Water Year 2011
Seawater Intrusion Analysis Report
Seaside Basin, Monterey County
California

Prepared for:
Seaside Basin Watermaster

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Prepared by:

HydroMetrics WRI

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ABBREVIATIONS

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
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 ≈ 1 part per million

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EXECUTIVE SUMMARY

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. Fortunately, no seawater intrusion is currently observed in existing monitoring wells, as demonstrated by the different tools and analyses that were used to investigate for evidence of seawater intrusion:

- Piper diagrams for groundwater samples collected from depth-discreet monitoring wells during Water Year 2011 show no changes towards seawater.

- No groundwater samples analyzed with Stiff diagrams are indicative of incipient seawater intrusion.

- Wells with chloride concentration increases over the past year are: PCA-W deep, MSC deep, sentinel wells SBWM-4 shallow, SBWM-4 deep, SBWM-5 shallow, and SBWM-5 deep. Although the increases mentioned above do not indicate seawater intrusion, their future trends must continue to be followed. Stiff and Piper diagrams for these wells do not indicate seawater intrusion, and it is likely that the increase is merely a localized fluctuation that occurs due to natural changes and is unrelated to seawater intrusion. No increase from the current monitoring frequency is warranted.

- Of the wells from last year's SIAR that had increasing chloride concentrations, the deep PCA-W well is the only monitoring well that continued with an increase over the past year. Stiff and Piper diagrams for this well do not indicate seawater intrusion, and it is likely that the increase is merely a localized fluctuation that is unrelated to seawater intrusion. No increase from the current monitoring frequency is warranted.

- No wells display decreasing sodium/chloride ratios that would indicate seawater intrusion.

- Maps of chloride concentrations do not show chlorides increasing towards the coast.

- 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.

- Sand City's Public Works well in the Aromas/Dune Sands had an increase in chloride concentration of almost 100 mg/L. This is now the highest chloride concentration in the basin (330 mg/L).

- In Water Year 2011 Watermaster producers pumped 396 acre-feet less than Water Year 2010. The amount pumped, 4,151.5 acre-feet, was also less than the Court-mandated operating yield of 5,040 acre-feet per year.

- Groundwater levels continue to be below preliminary protective elevations in all deep coastal target monitoring wells (MSC deep, PCA-W, and Sentinel Well 3). Two of the three shallow wells' groundwater levels are above protective elevations: PCA-W shallow and CDM-MW4. MSC shallow remains below preliminary 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. **Semi-Annual Water Quality Sampling in Well SBWM-4**
   Continue to collect semi-annual samples at sentinel well SBWM-4 because chloride concentrations from a depth of 900 feet below surface are still greater than 250 mg/L.

2. **Water Quality Resampling in Sand City Public Works Well**
   It is recommended that Sand City's Public Works well be resampled within the next month to confirm the 4th quarter 330 mg/L chloride concentration. If a concentration over 250 mg/L persists, the Watermaster TAC should determine whether this well should be sampled in both the second and fourth quarters.

3. **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.

4. **Refine Preliminary Protective Groundwater Elevations**
   Once the water supply parameters of the Coastal Water Project are better defined, it is recommended that the preliminary protective groundwater elevations be refined using final calibrated aquifer properties from the Seaside Basin groundwater flow model. It is expected that the protective elevations will be decreased up to a few feet, which will make them more practical to meet.

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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 fourth 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.

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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.

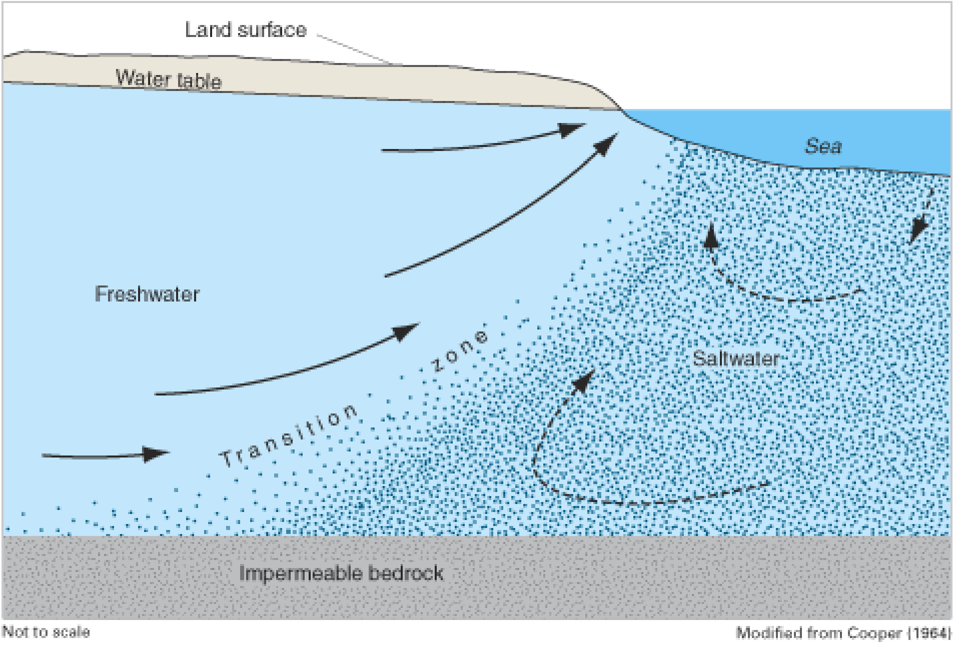

Figure 1: Seawater Wedge in a Simple Coastal Aquifer (from Barlow, 2003)

In more complex, layered groundwater systems, the location of the seawater/freshwater interface may vary among the different aquifers. Such a situation is illustrated in 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.

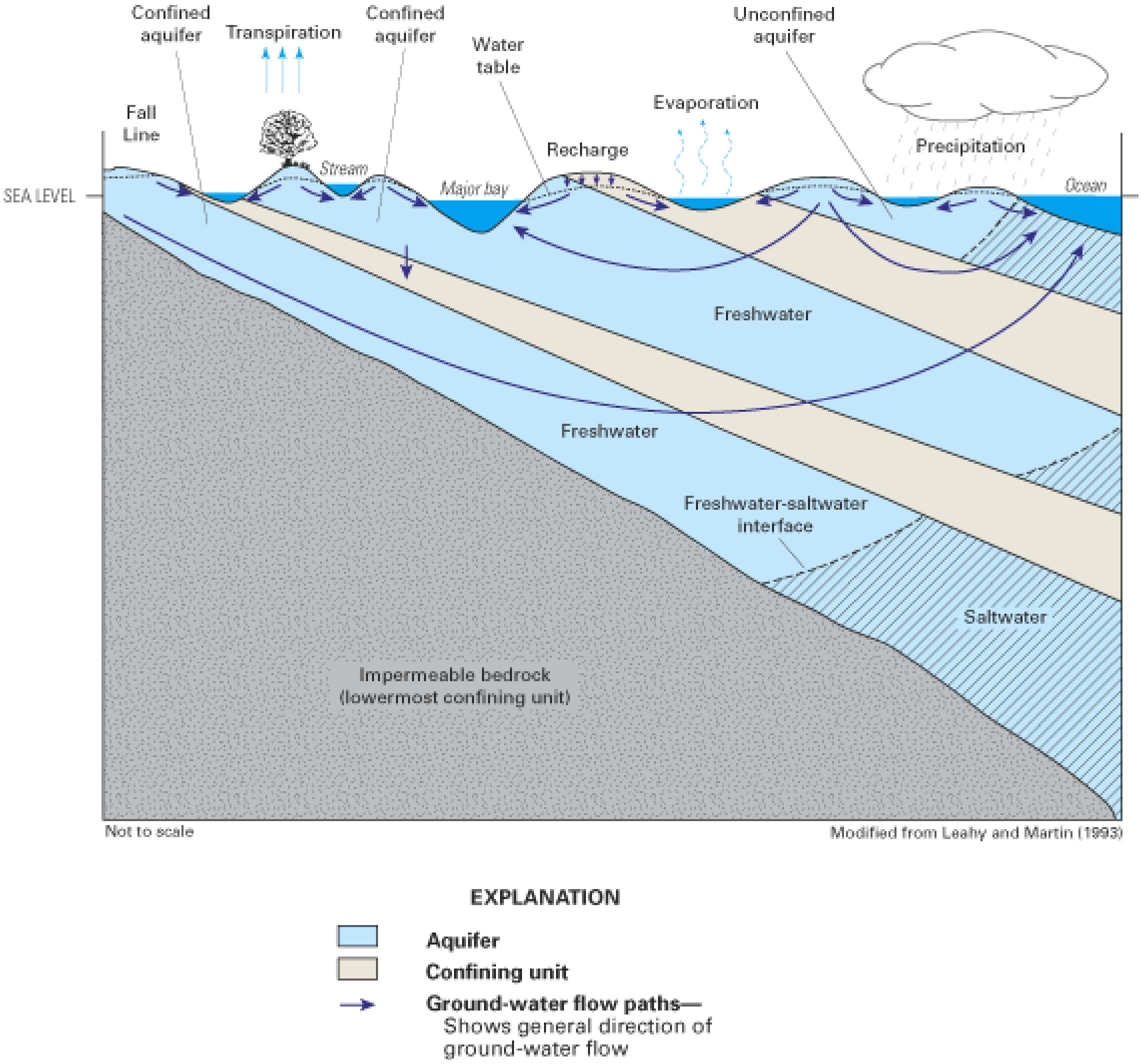

Figure 2: Seawater Wedge in a Layered Coastal Aquifer (from Barlow, 2003)

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.

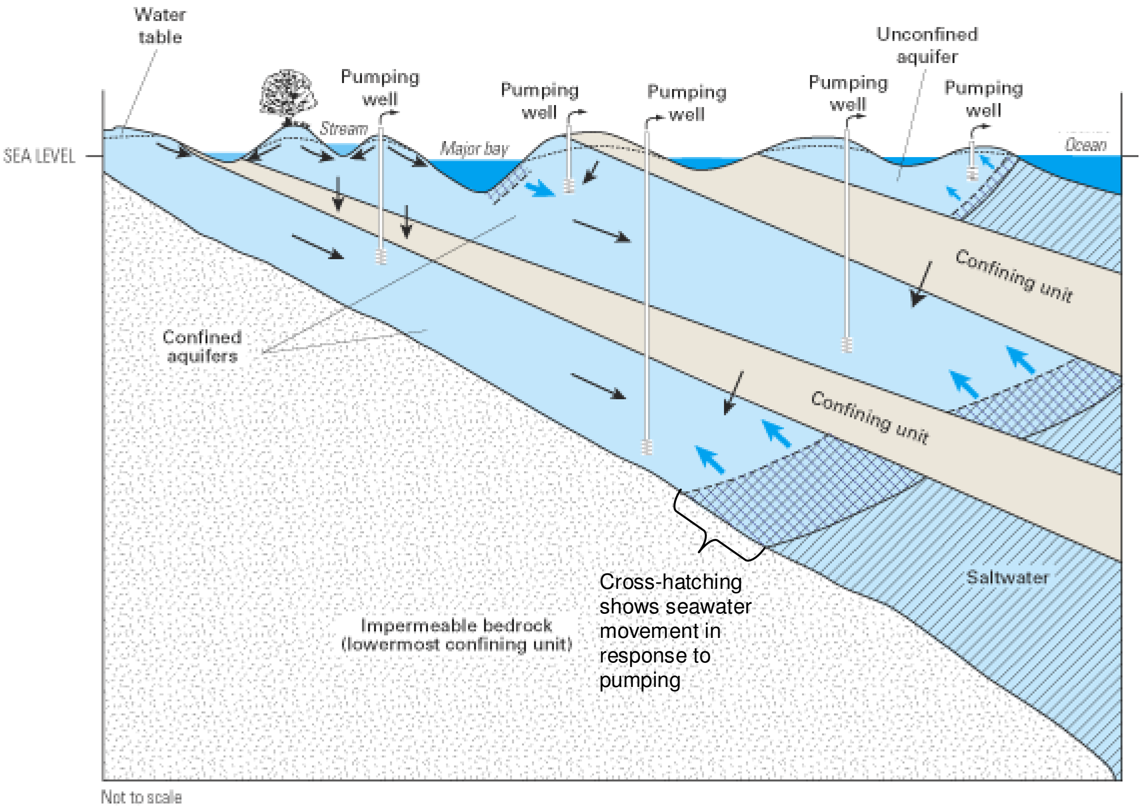

Figure 3: Interface Migration in Response to Groundwater Pumping (from Barlow, 2003)

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 in 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 in 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 in 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 in 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 in 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 16.

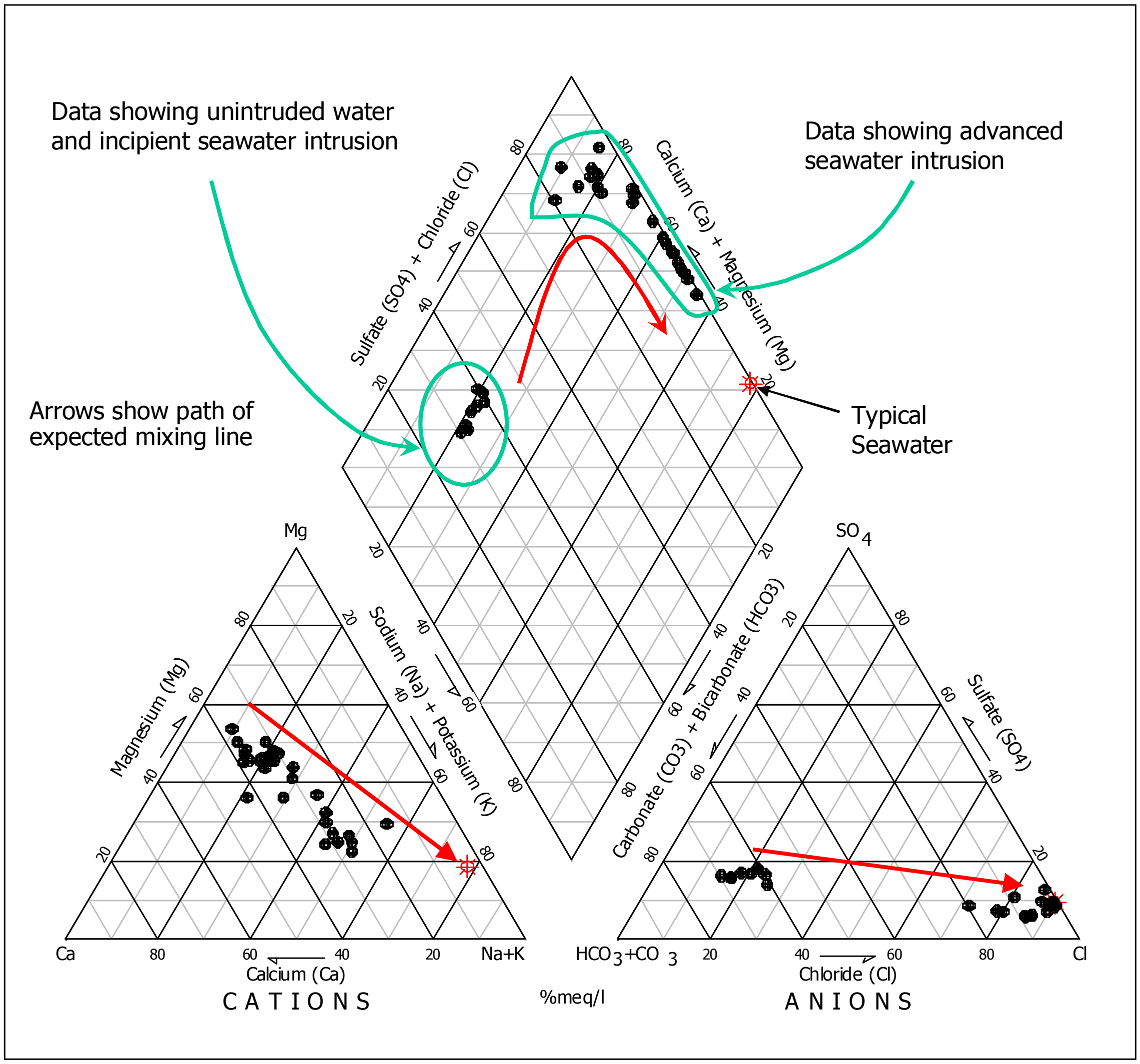

Figure 4: Piper Diagram for Groundwater in Pajaro Valley
(Data source: PVWMA)

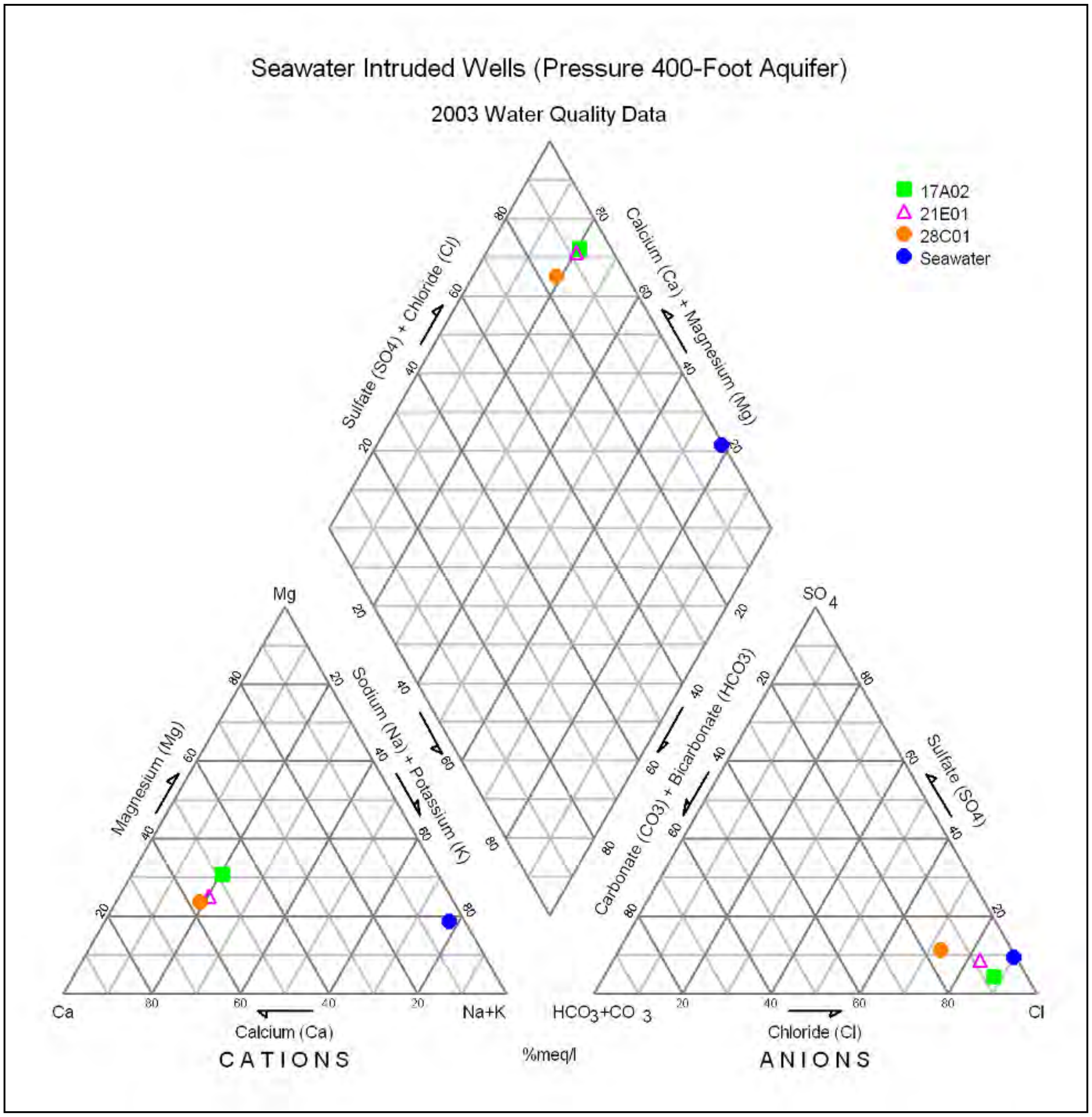

Figure 5: Piper Diagram for Groundwater in Salinas Valley
(Source: MCWRA)

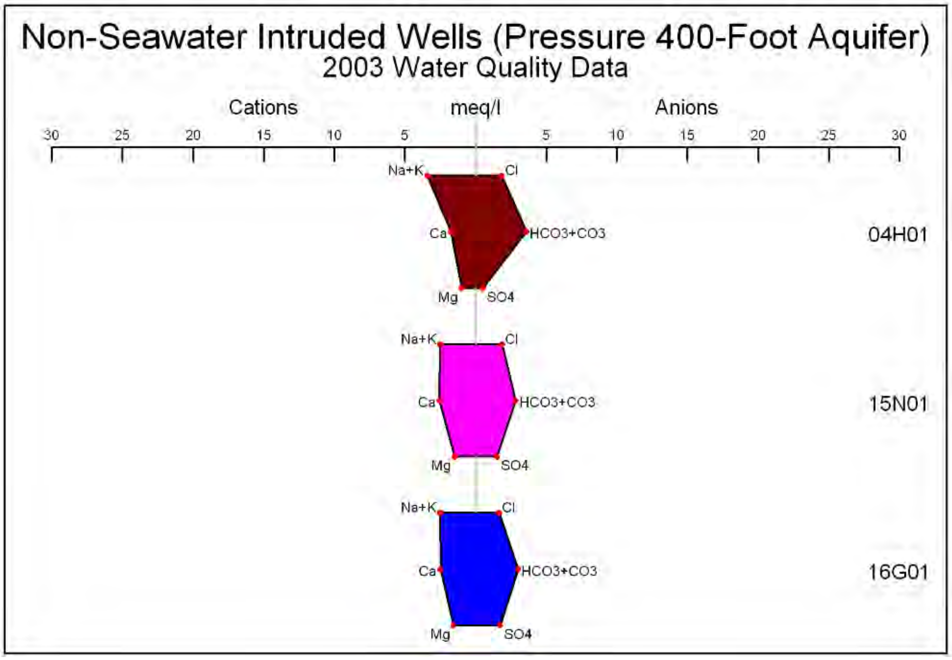

Figure 6: Stiff Diagrams from Salinas Valley Wells without Seawater Intrusion (Source: MWCRA)

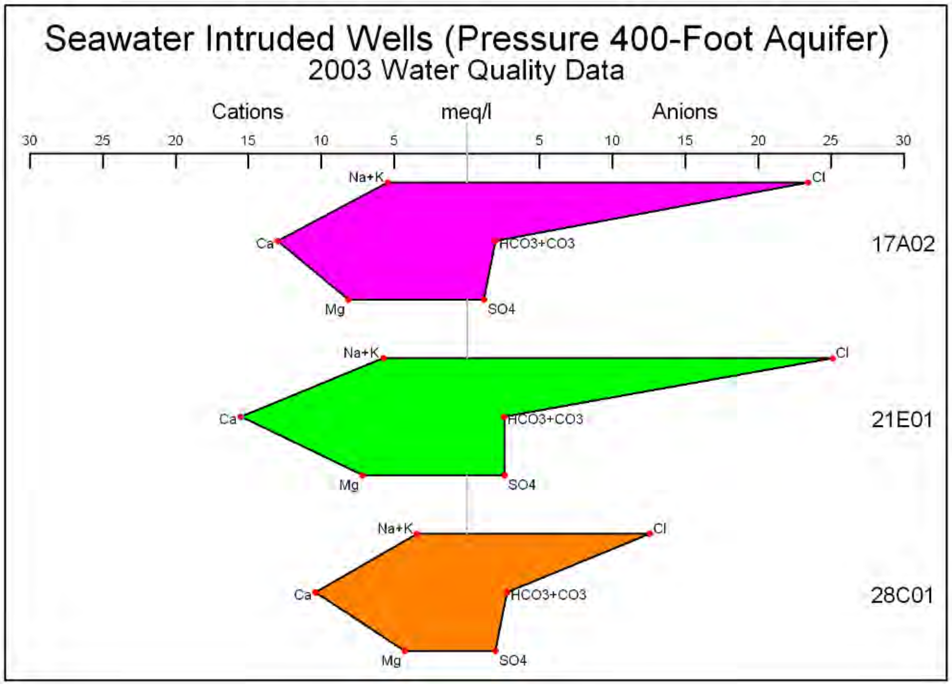

Figure 7: Stiff Diagrams from Salinas Valley Wells with Seawater Intrusion (Source: MWCRA)

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 in 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 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.

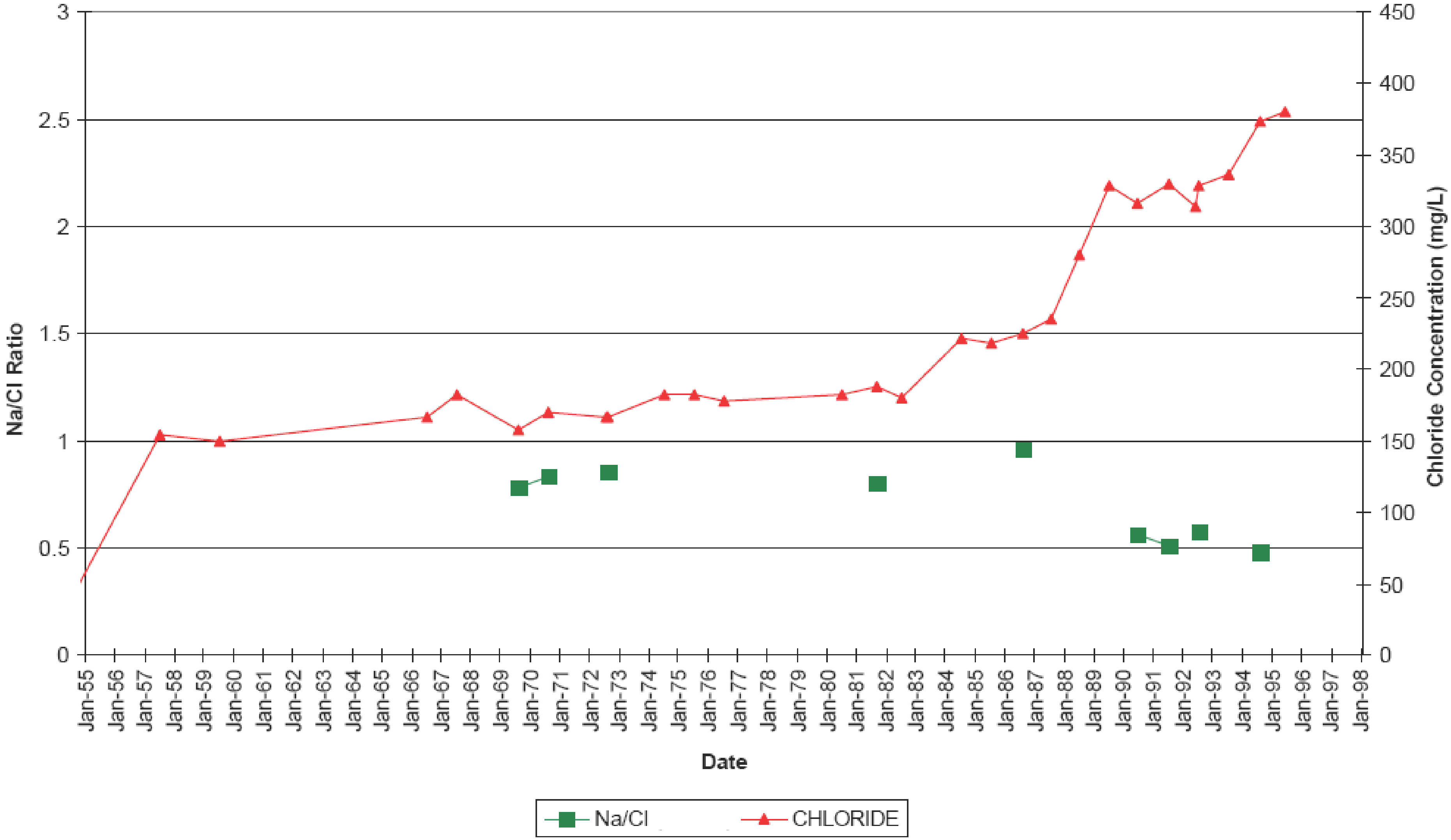

Figure 8: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Salinas Valley Showing Incipient Intrusion
(Source: MCWRA)

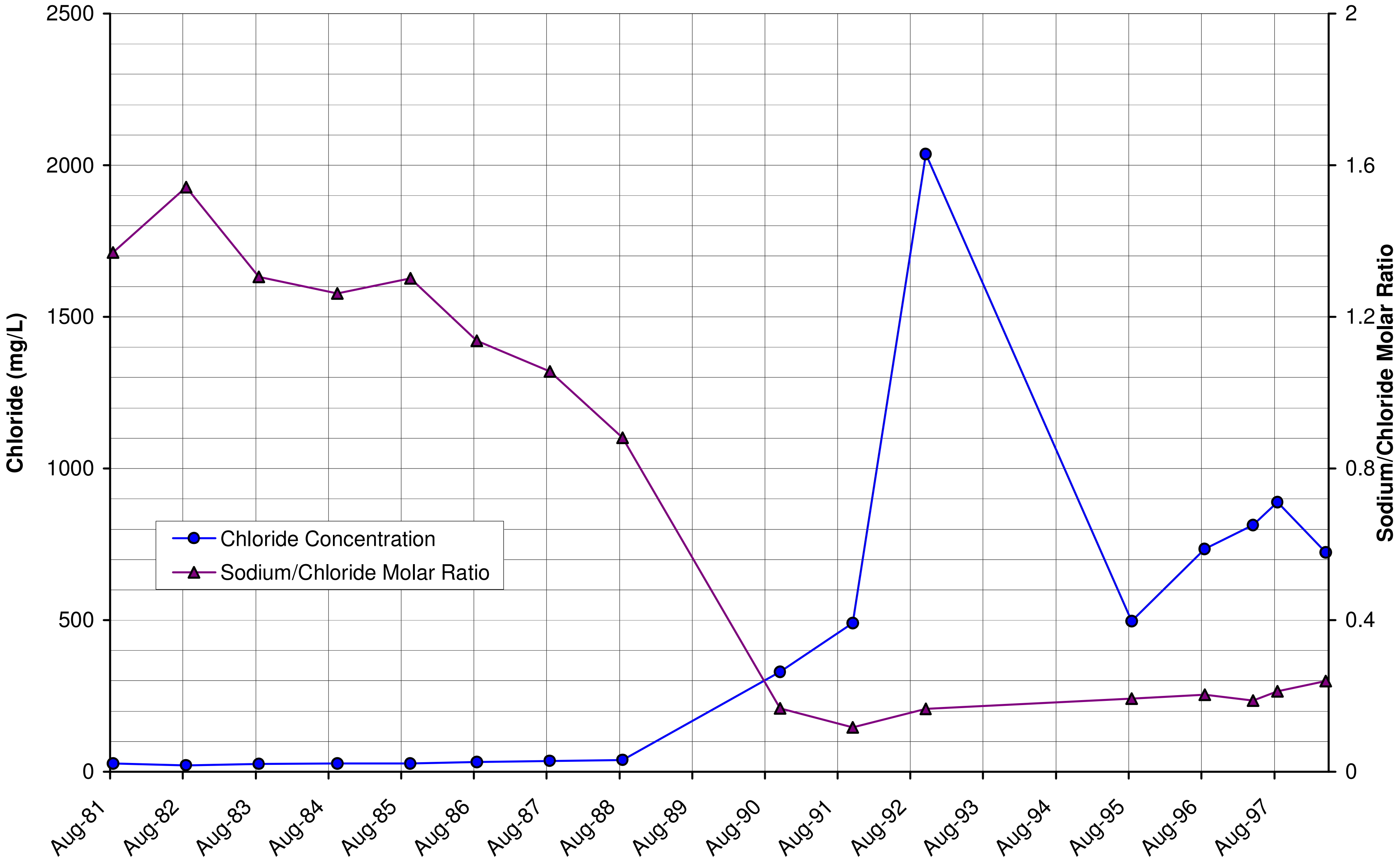

Figure 9: Historical Chloride Concentrations and Sodium/Chloride Ratios for a Well in Pajaro Valley Showing Incipient Intrusion (Data source: PVWMA)

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 Watermater'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 data exist for the minor constituents such as iodide and barium; and only limited historical data exist for bromide and boron.

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 may 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 point to seawater intrusion.

ANALYSIS APPROACH

As was used in previous Seawater Intrusion Analysis Reports (RBF, 2007; HydroMetrics LLC, 2008; HydroMetrics LLC, 2009a; HydroMetrics WRI, 2009b; HydroMetrics WRI, 2010), this report includes a number of approaches to evaluate seawater intrusion. Data for the 2nd quarter of Water Year 2011 (sampled and measured January-March 2011) and 4th quarter of Water Year 2011 (sampled and measured July-August 2011) 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

Eighteen monitoring wells and 17 production wells were used for the geochemical trend analyses (Figure 10). Of the 18 monitoring wells, four are the deep sentinel wells installed by the Watermaster in 2007, and two are the SBMW-5 shallow and SBMW-5 deep well pair located on the east side of the Bureau of Land Management's Camp Huffman complex. The remaining 12 monitoring wells represent six well pairs from the MPWMD monitoring well network. 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 17 production wells included in the analysis are water purveyor wells that are sampled annually for general inorganic minerals as 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 2011 (JANUARY-MARCH 2011)

A Piper diagram displaying analyses from eight monitoring wells in the Seaside Groundwater Basin for the 2nd quarter Water Year 2011 (January-March 2011) is shown in Figure 11. Analyses from only eight wells are shown because most of the monitoring well pairs, and all of the production wells, 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 trends 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 water[1]. The diagrams in Appendix A show no trends over time towards typical seawater on the Piper diagrams; indicating that there is no seawater intrusion at any of the analyzed wells.

Stiff diagrams for the monitoring wells sampled during the 2nd quarter of Water Year 2011 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

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[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 cation triangle, the water is classed as chloride type water.

monitoring wells in the Northern Subbasin are similar to the shapes of the 4th quarter 2010 data.

FOURTH QUARTER WATER YEAR 2011 (JULY-AUGUST 2011)

Piper diagrams displaying groundwater quality data from 18 monitoring wells and 17 production wells in the Seaside Groundwater Basin for the 4th quarter of Water Year 2011(July-August 2011) are shown in 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 the 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 2010. 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) appear to be trending towards being more chloride-rich over time. However, this trend 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. Overall, the Piper diagrams show no indication of seawater intrusion at any of the analyzed wells.

Stiff diagrams for the 18 monitoring wells sampled during the 4th quarter of Water Year 2011 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, with the exception of sentinel well SBWM-4 715 foot depth (shallow) which had much less chloride and carbonates than previous samples. Stiff diagrams for the 17 production wells sampled during the 4th quarter of Water Year 2011 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 2010. None of the Stiff diagrams show the high chloride spike shown on Figure 7 that indicates seawater intrusion.

The York School well, in the Laguna Seca subarea, and Public Works Corp Yard 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 high chloride spike associated with seawater intrusion. None of the production wells analyzed shows any indication of seawater intrusion.

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 Figure 21. The complete set of chemographs is included in Appendix B.

Overall there has been a decrease in chloride concentration for monitoring wells that had slight increases in Water Year 2010. However, a few wells had increasing concentrations. These are: PCA-W deep (15 mg/L increase over the past year), MSC deep (20 mg/L increase over the past year), sentinel well SBWM-4 shallow (20 mg/L increase over the past year) and SBWM-4 deep (50 mg/L increase over the past year), SBWM-5 shallow (30 mg/L increase over the past year) and SBWM-5 deep (10 mg/L increase over the past year). The remainder of the wells remained stable or had decreasing concentrations.

Seawater intrusion will be identified by a sustained chloride concentration increase over time along with other positive indicators. Stiff and Piper diagrams for wells with increasing chloride concentrations did not indicate seawater intrusion. It is likely that the increases are merely due to localized fluctuations that are unrelated to seawater intrusion. No increase from the current monitoring frequency is warranted, although their future trends need to be followed.

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

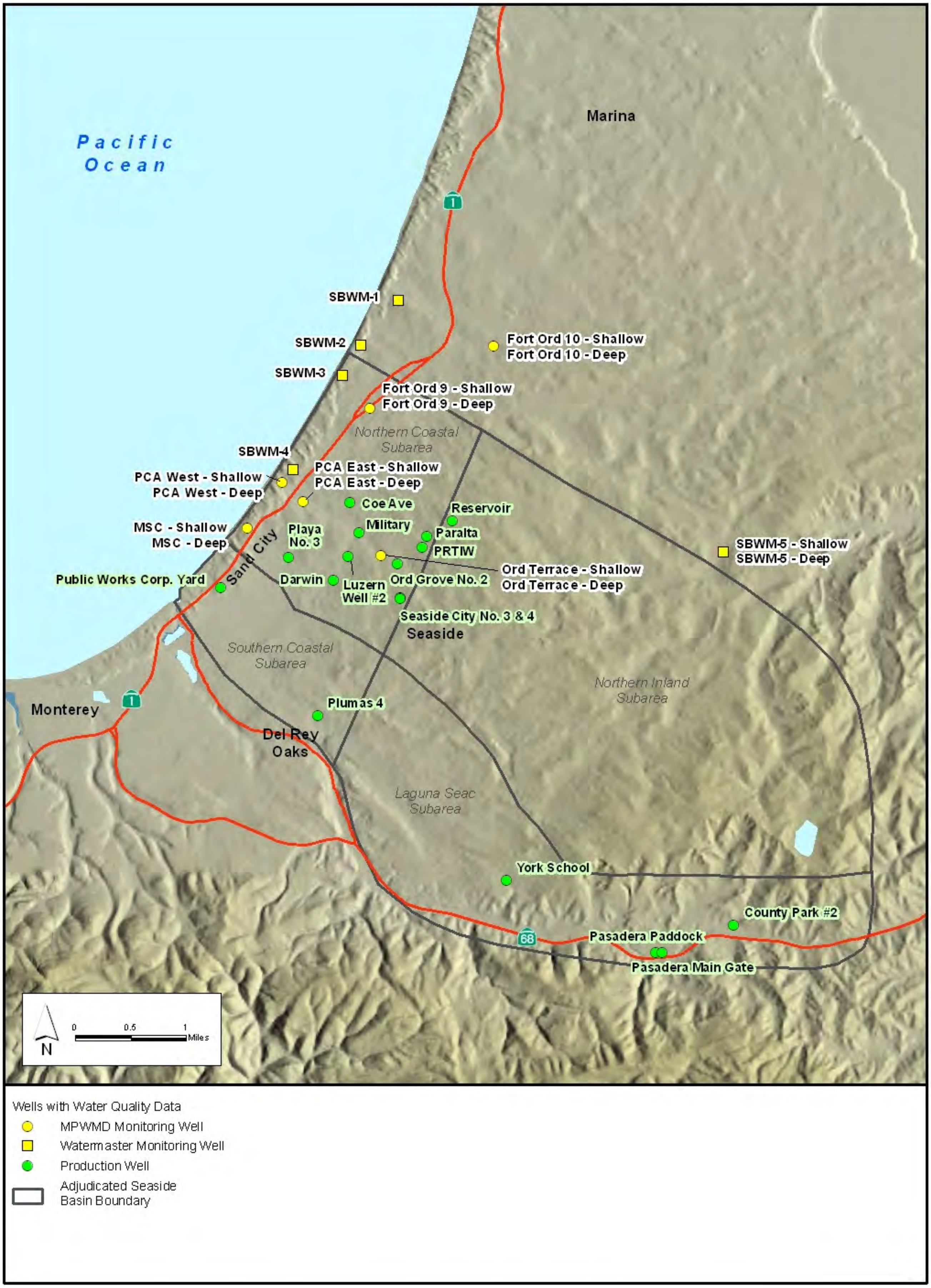


Figure 10: Wells Used for Current Seawater Intrusion Analyses

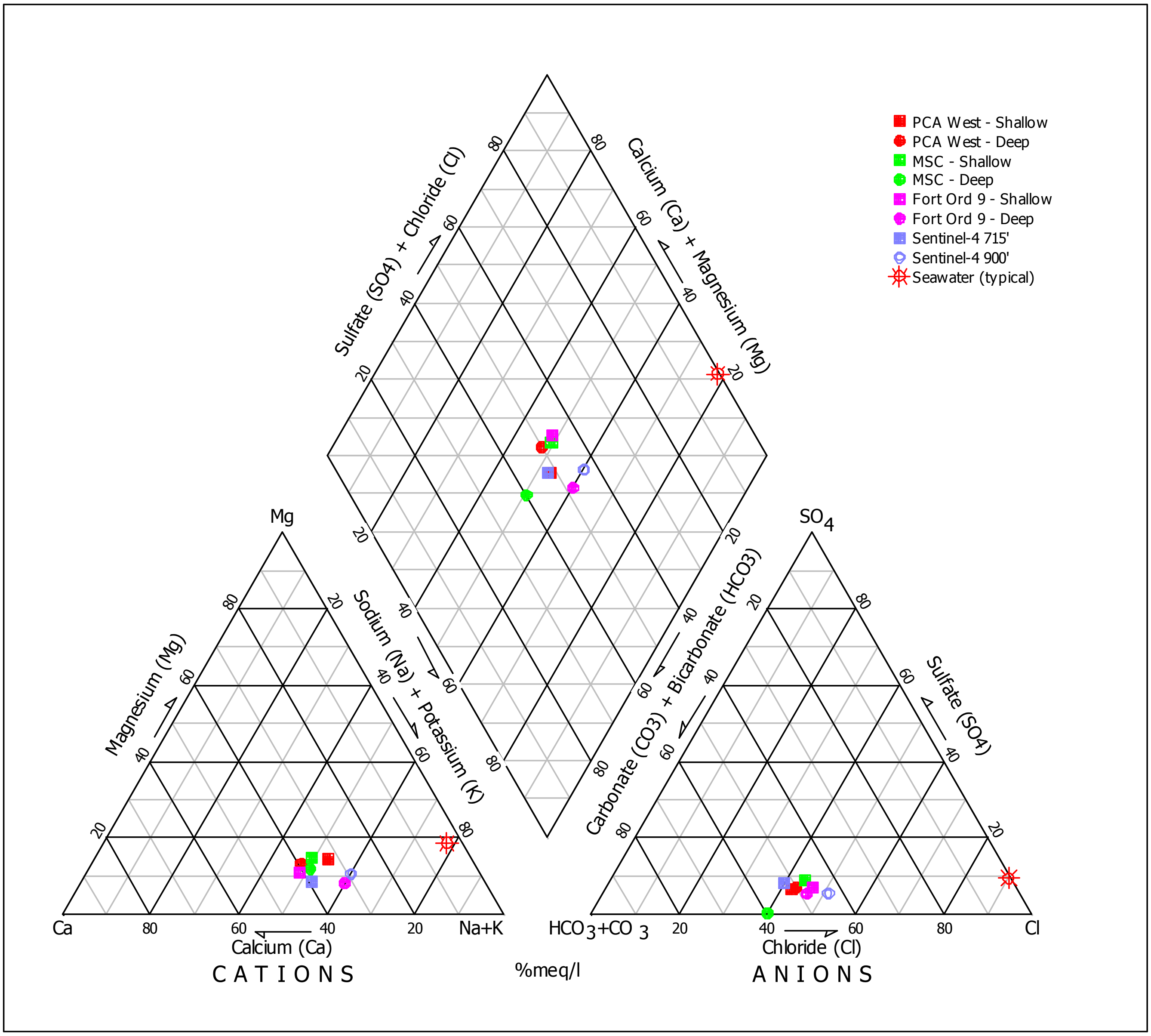


Figure 11: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 2nd Quarter Water Year 2011 (January-March 2011) (Data source: Watermaster)

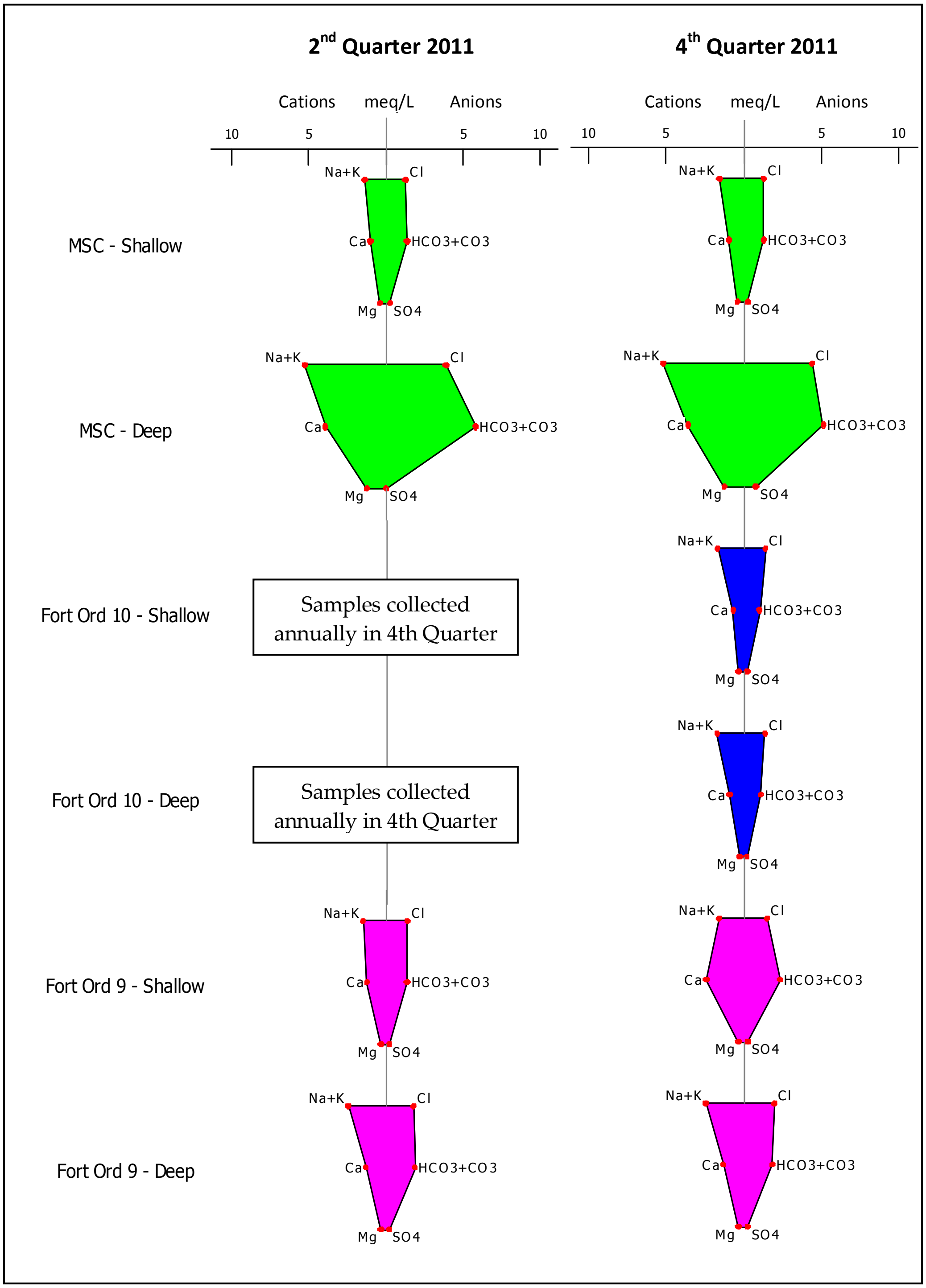


Figure 12: Stiff Diagrams for MSC, Fort Ord 9, and Fort Ord 10 Wells (Data source: Watermaster)

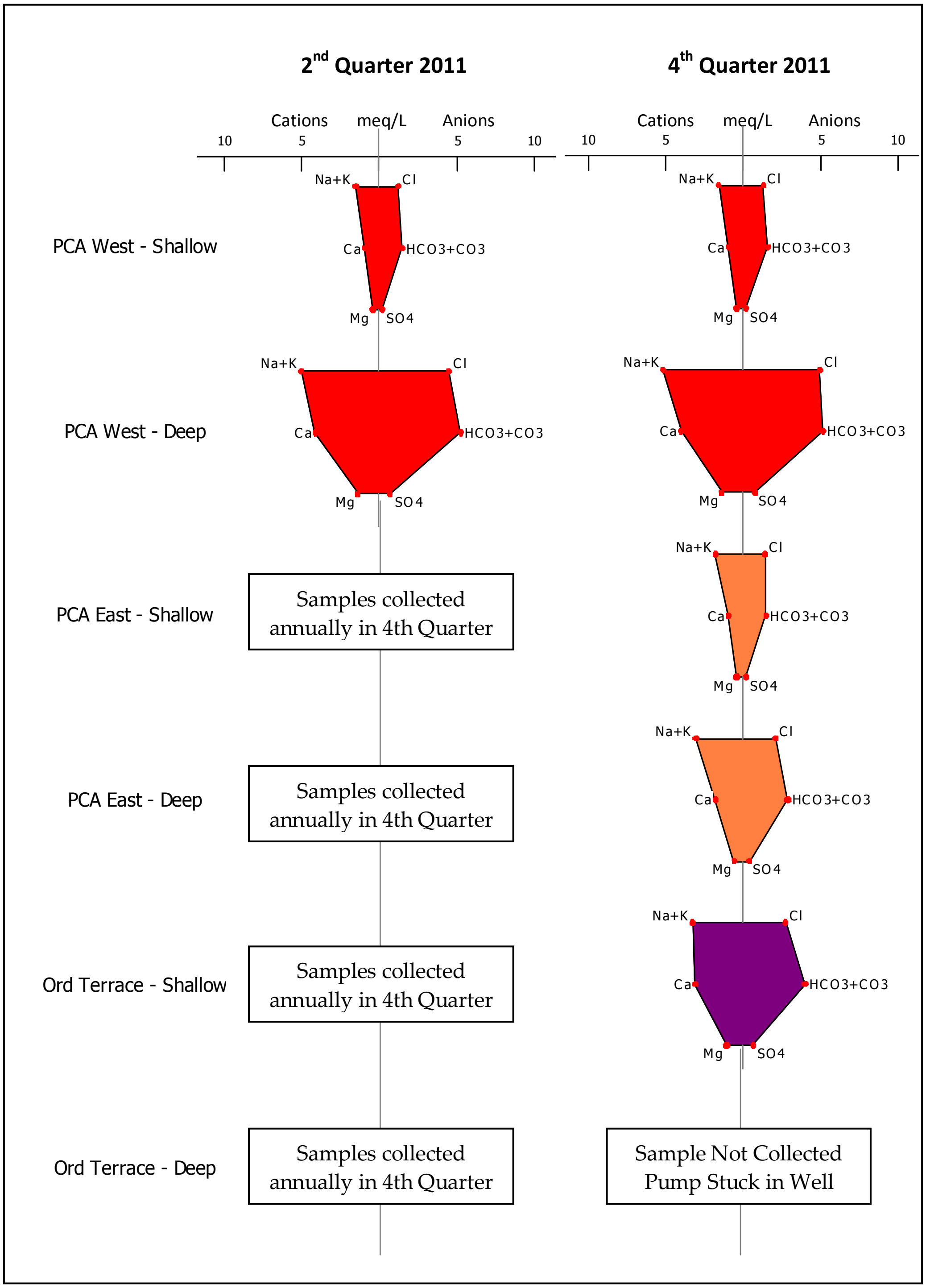


Figure 13: Stiff Diagrams for PCA West, PCA East, and Ord Terrace Wells (Data source: Watermaster)

Note: The Ord Terrace shallow well is designated as shallow but it was completed in the upper part of the Santa Margarita aquifer. This is evident in similar shape of the Stiff diagrams for the shallow and deep zones.

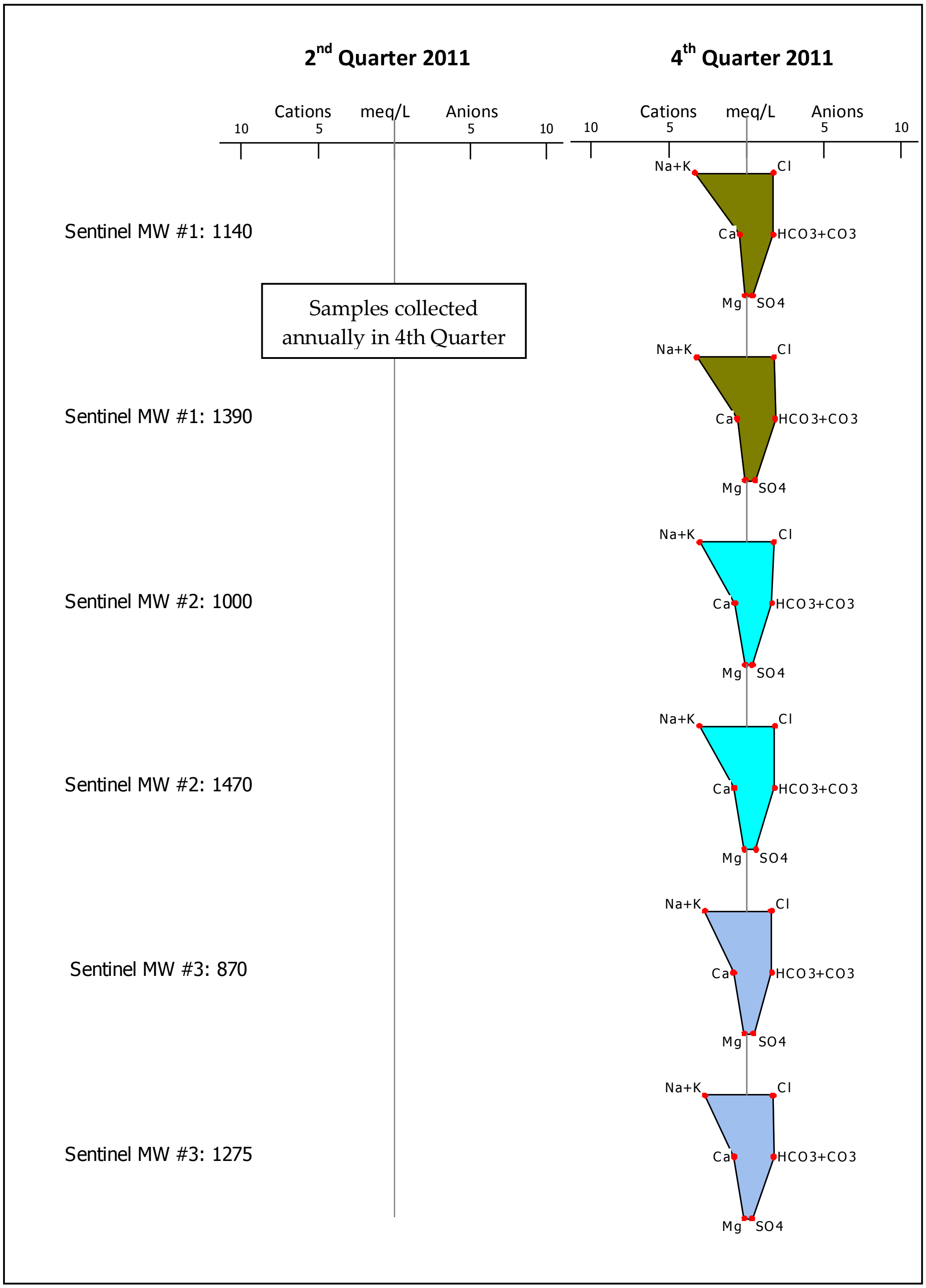


Figure 14: Stiff Diagrams for Watermaster Monitoring Wells 1 - 3
(Data source: Watermaster)

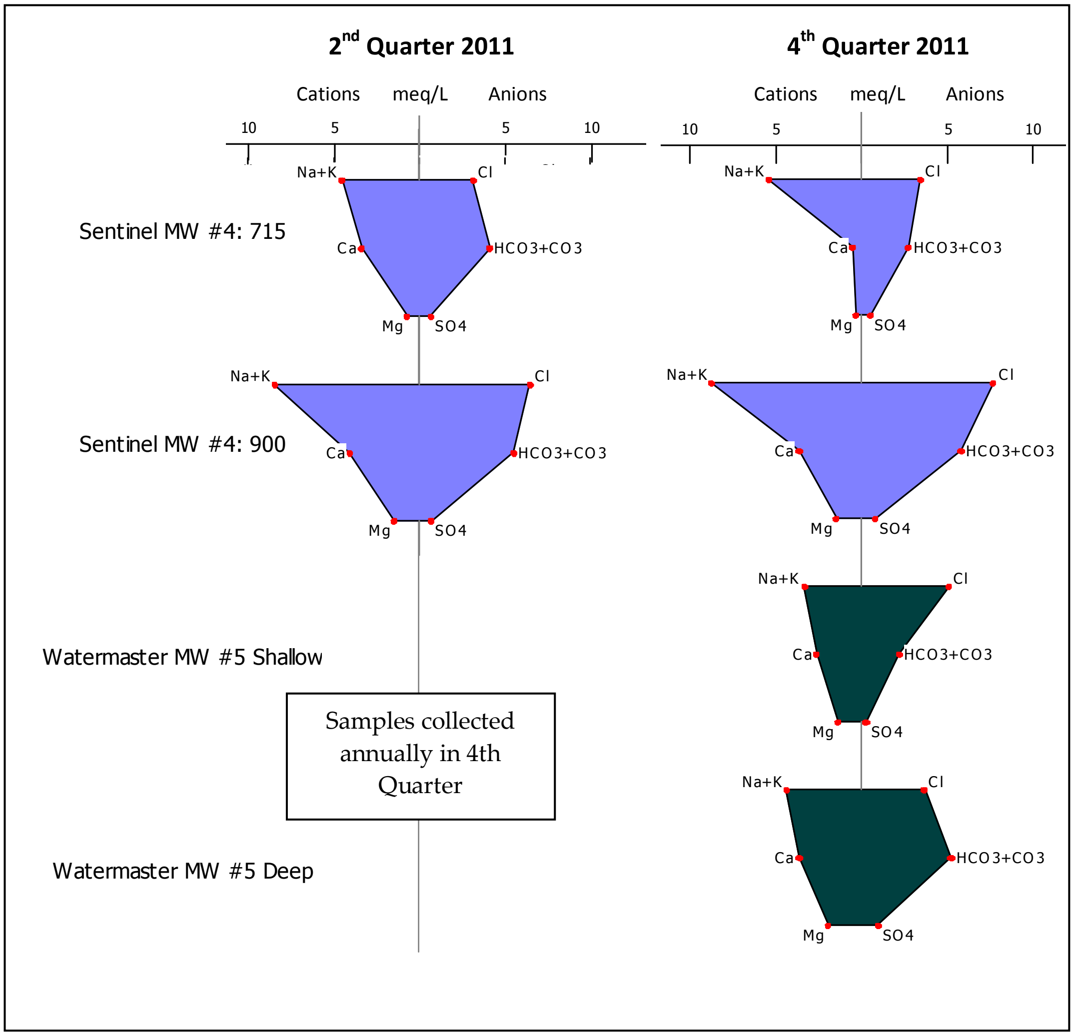


Figure 15: Stiff Diagrams for Watermaster Monitoring Wells 4 - 5 (Data source: Watermaster)

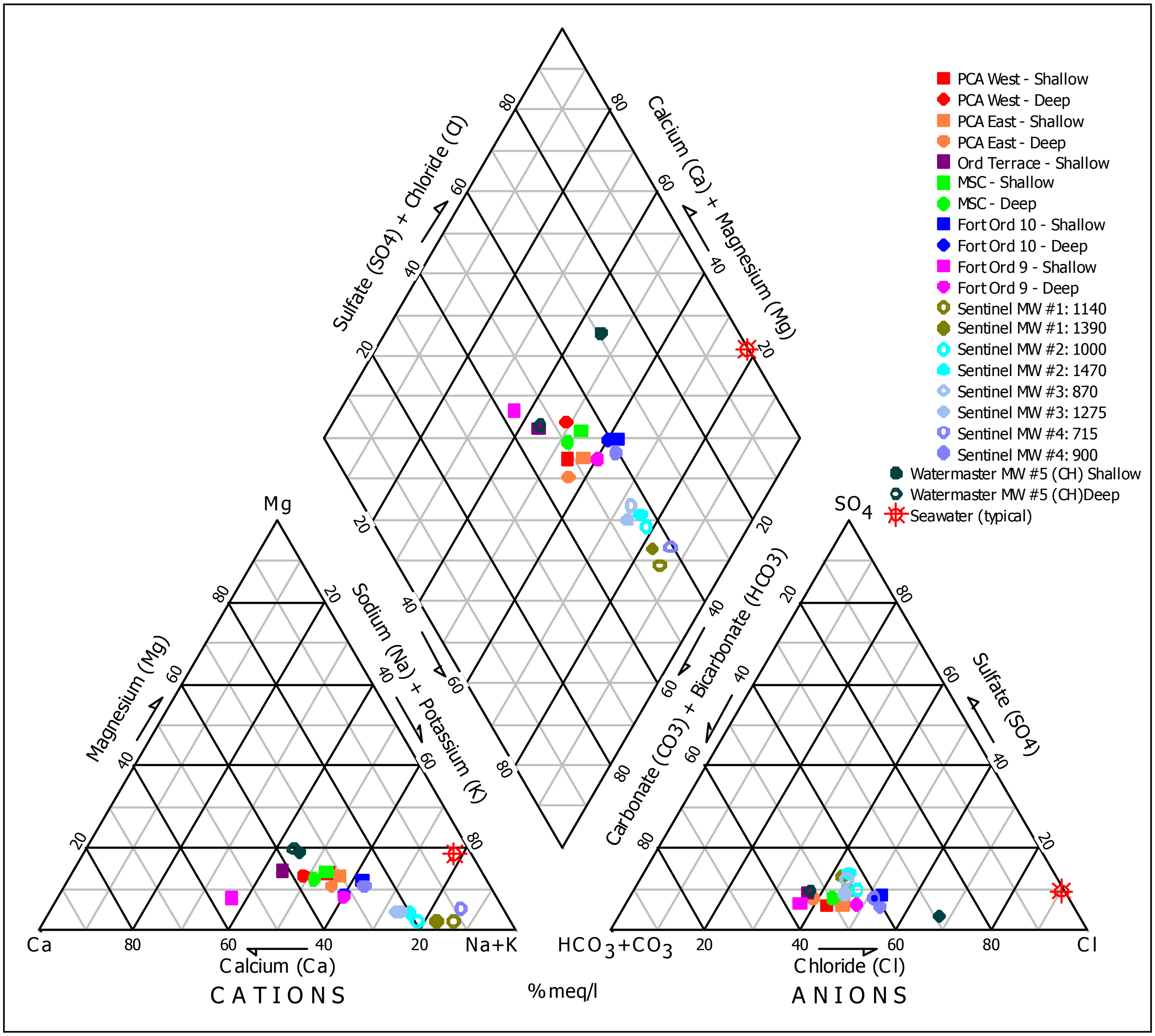


Figure 16: Piper Diagram for Seaside Groundwater Basin Monitoring Wells, 4th Quarter Water Year 2011 (July-August 2011) (Data source: Watermaster)

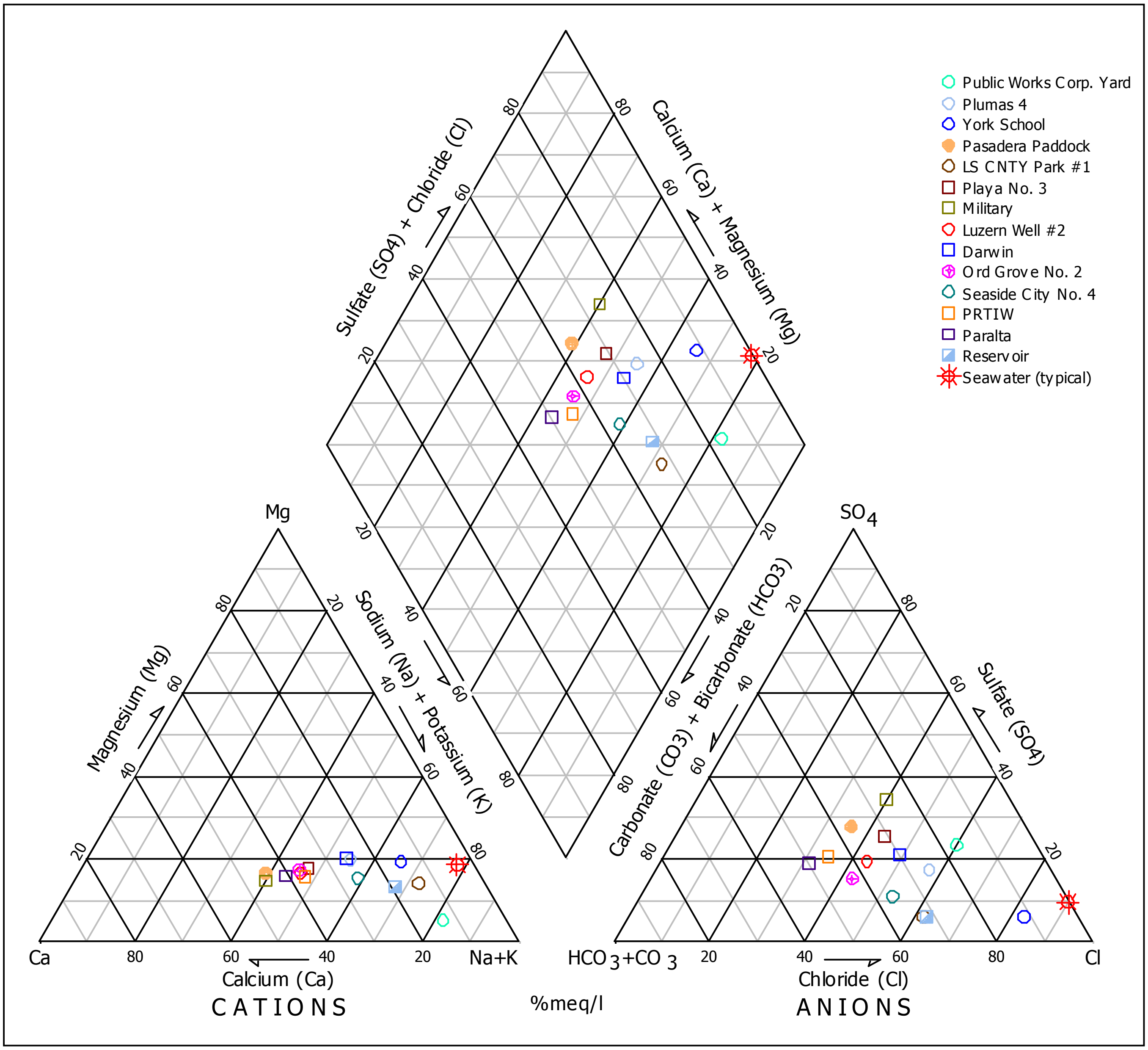


Figure 17: Piper Diagram for Seaside Groundwater Basin Production Wells, 4th Quarter Water Year 2011 (July-August 2011) (Data source: Watermaster)

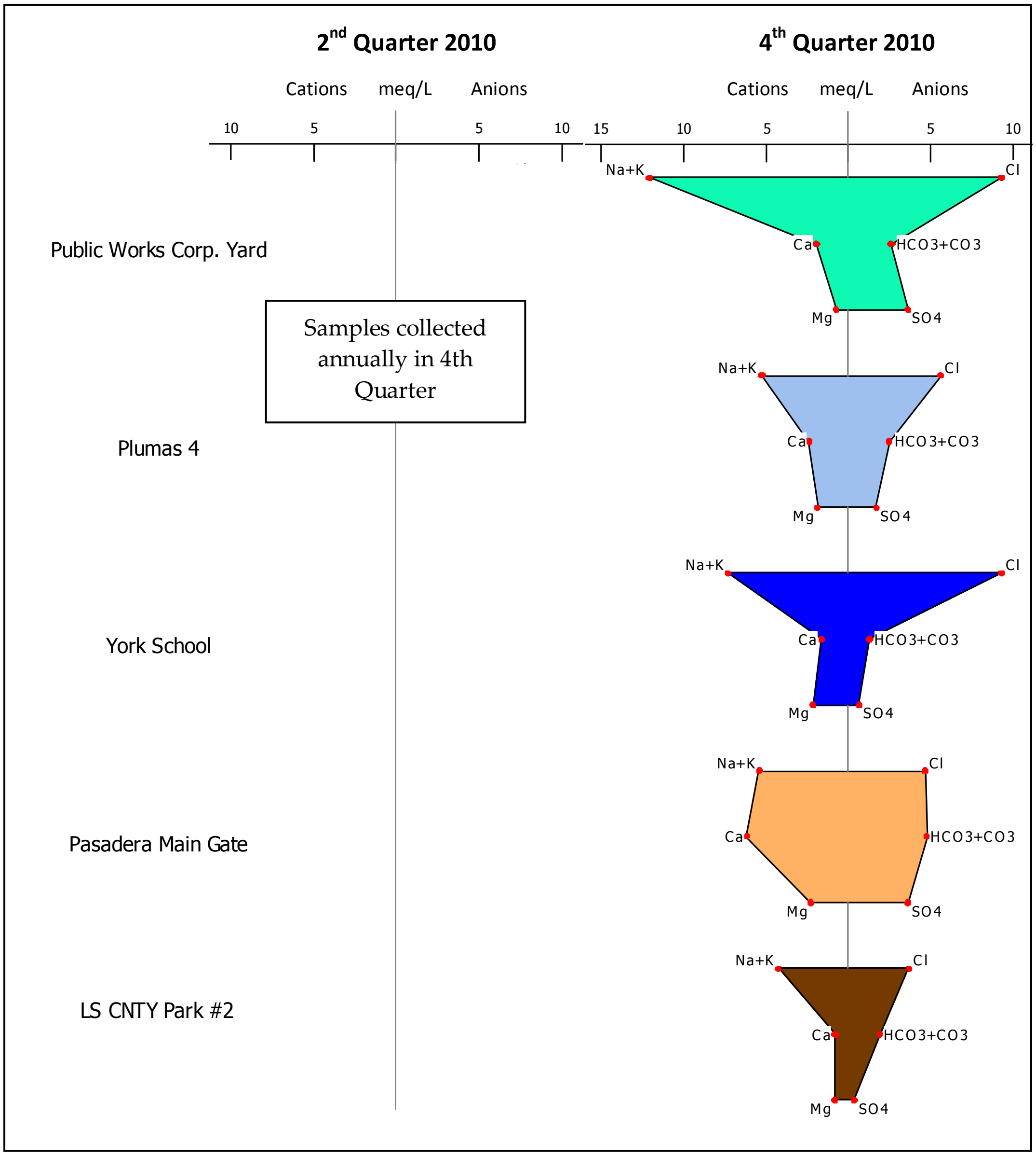


Figure 18: Stiff Diagrams for Southern Subbasin Production Wells (Data source: Watermaster)

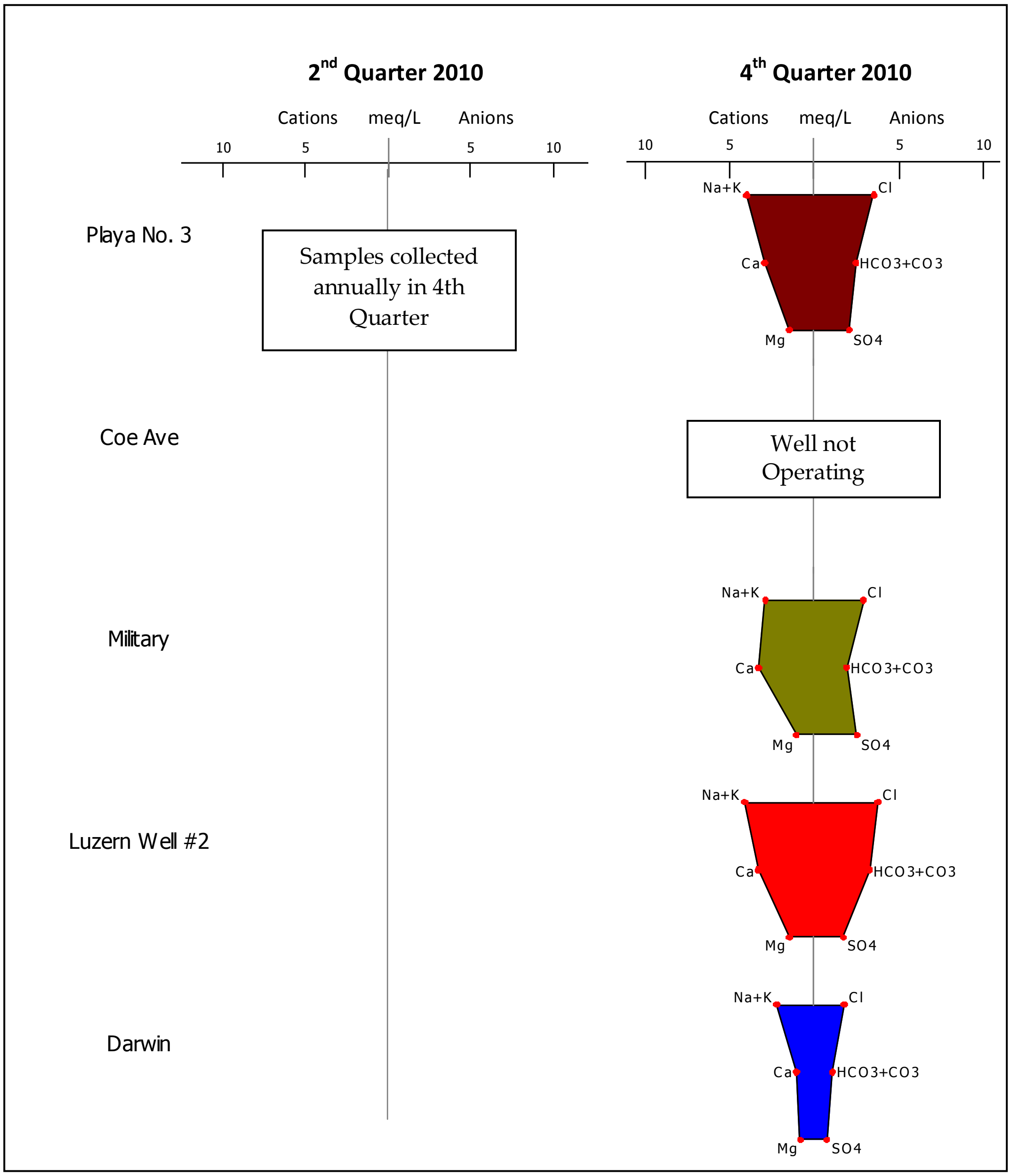


Figure 19: Stiff Diagrams for Northern Subbasin Production Wells #1 (Data source: Watermaster)

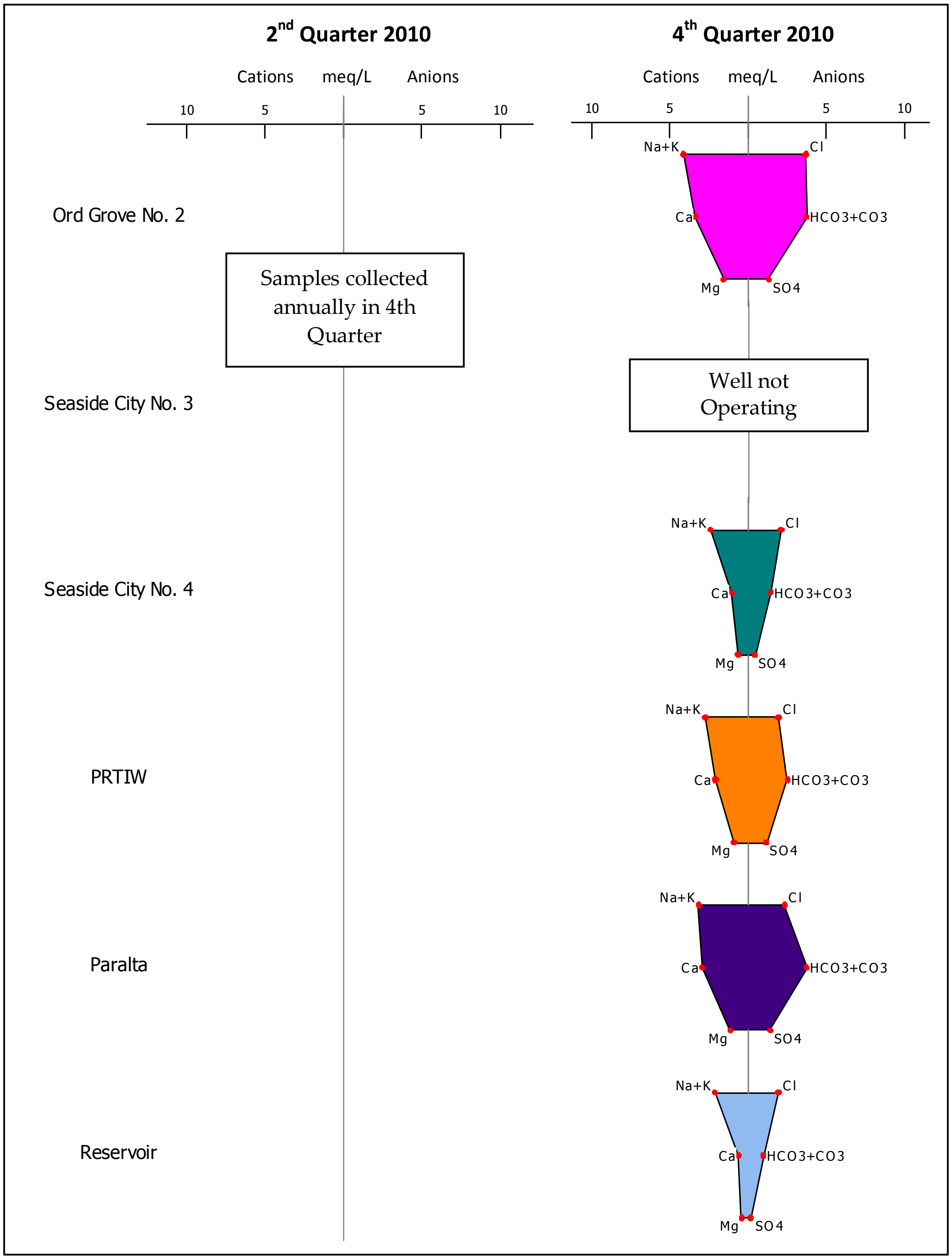


Figure 20: Stiff Diagrams for Northern Subbasin Production Wells #2 (Data source: Watermaster)

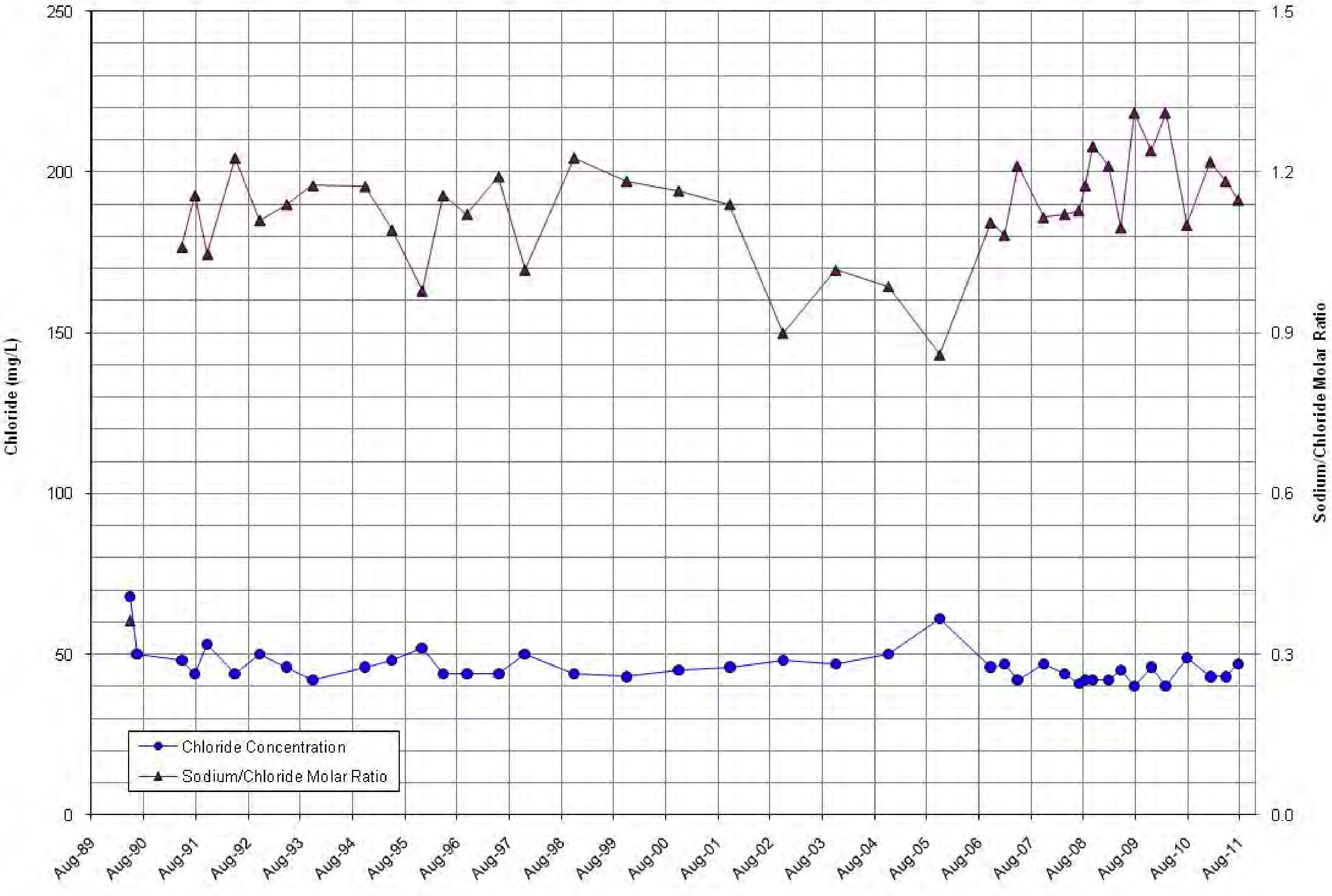


Figure 21: Historical Chloride and Sodium/Chloride Molar Ratios, Shallow PCA West Well

CHLORIDE CONCENTRATION MAPS

FOURTH QUARTER WATER YEAR 2011 (JULY-AUGUST 2011)

Fourth quarter Water Year 2011 chloride concentrations were mapped using data from July and August 2011. The maps for the shallow and deep zones are included on Figure 22 and Figure 23 respectively.

The shallow zone 4th quarter Water Year 2011 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 49 mg/L. More inland wells have consistently shown higher chloride concentrations than the coastal wells. Based on the existing data, there is no discernable spatial trend of higher coastal chloride concentrations, and therefore no indication of seawater intrusion.

The deep zone 4th quarter Water Year 2011 chloride concentration map is shown on Figure 23. Because the chloride data shows no discernable spatial distribution, with high concentrations in close proximity to low concentrations, the data cannot be readily contoured. For the data available in the deep zone, chloride concentrations near the coast range between 60 and 330 mg/L; this is similar to the previous year's concentrations, except Sand City's Public Works well which had a chloride increase of almost 100 mg/L. The Public Works well now has the highest chloride concentration by almost 60 mg/L. This well should be resampled within the next month to confirm the concentration. Of note, is that the Public Works well is located within the Dune Sands along the coast and may not be connected to the basin's shallow Paso Robles aquifer. If continued increases in chloride are observed at this well, the cause for the increase will need to be investigated.

Based on the existing data, there is no discernable spatial trend of higher coastal chloride concentrations, and therefore no indication of indication of seawater intrusion.

SODIUM/CHLORIDE RATIOS

Chemographs showing sodium/chloride molar ratios over time are plotted for each of the 18 monitoring wells plotted on the Piper and Stiff diagrams. An example plot displaying ratios for the shallow PCA West well is shown on Figure 21. The complete set of chemographs is included in Appendix B.

Although sodium/chloride ratios dropped in some wells during 2011; none of the data from the monitoring wells display a steady downward trend in sodium/chloride ratios. Furthermore, the majority of the ratios are consistently above 0.9. The sodium/chloride ratios, therefore, do not indicate any incipient or ongoing seawater intrusion.

Figure 22: Shallow Zone Chloride Concentration Map – 4th Quarter WY 2011

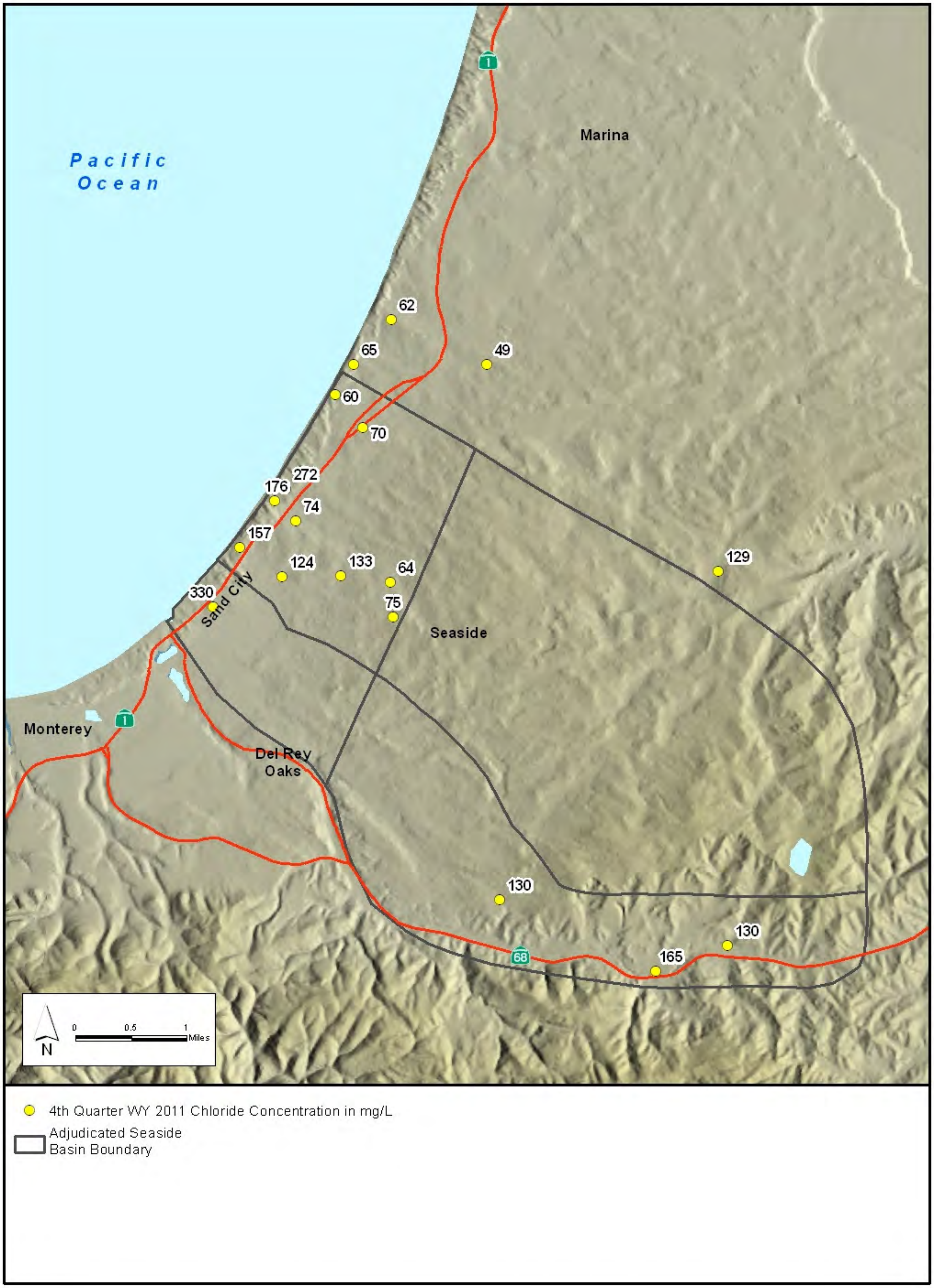


Figure 23: Deep Zone Chloride Concentration Map – 4th Quarter WY 2011

ELECTRIC INDUCTION LOGS

Two induction logging events took place in the sentinel wells during WY 2011. As occurred last water year, the first logging event was conducted in January, and the second in July. The logs from these events are included in Figure 24, along with the average readings from 2007 through 2010.

Feeney (2007) described the 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 μmhos/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 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. In previous years, the Dune Sands and Aromas Formation have shown slight increases in salinity. This trend has continued for sentinel well SBWM-2, SBMW-3, and SBMW-4 in Water Year 2011. SBMW-1, however, shows decreasing salinity compared to previous results. As has been the case historically, none of the wells show detectable changes to the lower aquifers where production wells extract groundwater. This indicates that there is no seawater intrusion into these deeper aquifers.

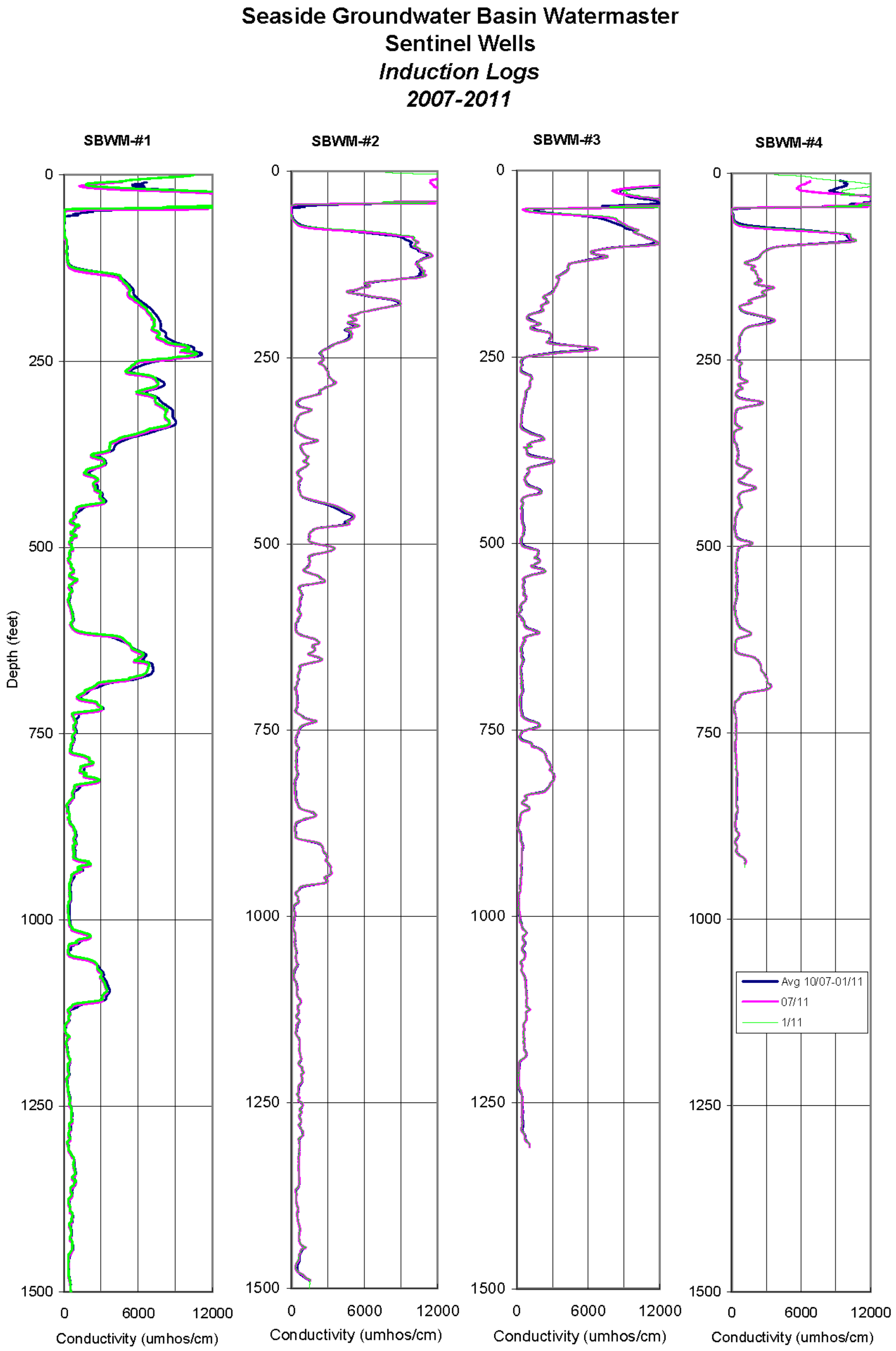


Figure 24: Sentinel Well Induction Log

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 25.

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 are well below sea level. The monthly groundwater levels are similar to what they were two years ago, but still higher than the low experienced in Water Year 2008. The hydrograph peaks and lows are strongly influenced by pumping and/or injection occurring in the area upgradient of the monitoring well when the water level measurements were taken. For example, CAW production in Water Year 2011 started a month earlier than in Water Year 2010 which likely influenced the spring peak groundwater levels. 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 25 shows an overall decline in groundwater levels until 2009, thereafter levels have more or less stabilized over the past three years.

The amount injected into the deep Santa Margarita aquifer was essentially the same amount that was extracted as part of the aquifer storage and recovery program.

Although groundwater levels appear to be stabilizing after 14 years of decline, it is still 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.

In the shallow zone, recent groundwater levels have continued their gradual increase (Figure 25). The triennial reduction in pumping is likely responsible for these increases. Seasonal increases 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 25). 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 2011 (JANUARY-MARCH 2011)

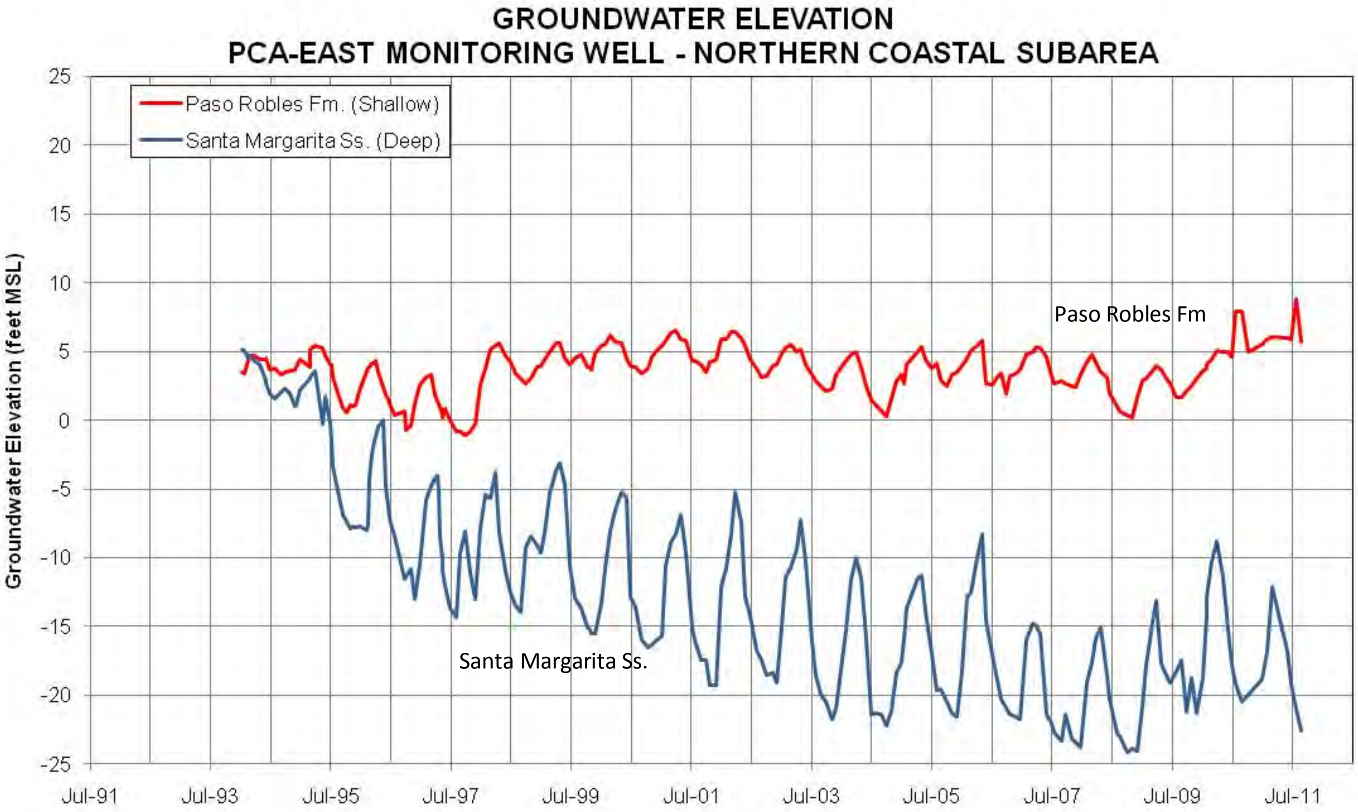
Groundwater level maps for the shallow and deep aquifer zones for the 2nd quarter of Water Year 2011 are shown on Figure 26 and Figure 27 respectively.

The shallow aquifer does not show seasonal fluctuations to the same extent as the deep aquifer. The groundwater level contours for Water Year 2011 remains essentially the same along the coast and in the Laguna Seca subarea. The Northern Coastal subarea pumping depression is slightly larger than the previous year due to lowered groundwater levels, as discussed under the groundwater level trends section above. 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 26). Of note is that many of the production well water levels usually used for contouring the shallow aquifer were missing, particularly for the 4th quarter. This was because the well was pumping at the time the reading was taken.

Second quarter groundwater levels in the deep aquifer, particularly along the coast, are generally higher than 4th quarter groundwater levels by up to 10 feet due to the seasonal variations seen on Figure 25. The 20 foot below sea level contour around CAW's main production wells in the Northern Coastal subarea reoccurred in Water Year 2011 after being absent in Water Year 2010. This is likely due to the addition of the MPWMD Santa Margarita well pumping by CAW to assist in recovery of injected water. The impact of adding this well to this area, which already has a number of pumping wells, has increased the instantaneous pumping depression caused when all wells are operating at the same time. Overall, it appears that groundwater elevations in the coastal subareas have declined over elevations from the previous water year, but as described in the section above on Trends, this may be a function of operational changes. Groundwater elevations in the Laguna Seca subarea dropped approximately two feet from the previous water year.

FOURTH QUARTER WATER YEAR 2011 (JULY-AUGUST 2011)

Groundwater elevation maps for the shallow and deep aquifer zones for the 4th quarter of Water Year 2011 are shown on Figure 28 and Figure 29 respectively. The contours for the shallow aquifer reflect a slight decrease in groundwater levels, particularly in the Northern Coastal subarea (Figure 28). The 4th quarter deep zone groundwater elevations (Figure 29) show the coastal pumping depression increased from the previous water year.



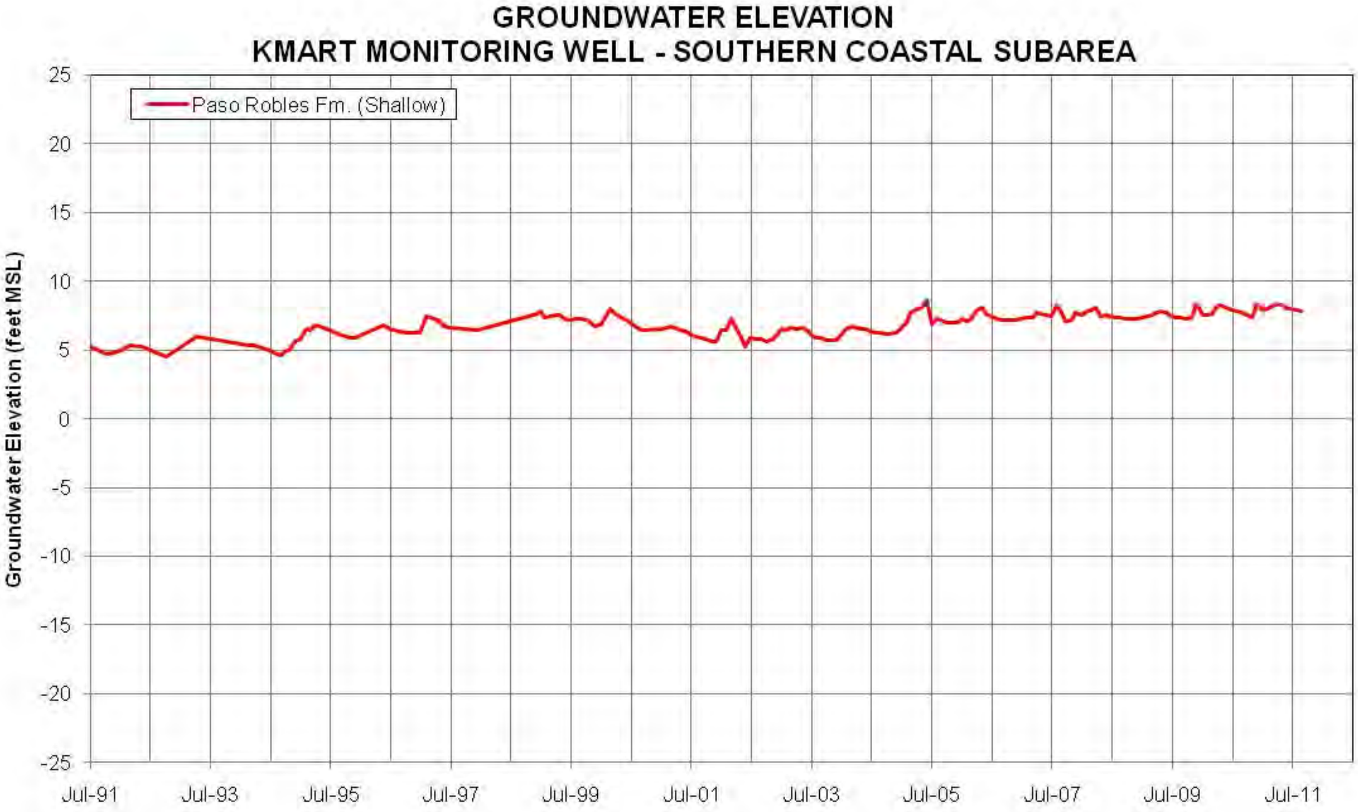
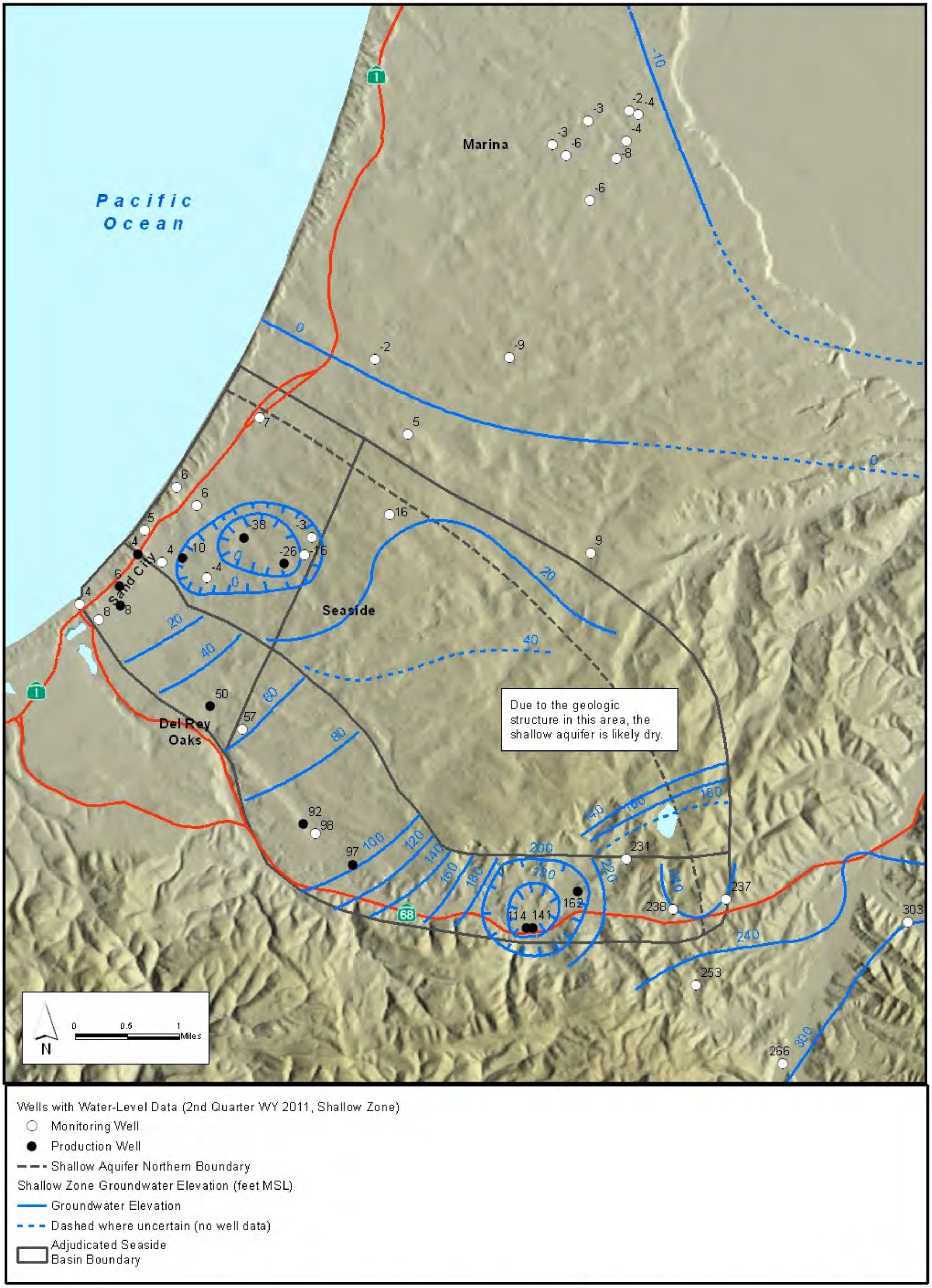


Figure 25: Example Hydrographs (Source: Watermaster)



Due to the geologic structure in this area, the shallow aquifer is likely dry.

Figure 26: Shallow Zone Water Elevation Map – 2nd Quarter WY 2011 (January-March 2011)

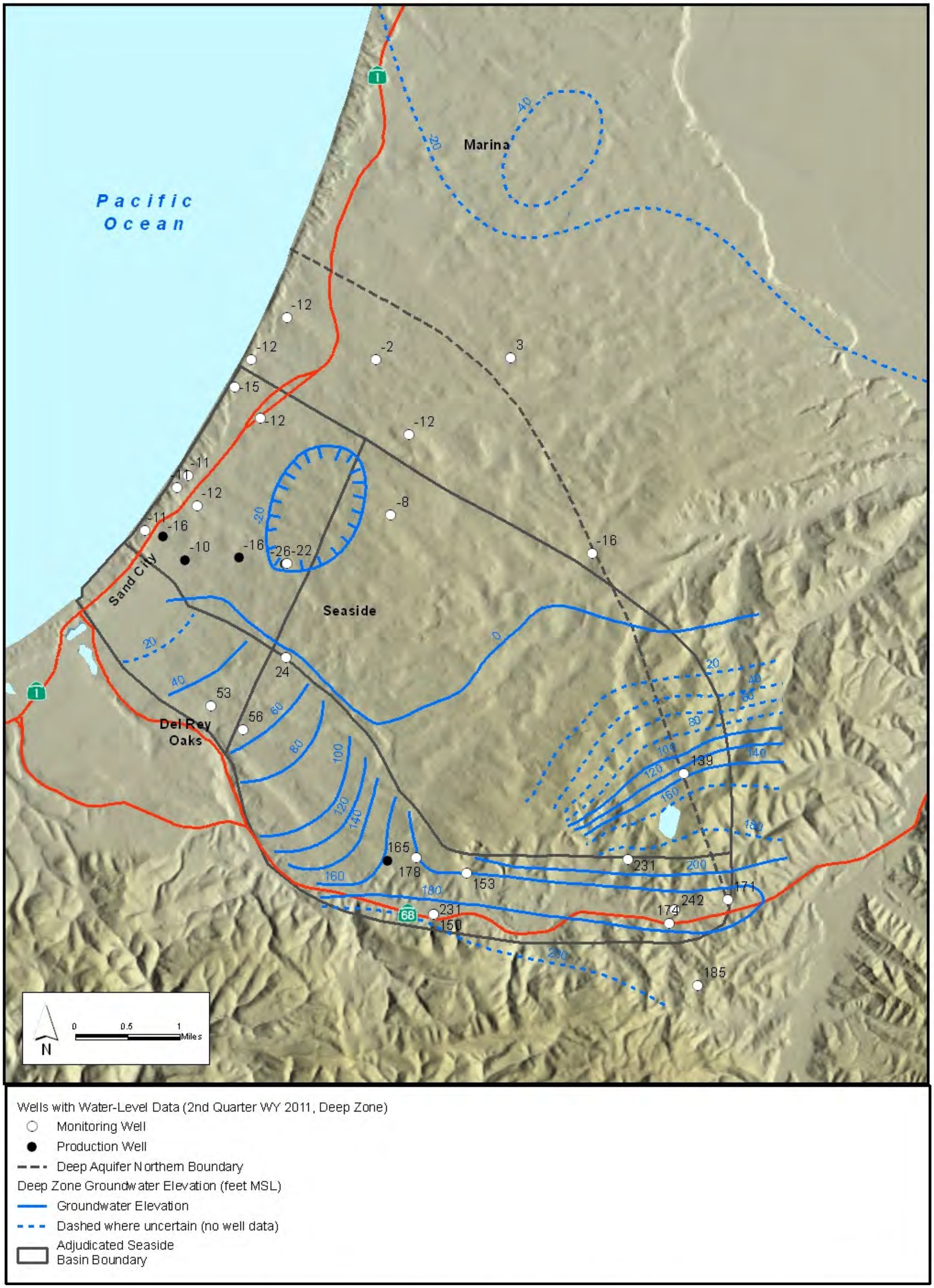


Figure 27: Deep Zone Water Elevation Map – 2nd Quarter WY 2011 (January-March 2011)

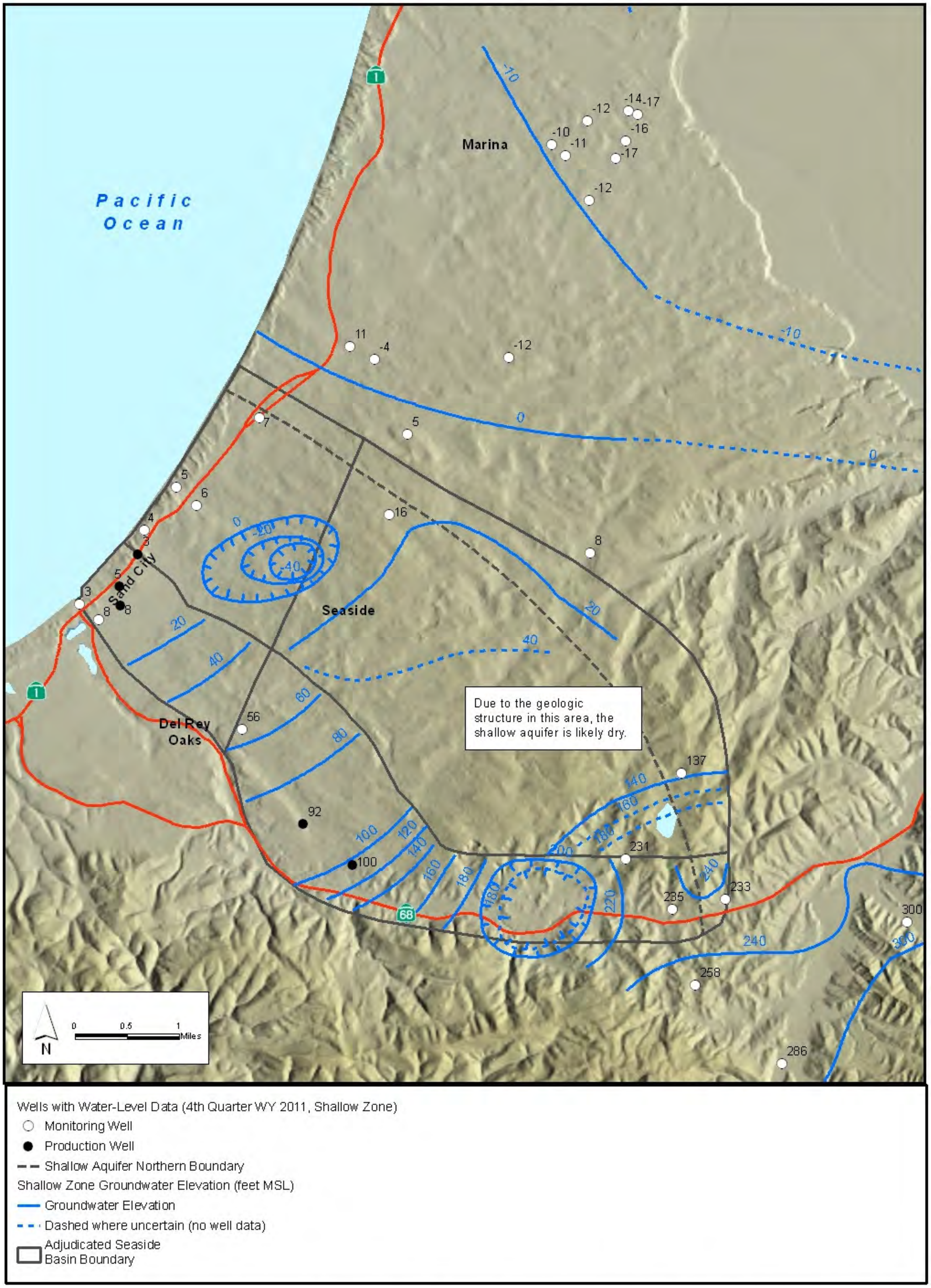


Figure 28: Shallow Zone Water Elevation Map – 4th Quarter WY 2011 (July/August 2011)

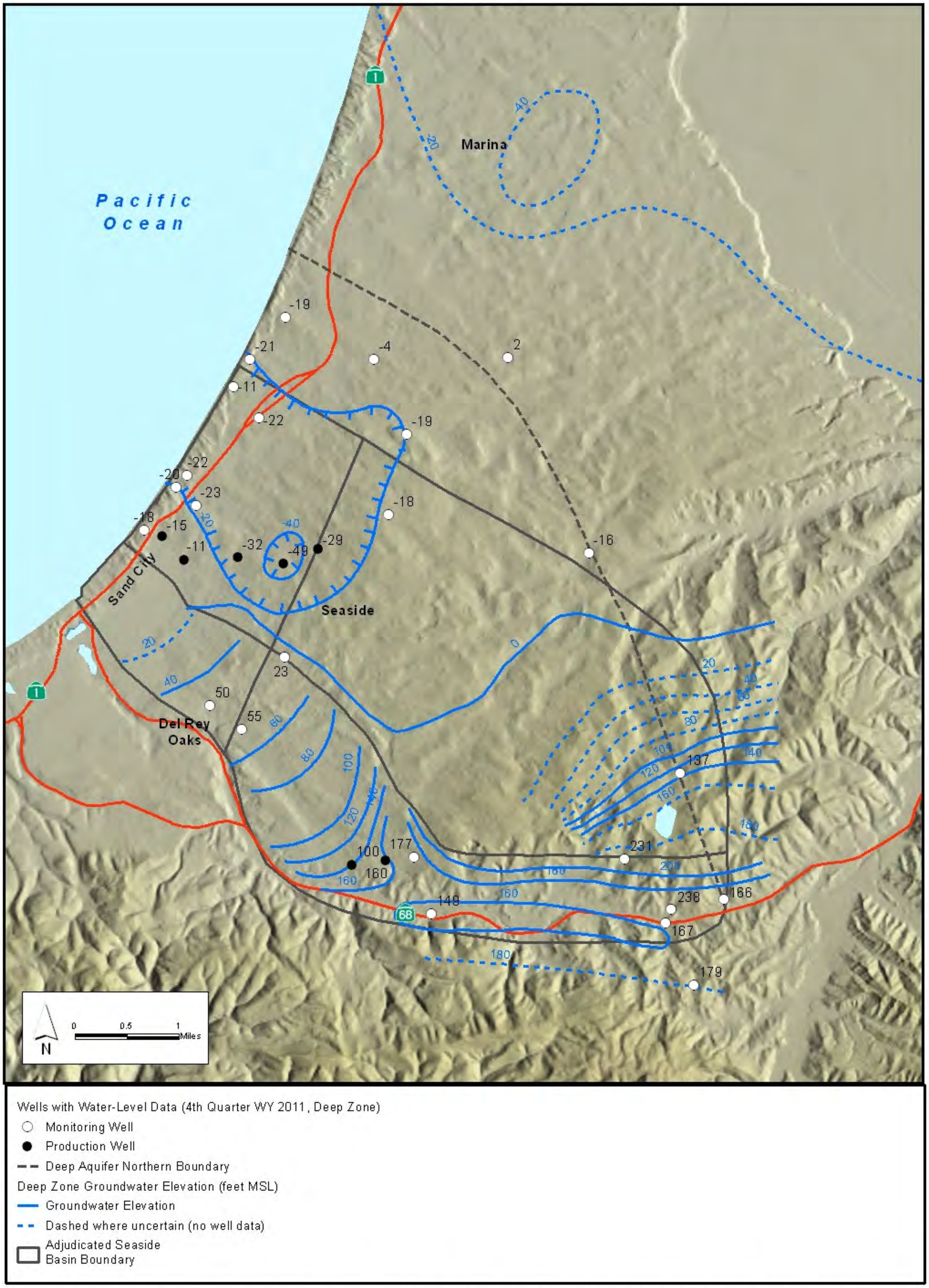


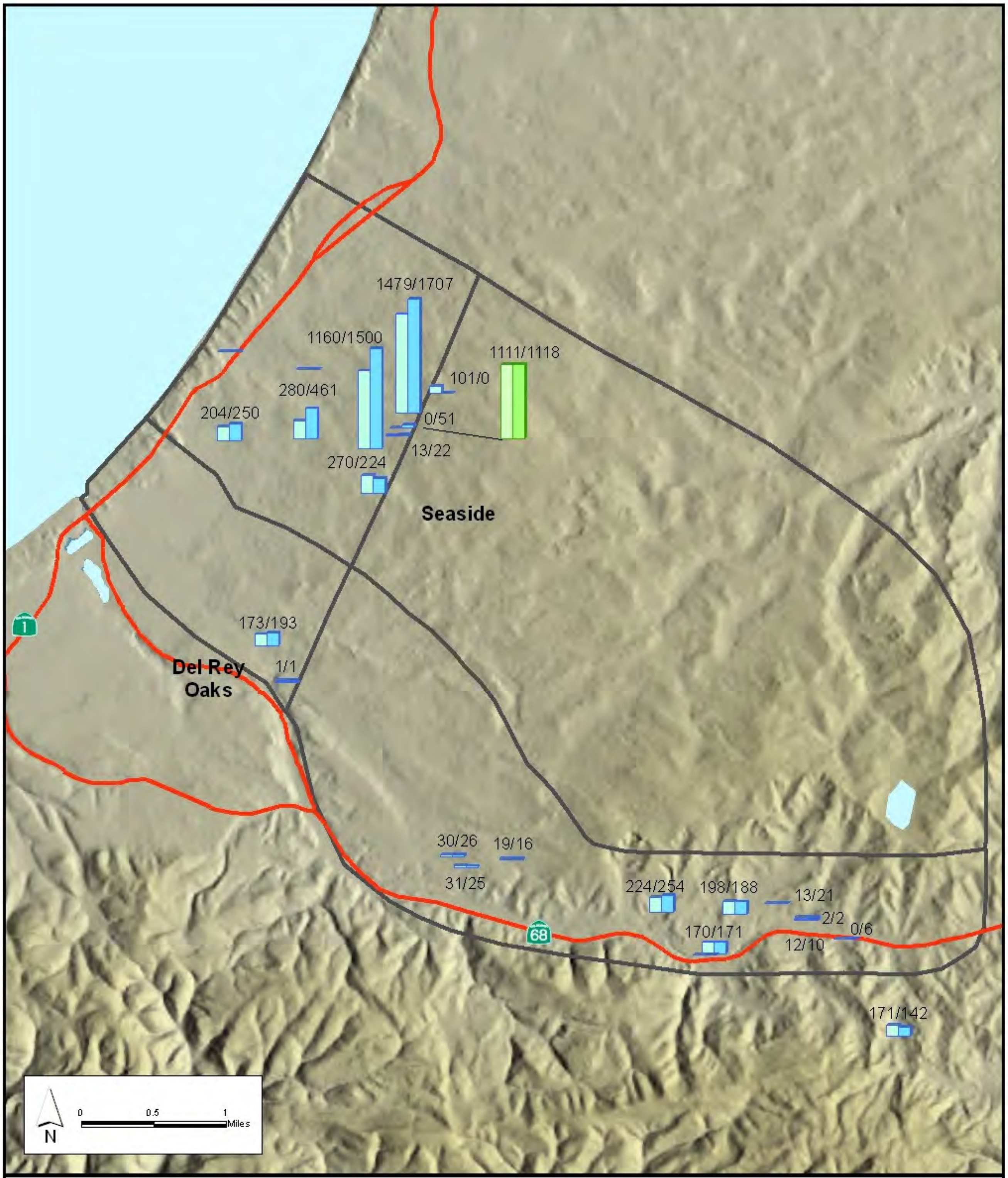
Figure 29: Deep Zone Water Elevation Map – 4th Quarter WY 2011 (July/August 2011)

PUMPING

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 2011 was 4,151.5 acre-feet, which is 396.1 acre-feet less than Water Year 2010. Net pumping is the amount pumped after the aquifer storage and recovery program is taken into account. This means that more water is actually pumped from CAW's wells to recover water injected the previous operational year. The blue charts on Figure 30 reflect the actual or gross amounts pumped from each well, and the green chart reflects the amount of water injected during Water Year 2011. As with previous years, the majority of pumping occurs at CAW's Ord Grove 2 and Paralta wells. These wells, together with the MPWMD's Santa Margarita well were also used for recovery of injected water. Water Year 2011 volumes for these wells are therefore greater than in Water Year 2010.

Annual reported production for Water Year 2011 was less than the Court-ordered operating yield of 5,040 acre-feet (Figure 31).



Wells pumping less than 1 acre-foot per year are not included. Where possible, the well is located at the bottom of the bar chart representing production. If a number of wells are in close proximity, the chart is moved to prevent overlap.

Pumping for the two Pasadera Golf Course wells (Paddock and Main Gate) are combined, as they are not metered separately.

The blue charts reflect the actual or gross amounts pumped from each well, and the green chart reflects the amount of water injected. The gross amount pumped less the amounts injected or transfered to the City of Seaside equals the net production reported to the Watermaster.

Figure 30: Watermaster Producers' Pumping Distribution for Water Years 2010 and 2011

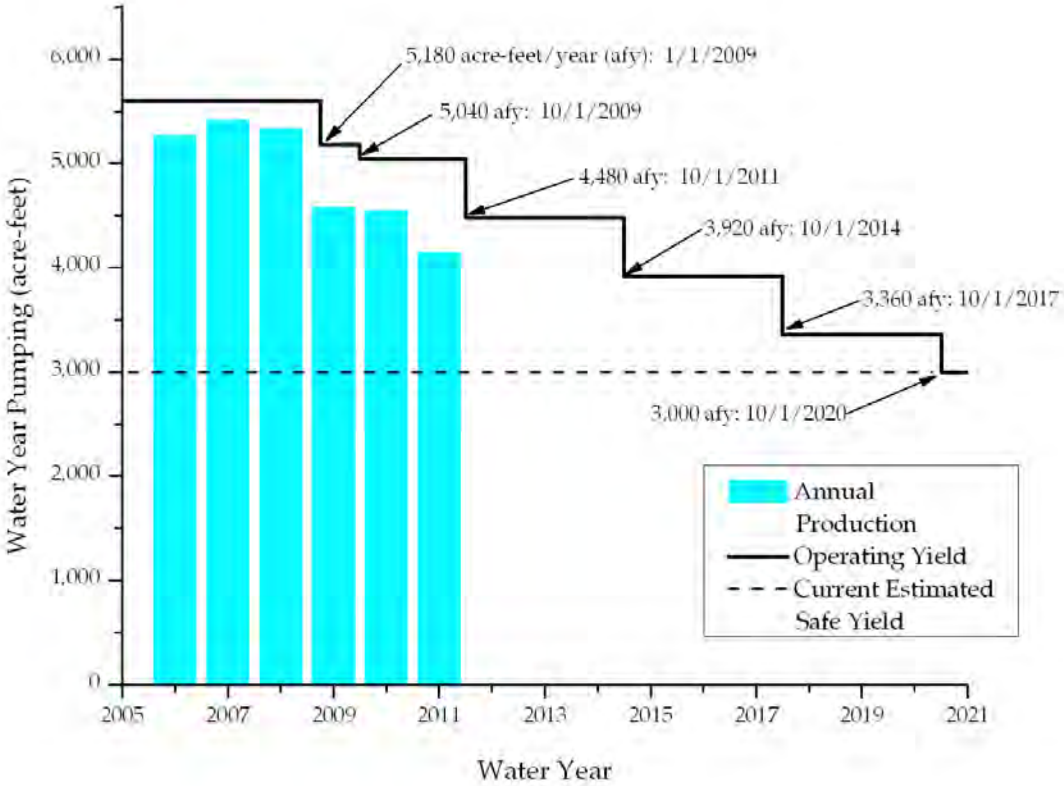


Figure 31: Annual Reported Groundwater Production and Operating Yield for Watermaster Producers

PROTECTIVE GROUNDWATER ELEVATIONS

Preliminary protective groundwater elevations were determined in 2009 using the Seaside Groundwater Basin groundwater flow model and cross-sectional modeling (HydroMetrics LLC, 2009b). Preliminary protective elevations for both the deep and shallow aquifers were established for monitoring well pairs with both a shallow and deep completion. Preliminary protective elevations are shown in Table 1.

Table 1: Summary of Preliminary 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 32 through Figure 35 show the historical groundwater elevations at each of the target protective elevation locations. Groundwater levels continue to be below preliminary protective elevations in all deep target monitoring wells (MSC deep, PCA-W deep, and Sentinel Well 3). Two of the three shallow wells' groundwater levels are above preliminary protective elevations: PCA-W shallow and CDM-MW4. MSC shallow is the only shallow target well with levels below its preliminary protective elevation.

The preliminary protective elevations for all wells could be fine-tuned and probably decreased by up to a few feet for some of them if aquifer properties estimated using the final calibrated Seaside Basin flow model are used in place of the properties used during initial cross-sectional modeling (HydroMetrics LLC, 2009b). The calibrated values were not used in the first attempt due to the timing of getting the model report out in time to meet the Watermaster's annual deadline. Work to refine the protective elevations may be performed when the water supply parameters of the Coastal Water Project are better defined.

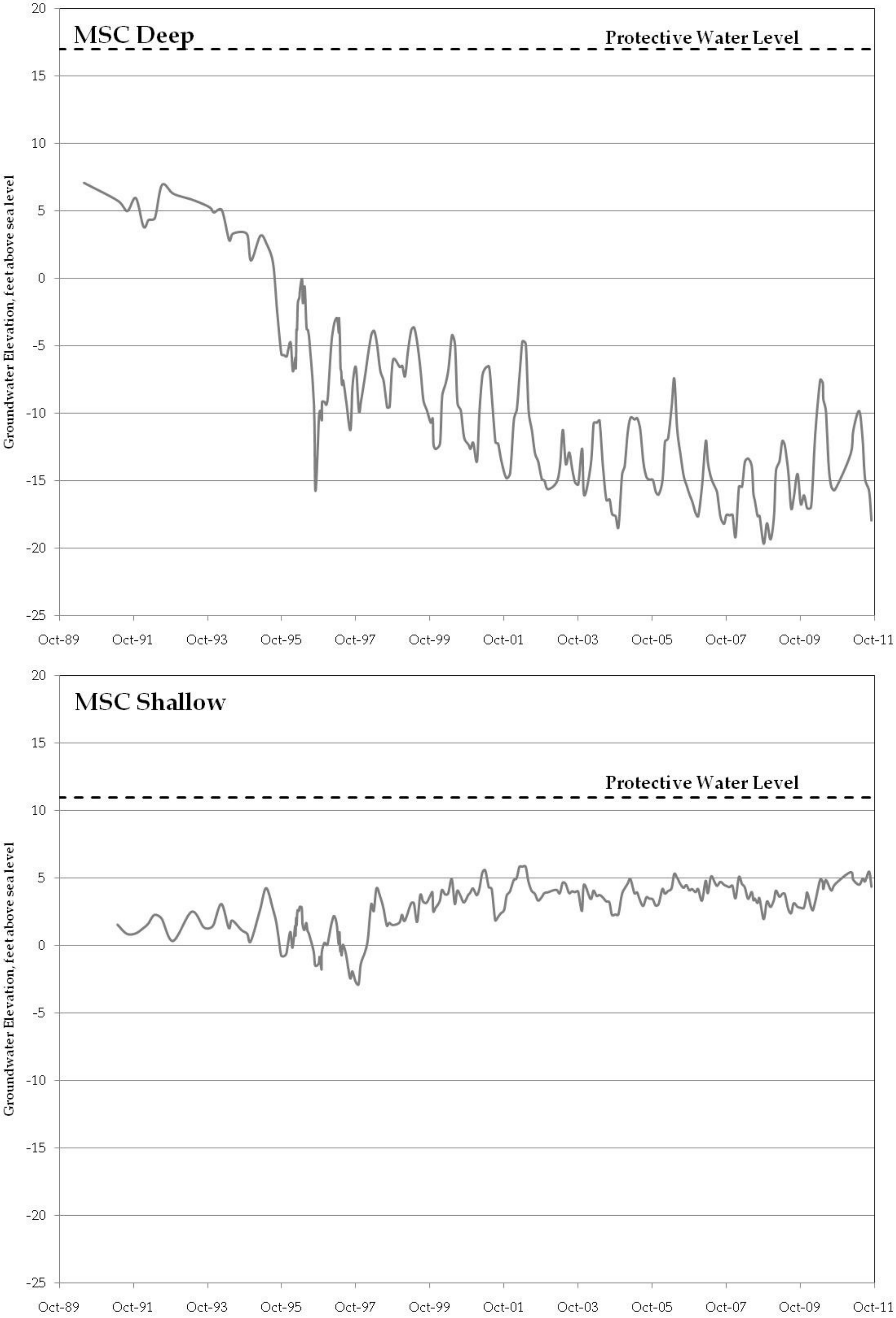


Figure 32: MSC Deep and Shallow Groundwater and Preliminary Protective Elevations

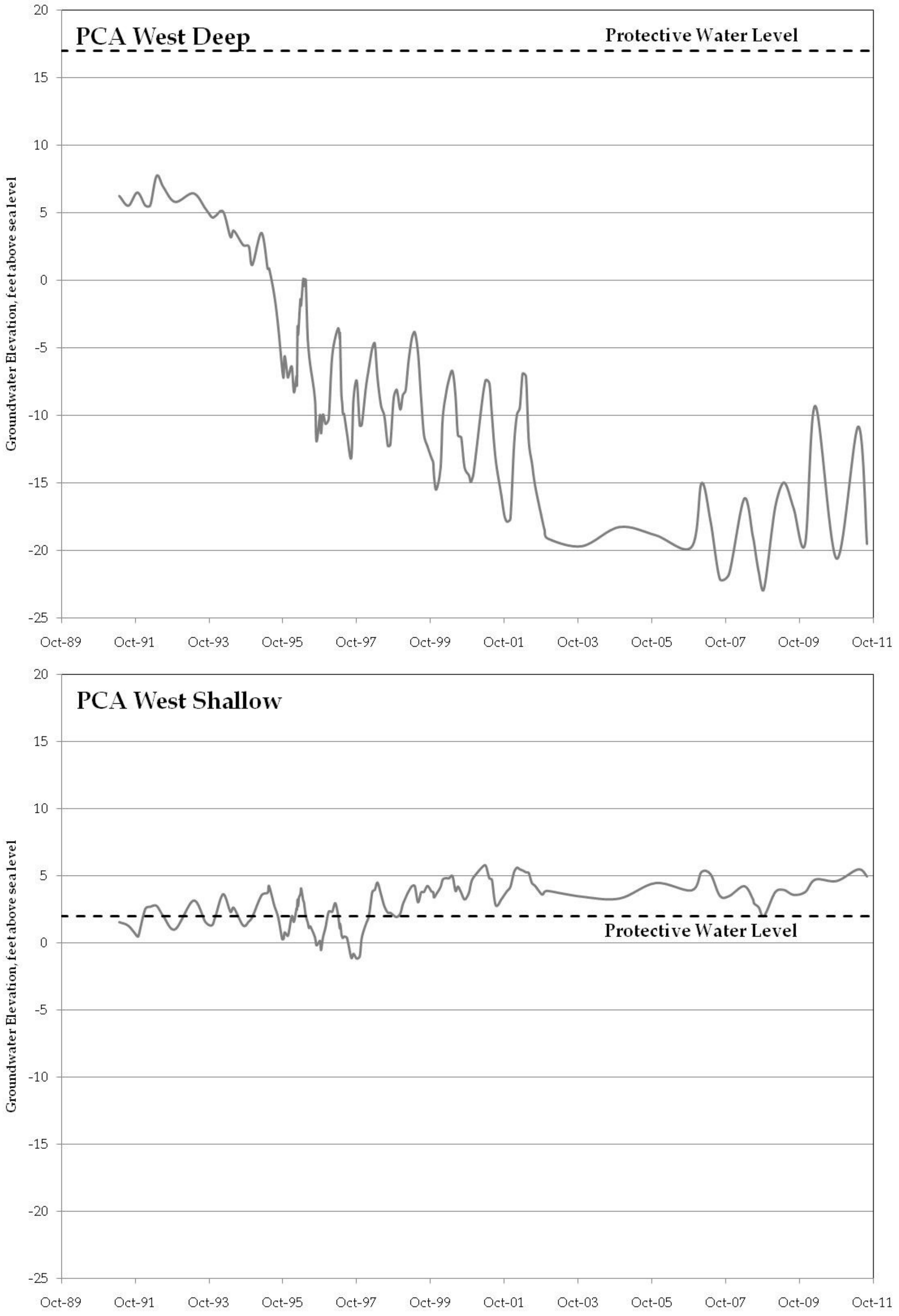


Figure 33: PCA West Deep and Shallow Groundwater and Preliminary Protective Elevations

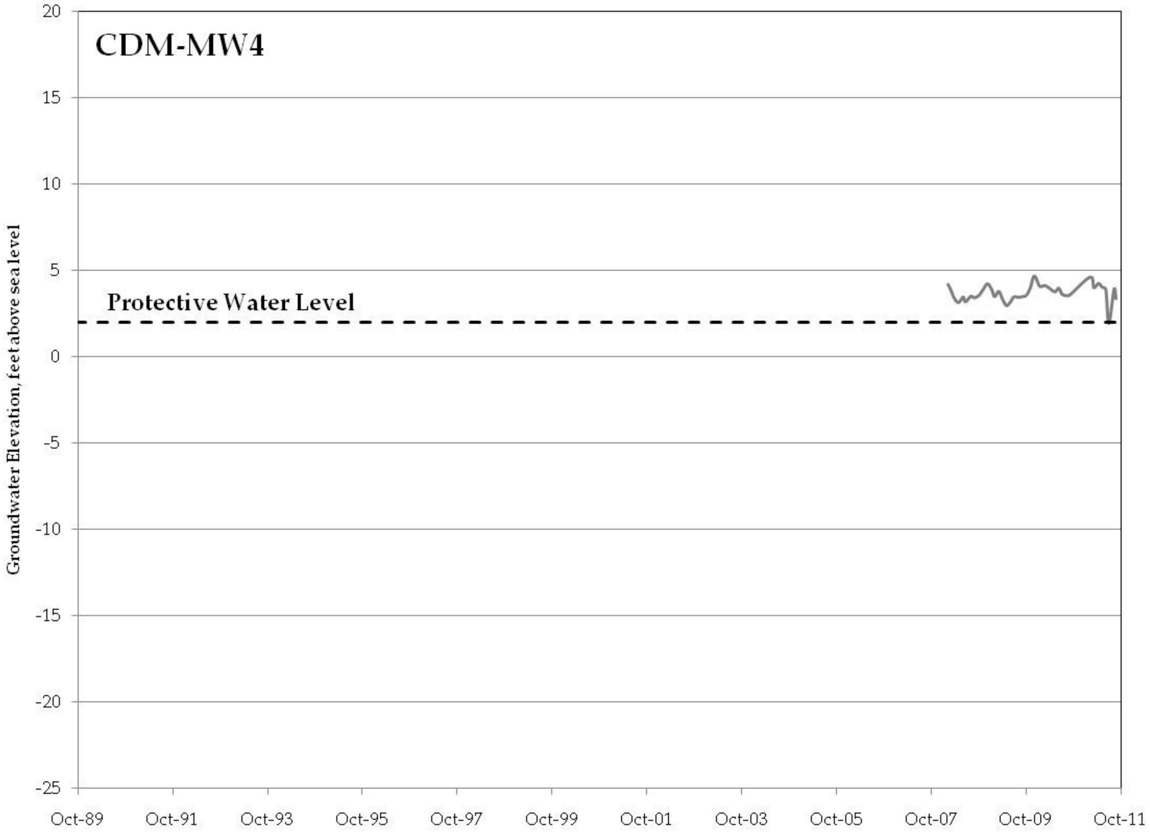


Figure 34: CDM-MW4 Groundwater and Preliminary Protective Elevations

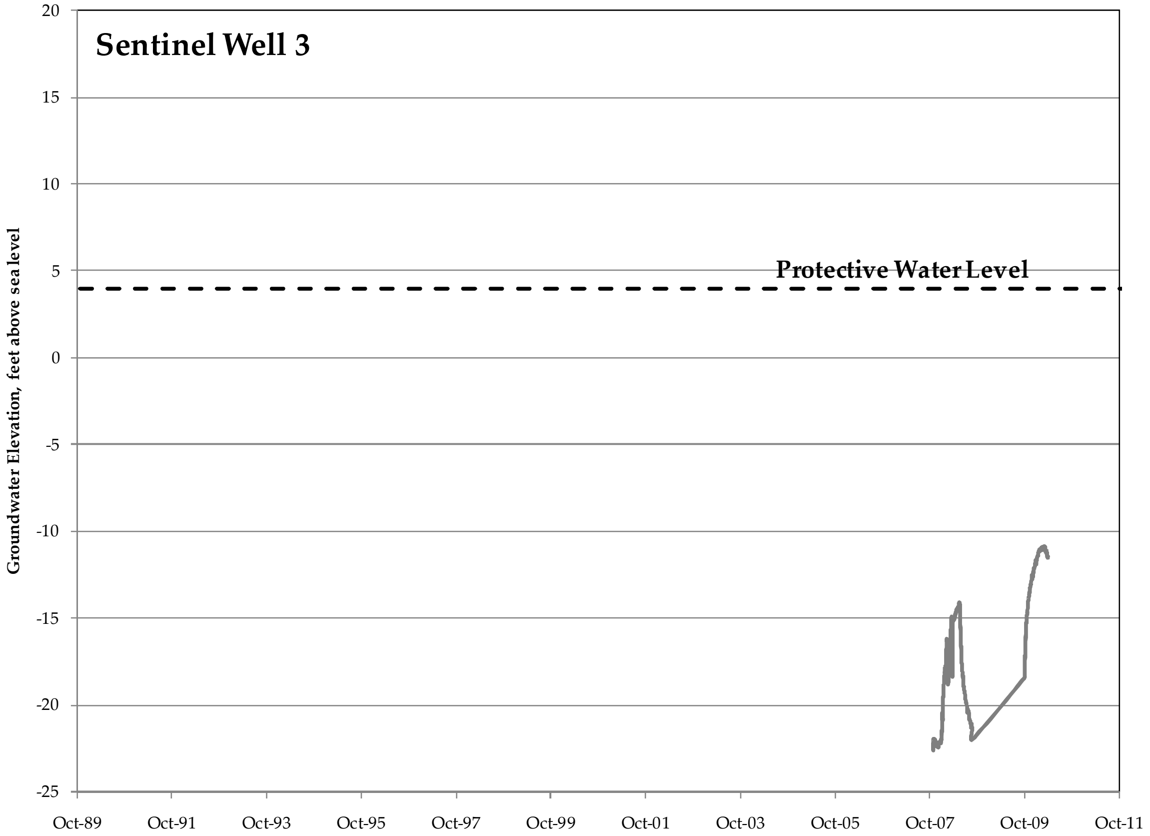


Figure 35: Sentinel Well 3 Groundwater and Preliminary Protective Elevations

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 is currently observed in existing monitoring or production wells. Analyses which indicate that seawater intrusion is not occurring include:

- All water samples for Water Year 2011 from depth-discreet monitoring wells plot generally in a single cluster on Piper diagrams, with no geochemical evolution towards seawater.

- Water samples collected from coastal sentinel wells generally plot in a single cluster on Piper diagrams.

- 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.

- Sand City's Public Works well has the highest chloride concentration in the basin (330 mg/L) and should be resampled within the next month to confirm the concentration. If concentrations over 250 mg/L persist, the Watermaster TAC should determine whether this well should to be sampled in both the second and fourth quarters.

- Stiff diagrams of production wells were not indicative of incipient seawater intrusion.

- Wells with chloride concentration increases over the past year are: PCA-W deep (15 mg/L increase over the past year), MSC deep (20 mg/L increase over the past year), sentinel well SBWM-4 shallow (20 mg/L increase over the past year), SBWM-4 deep (50 mg/L increase over the past year), SBWM-5 shallow (30 mg/L increase over the past year), and SBWM-5 deep (10 mg/L increase over the past year). Although the increases do not indicate seawater intrusion, their future trends must continue to be followed. Stiff and Piper diagrams for these wells do not indicate seawater intrusion, and it is likely that the increase is merely a natural localized fluctuation that is unrelated to seawater intrusion. No increase from current levels of monitoring is warranted.

- Of the wells from last year's SIAR that had increasing chloride concentrations, the deep PCA-W well is the only monitoring well that continued with an increase over the past year. Stiff and Piper diagrams for this well do not indicate seawater intrusion, and it is likely that the increase is merely a localized fluctuation that is unrelated to seawater intrusion. No increase from current levels of monitoring is warranted.

- No wells display decreasing sodium/chloride ratios that would indicate seawater intrusion.

- Maps of chloride concentrations do not show chlorides increasing towards the coast.

- 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.

- Groundwater production in the Seaside Groundwater Basin for Water Year 2011 was 4,151.5 acre-feet, which is 396.1 acre-feet less than Water Year 2010. This amount is less than the Court-mandated operating yield of 5,040 acre-feet per year that was required by October 1, 2011. The lower than historic pumping is a result of implementing the Court-mandated triennial reduction in an effort to bring the basin closer to hydrologic balance which is necessary to prevent seawater intrusion.

- Groundwater levels remain below preliminary protective elevations in all deep target monitoring wells (MSC deep, PCA-W, and Sentinel Well 3). Two of the three shallow wells' groundwater levels are above protective elevations: PCA-W shallow and CDM-MW4. MSC shallow remains below preliminary 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 27 and

Figure 29). Two potential processes may explain why no seawater intrusion has 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 many 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 27 and Figure 29), suggesting that this aquifer is not in close communication with the ocean. This is further evidence that groundwater in the deep aquifer is being mined rather than replaced by seawater.

These two processes are displayed in Figure 36. The two processes are not independent, and it is likely that some combination of both factors is occurring.

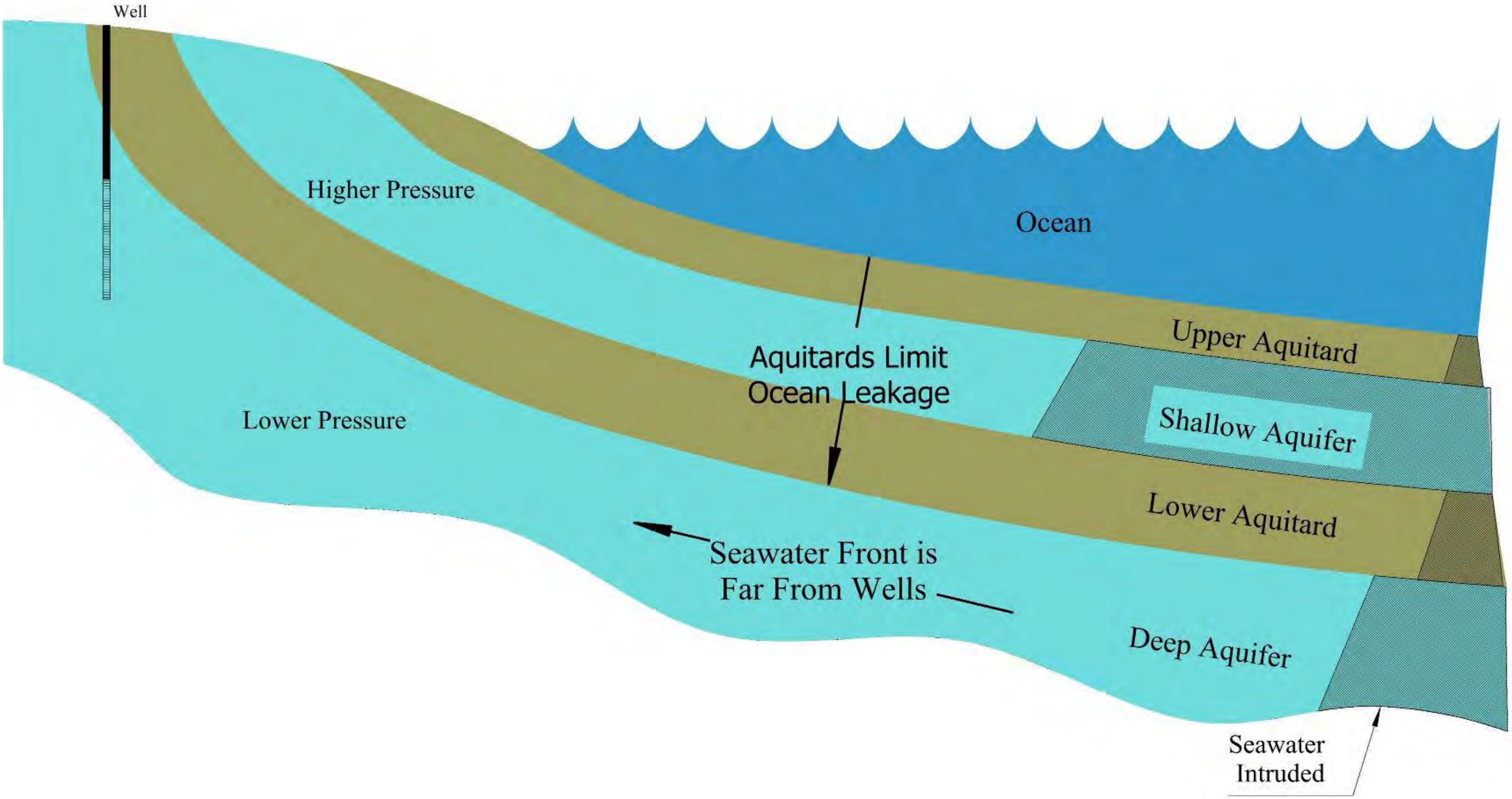


Figure 36: Possible Processes Limiting Seawater Intrusion

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.

SEMI-ANNUAL WATER QUALITY SAMPLING IN WELL SBWM-4

It is recommended that semi-annual samples continue to be collected at sentinel well SBWM-4 because chloride concentrations from a depth of 900 feet below surface remain greater than 250 mg/L.

WATER QUALITY RESAMPLING IN SAND CITY PUBLIC WORKS WELL

It is recommended that Sand City's Public Works well be resampled within the next month to confirm the 4th quarter 330 mg/L chloride concentration. If a concentration over 250 mg/L persists, the Watermaster TAC should determine whether this well should be sampled in both the second and fourth quarters.

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 be developed every year.

REFINE PRELIMINARY SHALLOW PROTECTIVE GROUNDWATER ELEVATIONS

Once the water supply parameters of the Coastal Water Project are better defined, it is recommended that the preliminary protective groundwater elevations (HydroMetrics LLC, 2009b) be refined using final calibrated aquifer properties from the Seaside Basin groundwater flow model. It is expected that the protective elevations will be decreased up to a few feet, which will make them more practical to meet.

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SECTION 6
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APPENDIX A: PIPER DIAGRAMS FOR INDIVIDUAL WELLS

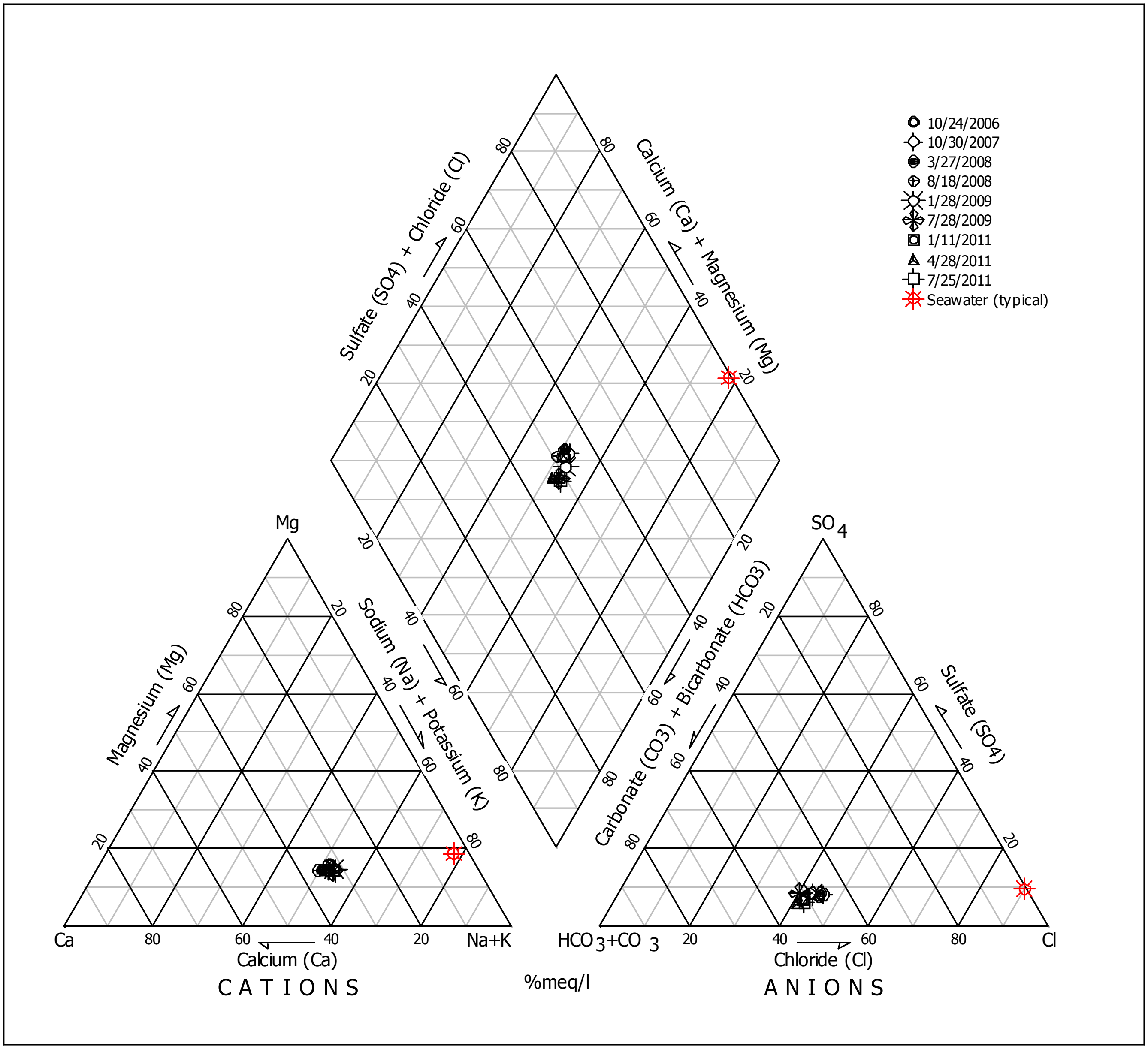


Figure A-1: Piper Diagram of PCA West Shallow

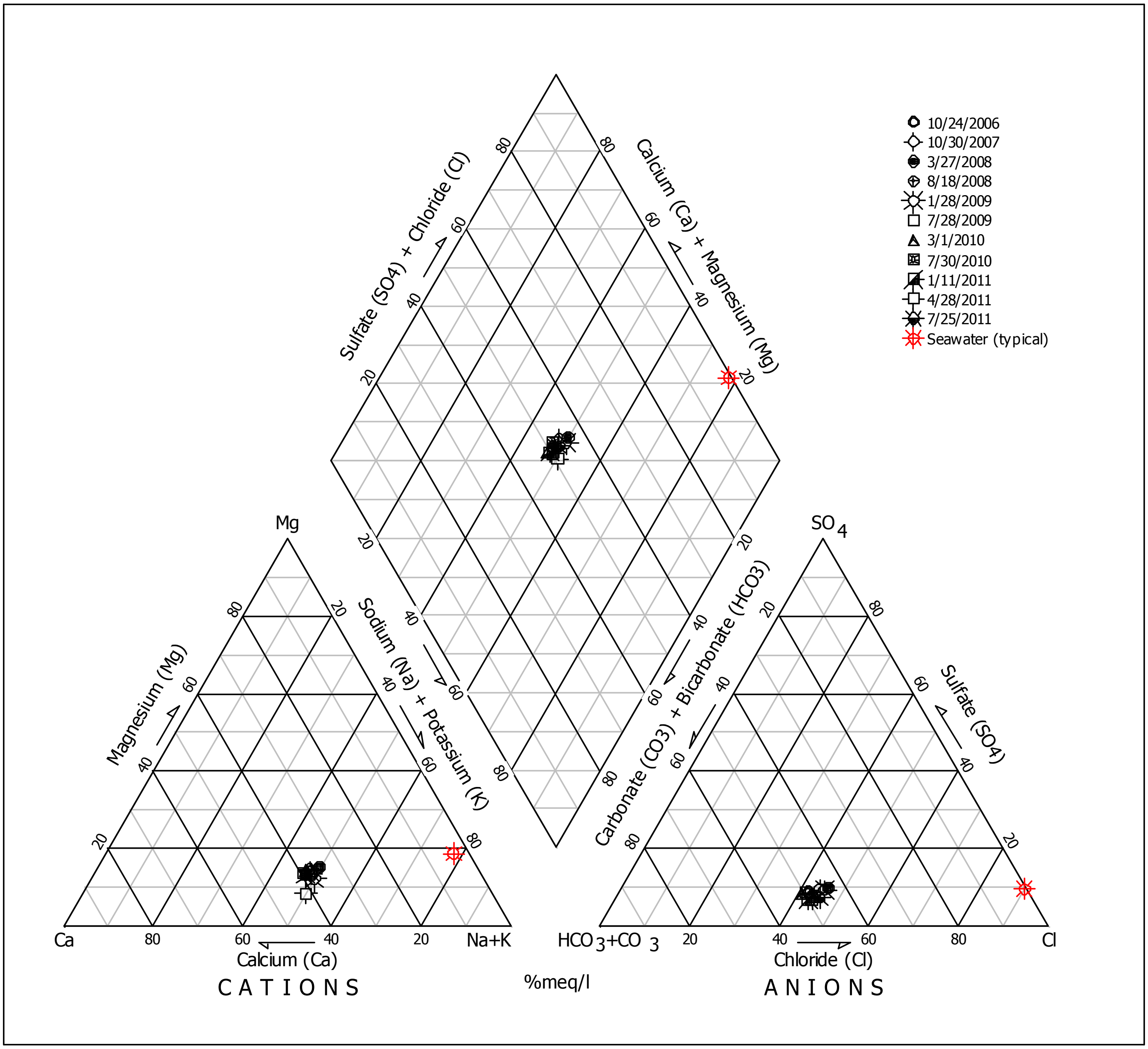


Figure A-2: Piper Diagram of PCA West Deep

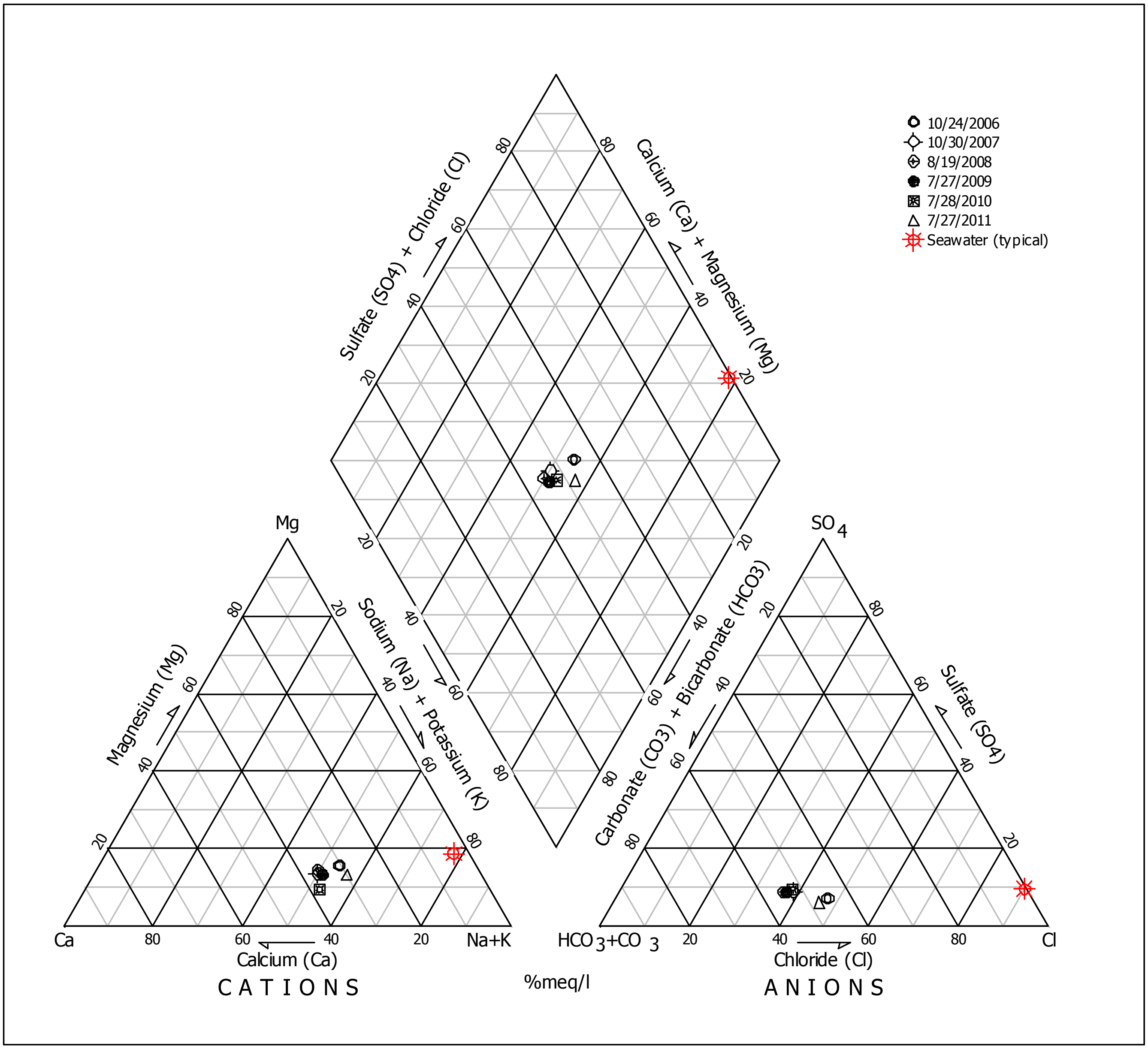


Figure A-3: Piper Diagram of PCA East Shallow

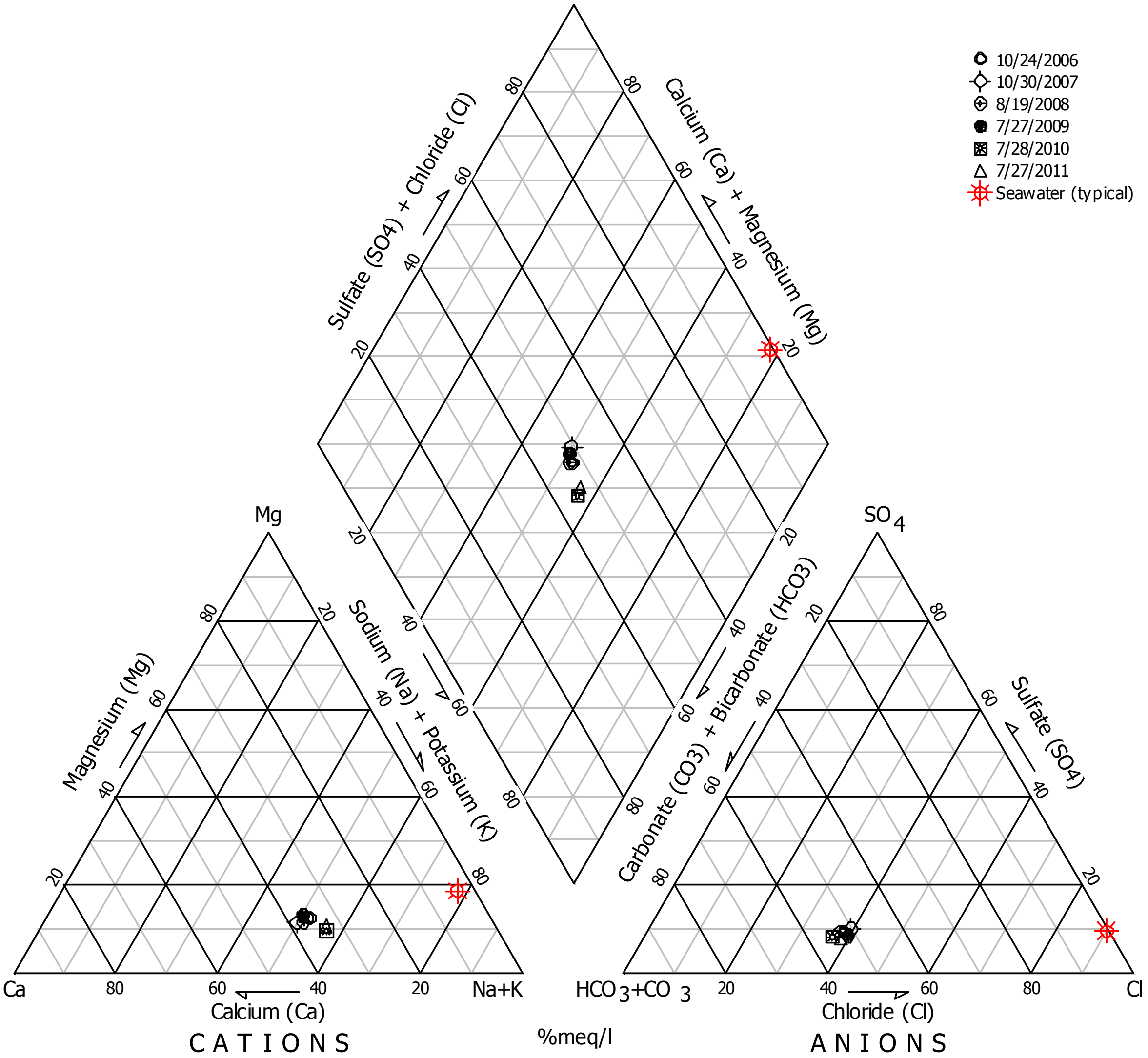


Figure A-4: Piper Diagram of PCA East Deep

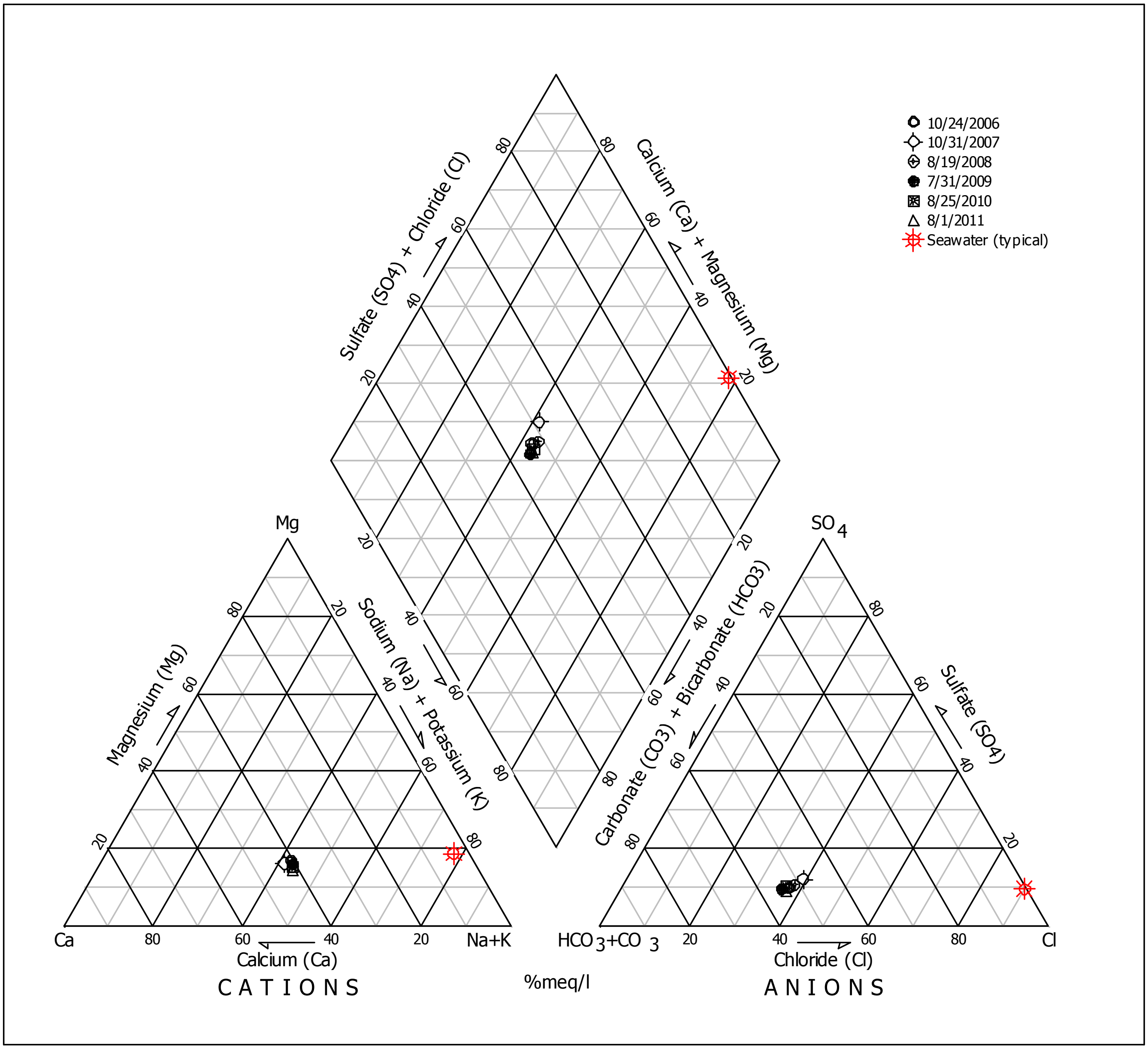


Figure A-5: Piper Diagram of Ord Terrace Shallow

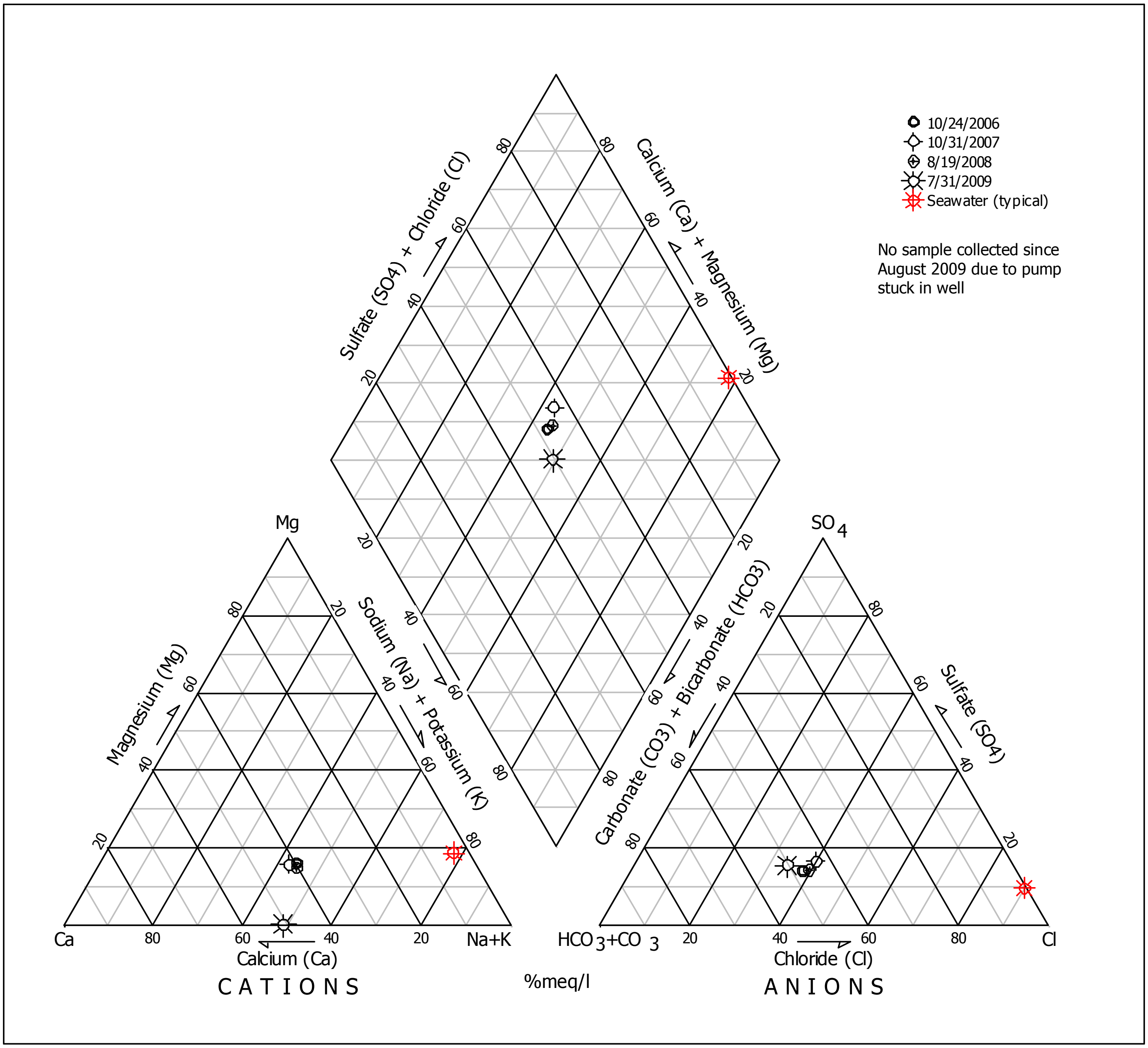


Figure A-6: Piper Diagram of Ord Terrace Deep

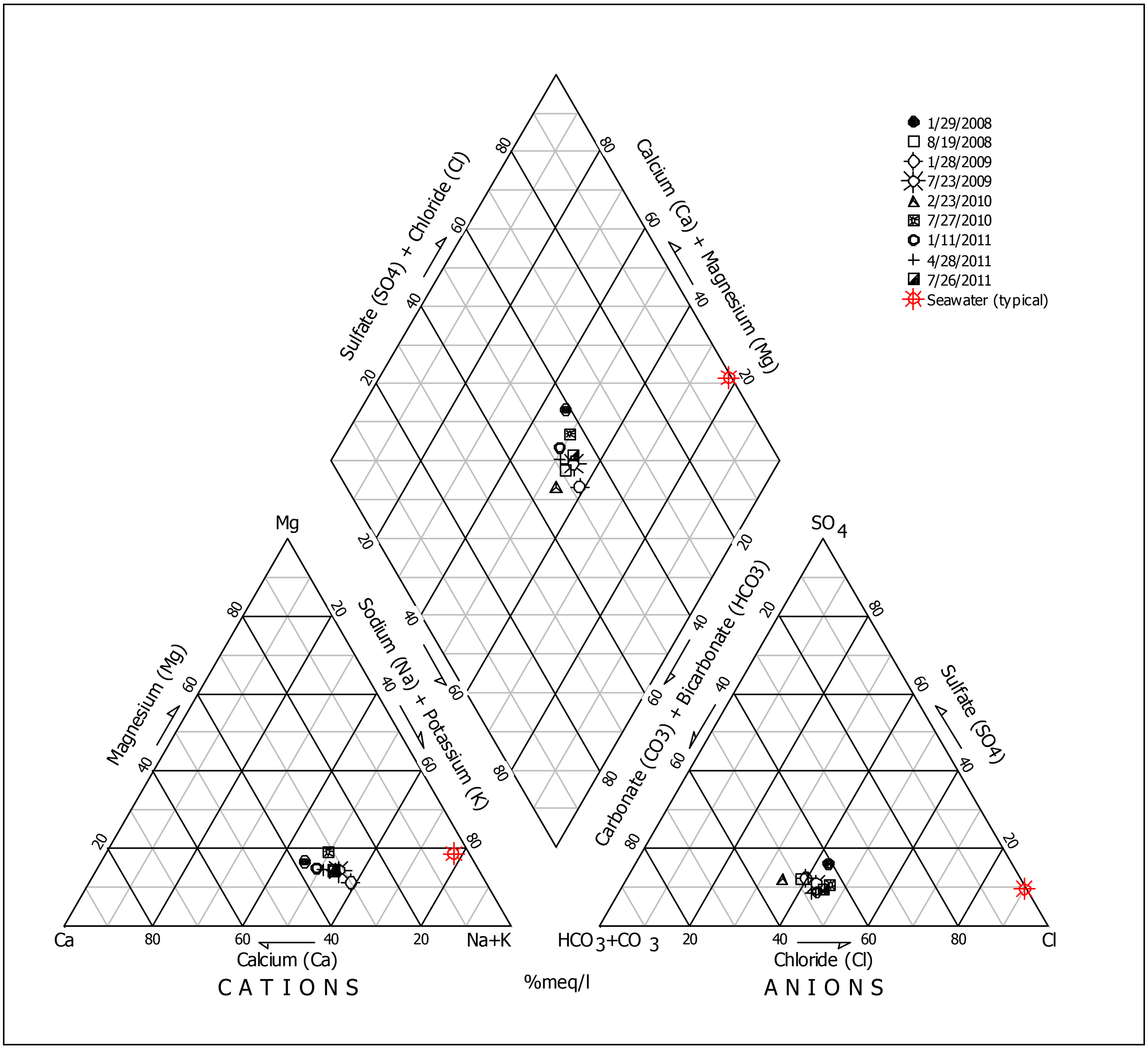


Figure A-7: Piper Diagram of MSC Shallow

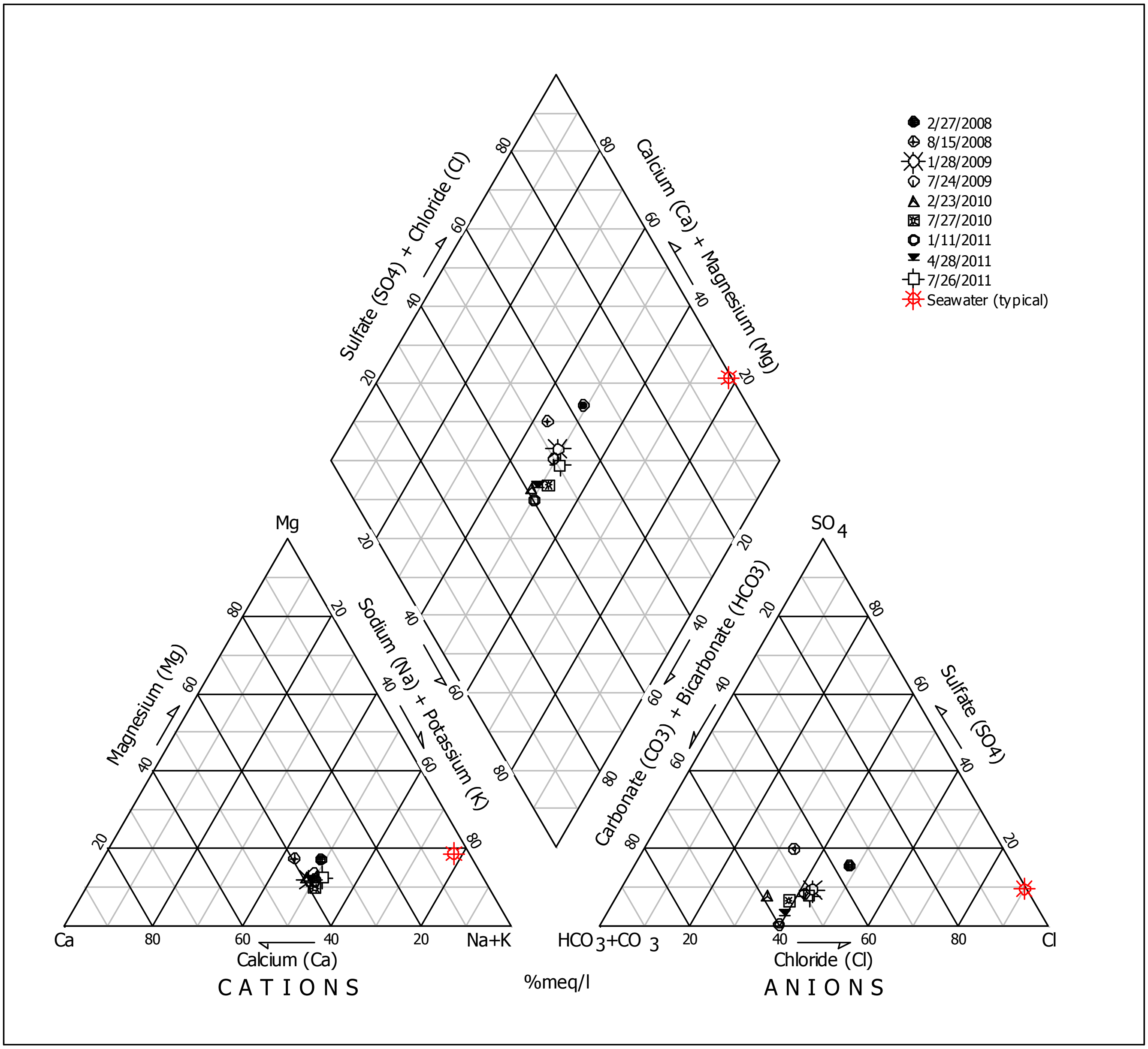


Figure A-8: Piper Diagram of MSC Deep

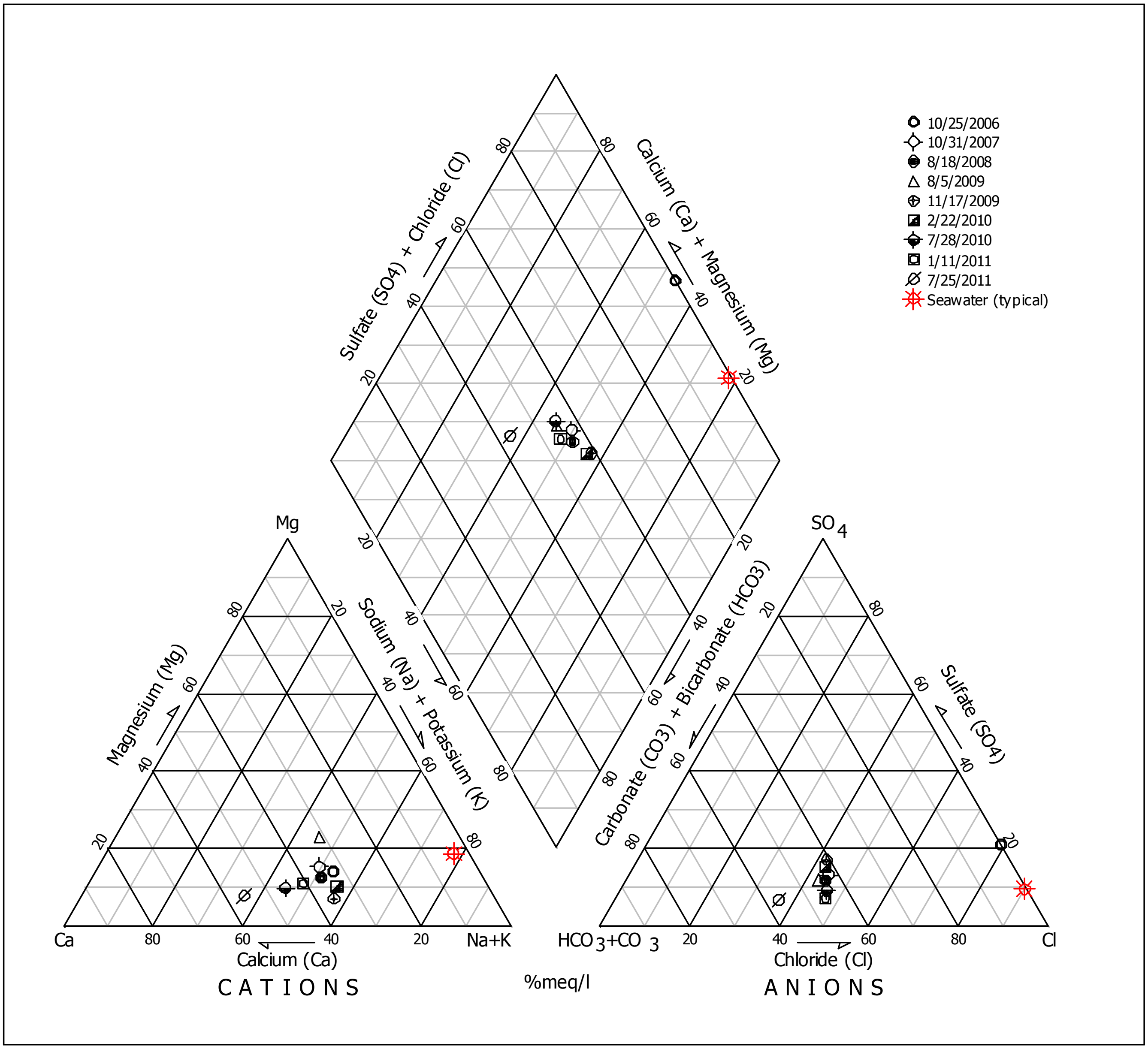


Figure A-9: Piper Diagram of Fort Ord 9 Shallow

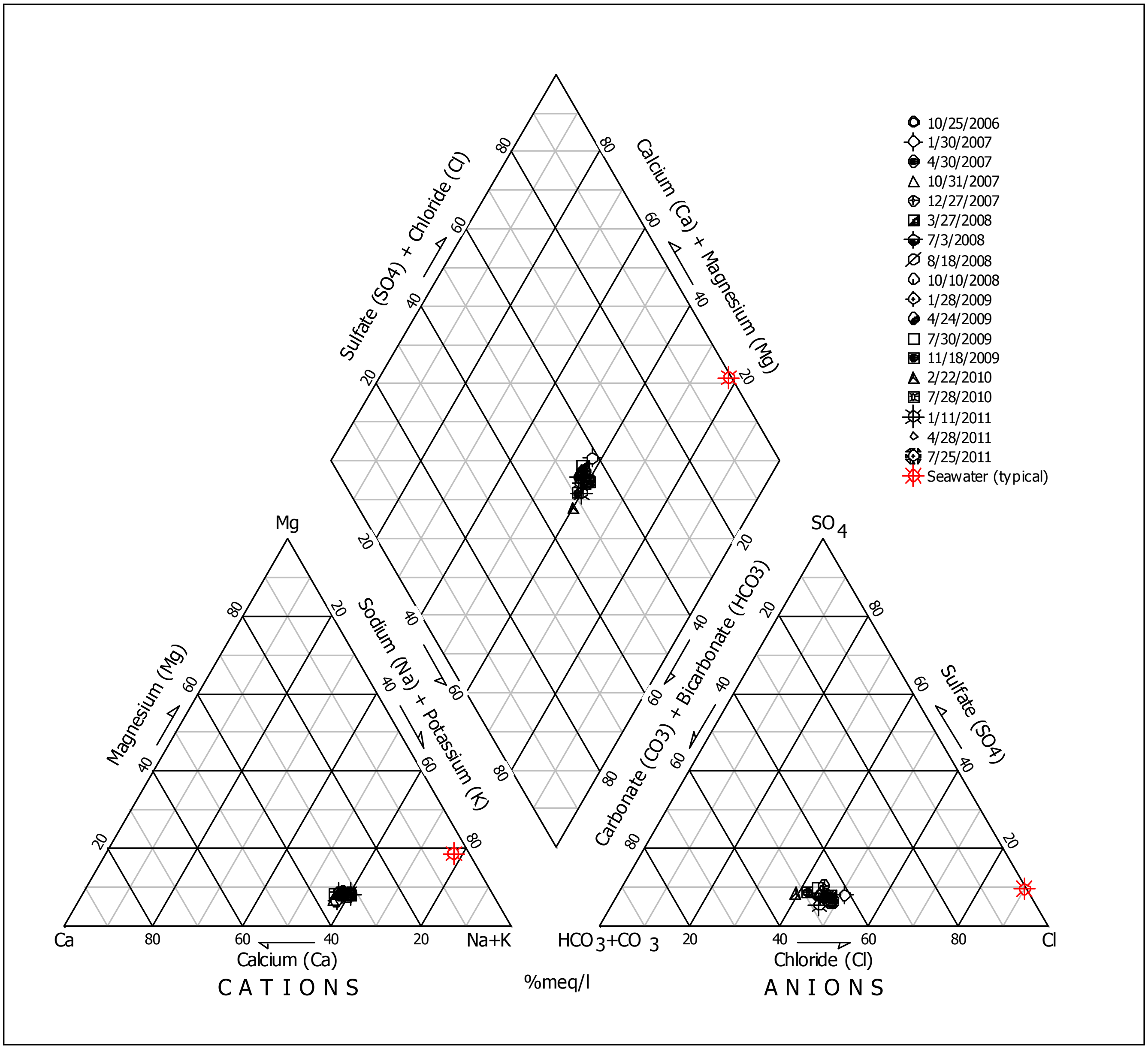


Figure A-10: Piper Diagram of Fort Ord 9 Deep

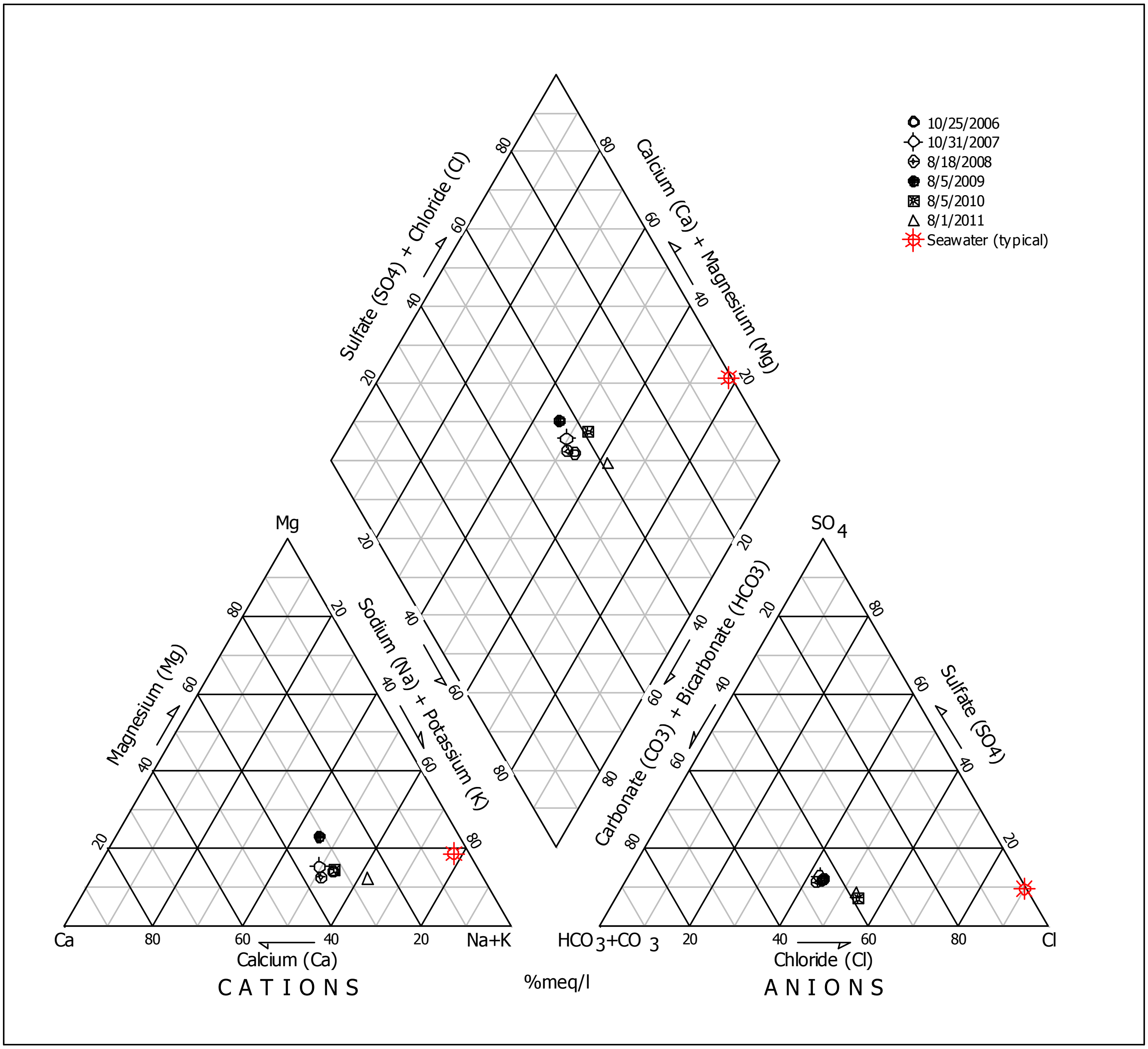


Figure A-11: Piper Diagram of Fort Ord 10 Shallow

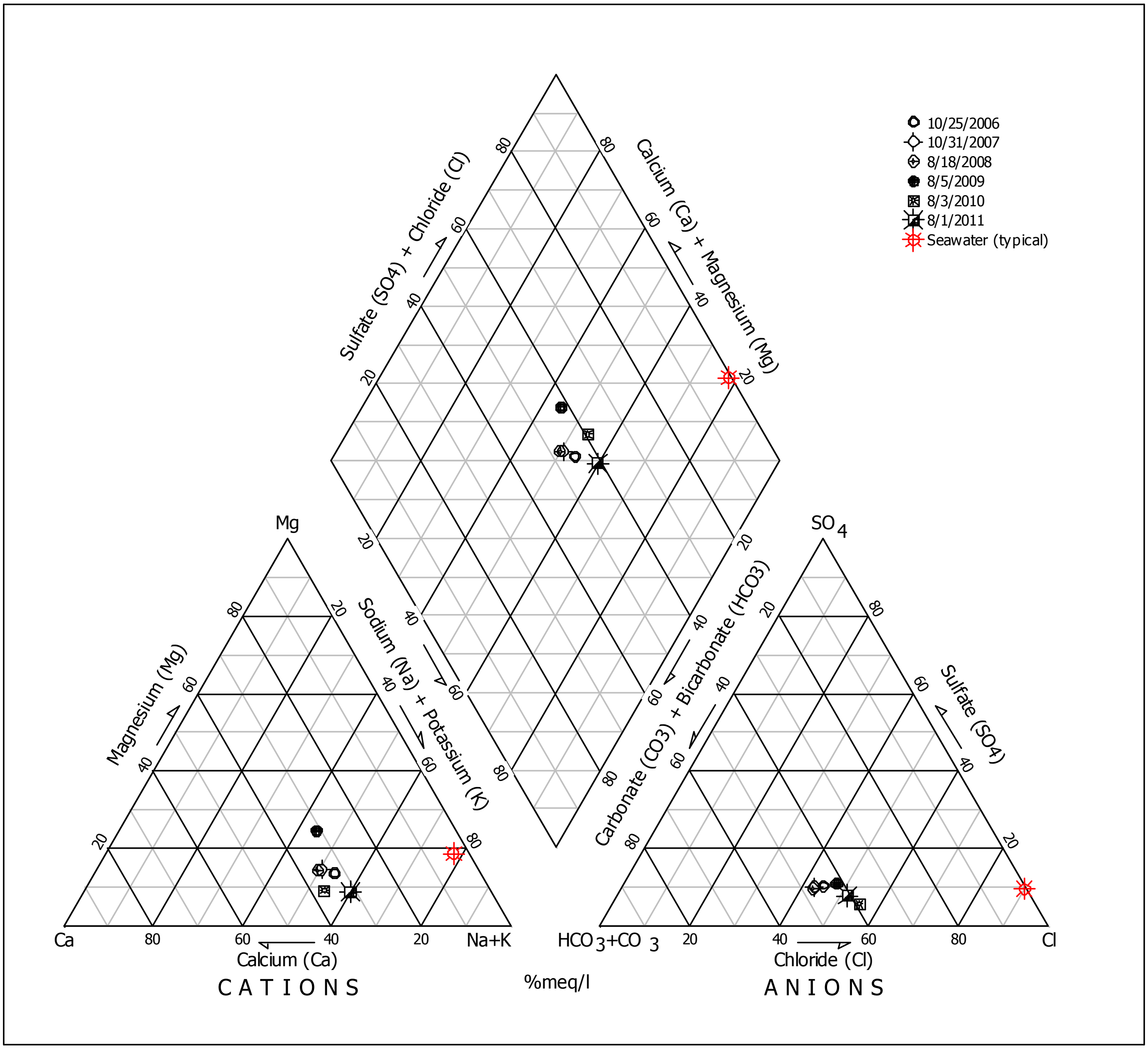


Figure A-12: Piper Diagram of Fort Ord 10 Deep

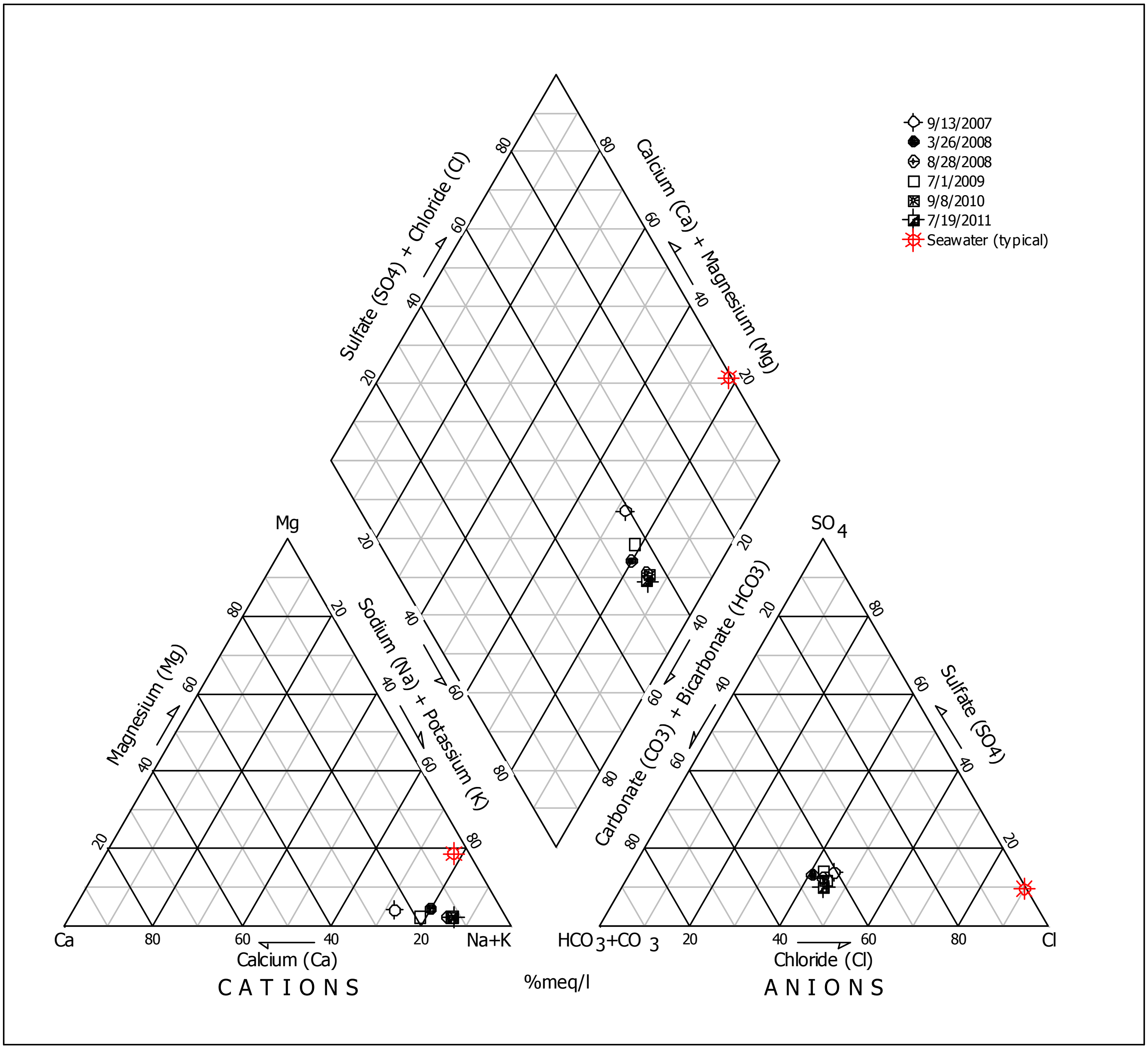


Figure A-13: Piper Diagram of SBWM-1 1,140 ft sample

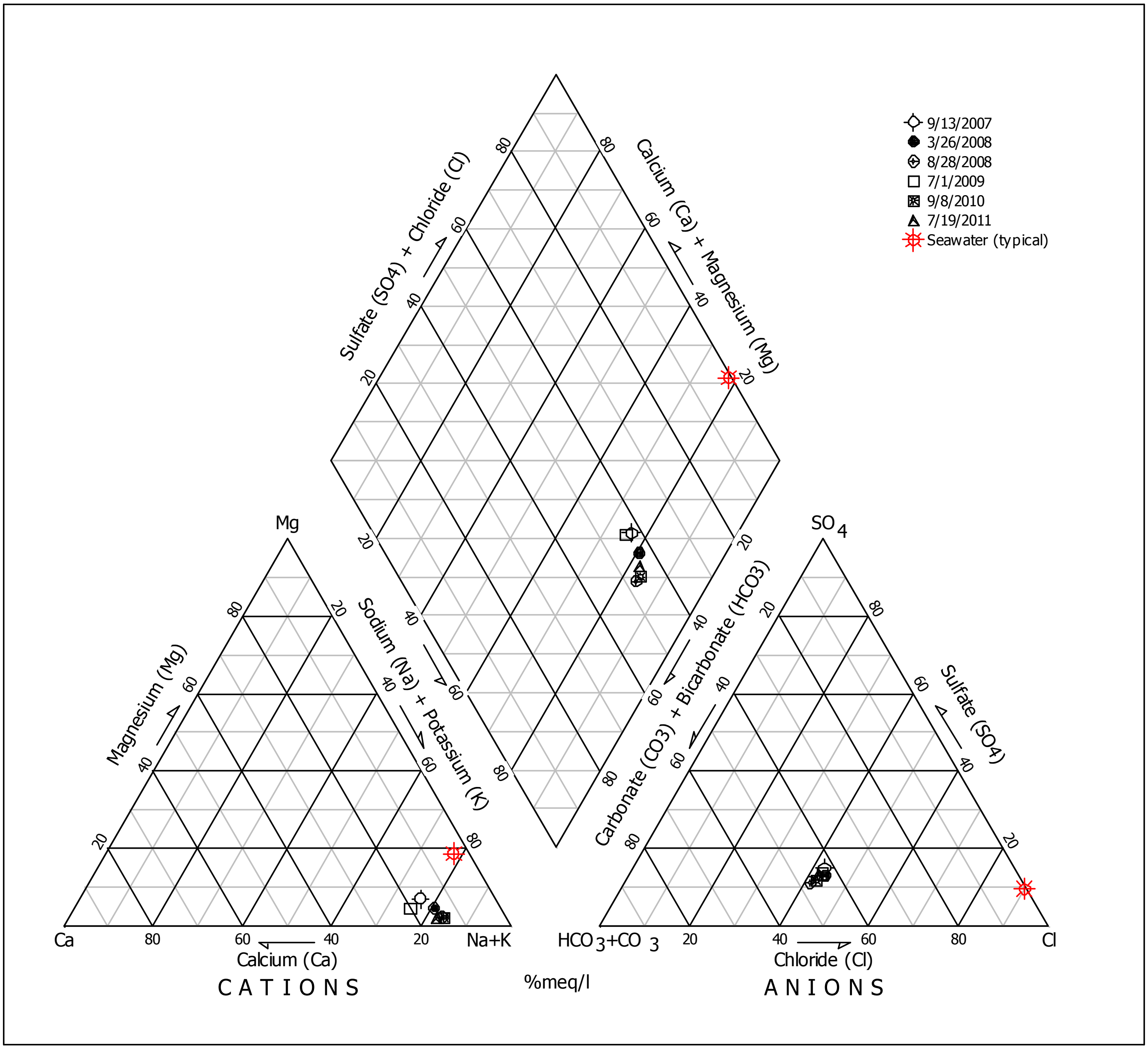


Figure A-14: Piper Diagram of SBWM-1 1,390 ft sample

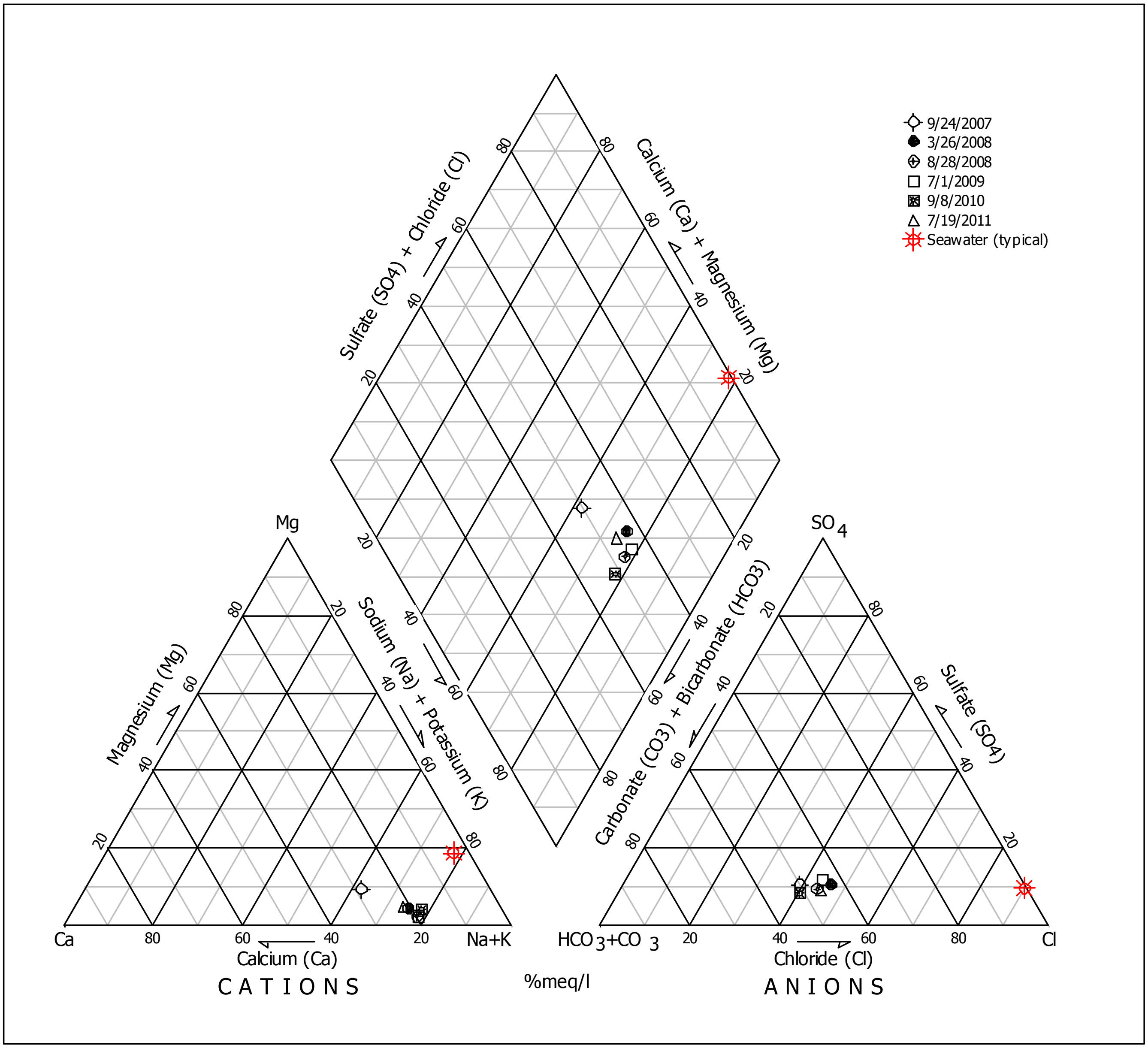


Figure A-15: Piper Diagram of SBWM-2 1,000 ft sample

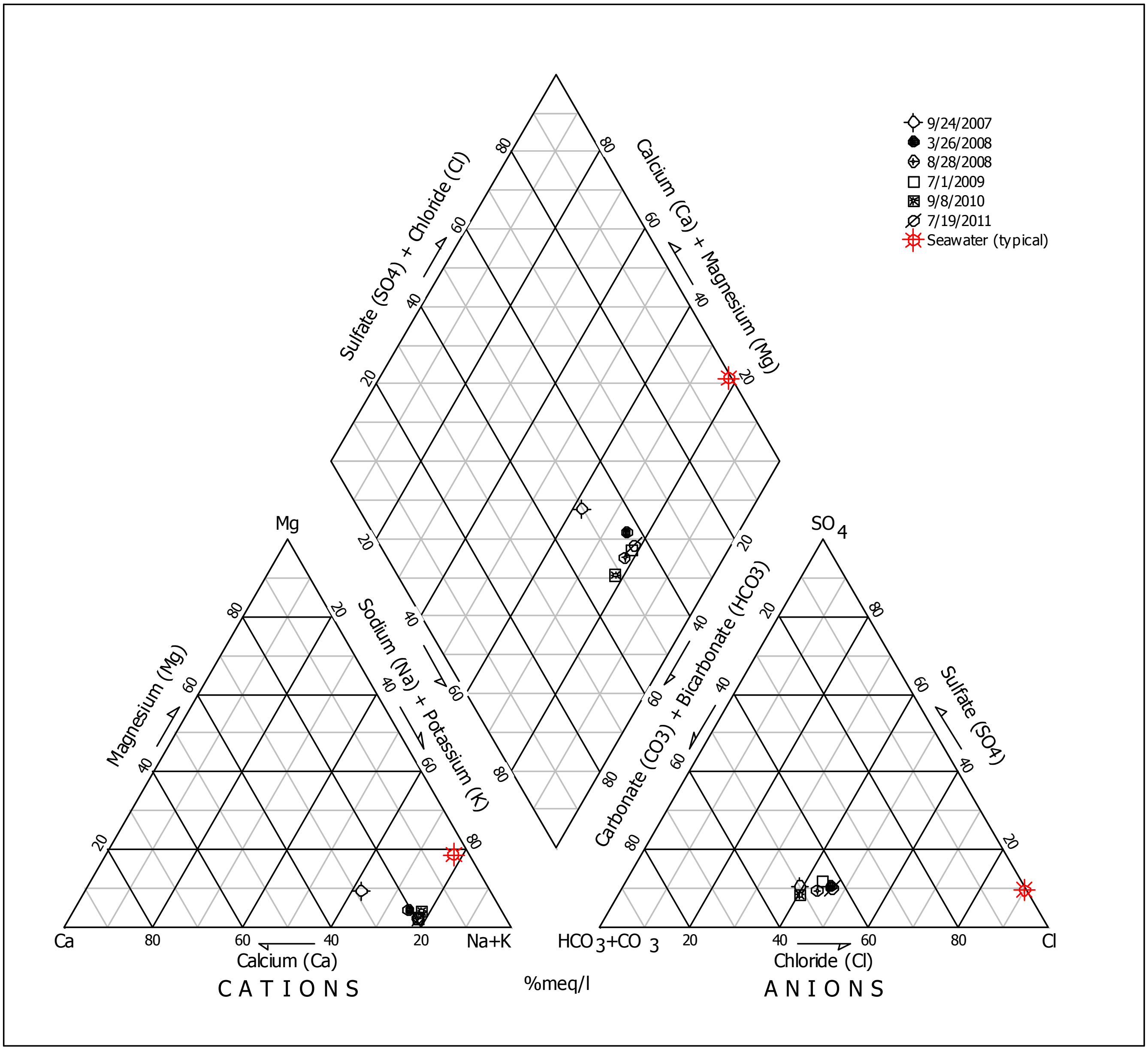


Figure A-16: Piper Diagram of SBWM-2 1,470 ft sample

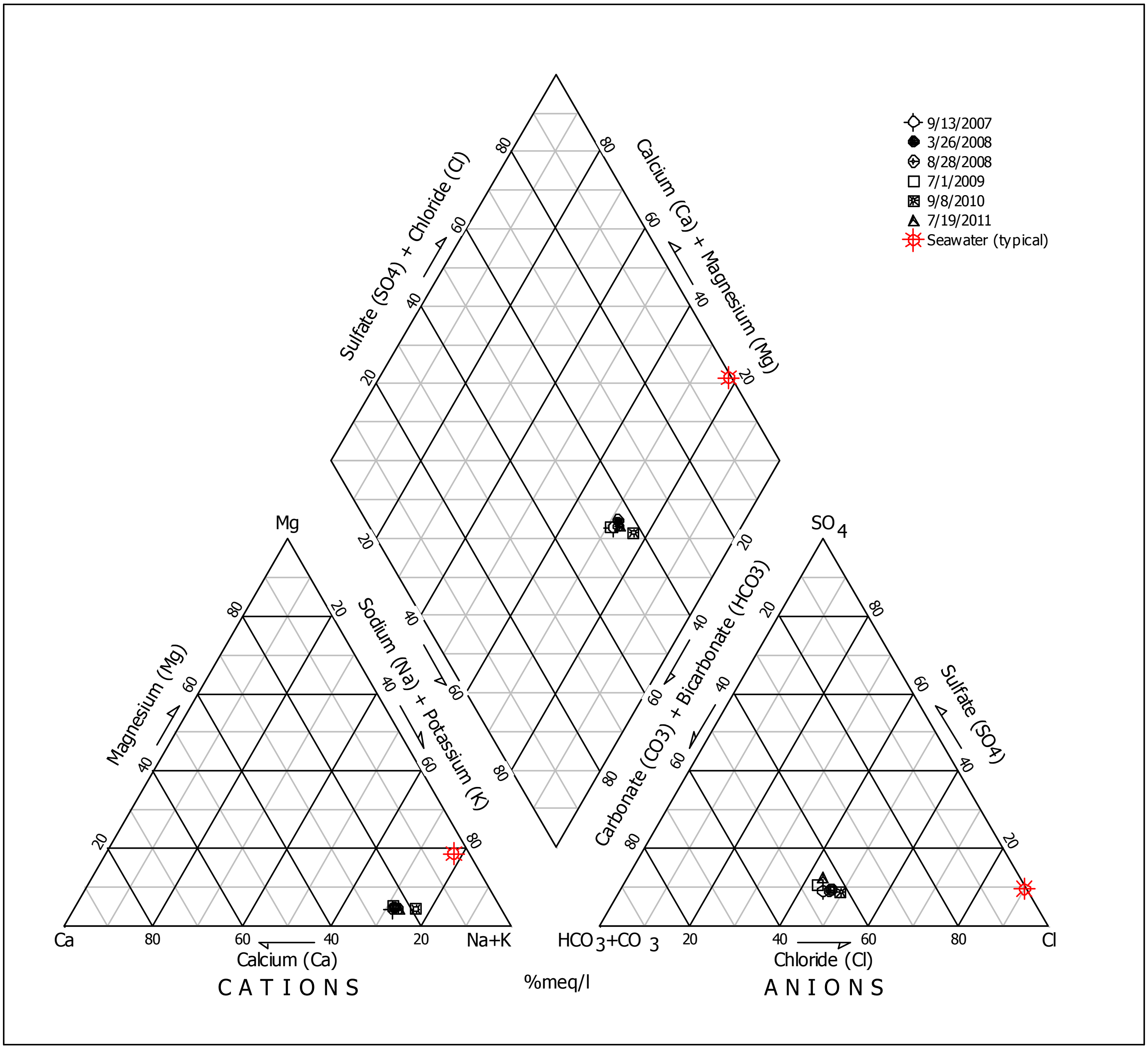


Figure A-17: Piper Diagram of SBWM-3 870 ft sample

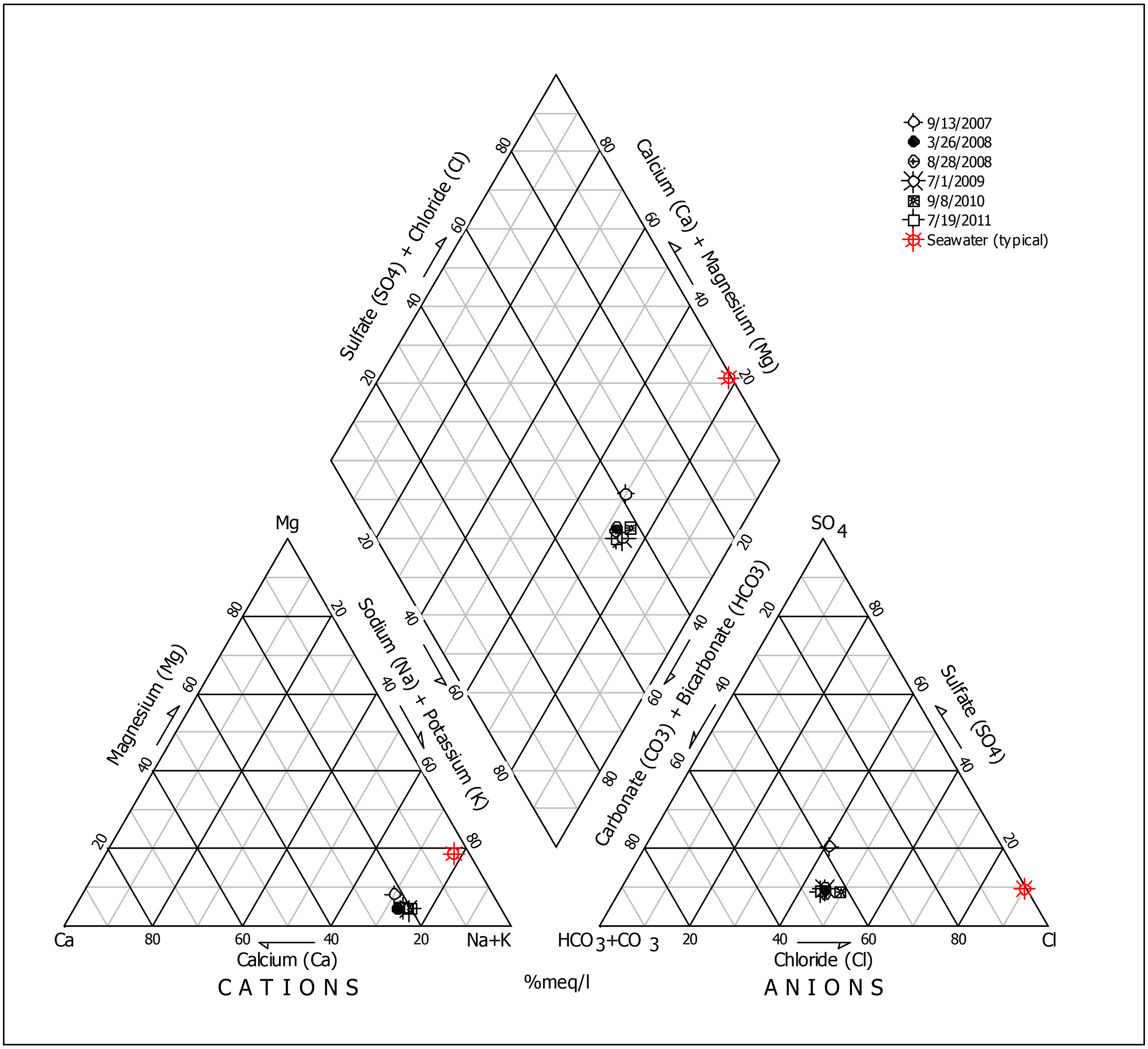


Figure A-18: Piper Diagram of SBWM-3 1,275 ft sample

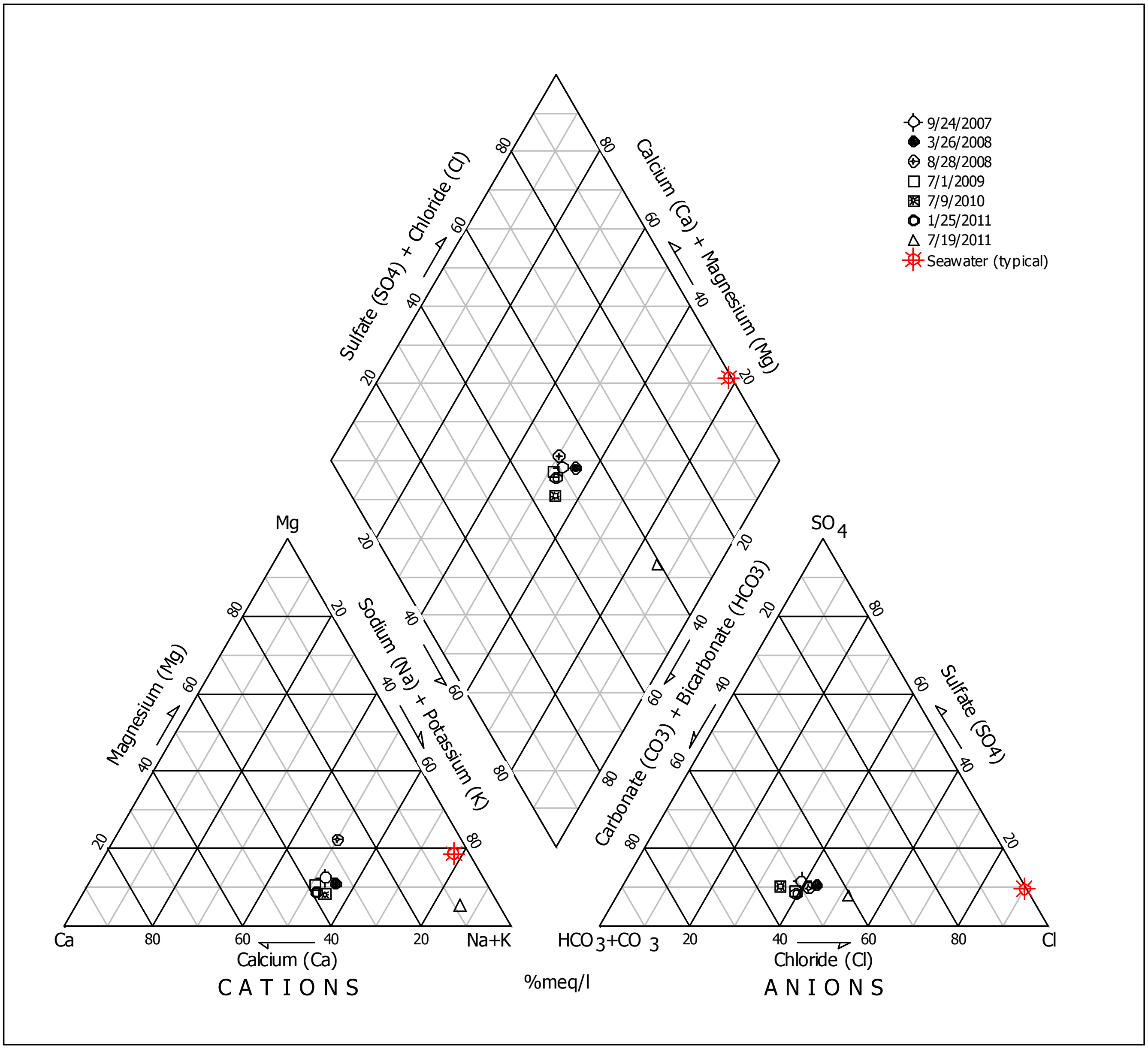


Figure A-19: Piper Diagram of SBWM-4 715 ft sample

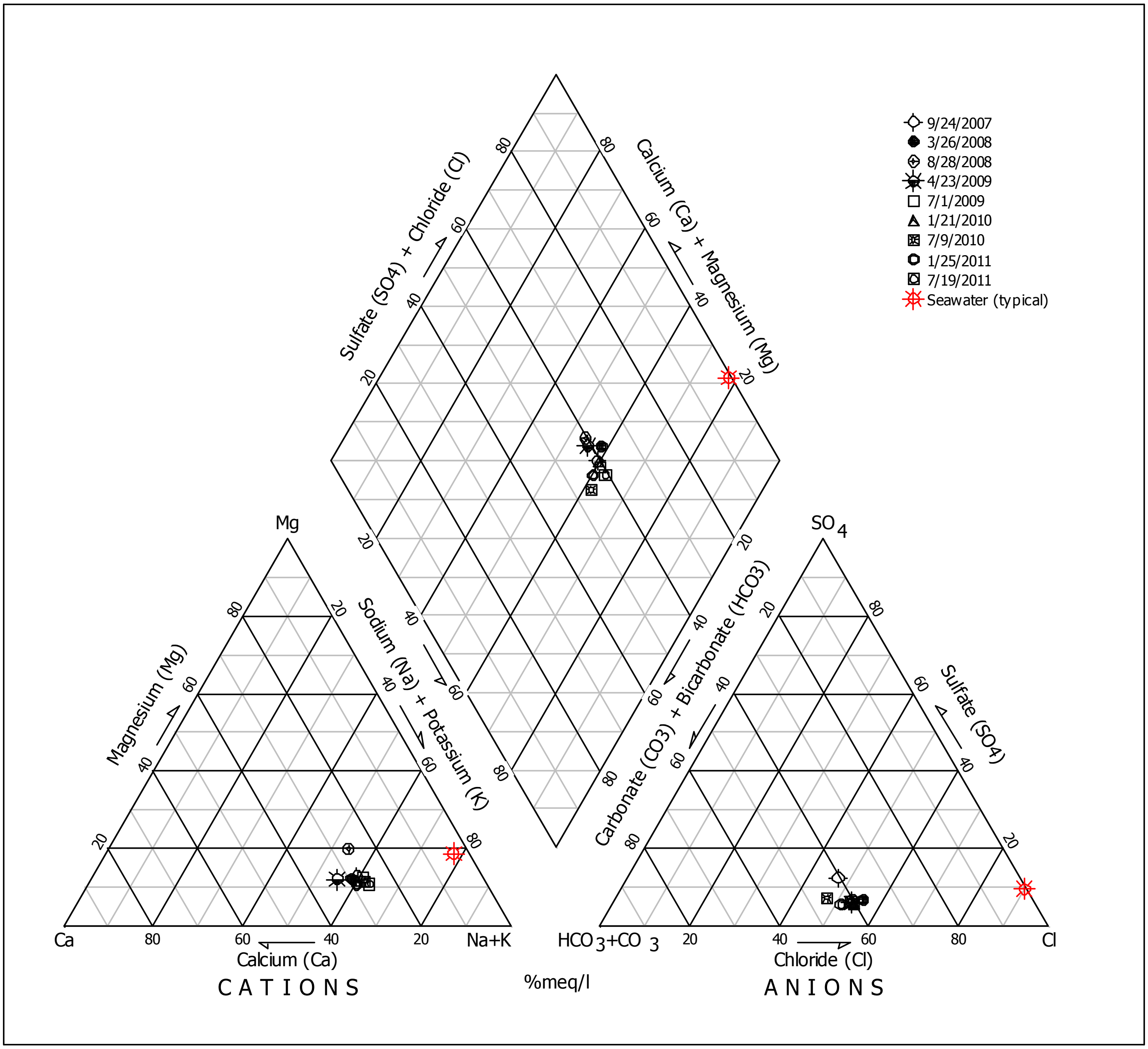


Figure A-20: Piper Diagram of SBWM-4 900 ft sample

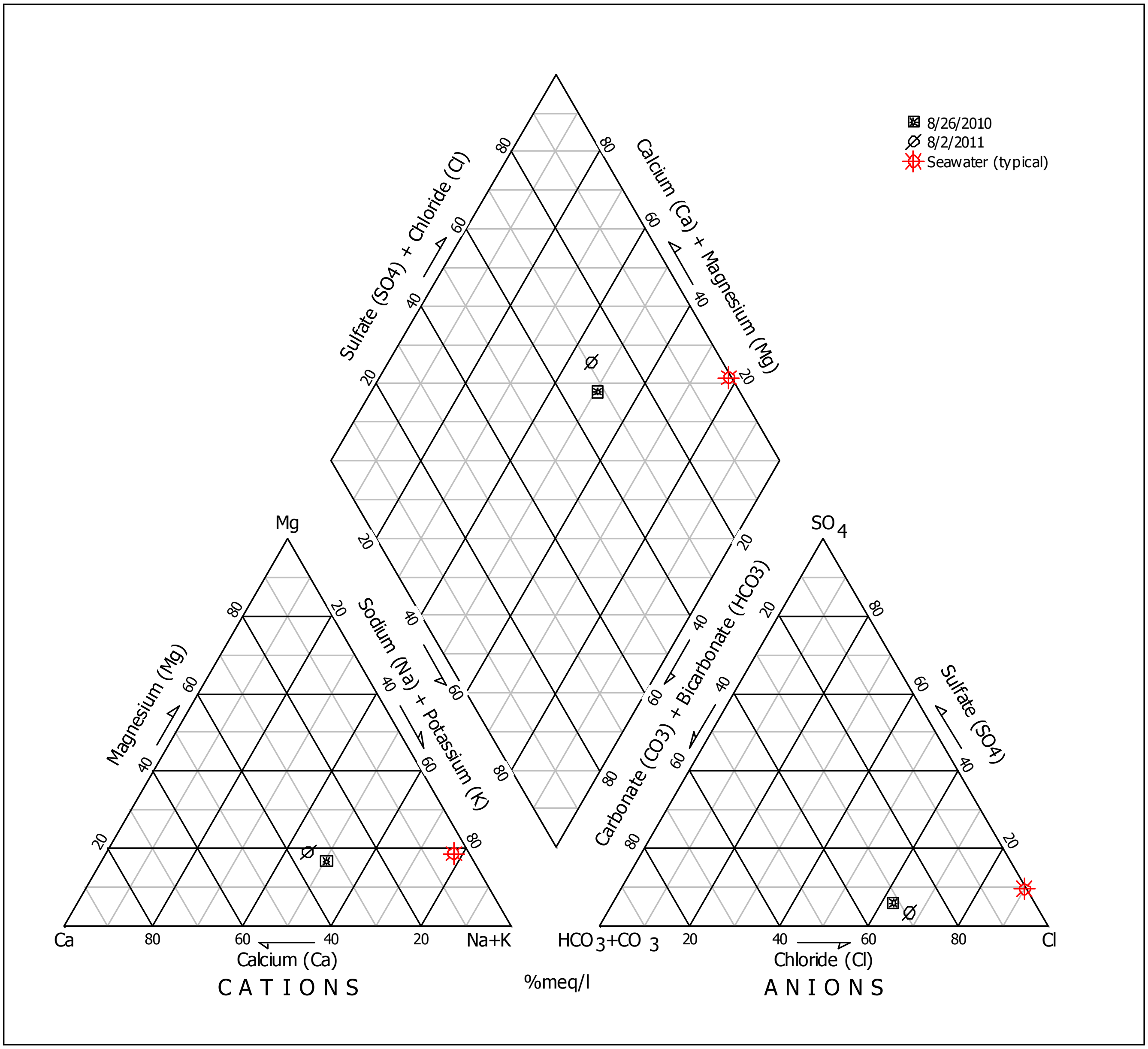


Figure 37: Piper Diagram of SBMW-5 Shallow Well

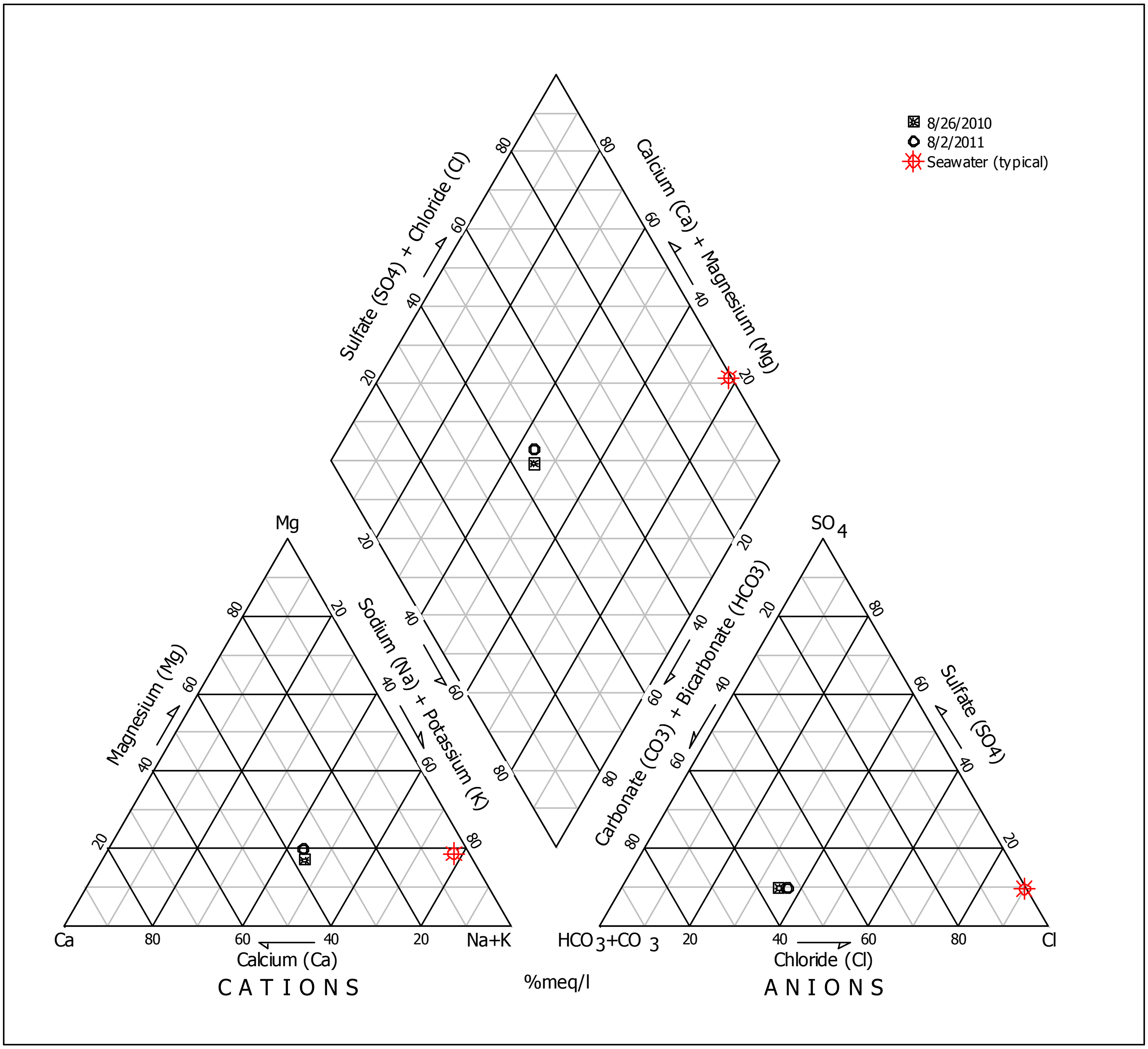


Figure 38: Piper Diagram of SBMW-5 Deep Well

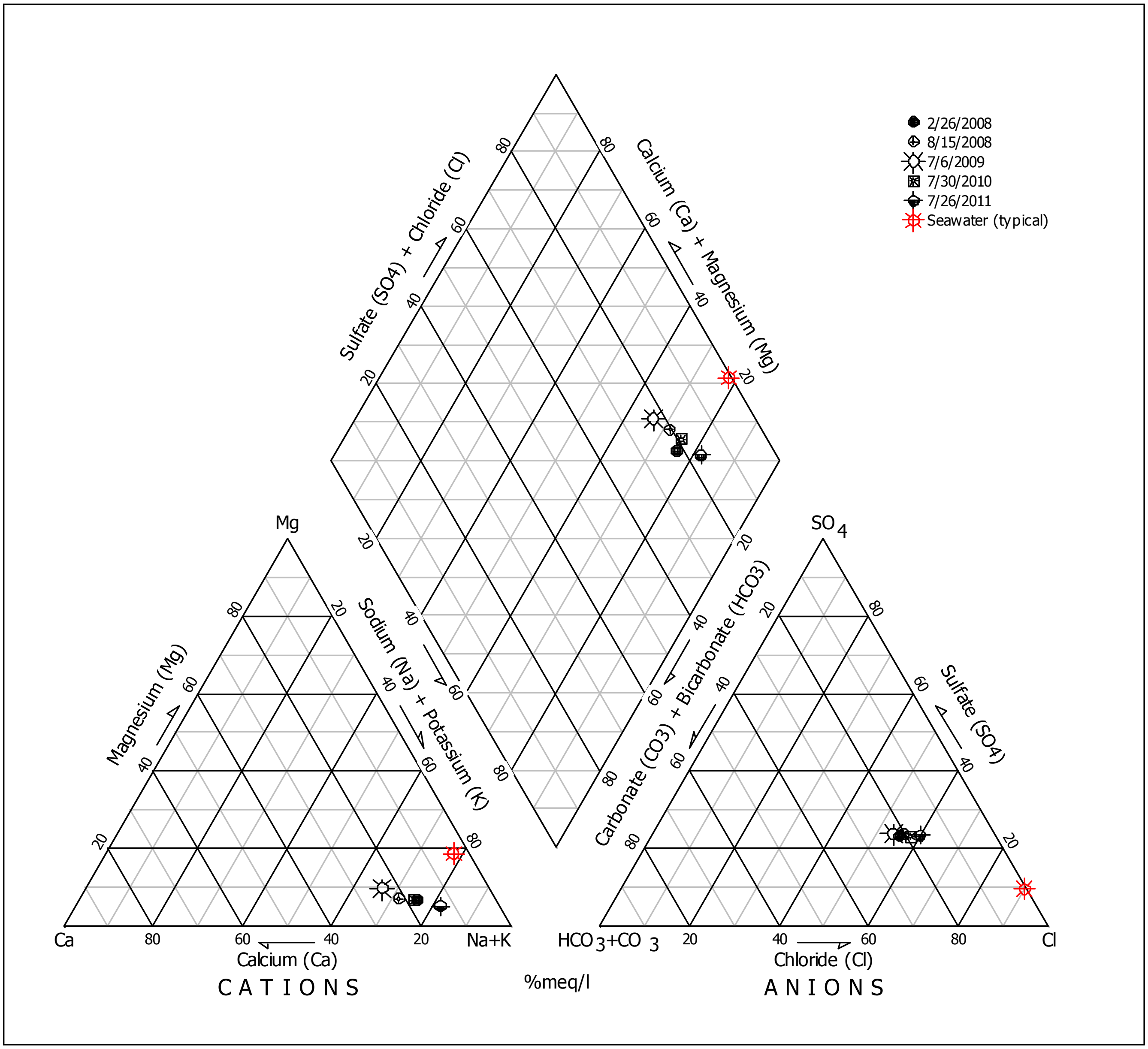


Figure A-21: Piper Diagram of Public Works Corp. Yard Production Well

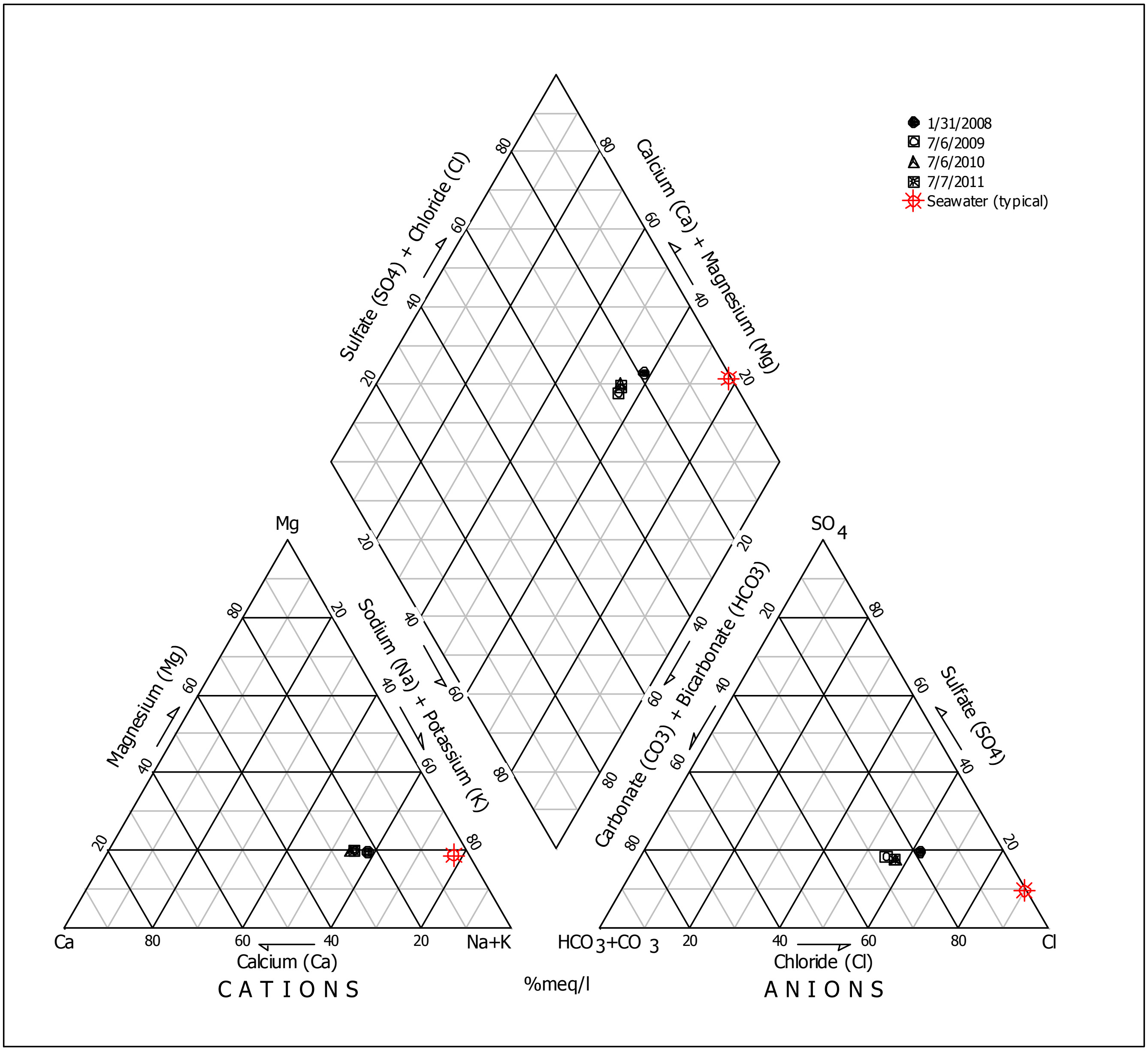


Figure A-22: Piper Diagram of Plumas 4 Production Well

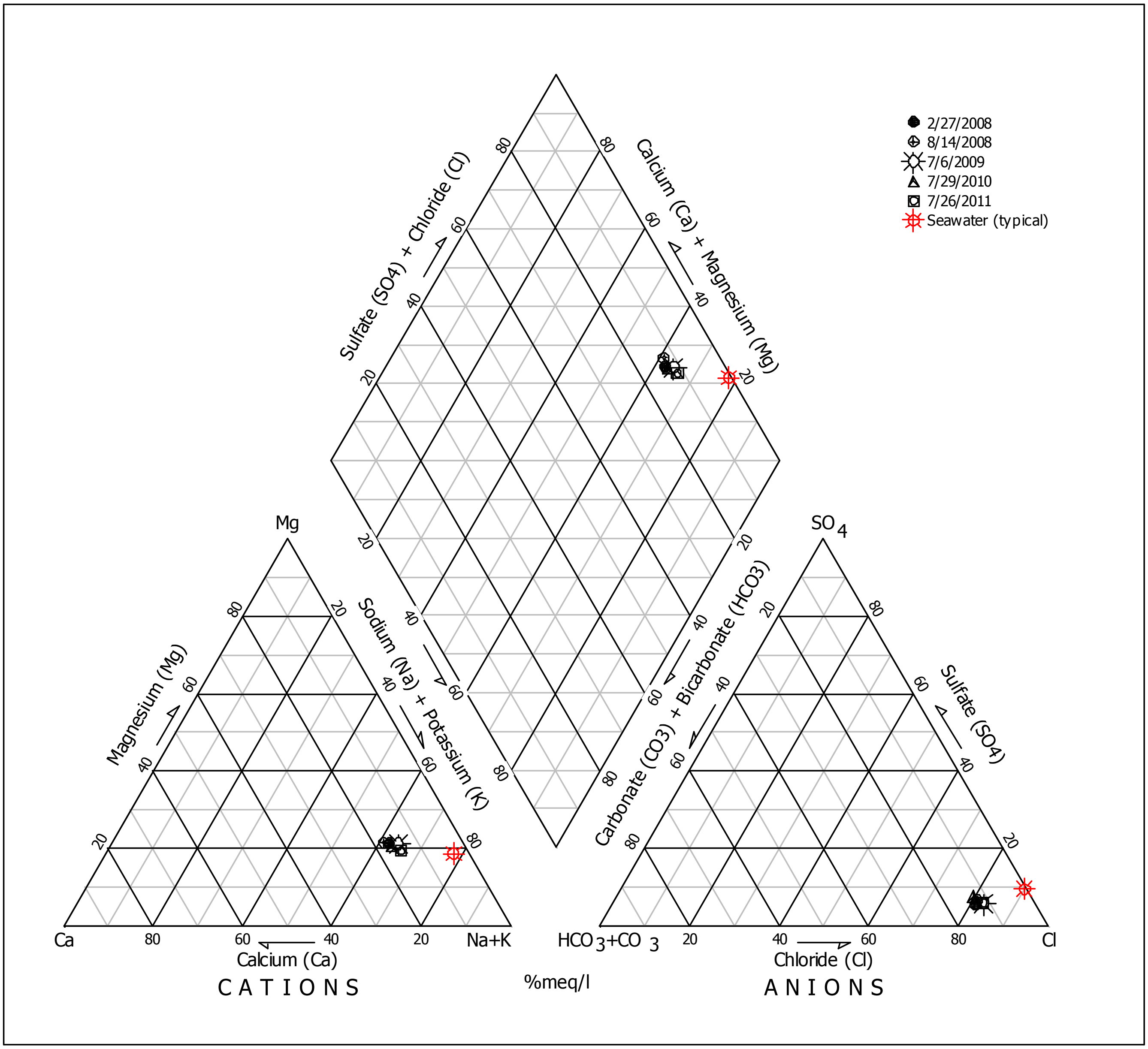
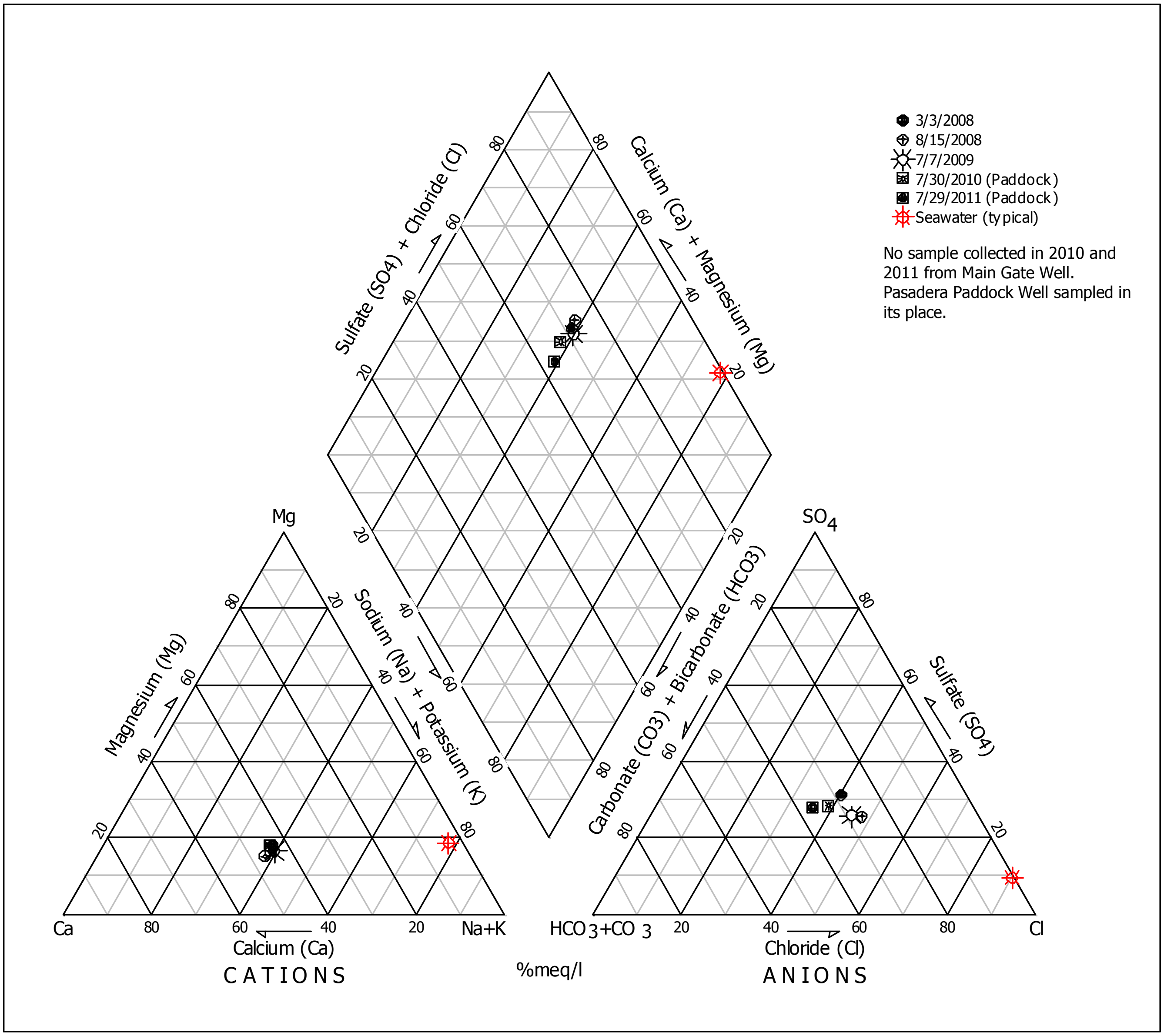


Figure A-23: Piper Diagram of York School Production Well



No sample collected in 2010 and 2011 from Main Gate Well. Pasadera Paddock Well sampled in its place.

Figure A-24: Piper Diagram of Pasadera Main Gate Production Well

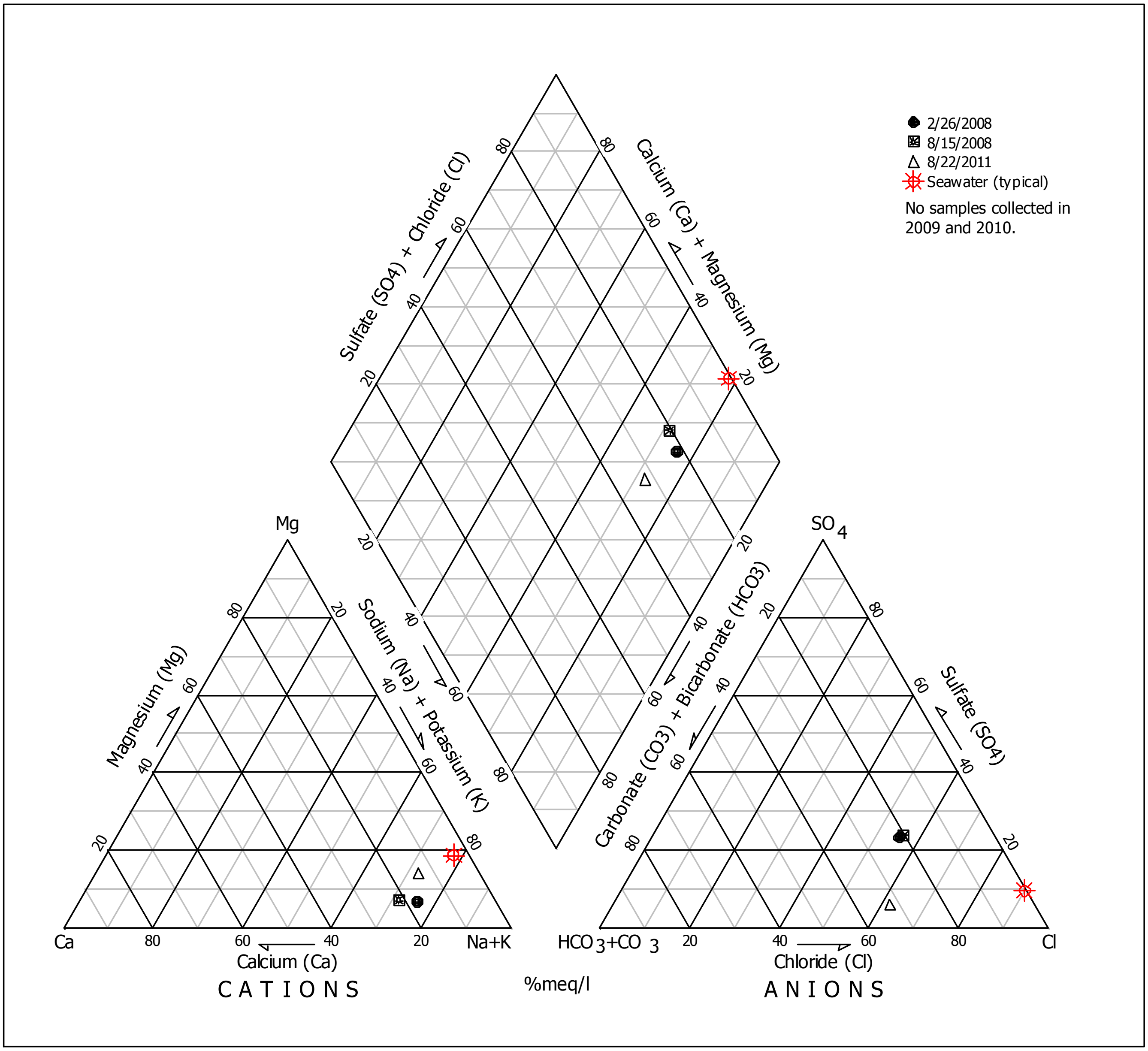


Figure A-25: Piper Diagram of LS County Park #1 Production Well

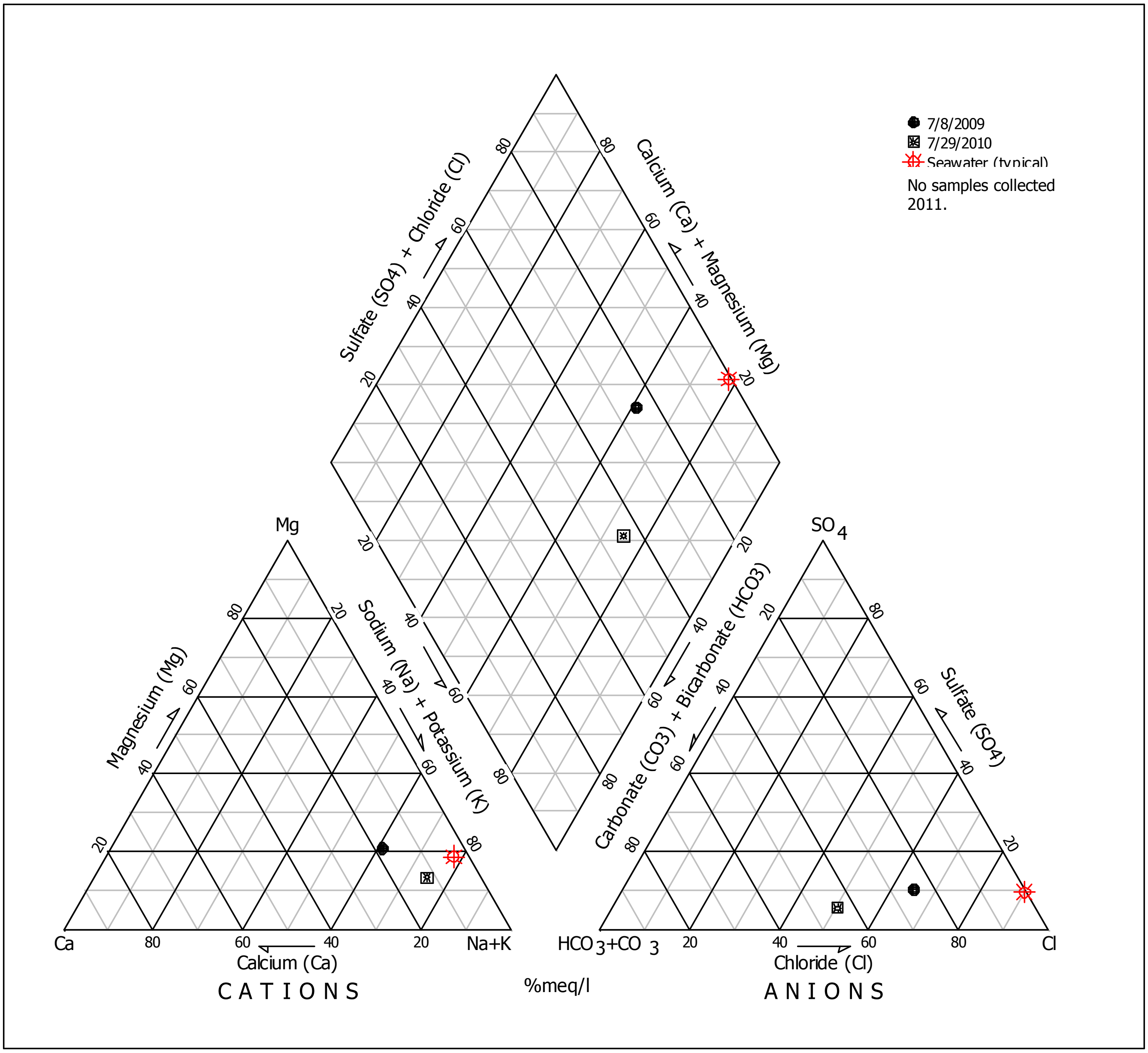


Figure A-26: Piper Diagram of LS County Park #2 Production Well

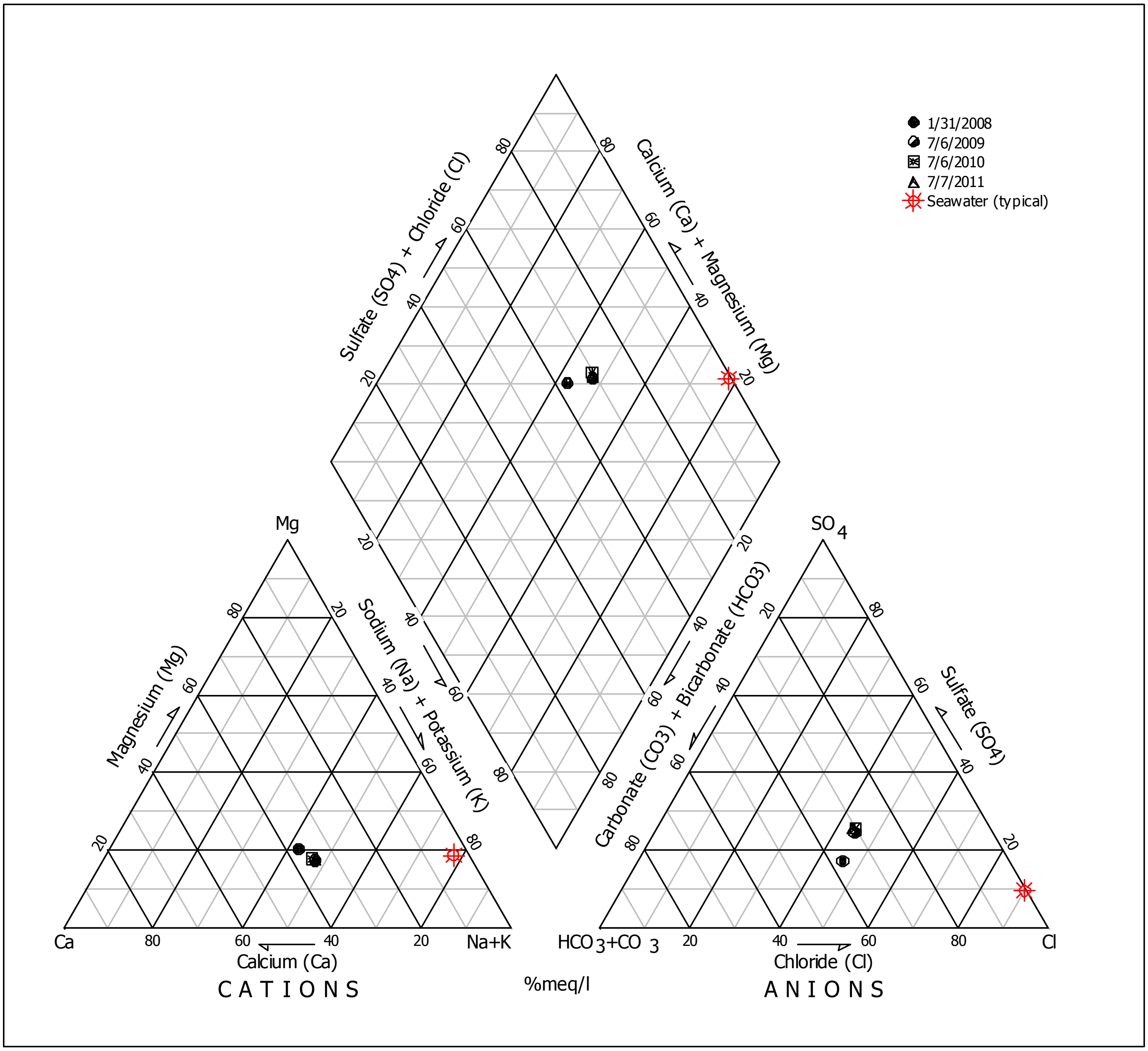


Figure A-27: Piper Diagram of Playa No. 3 Production Well

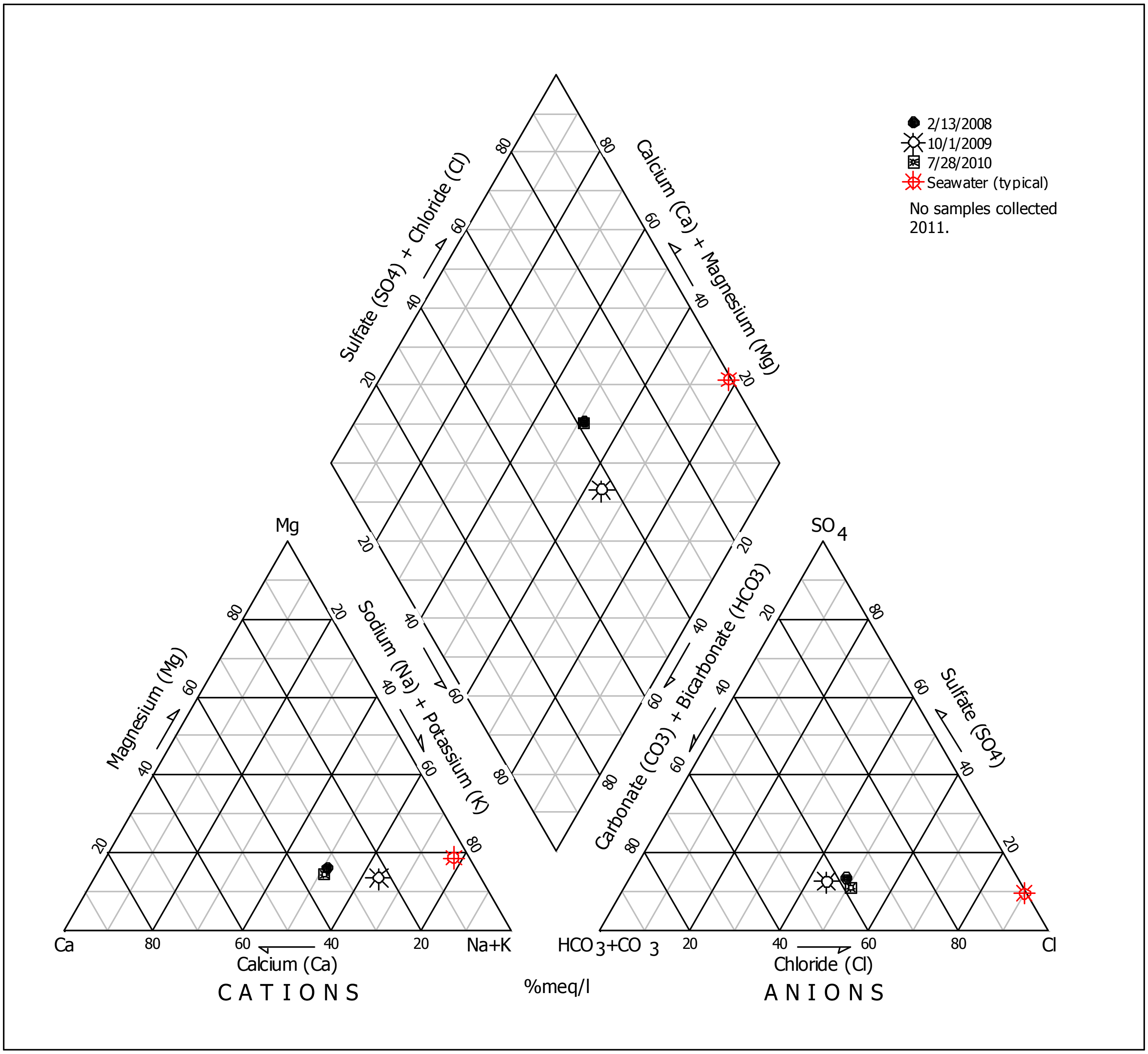


Figure A-28: Piper Diagram of Coe Ave. Production Well

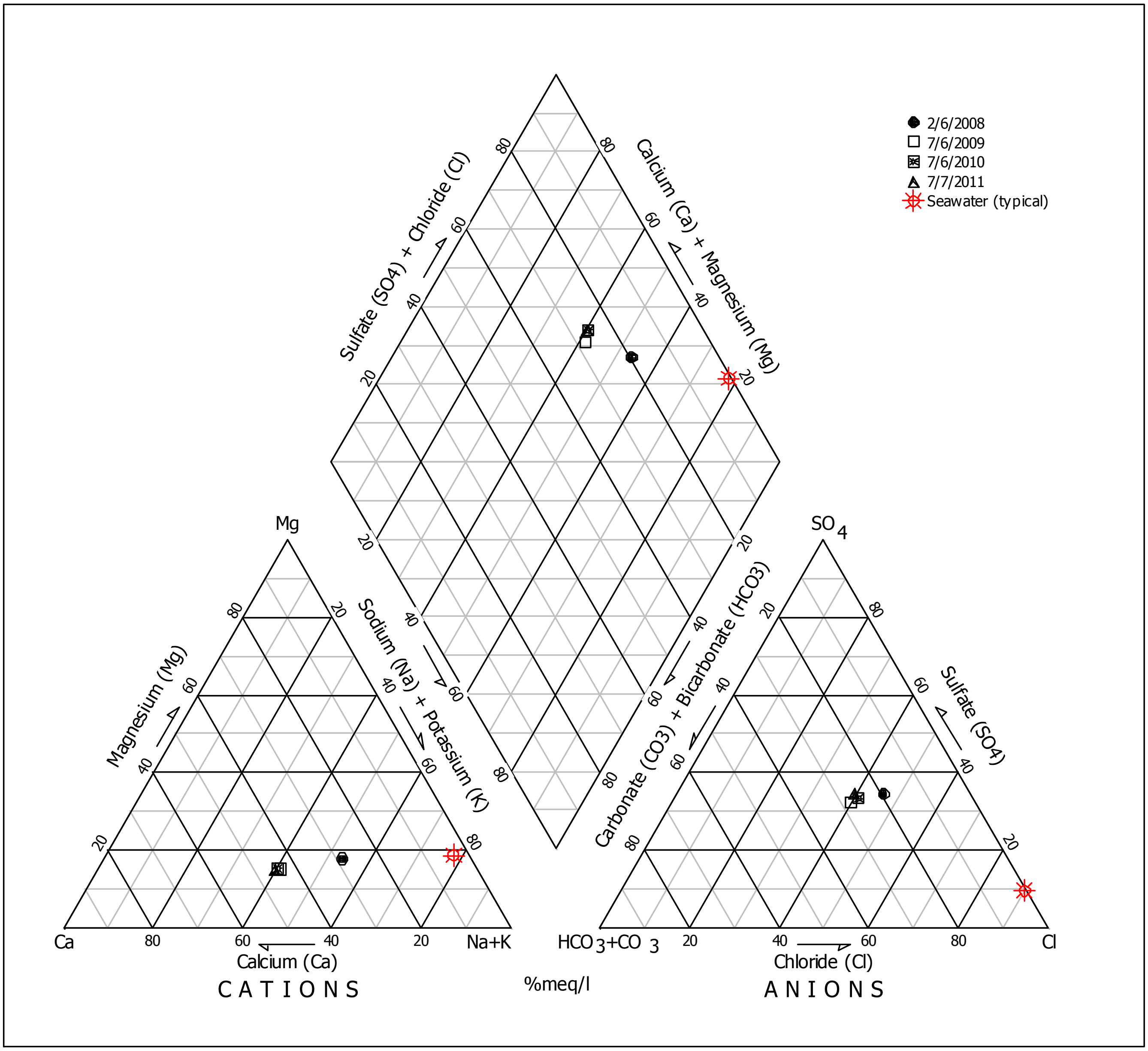


Figure A-29: Piper Diagram of Military Production Well

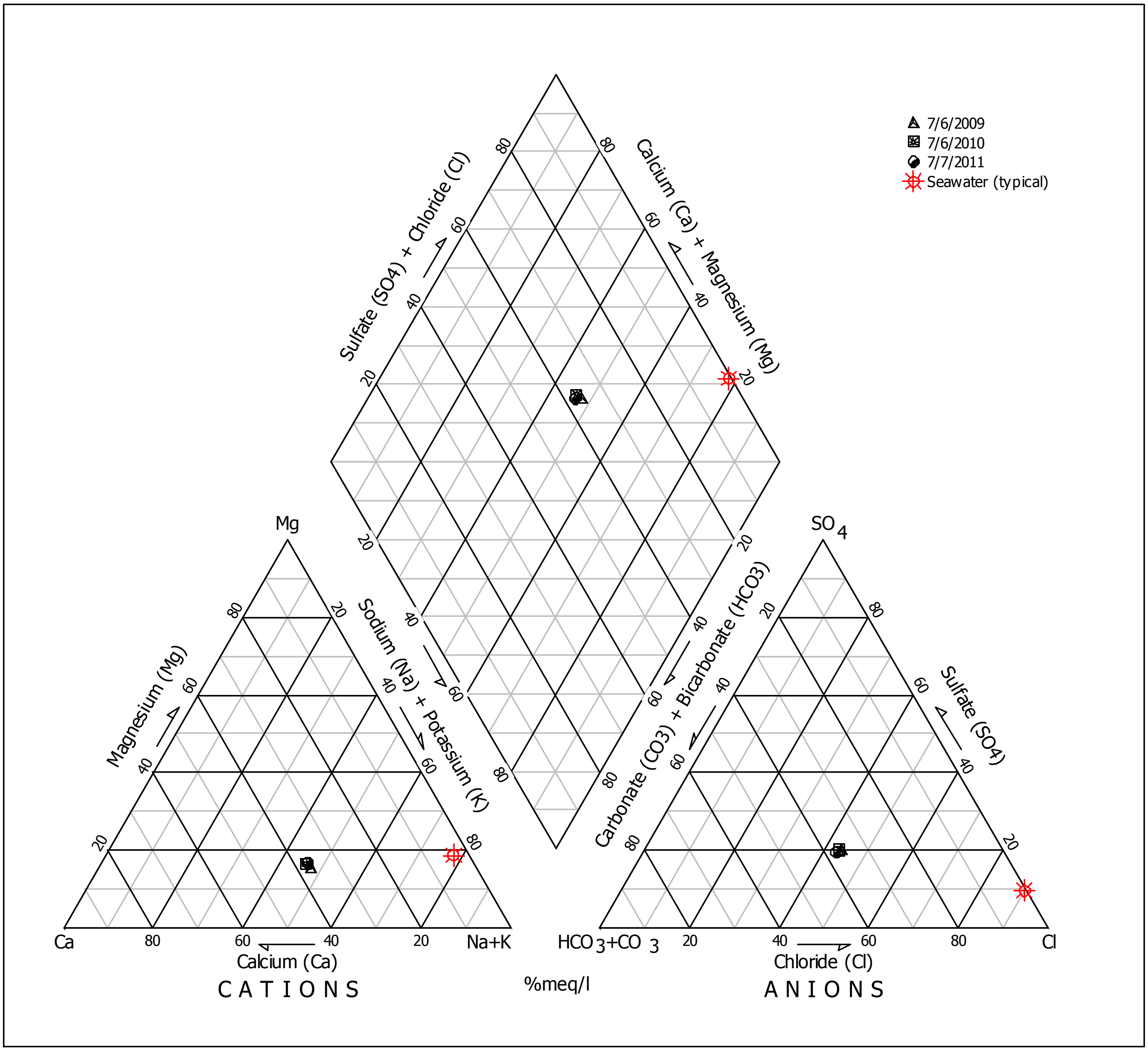


Figure A-30: Piper Diagram of Luzern #2 Production Well

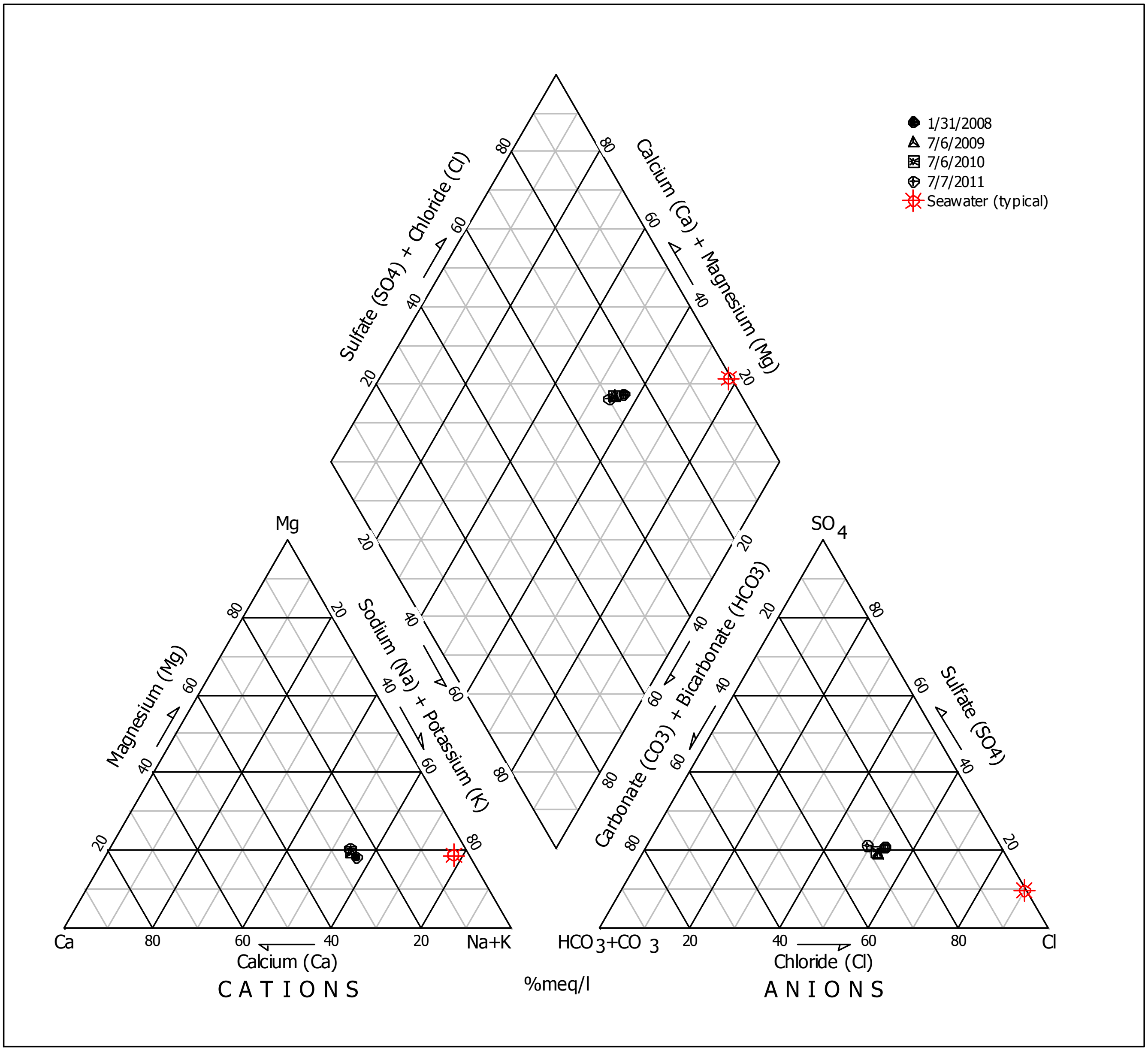


Figure A-31: Piper Diagram of Darwin Production Well

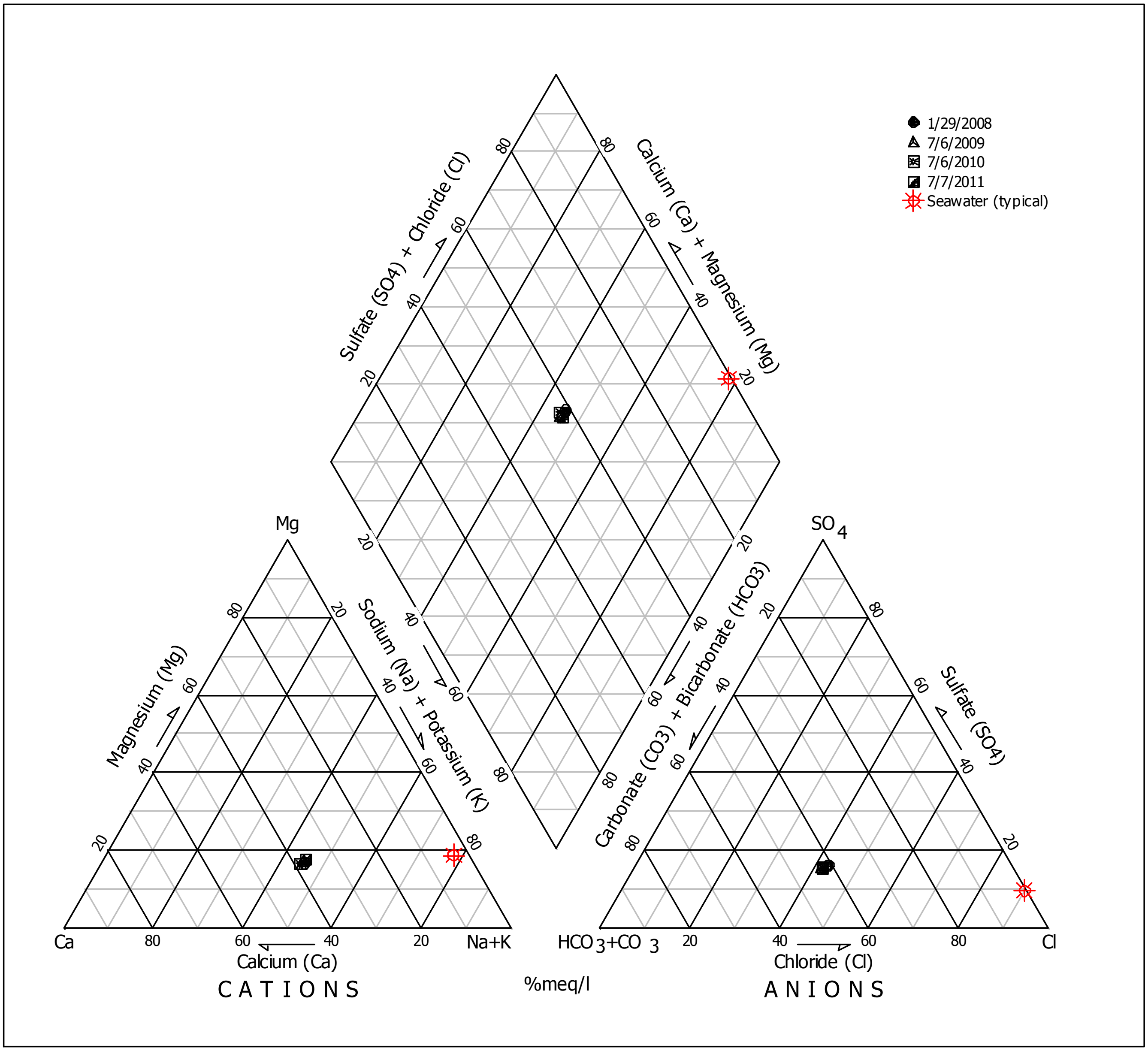


Figure A-32: Piper Diagram of Ord Grove No. 2 Production Well

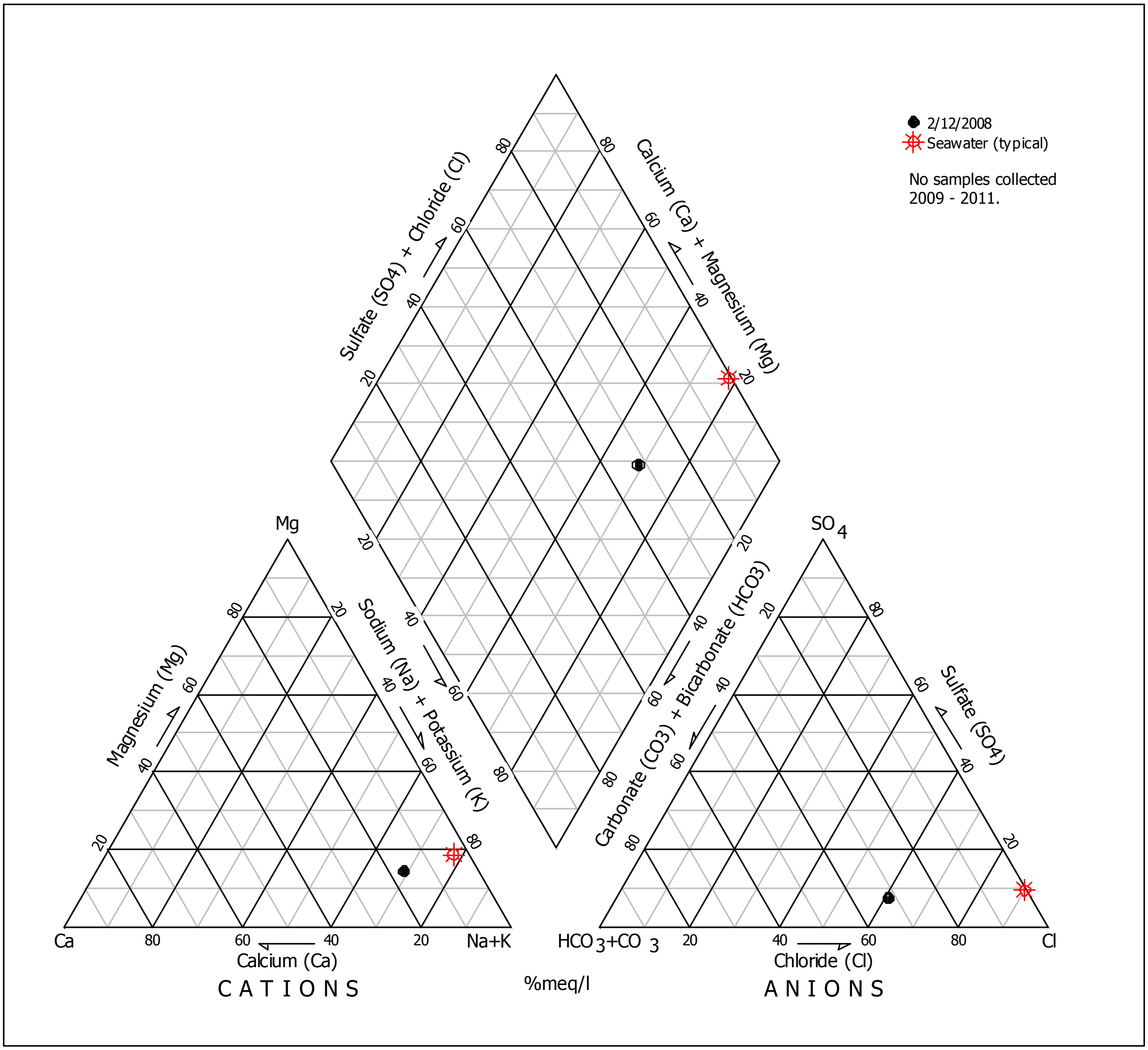


Figure A-33: Piper Diagram of Seaside City No. 3 Production Well

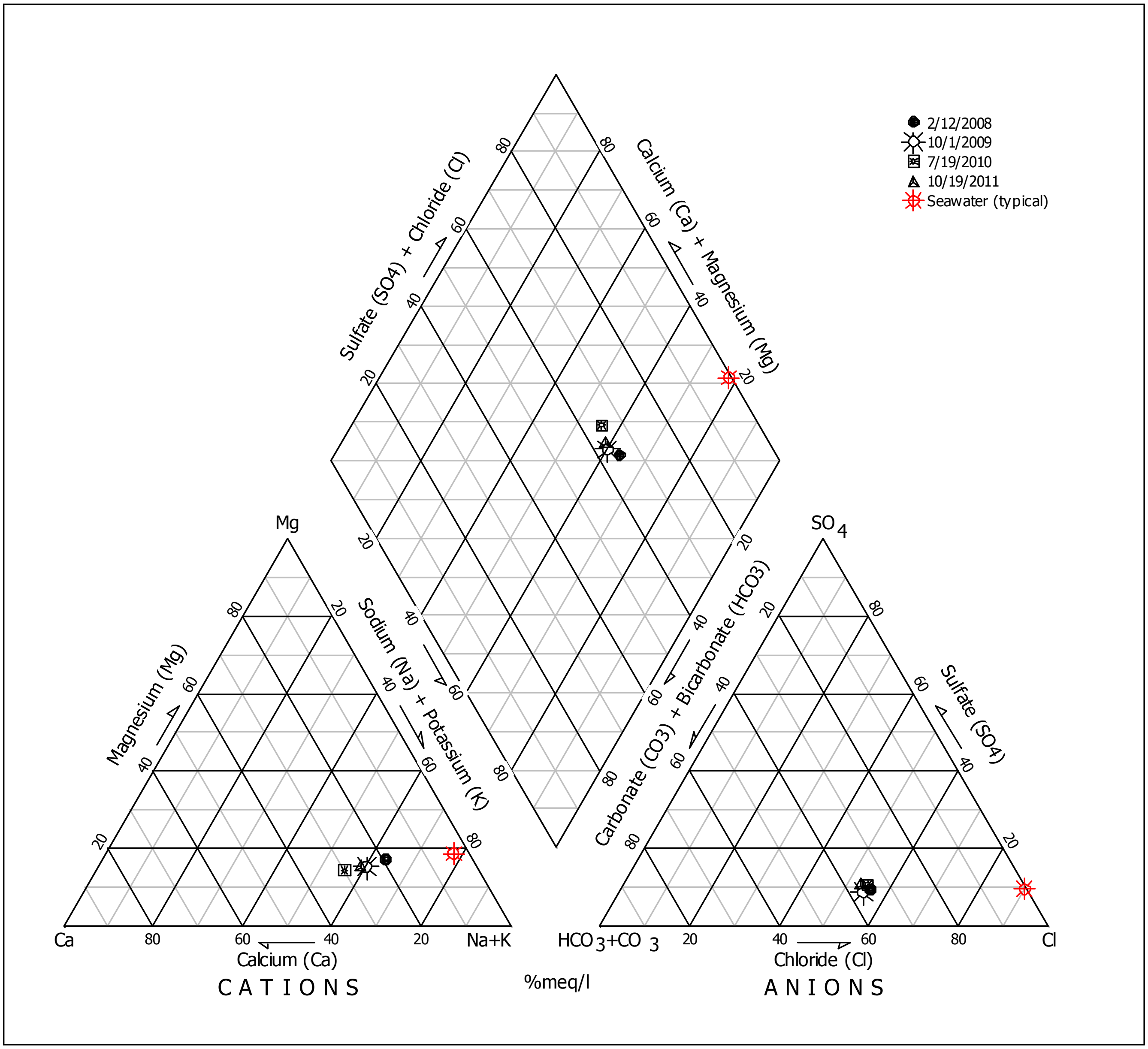


Figure A-34: Piper Diagram of Seaside City No. 4 Production Well

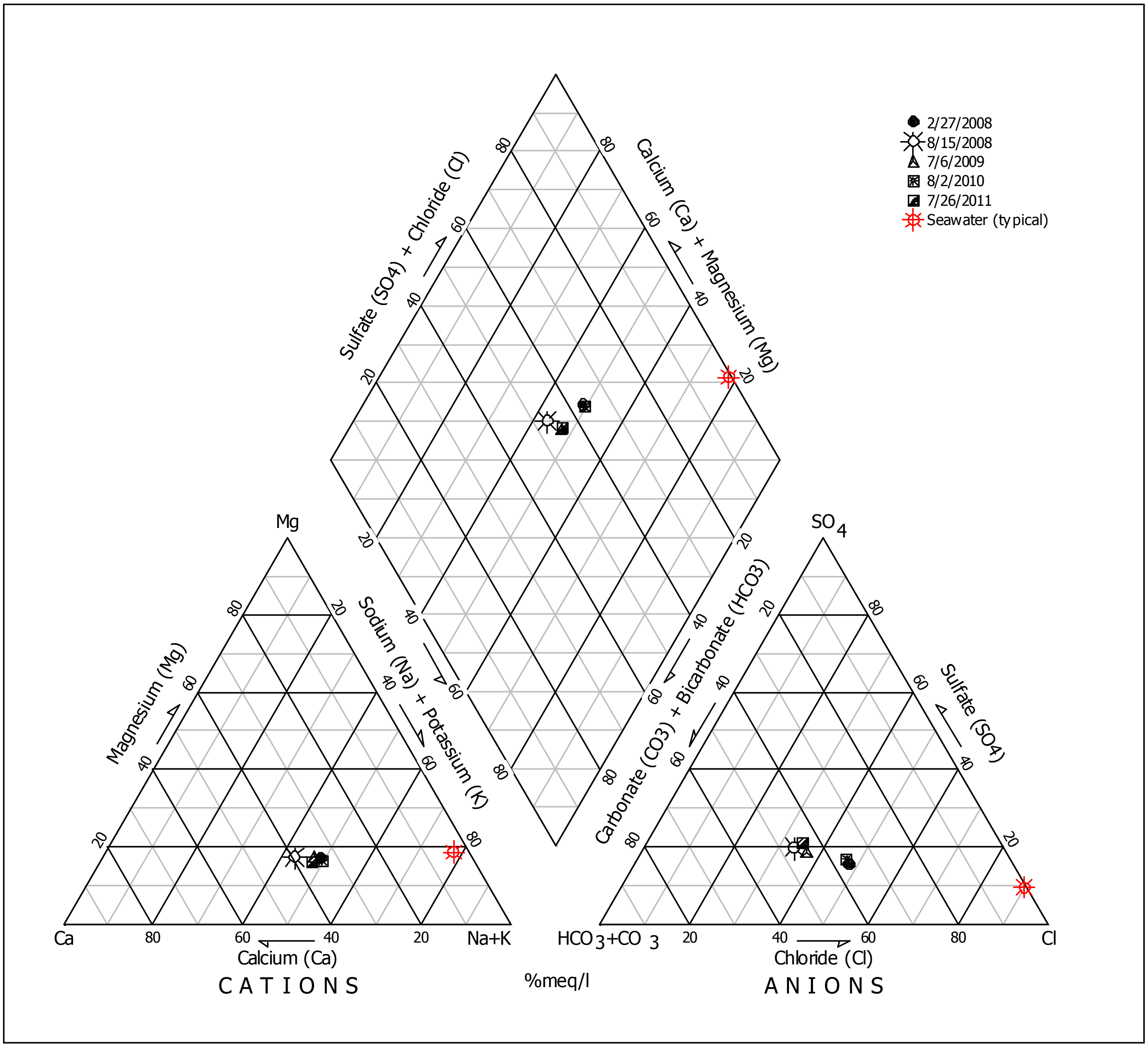


Figure A-35: Piper Diagram of PRTIW

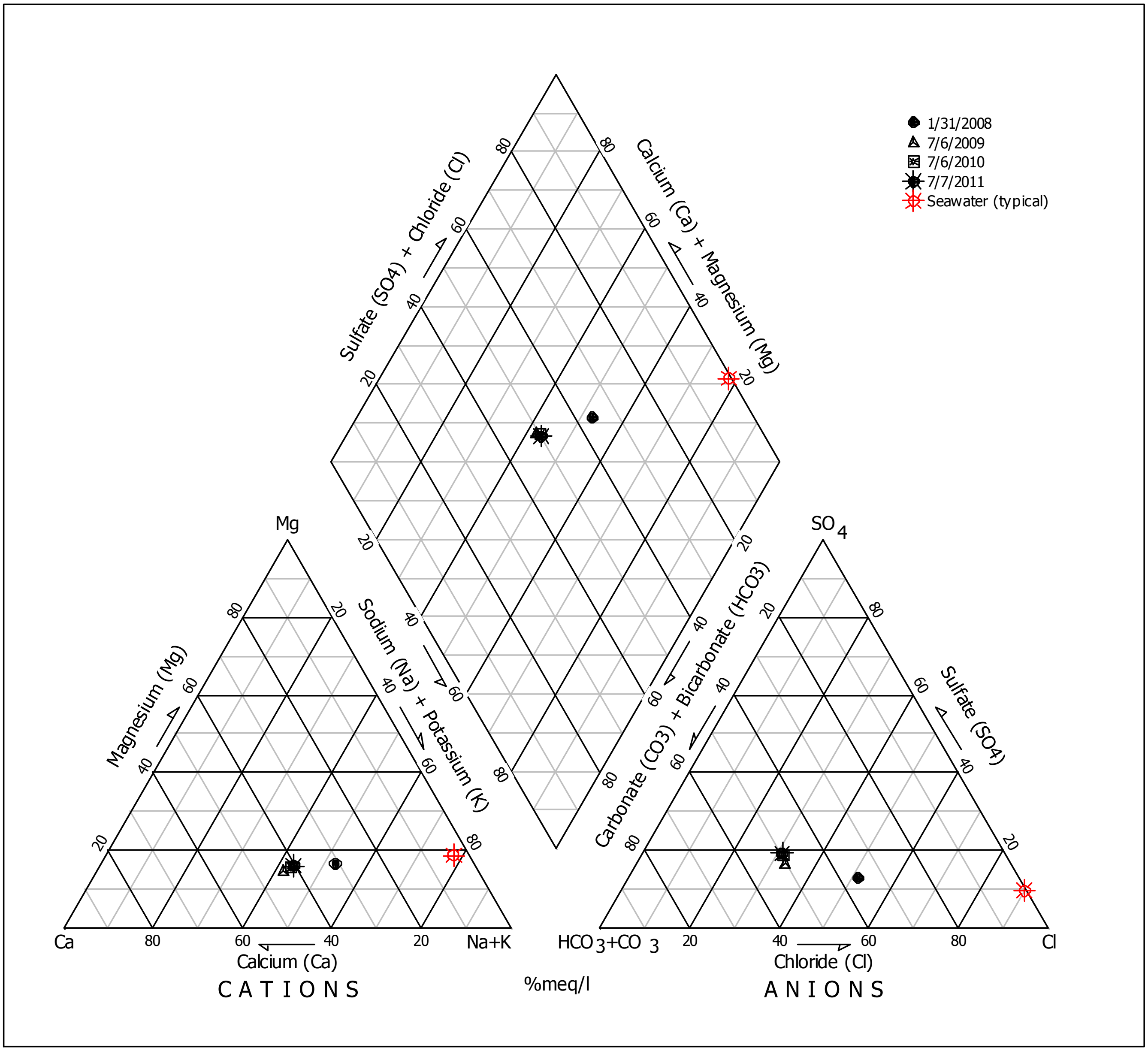


Figure A-36: Piper Diagram of Paralta Production Well

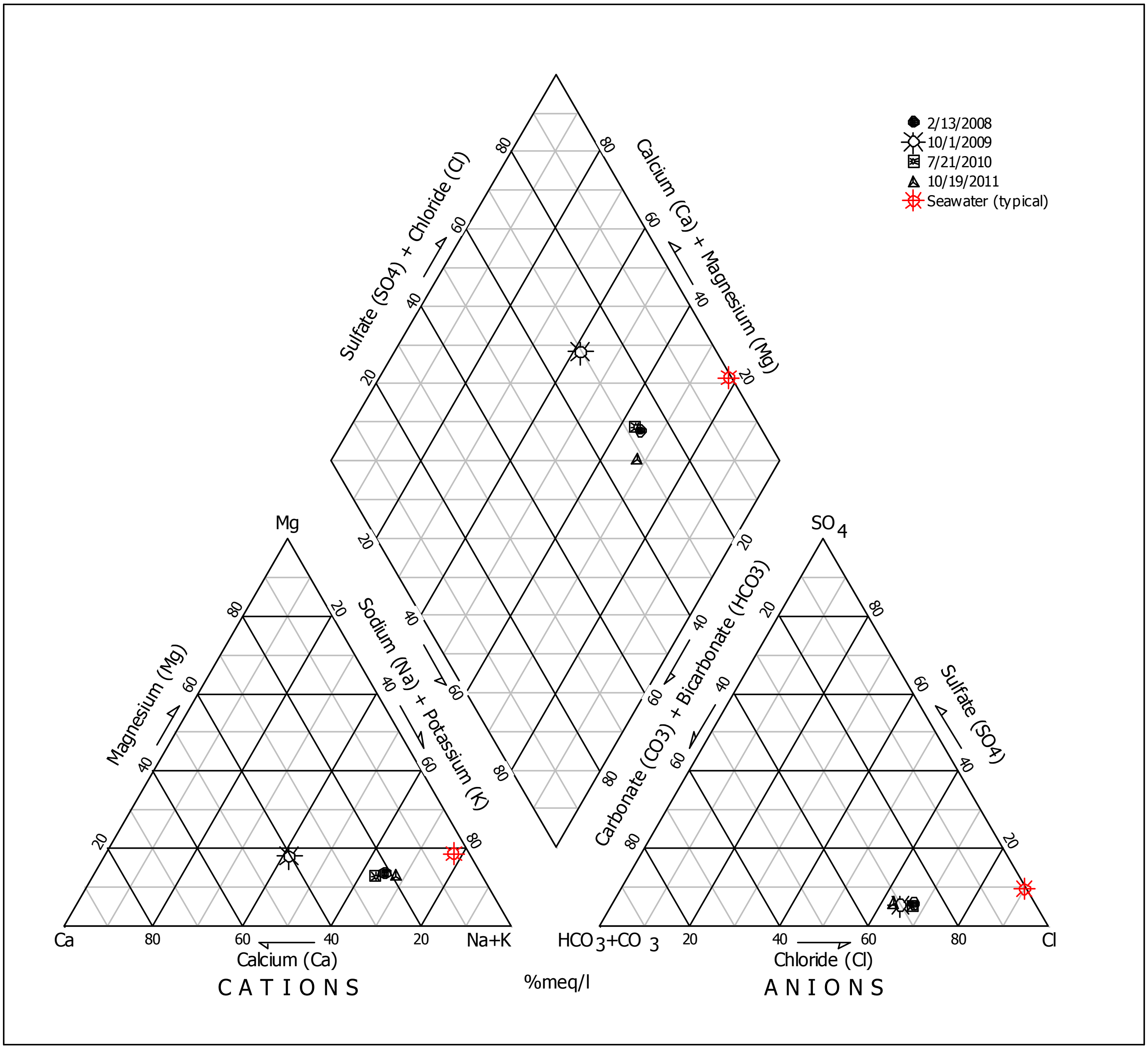


Figure A-37: Piper Diagram of Reservoir Production Well

APPENDIX B: CHLORIDE AND SODIUM/CHLORIDE RATIO GRAPHS

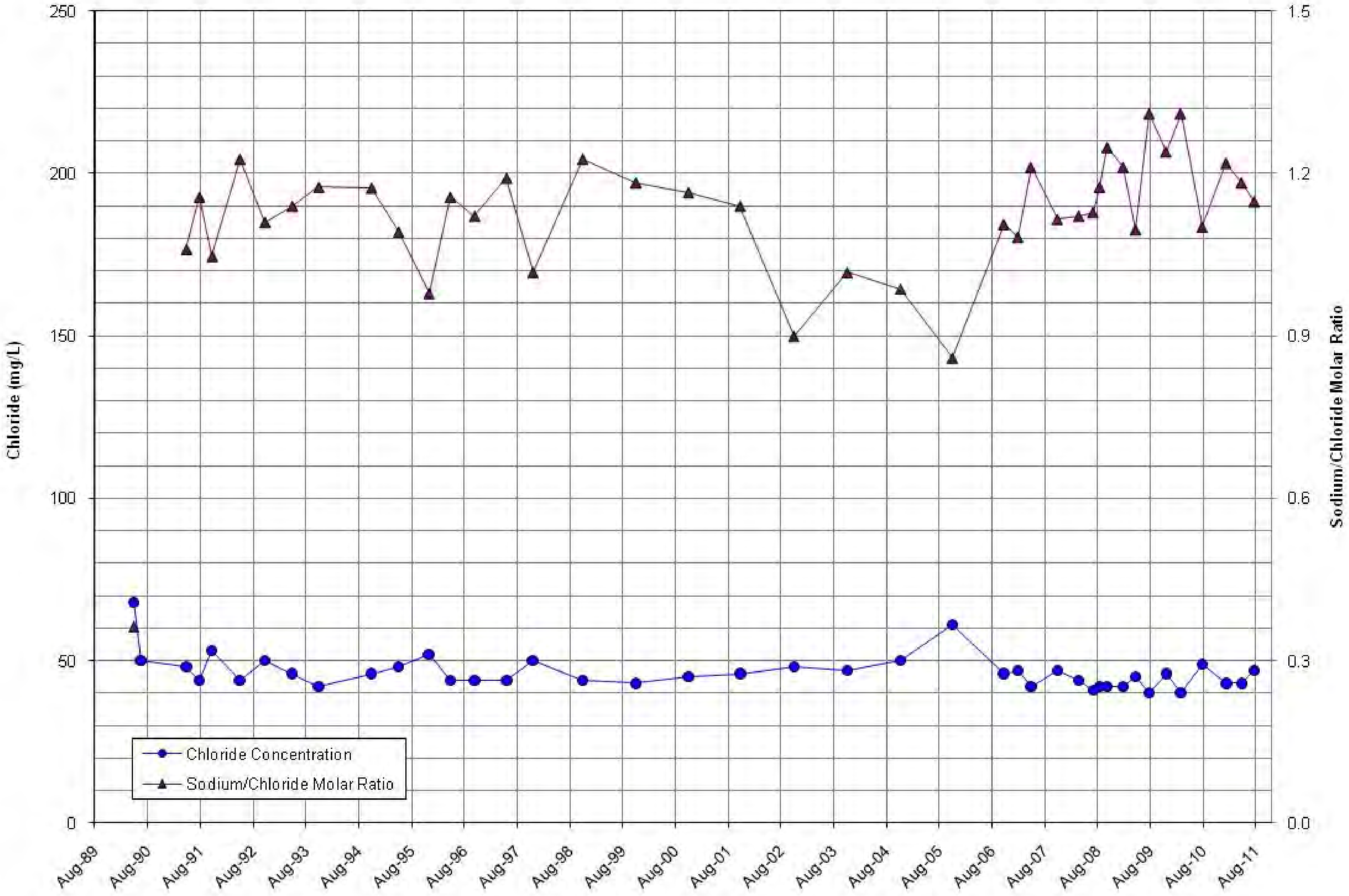


Figure B-1: PCA West Shallow Well Chemograph

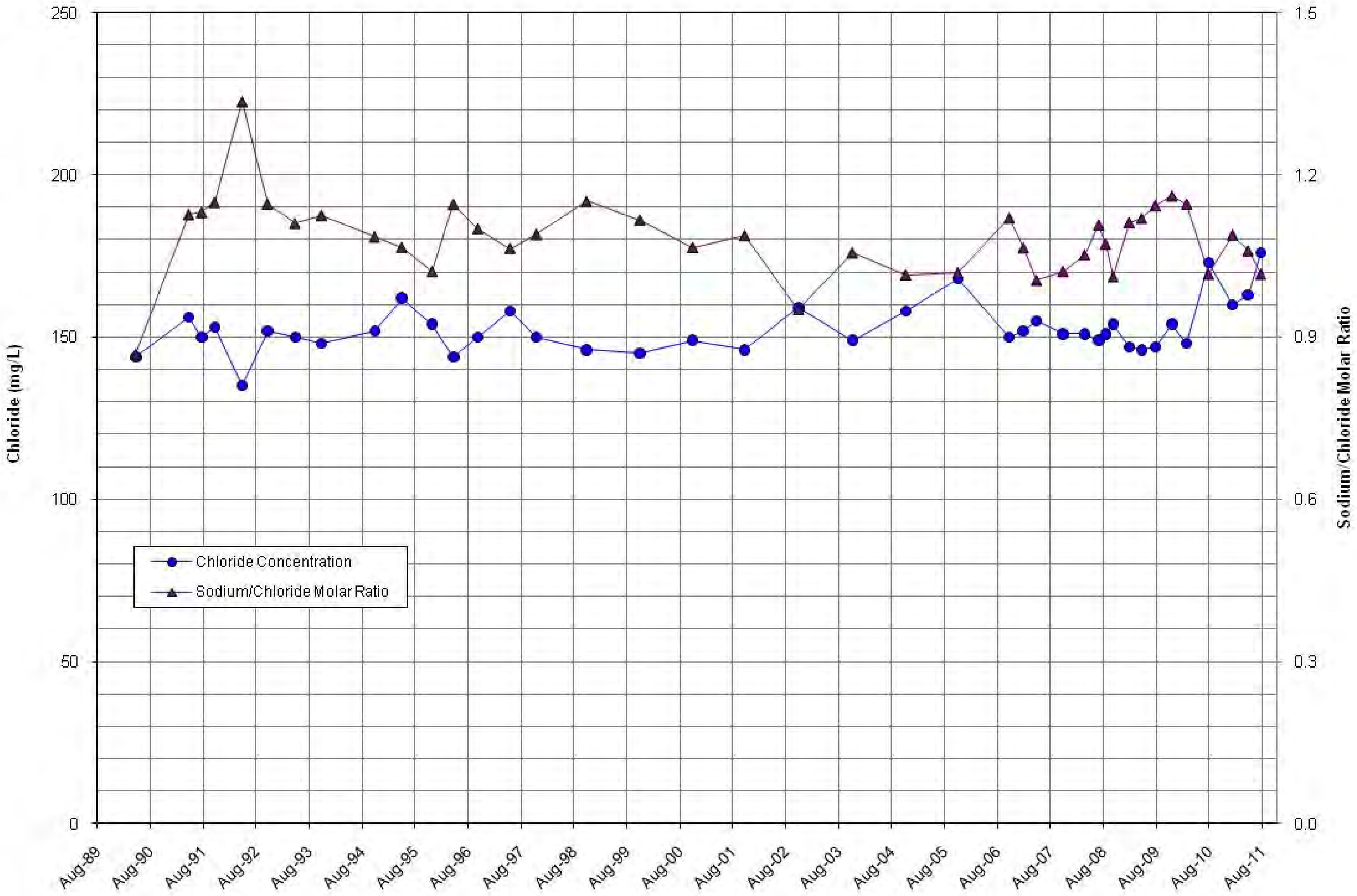


Figure B-2: PCA West Deep Well Chemograph

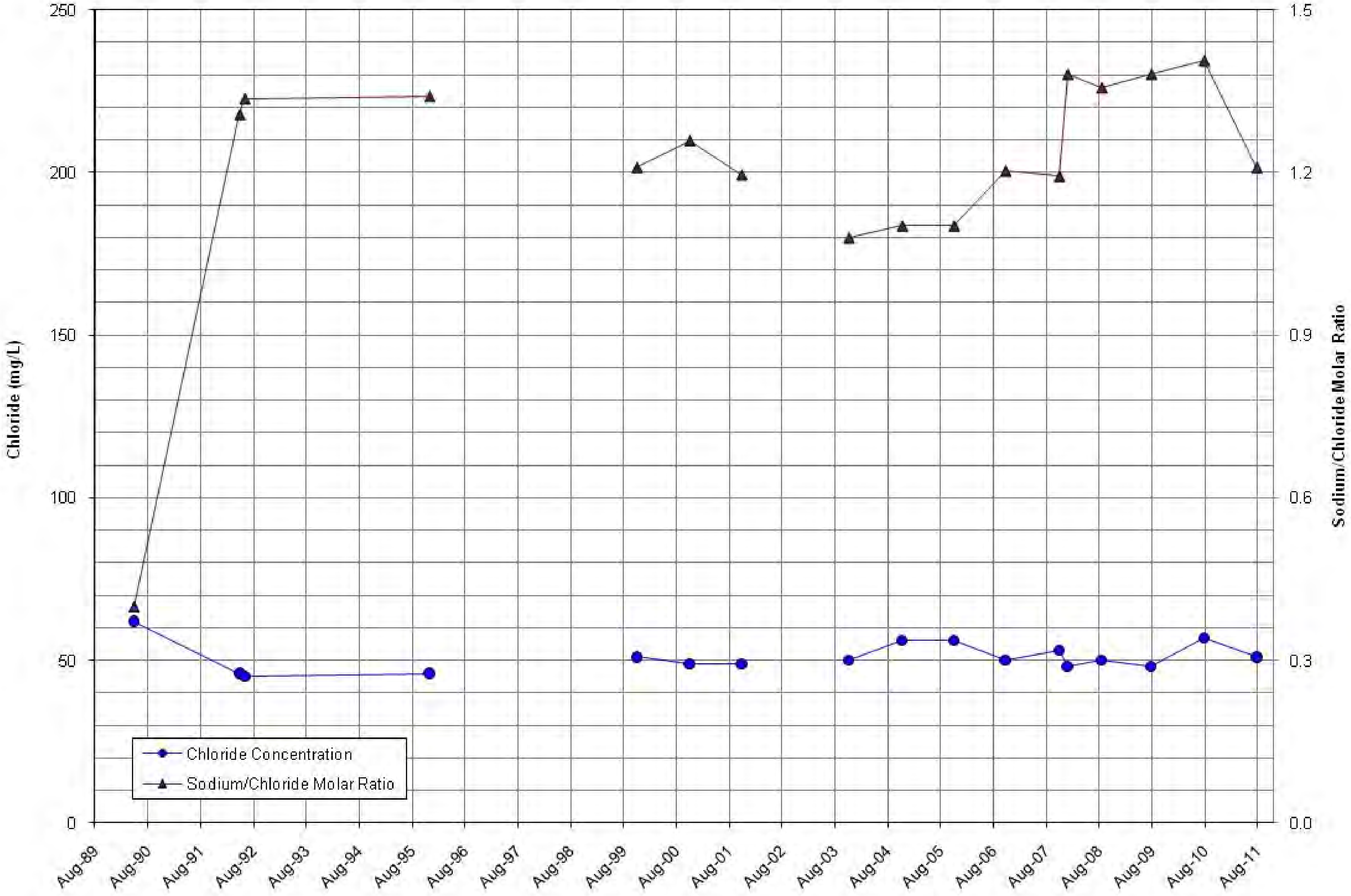


Figure B-3: PCA East Shallow Well Chemograph

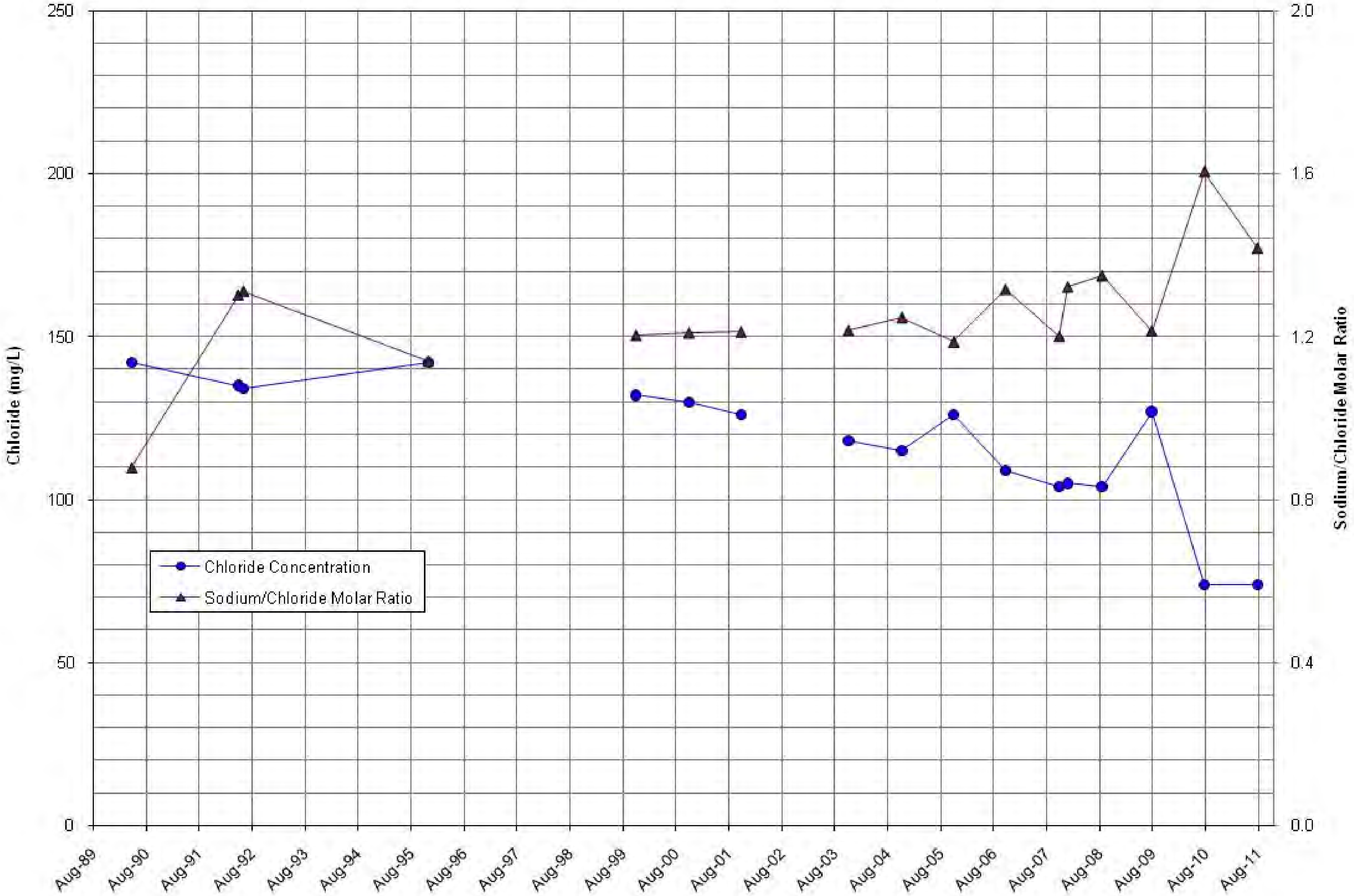


Figure B-4: PCA East Deep Well Chemograph

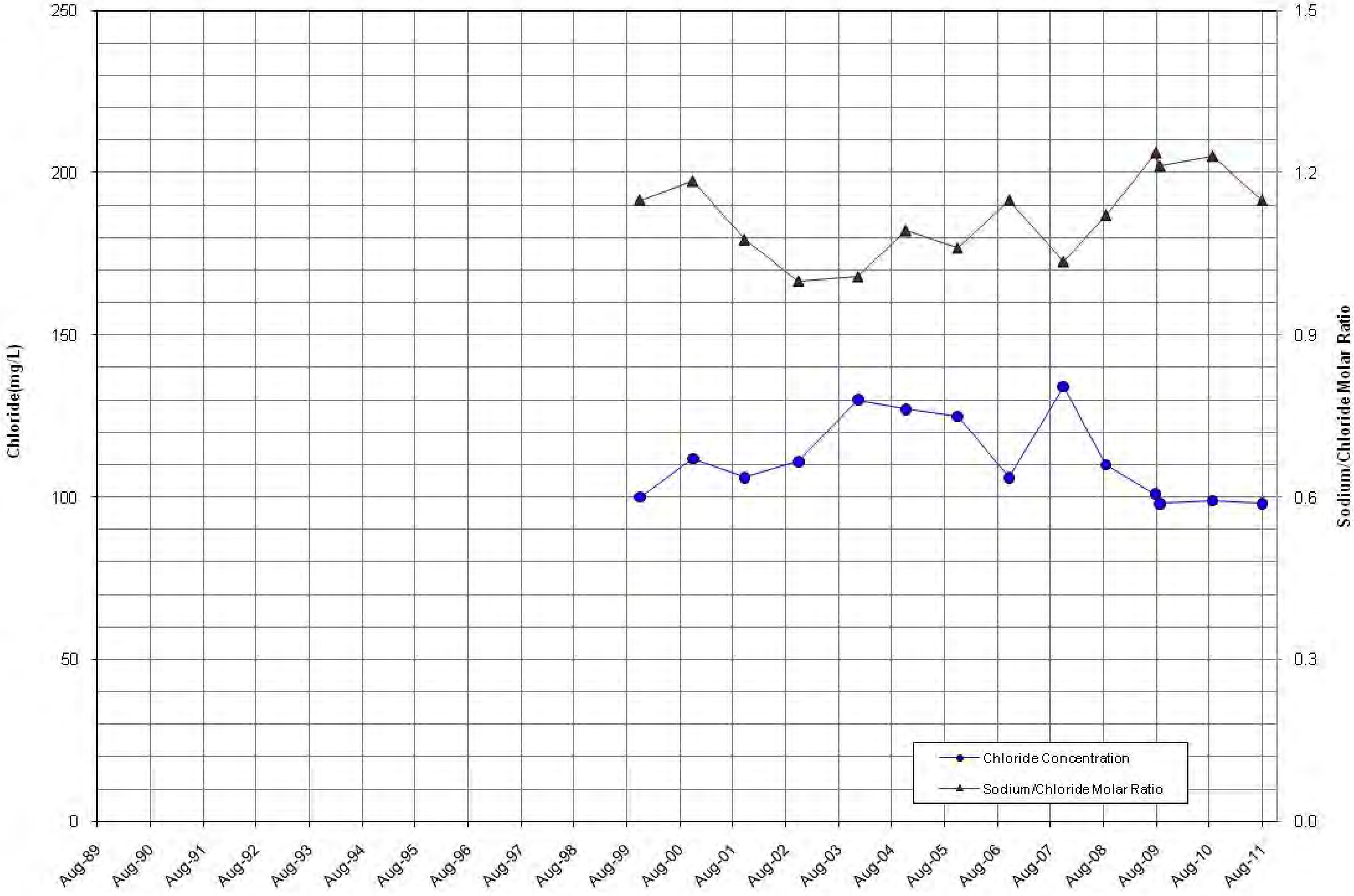


Figure B-5: Ord Terrace Shallow Well Chemograph

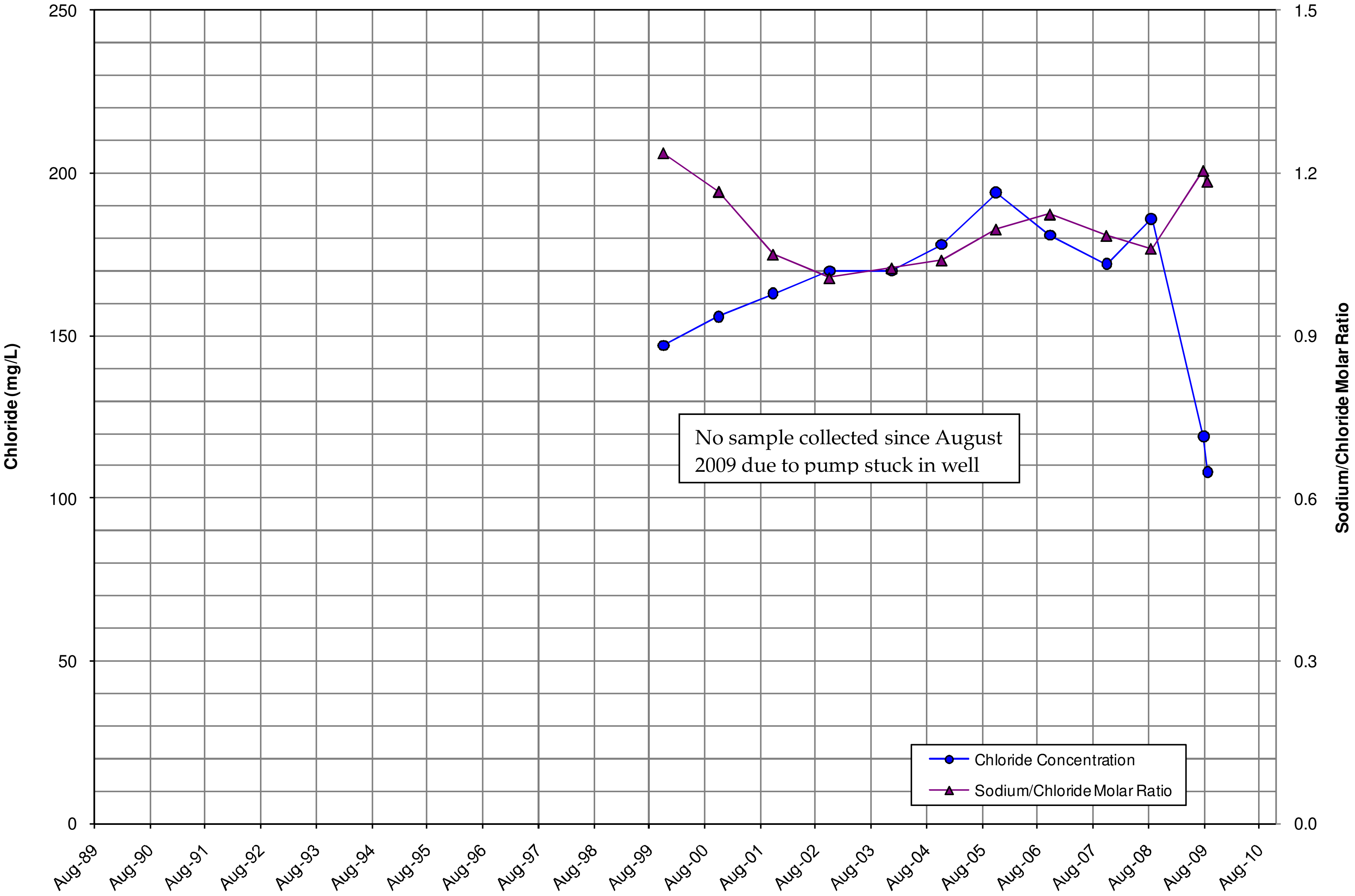


Figure B-6: Ord Terrace Deep Well Chemograph

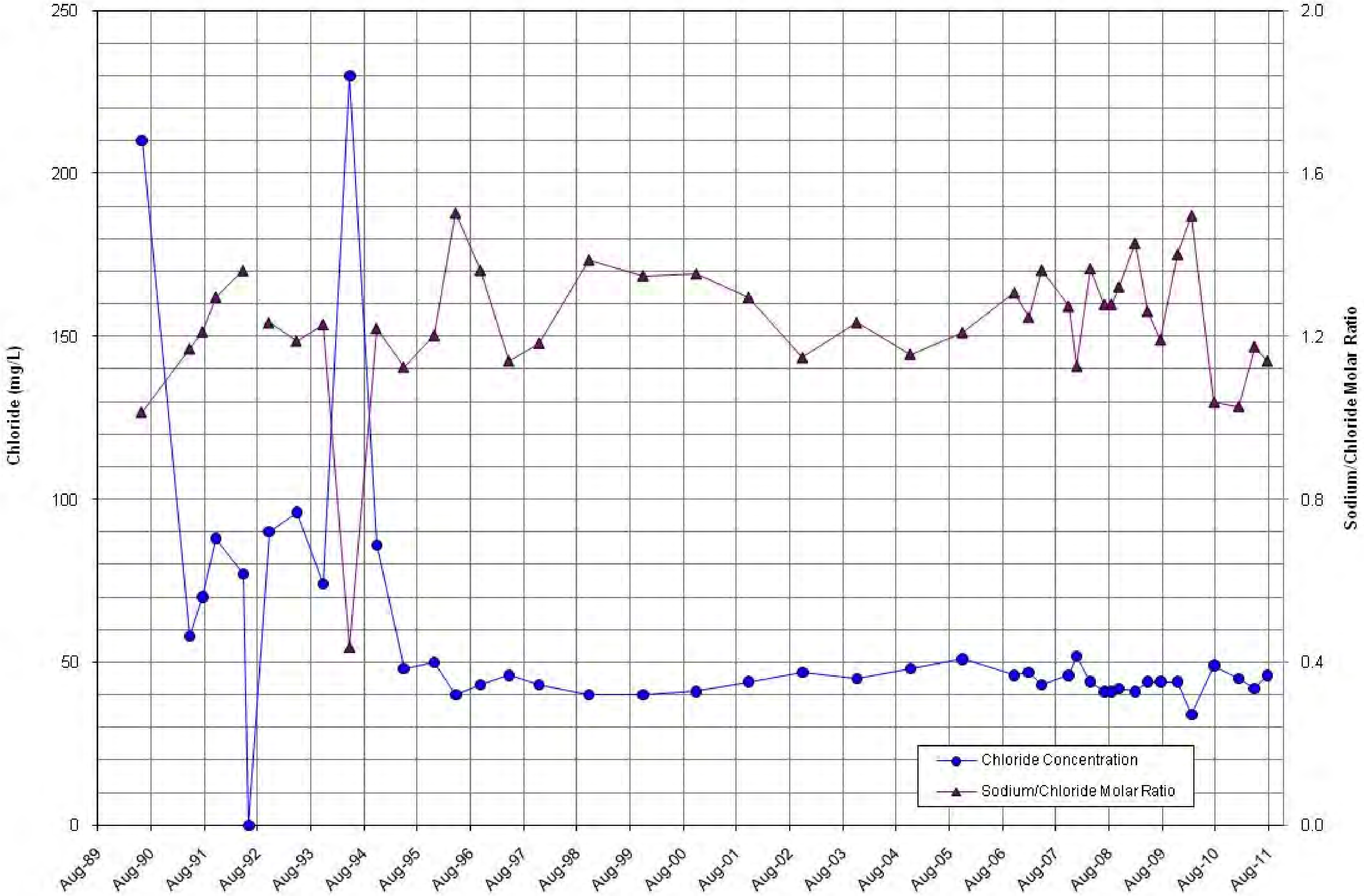


Figure B-7: MSC Shallow Well Chemograph

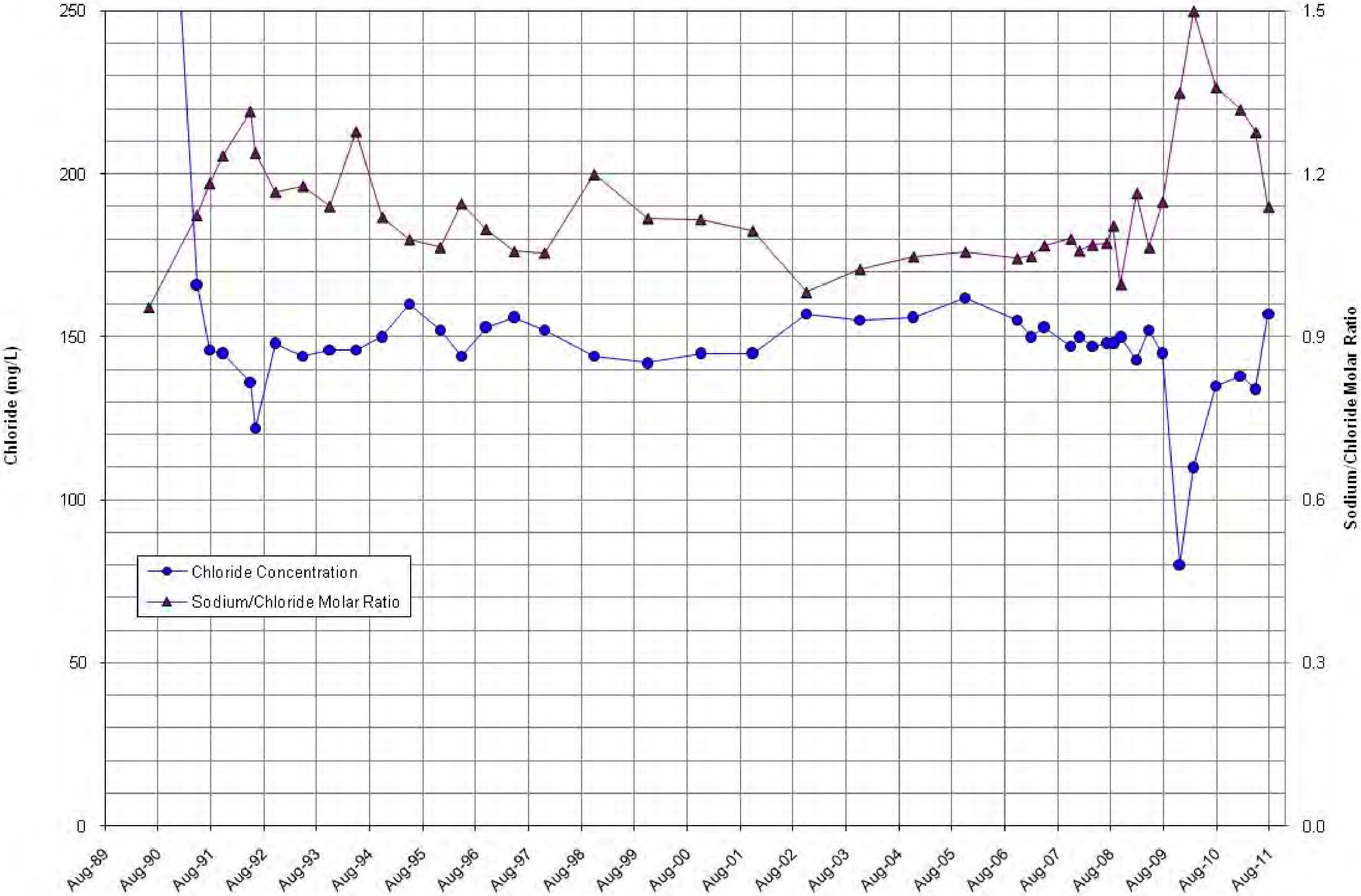


Figure B-8: MSC Deep Well Chemograph

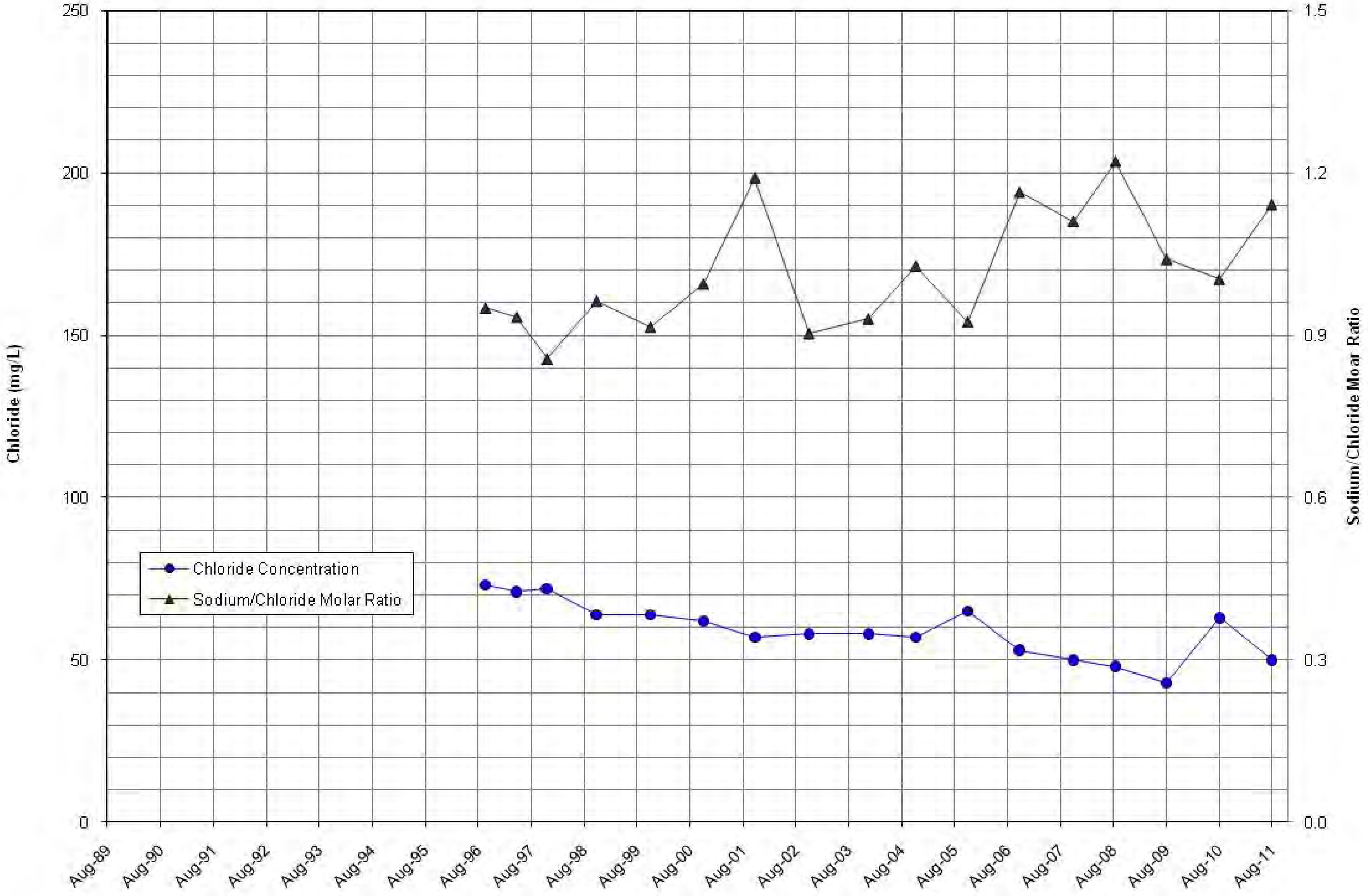


Figure B-9: Fort Ord 10 Shallow Well Chemograph

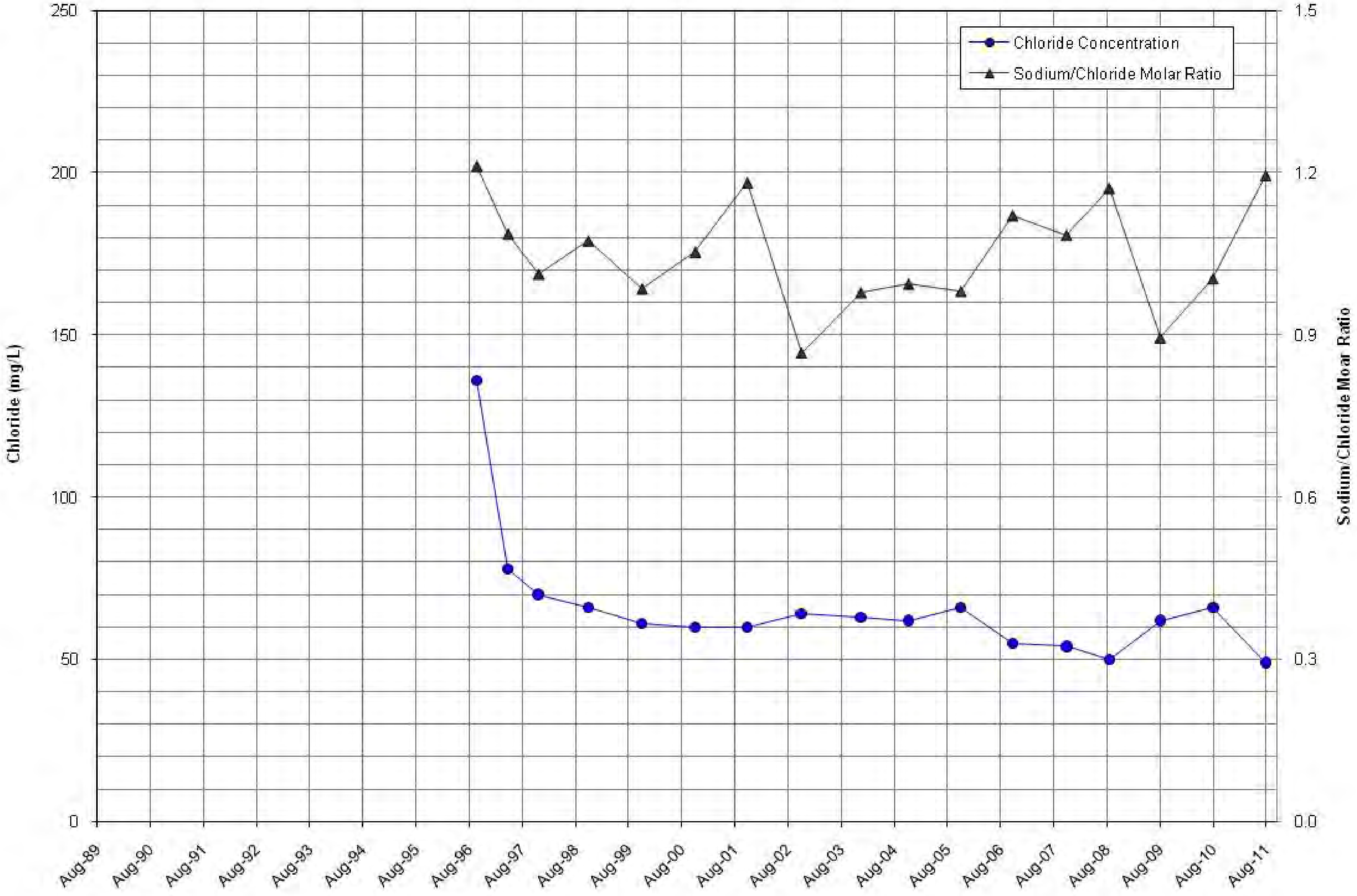


Figure B-10: Fort Ord 10 Deep Well Chemograph

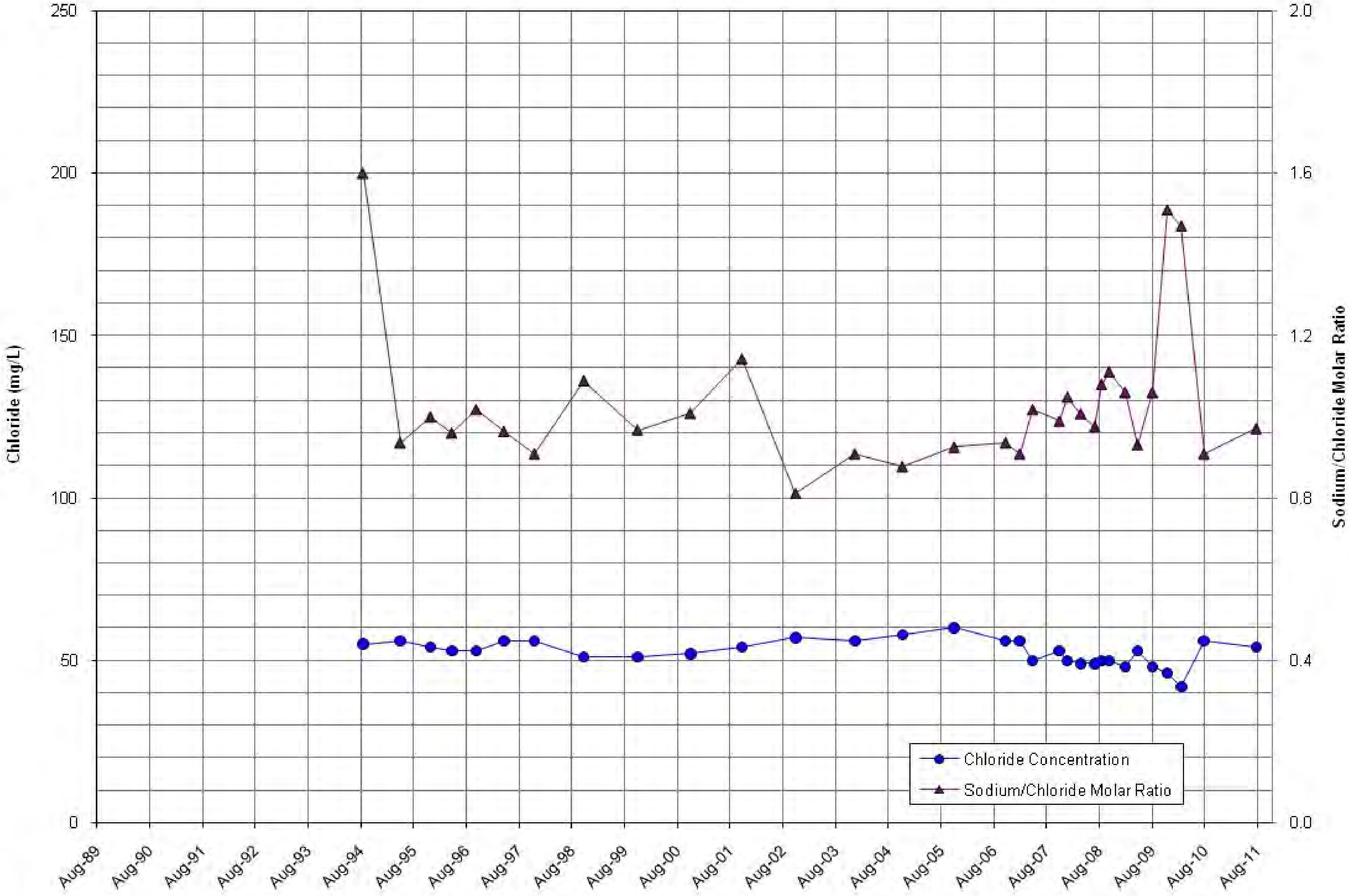


Figure B-11: Fort Ord 9 Shallow Well Chemograph

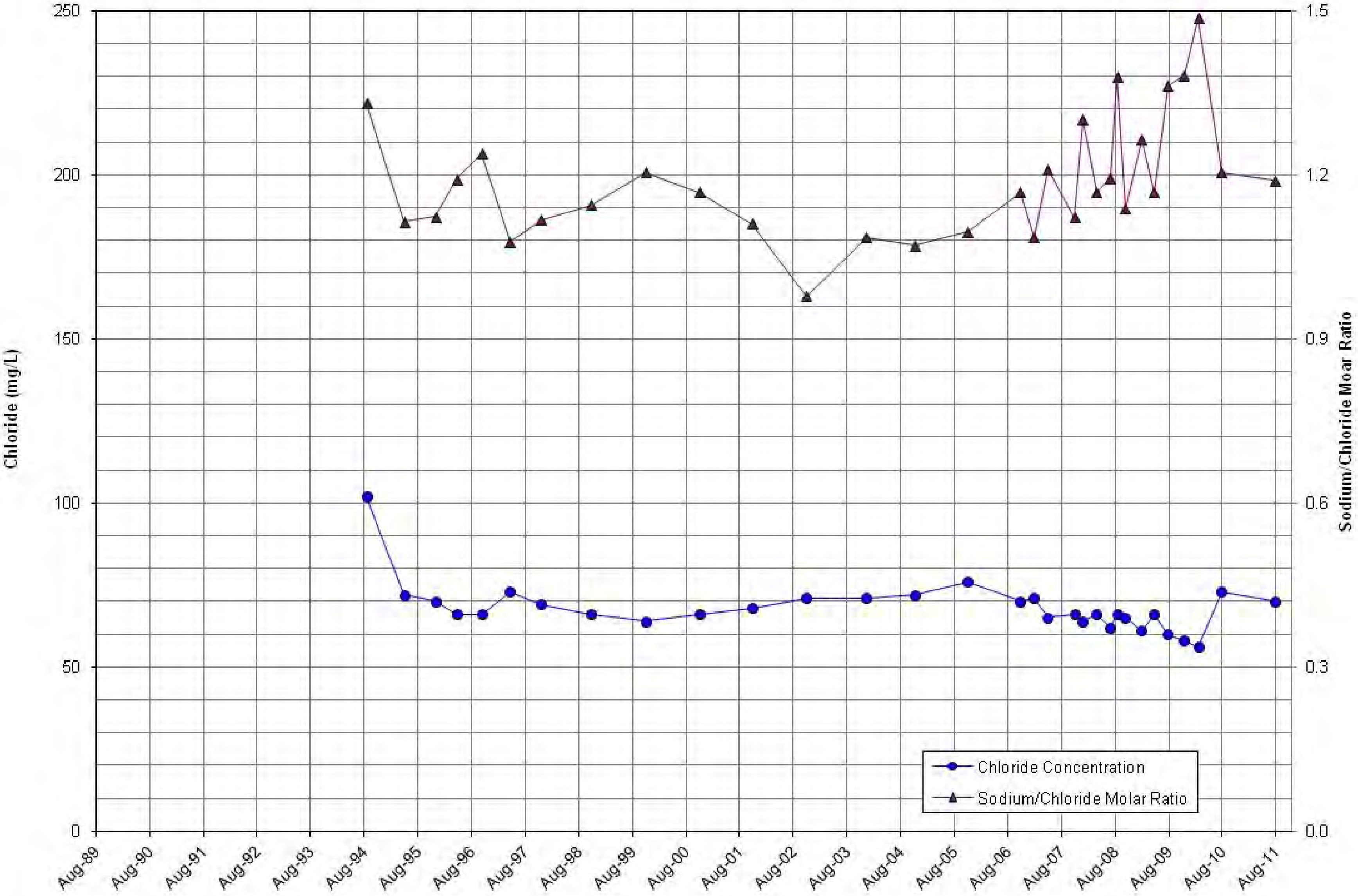


Figure B-12: Fort Ord 9 Deep Well Chemograph

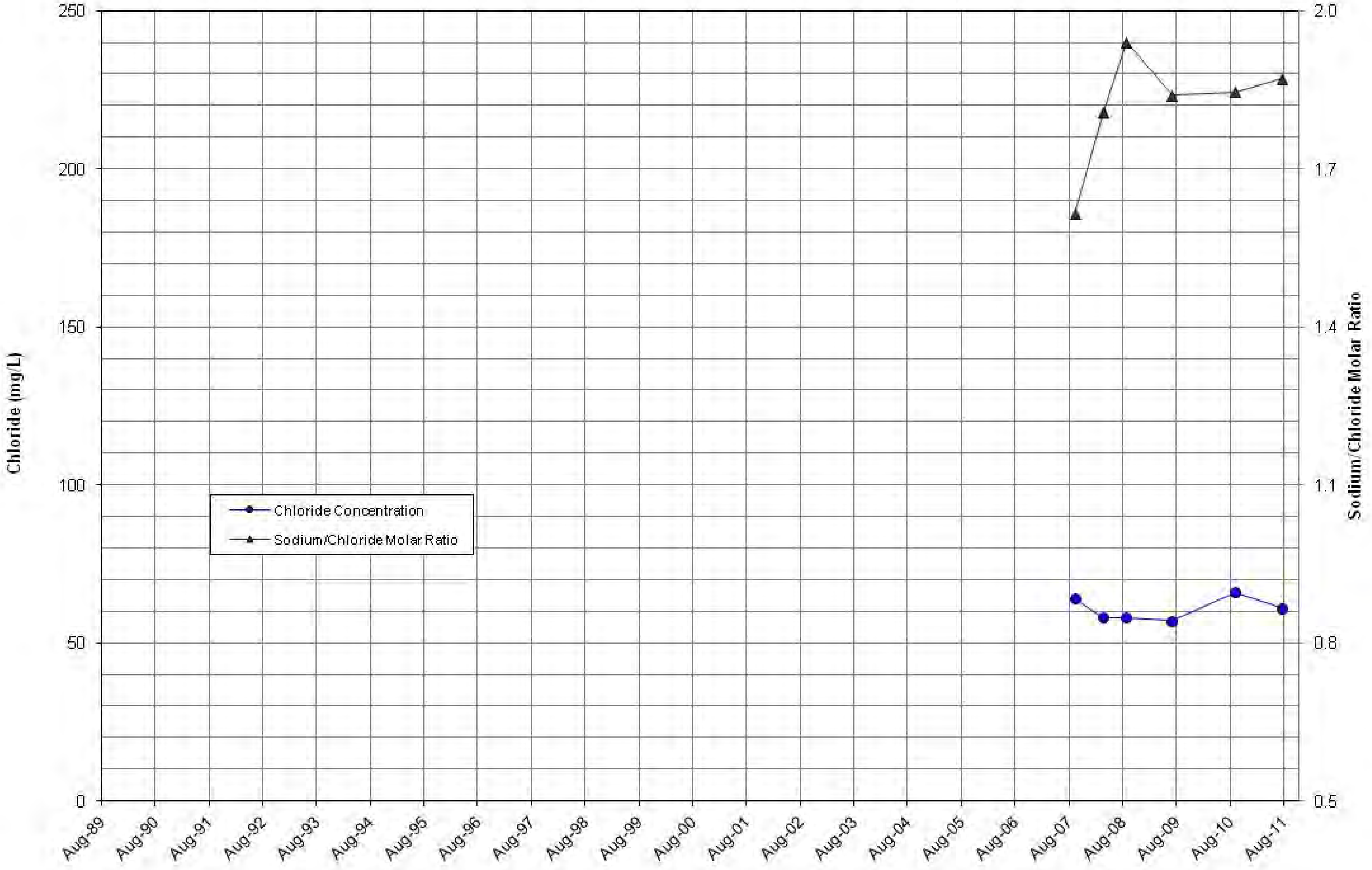


Figure B-13: SBWM-1: 1,140 foot depth sample Chemograph

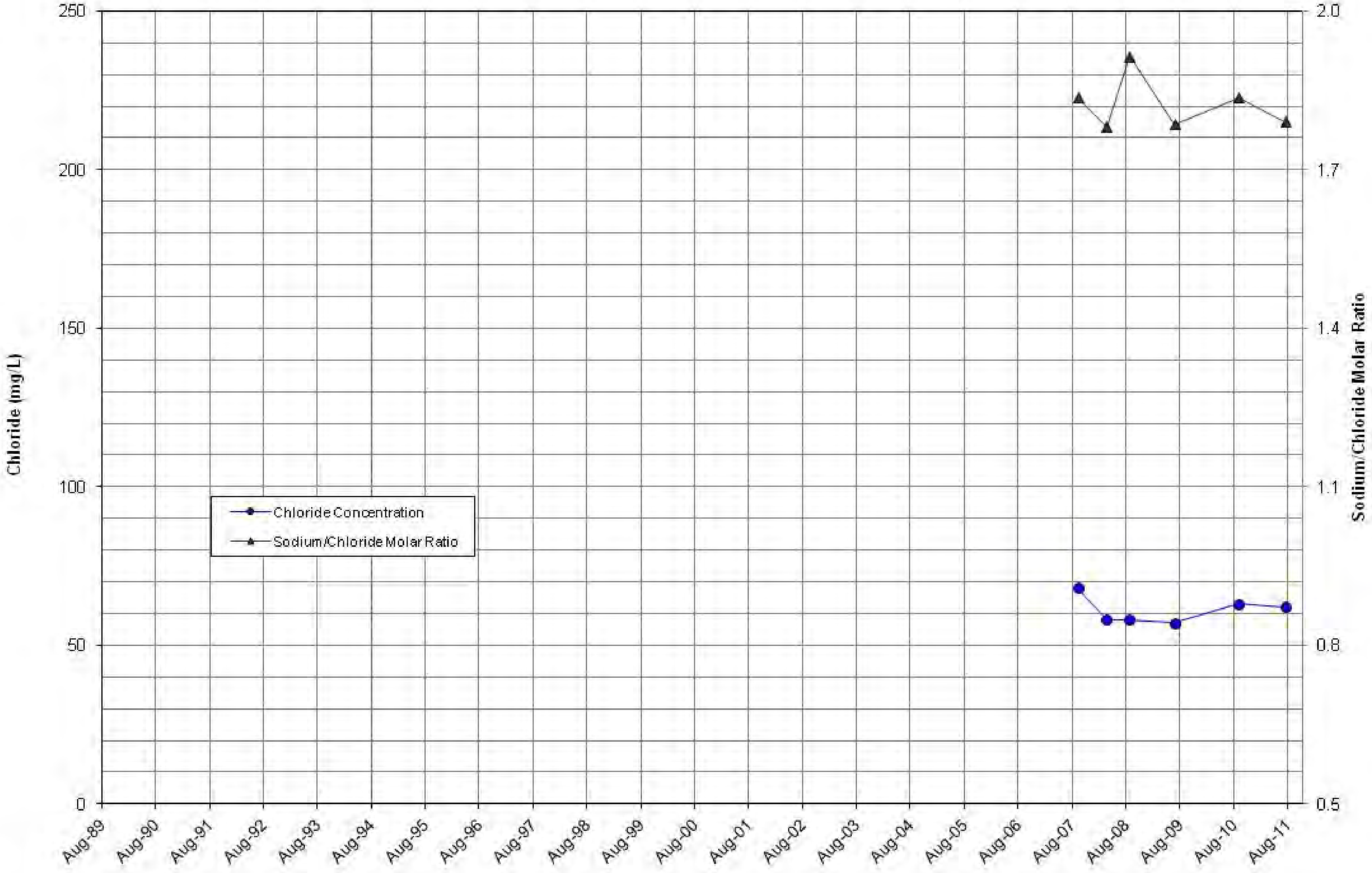


Figure B-14: SBWM-1: 1,390 foot depth sample Chemograph

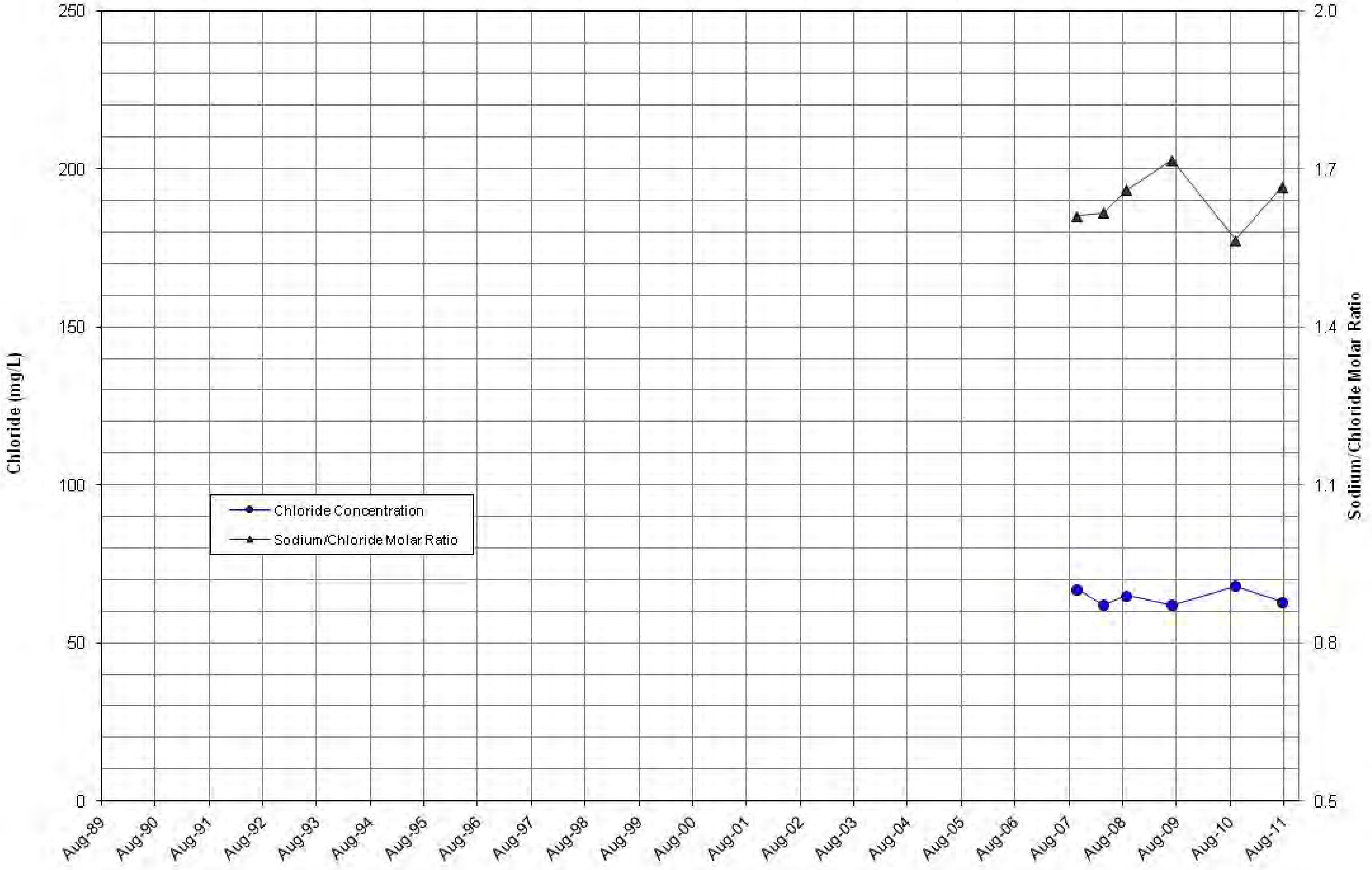


Figure B-15: SBWM-2: 1,000 foot depth sample Chemograph

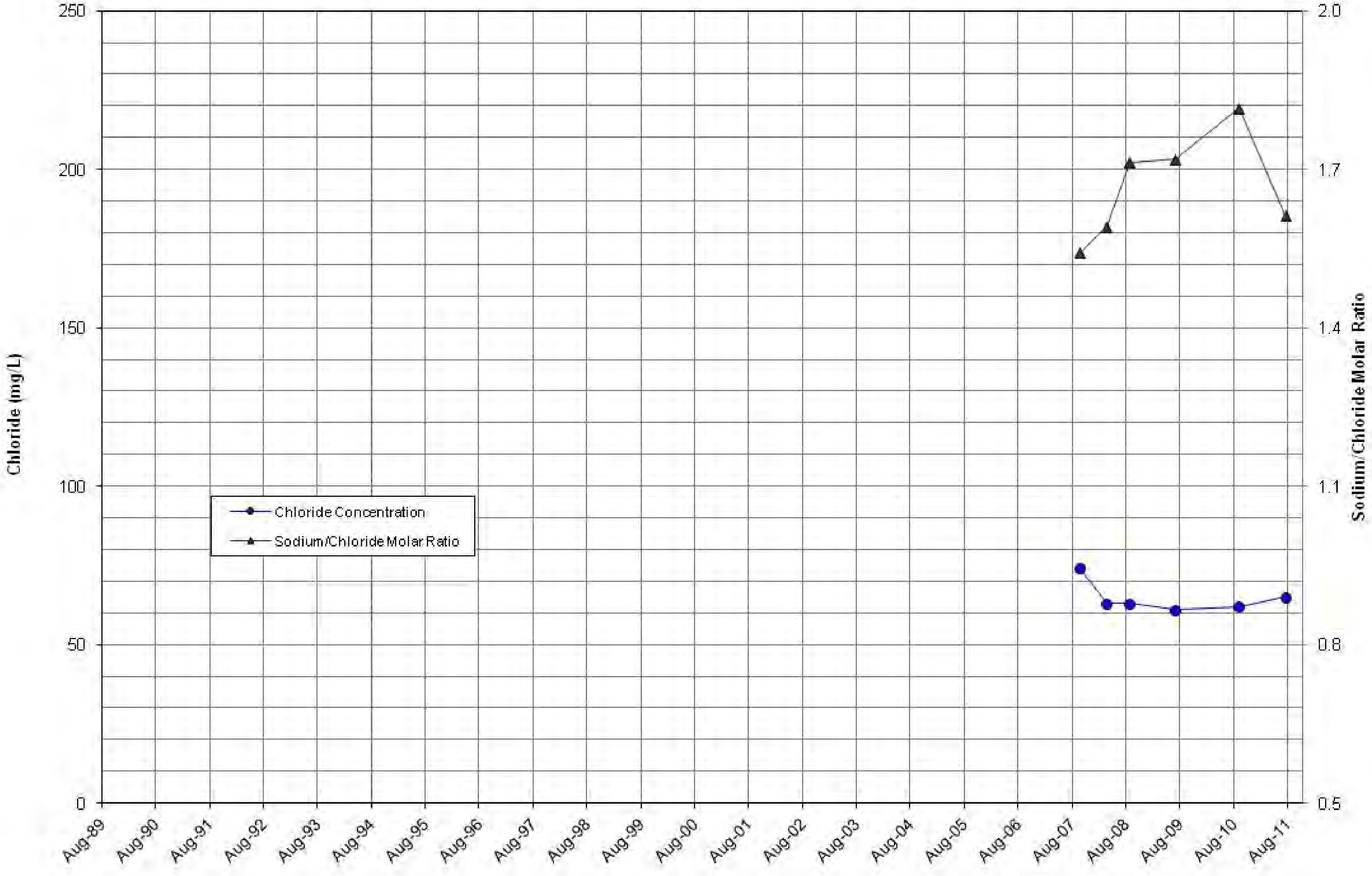


Figure B-16: SBWM-2: 1,470 foot depth sample Chemograph

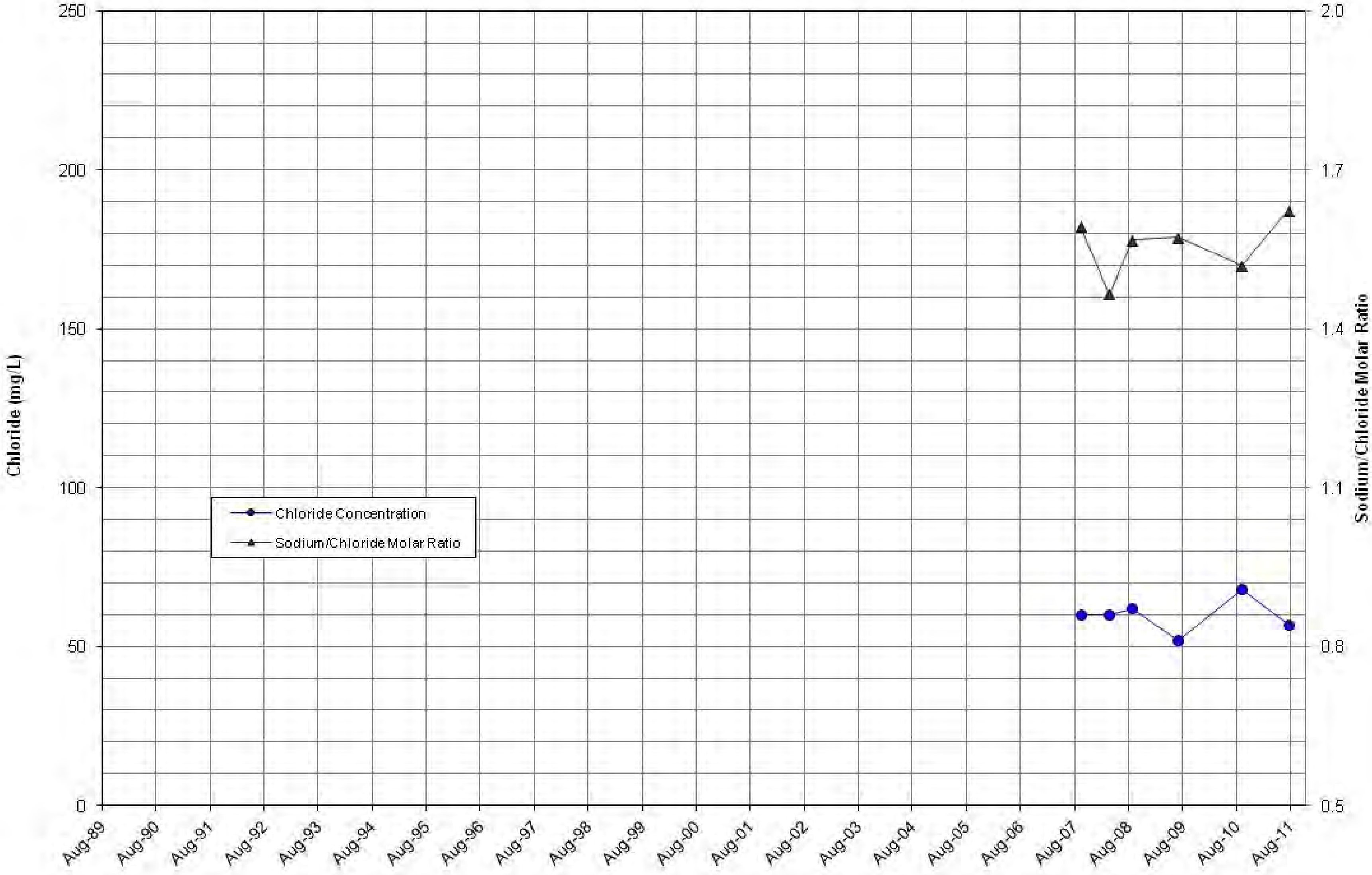


Figure B-17: SBWM-3: 870 foot depth sample Chemograph

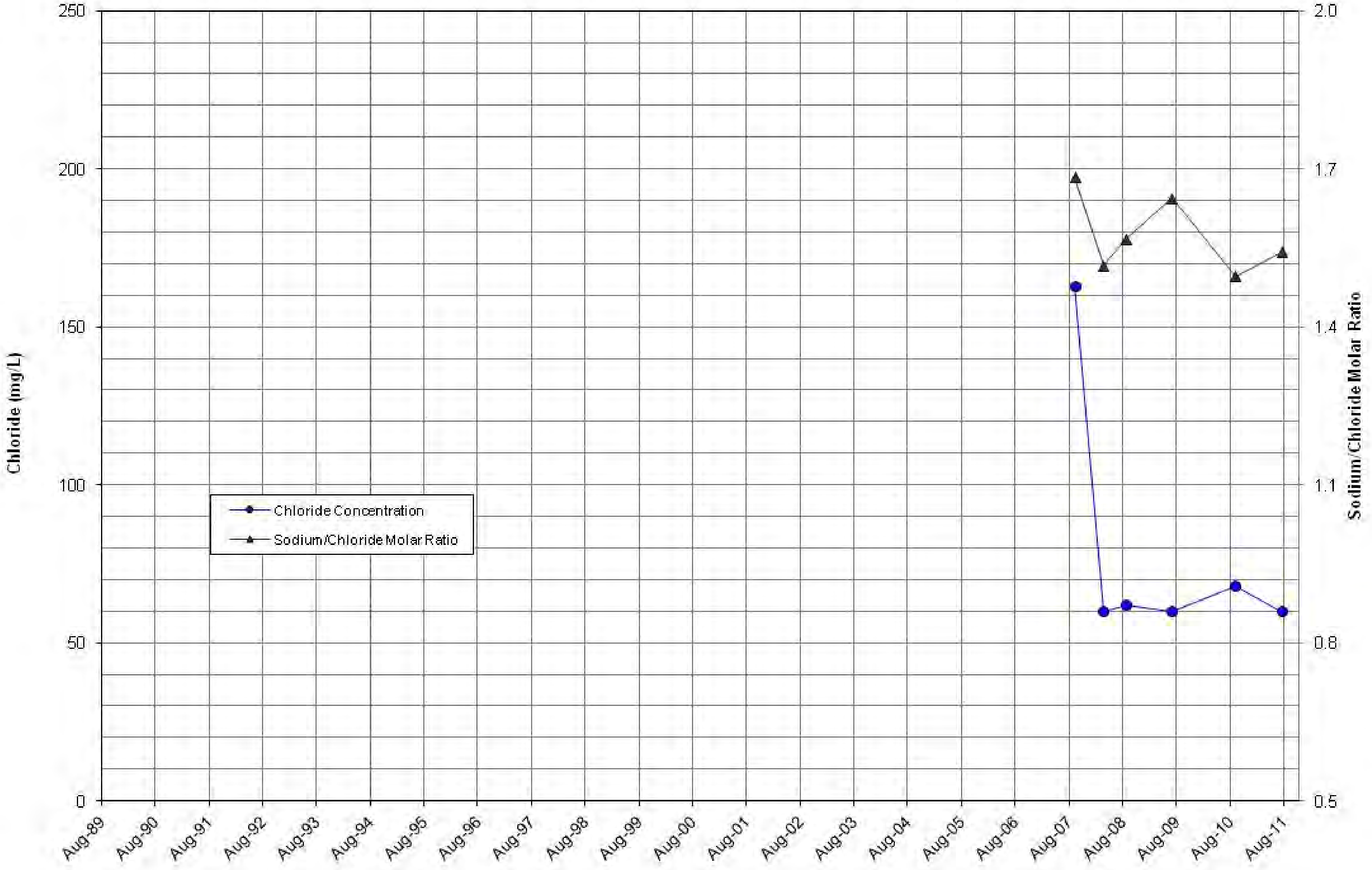


Figure B-18: SBWM-3: 1,275 foot depth sample Chemograph

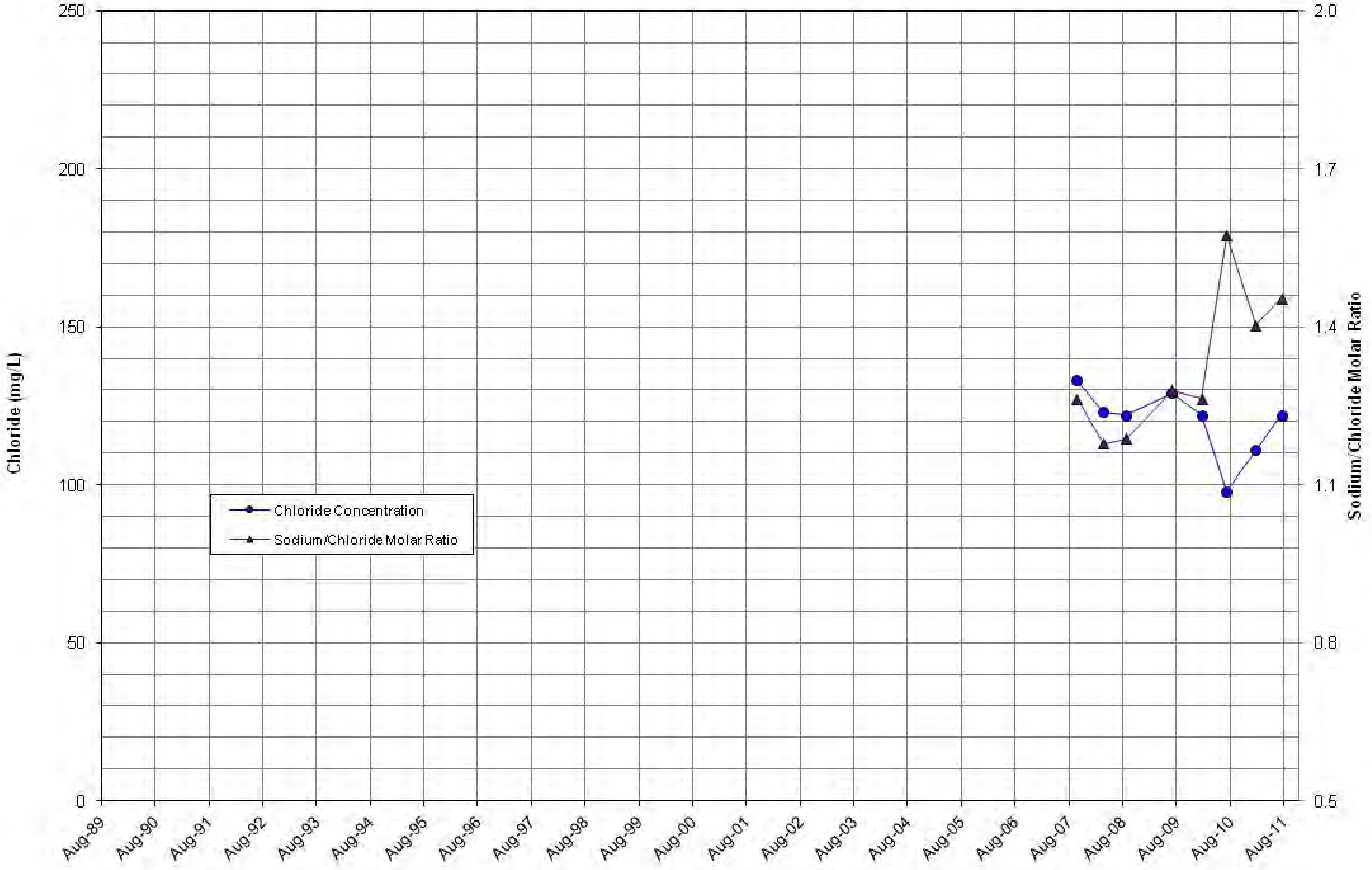


Figure B-19: SBWM-4: 715 foot depth sample Chemograph

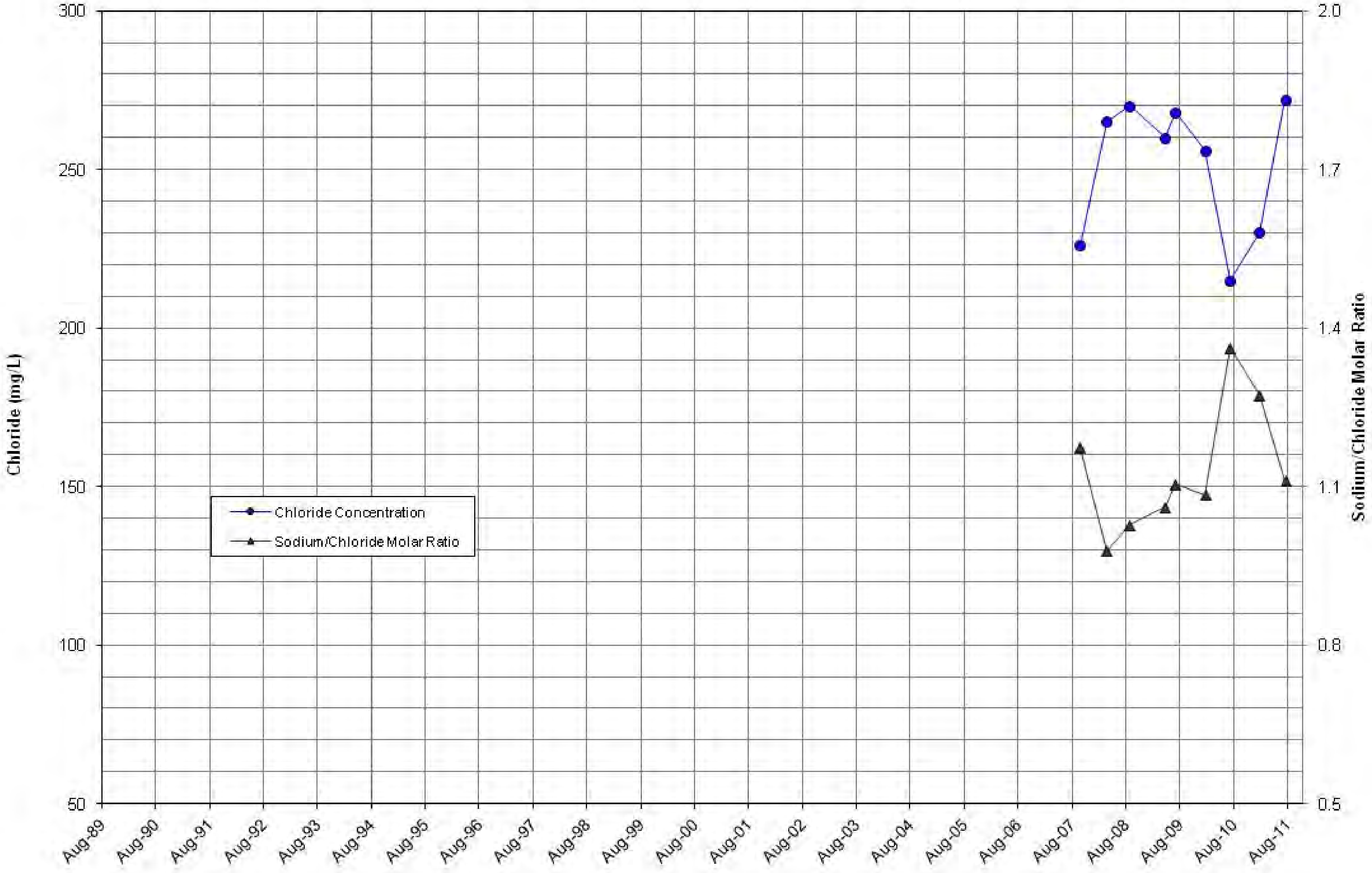


Figure B-20: SBWM-4: 900 foot depth sample Chemograph

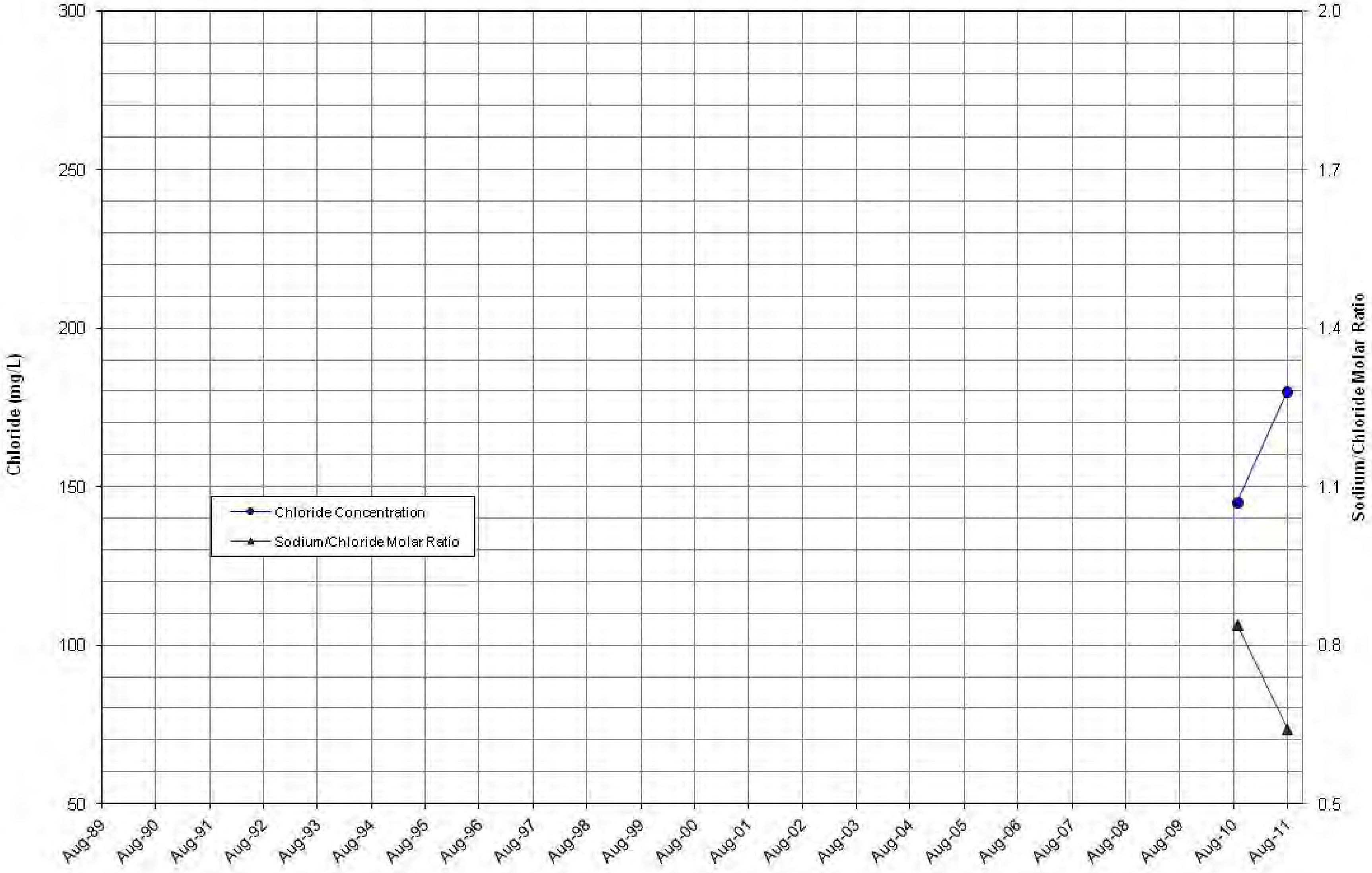


Figure B-21: SBWM-5: Shallow Well Chemograph

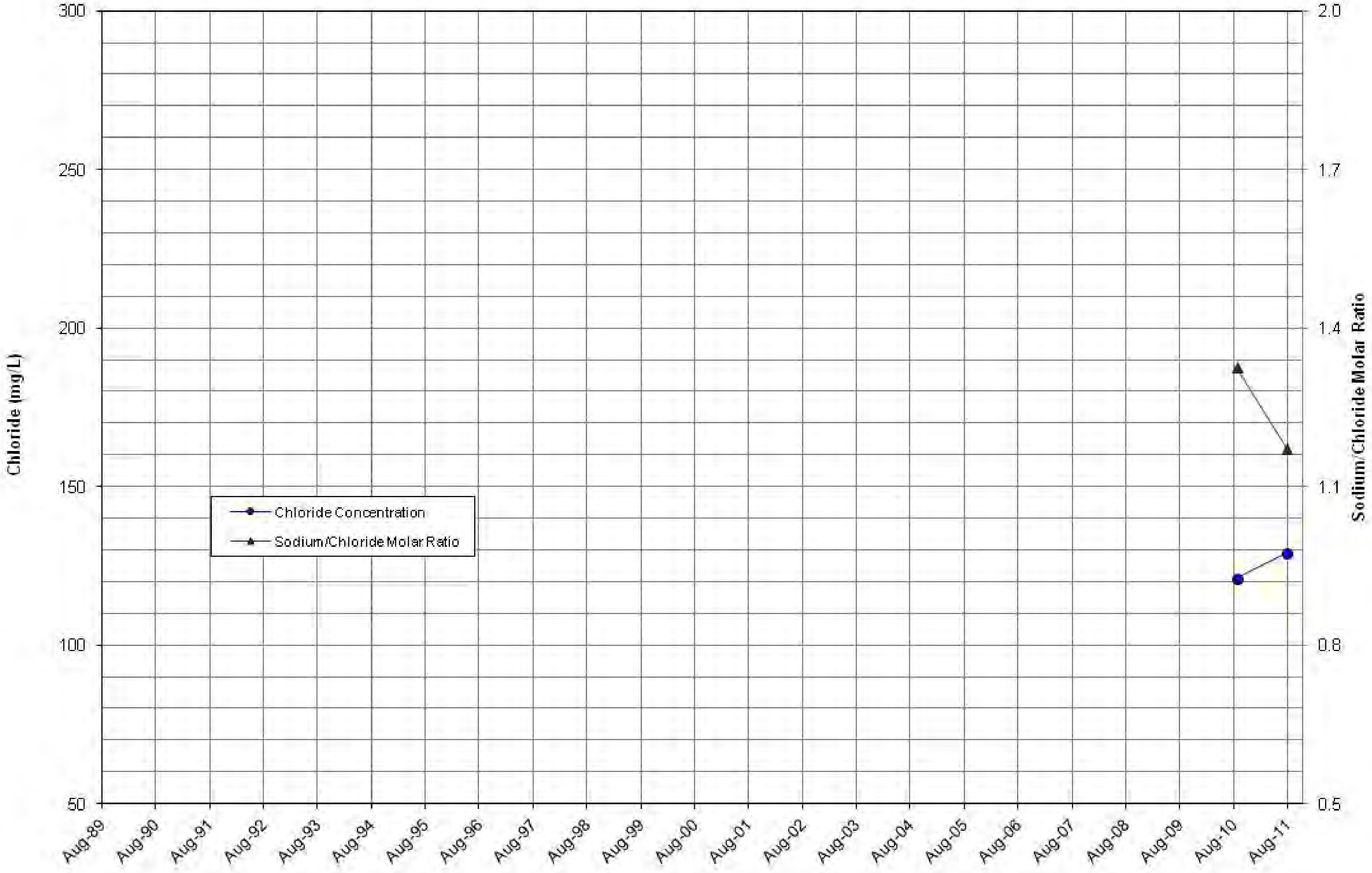


Figure B-22: SBWM-5: Deep Well Chemograph