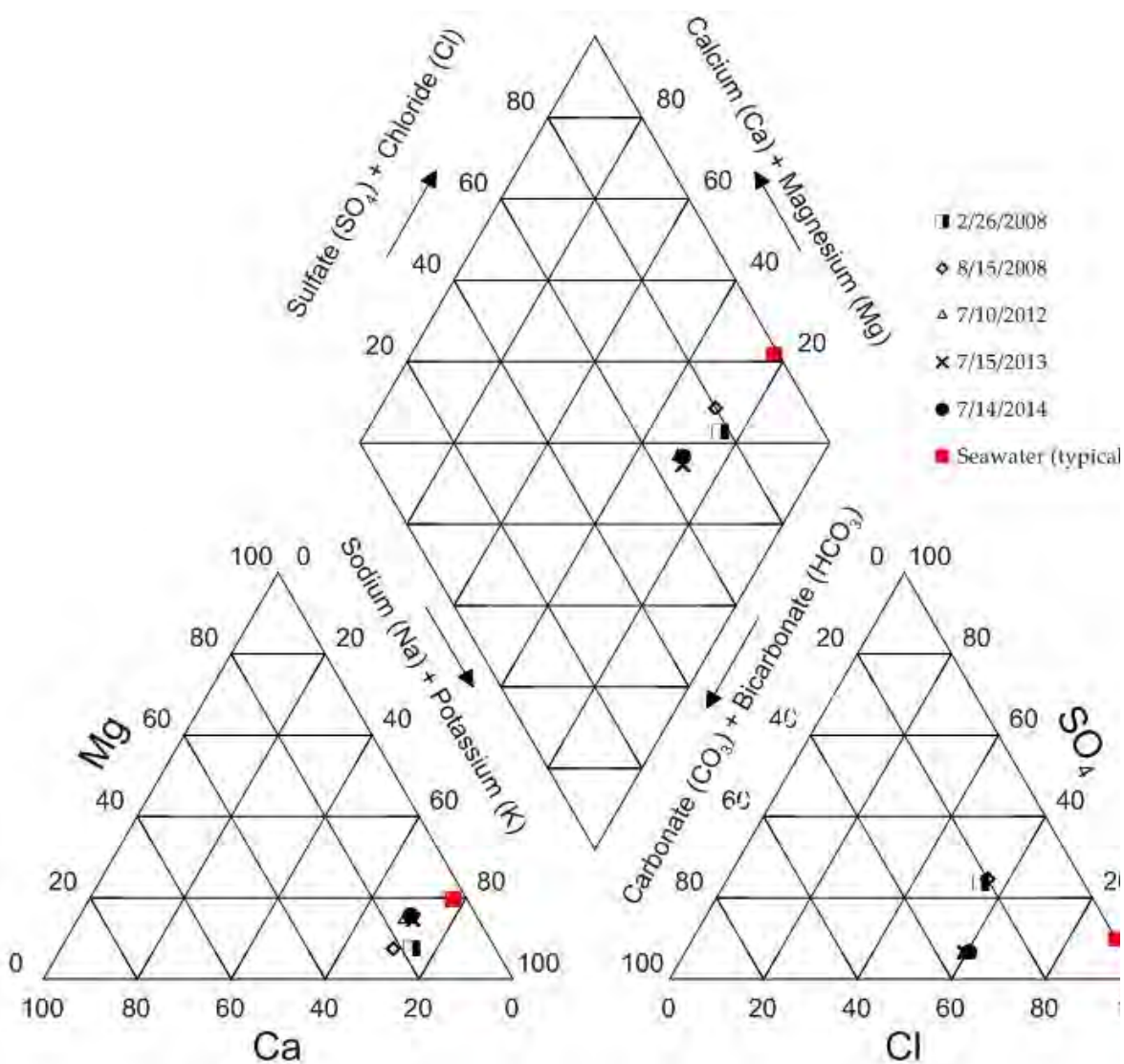


Figure A-27: Piper Diagram of LS County Park #1 Production Well

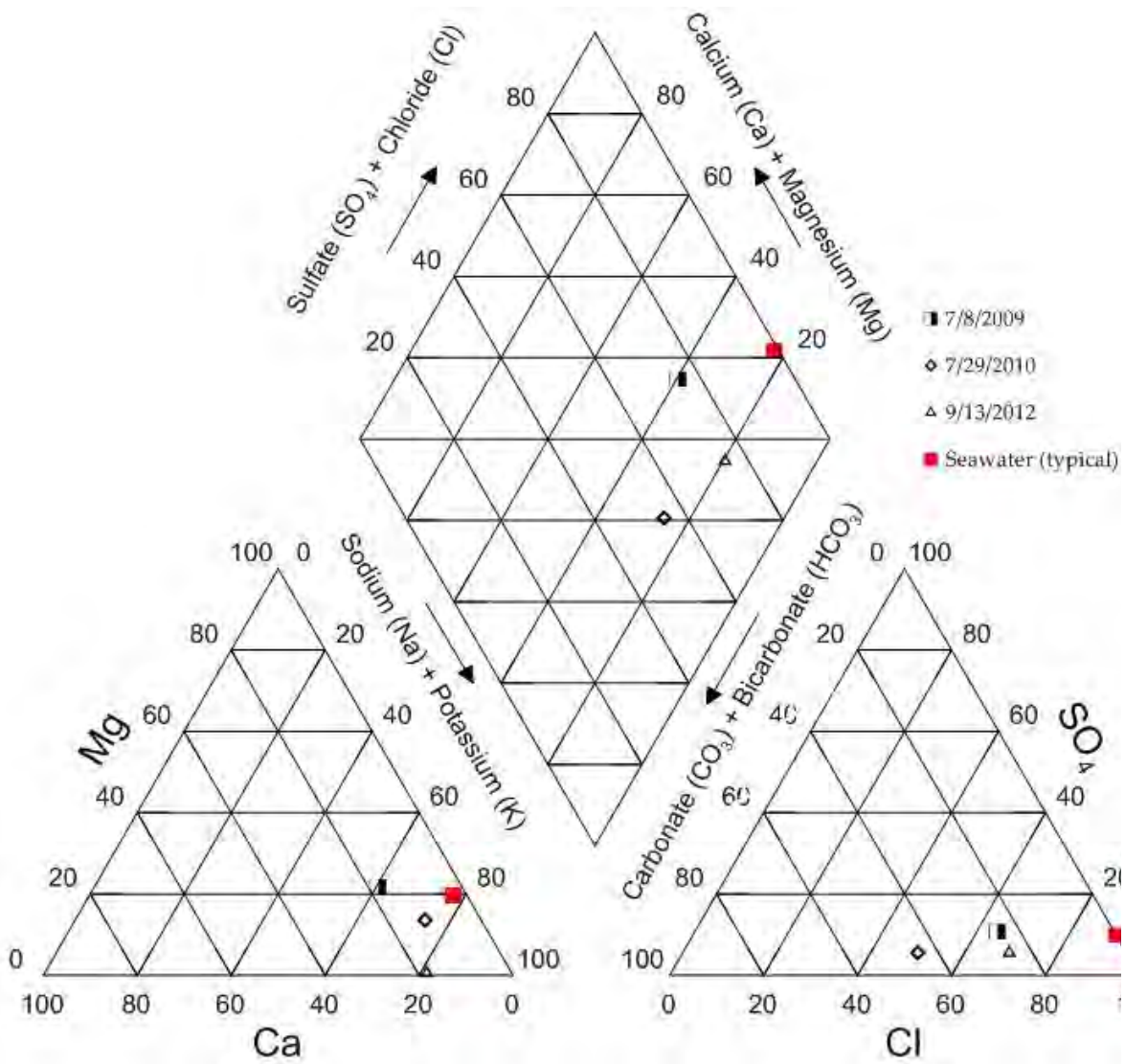


Figure A-28: Piper Diagram of LS County Park #2 Production Well

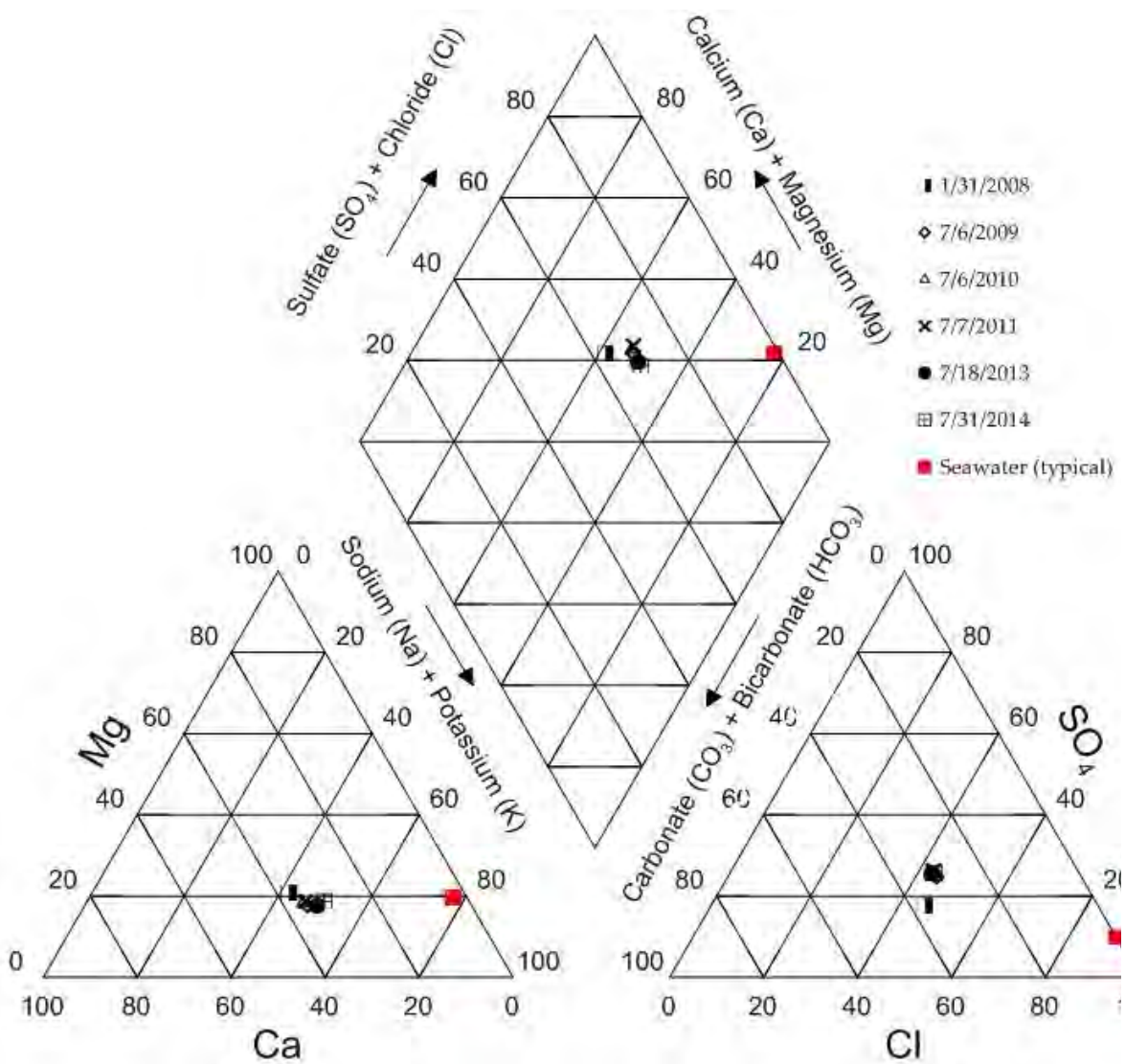


Figure A-29: Piper Diagram of Playa No. 3 Production Well

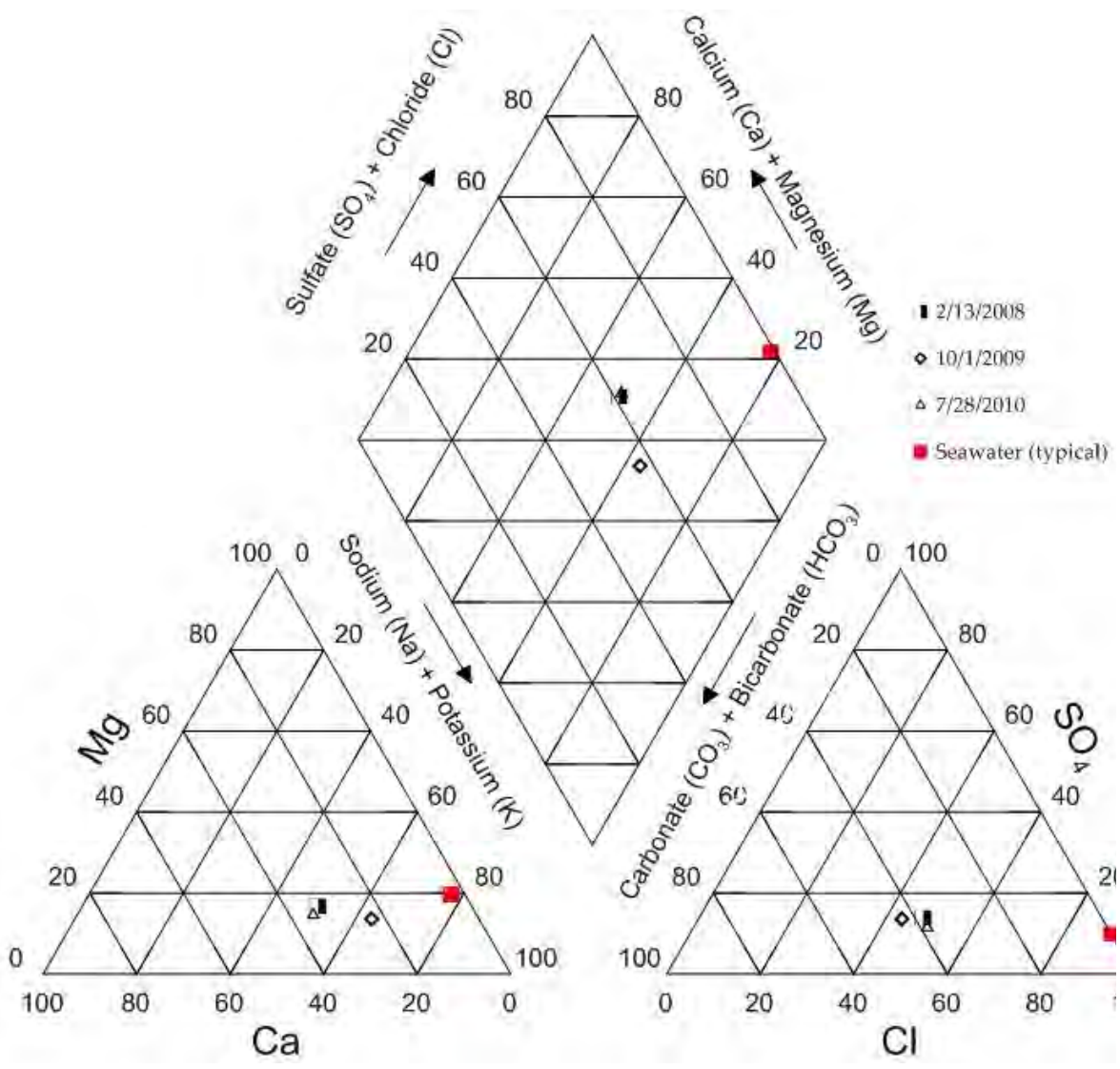


Figure A-30: Piper Diagram of Coe Ave. Production Well

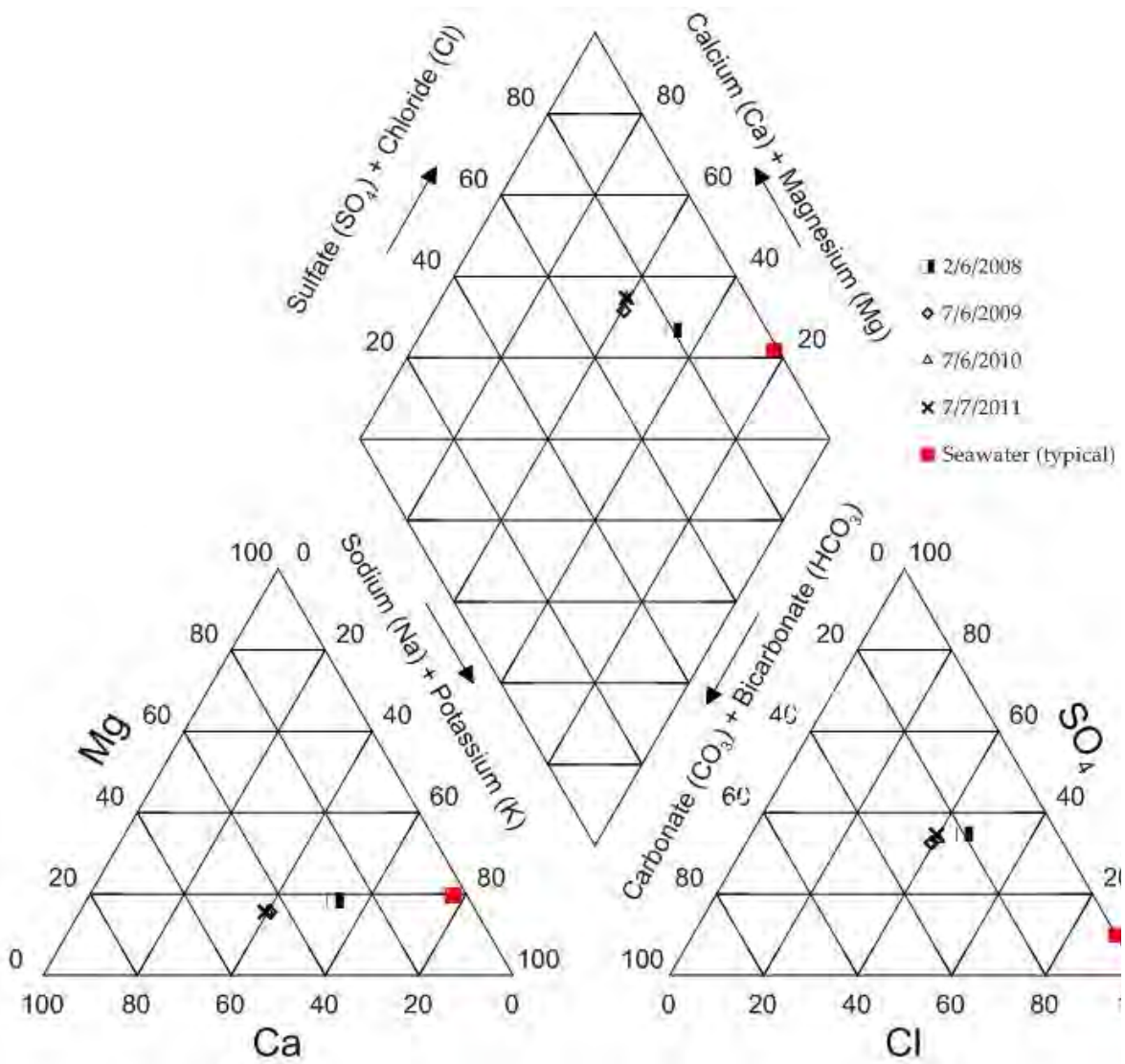


Figure A-31: Piper Diagram of Military Production Well

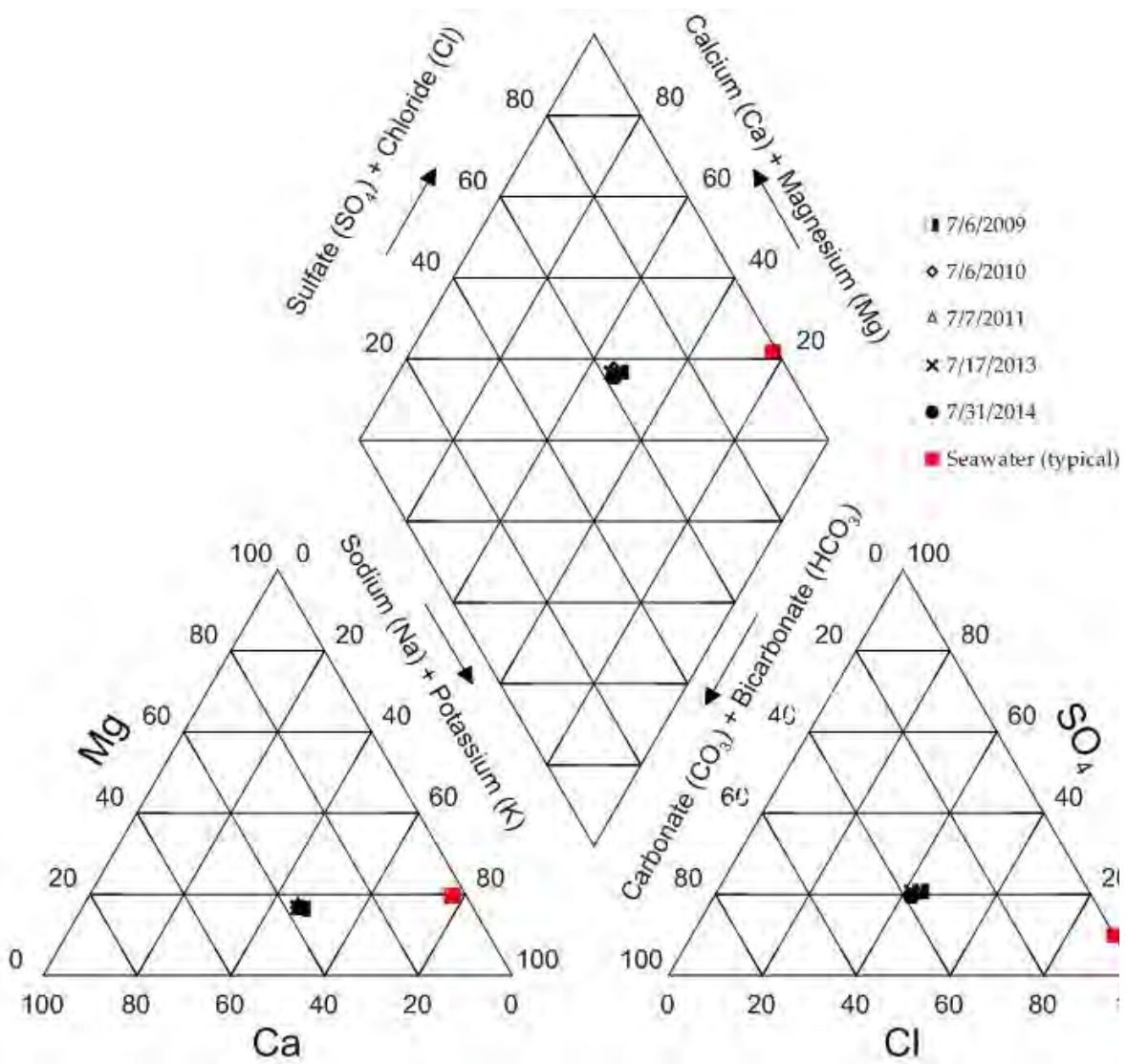


Figure A-32: Piper Diagram of Luzern #2 Production Well

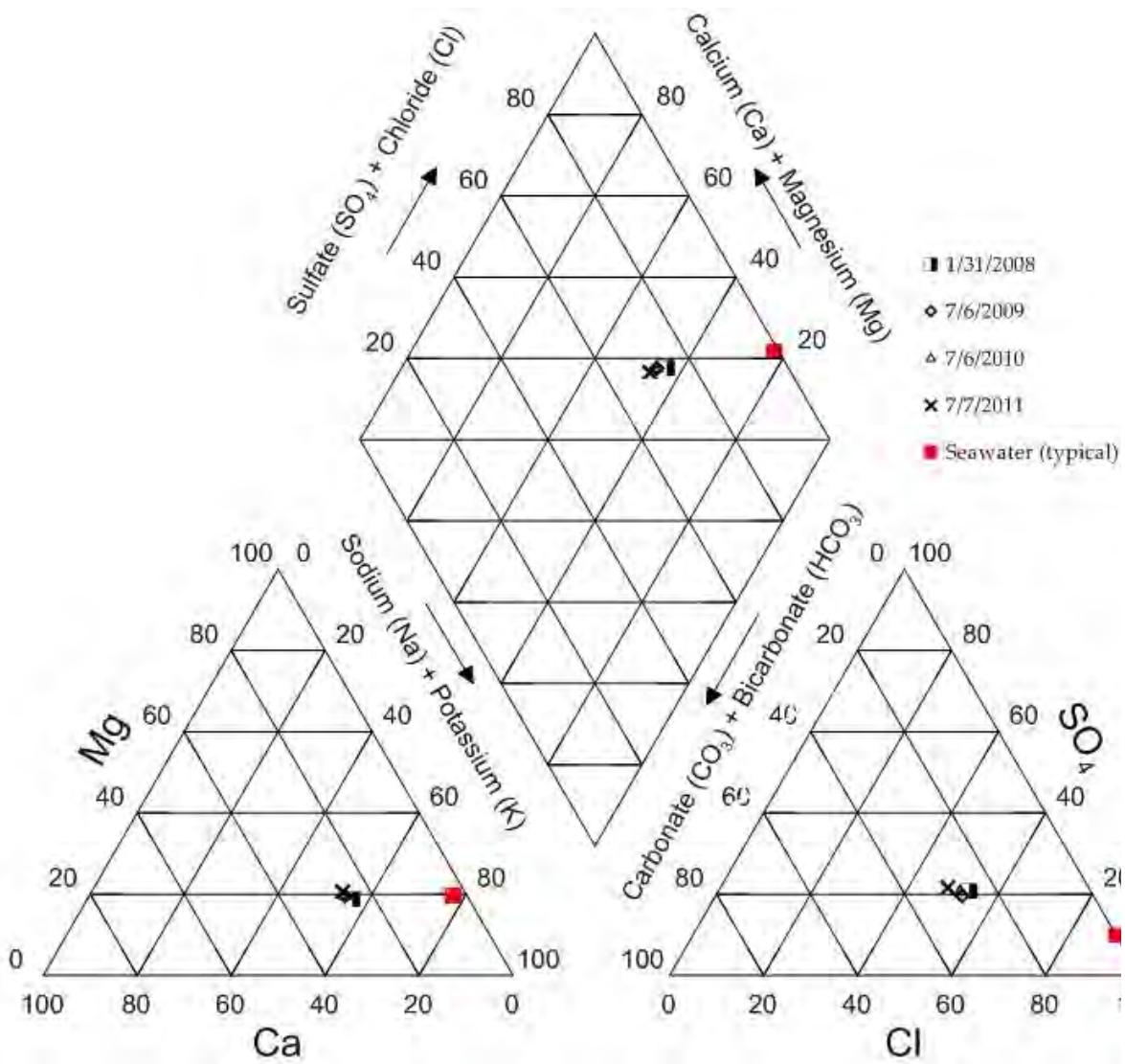


Figure A-33: Piper Diagram of Darwin Production Well

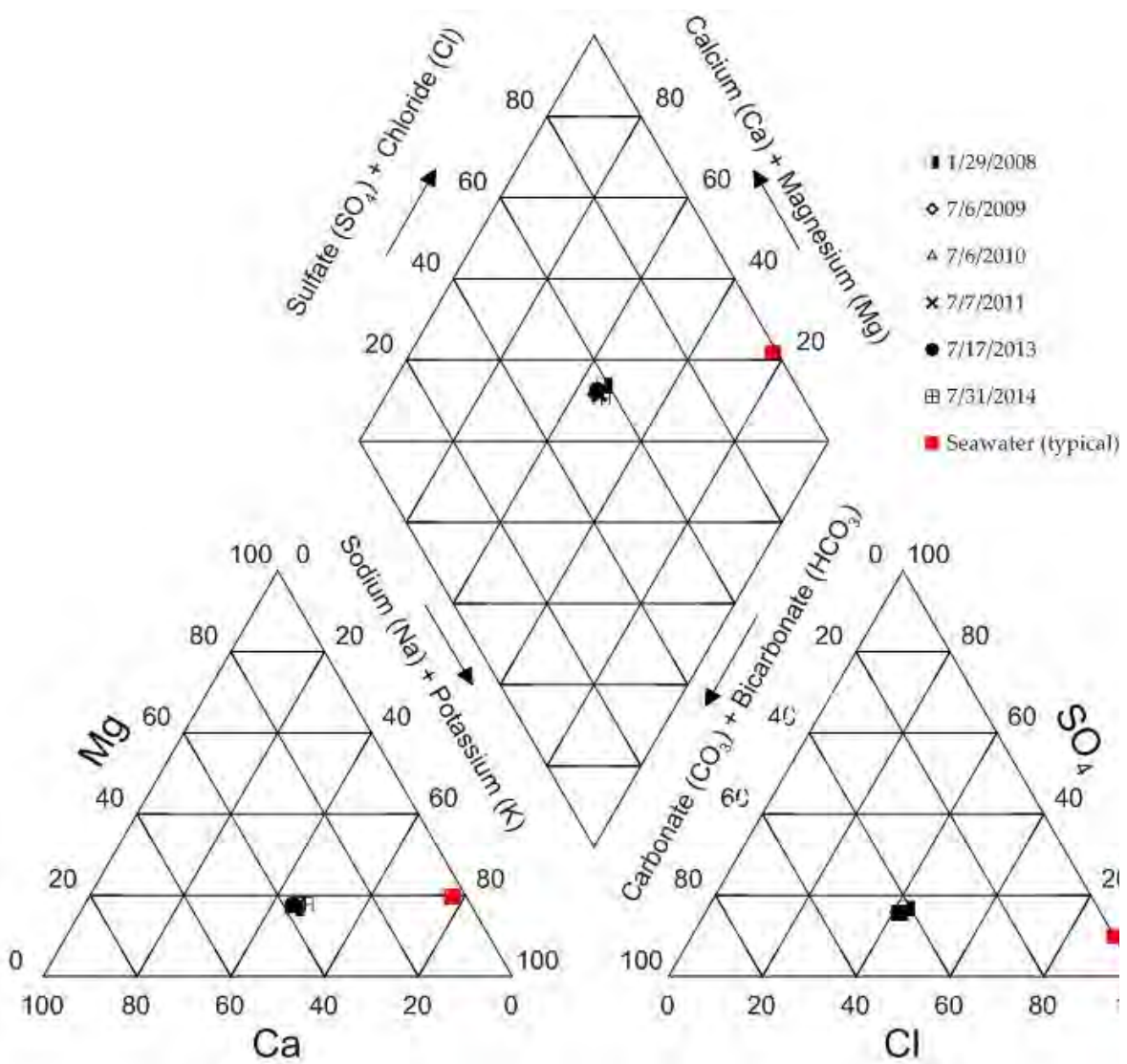


Figure A-34: Piper Diagram of Ord Grove No. 2 Production Well

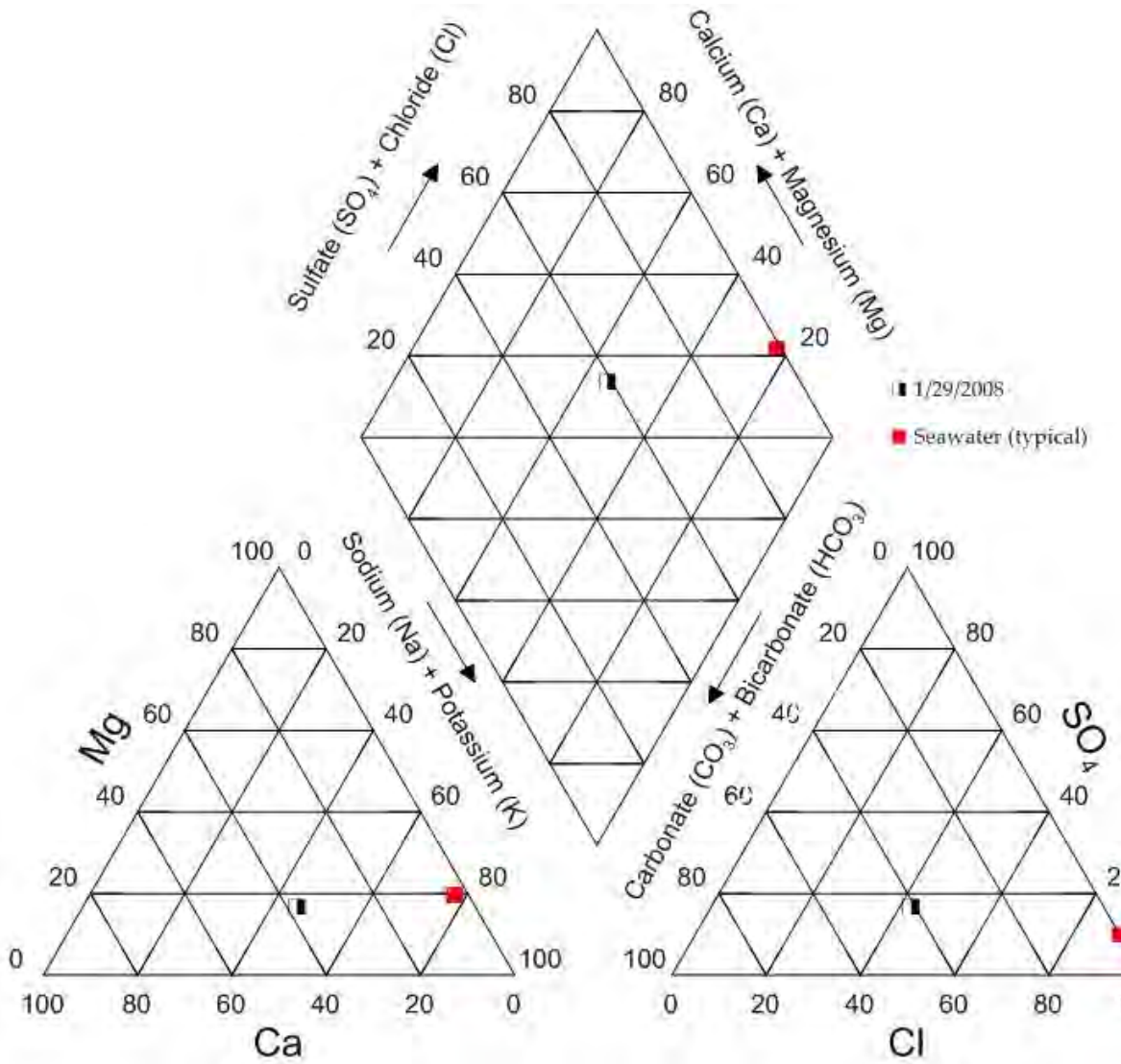


Figure A-35: Piper Diagram of Seaside City No. 3 Production Well

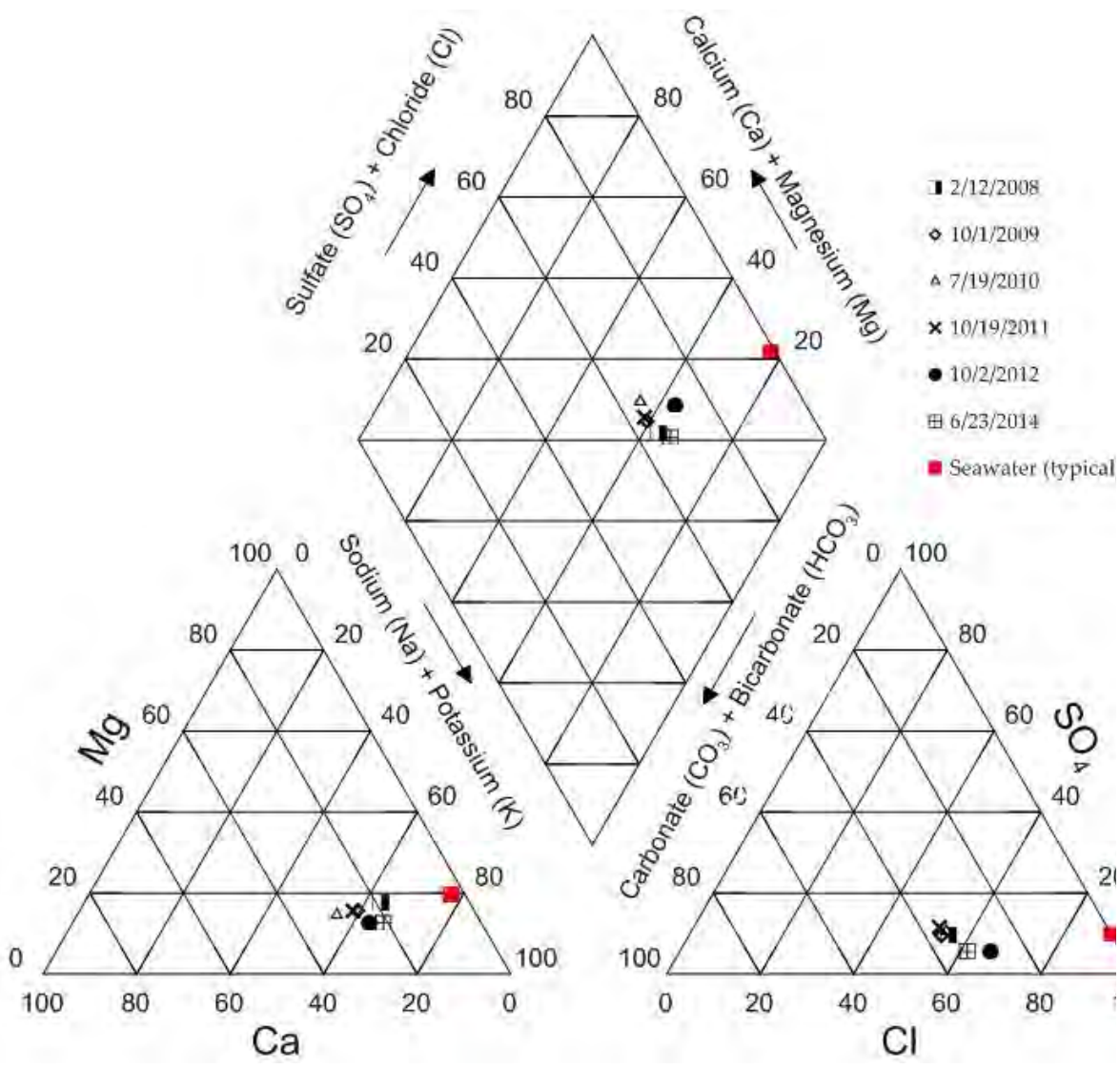


Figure A-36: Piper Diagram of Seaside City No. 4 Production Well

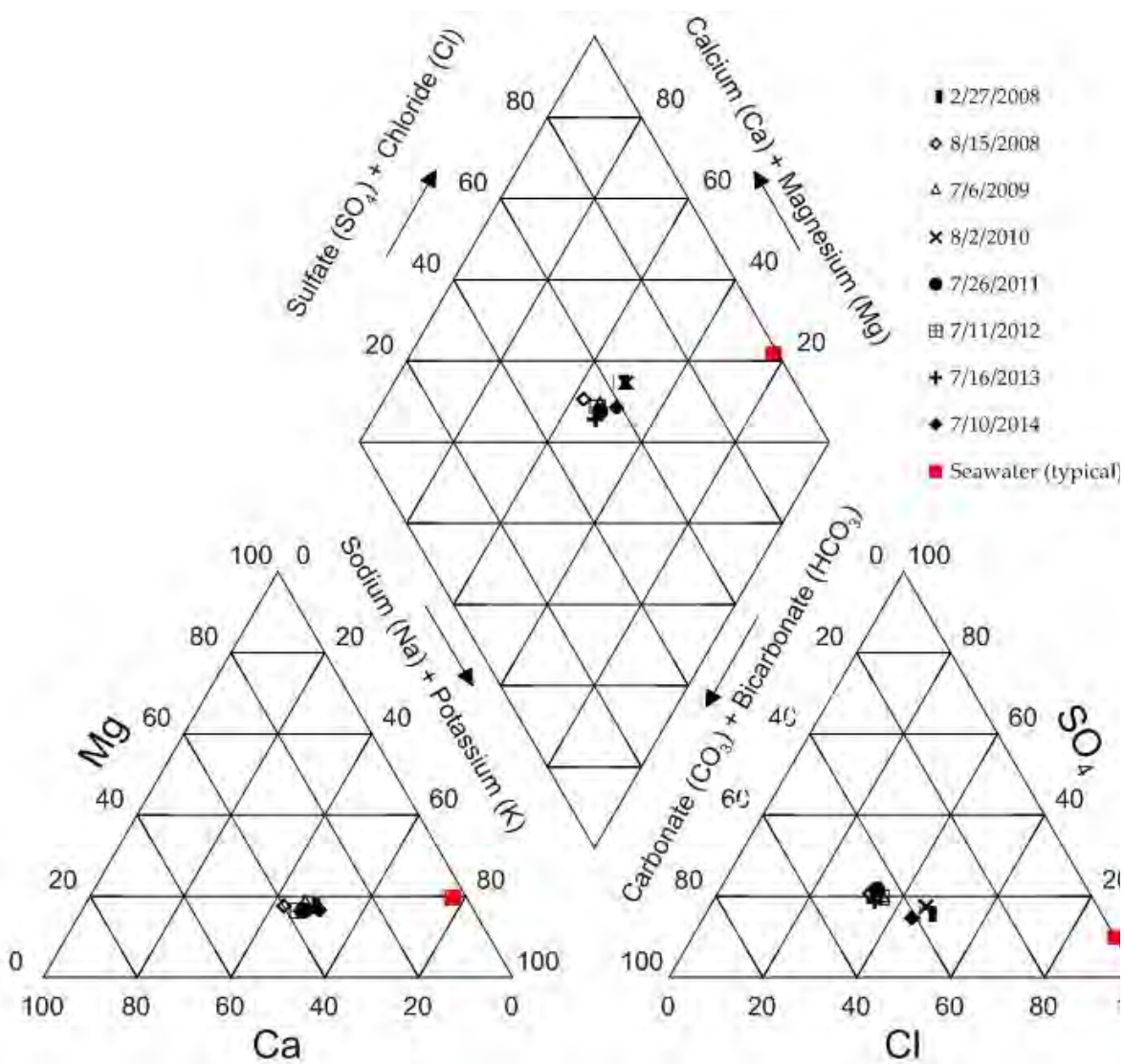


Figure A-37: Piper Diagram of Mission Memorial (formerly PRTIW)

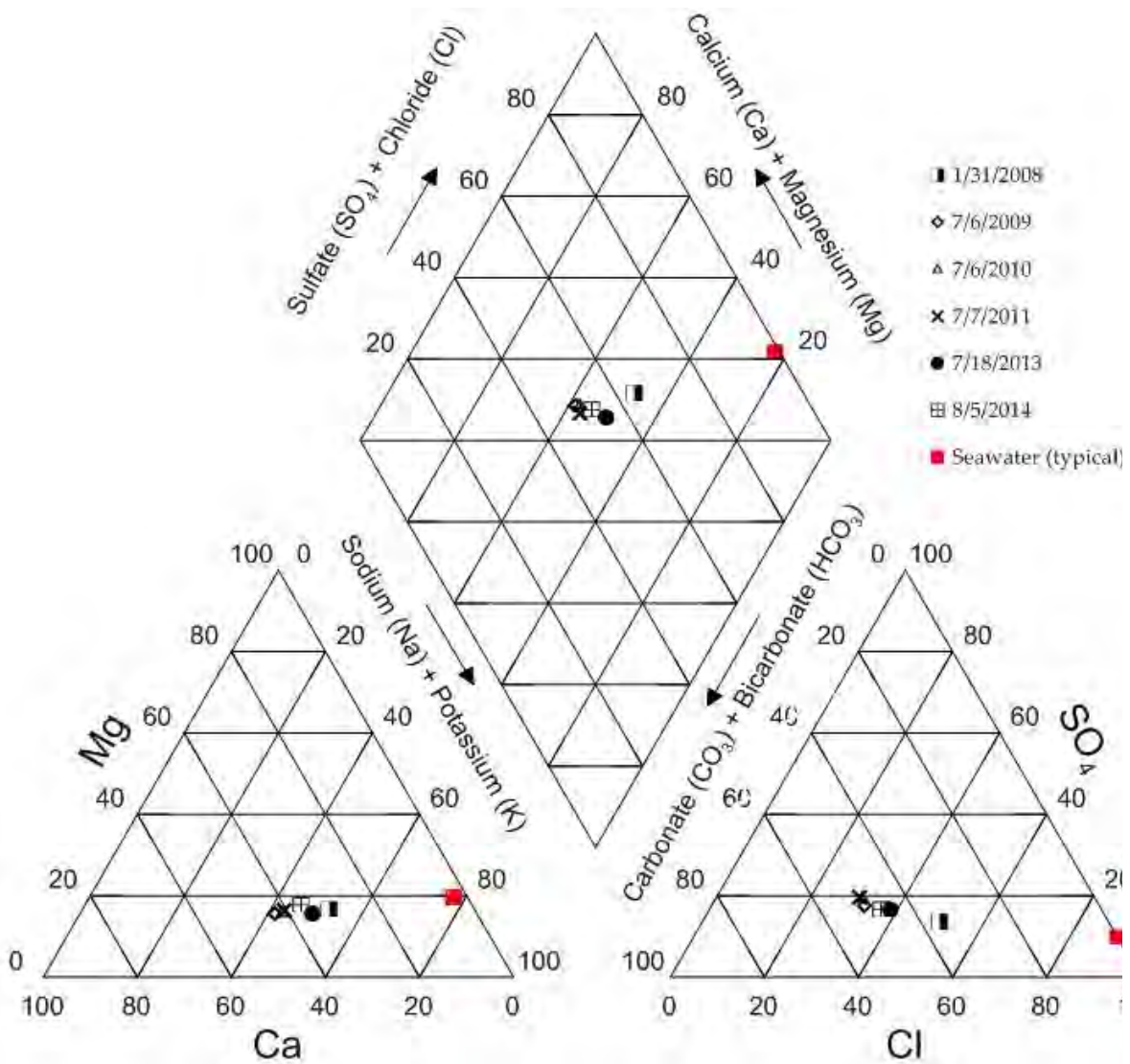


Figure A-38: Piper Diagram of Paralta Production Well

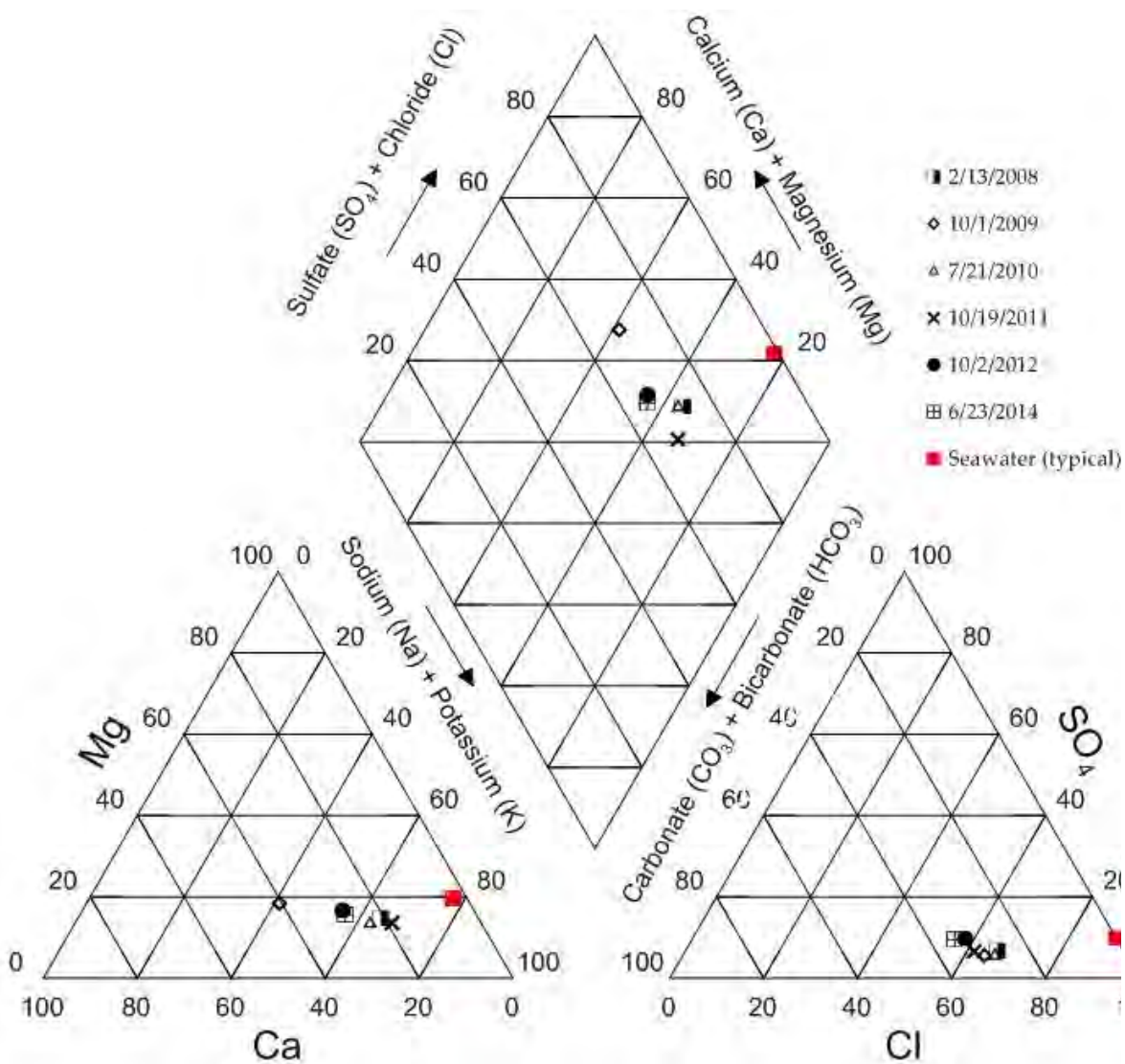


Figure A-39: Piper Diagram of Reservoir (Bayonet Blackhouse) Production Well

**APPENDIX B: CHLORIDE AND SODIUM/CHLORIDE
MOLAR RATIO GRAPHS**

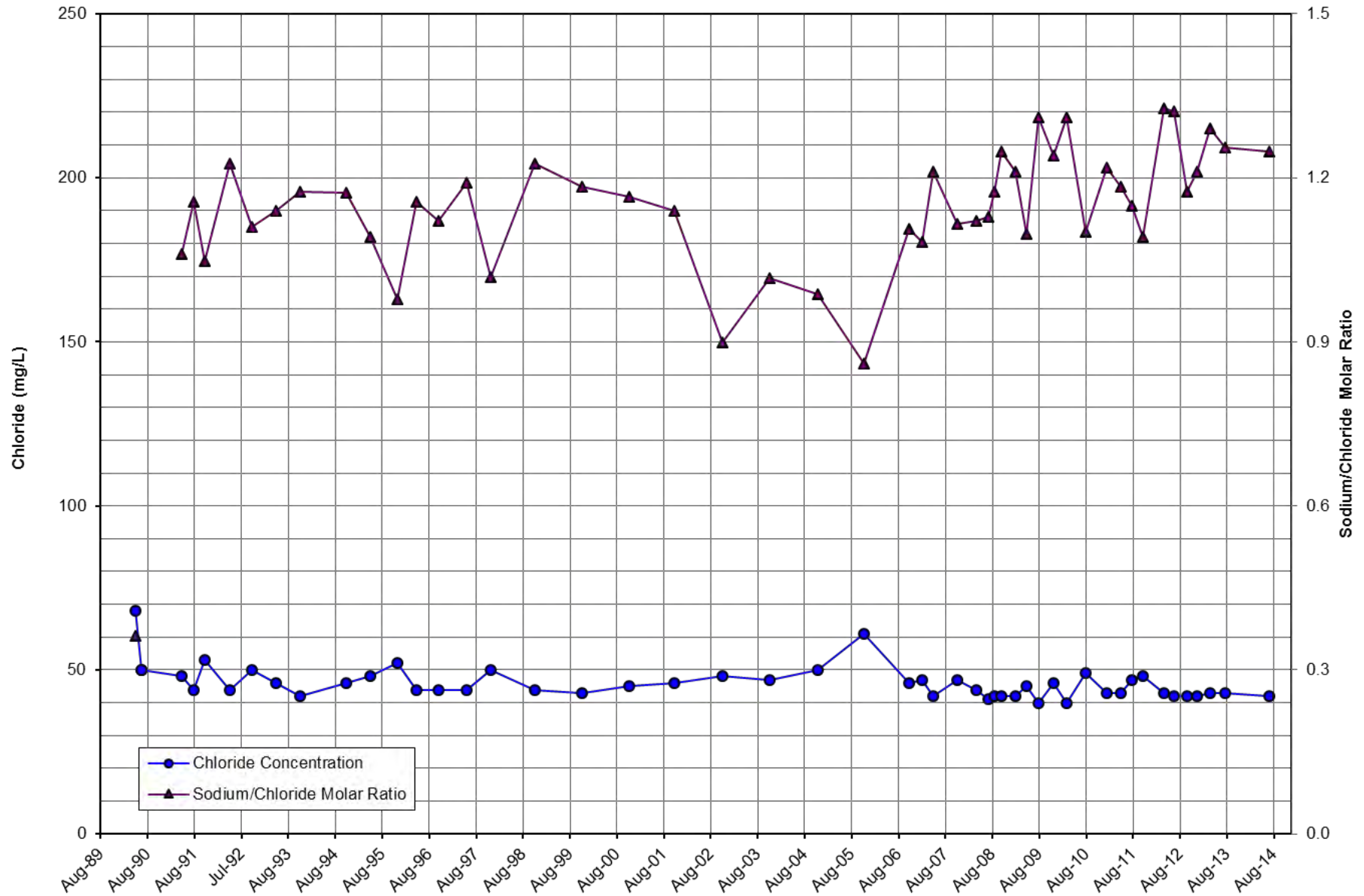


Figure B-1: PCA West Shallow Well Chemograph

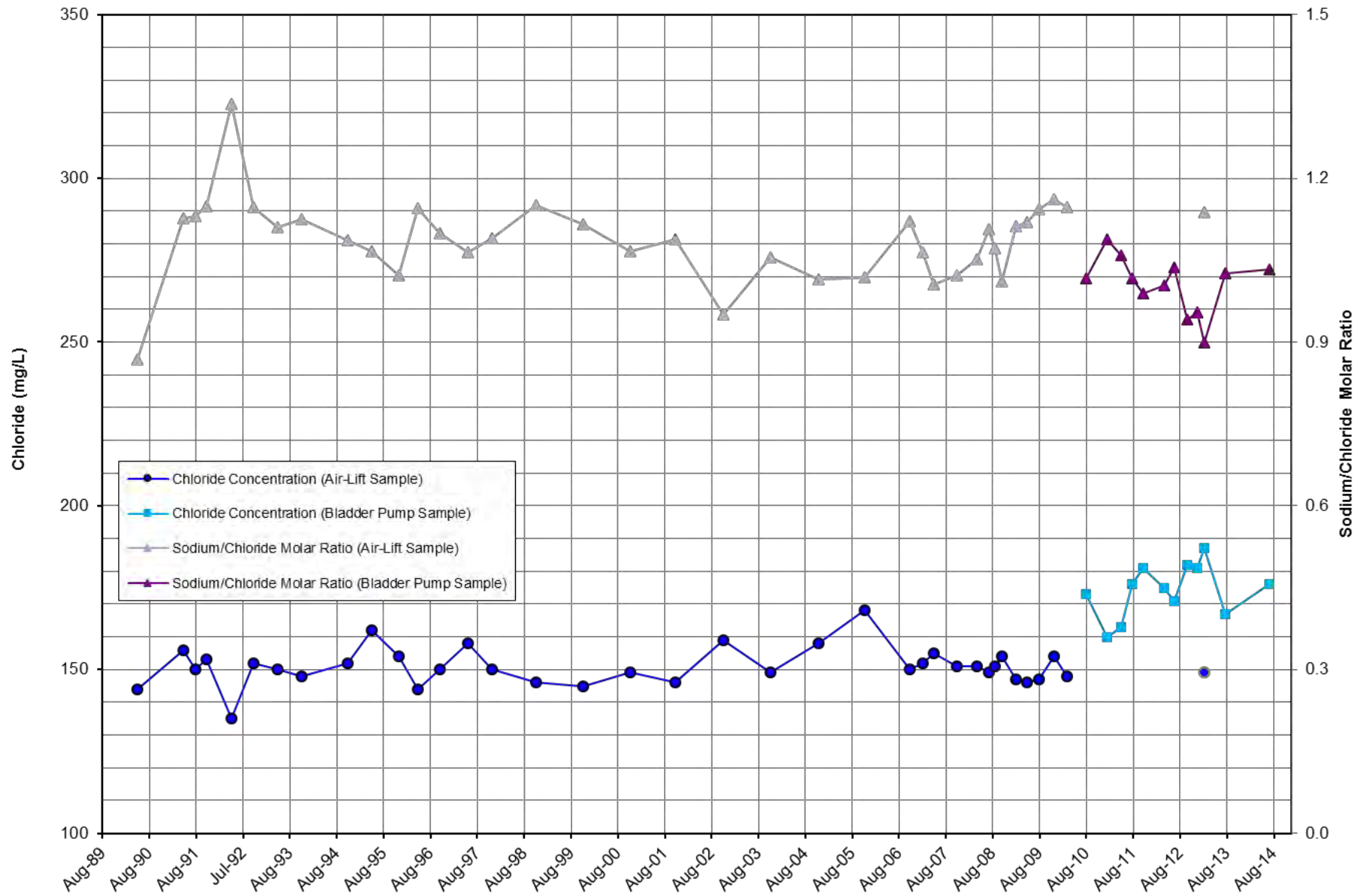


Figure B-2: PCA West Deep Well Chemograph

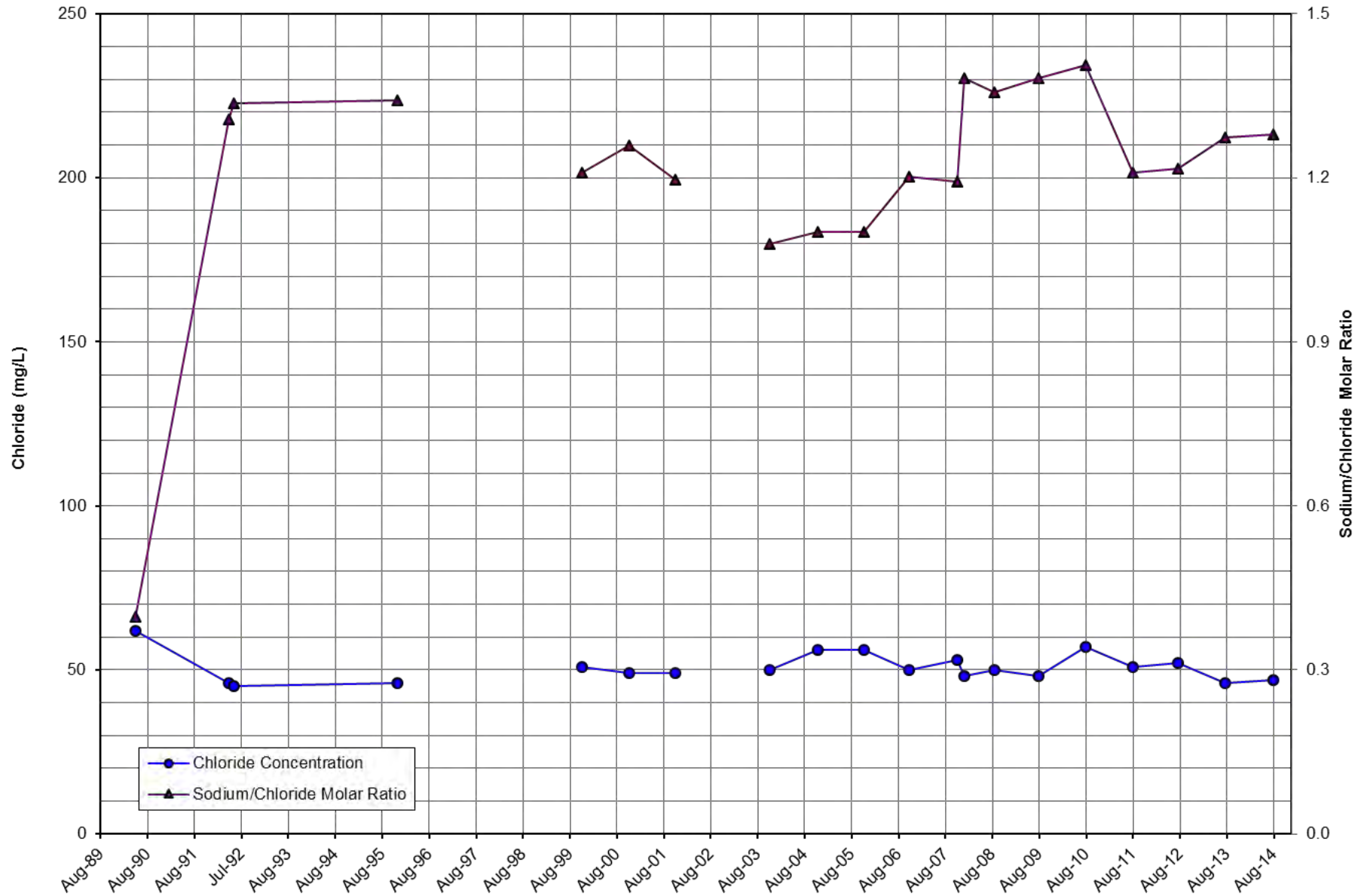


Figure B-3: PCA East Shallow Well Chemograph

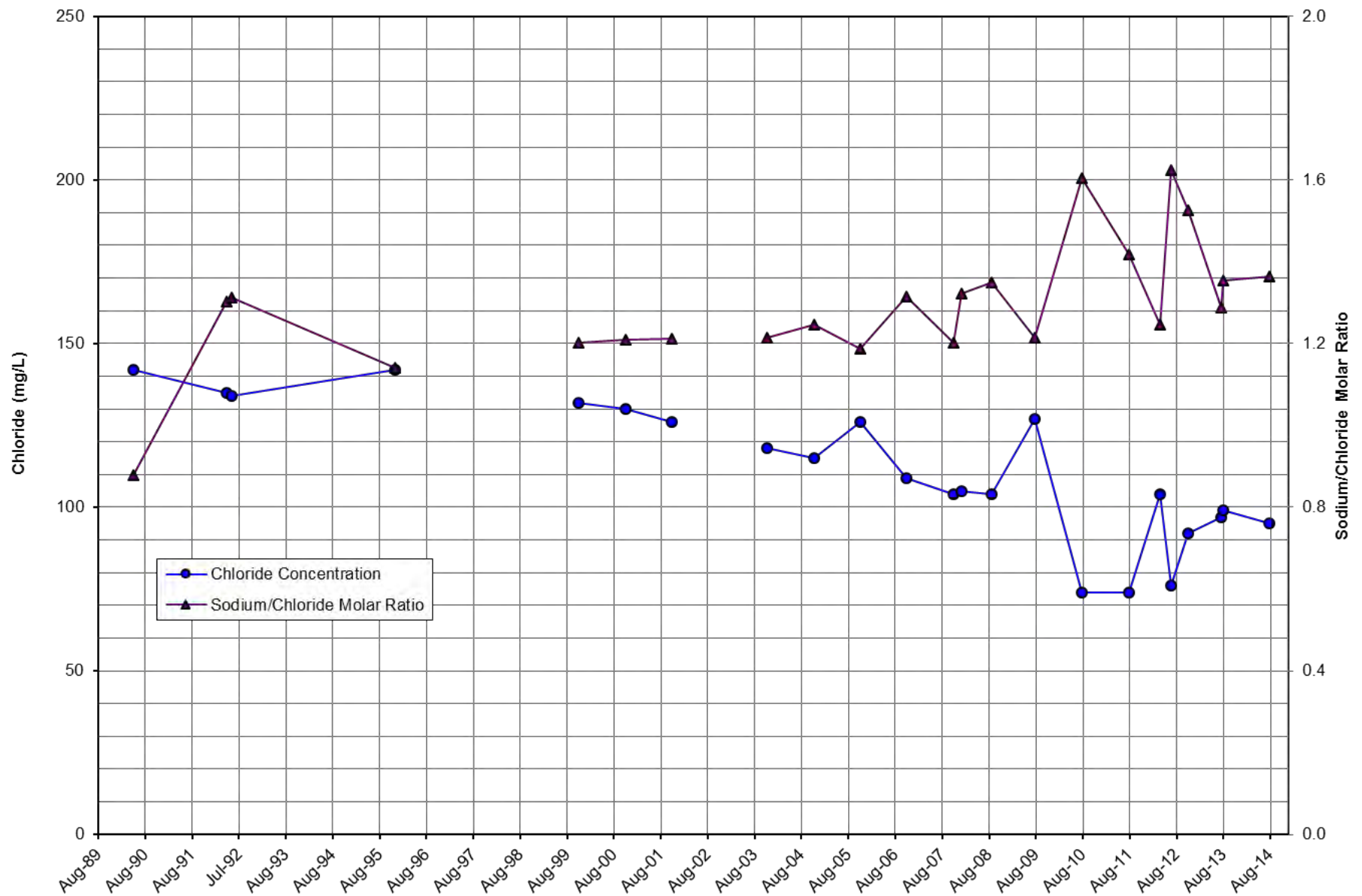


Figure B-4: PCA East Deep Well Chemograph

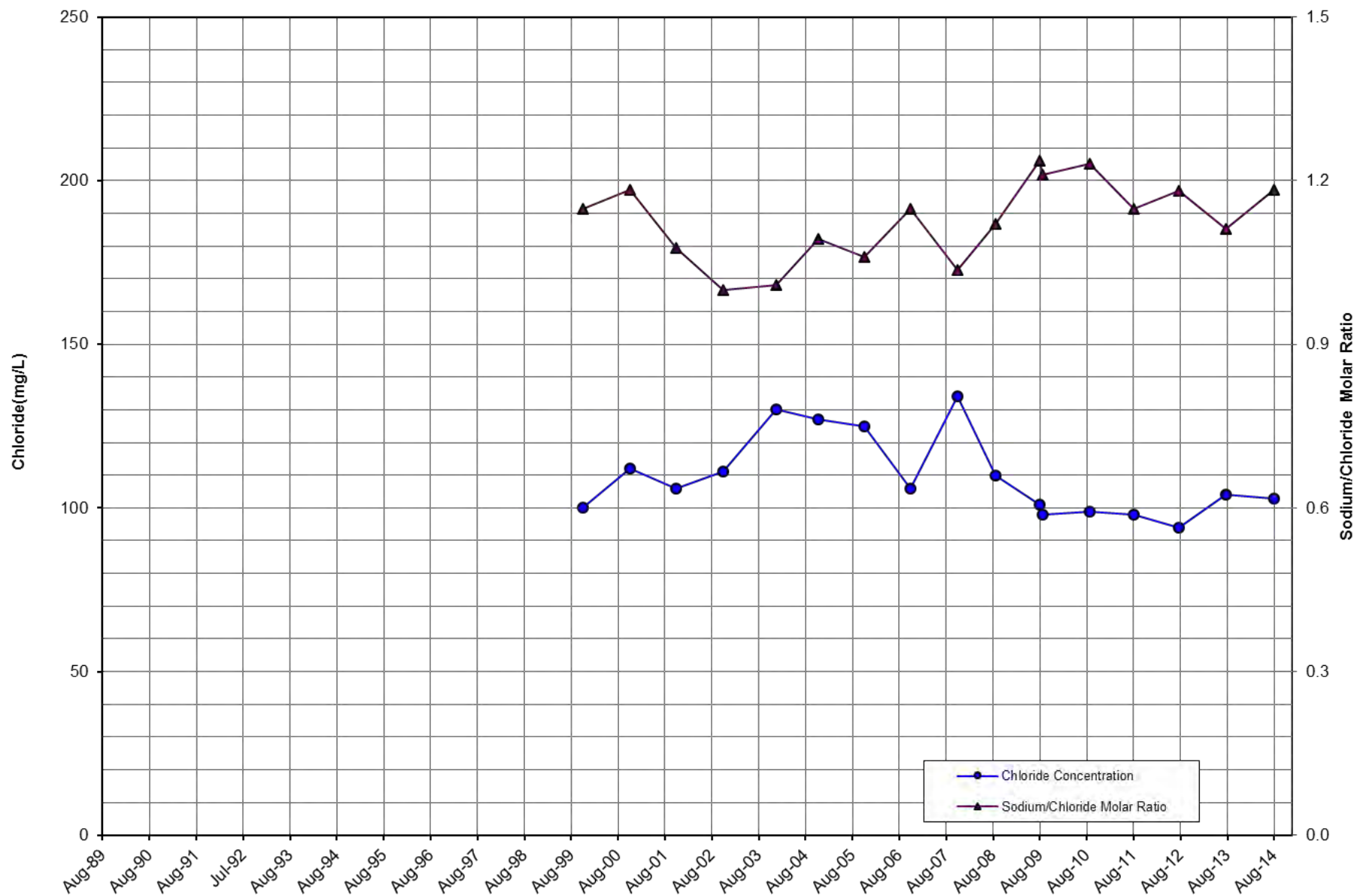


Figure B-5: Ord Terrace Shallow Well Chemograph

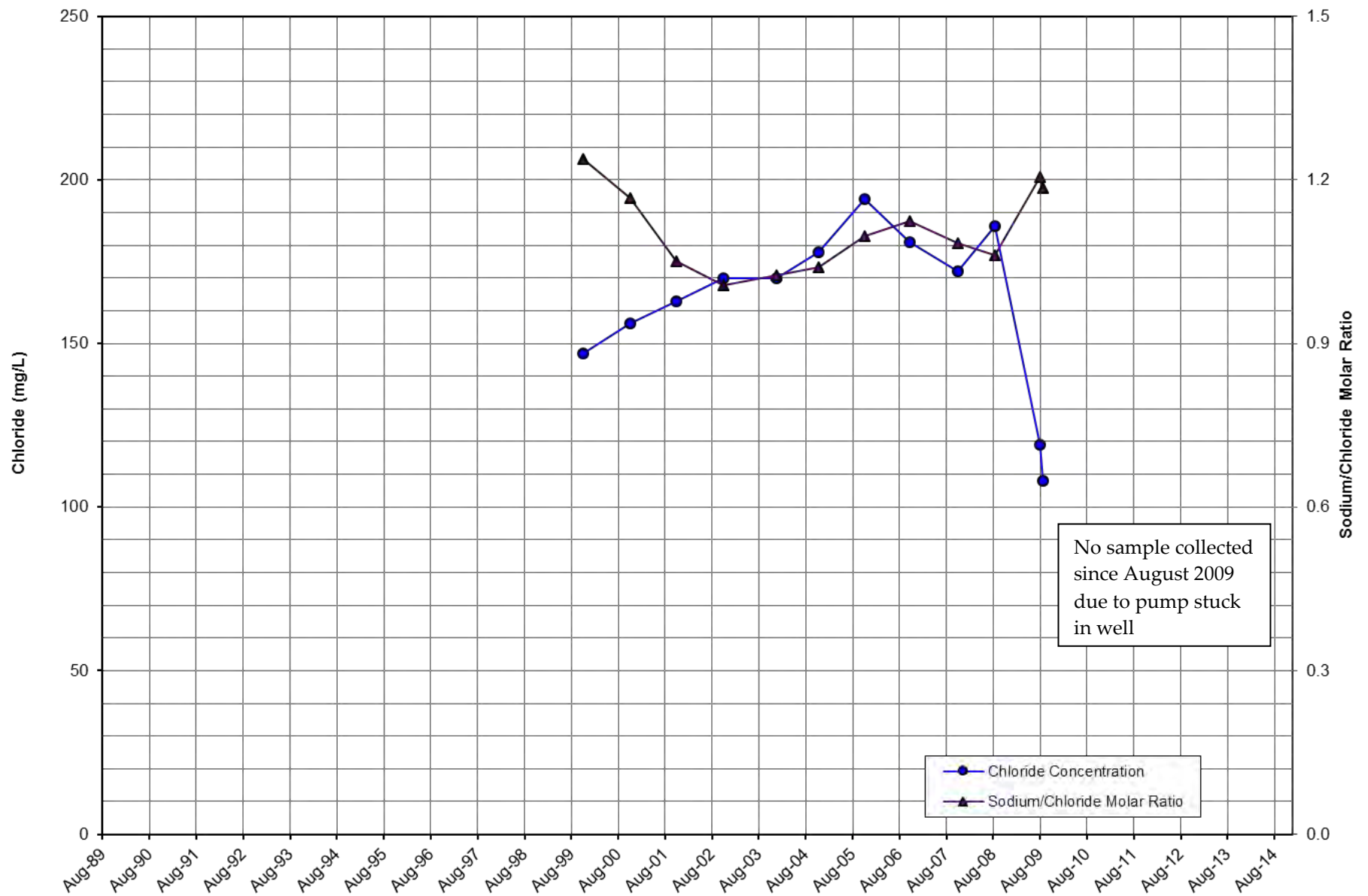


Figure B-6: Ord Terrace Deep Well Chemograph

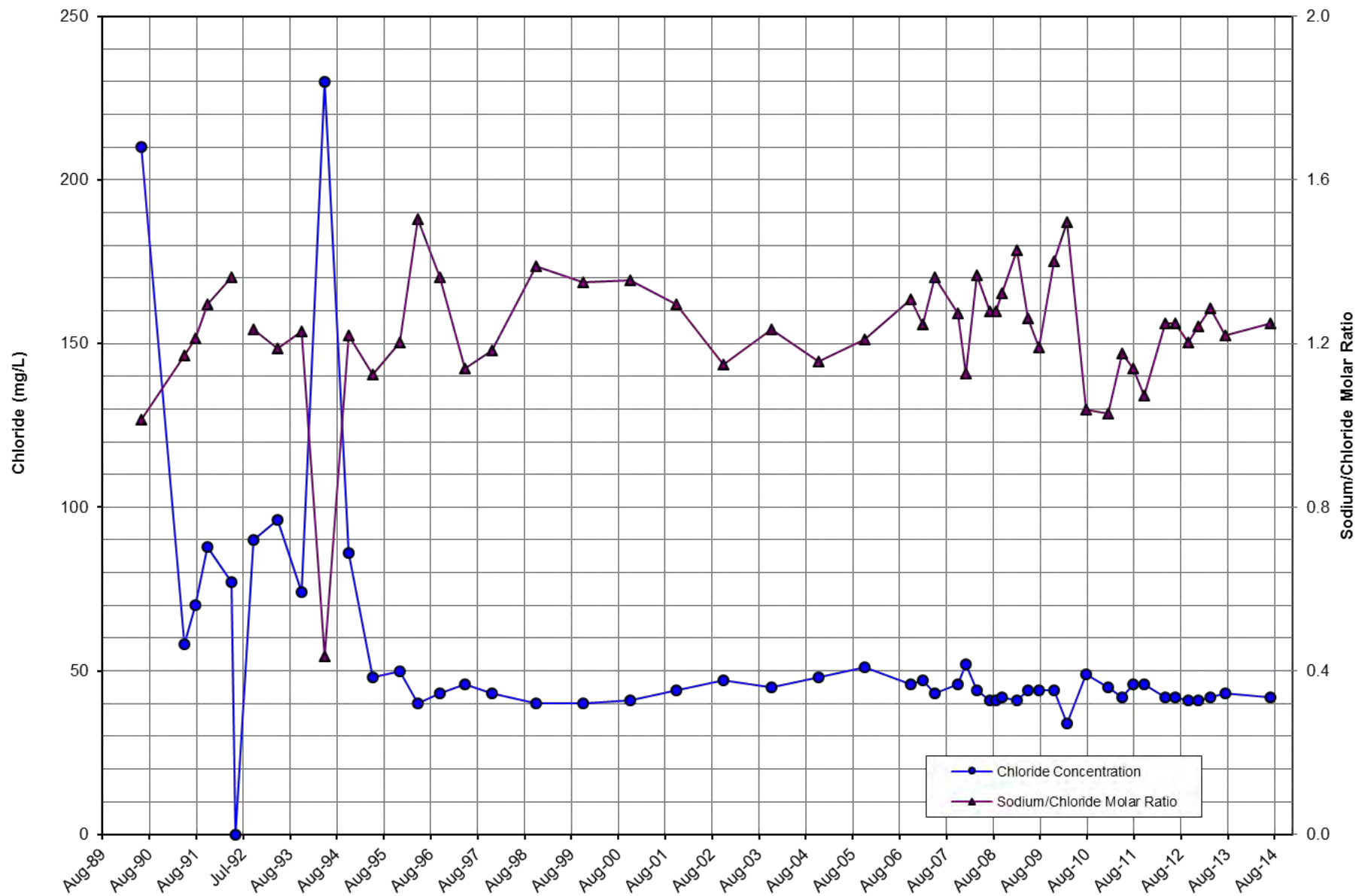


Figure B-7: MSC Shallow Well Chemograph

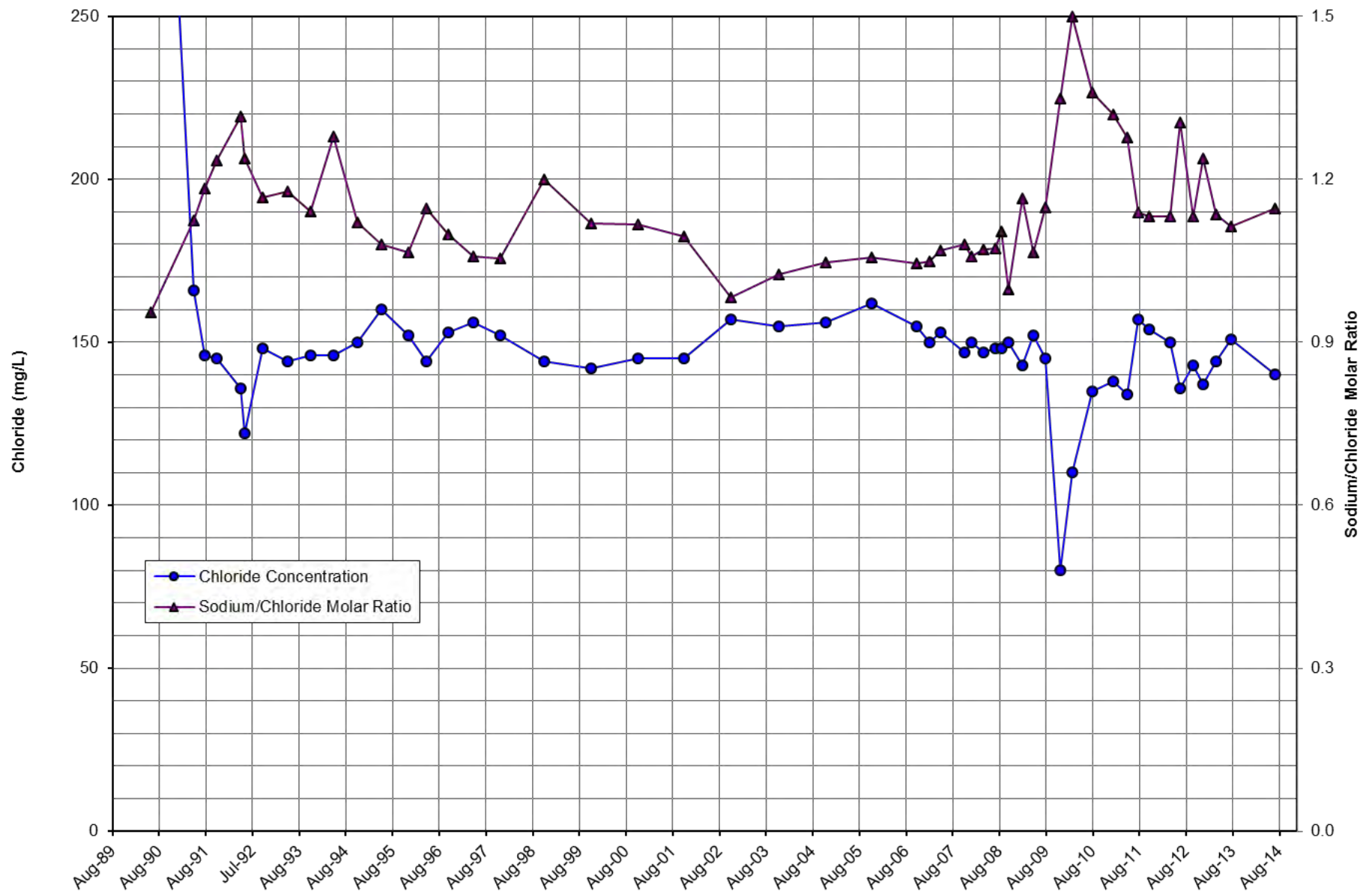


Figure B-8: MSC Deep Well Chemograph

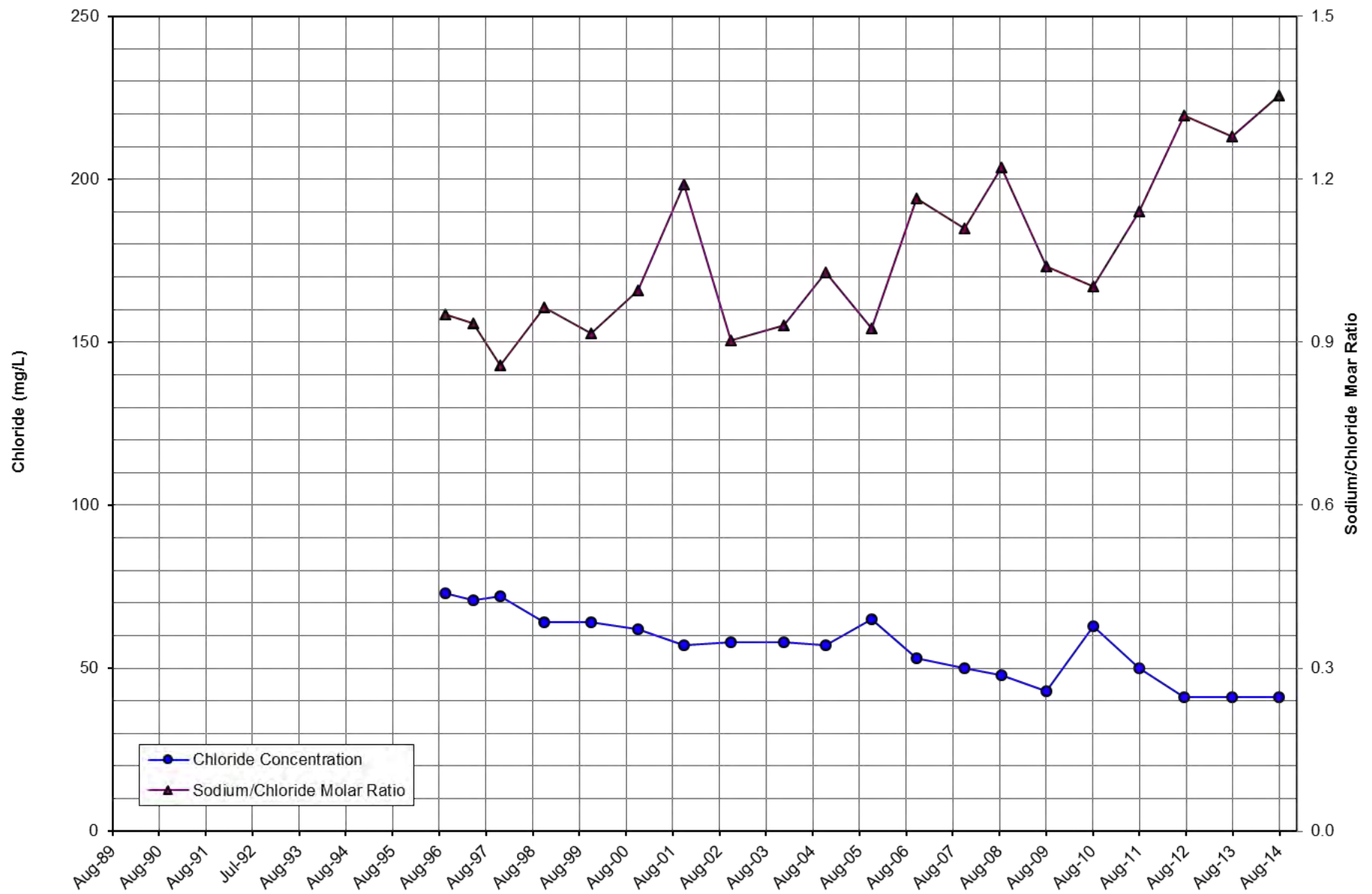


Figure B-9: Fort Ord 10 Shallow Well Chemograph

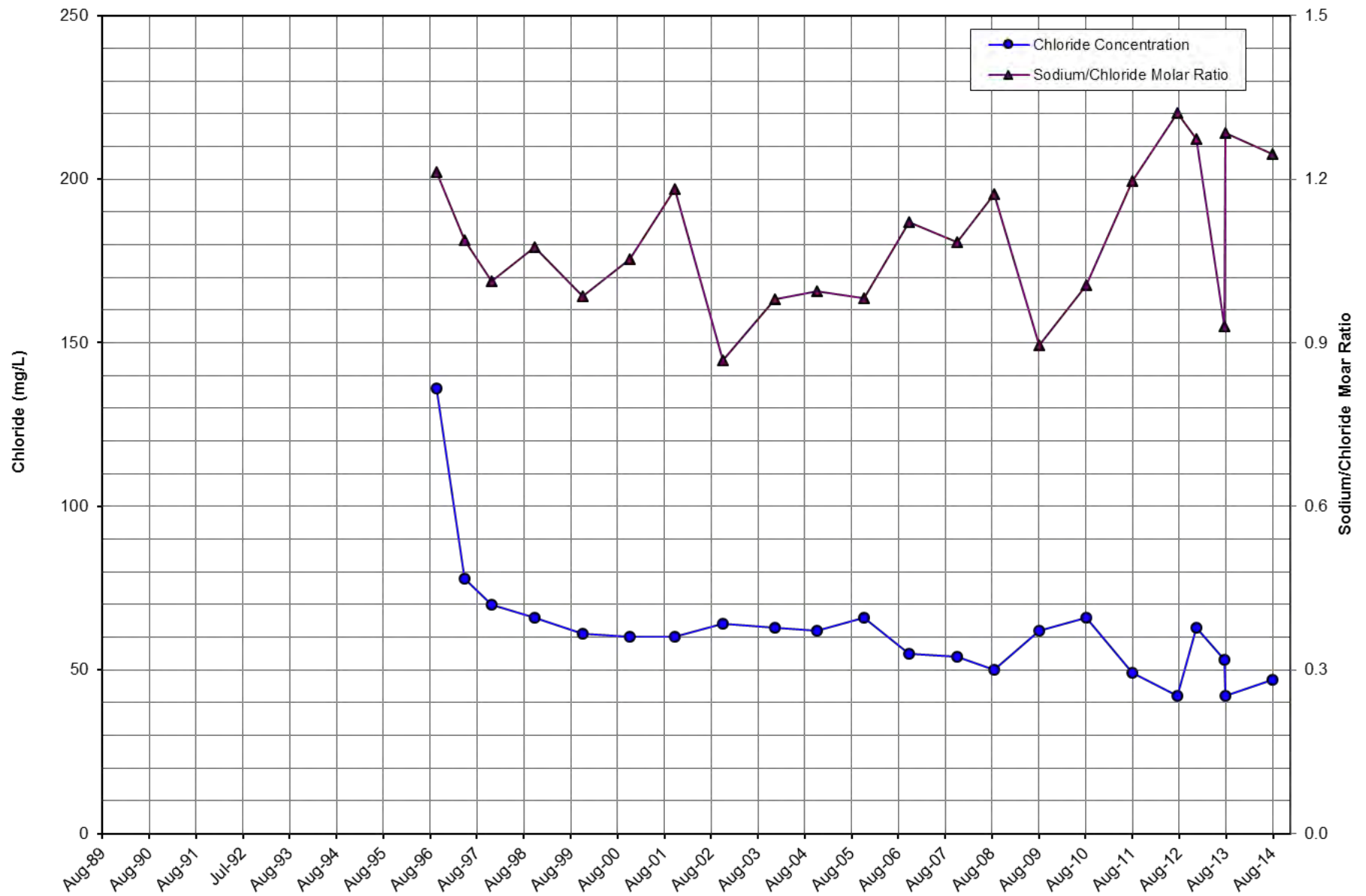


Figure B-10: Fort Ord 10 Deep Well Chemograph

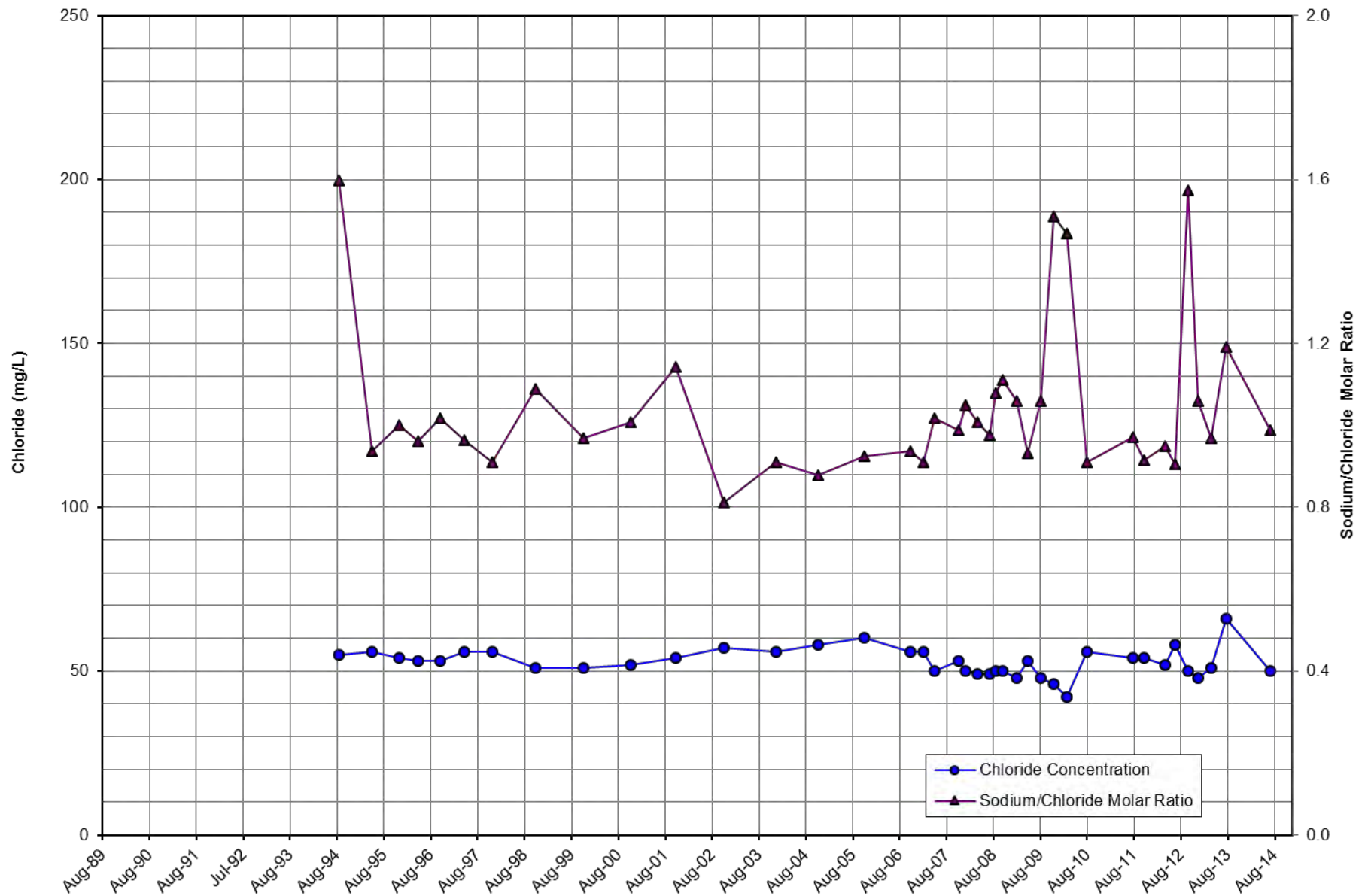


Figure B-11: Fort Ord 9 Shallow Well Chemograph

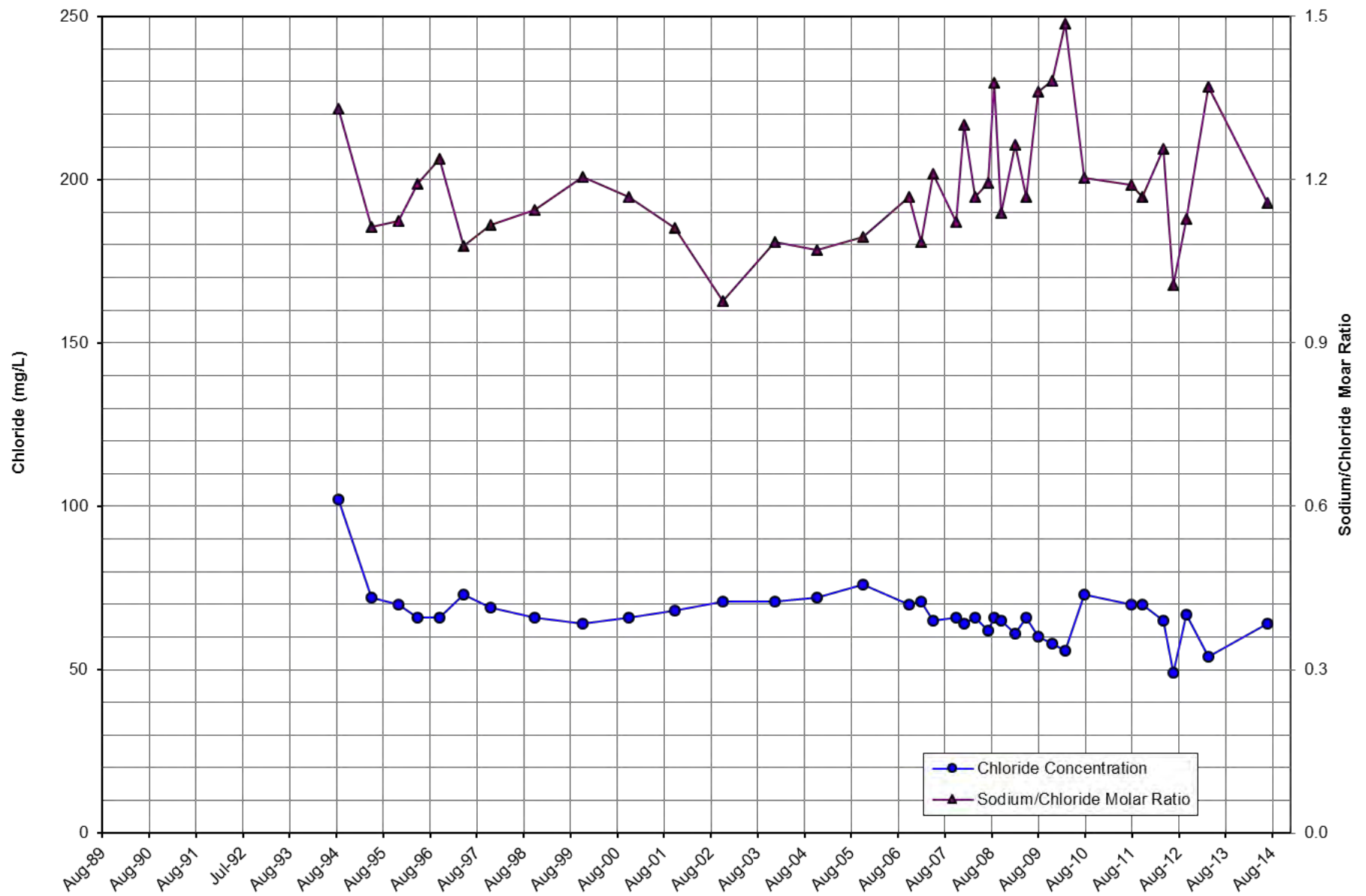


Figure B-12: Fort Ord 9 Deep Well Chemograph

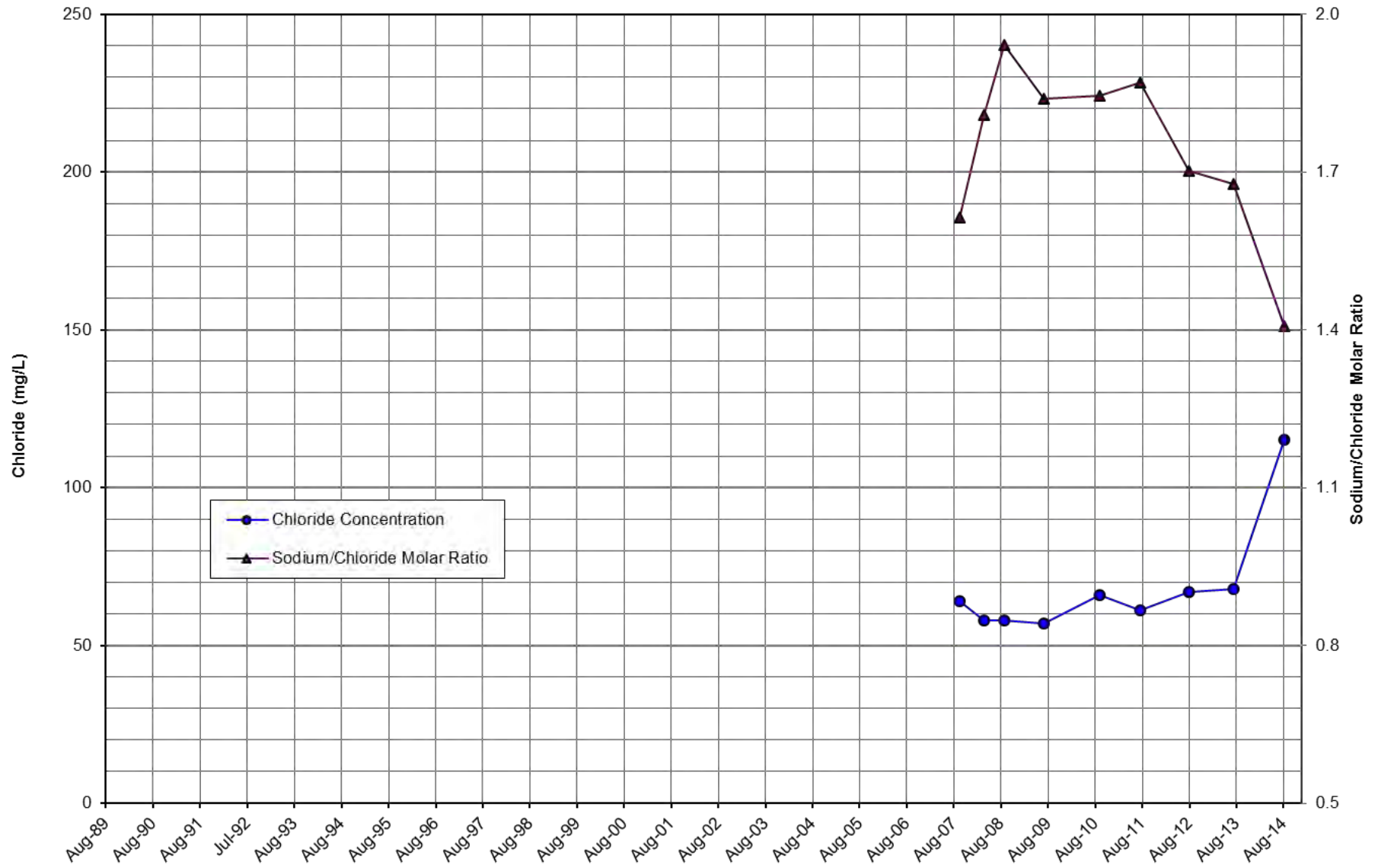


Figure B-13: SBWM-1: 1,140 foot depth sample Chemograph

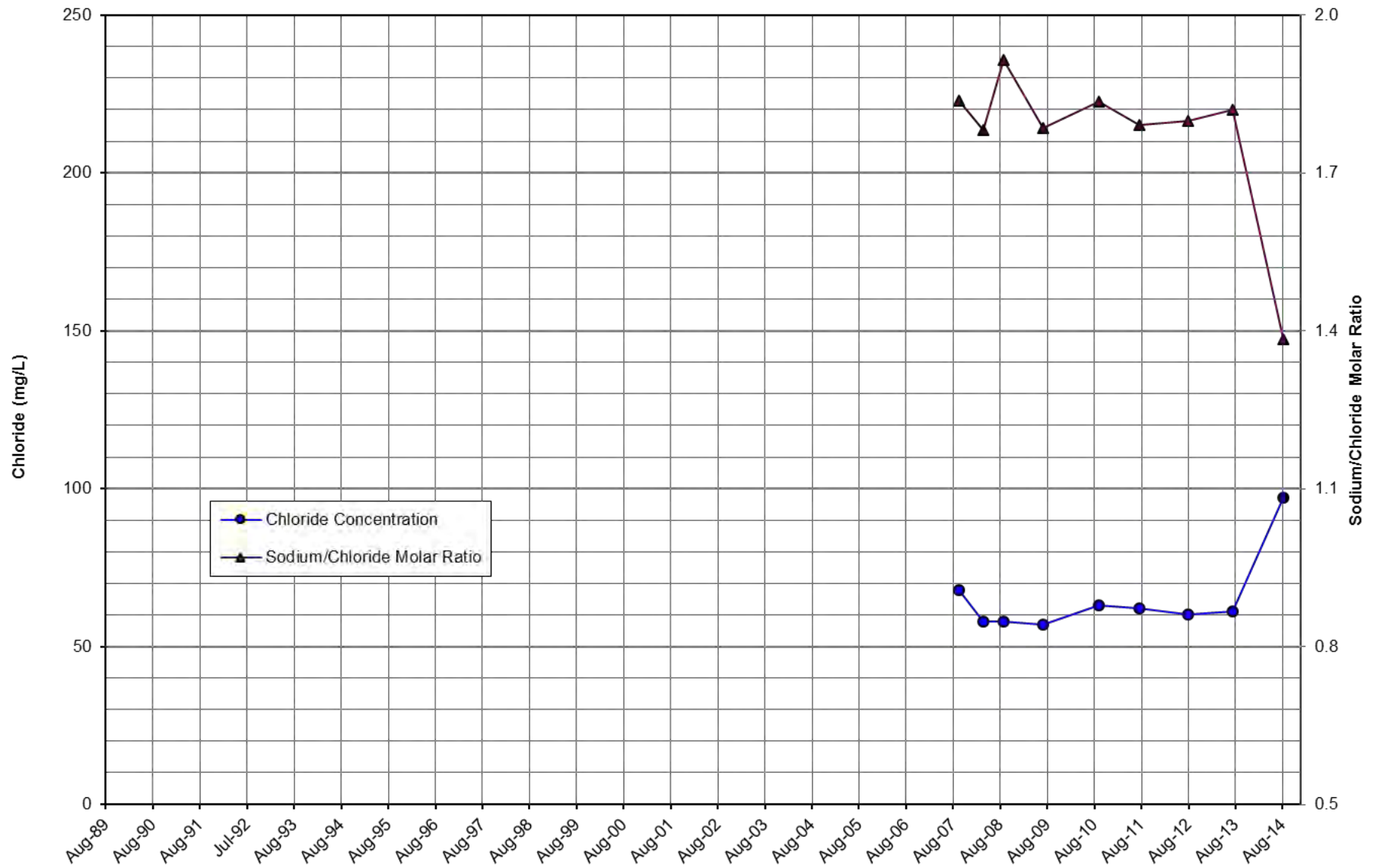


Figure B-14: SBWM-1: 1,390 foot depth sample Chemograph

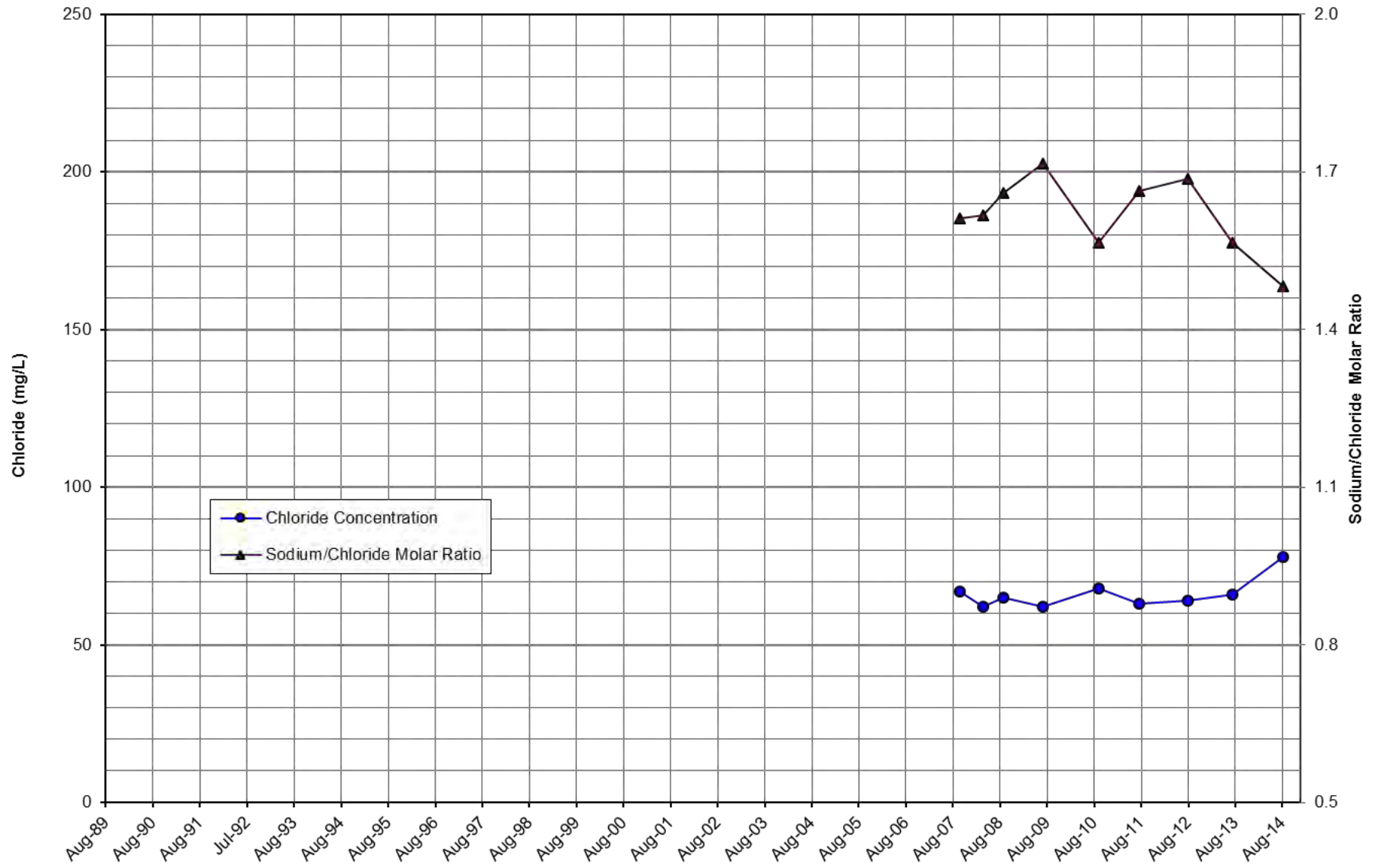


Figure B-15: SBWM-2: 1,000 foot depth sample Chemograph

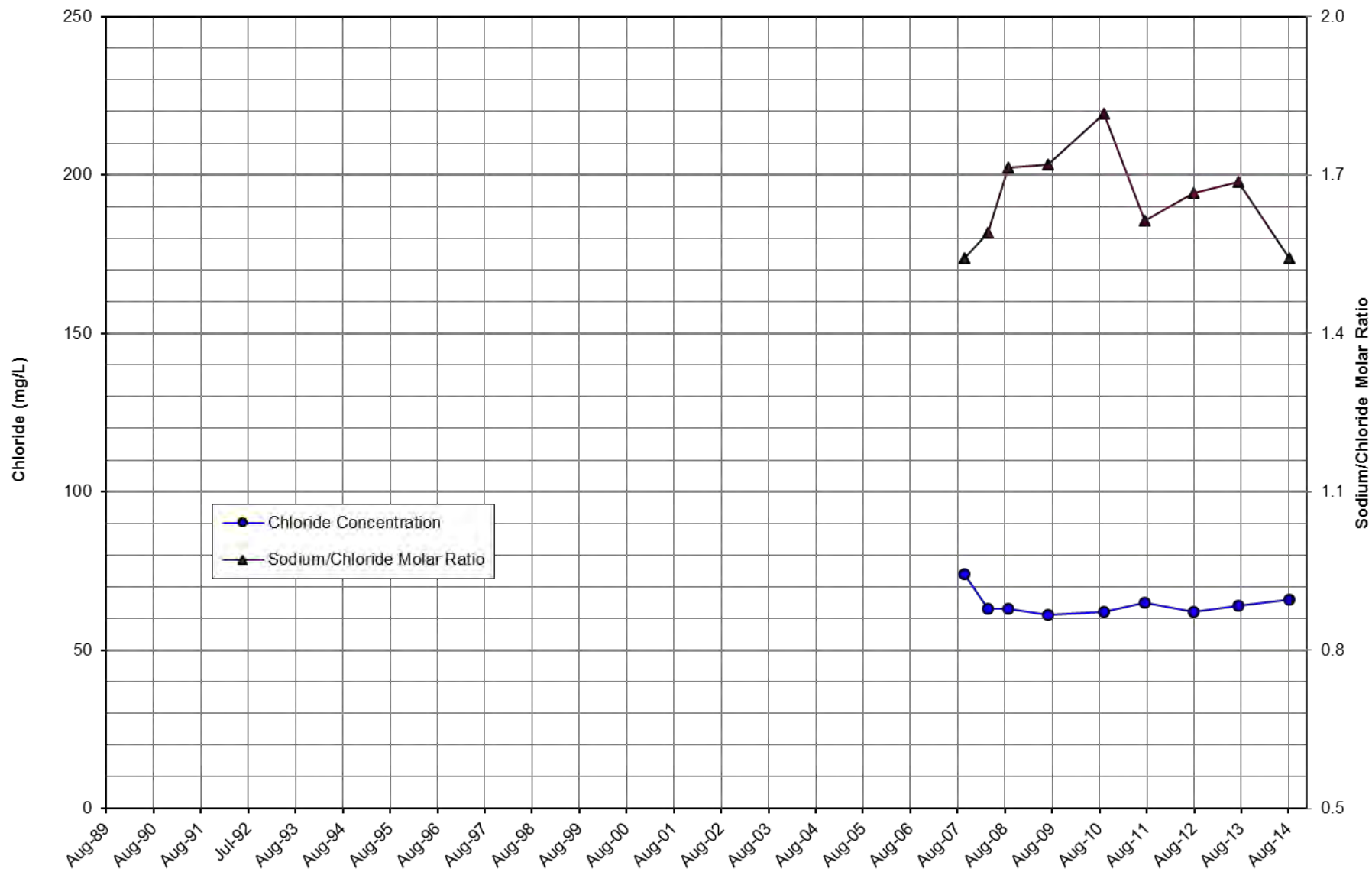


Figure B-16: SBWM-2: 1,470 foot depth sample Chemograph

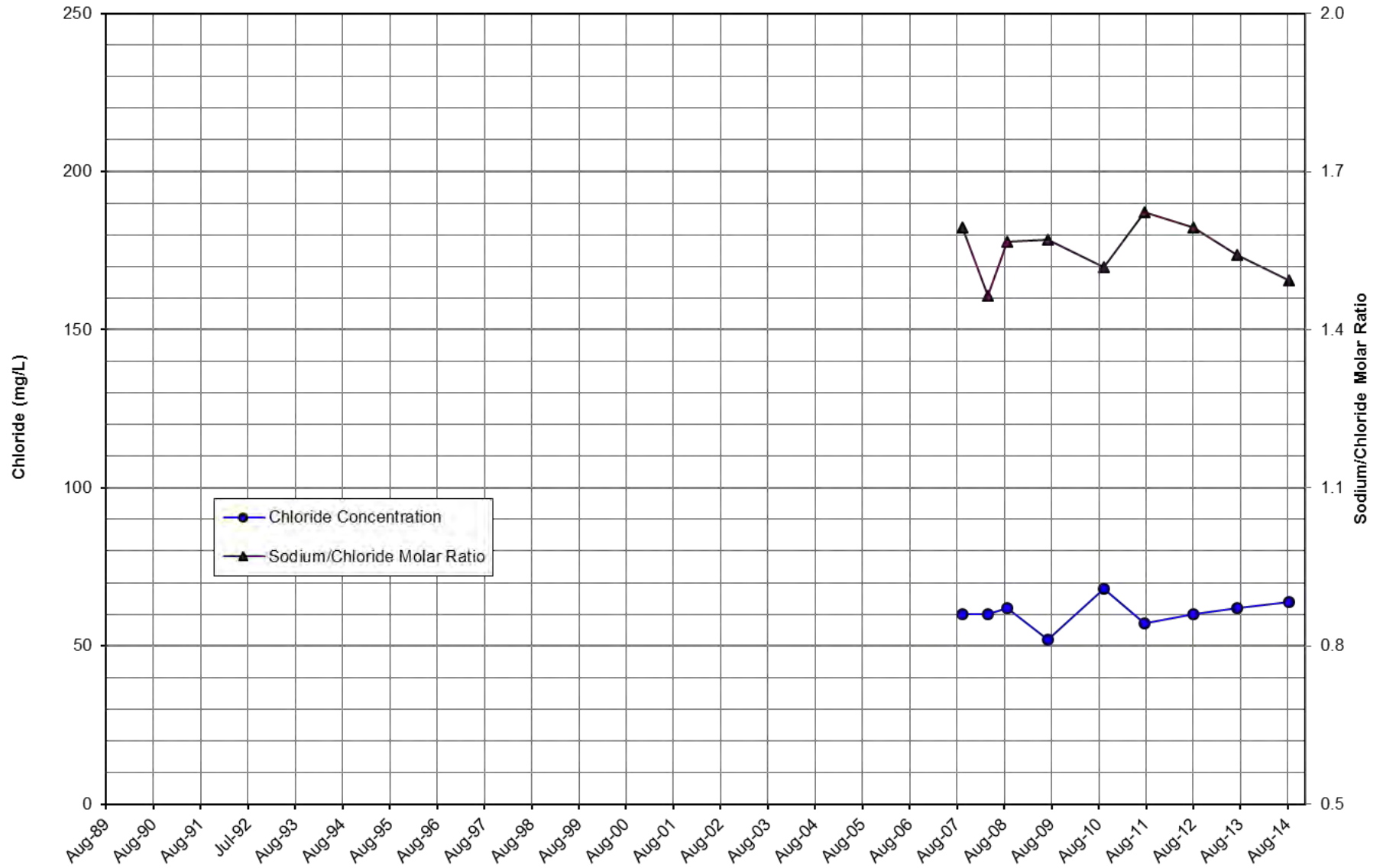


Figure B-17: SBWM-3: 870 foot depth sample Chemograph

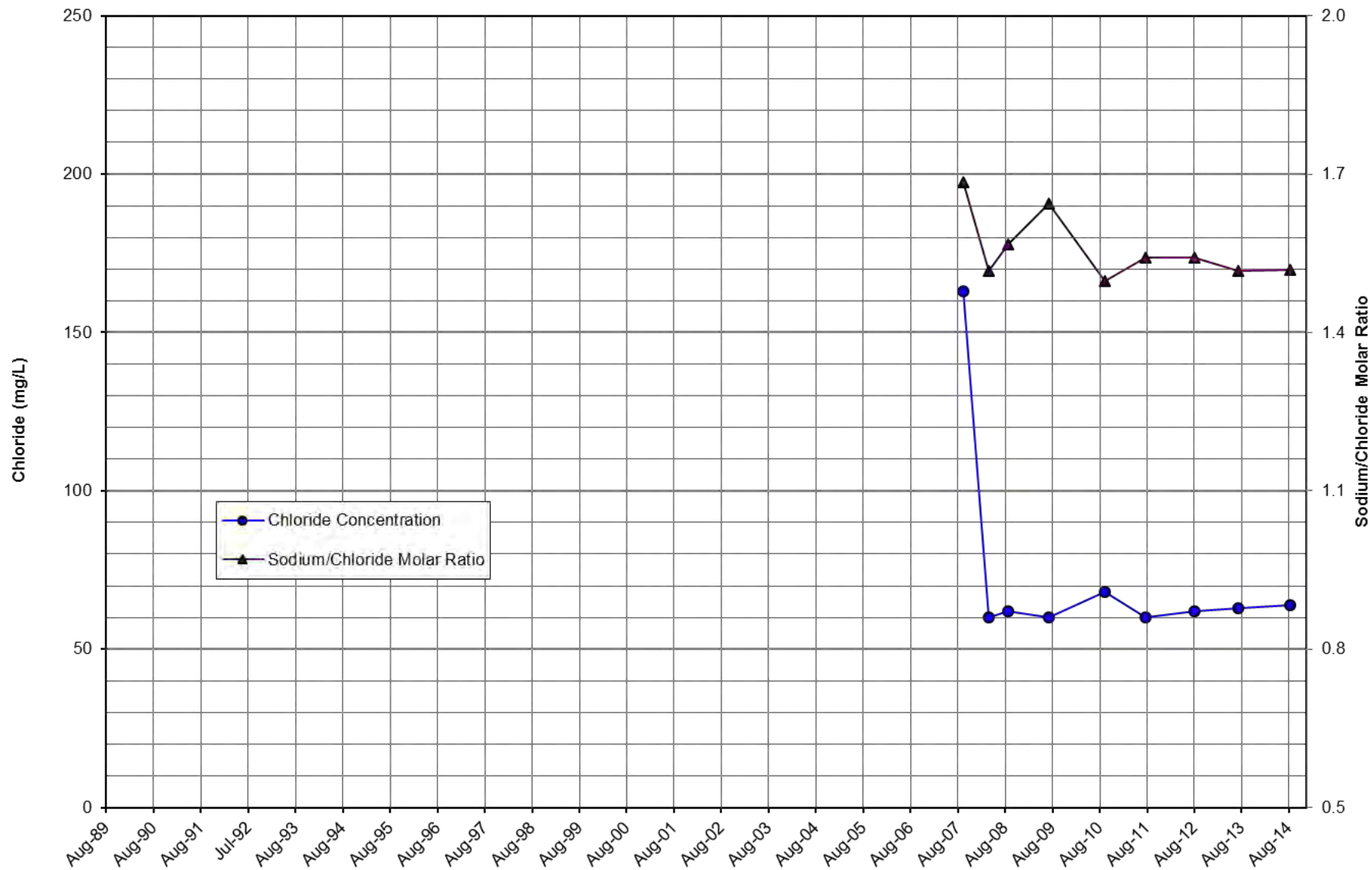


Figure B-18: SBWM-3: 1,275 foot depth sample Chemograph

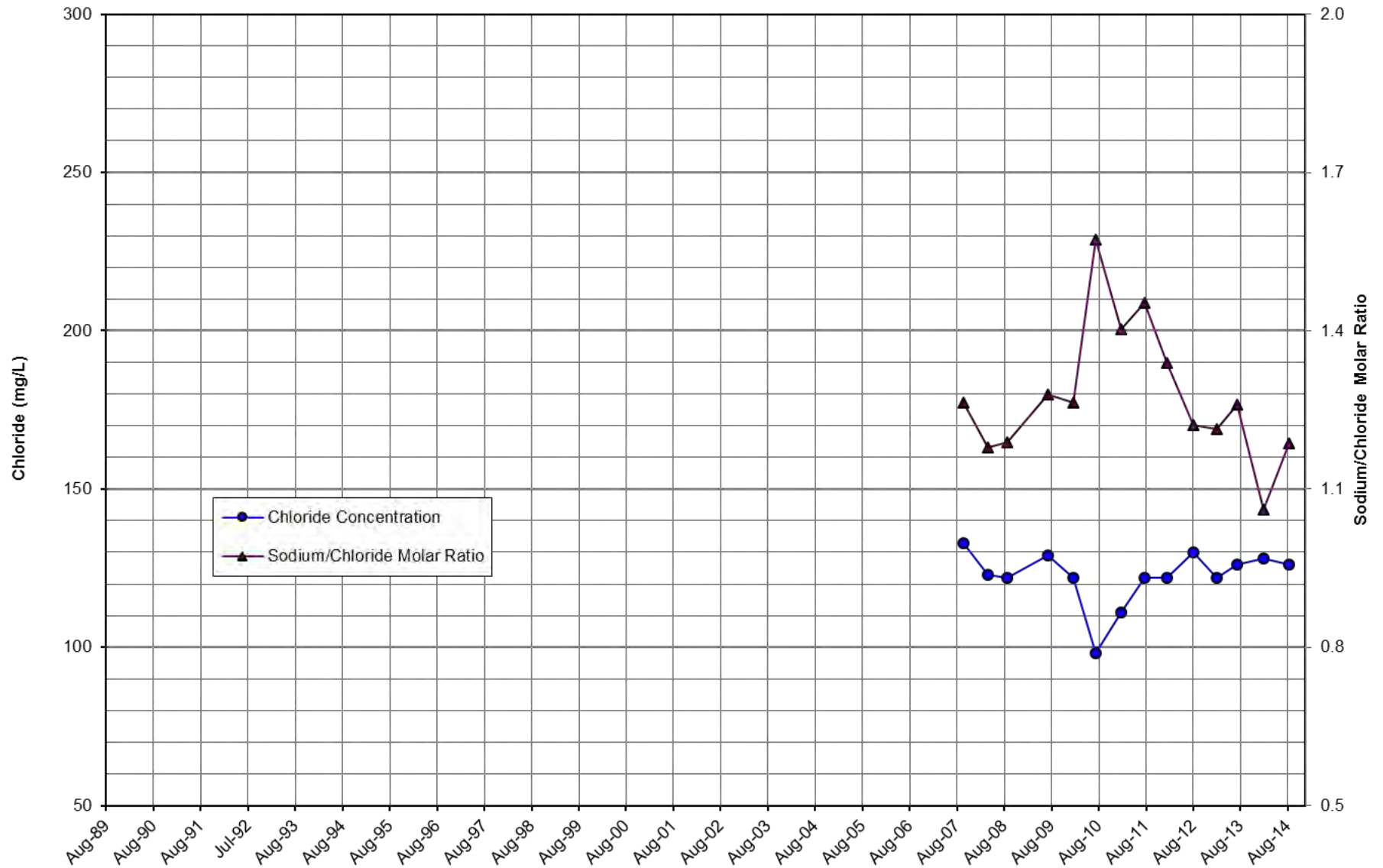


Figure B-19: SBWM-4: 715 foot depth sample Chemograph

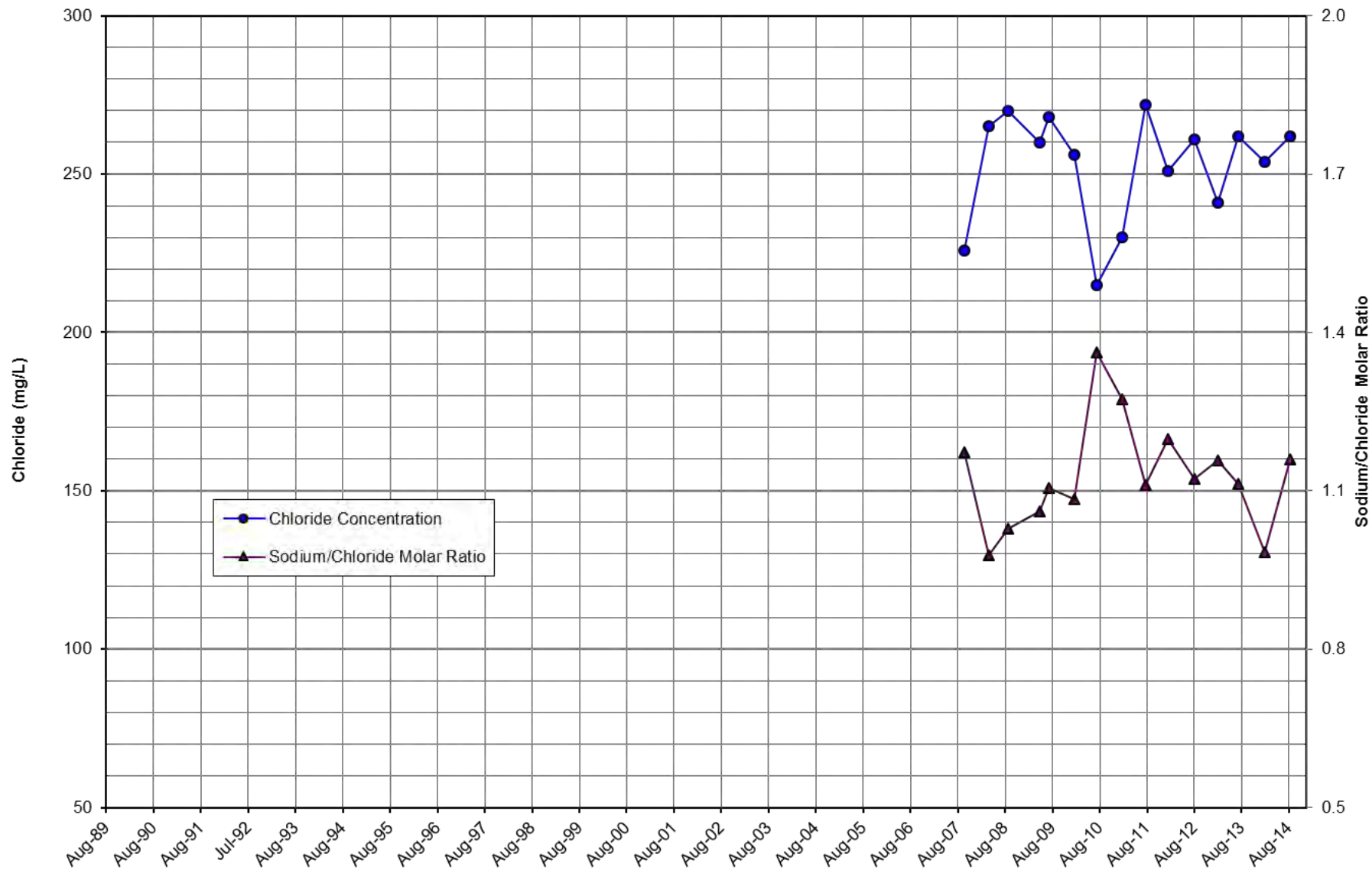


Figure B-20: SBWM-4: 900 foot depth sample Chemograph

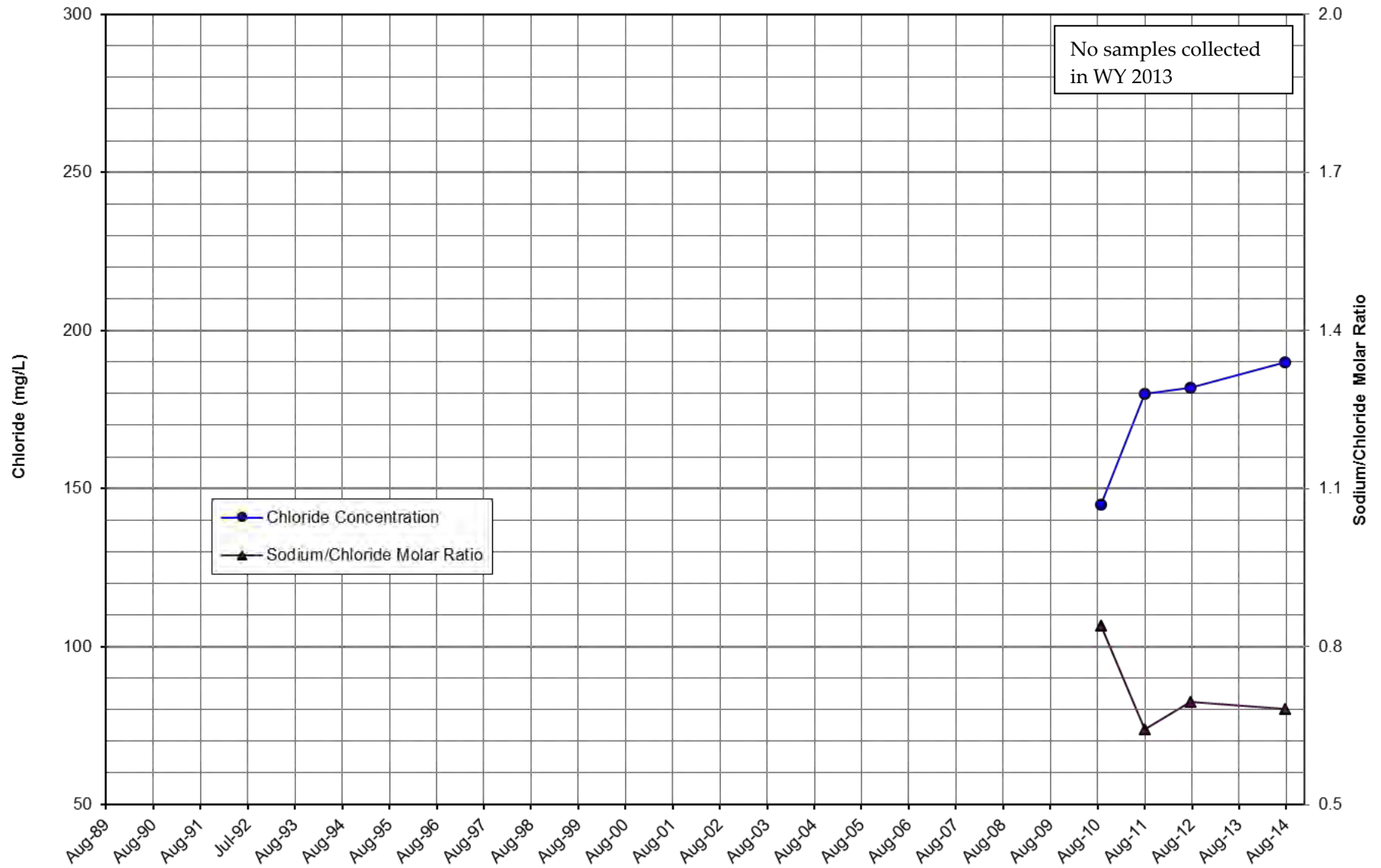


Figure B-21: SBWM-5: Shallow Well Chemograph

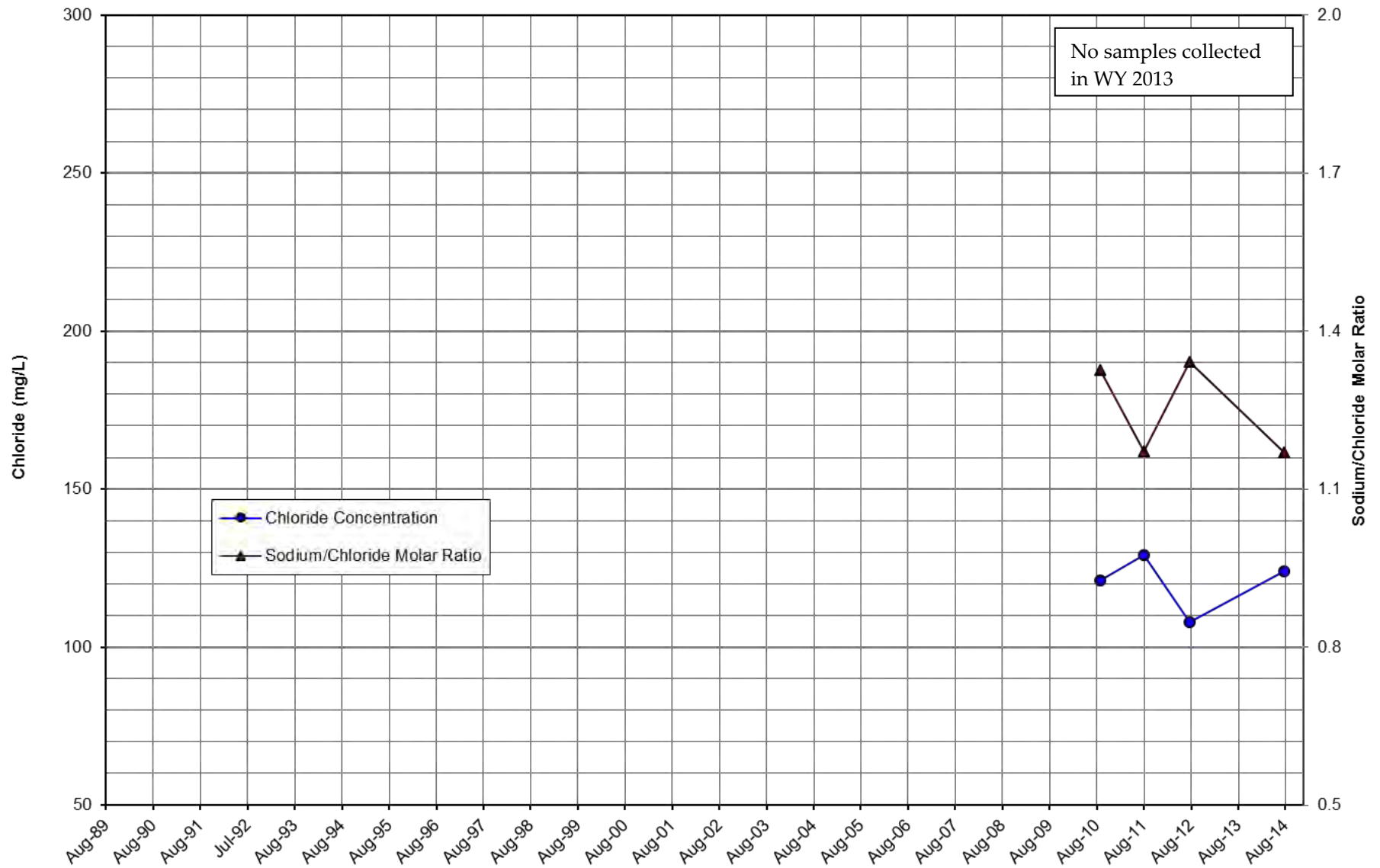


Figure B-22: SBWM-5: Deep Well Chemograph