PNEUMATIC TESTING AND RECOMMENDED CHANGES AT THE SUNSHINE CANYON LANDFILL SYLMAR, CALIFORNIA

March 11, 2015

Prepared for:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
21865 Copley Drive
Diamond Bar, California 91765
(909) 396-2000

Prepared by:

HYDRO GEO CHEM, INC.
51 West Wetmore Road, Suite 101
Tucson, Arizona 85705-1678
(520) 293-1500

Project Number 2013009.00-05.0

HYDRO GEO CHEM, INC.
Environmental Science & Technology

PNEUMATIC TESTING AND RECOMMENDED CHANGES AT THE SUNSHINE CANYON LANDFILL

SYLMAR, CALIFORNIA

Prepared for:

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
21865 Copley Drive
Diamond Bar, California 91765
(909) 396-2000

Prepared by:

Stewart J. Smith
Associate Hydrologist

Harold W. Bentley, Ph.D.
Principal Scientist

March 11, 2015

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLES

FIGURES

TABLE OF CONTENTS (Continued)

FIGURES (Continued)

TABLE OF CONTENTS (Continued)

FIGURES (Continued)

TABLE OF CONTENTS (Continued)

APPENDICES

1. INTRODUCTION

This report discusses the collection and analysis of baro-pneumatic and shut-in test data at the active Sunshine Canyon Municipal Solid Waste (MSW) Landfill located in Sylmar, California. The work was performed by Hydro Geo Chem, Inc. (HGC) under contract with the South Coast Air Quality Management District (SCAQMD). The purpose of the testing was to evaluate the performance of the existing landfill gas collection system (LFGCS) in controlling odors at the site and to make recommendations based on the results of the testing. This revised draft incorporates HGC's Responses to SCAQMD staff Comments and to Sunshine Canyon Landfill Comments.

Of particular interest in HGC's evaluation was the effect on the LFGCS of adding a relatively thick (minimum 9-inch thick) compacted daily cover soil that is landfilled with the refuse rather than being removed prior to adding more refuse. This practice has been required by Los Angeles County Department of Public Works (LACDPW) since September 2010 due to continuing odor complaints. Because the daily cover soil was thought to have a relatively low permeability, landfilling the daily cover soil had the potential to interfere with LFGCS operation by pneumatically isolating portions of the refuse from the LFGCS. Any pockets of refuse not under control by the LFGCS have the potential to expel landfill gas (LFG) to the atmosphere and contribute to odors.

HGC's evaluation relied on collecting atmospheric and subsurface pressure data within the landfill and analyzing them both qualitatively and quantitatively. The qualitative analysis focused on the lateral influence of LFG extraction wells operating in the landfill, and the ability of the cover material (in conjunction with LFGCS operation) to pneumatically isolate the refuse from the atmosphere. The quantitative analysis focused on evaluating the pneumatic properties of the refuse and cover materials, and the current rate of LFG generation in the landfill. The results of the analyses were used to revise the site conceptual model and to recommend improvements to LFGCS operation and odor control.

Data collection was performed within three representative portions of the landfill referred to as test areas. Figure 1 shows the overall site topography and approximate locations of test areas. The three test areas represented three different ages of waste that were considered representative of the evolving landfilling practices at the site. Baro-pneumatic and shut-in test data were collected in each test area. Baro-pneumatic data collection consisted of continuously measuring atmospheric pressure and subsurface pressures over periods of several days under steady (as possible) operation of the LFGCS system. Subsurface pressures were collected at various depths and distances from the central extraction well in each test area. Extraction flow rates at wells within and surrounding each test area were periodically measured to verify that LFGCS operation was relatively steady and for use in quantitative analyses. At the end of the baro-pneumatic data collection periods the central extraction well within each test area was closed off (shut-in) for approximately three hours, then re-opened while atmospheric and subsurface pressure data collection continued.

The conditions under which testing was conducted were non-standard. Typically, HGC conducts these types of tests with the LFGCS shut down, or at least shut down within and surrounding the portions of the landfill to be tested. Testing methods were modified to comply with constraints imposed by the particular site conditions which required that an absolute minimum of LFGCS extraction wells be shut down and for as short a time as possible. These particular constraints presented challenges for the interpretation and analysis of the test data. For example, the shut-in tests conducted in lieu of pumping tests at LFGCS extraction wells CGW740, CGW575, and GW7024 allowed minimum disruption of LFGCS operation, but reduced the signal-to- noise ratio of collected data.

Qualitative data analysis consisted of plotting atmospheric and subsurface pressures measured during the testing, and calculating and plotting the subsurface pressure changes resulting from shut-in tests. The quantitative analysis included the use of numerical and analytical models. An analytical model was used to estimate subsurface pneumatic properties based on shut-in test data. One dimensional (1-D) numerical models calibrated to the baro-pneumatic data at each measurement location were used to estimate the vertical gas permeability of refuse and cover materials, and the rate of LFG generation at each measurement location.

Information needed to interpret data collected by HGC was supplied in part by SCAQMD. This included site-wide maps and construction diagrams for the central extraction wells in each test plot; background information that included current and historical gas well data; a Tetra Tech report evaluating the existing LFG system (Tetra Tech BAS, 2011); landfill operations maps and plans; geotechnical data; leachate data; weather data; and landfill permit information.

2. SITE DESCRIPTION AND BACKGROUND

The Sunshine Canyon Landfill (SCL) is an active, partly lined, MSW landfill that is permitted for a total of approximately 363 acres of disposal area with a final waste in place limit of 141,200,000 cubic yards (yd^3) MSW. As of 2011, the waste footprint consisted of approximately 201 lined acres and 163 acres of closed unlined landfill (Figure 1), with approximately 51,662,000 tons of waste in place (Tetra Tech BAS, 2011).

The SCL is located within both the City of Los Angeles and unincorporated Los Angeles County. The City side of the landfill accepted MSW beginning in about 1958, the County side in 1993. The landfill was issued a joint City/County facility permit in 2008 and began operating jointly in 2009.

The SCL is equipped with a landfill gas collection and control system designed and operated to comply with landfill gas (LFG) control requirements of the federal New Source Performance Standards for MSW Landfills and to comply with LFG control requirements of the SCAQMD Regulation XI Rule 1150.1. Extracted LFG is flared at multiple flare stations. As of 2011, the total LFG flared was approximately 10,200 standard cubic feet per minute (scfm) [Tetra Tech BAS, 2011].

Landfilling practices have evolved over the lifetime of the facility in an effort to minimize the amounts of landfilled waste. In recent years, the relative proportion of food wastes has increased as the result of a recycling program. The resulting material, expected to have relatively high moisture contents due to the increased proportion of food wastes, is then compacted to a relatively high degree, which further reduces air porosity and the ability of the waste to transport LFG to LFGCS extraction wells. In addition, since 2010, instead of using tarps for daily cover, a required minimum of 9 inches of compacted soil is applied over the working face and then landfilled rather than removed. This latter measure, originally implemented for vector control, helps reduce escape of LFG and odors, but is potentially counter-productive as it may interfere with LFGCS operation. Landfilling the 9-inch compacted daily cover soil (hereafter referred to as the 'daily cover soil') could interfere with LFGCS operation should the material have a low permeability and interfere with the flow of LFG to LFGCS extraction wells. Furthermore, during installation of LFG extraction wells, perched water has been detected at some locations within the refuse. High water saturations and low gas porosities and permeabilities in saturated or near-saturated refuse are also expected to interfere with efficient LFG collection.

Although landfilling practices and waste composition have evolved over time, precise characterization of waste composition in the three test areas is not needed for baro-pneumatic analysis. The method relies only on pressure measurements to characterize the pneumatic properties of the subsurface materials.

3. DATA COLLECTION

Representative areas of the landfill were identified in consultation with site personnel and SCAQMD that reflect differences in landfill practices and waste composition. Three test areas shown in Figure 1 were selected to center on LFG extraction wells CGW740, CGW575, and GW7024. Figures 2, 3 and 4 are detail maps of the three test areas. The vicinity of LFG extraction well GW7024 consists of older mixed waste, the vicinity of LFG extraction well CGW575 consists of more recent more highly compacted waste having an increased proportion of food waste, and the vicinity of LFG extraction well CGW740 consists of recent more highly compacted waste having an increased proportion of food waste and also incorporates the daily cover soil.

Data collection consisted of the measurement of atmospheric and subsurface gas pressures at various locations and depths within the three test areas and included measurement of changes in subsurface pressures during shut-in tests. Gas quality monitoring of LFG extraction wells CGW740, CGW575, and GW7024 was also performed. Details of data collection procedures are provided in the following Sections.

3.1 Gas Monitoring Probe and Pressure Transducer Installation

Six (6) gas monitoring probes were installed within the refuse at each test location for a total of eighteen (18). Shallow probes were installed at 4 locations in each test area at distances of 15, 45, 75, and 105 feet (ft) from the central extraction well (CGW740, CGW575, or GW7024) and two additional probes at greater depths were installed at each of the 15 ft locations to form a probe nest. Target depths were 100 ft below land surface (bls) for deep probes, 50 ft bls for middle-depth probes, and at 10 to 20 ft bls for shallow probes. In the test area centered on extraction well CGW740, near-saturated to saturated conditions were encountered at depths below about 70 ft bls. To ensure that useful data could be collected, the deep probe was completed to a depth of 70 ft bls and the middle-depth probe to a depth of 30 ft bls. At the test area centered on GW7024, shallow probes were completed at depths of 17 to 20 ft bls due to relatively thick cover at that location. Table 1 summarizes probe construction characteristics. Appendix A contains probe construction schematics and boring logs.

The numbering convention for probes is as follows: extraction well name – distance from extraction well – probe depth. For example, the shallow probe located 15 feet from CGW740 is labeled CGW740-15-10.

All probes were installed under HGC supervision by Tetra Tech BAS using a CME 95 auger rig. Probes were constructed of flush-thread 1-inch diameter Schedule 40 PVC. Screened sections consisted of factory-slotted 0.05 slot screen and each screened section was completed with a filter pack consisting of #8-12 sand. Annular spaces above screened sections were sealed with hydrated bentonite and neat cement.

All gas monitoring probes were fitted with In Situ Level-Troll 500® differential pressure transducers. Each transducer was sealed in the probe using a gas-tight cap that accommodates an atmospheric reference pressure line. This line is open to the atmosphere at one end and the other end is connected to the transducer sealed in the probe or well to allow measurement of the difference between the pressure in the probe and atmospheric pressure.

3.2 Baro-pneumatic Testing

Baro-pneumatic testing consisted of measuring the atmospheric pressure and the differential pressures within the gas monitoring probes for approximately $4^3/_4$ days. Atmospheric pressure data were collected using an In Situ Mini-Troll® absolute pressure transducer. Pressure readings collected at one-minute intervals at each location were stored internally in the individual transducers and were periodically transferred to the hard disk of a laptop PC. Each transducer was programmed to begin recording at the same time.

LFG extraction rates were monitored during these tests to ensure that the LFGCS was operating at a relatively constant rate. Flow rates were measured periodically by hand using a VelociCalc® air velocity meter inserted into a section of pipe downstream of the well head. Flow rates were also measured using Pitot-tube type equipment that is incorporated into the extraction well heads. Measured flow rates and times of collection were recorded in the field notebook. VelociCalc® flow rate measurements were typically larger than the Pitot-tube type measurements and are considered more accurate.

Review of the data during collection indicated that, at most locations, pressures measured within the landfill were, on average, lower than average atmospheric pressure (e.g., under vacuum) except for the deep probes CGW740-15-70 and CGW575-15-100. Pressures in CGW740-15-70 were higher than atmospheric by approximately 0.33 psi. Pressures in CGW575-15-100 were initially higher than atmospheric by as much as 3 psi, but dropped to near-atmospheric after approximately 2 days. The vacuum measured in the majority of the probes results from LFGCS operation. If the LFGCS were not operating, all subsurface probes would be expected to have pressures greater than atmospheric. Because the majority of the probes are under vacuum, the

LFGCS is likely pumping at rates greater than the gas generation rates at most locations. The exceptions are CGW740-15-70 and CGW575-15-100 which appear to be relatively unaffected by the LFGCS system, either because the deep refuse at these locations is pneumatically isolated from the LFGCS or that deep pumping at these locations needs to be increased. Pneumatic isolation may result from high water saturation. However, as described below in Section 3.3, both probes responded to the shut-in test, and therefore did not appear to be isolated from the LFGCS, suggesting that deep pumping likely needs to be increased to maintain control of the deep refuse (at least at these locations).

Another feature evident in the CGW740 data included poor and erratic responses of CGW740-15-70 pressures to changes in atmospheric pressure suggesting that the deep refuse has a low permeability or that relatively impermeable or nearly saturated layers may exist between the deep refuse and the surface. Similarly, erratic pressure changes evident in CGW575-15-100 that cannot be attributed to changes in atmospheric pressure suggest similar isolation due to low gas permeability or because of relatively impermeable or nearly saturated layers between the surface and deep refuse. Conversely, responses to atmospheric pressure changes in GW7024-15-50 and GW7024-15-100 indicated no significant vertical pneumatic barriers within at least the upper 100 feet of refuse in the GW7024 test area.

The baro-pneumatic data will be presented and discussed in more detail in Section 4.1.

3.3 Shut-In Testing

After completion of the baro-pneumatic tests, shut-in tests were conducted at LFG extraction wells CGW740, CGW575, and GW7024. Monitoring of atmospheric and subsurface pressures continued at the same frequency during these tests as during the baro-pneumatic tests.

Each test consisted of shutting in the extraction well for approximately 3 hours, re-opening the well, and continuing to monitor the atmospheric pressure and subsurface pressures. Extraction rates were measured before and after the wells were shut-in as described in Section 3.2.

Due to various site constraints, the shut-in tests were performed in lieu of HGC's standard method of conducting extraction tests which involves pumping each test well at two to three different flow rates while monitoring flow rates and pressures. Pumping at more than one flow rate is beneficial in that it provides constraints on potential ranges in parameter values derived by inversion of the test data. This methodology also allows interpretation of pressure data from the pumped well and correction of those data for any well skin or non-linear well efficiency effect.

In addition, when conducting standard extraction tests, wells are pumped at high enough rates to ensure a high signal-to-noise ratio in the data.

After each well was shut-in, pressure responses were detected in all of the gas monitoring probes. Responses at shallow probes located 45 ft, 75 ft, and 105 ft from GW7024 are somewhat ambiguous because pressure changes were near the limit of detection and increases were preceded by short-term decreases of approximately the same magnitude as the later, longer-term increases. This behavior results from a combination of small pressure response to shut-in and changes in barometric pressure transmitted to the subsurface. The pressure changes resulting from GW7024 shut-in are of approximately the same magnitude as barometric pressure changes, yielding a low signal-to-noise ratio. Typically, these types of tests are conducted by pumping extraction wells at rates high enough to induce pressure responses much larger than barometric pressure changes. As this was not possible at the SCL site, and because extraction rates at GW7024 were too low to produce large changes in subsurface pressure once the well was shut in, additional correction was applied in an attempt to reduce the impact of barometric pressure changes. Because of the high permeability at GW7024, extraction rates 5 to 10 times higher for short-term testing purposes would have been desirable.

The raw subsurface data are collected using vented pressure transducers and are therefore automatically corrected in part for barometric pressure changes. However, because barometric pressure changes transmitted to the subsurface are delayed and attenuated, the automatic correction applied through the use of vented transducers is imperfect, and additional correction is needed in cases with low signal-to-noise ratios (such as GW7024). This type of additional correction is analogous to the correction of water levels for barometric pressure changes when conducting aquifer tests. The application of additional corrections is discussed in Section 5.

Once re-opened, pressure decreases were detected in all of the gas monitoring probes, although such changes were somewhat ambiguous at probes located 45 ft, 75 ft, and 105 ft from GW7024. Pressure changes detected as far as 105 feet from extraction wells CGW740 and CGW575 indicate good lateral pneumatic continuity within the refuse at these locations. The somewhat ambiguous responses at GW7024 result from the relatively low extraction rate at GW7024 which (as discussed above) limits the potential magnitudes of the responses, and from the relatively high permeability of the older waste at this location that also reduces pressure responses.

The shut-in test data will be presented and discussed in more detail in Section 4.2.

3.4 Gas Quality Monitoring

LFG composition at CGW740, CGW575, and GW7024 was also monitored at the time flow measurements were taken using a LandTec® meter. Constituents measured included the volume percent of carbon dioxide (CO_2), methane (CH_4), oxygen (O_2) and balance gas (the residual volume percent: 100% minus the sum of these measured constituents). Results of this monitoring are provided in Appendix C and will be discussed in Section 4.3.

4. QUALITATIVE DATA ANALYSIS AND RESULTS

Qualitative data analysis consisted of processing, plotting, and examining raw pressure data. Subsurface pressure data consisted of gage pressures collected using differential pressure transducers that record the differences between subsurface and atmospheric pressures. As part of processing, subsurface pressures are converted to absolute pressures (at a constant elevation) by adding the differential pressures to the atmospheric pressure (collected with an absolute pressure transducer). An advantage of this method is that the impacts of pressure change with elevation are automatically subtracted out.

After processing, data were separated into baro-pneumatic and shut-in test data. Shut-in test data were used to calculate and plot the pressure change at each monitoring probe resulting from the shut-in and re-opening of the central extraction well in each test area. The results of plotting and examination of the pressure data are provided in the following Sections.

4.1 Baro-pneumatic Testing

Atmospheric and subsurface pressure data from each measurement location are plotted in Figures 5 through 22. The atmospheric pressure data are included for purposes of comparison. Those portions of the data collected prior to the shut-in test periods designated in each figure are considered the 'baro-pneumatic' data.

4.1.1 CGW740

Pressure data from test location CGW740 are provided in Figures 5 through 10. Pressures in shallow subsurface probes (screened approximately 8-10 ft bls) responded strongly to changes in atmospheric pressure. Shallow probe pressure curves and atmospheric pressure curves differ only slightly in shape (Figures 5, 8, 9 and 10). The magnitudes of shallow subsurface pressure changes are only slightly smaller than corresponding changes in atmospheric pressure, and peaks and troughs (local maxima and minima) in the subsurface pressure curves lag corresponding peaks and troughs in the atmospheric pressure curve by only small amounts. Pressures in deeper probes (CGW740-15-35 and CGW-15-70, Figures 6 and 7) appear to respond inconsistently to changes in atmospheric pressure. Over some time periods the changes in CGW740-15-35 pressures are greater than changes in atmospheric pressure indicating they cannot directly result from atmospheric pressure changes. CGW740-15-70 pressures respond poorly and somewhat erratically to atmospheric pressure changes.

Subsurface pressures in all probes except CGW740-15-70 are also lower than atmospheric pressure indicating that the subsurface is under vacuum at least to a depth greater than or equal to 35 ft bls. However, the magnitudes of the vacuums at shallow probes CGW740-75-10 and CGW740-105-10 are generally so small as to be within measurement error.

The data demonstrate that cover material (approximately $1^1/_2$ feet thick at this location) provides only a slight barrier to pneumatic communication between the atmosphere and the subsurface, consistent with its thinness and a moderately high vertical permeability. The data also suggest that the vertical permeability of at least the shallowest refuse (between $1^1/_2$ feet and 8 feet in depth) is relatively high. The apparent poor communication of deep refuse with the atmosphere suggests that the deep refuse has a low gas permeability or that partial pneumatic barriers exist in the refuse at depths greater than approximately 35 feet bls, possibly the result of layers having high water contents and low gas porosity.

The data also demonstrate the impact of the LFGCS. Measured vacuums result from operation of the LFGCS and, in particular, operation of gas extraction well CGW740. The magnitudes of the vacuums in the shallow probes decrease with distance from CGW740 until they are almost negligible at distances of 75 feet or greater. At the probes located 15 feet from CGW740, the vacuum at the 35 ft bls probe (CGW740-15-35) is nearly an order of magnitude larger than the vacuum at the shallow probe (CGW740-15-10). The observed pattern of vacuums is consistent with generally radial flow toward CGW740 and vertical flow (induced by the partial penetration of CGW740) enhanced by surface leakage Vacuums decrease with distance from CGW740 as a result of both radial flow and surface leakage. Vertical flow enhanced by surface leakage causes vacuums in shallow probe CGW740-15-10 to be smaller than in the deeper probe (CGW740-15-35) located at the same distance from CGW740. Vertical flow is induced by the partial penetration of CGW740, which is screened beginning at a depth of approximately 29 ft bls (Appendix B), nearly 20 feet below the shallow probes.

As discussed in Section 3.2, because the majority of the probes are under vacuum, the LFGCS is likely pumping at rates greater than the gas generation rate. The exception is CGW740-15-70 which appears to be relatively unaffected by the LFGCS system either because the deep refuse at this location is pneumatically isolated from the LFGCS or because deep pumping needs to be increased. Increasing deep pumping at this location may be problematic because of the near-saturated to saturated conditions encountered when installing CGW740-15-70. Overall, the LFGCS appears to be effective at this location except in the deep refuse where pressures are greater than atmospheric and at distances greater than 75 feet from CGW740 where LFGCS-induced vacuums are slight.

4.1.2 CGW575

Pressure data from test location CGW575 are provided in Figures 11 through 16. Pressure curves from shallow subsurface probes (screened approximately 8-10 ft bls) differ moderately in shape from atmospheric pressure curves (Figures 11, 14, 15 and 16), and differences are more noticeable than with the CGW740 data. The magnitudes of shallow subsurface pressure changes are noticeably smaller than corresponding changes in atmospheric pressure, and peaks and troughs (local maxima and minima) in the subsurface pressure curves noticeably lag corresponding peaks and troughs in the atmospheric pressure curve. Pressure changes in deep probe CGW575-15-100 (Figure 13) are erratic. Because pressure changes in the deep probe are often larger than changes in atmospheric pressure, they cannot directly result from changes in atmospheric pressure.

The shape of the pressure curve from CGW575-15-50 appears to be nearly identical to the atmospheric pressure curve, suggesting a leak or possible malfunction of the vented pressure transducer (Figure 12). The pressure transducer was determined to be partially malfunctioning and to have poor sensitivity to small differences between subsurface and atmospheric pressures. This caused the transducer to return values during baro-pneumatic testing that were near zero, and the processed pressures (differential + atmospheric) thus appear to be nearly identical to atmospheric.

Subsurface pressures in all shallow probes are lower than atmospheric pressure indicating that at least the shallow refuse is under vacuum. Pressures in CGW575-15-100 were substantially higher than atmospheric initially (approximately 3 psi higher), but dropped to near-atmospheric levels after approximately two days. Pressures in many of the other probes also decreased for the first day or two after installation. This behavior suggests that time was needed for equilibration to occur. However, the large pressure drop in the CGW575-15-100 suggests that another as yet unidentified mechanism affects pressures in the deep refuse.

The data demonstrate that cover material that is approximately 6 feet thick at this location provides a barrier to pneumatic communication between the atmosphere and the subsurface that is larger than at CGW740, consistent with its greater thickness. The apparent poor communication of deeper refuse (> 95 ft bls) with the atmosphere suggests that at least partial pneumatic barriers exist in the refuse. The depths of any such barriers are likely between about 33 ft bls (the top of the screened interval at CGW575, as shown in Appendix B) and 95 feet bls, possibly the result of layers having high water contents and low to negligible gas porosity. Barriers shallower than 33 ft bls are unlikely because they would prevent responses in shallow probes during the shut-in test (described in Section 4.2). The apparent malfunctioning of the pressure transducer in the 50 ft bls probe (CGW575-15-50) prevents further refinement of the potential depths of any such layers.

The data also demonstrate the impact of the LFGCS. Measured vacuums result from operation of the LFGCS and, in particular, operation of gas extraction well CGW575. The magnitudes of the vacuums in the shallow probes decrease with distance from CGW575; however, they drop off minimally from approximately 0.25 psi at a distance of 15 feet to approximately 0.15 psi at distances of 75 feet or greater. This demonstrates the overlapping impact of other nearby extraction wells on vacuums near CGW575. At probes located 15 feet from CGW575, the vacuum at CGW575-15-50 is approximately 50% larger than the vacuum at the shallow probe (CGW575-15-10). The general pattern of vacuums is consistent with generally radial flow toward CGW575 and vertical flow enhanced by surface leakage. Vacuums decrease with distance from CGW575 as a result of both radial flow and surface leakage. Vertical flow enhanced by surface leakage causes vacuums in shallow probe CGW575-15-10 to be smaller than in the deeper probe (CGW575-15-50) located at the same distance from CGW575. Vertical flow is induced by the partial penetration of CGW575, which is screened beginning at a depth greater than 33 ft bls (Appendix B), more than 20 feet below the shallow probes. However, the relatively small reduction in vacuum with distance from CGW575 indicates that nearby extraction wells have a significant influence on the CGW575 area.

As discussed in Section 3.2, because the majority of the probes are under vacuum, the LFGCS is likely pumping at rates greater than the gas generation rate. The exceptions are CGW575-15-50 and CGW575-15-100 which do not appear to be under vacuum. The apparent malfunctioning of the pressure transducer in CGW575-15-50 makes the actual status of the refuse at this depth indeterminate. However, since the pressure transducer at this location appears to be insensitive to only small pressure differences, it is unlikely that the refuse at 50 ft bls is under either a large pressure or vacuum. Overall, the LFGCS appears to be effective at this location except within the deep refuse

4.1.3 GW7024

Pressure data from test location GW7024 are provided in Figures 17 through 22. Pressure curves from shallow subsurface probes (screened approximately 18-20 and 15-17 ft bls) differ only slightly in shape from atmospheric pressure curves (Figures 17, 20, 21 and 22). The magnitudes of shallow subsurface pressure changes are only slightly smaller than corresponding changes in atmospheric pressure, and peaks and troughs (local maxima and minima) in the subsurface pressure curves lag corresponding peaks and troughs in the atmospheric pressure curve by almost negligible amounts. Noticeable lags and attenuation are present in deeper probes GW7024-15-50 and GW7024-15-100 (Figures 18 and 19) due to their greater depths and the consequently greater thicknesses of subsurface materials through which atmospheric pressure changes are transmitted. The general pattern of decreasing response with depth is consistent with atmospheric pressure change transmission vertically downward from the surface. Subsurface pressures in all probes are also lower than atmospheric pressure indicating that the subsurface is under vacuum.

The data demonstrate that cover material that is approximately 10 feet thick at this location provides only a small barrier to pneumatic communication between the atmosphere and the subsurface, consistent with a relatively high vertical permeability. The apparently good pneumatic communication between deeper refuse and the atmosphere suggests that the refuse has a relatively high vertical permeability.

The data also demonstrate the impact of the LFGCS. Measured vacuums result from operation of the LFGCS and, in particular, operation of gas extraction well GW7024. However, the magnitudes of the vacuums in the shallow probes decrease from approximately 0.007 psi to 0.002 psi at distances of 15 and 45 feet, respectively, from GW7024, then increase to 0.005 psi and 0.006 psi at 75 and 105 feet, respectively, from GW7024, indicating the overlapping impact of other nearby extraction wells on vacuums near GW7024. Although these vacuums are small enough to be near the sensitivity of the transducers, they are measurable. The small vacuums are the result of both high permeability and a relatively low extraction rate. As will be discussed in Section 5.3, significant air intrusion, consistent with high vertical permeability, was detected at CGW7024.

At probes located 15 feet from GW7024, the vacuum increases with depth and is larger by a factor of approximately four at GW7024-15-100 compared to the vacuum at the shallow probe (GW7024-15-20). The general pattern of vacuums is consistent with generally radial flow toward GW7024, and vertical flow enhanced by surface leakage. Vacuums decrease with distance from GW7024 as a result of both radial flow and surface leakage. Vertical flow enhanced by surface leakage causes vacuums in shallow probe GW7024-15-20 to be smaller than in the deeper probes (GW7024-15-50 and GW7024-15-100) located at the same distance from GW7024. Vertical flow is induced by the partial penetration of GW7024 which is screened beginning at a depth greater than 33 ft bls (Appendix B), more than 10 feet below the shallow probes. However, the reduction and then increase in vacuum with distance from GW7024 indicates that nearby extraction wells have a significant influence on the GW7024 area.

As discussed in Section 3.2, because the probes are under vacuum, the LFGCS is likely pumping at rates greater than the gas generation rate. Overall, GW7024 appears to be effective to depths of at least 100 feet and to distances greater than 15 feet but less than 45 feet. At a distance of 45 feet, shallow refuse vacuums are small enough that escape of LFG through the surface becomes likely. At distances greater than 45 feet, vacuums increase presumably due to the overlapping influence of nearby extraction wells.

4.2 Shut-in Testing

Shut-in test data are provided in Figures 23 through 28, which show the measured change in pressure with time at each monitored location. Responses to the shutdown of each extraction well produced measurable responses at all monitored locations indicating good lateral pneumatic continuity in each test location. The responses decreased with distance at all locations except at distances greater than about 45 feet from GW7024. Responses at shallow probes GW7024-45-20, GW7024-75-20, and GW7024-105-20 are somewhat ambiguous because pressure changes were near the limit of detection. The decrease in response with distance was most pronounced at CGW740 and least pronounced at GW7024.

Pressure responses at many probes, in particular the shallow probes, display a noticeable ‘flattening’ which is consistent with vertical leakage. This flattening is most noticeable at shallow probes in the CGW740 and GW7024 test areas, consistent with relatively large vertical leakage. Although not as pronounced, this flattening of pressure response is also evident in shallow probes in the CGW575 test area.

The flattening of pressure responses in shallow CGW740 and GW7024 probes, CGW740-15-35, GW7024-15-50, and GW7024-15-100, was pronounced enough that pressure change essentially halted, indicating the achievement of near steady-state conditions. While flattening of pressures occurred in shallow CGW575 probes, steady-state conditions were not achieved. As will be noted in Section 5, the achievement of steady-state conditions did not affect the quantitative analysis of the shut-in test data.

Pressures at many probes also display a temporary decrease before increasing. This is most notable at shallow probes near GW7024 (GW7024-15-20, GW7024-55-20, GW7024-75-20, GW7024-105-20), where the magnitude of the temporary decrease in pressure is nearly as large as the eventual increase in pressure. As discussed in Section 3.3, low extraction rates and high permeability at GW7024 limit pressure responses during shut-in to levels similar to changes in barometric pressure, resulting in a low signal-to-noise ratio.

Once re-opened, pressure decreases were detected in all of the gas monitoring probes except shallow probes located 45 ft, 75 ft, and 105 ft from GW7024, where changes may have been too small above background noise to be detected. Pressures in many probes also did not return to pre-shut-in levels. This behavior may be attributable to changes in LFGCS operation, or to barometric effects that have an outsize impact due to low signal-to-noise ratio.

Overall, the shut-in test data are consistent with cover permeabilities large enough to allow significant communication between the refuse and the atmosphere, especially in the CGW740 and GW7024 areas.

4.2.1 CGW740

Shut-in test responses at probes near CGW740 are provided in Figures 23 and 24. Shut-in test responses are smallest in shallow probes and decrease with distance from CGW740 (Figure 24). The response at the shallow probe located 15 feet from CGW740 (CGW740-15-10) is approximately 3 times greater than the response at 45 feet (CGW740-45-10). The response in shallow probe CGW740-45-10 is approximately twice the response in shallow probe CGW740-105-10.

Pressures in many probes did not return to pre-shut-in levels. Pressures at the end of the test were sometimes slightly higher and sometimes slightly lower than starting pressures. These effects likely result in part from barometric effects and in part from changes in pumping at nearby LFGCS extraction wells. These effects were negligible at the CGW740 test location compared to the CGW575 and GW7024test locations.

Responses in deep probes are larger than in shallow probes, with the largest response at CGW740-15-35 and the next largest at CGW740-15-70. Responses with depth are consistent with the screened sections of CGW740 (approximately 29 to 65 ft bls, and 77 to 159 ft bls, as shown in Appendix B). CGW740-15-35 is screened within the shallow screened interval of CGW740; shallow probes completed to 10 ft bls and CGW740-15-70 are screened above and below the shallow screen of CGW740. Saturated conditions that develop between 70 and 80 ft bls (based on drilling logs) presumably limit or prevent pneumatic communication between deep and shallower refuse and between deep and shallow screens. Otherwise, the largest response would occur in CGW740-15-70 rather than in CGW740-15-35. The general pattern of responses is consistent with radial flow, the partial penetration of CGW740, vertical pneumatic communication within the shallow refuse, and a lack of vertical communication between deep (greater than 70 ft bls) and shallower refuse.

As discussed above, significant flattening of the shut-in test responses are evident especially in the shallow probes and CGW740-15-35, consistent with vertical leakage through the cover. This behavior also demonstrates that 1) the vertical permeability of the relatively shallow refuse (upper 35 feet) is high enough that pressures at 35 ft bls are impacted by vertical leakage, and 2) the shallowest refuse located above the screened interval of CGW740 is affected by pumping at CGW740. Conversely, while pressures in the 70 ft bls probe do not appear to respond to changes in atmospheric pressure, suggesting at least a partial vertical pneumatic barrier somewhere between 35 and 70 ft bls, there is no lateral pneumatic barrier between CGW740 and CGW740-15-70. A pneumatic restriction or barrier between 35 and 70 ft bls possibly results from layer(s) having high water contents and low to negligible gas porosity

Overall, the shut-in test responses demonstrate that, at least above 70 ft bls, lateral pneumatic continuity within the CGW740 test area is good, and that the lateral influence of CGW740 is limited by vertical leakage.

4.2.2 CGW575

Shut-in test responses for probes near CGW575 are provided in Figures 25 and 26. Shut-in test responses are smallest in shallow probes (Figure 26) and decrease with distance from CGW575. The response at shallow probe CGW575-15-10 is approximately 75% greater than the response at shallow probe CGW575-45-10. The response at CGW575-45-10 is approximately 50% greater than at CGW575-105-10. The largest and second largest responses occur at CGW575-15-100 and CGW575-15-50, respectively. The actual pressure response at CGW575-15-50 is larger than measured because the pressure transducer at this location appears to have been insensitive to small pressure differences. The general pattern of responses is consistent with radial flow, the partial penetration of CGW575 which is screened below approximately 33 ft bls (Appendix B), and vertical pneumatic communication at least within the refuse shallower than approximately 33 ft bls. A lack of response of CGW575-15-100 to changes in atmospheric pressure (as discussed in Section 4.1) indicates at least partial vertical pneumatic isolation of the deep refuse from shallower refuse.

Pressures in CGW575 probes did not return to pre-shut-in levels. All pressures at the end of the testing were significantly higher than starting pressures. This behavior implies a trend likely resulting from increases in pumping at nearby LFGCS extraction wells during the test period. On a relative basis these effects were smaller at the CGW575 test location compared to the GW7024 test location.

As discussed above, flattening of the shut-in test responses are evident in the shallow probes although to a smaller degree than in the shallow probes near CGW740. This flattening is consistent with vertical leakage through the cover. The smaller degree of flattening compared to CGW740 is consistent with the thicker cover at CGW575; approximately 6 feet at CGW575 compared to $1^1/_2$ feet at CGW740. Assuming that the composition and compaction of the cover material is the same at both locations, the thicker cover at CGW575 is expected to restrict vertical leakage more at CGW575 than at CGW740.

Overall, the shut-in test responses demonstrate that, at least above 100 ft bls, lateral pneumatic continuity within the CGW575 test area is good, and that the lateral influence of CGW575 is limited by vertical leakage to a lesser extent than at CGW740.

4.2.3 CGW7024

Shut-in test responses for probes near GW7024 are provided in Figures 27 and 28. Shut-in test responses are smallest in shallow probes (Figure 28) and decrease between 15 and 45 feet from GW7024 but do not appear to decrease measurably at distances greater than 45 feet from GW7024. Magnitudes of responses in deep probes (GW7024-15-50 and GW7024-15-100) were similar and larger than in shallow probes. As discussed above, pressures display a temporary decrease before increasing. At shallow probes GW7024-15-20, GW7024-45-20, GW7024-75-20, GW7024-105-20, the magnitude of the temporary decrease in pressure is nearly as large as the eventual increase in pressure.

Once re-opened, pressure decreases were not unambiguously detected in shallow probes located 45 feet or more from GW7024 (GW7024-45-20, GW7024-75-20, and GW7024-105-20) possibly because these changes were too small to be measured. Pressures in GW7024 probes did not return to pre-shut-in levels at the end of the test. In addition, once GW7024 was re-opened, pressures in GW7024-15-100 increased by approximately 50% after slightly decreasing. As discussed in Section 3 this behavior results from a combination of small shut-in pressure responses and changes in barometric pressure transmitted to the subsurface. The pressure changes resulting from GW7024 shut-in are approximately the same magnitude as barometric pressure changes, yielding a low signal-to-noise ratio. Typically, these types of tests are conducted by pumping extraction wells at rates high enough to induce pressure responses much larger than barometric pressure changes. As this was not possible at the SCL, and because extraction rates at GW7024 were too low to produce large changes in subsurface pressure once the well was shut in, an additional correction was applied in an attempt to reduce the impact of barometric pressure changes.

The raw subsurface data for both baro-pneumatic and shut-in tests are collected using vented pressure transducers. Pressure changes resulting from shut-in are therefore automatically corrected in part for barometric pressure changes. However, because of the delay and attenuation of barometric pressure changes transmitted to the subsurface (which constitutes the baro-pneumatic ‘signal’), this automatic correction is imperfect with respect to the shut-in test data, and additional correction is needed in cases with low signal-to-noise ratios. This type of additional correction is analogous to the correction of observation well water levels for barometric pressure changes when conducting aquifer tests.

The general pattern of shut-in test responses is, however, consistent with radial flow, the partial penetration of GW7024 which is screened between approximately 35 and 80 ft bls (Appendix B), and vertical pneumatic communication within the refuse.

Flattening of the shut-in test responses is evident in both shallow and deep probes. This flattening is consistent with vertical leakage through the cover and vertical communication between the cover and depths of at least 100 ft bls in the refuse. The degree of flattening is larger than in pressure responses measured in probes at CGW575 even though the cover at GW7024 is approximately 10 feet thick and only 6 feet thick at CGW575. This behavior suggests that the composition of the cover, the degree of compaction of the cover, or both, differ at these two locations. The cover at GW7024 has a higher effective gas permeability than the cover at CGW575.

Overall, the shut-in test responses demonstrate that, at least above 100 ft bls, lateral pneumatic continuity within the GW7024 test area is good and the lateral influence of GW7024 is limited by vertical leakage to a greater extent than at CGW575.

4.3 Gas Quality Monitoring Results

Gas quality monitoring results collected during periods of LFGCS pumping are tabulated in Table C.1 of Appendix C. As indicated, methane concentrations are highest in CGW740D and lowest in GW7024. Carbon dioxide concentrations are also lowest in GW7024. Oxygen concentrations are low to non-detect in all wells. Although oxygen concentrations are low or non-detect, balance gas concentrations (calculated as the difference between 100% and the sum of the percentages of oxygen, carbon dioxide, and methane) are as high as 18% at CGW575 and 57% at GW7024, indicating significant air intrusion. Balance gas is assumed to be composed of nitrogen and argon. These data will be discussed in more detail in Section 5.3.

4.4 Implications for Conceptual Model

Overall, the baro-pneumatic and shut-in test data demonstrate that LFGCS is generally working well, but that areas exist where escape of LFG to the surface is possible. Escape of LFG to the surface may occur in areas where the shallow refuse is under negligible vacuum (e.g., CGW740-75-10 and CGW740-105-10), and areas of deep refuse that are under pressure and that may daylight on side slopes (e.g., CGW740-15-70). The data also indicate that the LFGCS is pumping at rates higher than the LFG generation rates in the test areas and that significant inward surface leakage occurs, especially in the CGW740 and GW7024 areas. Gas quality monitoring data presented in Appendix C are consistent with inward surface leakage especially at GW7024 (quantified in Section 5.3). In addition, the data demonstrate lateral pneumatic continuity to distances of at least 105 feet from the extraction wells in all three test areas.

HGC's conceptual model of the site has evolved based on review of available data and on discussions with the various interested parties. Concerns over the ability of the LFGCS to prevent escape of LFG and control odors have centered on changes in waste composition and handling practices, as discussed in Section 2. In particular, more recent waste has a higher proportion of food wastes as the result of a recycling program. The resulting material, which is expected to have relatively high moisture contents due to the increased proportion of food wastes, is then compacted to a relatively high degree, which further reduces air porosity and the ability of the waste to transport LFG to LFGCS extraction wells. In addition, since 2010, instead of using tarps, a required minimum of 9 inches of compacted soil (daily cover soil) is applied over the working face and then landfilled rather than removed. This latter measure, originally implemented for vector control, helps reduce escape of LFG and odors, but is potentially counter-productive as it may interfere with LFGCS operation. Landfilling the daily cover soil could compromise LFGCS operation if the material has a low enough permeability to interfere with the flow of LFG to LFGCS extraction wells. Such interference would be enhanced should near-saturated or saturated conditions develop within landfilled cover material.

The three test areas in this study were chosen to compare the differences in pneumatic behavior between older mixed waste (test area GW7024), more recent waste containing a relatively higher proportion of food waste (test area CGW575), and recent waste containing a relatively higher proportion of food waste that incorporates the daily cover soil (test area CGW740).

The baro-pneumatic and shut-in test data show that, contrary to expectation, landfilled daily cover soil in the CGW740 test area does not appear to interfere with lateral flow of LFG to CGW740, at least within the shallower refuse (< 70 ft bls), nor does the cover material appear to have as low a permeability under field conditions as expected. That the permeability of the cover material is higher than expected under field conditions is demonstrated by significant surface leakage and by the landfilled cover material's apparent minimal interference with lateral (or vertical) flow to the extraction well, at least within the shallower (< 70 ft bls) refuse. Within the shallowest refuse (upper 30 feet), a layer of buried daily cover soil is expected to be present between the depths of the shallowest probes (approximately 10 ft bls) and the top of the CGW740 well screen (29 ft bls). Because the shallow probes responded to shut-in of CGW740, such a layer does not appear to provide a significant pneumatic barrier. Furthermore, the composition and compaction of the newer waste do not appear to have reduced the permeability of the waste to a degree that interferes significantly with LFG collection. With regard to the newer waste (CGW575 and CGW740), high water saturation of deeper waste and potential perching of water in portions of the shallower waste appear to be important factors reducing the efficient operation of the LFGCS.

To the extent that the cover material permeability is lower than the waste permeability, the potential exists for the landfilled daily cover soil to restrict downward water movement. This behavior may result in high enough water saturations in the landfilled daily cover soil to locally perch water and restrict gas movement. Although no evidence in the pneumatic test data supports such restriction in the shallower refuse, landfilled daily cover soil may contribute, at least locally, to high water saturations in portions of the deeper refuse.

Furthermore, changes in waste composition and landfilling practices that increased compaction and the proportion of food wastes may have altered the typical ratios of horizontal to vertical permeability of newer waste to an extent that reduces the lateral influence of LFG extraction wells. This is of particular concern for waste younger than that landfilled at GW7024. Estimates of horizontal and vertical permeability are presented in Section 5.

5. QUANTITATIVE DATA ANALYSIS AND RESULTS

Baro-pneumatic data were analyzed quantitatively using 1-D numerical gas flow models. The measured atmospheric pressure was used as a boundary condition for the ground surface.

Use of vertical 1-D models for baro-pneumatic analysis is considered appropriate because the baro-pneumatic data are consistent with transmission of atmospheric pressure changes vertically downward through the cover and refuse. Furthermore, although the LFGCS was not shut down in the test areas, it was operated at a relatively constant rate during the testing, such that subsurface pressure responses resulted primarily from transmission of atmospheric pressure changes to the subsurface.

The data were analyzed in two steps: interim and final. The interim step was used to estimate permeability, with the vacuums induced by the LFGCS subtracted from the subsurface pressure data so that the average subsurface pressures were the same as average atmospheric pressure. This is appropriate because the shape of the subsurface pressure curve is determined by the permeability and porosity, not the gas generation (or sink) rate. Subtracting the vacuum induced by the LFGCS reduced the analysis to the case where the gas generation rate is zero, and is essentially equivalent to the methodology presented in Weeks (1978). The permeability and porosity of cover and refuse materials were varied until acceptable matches between measured and simulated subsurface pressures were obtained.

The final step involved estimation of LFG generation rates. LFG generation rates were estimated by two different methods described in Section 5.2.2. Both are non-standard and were developed because of the particular constraints imposed on data collection at this site. LFG generation rates are typically measured with the LFGCS shut down or at least shut down within and surrounding the area to be measured to an extent that pneumatically isolates the test area(s) from operating portions of the LFGCS. Shutting down extensive portions of the LFGCS over extended periods was not possible so the alternate methods were employed. Because the non-standard methods required many additional assumptions, the LFG generation estimates derived using these methods are not as reliable as would those obtained using the standard baro-pneumatic method.

Analyses of the shut-in tests were also influenced by the non-standard methodology used to conduct the tests as described in Section 3.3 This, in particular, affected analysis of the GW7024 data which has a low signal-to-noise ratio. Shut-in test data were analyzed using a proprietary pneumatic test analysis computer program (ASAP). This program uses the measured flow rates and pressure responses as input, and solves for pneumatic properties using an automated parameter estimation routine. ASAP is designed to simulate transient conditions and does not require that steady-state conditions be achieved.

Flow rates used in the analyses were based on measurements using the VelociCalc® air velocity meter which were considered more accurate. These measurements yielded flow rates of approximately 110, 54, and 38 standard cubic feet per minute (scfm), respectively, for wells CGW740, CGW575, and GW7024.

The quantitative analyses and results of shut-in and baro-pneumatic tests are provided in the following Sections.

5.1 Shut-in Test Analyses and Results

Flow rate and pressure data collected from the CGW740 and CGW575 areas during the shut-in tests were analyzed using ASAP, a proprietary pneumatic test analysis software package developed by HGC. Quantitative analyses of GW7024 shut-in test data were not as reliable as analyses of CGW740 and CGW575 data due to generally low signal-to-noise ratios as described previously. However, the analyses of GW7024 data yielded results that were reasonable based on the flow rate and the magnitudes of pressure changes, which are consistent with horizontal refuse air permeabilities of tens to more than 100 darcies.

Quantitative analysis of the shut-in test data from CGW740 were complicated by uncertainties in apportioning flow to deep and shallow screens at that location because only the combined flow was measured with the VelociCalc® air velocity meter. HGC was unable to use the VelociCalc® to measure flows from deep and shallow screens separately. Measured pressure responses demonstrated that probes responded primarily to the shallow screen. In addition, deep refuse (> 70 ft bls) appeared to be saturated at this location, suggesting that flow was primarily to the shallow screen and that any deep flow would not affect measured pressure responses at depths shallower than 70 ft bls. As a result of these and other uncertainties, the data were analyzed two ways: assuming 1) the measured flow (approximately 110 scfm) originated entirely from the shallow screen, and 2) only half the measured flow (approximately 55 scfm) originated from the shallow screen.

In preparing the shut-in test data for analysis, the total number of records was reduced. In general, all data collected in the first 10 minutes were retained, then every 2nd, then 3rd, then 4th, etc., record was retained for analysis. For example, if the first 10 records were retained (10 minutes of data at 1-minute intervals), the next records to be retained would be the 12th, the 15th, the 19th, the 24th, etc. The same procedure was applied to data immediately following both the shut-in and re-opening of each well. This methodology maintains a higher data density during periods when pressures are changing rapidly while reducing the time needed for data analysis, particularly important when using automatic parameter estimation.

As discussed in Section 4, pressures in many probes did not recover to pre-test values once wells were re-opened, suggesting the shut-in test data were impacted by larger-scale pressure trends unrelated to changes induced by the shut-in tests. These apparent trends were significant enough in CGW575 and GW7024 data to require correction. Trends in the CGW575 shut-in test data were relatively linear, and were subtracted from the data prior to analysis, as shown in Figures 29 through 33. Apparent trends and noise in GW7024 test data were addressed by applying barometric corrections prior to quantitative analysis. Figure 34 shows the corrected GW7024 data. To a large extent the corrections removed the initial short-term decreases in pressure and to a smaller extent allowed return of late-time pressures to initial levels.

Data were analyzed primarily to estimate the average horizontal gas permeabilities and effective gas porosities of the refuse, but vertical gas permeabilities of refuse and cover were also estimated. The results of the analyses are provided in Table 2 and Figures 35 through 61.

As shown in Table 2, estimates of pneumatic properties based on data collected during a single test vary depending on the analyzed observation point. For example, estimated horizontal permeabilities range from 3.2 to 12 darcies at test area CGW740 assuming the higher extraction rate, and from 1.4 to 6.8 darcies assuming the lower extraction rate; from 3 to 4.5 darcies at test 2area CGW575; and from 25 to 130 darcies at test area GW7024. Under homogeneous conditions, one set of parameters would theoretically fit all observation points. However, even under heterogeneous conditions such as are evident in the data, when considering only distal shallow probes (at distances greater than or equal to 45 feet), reasonable fits can be obtained with one set of parameters, as shown in Table 2 and Figures 41, 48, 54 and 61.

The site is also heterogeneous on a larger scale, as indicated by the range in gas permeabilities estimated from three test areas (Table 2). Horizontal permeability estimates were highest in test area GW7024 (averaging 96 darcies) and lowest in test area CGW575 (averaging 4 darcies). The average horizontal gas permeability of test area CGW740 was similar to that of CGW575 and ranged from 5 to 9 darcies depending on the flow rate assumed in the analysis.

Estimates of vertical gas permeability were also obtained (Table 2), but are not considered as reliable as the estimates obtained from the baro-pneumatic data presented in Section 5.2.2 and Table 3. Based on the shut-in data, vertical permeability estimates in test area CGW740 ranged from 0.019 to 1.4 darcies for refuse and from 0.02 to 0.23 darcies for the cover soils; in test area

CGW575 ranged from 0.03 to 2.5 darcies for refuse and from 0.02 to 0.39 darcies for the cover soils; and in test area GW7024 ranged from 1 to 6 darcies for refuse and from 0.2 to 0.5 darcies for the cover soils. The lowest estimates of cover permeability were derived from deep probe data which are more sensitive to the vertical refuse permeability than the cover permeability. If cover permeability estimates from deep probe data are excluded, estimates range from 0.1 to 0.23 darcies in test area CGW740; from 0.25 to 0.39 darcies in test area CGW575; and from 0.3 to 0.5 darcies in test area GW7024.

Estimates of gas porosity were also made from the shut-in test data. Gas porosity estimates for refuse ranged from 0.13 to 0.25 in test area CGW740; from 0.22 to 0.25 in test area CGW575 (excluding a value of 3.5 for CGW575-15-100 that is clearly erroneous); and from 0.35 to 0.5 in test area GW7024 (excluding a value of 5 for GW7024-15-50 that is clearly erroneous) The unreasonably large porosity values are likely related to storage effects not accounted for in the analysis.

Analysis of the shut-in test data indicate that, in general, the ratio of horizontal to vertical permeability is generally higher in test areas CGW740 and GW7024 compared to test area CGW575. Overall, ratios of horizontal to vertical permeability are greater than 1 but vary over three orders of magnitude, consistent with heterogeneous conditions.

5.2 Baro-pneumatic Test Analysis and Results

Vertical gas permeabilities and porosities were estimated from the baro-pneumatic data using the numerical finite difference computer code TRACRN (Travis and Birdsell, 1988). TRACRN was developed at Los Alamos National Laboratories and is capable of simulating gas and liquid flow, and solute transport in three dimensions, within variably saturated porous media. LFG generation rates were also estimated by two different methodologies as described below. Because the tests were conducted in non-standard fashion due to site constraints, these alternate methodologies were developed.

One-dimensional (1-D) models were developed for each monitored location that had interpretable subsurface pressures. Each model contained layers of constant thickness except where necessary to accurately represent cover thickness and was calibrated to the baro-pneumatic data for the corresponding location. The total thickness of unsaturated refuse represented in each model was based on information from the probe installation drilling. Gas flow was assumed to be negligible in the refuse at depths of greater than 100 feet at GW7024 and CGW575, and greater than 70 feet at CGW740 due to high water content.

5.2.1 Model Construction and Calibration

Each numerical model was constructed to represent the conditions reported during drilling. The refuse and cover thickness, and deep saturated conditions, were represented. Each model contained 36 layers; refuse layers were of constant thickness.

5.2.1.1 Material Distribution

Material types represented in the 1-D models included refuse, cover materials, and saturated refuse. Saturated refuse was assumed for modeling purposes to be impermeable to gas. In general, the uppermost 1 to 4 layers represented cover material and the underlying layers represented refuse.

5.2.1.2 Boundary Conditions

Because the models were 1-D in the vertical direction, the lateral boundaries were assumed to be no flow. The bottom boundary was also assumed to be no flow. The upper boundary was assigned a varying pressure condition equivalent to the measured atmospheric pressure during the testing.

5.2.1.3 Model Calibration

Each model was calibrated by varying the pneumatic properties (air permeability and porosity) of the cover and refuse materials until the simulated subsurface pressures were in reasonable agreement with the measured subsurface pressures at each measurement location. Only the latter portion of the baro-pneumatic data (between approximately 2 and 4½ days) was analyzed. This ensured that any lingering effects related to probe and pressure transducer installation were minimized. Automatic parameter estimation was used in many cases to improve the quality of the fit to the data.

Calibration involved the interim and final steps described previously. The interim step estimated pneumatic properties only; each model was calibrated to subsurface data that had LFGCS-induced vacuums subtracted out. The final step was designed to estimate LFG generation rates by the two non-standard methodologies described in Section 5.2.2

5.2.2 Results

Figures 62 through 73 compare the measured and simulated subsurface pressures from the final step used to estimate LFG generation rates. For clarity, data are plotted at 30-minute intervals. Pneumatic parameter estimates derived through model calibration are summarized in Table 3.

The fit achieved between measured and simulated pressures were good at most of the locations. An exception is the fit to the data at CGW740-15-10 (Figure 62). Changes in subsurface pressures at this location correlated poorly with atmospheric pressure changes except during the middle portion of the simulation period. Therefore only this portion of the data was considered in the analysis.

As shown in Table 3, vertical refuse permeability estimates were highest at GW7024 (except for the deep waste) and lowest at CGW740. Values reported for CGW575 and CGW740 are primarily representative of the shallow refuse because data from deep probes were not interpretable. Reasonable fits were obtained for all GW7024 shallow probes using a vertical refuse permeability of 3.5 darcies; for all CGW575 shallow probes using a vertical refuse permeability of 3 darcies; and for all shallow CGW740 probes using a vertical refuse permeability of 2 darcies. Interpretation of data from deep probes at GW7024 indicated that deep refuse (>50 feet deep) at that location has a vertical gas permeability of approximately 0.83 darcies. Deep refuse at CGW575 and CGW740 also likely has low gas permeability due to high water content, but because deep probe data were not interpretable, quantitative estimates could not be obtained.

Vertical cover permeability estimates were also highest at GW7024; good fits were obtained for all probes using a value of 2.13 darcies. Vertical cover permeability estimates were lowest at CGW575; good fits were obtained for all probes using a value of 0.25 darcies. Vertical cover permeability estimates at CGW740 ranged from 0.54 to 1.73 darcies.

Gas porosity estimates ranged from 0.2 to 0.28 for refuse and from 0.1 to 0.38 for cover. The relatively low effective gas porosity estimate (0.1) and relatively high permeability estimate (2.13) for the cover at GW7024 suggests channeling.

Two non-standard methodologies were developed to estimate LFG generation rates as described below.

5.2.2.1 Method 1

Method 1 was used for the GW7024 and CGW575 test areas since both have a single screened interval. Extraction rate estimates at these wells are considered more reliable than at CGW740, and were used in estimating the LFG generation rates. At both locations, the measurable influences of GW7024 and CGW575 were assumed to extend to a radius of 105 feet.

Subsurface vacuums persisted during the shut-in tests, indicating that the vacuums induced by nearby extractions wells (that continued to pump during the tests) overlapped the vacuums induced by GW7024 and CGW575. The measured vacuums result from extraction rates that exceed LFG generation rates in the test areas. The differences between LFG generation and extraction rates can be defined as the ‘net sink rates’, expressed as standard cubic feet per minute per cubic foot of refuse (scfm/ft^3). The 1-D numerical models were used to solve for the net gas sink rates at the probe locations by calibrating to the subsurface pressures measured during the baro-pneumatic tests. Figures 66 through 73 compare the measured and simulated subsurface pressures. The resulting gas sink rates were then weighted based on the relative volume of refuse assumed to be represented by each probe and corrected for the fraction of the sink rate attributable to the central extraction wells.

Because of radial flow and the cylindrical volumes impacted by gas extraction, the volume-based weighting assigned cylindrical or annular volumes to each probe. The volume assigned to the closest probes (15 feet from the central extraction well) was a cylinder with a radius of 30 feet (halfway between the probes having radii of 15 feet and 45 feet). The volumes assigned to the more distant probes located 45, 75 and 105 feet from the central extraction wells were annular, having inner and outer radii of 30 and 60 feet, 60 and 90 feet, and 90 and 105 feet, respectively. Volume-based weighting factors of approximately 0.08, 0.24, 0.41, and 0.27 were calculated for probes located 15, 45, 75 and 105 feet from the central extraction wells, respectively.

The fractions of the sink rates attributable to the central extraction well were calculated based on the relative distances of shallow probes to the central extraction well and the next three closest extraction wells assuming superposition, homogeneous conditions, and similar extraction rates for each well. Fractional proportions of sink rates attributable to GW7024 pumping ranged from 0.97 (for GW7024-15-20 located closest to the GW7024 and least affected by the other 3 wells) to 0.38 (for GW7024-105-17, farthest from GW7024 and the most affected by the other 3 wells). Fractional proportions of sink rates attributable to CGW575 pumping ranged from 0.95 (for CGW575-15-10 located closest to the CGW575 and least affected by the other 3 wells) to 0.21 (for CGW575-105-10, farthest from CGW575 and the most affected by the other 3 wells).

The average gas sink rates attributable to extraction from the central wells were then calculated by dividing the measured pre-shut-in extraction rates of the central extraction wells (GW7024 or CGW575) by the entire volume assumed to be measurably impacted by the central extraction well (a cylinder with radius of 105 feet), yielding rates in units of $scfm/ft^3$. The LFG generation rates (in units of $scfm/ft^3$) in the two test areas were then calculated as the differences between the sums of the weighted and corrected sink rates calculated at each probe and the average gas sink rate attributable to extraction at GW7024 or CGW575.

5.2.2.2 Method 2

An alternate non-standard methodology (Method 2) was used to estimate LFG generation rates in the CGW740 test area because of uncertainty in CGW740 extraction rate measurements and the distribution of flow between deep and shallow screens. Subsurface pressures in shallow probes at this location rapidly increased above atmospheric pressure and the difference between atmospheric and subsurface pressure appeared to stabilize during the shut-in period. The pressures measured in shallow probes after CGW740 shut-in were assumed to represent the difference between pressure resulting from LFG generation and the vacuum induced by the 3 nearest extraction wells (6051, 737, and 741SD) that continued to pump after CGW740 shut-in. The increases in subsurface pressures during CGW740 shut-in are indicative of the impact of CGW740 pumping and imply that subsurface pressures measured prior to shut-in would be on average greater than atmospheric by the same factor as measured during shut-in if CGW740 had been shut-in at the start of the baro-pneumatic testing. On this basis and for purposes of analysis, subsurface pressures measured in the shallow probes prior to shut-in were adjusted to the level expected if CGW740 had been shut-in at the start. This entailed increasing the pre-shut-in pressures above atmospheric pressure by the measured difference between atmospheric and subsurface pressure during CGW740 shut-in. Shallow-probe numerical models were then calibrated to these adjusted pressures to yield intermediate LFG generation rates. Figures 62 through 65 compare the simulated pressures to the pressures derived from this procedure.

The intermediate LFG generation rates yielded by the model calibrations were smaller than the actual rates because the pressures the models were calibrated to were lower than the pressures that would have been measured had all of the nearby extraction wells been shut-in during the test. Therefore, an additional correction was applied based on the relative distances of shallow probes to CGW740 and the next 3 closest extraction wells assuming superposition, homogeneous conditions, and similar extraction rates for each well. Calculated correction factors ranged from 1.09 (for CGW740-15-10, closest to CGW740 and least affected by the other 3 wells) to 3.8 (for CGW740-105-10, farthest from CGW740 and the most affected by the other 3 wells). After correcting for the impact of other wells, the results were volume-weighted as described above in Method 1.

5.2.2.3 LFG Generation rates and Discussion

Table 4 summarizes the results of LFG rate estimates for the three test areas. The estimated rates are 1.16×10^{-5} scfm/ft^3 for GW7024; 8.7×10^{-6} scfm/ft^3 for CGW575; and 2.4×10^{-5} scfm/ft^3 for CGW740.

As shown in Table 4, the estimated LFG generation rate is highest for the CGW740 test area and lowest for the CGW575 test area. However, because the waste at GW7024 is the oldest and presumably most degraded, it is reasonable to expect the estimated rate for this area (rather than for the CGW575 area) to be the lowest. As discussed above, the LFG generation rate estimates are affected by the non-standard methodologies used to collect and interpret the data. In particular, the number of additional assumptions needed introduce additional potential error. Some of the largest potential sources of error introduced by these additional assumptions include:

1. nearby wells have extraction rates similar to those of CGW740, CGW575, and GW7024
2. cylindrical weighting of net sink/LFG generation rates is appropriate
3. the influence of CGW740, CGW575, and GW7024 becomes negligible at radii greater than 105 feet

Furthermore, and independent of the additional assumptions needed, the high permeabilities in the GW7024 test area reduce the sensitivity and accuracy of the baro-pneumatic method which introduces additional potential error. LFG generation rate estimates from the GW7024 area are therefore the most uncertain due to the combination of the assumptions listed above and the relatively low sensitivity of the method resulting from the high permeability of both refuse and cover at this location.

5.3 Results of Gas Quality Analysis

Gas quality monitoring results for the four test wells are tabulated in Table C.1 of Appendix C. Although oxygen concentrations are low or non-detect, balance gas concentrations as high as 18% at CGW575 and as high as 57% at GW7024 indicate significant air intrusion, as described in Section 4.3.

Low oxygen concentrations in extracted gas at the SCL have been used to suggest that air intrusion is minimal. However, oxygen is not likely to be a good indicator of surface leakage because it is not conservative. Oxygen entering the waste via vertical leakage will induce aerobic biodegradation, and some or all of the oxygen will be consumed before reaching the extraction well screens at > 30 foot depths.

Air leakage directly into the LFGCS piping can be distinguished from air intrusion into the waste by measuring the volumetric ratio of the LFG's inert balance gases (nitrogen plus argon) to oxygen in the LFG collection stream (Table C.2). Gas that leaked in via the LFGCS will not have been drawn through microbe-rich solid waste and consequently will maintain its ratio of balance gas to oxygen, whereas gas that is drawn through a landfill's waste will have lost oxygen to microbial oxidation and exhibit balance gas-to-oxygen ratios higher than 3.8, the balance gas-to-oxygen ratio of ambient air (Table C.2). Dividing the sample's % balance gas by 79% (the % balance gas of air) yields an estimate of percent air intrusion.

Tables C.3 to C.6 list field gas-composition data from, respectively, test wells GW7024, CGW-740S, CGW-740D, and CGW-575 during periods of pumping. It is clear from these tables that:

1. The ratio of balance gas to oxygen is much higher than 3.8, indicating microbial consumption of oxygen carried into the LFGCS via surface leakage rather than by air leakage directly into the collection system's piping,
2. Air intrusion is very high at two of the three test extraction wells, averaging 65% in GW7024 (Table C.3), and 20% in CGW575 (Table C.6). The N_2 content of GW7024 probably exceeds 20%, the Environmental Protection Agency (EPA) proposed limit for collected LFG in their New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills. As will be described in Section 6, the greater air intrusion at CGW575 compared to CGW740 (Tables C.4 and C.5) is the result of a greater degree of overpumping at CGW575 compared to CGW740. Air intrusion at both GW7024 and CGW575 are high enough to raise concerns of the potential for an internal landfill fire. This concern is supported by the high gas temperature of 128 to 131^{o}F at GW7024, indicating substantial aerobic biodegradation and affirming the need for additional monitoring as described in Section 8.

6. SUMMARY AND CONCLUSIONS

Qualitative and quantitative analyses of the baro-pneumatic and shut-in test data indicate the following:

1. Contrary to conceptual model expectations, the field-obtained baropneumatic estimates of gas permeabilities of the soil cover materials are high for a cover, ranging from 0.25 to 2.13 darcys and averaging 1.1 darcy (1 darcy ≈ 10-3 cm/s), whereas laboratory analysis of compacted soil samples from the landfill's cover-soil stockpile area resulted in permeability estimates of 10^{-5} to 10^{-7} cm/s (10^{-2} to 10^{-4} darcys), approximately three orders of magnitude lower in range: The laboratory analysis was performed on soil samples that were compacted by the laboratory to a specified degree. HGC's estimates are based on measurements made under actual field conditions. There are several reasons that the laboratory measurements may not be representative of field conditions.

   First, the laboratory samples were compacted to a specified degree, but this level of compaction has not to HGC's knowledge been verified in the field. Unless the entire cover soil area is compacted uniformly to the same degree as the laboratory samples, the effective field permeability will be higher. Second, the field samples are likely not large enough to constitute representative elementary volumes of the material and will not reproduce the same degree of heterogeneity, macropore distribution, etc, that will impact the material under field conditions. Third, aging of the cover material and settling under field conditions is likely to change the effective permeability of the material.

2. The relatively high field-scale cover-soil permeabilities derived from the pneumatic tests are consistent with field characterization of the stockpiled soil as "sandy loam" and with logging of soil borings conducted during probe installation. These relatively high cover-soil permeabilities imply potentially excessive surface leakage of LFG in waste areas that exhibit higher-than-atmospheric operational gas pressures, reduction in the lateral influence of extraction wells owing to surface leakage, and air intrusion in waste areas that exhibit lower-than-atmospheric-operational gas pressures. Significant air intrusion near extraction wells (in particular GW7024) is consistent with the results of gas quality monitoring described in Section 5.3. The higher cover-soil gas permeability may also lead to greater infiltration of rainfall, increasing refuse soil moisture, adding to leachate volume, and reducing waste gas permeability and the effectiveness of LFG collection.

3. The nature of the cover material indicates that a revision of the site conceptual model is needed. The cover material is not a strong barrier to surface leakage, and landfilling of daily cover soil does not appear to block lateral gas transport in the landfill. Good lateral pneumatic continuity is indicated by shut-in test data. However, to the extent that the cover material permeability is lower than the waste permeability, the potential exists for the landfilled daily cover soil to restrict downward water movement. This behavior may result in high enough water saturations in the landfilled daily cover soil to locally perch water and restrict gas movement. Although no evidence in the pneumatic test data supports such restriction in the shallower refuse, landfilled daily cover soil may

contribute (at least locally) to high water saturations in portions of the deeper refuse. This premise is supported by the lower vertical gas permeabilities (hundredths of darcies [10^{-5} cm/s range]) obtained from the shut in test data at depths of 70 ft bls at CGW740 and 100 ft bls at CGW575.

4. Surface leakage limits the lateral influence of extraction wells by increasing the ratio of vertical to horizontal flow to the wells. Well CGW575 has a stronger lateral influence than CGW740 or GW7024 because of its smaller ratio of vertical leakage (and vertical flow) to horizontal flow. The cover materials at both CGW575 and CGW740 are presumed to be highly compacted but are 4 times thicker at CGW575 (6 ft at CGW575 compared to $1^1/_2$ ft at CGW740) which accounts for the smaller ratio of vertical leakage to horizontal flow at CGW575. The cover at GW7024 is thickest (10 ft) but is presumably less compacted and possibly coarser-grained, and therefore a relatively poor barrier to surface leakage. Although surface leakage at CGW575 is limited by the thicker cover, the gas quality is poorer than at CGW740 due to a greater degree of overpumping (pumping at rates > LFG generation rates). Overpumping at CGW575 induces large vacuums that increase leakage through the upper surface and presumably through side slopes intercepting shallower refuse near CGW575.

5. The existing LFG collection system is working relatively well and is keeping much of the refuse under vacuum. Exceptions are the deep refuse at CGW575 which exhibited pressures oscillating above and below atmospheric, and that were initially nearly 3 psi above atmospheric, and the deep refuse at CGW740 which had measured pressures greater than atmospheric. Water saturations at CGW740-15-70 are expected to be elevated as a result of capillarity and the saturated conditions encountered at 80 ft bls. Under these conditions, deep refuse is a potential source of gas escape on any side-slopes where the deep refuse daylights. Also, shallow refuse at distance from extraction wells CGW740 and GW7024 is under a vacuum so small as to be within measurement error. Some LFG emissions and air intrusion through the cover via advection and/or diffusion are likely in areas distant from extraction wells.

6. The LFGCS is generally overpumping (pumping at rates > LFG generation rates), especially near CGW575 as described above. The overlapping influence of extraction wells is most evident at CGW575 and GW7024, consistent with the relatively poor gas quality at these wells. Where the cover is permeable, as is evident at the SCL test sites, the cover soils will provide only a weak pneumatic barrier to atmospheric air intrusion, reducing the radius of influence of the LFG extraction wells.

7. LFG generation rate estimates cannot be made using HGC's standard baro-pneumatic method because it was not possible to shut down extraction wells within and surrounding the test plots during baro-pneumatic data collection. Alternate methods, which are not as desirable as the standard method, were developed and yielded estimates that ranged from 8.7×10^{-6} scfm/ft^3 to 2.4×10^{-5} scfm/ft^3.

Furthermore, regardless of the impacts of the site-specific limitations on data collection and analysis procedures, the results of the quantitative analyses are consistent with and support the results of the qualitative analyses. HGC's conclusions regarding site behavior and HGC's recommended changes (Section 8) would be the same whether or not the quantitative analyses had been performed.

Overall, the LFGCS appears to be working well considering some of the challenges imposed by the nature of the refuse and the need to control odors, but improvements that would increase LFG quality and reduce potential leakage and odors are possible. Measures taken to reduce surface gas leakage and reduce water contents of deep refuse will likely provide the greatest improvement. As will be discussed in Section 8, surface leakage and infiltration of precipitation can be reduced by increasing the thickness and compaction of the material currently used for intermediate/final cover, by using an alternative, lower permeability material for intermediate/final cover, or by modifying the existing intermediate cover to reduce permeability.

7. REVISED CONCEPTUAL SITE MODEL

Testing by HGC indicates that the pneumatic behavior of the SCL is typical of an MSW landfill with a few notable exceptions. The refuse displays good lateral pneumatic continuity, and gas permeabilities (at least in the shallower [<70 - 100 ft bls] refuse) are generally high enough to be conducive to LFG extraction using vertical wells. The pneumatic estimates suggest that the composition and compaction of the younger waste have not reduced the gas permeability of most of the waste to the degree of significant interference with LFG collection. Ratios of horizontal to vertical gas permeability are greater than 1 but vary over three orders of magnitude, consistent with heterogeneity.

The relatively low ratios of horizontal to vertical gas permeability (< 10) detected in some portions of the younger waste will limit the lateral influence of LFGCS extraction wells. These relatively low ratios of horizontal to vertical gas permeability are likely attributable to changes in waste composition and handling that increased the proportion of food wastes.

In addition, some portions of the younger refuse have generally low gas permeabilities (both horizontal and vertical), consistent with heterogeneity and likely also attributable in part to changes in waste composition and handling. These lower permeability zones may be problematic with respect to gas collection. To the extent that these zones are surrounded by higher permeability material that is under control by the LFGCS, the potential problems will be minimized. However, wherever such low permeability zones contact the ground surface, LFG has a greater potential to escape.

Pneumatic testing indicates the cover permeability and potential for surface leakage is relatively high in all measured areas and highest in the GW7024 area. However, less potential for surface leakage was detected at CGW575 than CGW740 due to the greater thickness of the cover at CGW575 (6 ft vs 1.5 ft). Although the thickest cover was measured at GW7024, the material was a poor barrier to surface leakage, presumably due to lower compaction and possibly different composition compared to the CGW575 and CGW740 areas.

As discussed in Section 5.3, low oxygen concentrations in extracted gas have been used to suggest that air intrusion is minimal. However, oxygen is not likely to be a good indicator of surface leakage because it is not conservative. Oxygen entering the waste via vertical leakage will induce aerobic biodegradation, and some or all of the oxygen will be consumed before reaching the extraction well screens at > 30 foot depths.

Furthermore, surface methane measurements at SCL have been used as an indicator of LFG escape. However, aerobic biodegradation of methane is expected to occur within the cover due to diffusion of oxygen into the cover, which will impact surface methane emissions measurements. Overall, however, the surface emissions and gas quality data reviewed by HGC are generally consistent with the results of the pneumatic testing.

Vertical leakage facilitated by relatively high cover permeabilities is of greatest concern at the SCL because leakage will reduce extracted gas quality, limit the lateral influence of LFGCS extraction wells, and facilitate potential LFG migration through the cover in areas distant from extraction wells. Countering this latter problem by LFGCS over-pumping will further increase air intrusion, reduce gas quality, and increase the potential for an internal fire. The next most significant concern (at least for the youngest refuse) is the presence of zones in the deep waste that do not appear to be under the control of the LFGCS, most likely due to high water saturations and consequent low gas permeabilities that restrict the ability of the LFGCS to extract gas from these zones. As discussed above, wherever such zones contact the surface, LFG has a greater potential to escape. Side slopes intercepting deep waste that is not under control by the LFGCS are likely areas of LFG escape. The likelihood of escape of LFG on side slopes is enhanced by ratios of horizontal to vertical permeability that are greater than 1.

Furthermore, the higher than expected gas permeabilities of the cover soils in the test areas imply similarly higher hydraulic conductivities. Higher than expected conductivities will result in higher than expected infiltration of rainfall, consistent with the higher water saturations detected in deeper refuse, especially at CGW740 where the cover is thinnest.

The pneumatic test data demonstrate that the LFGCS is generally working well, but identify areas where escape of LFG to the surface is possible, in particular where the shallow refuse is under negligible vacuum (for example CGW740-75-10 and CGW740-105-10) and where areas of deep, younger refuse that are under pressure may daylight on side slopes (for example CGW740-15-70). The data also indicate that the LFGCS is pumping at rates higher than the LFG generation rates (overpumping) in the test areas, indicating air intrusion, and that the potential for surface leakage is greater in the CGW740 and GW7024 areas than in the CGW575 test area. A higher degree of air intrusion at CGW575 compared to CGW740 based on gas quality monitoring is the result of a greater degree of overpumping at CGW575. The pneumatic data indicate that cover material composition and compaction are similar in the CGW740 and CGW575 test areas. However, thinner cover in the CGW740 test area facilitates higher leakage potential. Relatively high leakage in the GW7024 test area is facilitated by the high permeability of the cover which outweighs the beneficial impact of its greater thickness. Relatively high permeability and relatively low effective gas porosity estimates for the GW7024 area cover suggest channeling. Compared to the other test areas, the pneumatic behavior of the GW7024 test area cover is consistent with a different composition, lower compaction, or both.

The pneumatic test data indicate that, contrary to expectation, landfilled daily-cover soil in the CGW740 test area does not significantly interfere with lateral flow of LFG to CGW740, at least within the shallower refuse. To the extent that the cover material permeability is lower than the waste permeability, the potential exists for the landfilled daily cover soil to restrict downward water movement. This behavior may result in high enough water saturations in the landfilled daily cover soil to locally perch water and restrict gas movement. Although no evidence in the pneumatic test data supports such restriction in the shallower refuse, landfilled daily cover soil may contribute (at least locally) to high water saturations in the deeper CGW740 refuse. The higher water infiltration rates expected at CGW740 due to the relatively thin cover would likely exacerbate this problem.

8. RECOMMENDED CHANGES

The following Sections discuss recommended changes based on the pneumatic testing results.

8.1 Intermediate Cover

To reduce surface leakage (inward leakage of air near LFGCS wells and outward leakage of LFG at distance from LFGCS wells), reduce rainfall infiltration, increase the lateral influence of LFGCS wells, and improve LFG quality, the following options have been considered:

a) Thicken and compact the intermediate cover. Because leakage will be affected by both the permeability and thickness of the cover, surface leakage would be reduced by increasing the thickness and compaction of the cover. However, compacting intermediate cover soils to the extent necessary to reduce their permeability by more than 1 to 2 orders of magnitude would be difficult if not impossible without unduly interfering with landfill operations and potentially damaging the in-place LFGCS consisting (in 2012) of 450 vertical gas wells, 50 horizontal collectors, 100 trench collectors and assorted perimeter and liner collectors and piping manifolds. Reducing intermediate cover permeability by a less disruptive method would likely be more feasible.

b) Locate a source of lower permeability soils (<0.05 darcies) to replace the current intermediate-cover material. Locating and importing an alternate lower permeability soil for use as cover material is also expected to be problematic and would be expensive, particularly when the value of lost air space is considered.

c) Modify the surficial intermediate-cover soils to reduce their permeability. This appears to be possible using spray-on intermediate cover-soil treatments such as those manufactured by New Waste Concepts Inc. (NWCI). Appendix D, prepared with assistance from NWCI, describes products and application recommendations for both the proposed intermediate and daily cover treatments. NWCI (nwci.com) recommends their HydraGuard 21 product for treatment of intermediate cover soils and their ProGuard SB2 for use as alternate daily cover (ADC).

   According to NWCI, HydraGuard 21, sprayed on in water solution, will infiltrate and saturate the surficial intermediate-cover soils to a depth of several inches. Because of shadow effects, application of spray-on material to the soil cover should be done from 2 to 3 directions and will require good access to make sure the entire area is covered.

The HydraGuard solution then hardens, reducing the soil cover's permeability and ruggedizing its surface to traffic and rainfall for a period of up to 0.5 years or more. The effectiveness and longevity of this alternative cover treatment is enhanced by first having the surface compacted and smoothed by a smooth roll vibrating compactor. Surfaces are coated until a donut-like glaze occurs. The relatively high permeability of SCL's intermediate cover soils would increase the depth and durability of HydraGuard penetration. Intermediate cover treatment maintenance would consist of regular inspection and periodic touchup followed by biannual reapplication (the frequency depending on the results of baro-pneumatic monitoring of the cover's effectiveness described below). A significant additional benefit of NWCI's technology would be its reduction of stormwater infiltration, perhaps sufficient to stop the flooding of gas well collectors.

8.2 Daily Cover

Daily cover soil is put in place for vector control and to restrict or prevent LFG and odors from escaping the working face. The current practice of landfilling the used daily cover soil is potentially problematic because the material has a lower permeability than the refuse and may restrict downward percolation of leachate, creating zones of elevated water saturation and low gas permeability, and consequently interfering with LFG flow to the LFGCS.

Furthermore, assuming compacted native soils exhibit high permeabilities similar to those in the three test areas, use of these materials as daily cover is not expected to significantly attenuate the surface emissions of the refuse's odiferous compounds. Use of alternate, imported low-permeability soils may be more effective as daily cover material, but incorporating low permeability material into the refuse at the start of each day's landfilling without creating buried low-permeability barriers to gas or liquid flow would be problematic.

The simplest course of action is to eliminate use of daily soil cover and replace with tarps. However, sealing a tarp against gas escape from a compacted-waste surface is a difficult exercise. Should eliminating the use of daily soil cover or incorporating the daily cover soil into landfilled additional waste be considered infeasible, use of an ADC that is degradable should be considered.

Regarding early morning odors, soil-based ADCs might impact nighttime/early morning refuse odors by overnight adsorption of odiferous compounds carried by LFG passing through the porous ADC media. Desorption of these compounds into the atmosphere would occur when the large surface area of the ADC is disturbed during the start of the morning's waste disposal activities at the working face. Decreasing the permeability of the ADC would decrease night-time gas flow through the cover, thereby reducing the concentrations of odiferous emissions created by disturbance of the cover at the start of the landfilling day.

Emissions through either the intermediate or daily cover materials are expected to be proportional to the thickness of the cover, the permeability of the cover, and the difference between landfill pressure and atmospheric pressure (the gage pressure). Assuming the gage pressure does not change, increasing the thickness of the cover or reducing the permeability of the cover by some factor is expected to reduce surface emissions by the same factor. For example, under conditions of constant gage pressure, halving surface emissions could be accomplished by either doubling the thickness of the cover or by halving the permeability of the cover. Should both the thickness of the cover be doubled and its permeability halved, a four-fold reduction in surface emissions would be expected.

8.3 Using an ADC

The desired characteristics of an ADC (assuming that it is left in place and landfilled rather than being removed prior to landfilling of additional refuse) are:

a) Low VOC and/or drying component content;

b) Relatively low permeability prior to burial so that it acts as a strong barrier to LFG escape through the surface (and reduces infiltration of precipitation); and

c) Relatively high permeability once landfilled (buried by additional waste) so that it does not interfere with LFG collection.

These desired characteristics can be achieved by using a cover material that initially has a low permeability but breaks down once landfilled so that it does not interfere with LFG collection. The two primary concerns are the effective permeability of the installed ADC and the future impact of the subsequently buried ADC on future gas and water flow in the refuse. Field pneumatic tests of the selected ADC (described below) are recommended to assess the permeability of in-place ADC. Barriers to gas or liquid flow should be preventable by avoiding burial of membranes or low-permeability materials that have not been sufficiently perforated or fragmented to avoid interference with the waste's gas or liquid flow, thereby impacting the efficiency of the LFGCS by flooding collector wells, perching leachate, isolating gas pockets, and interfering with the performance of the LFGCS and anticipated LFG-to-Energy system.

An example of an ADC that would address these concerns is NWCI's Proguard®, HydraGuard, or ConCover® product lines of spray-on emulsified slurries of cellulosic material and inorganic mineral polymers (Appendix D). Depending on the product choice, these low-permeability spray-on cover materials can be used for daily (as well as intermediate and final) covers with lifetimes ranging from 48 hours up to 18 months. The materials are dispersed in water and set up and harden shortly after being applied by a hydroseeding sprayer to a landfill's working face, but break up and fragment in the process of filling and compacting the next waste lift. According to the manufacturer, the residual fragmented cover materials do not consume significant air space or decrease waste fill permeability. Because of shadow effects, application of spray-on material to the soil cover should be done from 2 to 3 directions and will require good access to make sure the entire area is covered.

ProGuard SB2**,** the NCWI-recommended ADC (Appendix D), is a cellulosic and polymer based spray on coating that will degrade after application within about 14 to 30 days. The evaporative coating dries as the liquids that are held by the polymer evaporate. The dried flexible coating suppresses VOCs and odors, controls dust, and inhibits blowing litter. Once applied, the cover hardens in a few hours and fragments without loss of permeability during the next day's waste-compaction activities. This product mixes easily with water and becomes a viscous slurry that adheres well to all substrates. Time of application is approximately 30 minutes for 30,000 ft^2. The quality of the polymers allows for spraying in a light rain event and additives can be employed to withstand heavier rains.

8.4 Field Testing

As will be discussed below, pilot testing of any solution implemented to reduce intermediate or daily cover permeability (such as NWCI's product line) is recommended using the baropneumatic method to verify expected benefits before implementing its wide-spread use. The current method of using gas quality (primarily oxygen concentration) data and surface emissions (primarily methane concentration) data as indicators of permeability and surface leakage is not a direct method and is not as useful or as accurate as the pneumatic field testing methods developed by the USGS (Weeks, 1978) and employed by HGC as a component of the baro-pneumatic method. As discussed in Section 5.3, oxygen content of extracted gas is expected to be a poor indicator of surface leakage because it is not conservative. Oxygen entering the waste via vertical leakage (air intrusion) will induce aerobic biodegradation, and some or all of the intruded air's oxygen will be consumed before reaching the extraction well screens at greater than 30 foot depths. Also, aerobic biodegradation of methane is expected to occur within the cover due to diffusion of oxygen into the cover, which will impact surface emission measurements.

The three existing test areas are recommended for testing treatment of intermediate cover materials because the monitoring probes are already in place. If desired, other areas of higher permeability intermediate cover soils likely to have leakage could be identified by installing push probes and monitoring pressures. Alternatively, estimates of excessive air intrusion, obtained by field ‘balance gas’ analysis as described below and in Appendix C, could be used to identify areas of higher permeability, leaky, intermediate cover soils.

Testing would be performed by baro-pneumatic permeability testing of selected test areas before, during, and after applying the intermediate cover soil treatment in order to evaluate the effective reduction in permeability and changes in air intrusion/emissions with time. After the permeability tests are completed, selected pneumatic monitoring probes would be left in place to allow periodic reinstallation of recording pressure transducers and enable tracking of future cover performance. If future waste disposal atop the intermediate cover soils were to be required, the hardened HydraGuarded layer of shallow soils would need to be broken up by a compactor before additional waste disposal to ensure minimal interference with liquid and gas flow.

Suitable areas for testing ADC-treated working-face areas would be selected for their ease of access, given that these would be short term field tests involving less than a day to complete. Using drive points (instead of a drilling rig) to install probes for this testing would likely allow the maximum number of probes at minimal cost and disruption.

8.5 Enhance Drainage of Leachate

“Watering in” issues are commonly associated with LFG extraction wells, including some of the SCL wells. The gas permeability of liquid-saturated landfill refuse is effectively zero, which can reduce the extraction well’s gas collection efficiency to near zero as well. Resolving the problem of watering-in of wells will require consideration of both the leachate sources and sinks.

- The infiltration of stormwater may not have been adequately accounted for in the engineering design of the SCL owing to the low permeabilities derived by laboratory measurement of cover soil samples. The most effective way of addressing the wells’ flooding problems may be to revisit the landfill’s stormwater drainage design, including the use of an alternative intermediate cover to minimize infiltration.
- The observed widespread flooding problems suggest that the landfill needs to be dewatered to enable the LFGCS to operate effectively throughout the entire thickness of waste. Vertical wells properly designed and constructed can serve as both gas extraction

wells and dewatering wells to remove leachate. Note that dewatering can be a slow process; the same impediments to fluid flow, i.e. reduced-permeability partially-saturated soils, can slow the dewatering process. Additional vertical drains constructed of clean coarse stone or one- pass shredded tires can be installed to assist in draining leachate accumulating in intermediate lifts of waste toward the leachate collection system at the base of the landfill. Maintaining positive drainage on the operational surfaces of the landfill is also important to minimize infiltration of stormwater to the landfilled waste. As discussed above, modification of the surficial intermediate cover soils to reduce vertical permeability would also reduce stormwater infiltration.

- In addition to vertical wells, horizontal wells that also function as gas extraction wells can be used for dewatering purposes provided they are properly designed. The best means of mitigating flooding of horizontal wells (besides cutting off infiltration of stormwater) is to provide adequate slope to the collector to allow free drainage to a vertical drain, drain leg, or connection to the leachate collection system. In constructing waste lifts, it is recommended that the intermediate surface be constructed with a 4 to 6 % slope on which the horizontal collectors are to be placed to facilitate drainage of leachate/condensate. If necessary, vertical drains filled with clean coarse stone or one-pass shredded tires can be incorporated at low points along the piping network to drain liquids migrating through the horizontal pipe trenches.

An example of a successful case history (QEDenv.com), solved by installing and operating dual-phase pumps in the affected vertical wells and pumping down the excess leachate while extracting LFG, is as follows:

- Waste Management's Springhill Regional Landfill near Campbellton, Florida is equipped with a landfill gas to energy (LFGTE) system capable of producing 4.8 megawatts of power. In May of 2006, the plant was receiving only enough gas to run two of the six engines. Consulting engineers determined that many of the landfill gas extraction wells were watered in. High levels of liquid, primarily condensed water vapor, had flooded most of the wells' available surface area, lowering gas permeabilities and reducing gas extraction efficiency drastically. The excess liquid had to be pumped down. Temperatures in the wells exceeded 140 degrees Fahrenheit, and the condensate was highly corrosive. In August 2006, six air-powered AutoPump® AP4 units (QED Environmental Systems) were installed, followed by another six in October. By November, the landfill's gas supply was back to nominal levels and all six engines were running at capacity, generating the full 4.8 megawatts.
- The AutoPump units were developed specifically for difficult pumping applications at landfills and petroleum and solvent spill remediation sites. These types of pumps are designed to provide safety, simplicity, and long service life under harsh conditions of elevated temperatures, high solids levels, high viscosity fluids and corrosive fluids. Use of these or similar types of pumps at the SCL is expected to improve collection of LFG from deep refuse having high water saturations.

8.6 LFG Migration and Surface Leakage on SCL Sideslopes

The surface emissions of the SCL's side-slopes were not investigated during the HGC study. Part of the reason was the inaccessibility of the side-slopes to heavy equipment, such as drill rigs and trucks. However, the high pressures observed in deep monitoring probes and their low response to barometric pressure changes coupled with higher than expected gas permeabilities of available cover soil materials suggest the potential for gas migration from the landfill refuse to the side-slopes and subsequent gas emissions.

HGC recommends that a baro-pneumatic investigation of side-slope pneumatic properties be conducted including, if necessary, manual installation of ¾-inch pressure monitoring probes. The objectives of the study would be quantification of side-slope surface leakage of LFG, methane and NMOCs. If surface emissions are found to be significant, these data could be used to design an effective perimeter collection system for LFG migration and emissions (Smith et al., 2006).

Such a system might consist of a location-specific LFGCS. The design would be accomplished by conducting a pneumatic investigation of the side-slope areas as described above using hand-driven monitoring probes to collect LFG pressure data on landfill areas accessible by foot. The results would include estimates of vertical permeability, surface leakage rates, and horizontal and vertical pressure gradients, and would establish areas where shallow LFG pressures exceed atmospheric pressure, i.e., areas of surface emissions. If emissions are found to be unacceptably high, these pneumatic data would be used to design an efficient side slope gas collection system.

HGC proposes a preliminary investigation in a 400 x 400 foot side slope area, setting 16 probes into shallow solid waste at 200 foot centers. The monitoring probes for this initial investigation would be constructed from 8-foot lengths of ¾-inch steel pipe equipped with non-retrievable points and Fernco flexible couplers sized to mate with vented 5 psi pressure-recording transducers. This preliminary investigation would yield LFG pressure data for use in the cost-effective design of a full-scale side-slope investigation that would specify optimal probe spacings and depths, and allow estimation of gas extraction rates. The full scale investigation would be carried out in stages, addressing side slope areas of concern and providing data that allow cost effective addition to the SCL LFGCS.

8.7 LFG Quality Monitoring

Balance gas calculations derived from gas quality data described in Section 5.3 can be used to distinguish air intrusion from collection system gas leaks. It is recommended that the current periodic monitoring of SCL gas quality be expanded to include reporting of balance gas and the ratios of balance gas to oxygen and of the balance gas to air.

The air intrusion rates calculated for GW7024 and CW575 are high enough to raise concerns for an internal landfill fire, suggesting that wells in these and other areas should be monitored for increases in temperature and % balance gas**.**

9. REFERENCES

Scheutz, C. Skov, B. Cassini, F., Mou, Z. and Kjeldsen, P. 2013. Mitigation of methane emissions in a pilot-scale biocover system at the AV Miljø landfill, Denmark: Quantification of methane oxidation, in *Proceedings Sardinia 203, Fourteenth International Waste Management and Landfill Symposium S. Margherita di Pula, Cagliari, Italy; 30 September - 4 October 2013*, CISA, Environmental Sanitary Engineering Centre, Italy.

Smith, S.J., H.W. Bentley, K. Reaves. 2006. Systematic Design of Methane Migration Control Systems, Proceedings of the 29th Annual SWANA Landfill Gas Symposium, March 27-30, St. Petersburg, Florida.

Tetra Tech BAS. 2011. Evaluation of the Existing Landfill Gas Collection and Control System, Sunshine Canyon Landfill. November 29, 2011.

Travis, B. J., and K. H. Birdsell. 1988. TRACRN 1.0: A Model of Flow and Transport in Porous Media for the Yucca Mountain Project - Model Description and User's Manual. Los Alamos National Laboratories. TW5-ESS-5/10-88-08.

Weeks, E.P., 1978. Field Determination of Vertical Permeability to Air in the Unsaturated Zone. U.S. Geological Survey Professional Paper 1051.

10. LIMITATIONS STATEMENT

The opinions and recommendations presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time when HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.

11. ACKNOWLEDGEMENT

This report was prepared as a result of work sponsored, paid for, in whole or in part, by SCAQMD. The opinions, findings, conclusions, and recommendations are those of the author and do not necessarily represent the views of SCAQMD. SCAQMD, its officers, employees, contractors, and subcontractors make no warranty, expressed or implied, and assume no legal liability for the information in this report. SCAQMD has not approved or disapproved this report, nor has SCAQMD passed upon the accuracy or adequacy of the information contained herein.

TABLES

TABLE 1
Probe Construction Summary

Probe ID	Cover Thickness (ft)	Refuse Interval (ft bgs)	Probe Depths and (Screened Intervals) (ft bgs)	Probe Diameter (in)
CGW740 Probes				
CGW740-15-10	1.5	1.5-85 (TD)	10 (8-10)	1
CGW740-15-35	1.5	1.5-85 (TD)	35 (30-35)	1
CGW740-15-70	1.5	1.5-85 (TD)	70 (65-70)	1
CGW740-45	1.5	1.5-11 (TD)	10 (8-10)	1
CGW740-75	1.5	1.5-11 (TD)	10 (8-10)	1
CGW740-105	1.5	1.5-11 (TD)	10 (8-10)	1
CGW575 Probes				
CGW575-15-10	6	6-100 (TD)	10 (8-10)	1
CGW575-15-50	6	6-100 (TD)	50 (45-50)	1
CGW575-15-100	6	6-100 (TD)	100 (95-100)	1
CGW575-45	6	6-11 (TD)	10 (8-10)	1
CGW575-75	6	6-11 (TD)	10 (8-10)	1
CGW575-105	5	5-11 (TD)	10 (8-10)	1
GW7024 Probes				
GW7024-15-20	10	10-101.8 (TD)	20 (18-20)	1
GW7024-15-50	10	10-101.8 (TD)	50 (45-50)	1
GW7024-15-100	10	10-101.8 (TD)	100 (95-100)	1
GW7024-45-17	10	10-17.5 (TD)	17 (15-17)	1
GW7024-75-17	10	10-17.25 (TD)	17 (15-17)	1
GW7024-105-17	10	10-18 (TD)	17 (15-17)	1

Notes:
ft = feet
ft bgs = feet below ground surface
in = inches
TD = total depth

TABLE 2
Pneumatic Parameter Estimates Based on Shut-in Tests
Sunshine Canyon Landfill

Pumping Well	Observation Well	k_h	k_v	k_{conf}	ϕ
GW7024	GW7024-15-20	100.0	6.0	0.5	0.50
	GW7024-15-50	80.0	1.0	0.5	5.0*
	GW7024-15-100	25.0	1.0	0.2	0.35
	GW7024-45-17	120.0	4.0	0.5	0.40
	GW7024-75-17	120.0	4.0	0.5	0.40
	GW7024-105-17	100.0	4.0	0.3	0.40
	GW7024-15-20; 45-17; 75-17;105-17	130.0	6.0	0.5	0.49
CGW575	CGW575-15-10	4.5	2.50	0.25	0.22
	CGW575-15-100	4.2	0.03	0.02	3.5*
	CGW575-45-10	3	0.84	0.39	0.25
	CGW575-75-10	3	0.84	0.39	0.25
	CGW575-105-10	2.9	2.00	0.38	0.25
	CGW575-45-10; 75-10;105-10	3.7	0.85	0.32	0.25
CGW740	CGW740-15-10	10.0	1.38	0.16	0.25
(assuming 110	CGW740-15-35	4.0	1.40	0.12	0.25
scfm extraction)	CGW740-15-70	3.2	0.03	0.02	0.20
	CGW740-45-10	12.0	0.49	0.18	0.25
	CGW740-75-10	12.0	0.70	0.23	0.25
	CGW740-105-10	12.0	0.56	0.18	0.25
	CGW740-45-10; 75-10;105-10	12.0	0.60	0.20	0.25
CGW740	CGW740-15-10	5.0	1.05	0.12	0.15
(assuming 55	CGW740-15-35	1.9	0.70	0.07	0.15
scfm extraction)	CGW740-15-70	1.4	0.02	0.02	0.15
	CGW740-45-10	6.3	0.32	0.11	0.15
	CGW740-75-10	6.3	0.30	0.09	0.13
	CGW740-105-10	6.0	0.42	0.11	0.13
	CGW740-45-10; 75-10; 105-10	6.8	0.34	0.10	0.15

Notes:
** = Not reasonable (see text)*
k_h = Horizontal gas permeability (darcies)
k_v = Vertical gas permeability (darcies)
k_{conf} = Confining layer (cover) gas permeability in darcies
ϕ = Gas porosity

TABLE 3
Pneumatic Parameter Estimates Based on Baro-pneumatic Analysis
Sunshine Canyon Landfill

Location	k_v	k_{cov}	ϕ_1	ϕ_2
GW7024-15-20,50,100	0.83(D); 3.5(S)	2.13	0.28(D); 0.20(S)	0.10
GW7024-45-17	3.5	2.13	0.25	0.10
GW7024-75-17	3.5	2.13	0.25	0.10
GW7024-105-17	3.5	2.13	0.25	0.10
CGW575-15-10	3.0	0.25	0.20	0.38
CGW575-45-10	3.0	0.25	0.20	0.38
CGW575-75-10	3.0	0.25	0.20	0.38
CGW575-105-10	3.0	0.25	0.20	0.38
CGW740-15-10	2.0	0.54	0.20	0.20
CGW740-45-10	2.0	0.54	0.20	0.20
CGW740-75-10	2.0	0.67	0.20	0.20
CGW740-105-10	2.0	1.73	0.20	0.20

Notes:

D = Deep

S = Shallow

k_v = Vertical gas permeability (darcies)

k_{cov} = Cover gas permeability (darcies)

ϕ_1 = Gas porosity (refuse)

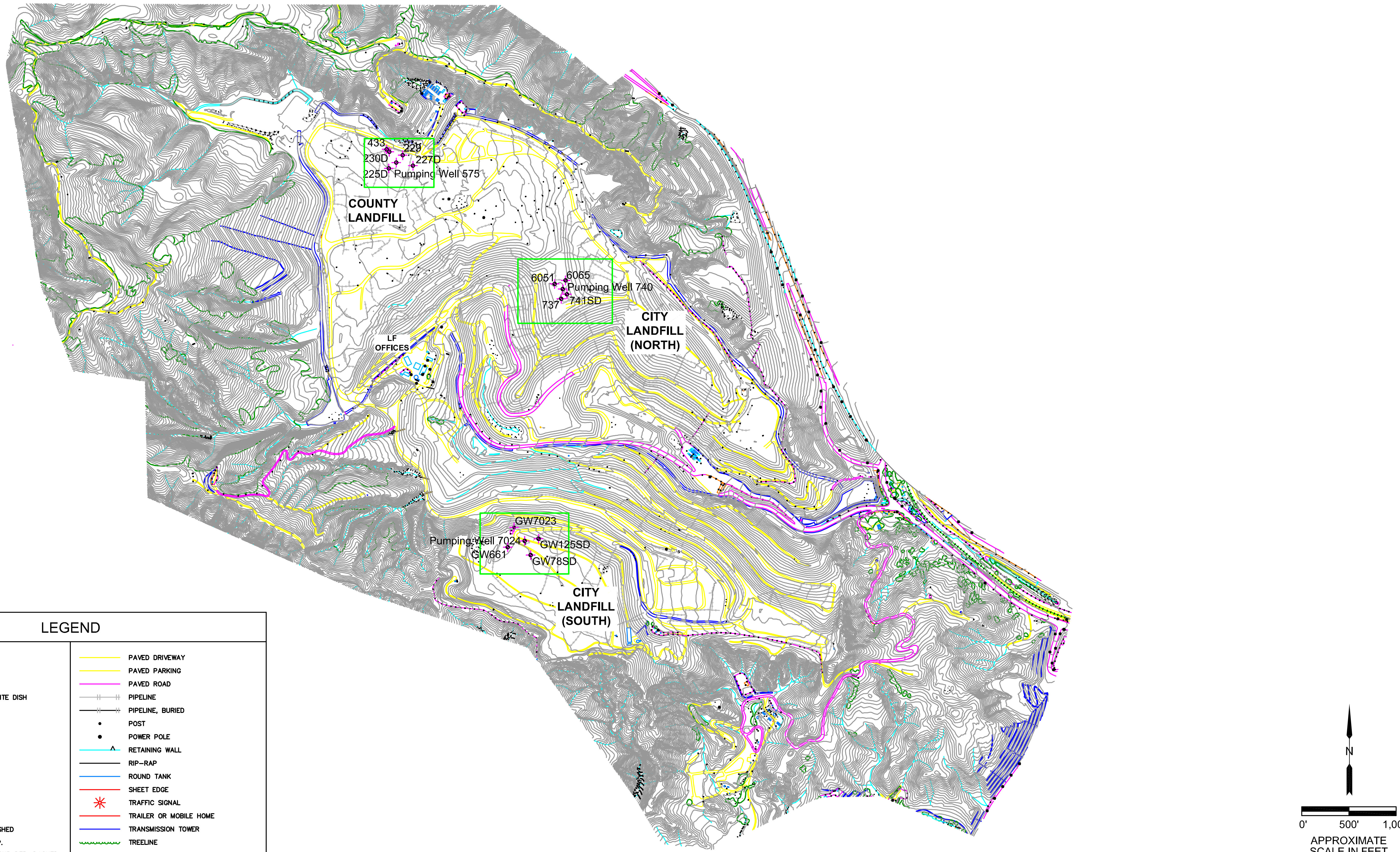
ϕ_2 = Gas porosity (cover)

TABLE 4
LFG Generation Rate Estimates
Sunshine Canyon Landfill

Location	Rate (scfm/ft^3)
CGW740	2.4×10^{-5}
CGW575	8.7×10^{-6}
GW7024	*1.16×10^{-5}

NOTES:
scfm/ft^3 =standard cubic feet per minute/cubic foot refuse
** may be substantially overestimated*

FIGURES



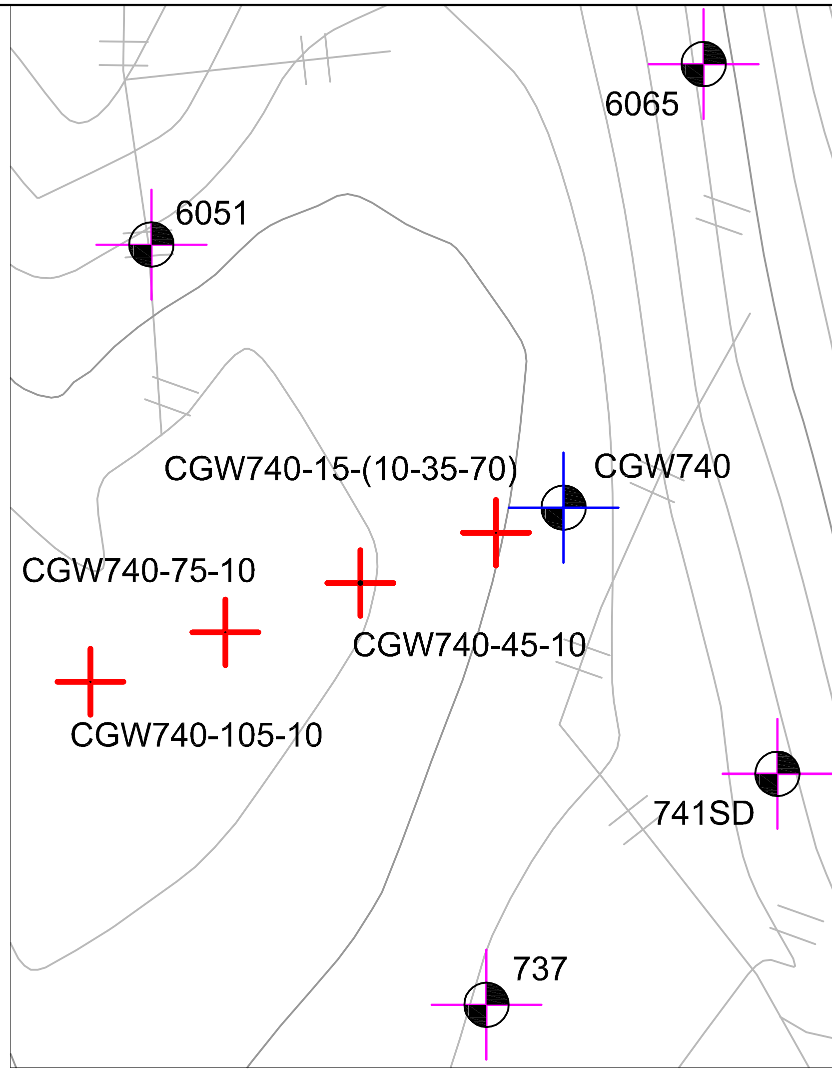
LEGEND

BRIDGE	PAVED DRIVEWAY
BUILDING	PAVED PARKING
CANOPY	PAVED ROAD
COMMERCIAL SATELLITE DISH	PIPELINE
CONCRETE DITCH	PIPELINE, BURIED
	POST
CONVEYOR BELT	POWER POLE
CULVERT PIPE	RETAINING WALL
DRAINAGE	RIP–RAP
FENCE	ROUND TANK
GUARDRAIL	SHEET EDGE
HEADWALL	TRAFFIC SIGNAL
INDEX CONTOUR	TRAILER OR MOBILE HOME
INDEX CONTOUR DASHED	TRANSMISSION TOWER
INDEX CONTOUR DEP.	TREELINE
INTERMEDIATE CONTOUR DEP. DASHED	UNPAVED
LARGE SIGN	VENT OR VAULT
LIGHT POLE	WALL
MISCELLANEOUS	WASH
MISCELLANEOUS SYMBOL	

HYDRO GEO CHEM, INC.

SITE PLAN
SUNSHINE CANYON LANDFILL
SYLMAR, CALIFORNIA

Approved	Date	Author	Date	File Name	Figure
SJS	10/29/14	JAA	10/29/14	2013009003A	1



LEGEND

INDEX CONTOUR
INDEX CONTOUR DASHED
INDEX CONTOUR DEP.
INTERMEDIATE CONTOUR DEP. DASHED
PIPELINE
PIPELINE, BURIED
6065 GAS EXTRACTION WELL
CGW740-45-10 PROBE
CGW740 GAS EXTRACTION WELL

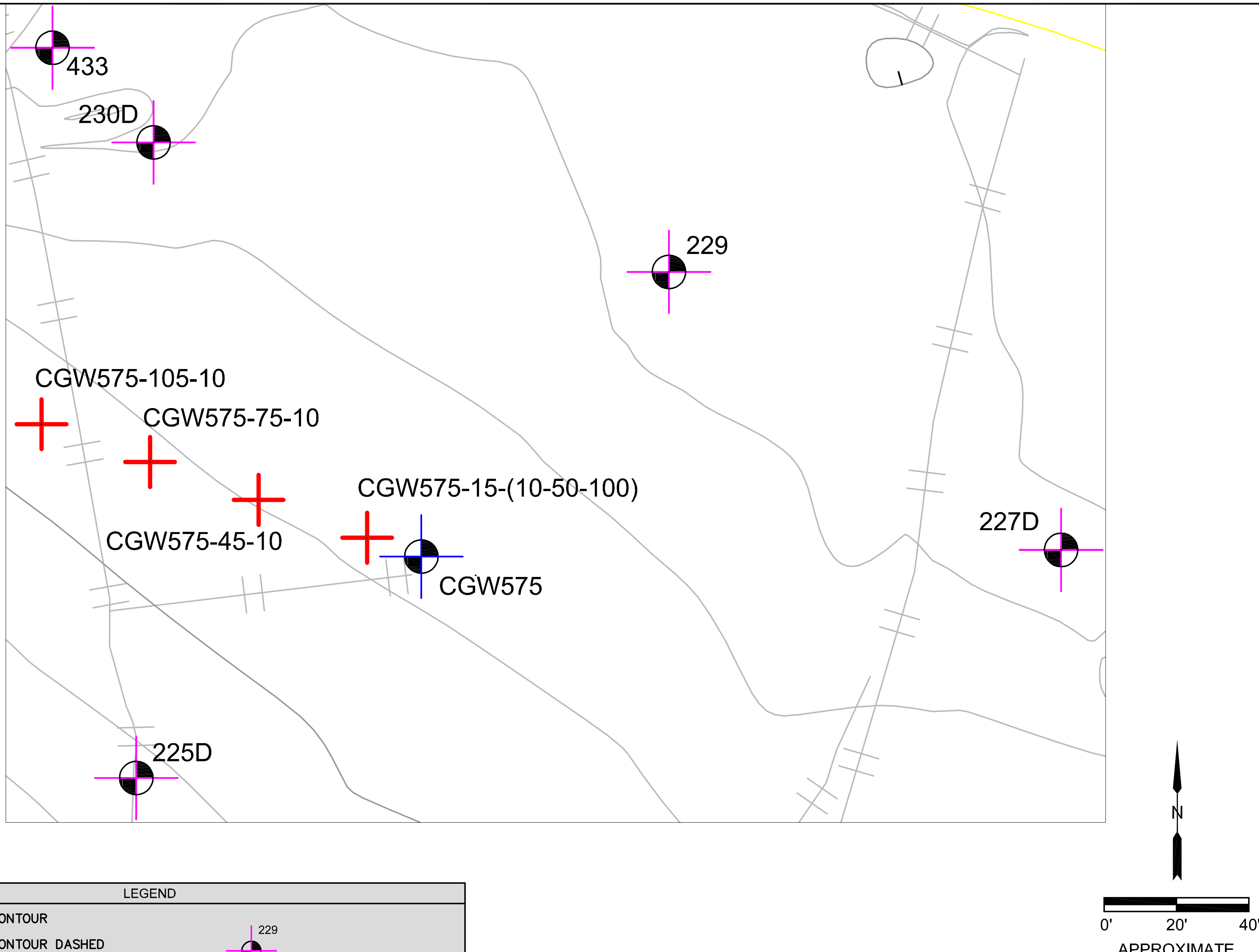
N

0' 20' 40'
APPROXIMATE SCALE IN FEET

HYDRO GEO CHEM, INC.

TEST AREA CGW740
SUNSHINE CANYON LANDFILL
SYLMAR, CALIFORNIA

Approved	Date	Author	Date	File Name	Figure
SJS	10/30/14	JAA	10/30/14	2013009004A	2



LEGEND

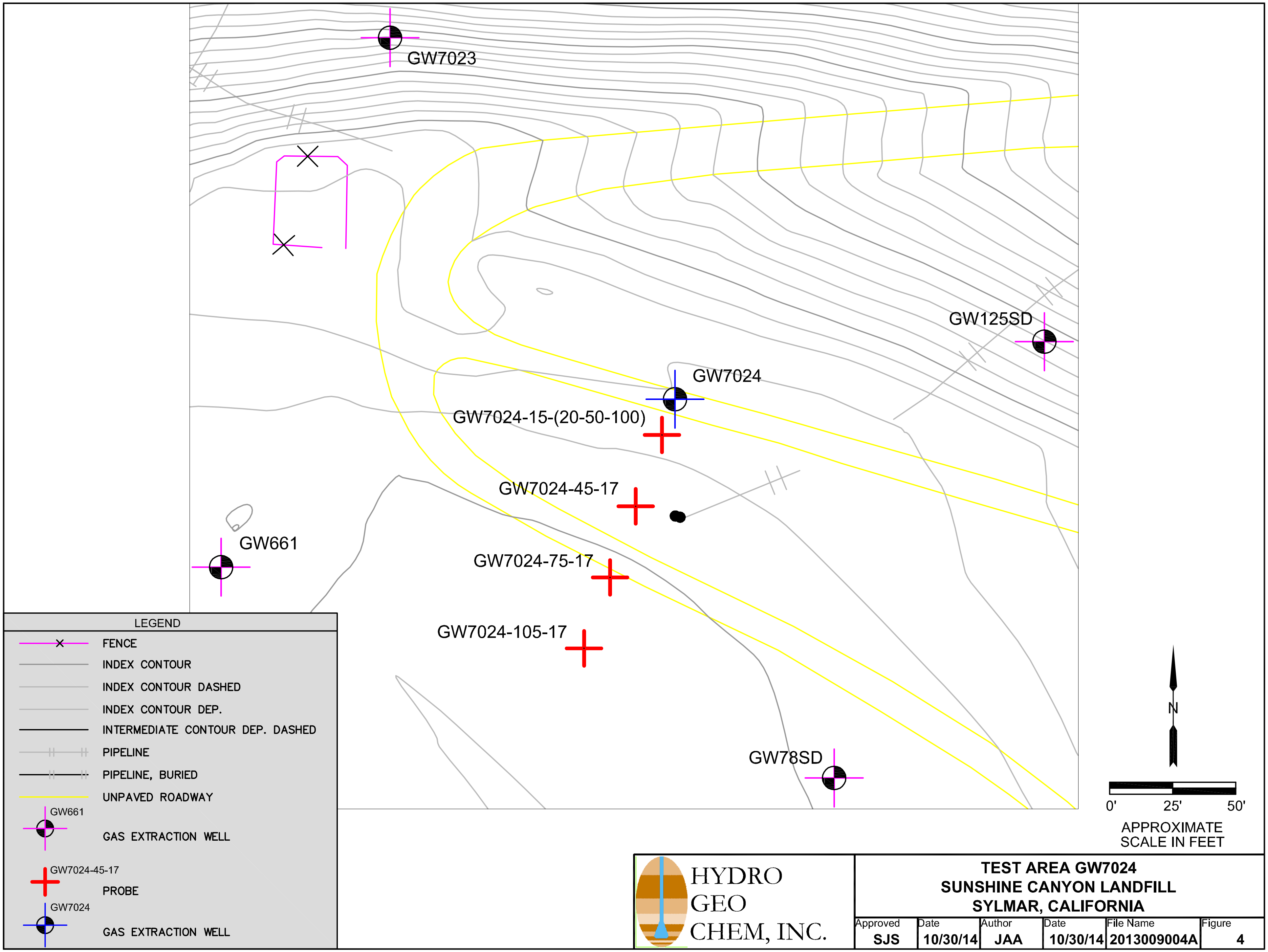
INDEX CONTOUR
INDEX CONTOUR DASHED
INDEX CONTOUR DEP.
INTERMEDIATE CONTOUR DEP. DASHED
PIPELINE
PIPELINE, BURIED
UNPAVED ROADWAY

229 GAS EXTRACTION WELL
CGW575-75-10 PROBE
CGW575 GAS EXTRACTION WELL

HYDRO GEO CHEM, INC.

TEST AREA CGW575
SUNSHINE CANYON LANDFILL
SYLMAR, CALIFORNIA

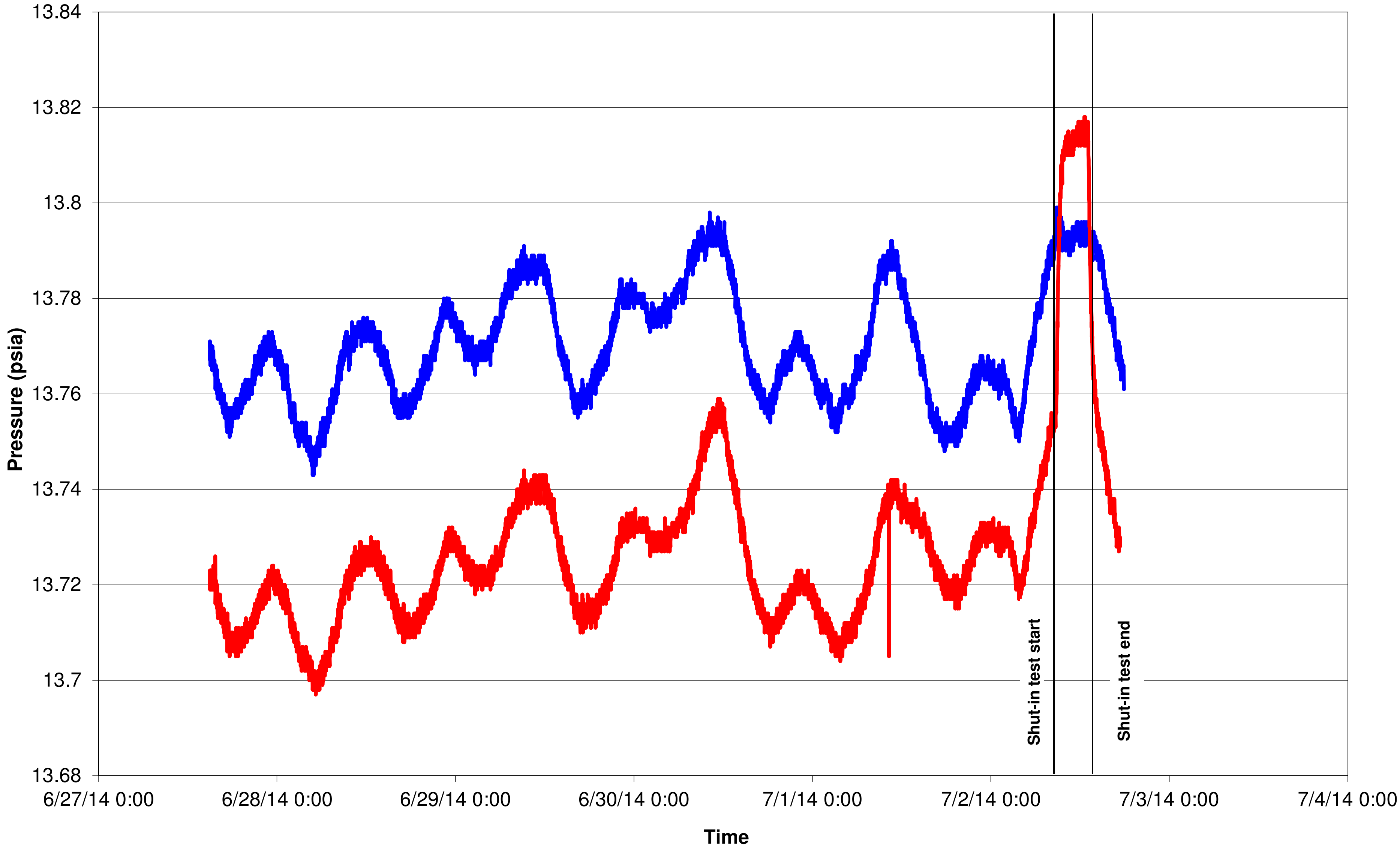
Approved	Date	Author	Date	File Name	Figure
SJS	10/30/14	JAA	10/30/14	2013009004A	3



HYDRO GEO CHEM, INC.

TEST AREA GW7024
SUNSHINE CANYON LANDFILL
SYLMAR, CALIFORNIA

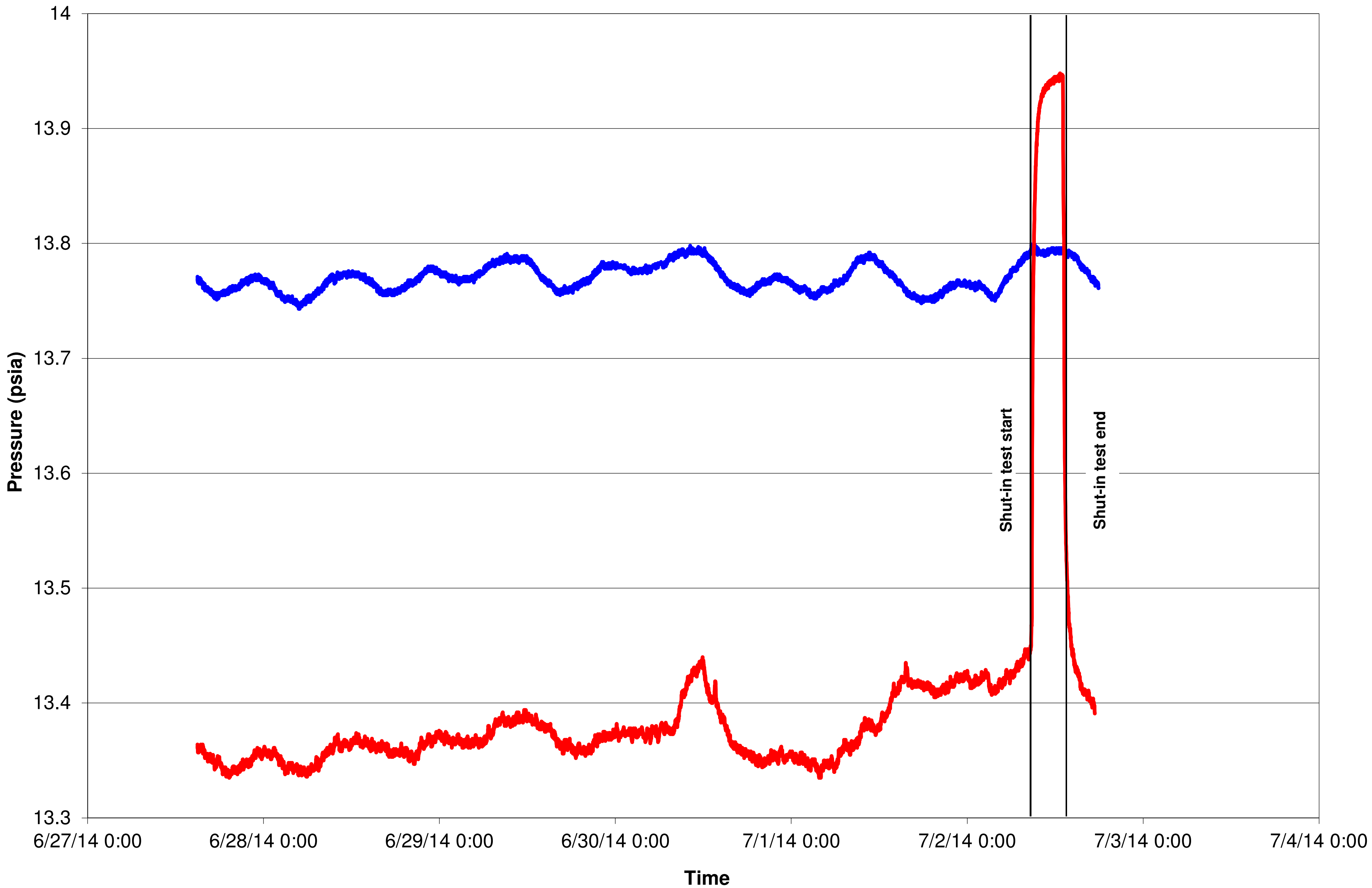
Approved	Date	Author	Date	File Name	Figure
SJS	10/30/14	JAA	10/30/14	2013009004A	4



HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-15-10 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009005	5

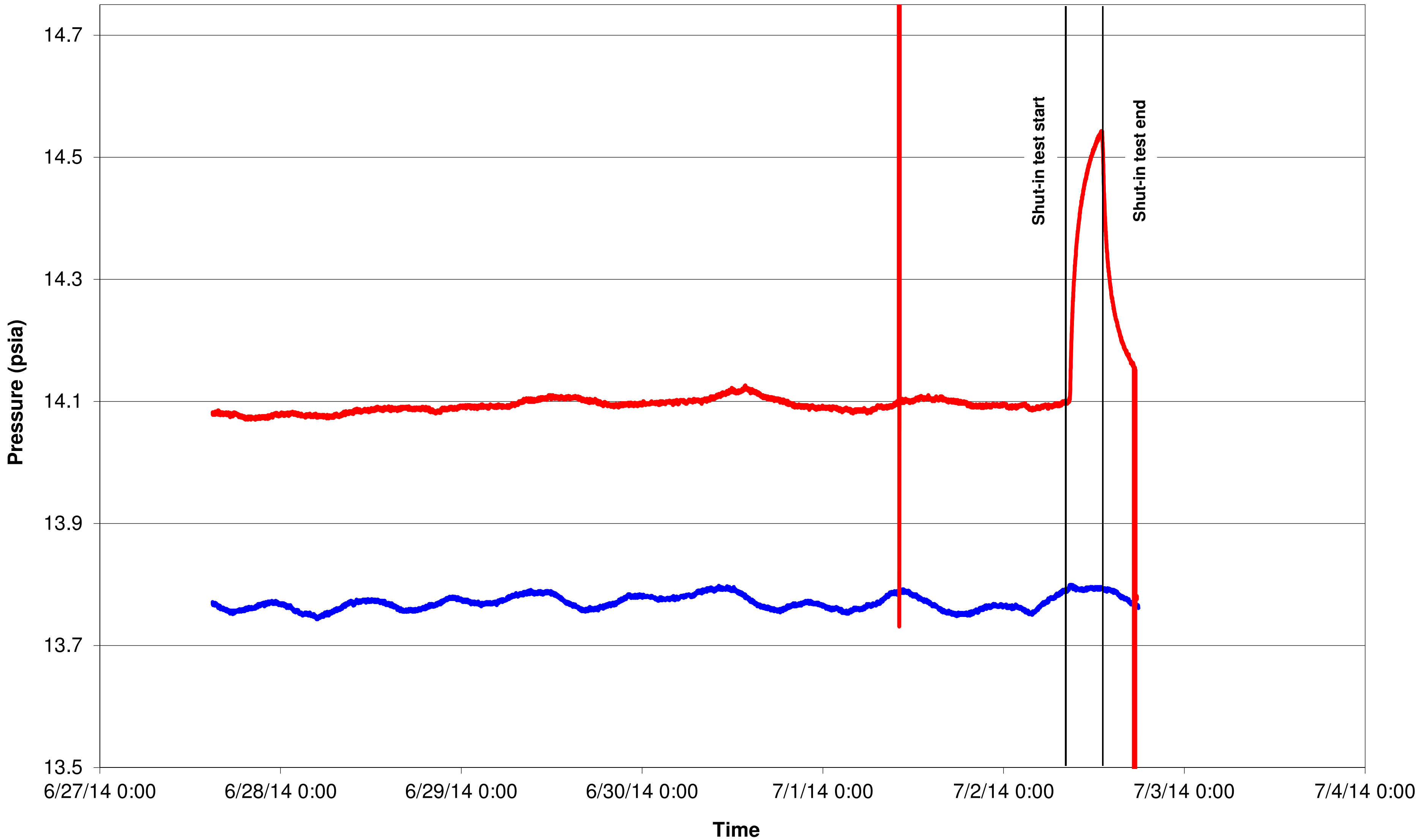


HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-15-35 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009006	6

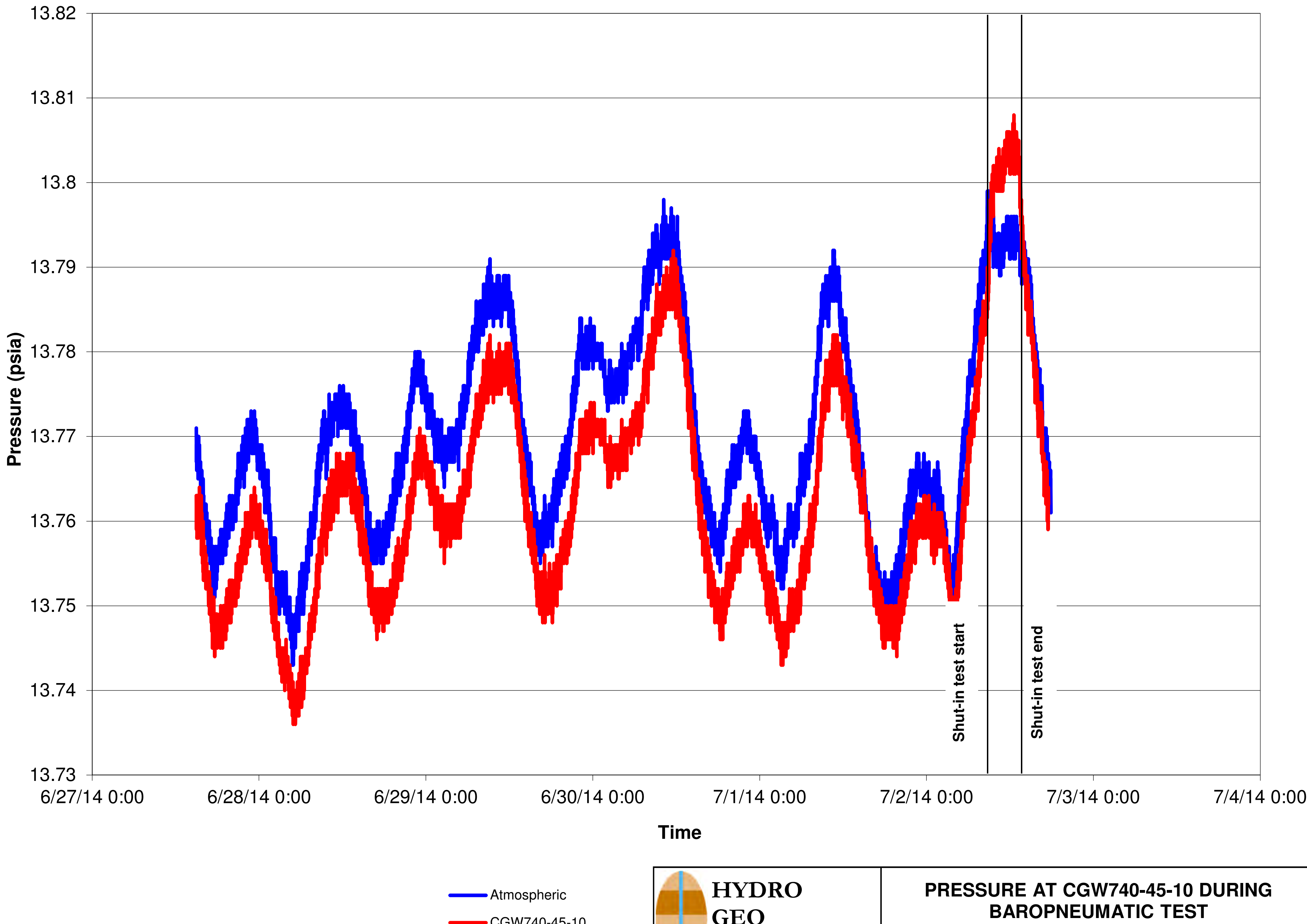
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\5_Figures5thru10.xls: Figure 6



HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-15-70 DURING BAROPNEUMATIC TEST

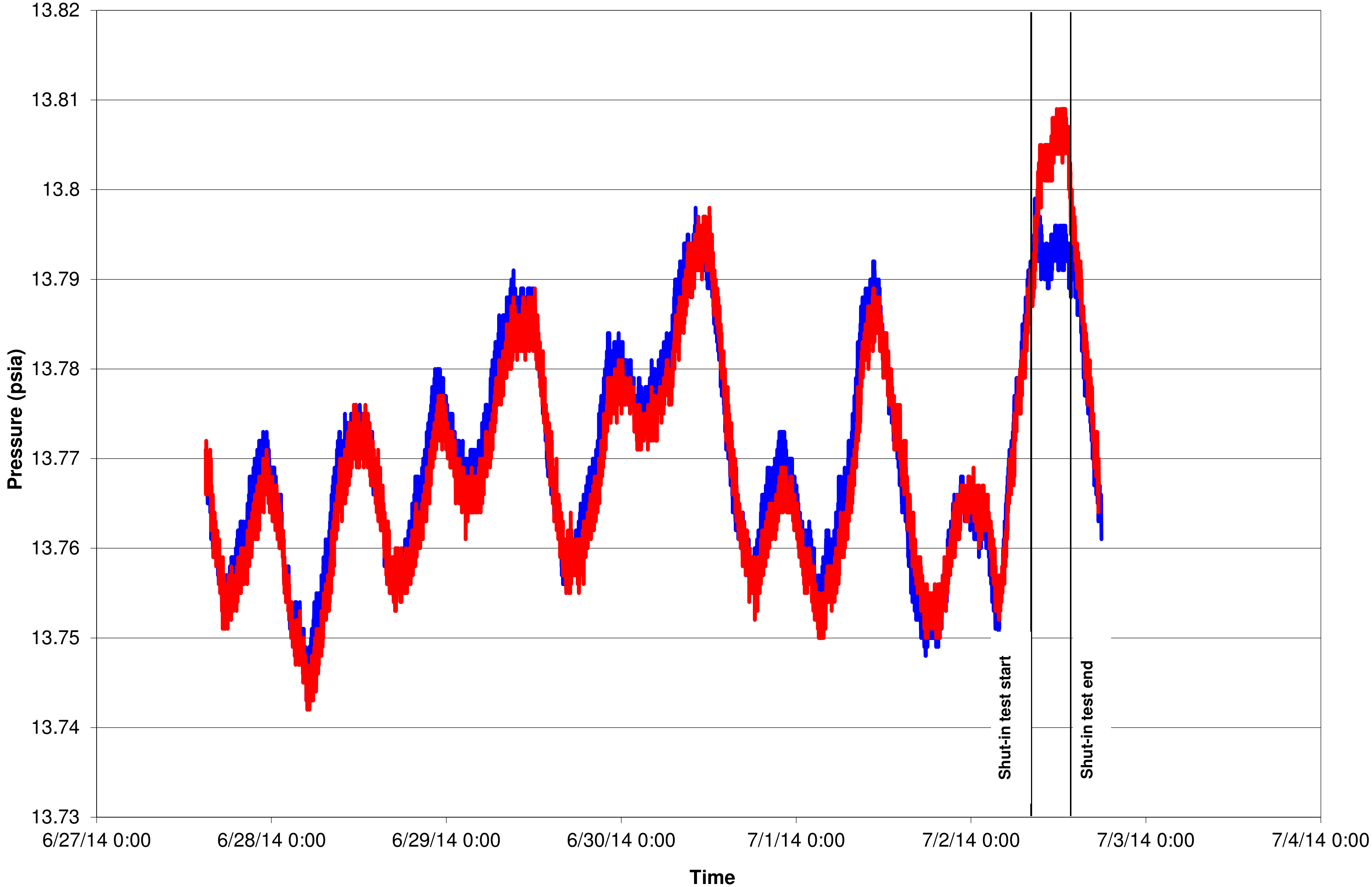
Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009007	7



HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-45-10 DURING BAROPNEUMATIC TEST

SJS	3/6/15	GEM	11/10/14	2013009008	8

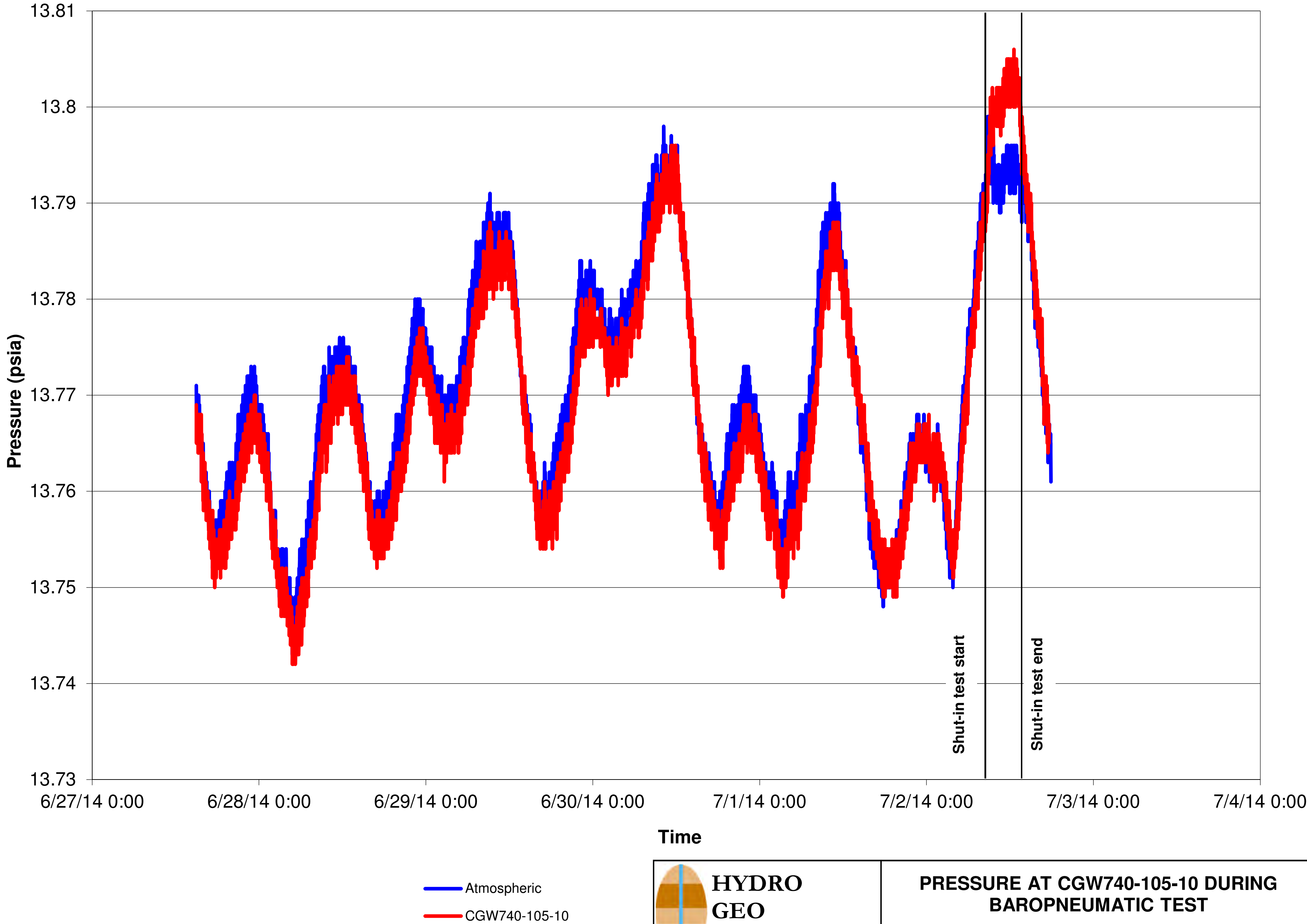


HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-75-10 DURING BAROPNEUMATIC TEST

SJS	3/06/15	GEM	11/10/14	2013009009	9

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\5_Figures5thru10.xls: Figure 9

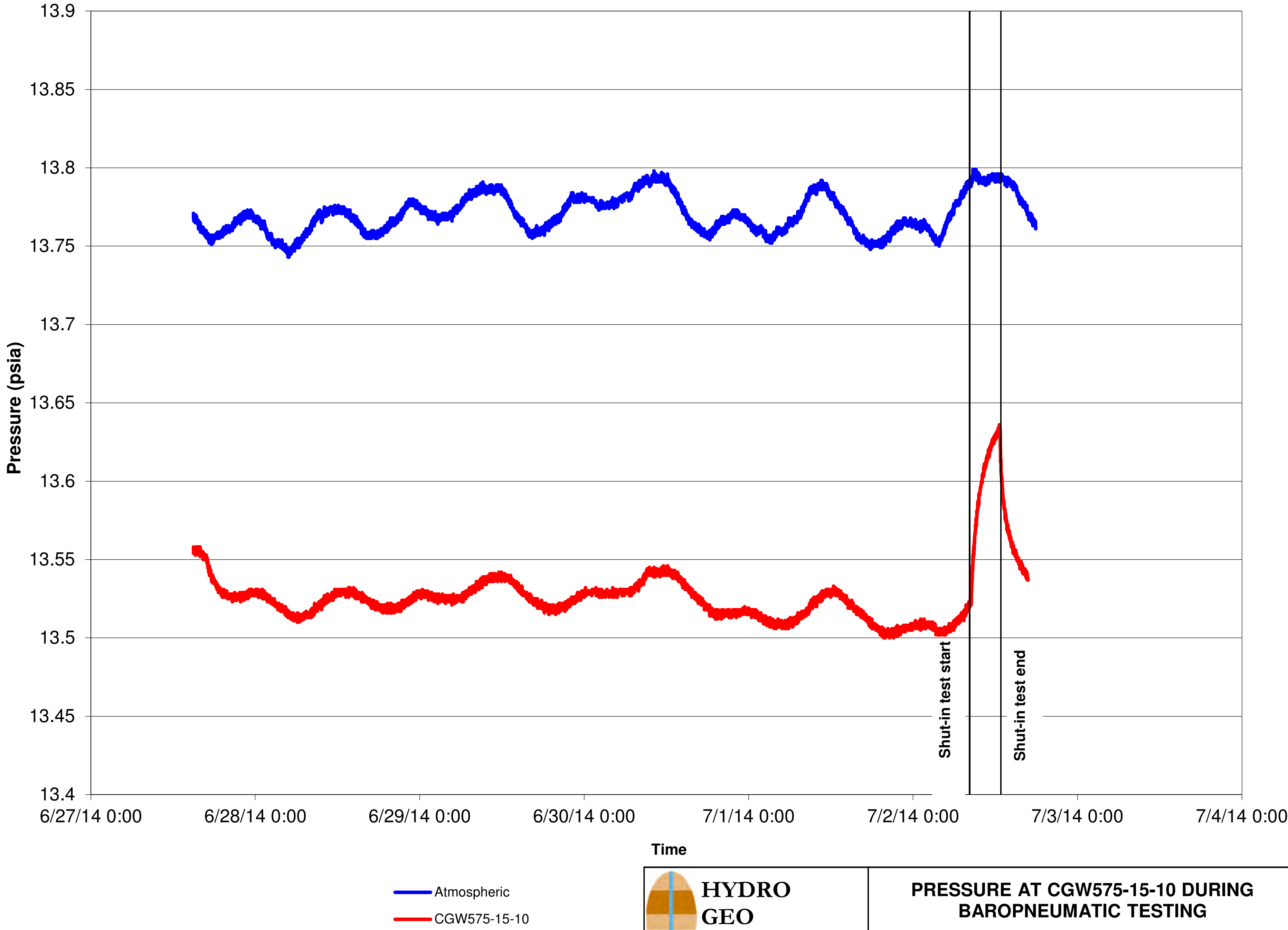


HYDRO GEO CHEM, INC.

PRESSURE AT CGW740-105-10 DURING BAROPNEUMATIC TEST

SJS	3/6/15	GEM	11/10/14	2013009010	10

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\5_Figures5thru10.xls: Figure 10

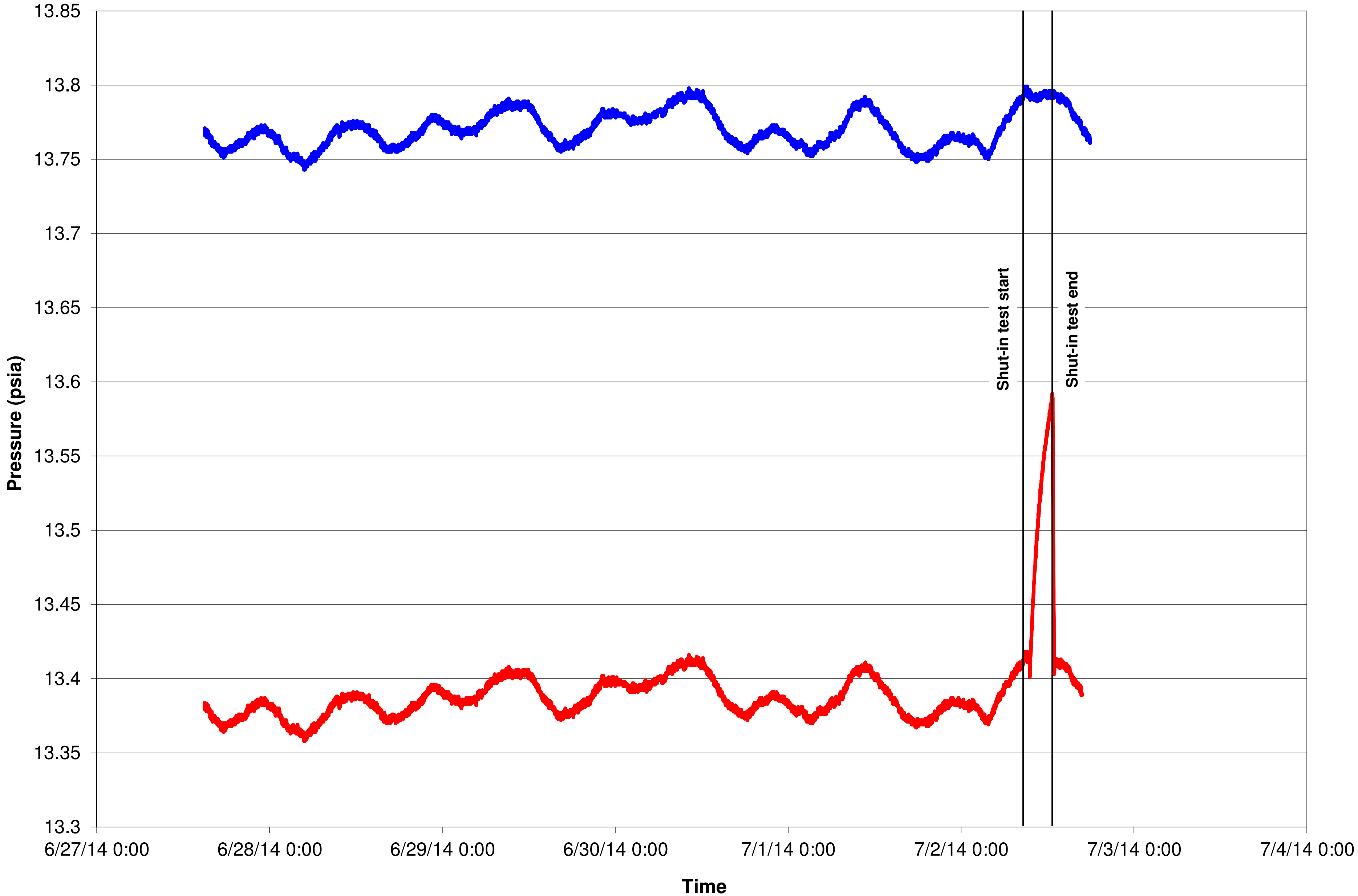


HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-15-10 DURING BAROPNEUMATIC TESTING

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009011	11

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\6_Figures11thru16.xls: Figure 11

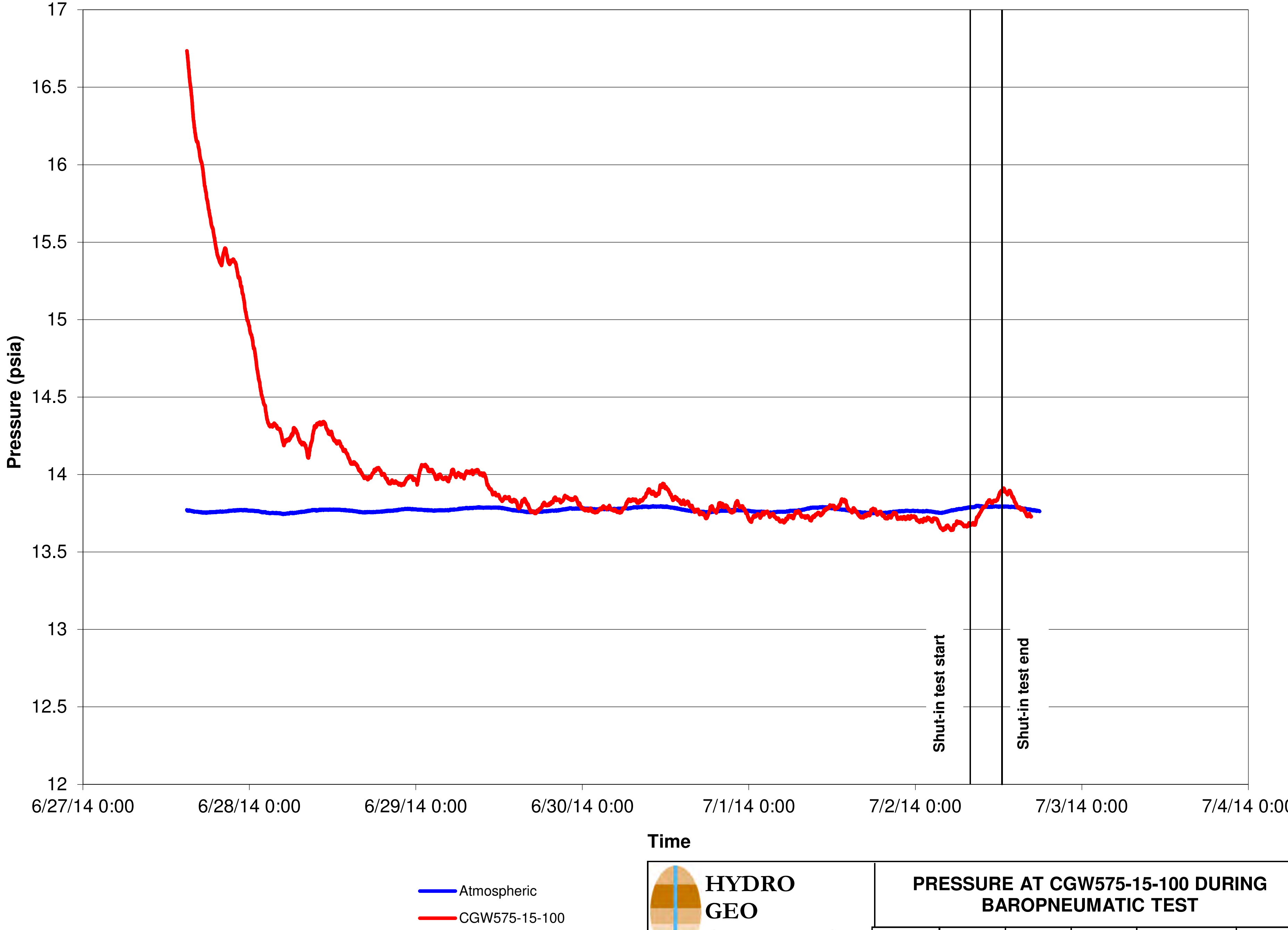


HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-15-50 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009012	12

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\6_Figures11thru16.xls: Figure 12

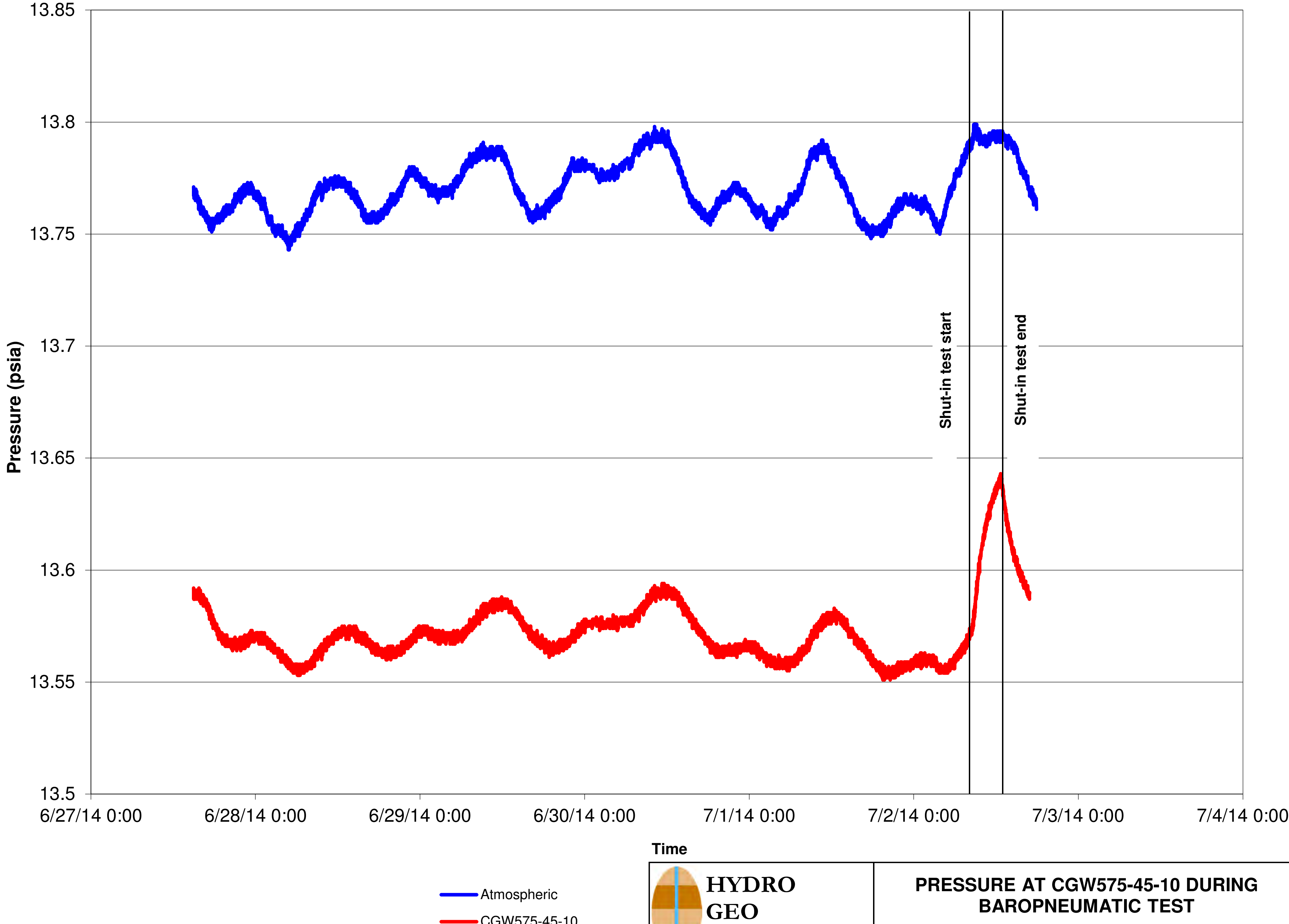


HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-15-100 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009013	13

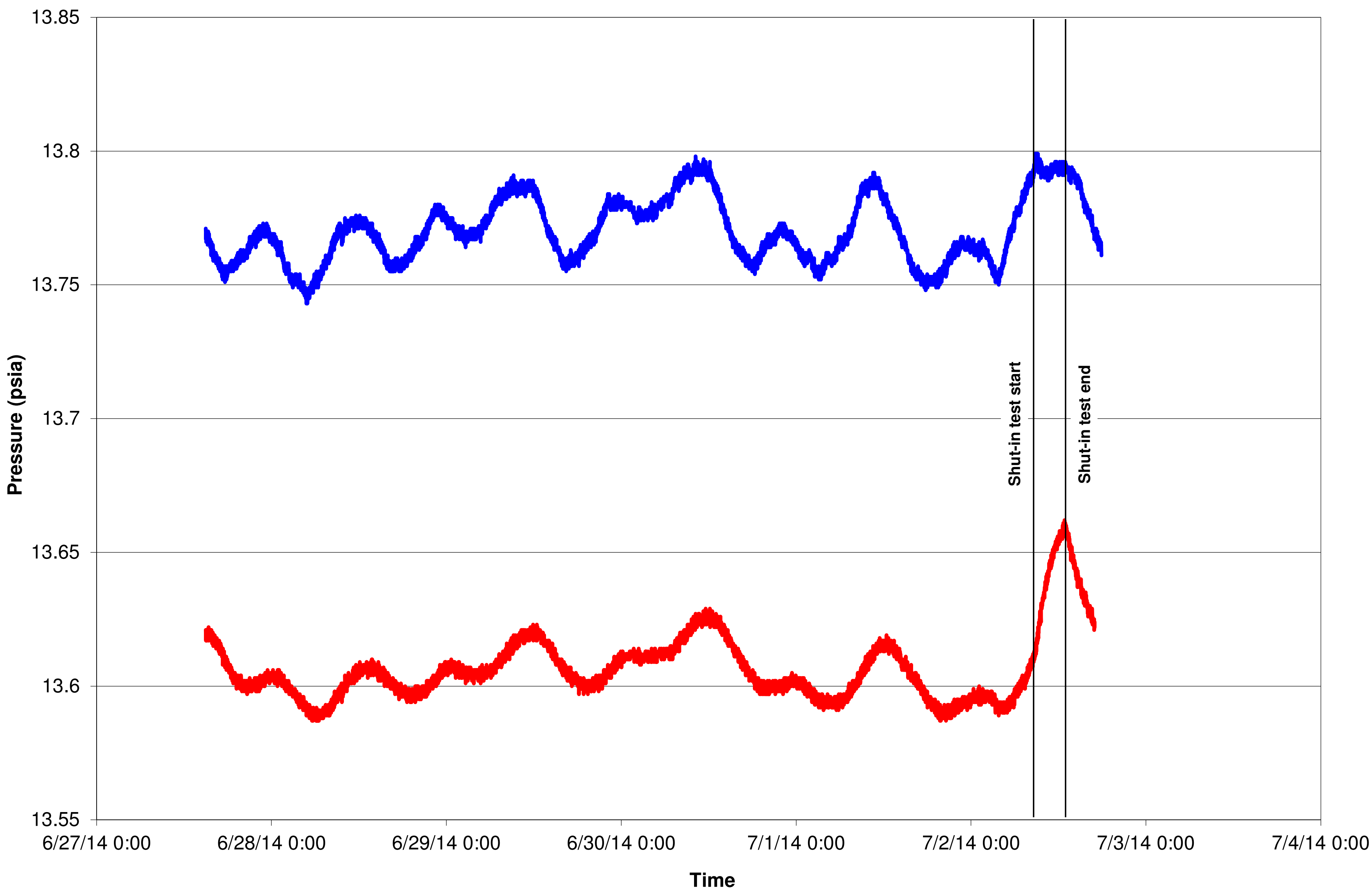
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\6_Figures11thru16.xls: Figure 13



HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-45-10 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009014	14

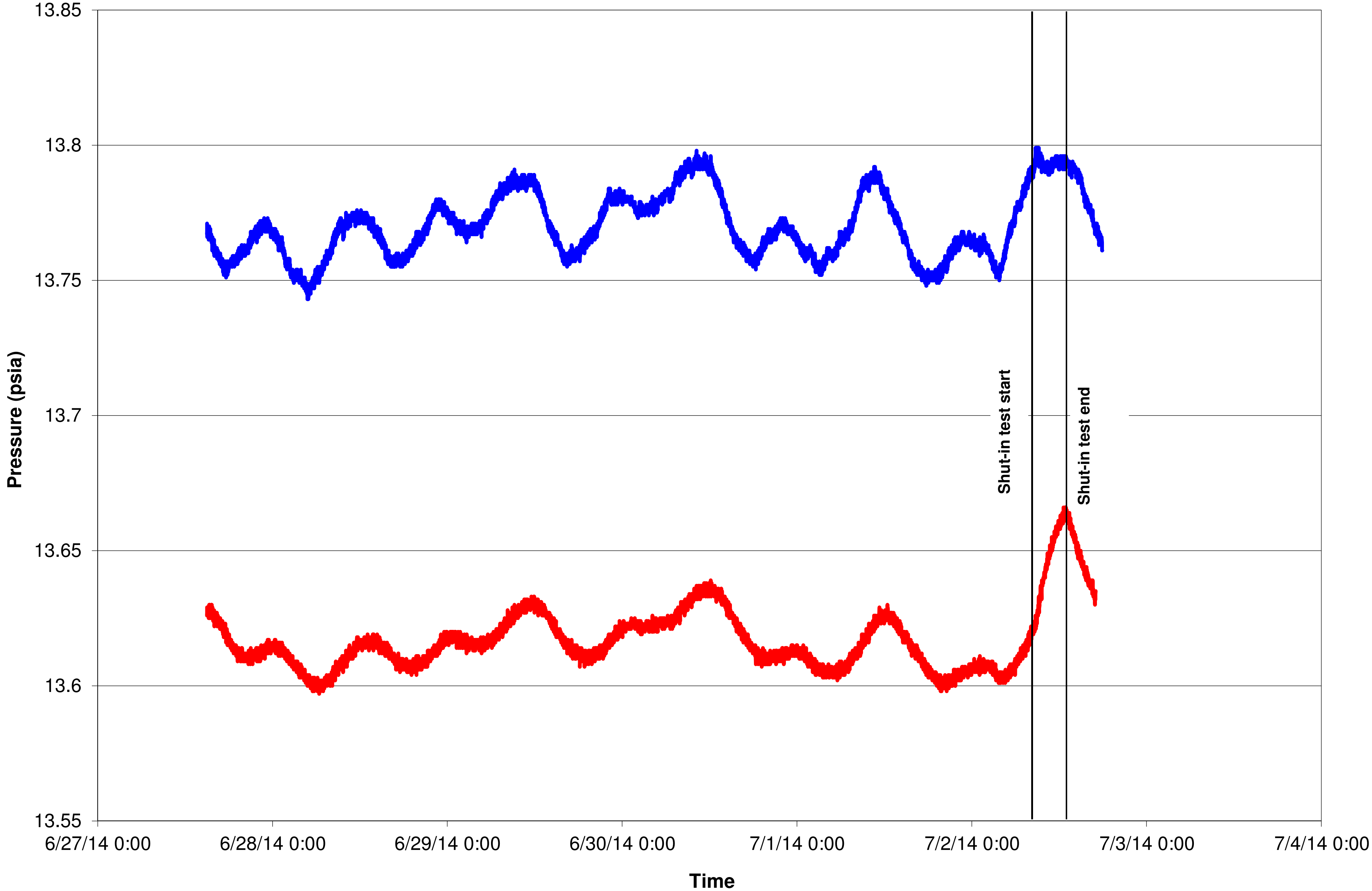


HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-75-10 DURING BAROPNEUMATIC TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009015	15

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\6_Figures11thru16.xls: Figure 15

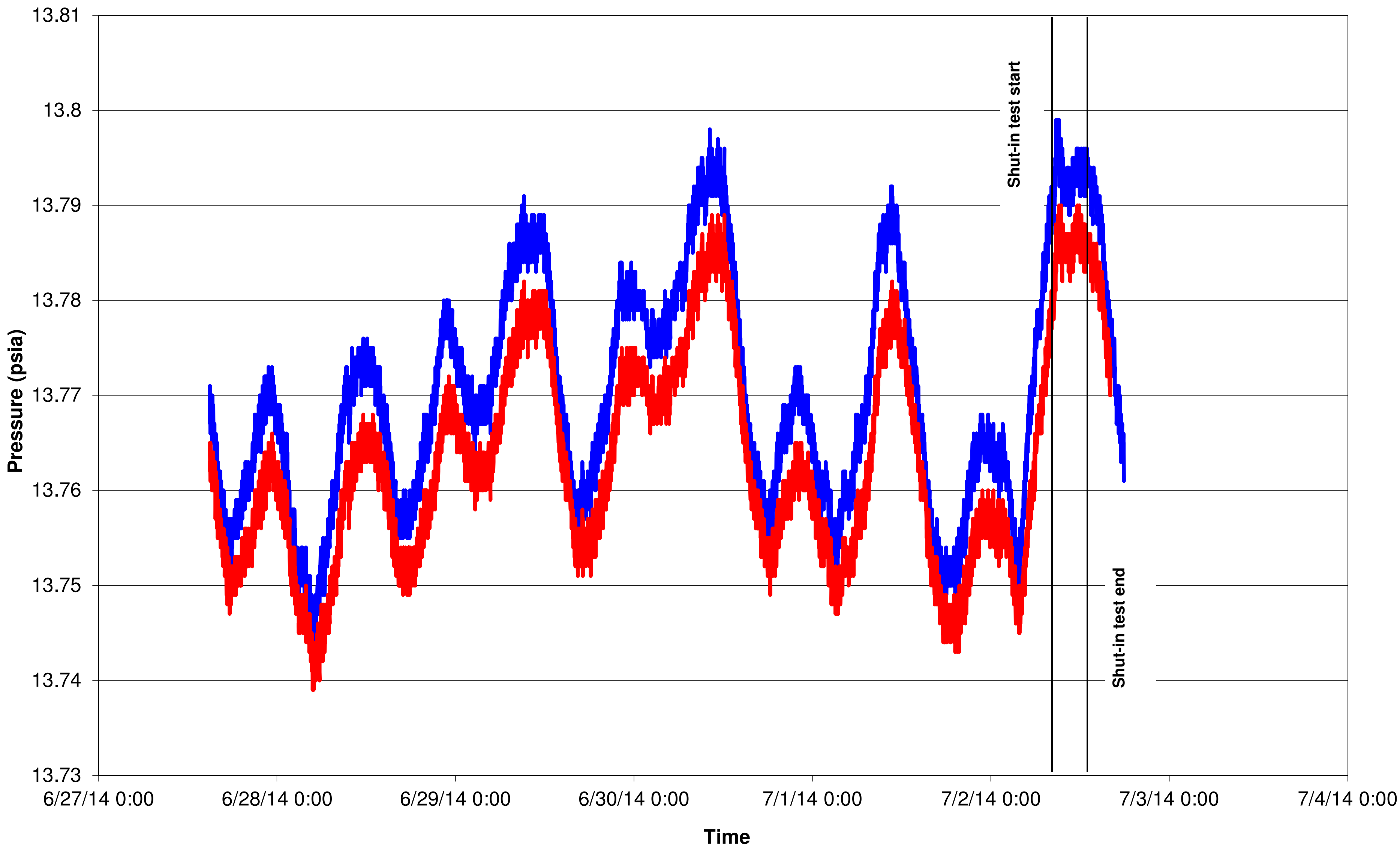


HYDRO GEO CHEM, INC.

PRESSURE AT CGW575-105-10 DURING BAROPNEUMATIC TEST

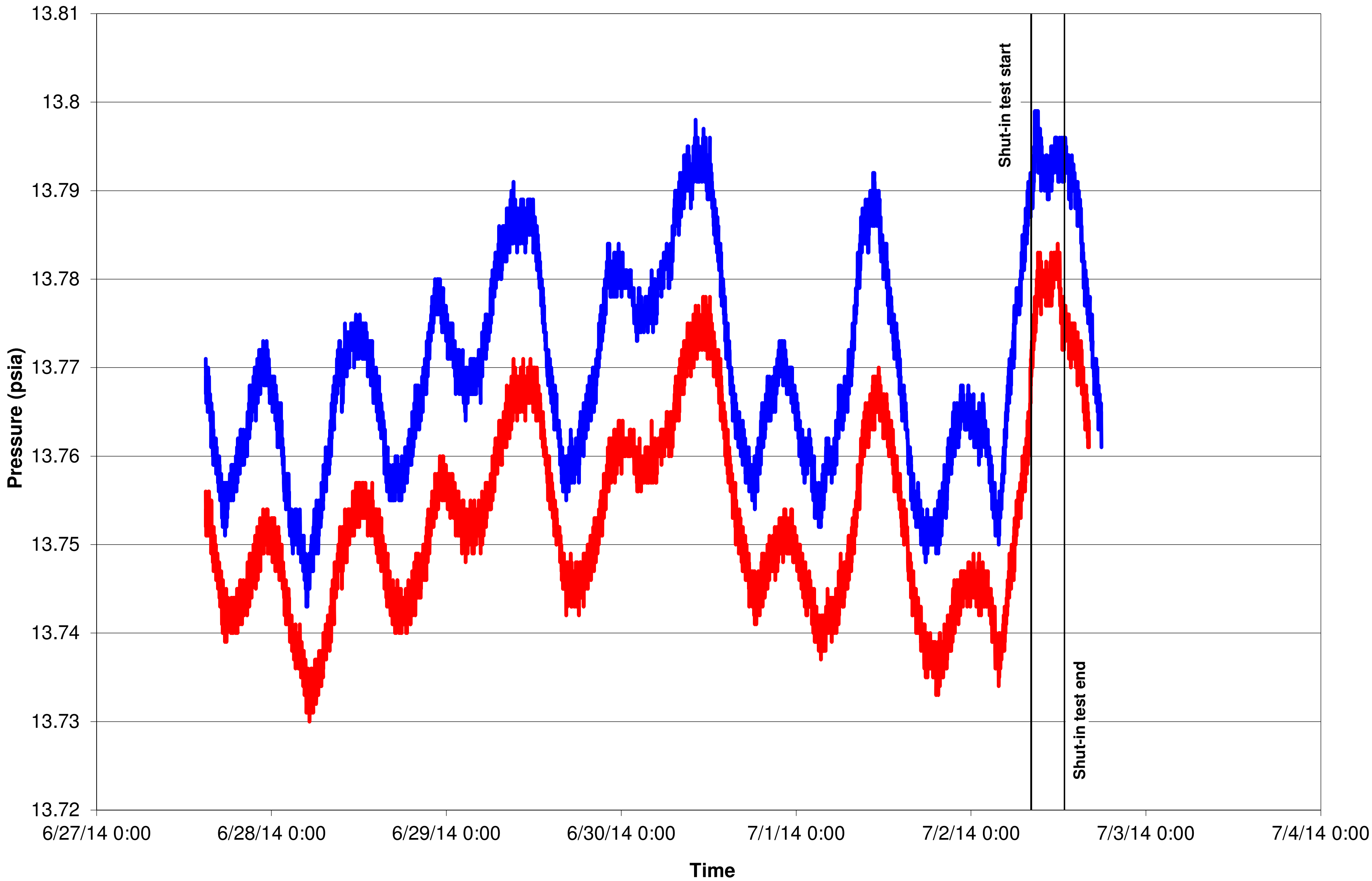
Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009016	16

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\6_Figures11thru16.xls: Figure 16



HYDRO GEO CHEM, INC.	PRESSURE AT GW7024-15-20 DURING BAROPNEUMATIC TEST					
	SJS	3/6/15	GEM	11/10/14	2013009017	17

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\7_Figures17thru22.xls: Figure 17

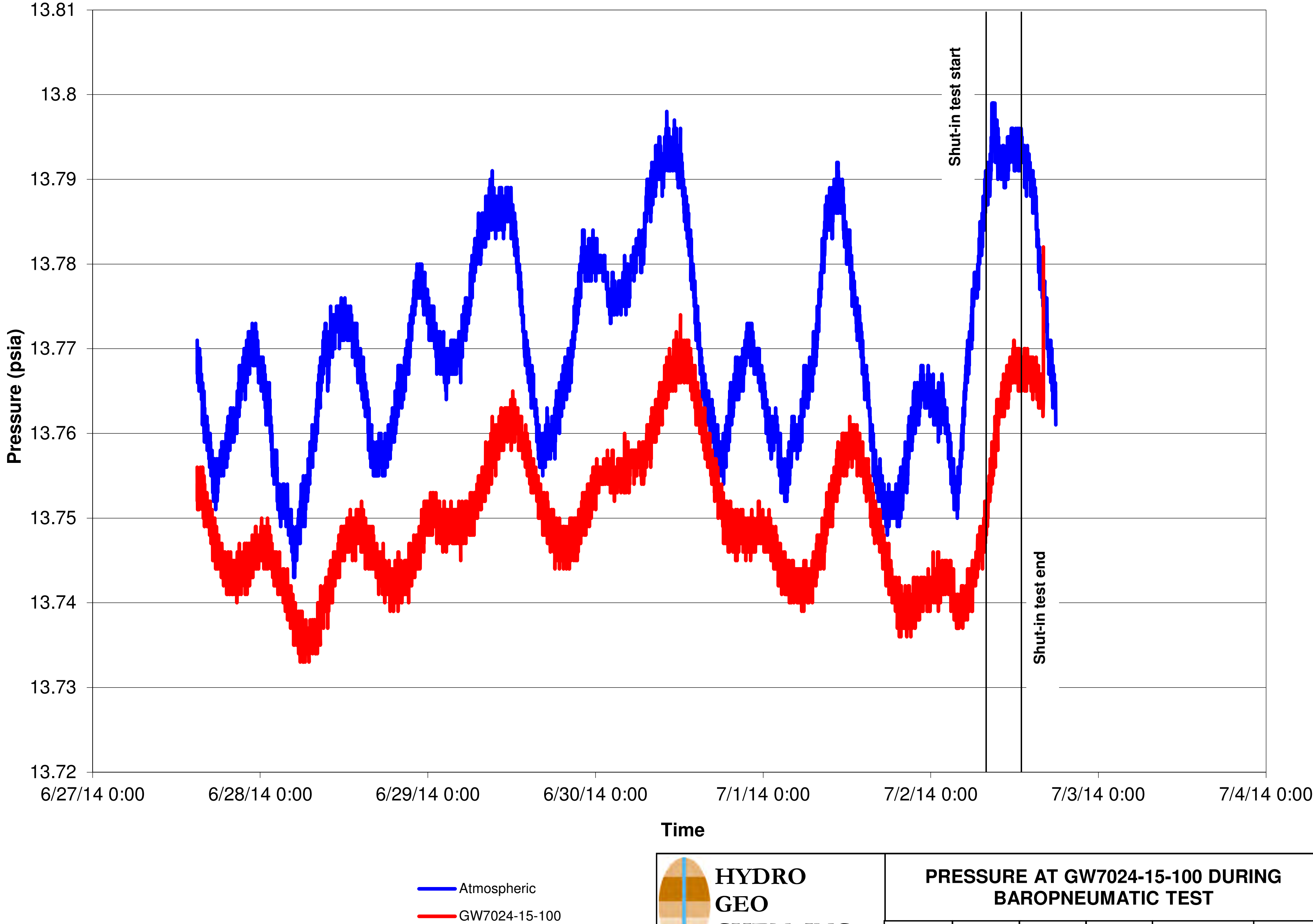


HYDRO GEO CHEM, INC.

PRESSURE AT GW7024-15-50 DURING BAROPNEUMATIC TEST

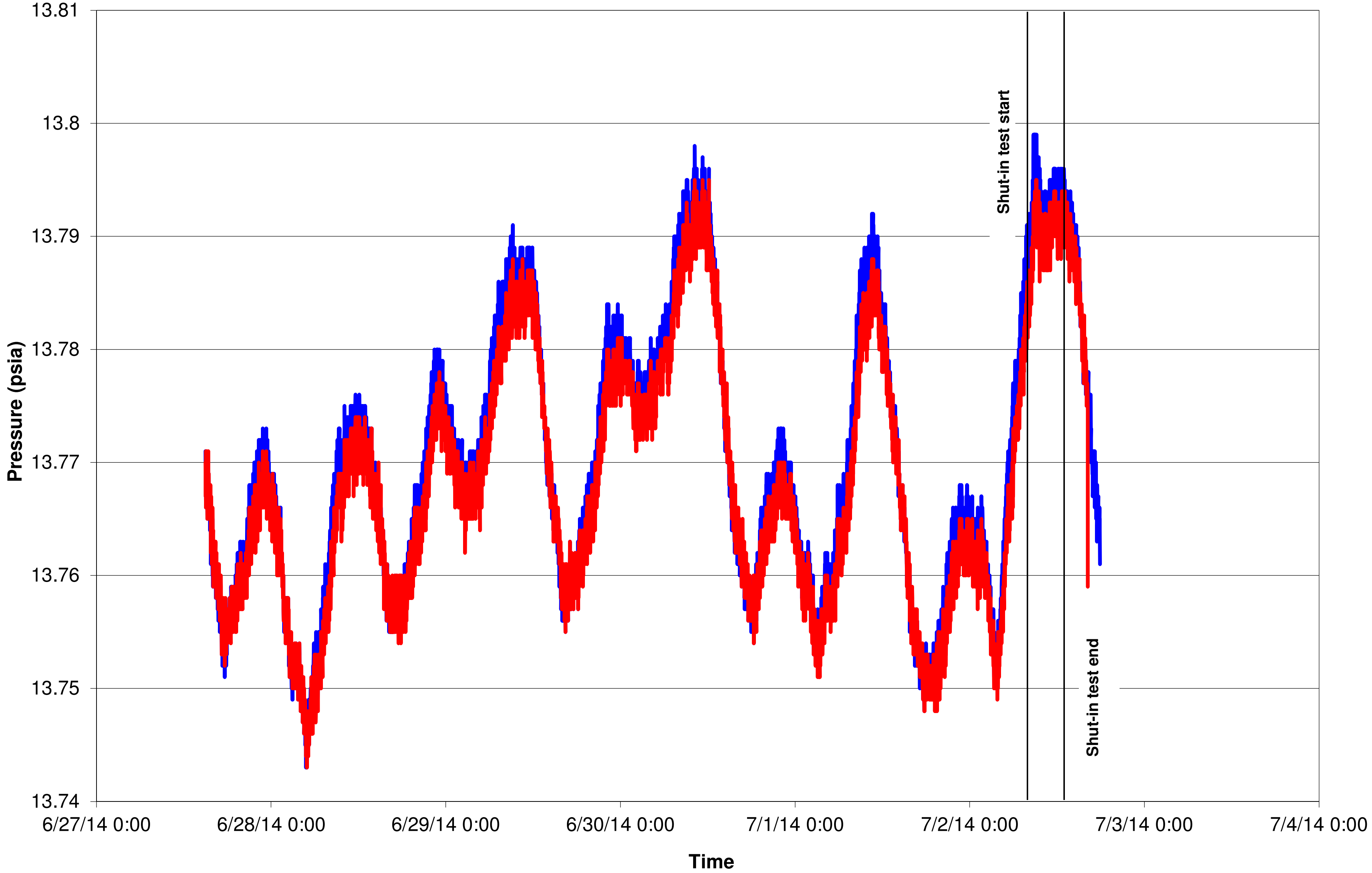
SJS	3/6/15	GEM	11/10/14	2013009018	18

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\7_Figures17thru22.xls: Figure 18



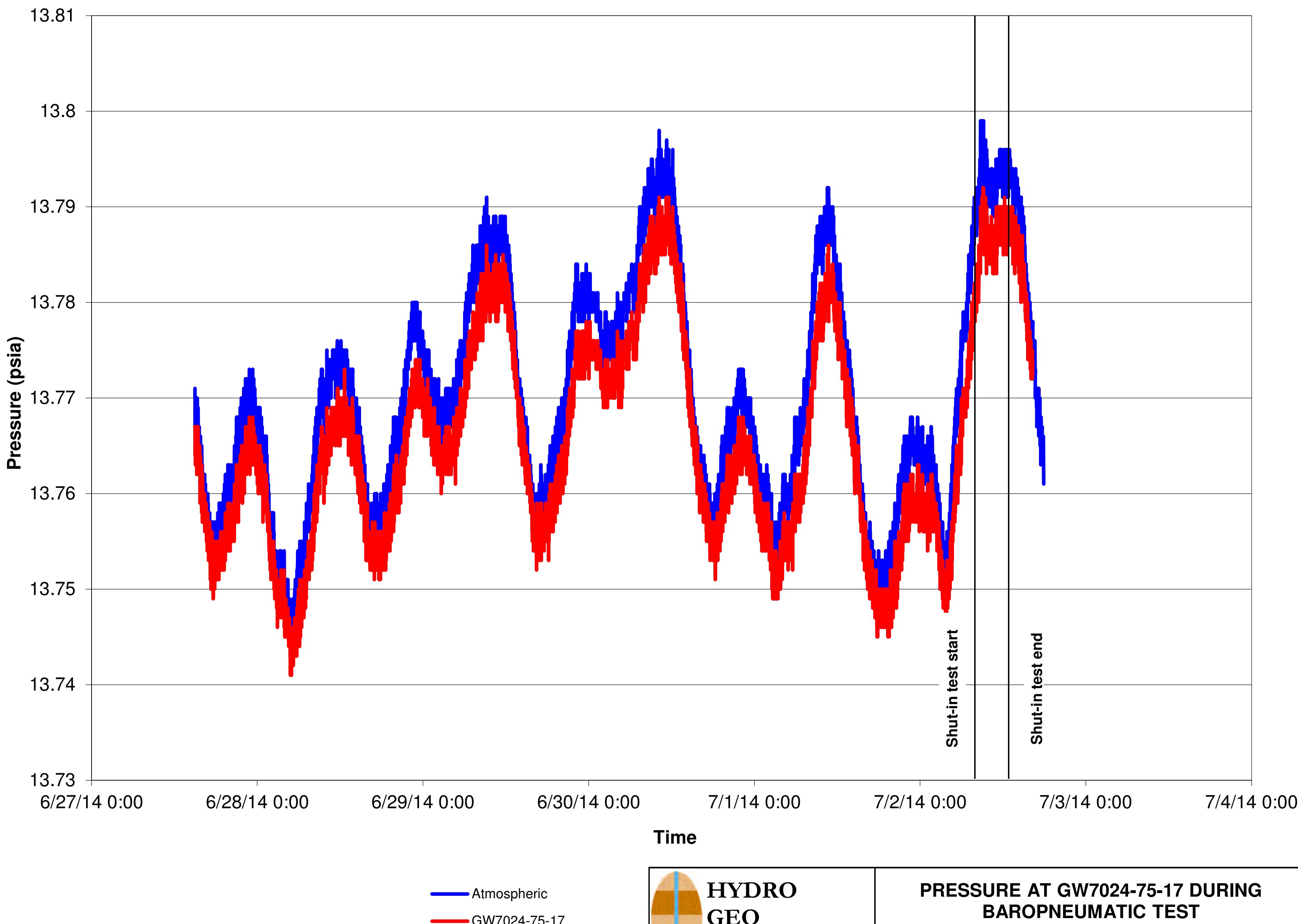
HYDRO GEO CHEM, INC.	PRESSURE AT GW7024-15-100 DURING BAROPNEUMATIC TEST					
	SJS	3/6/15	GEM	11/10/14	2013009019	19

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\7_Figures17thru22.xls: Figure 19



HYDRO GEO CHEM, INC.

PRESSURE AT GW7024-45-17 DURING BAROPNEUMATIC TEST					
SJS	3/6/15	GEM	11/10/14	2013009020	20

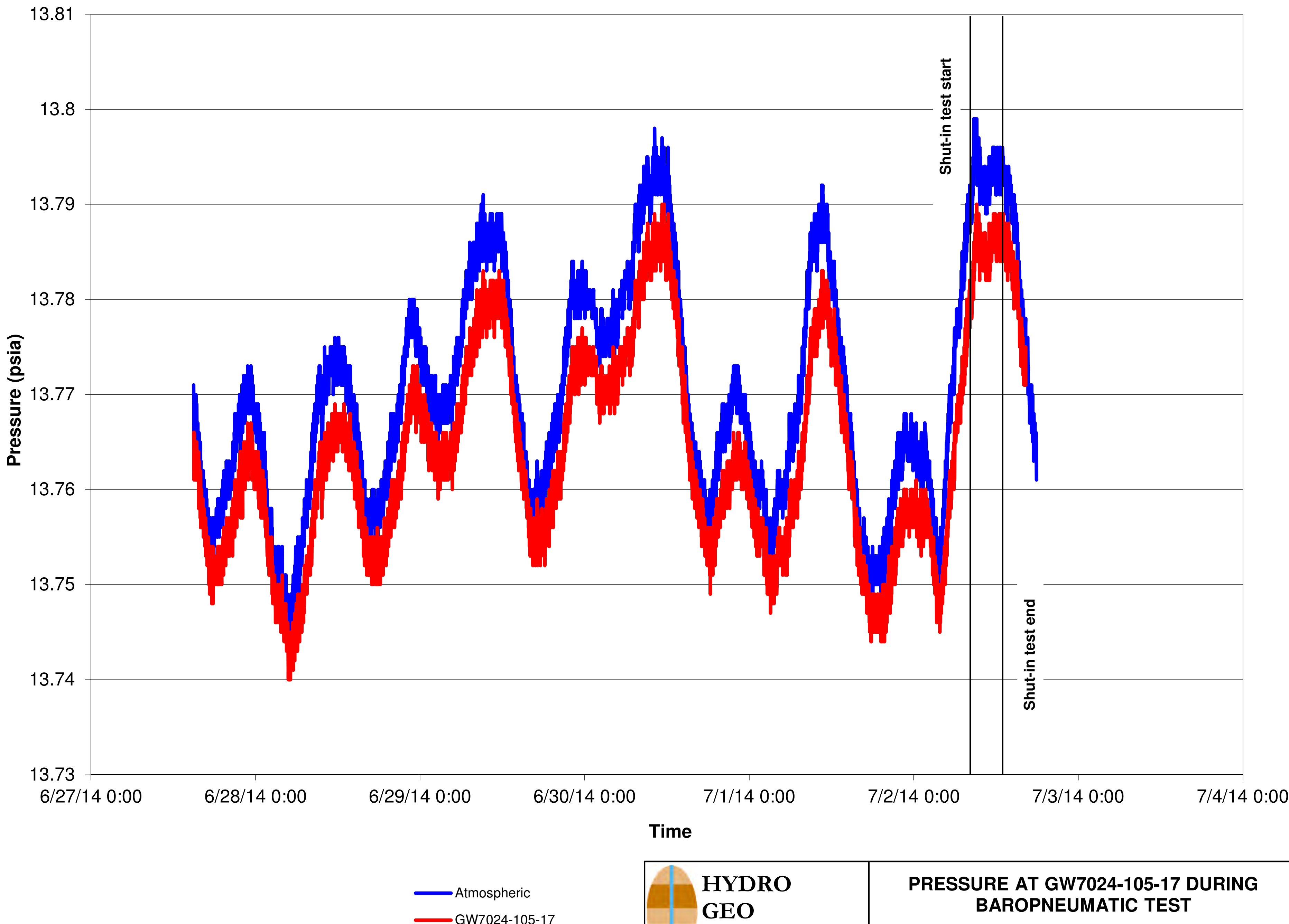


HYDRO GEO CHEM, INC.

PRESSURE AT GW7024-75-17 DURING BAROPNEUMATIC TEST

SJS	3/6/15	GEM	11/10/14	2013009021	21

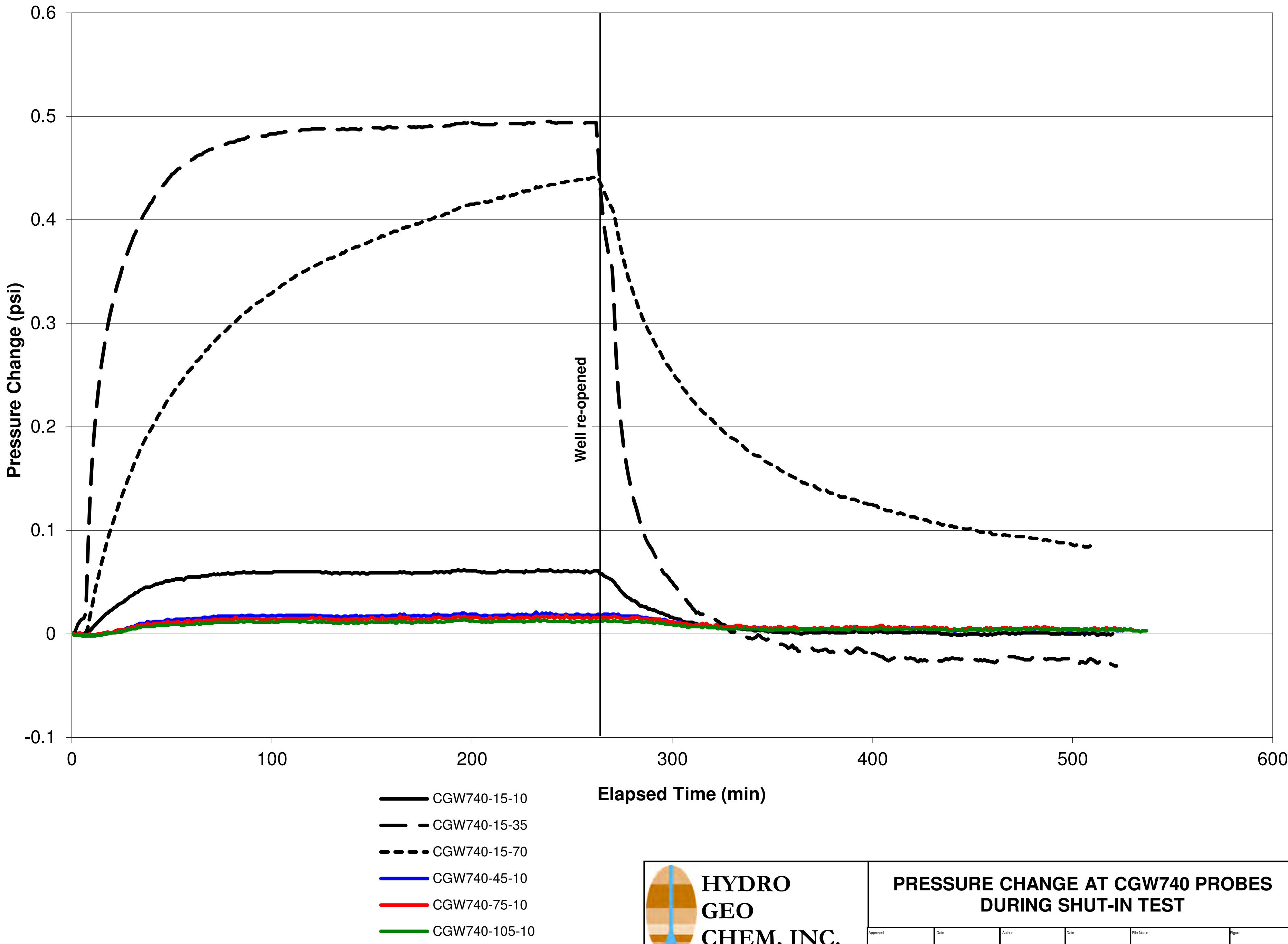
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\7_Figures17thru22.xls: Figure 21



HYDRO GEO CHEM, INC.

PRESSURE AT GW7024-105-17 DURING BAROPNEUMATIC TEST

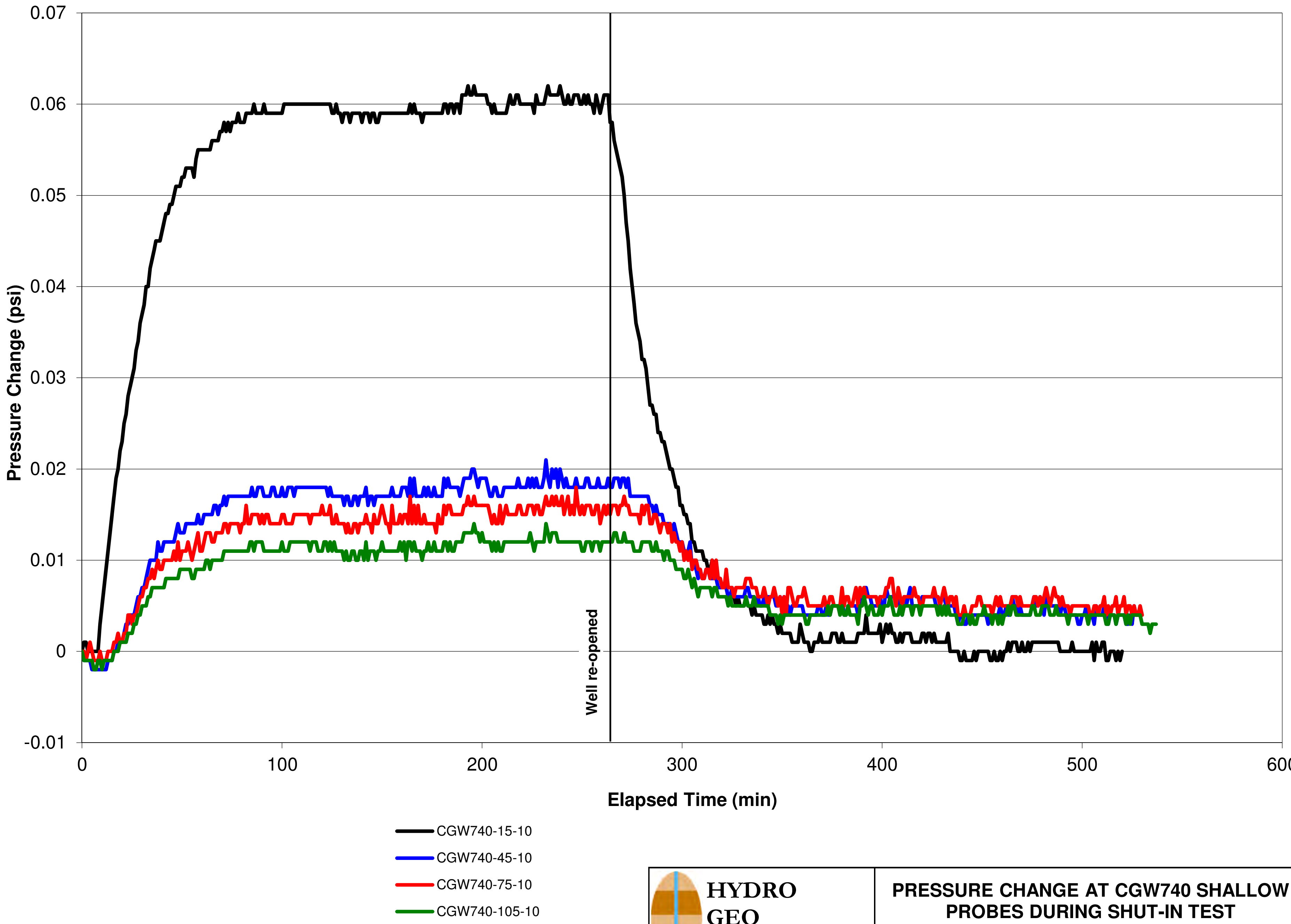
SJS	3/6/15	GEM	11/10/14	2013009022	22



HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT CGW740 PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009023	23

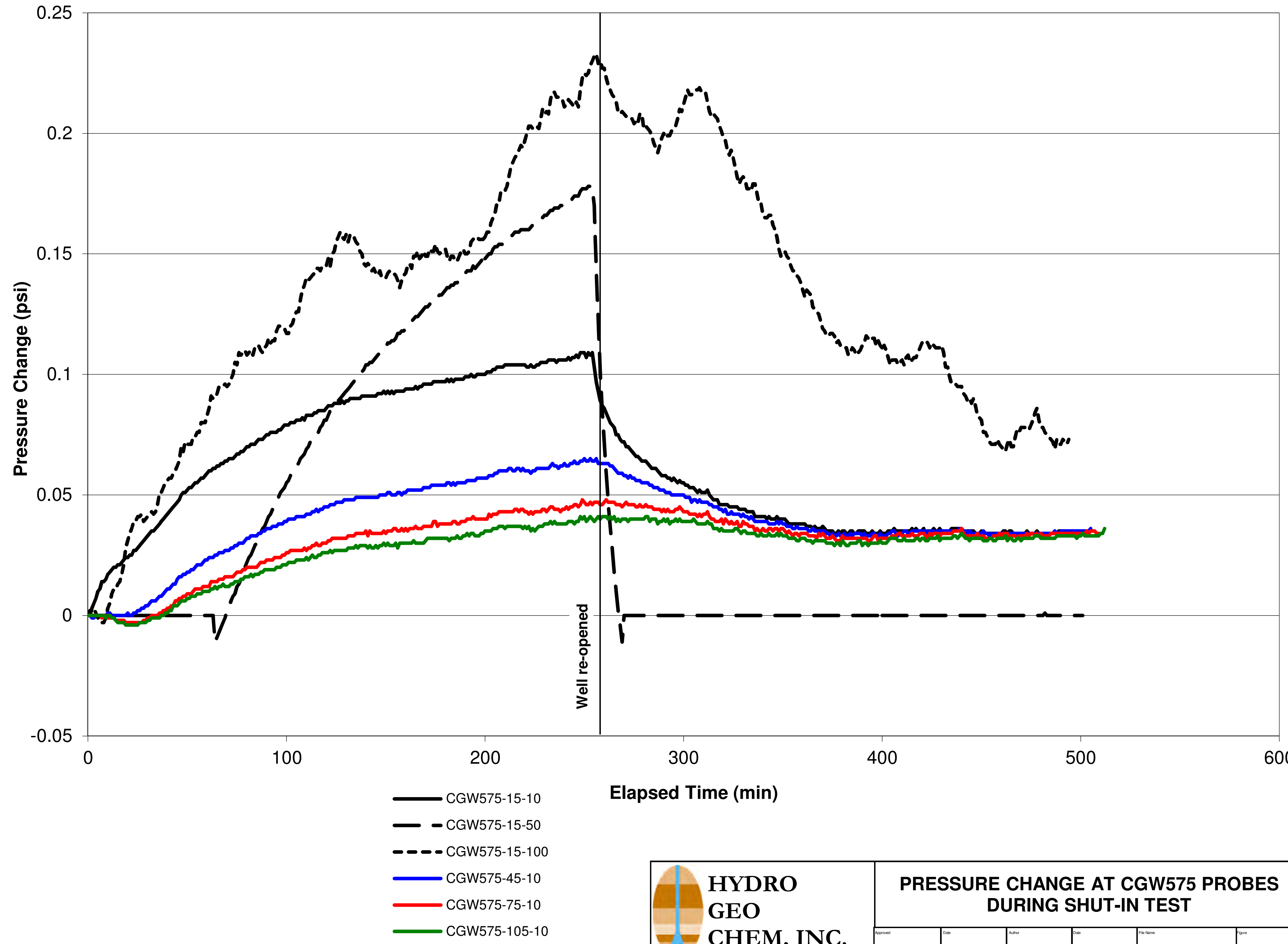


HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT CGW740 SHALLOW PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/10/14	2013009024	24

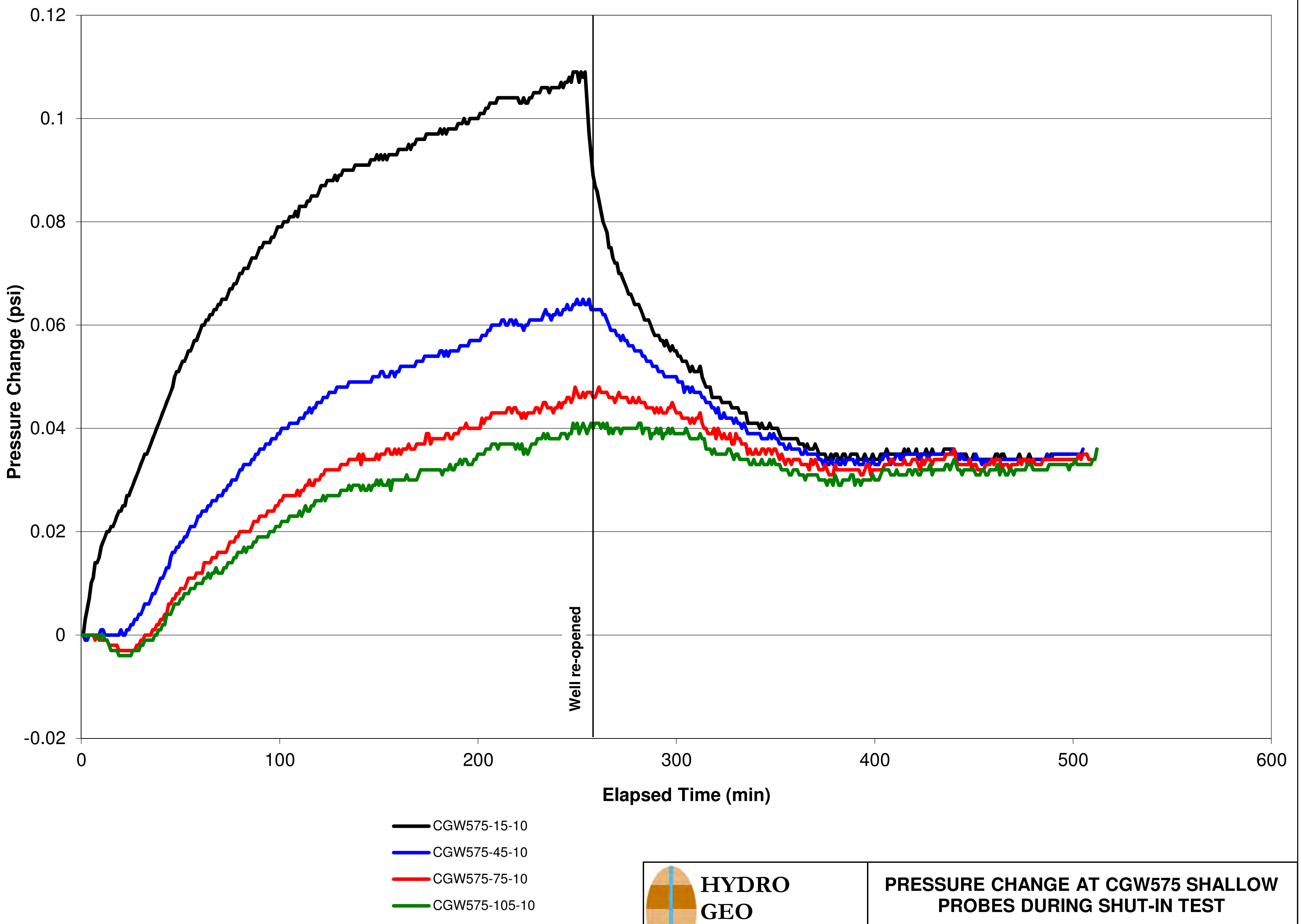
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\8_Figures23thru28.xls: Figure 24



HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT CGW575 PROBES DURING SHUT-IN TEST

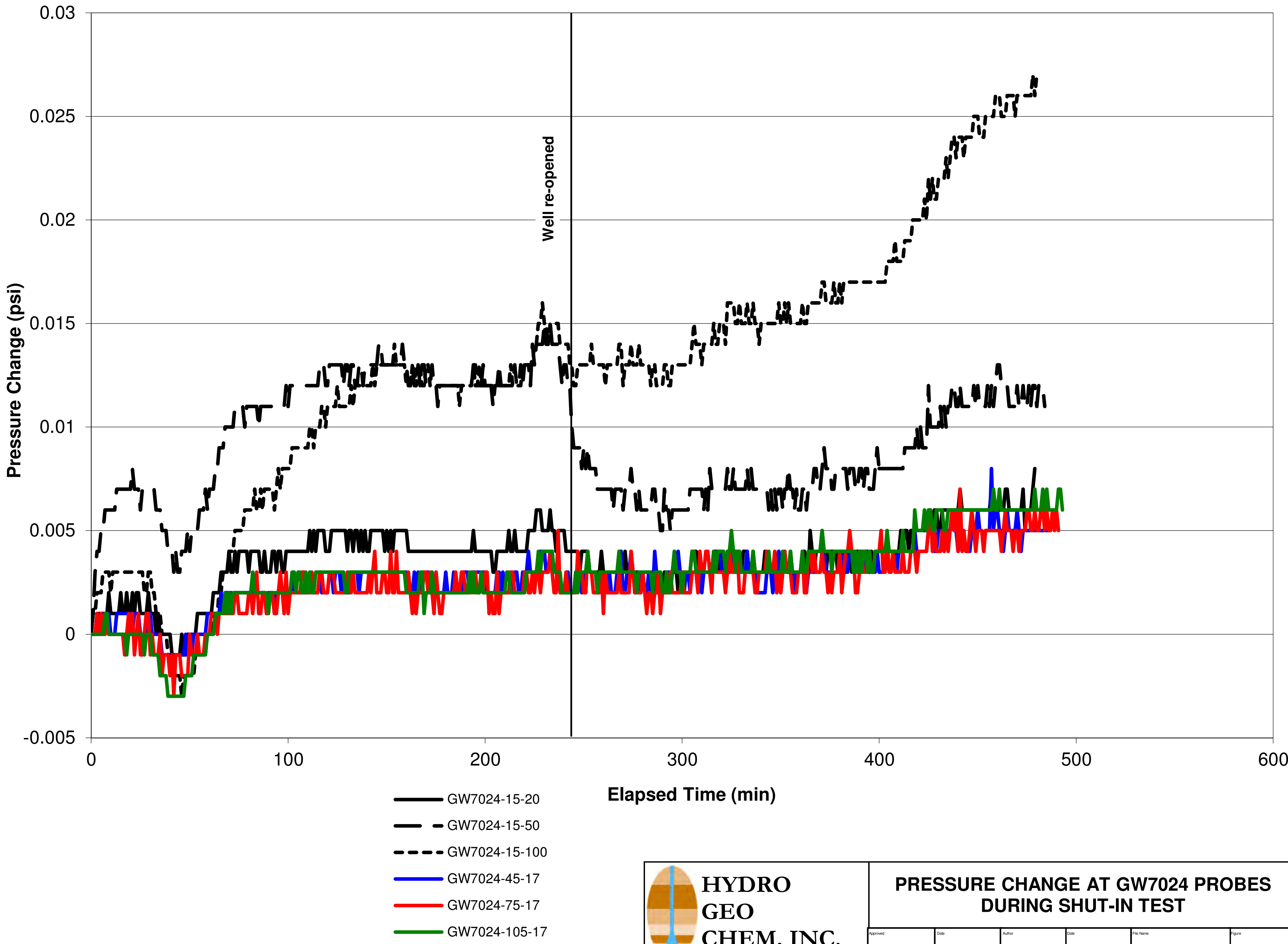
Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009025	25



HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT CGW575 SHALLOW PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009026	26

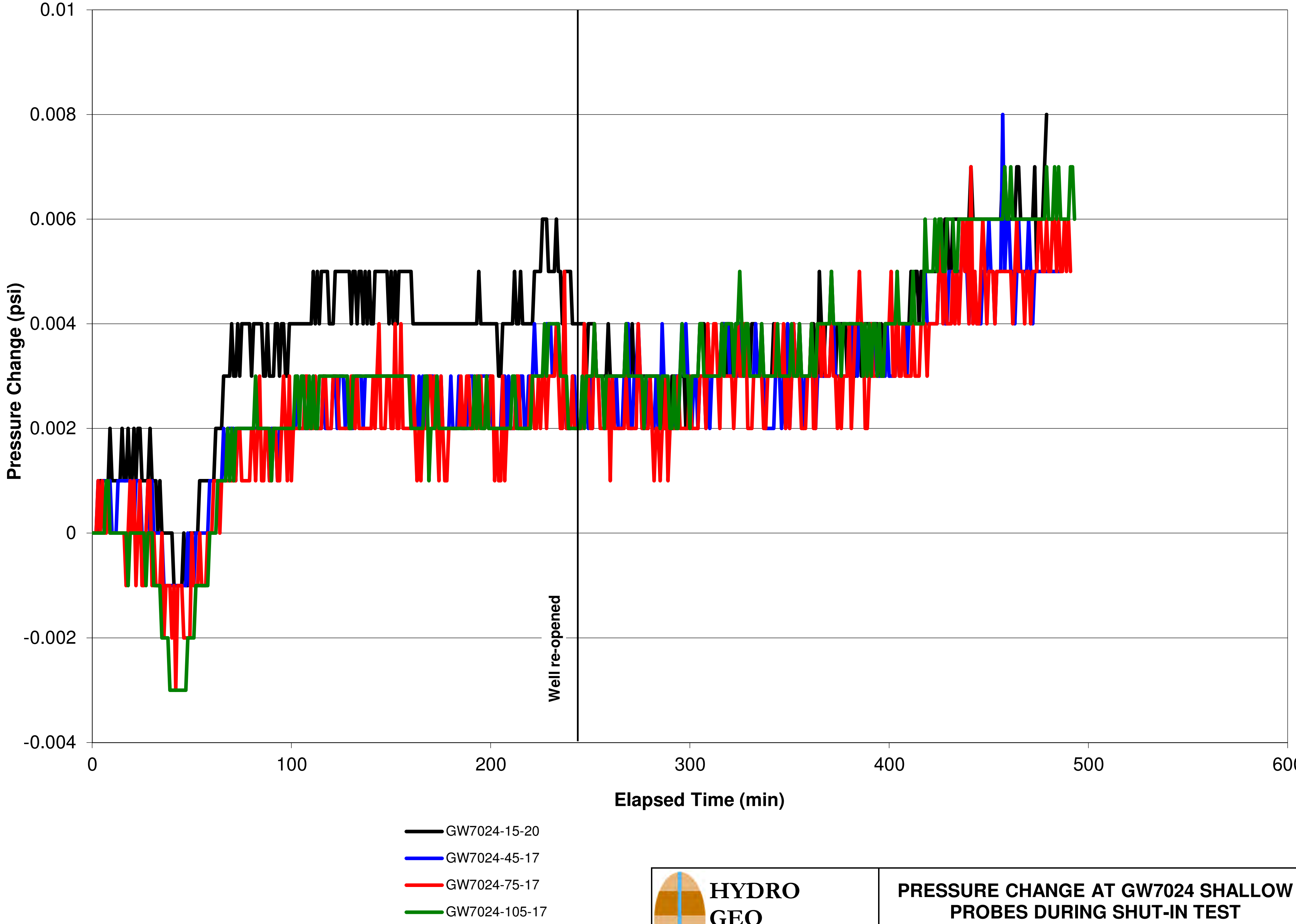


HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT GW7024 PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009027	27

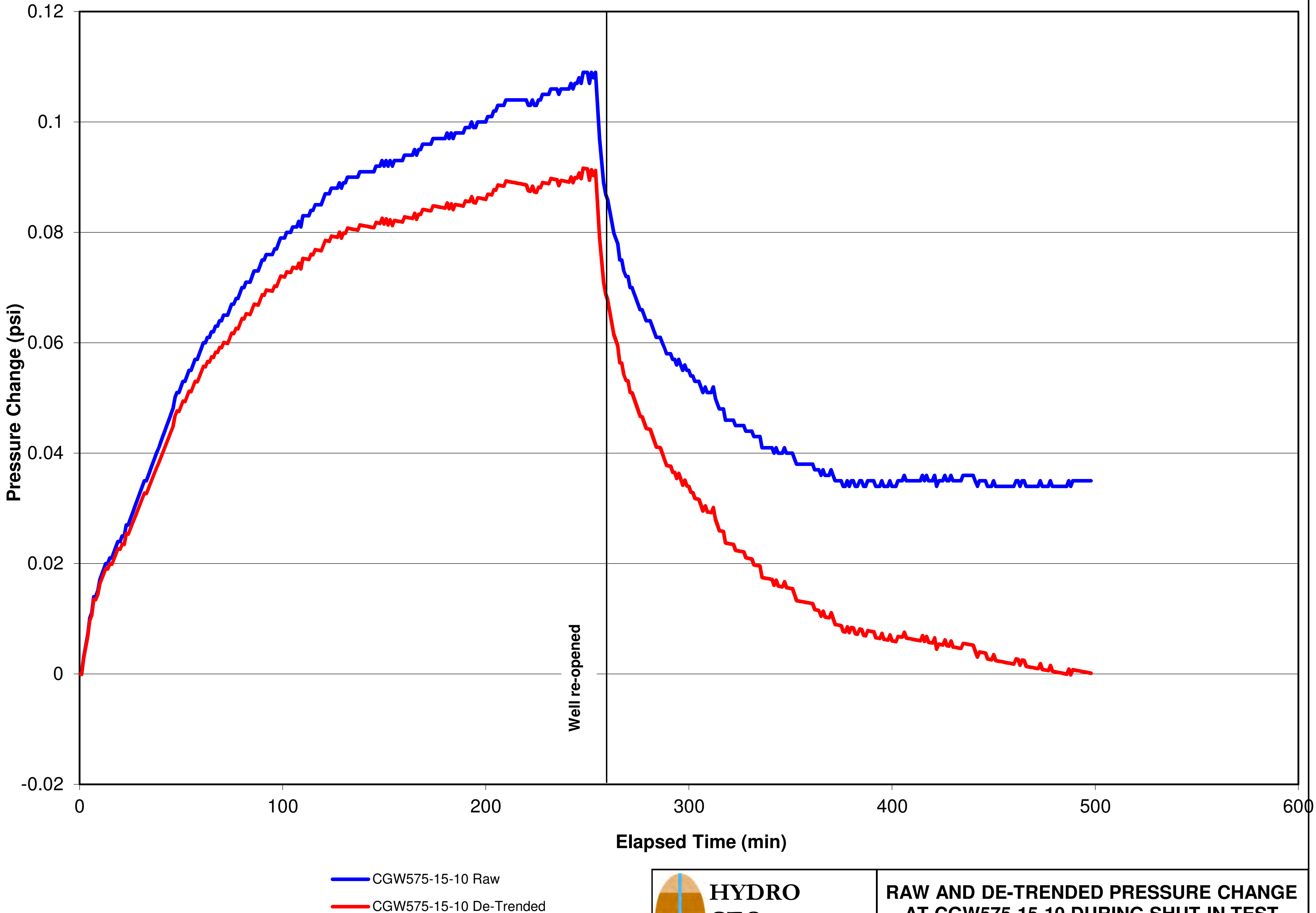
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\8_Figures23thru28.xls: Figure 27



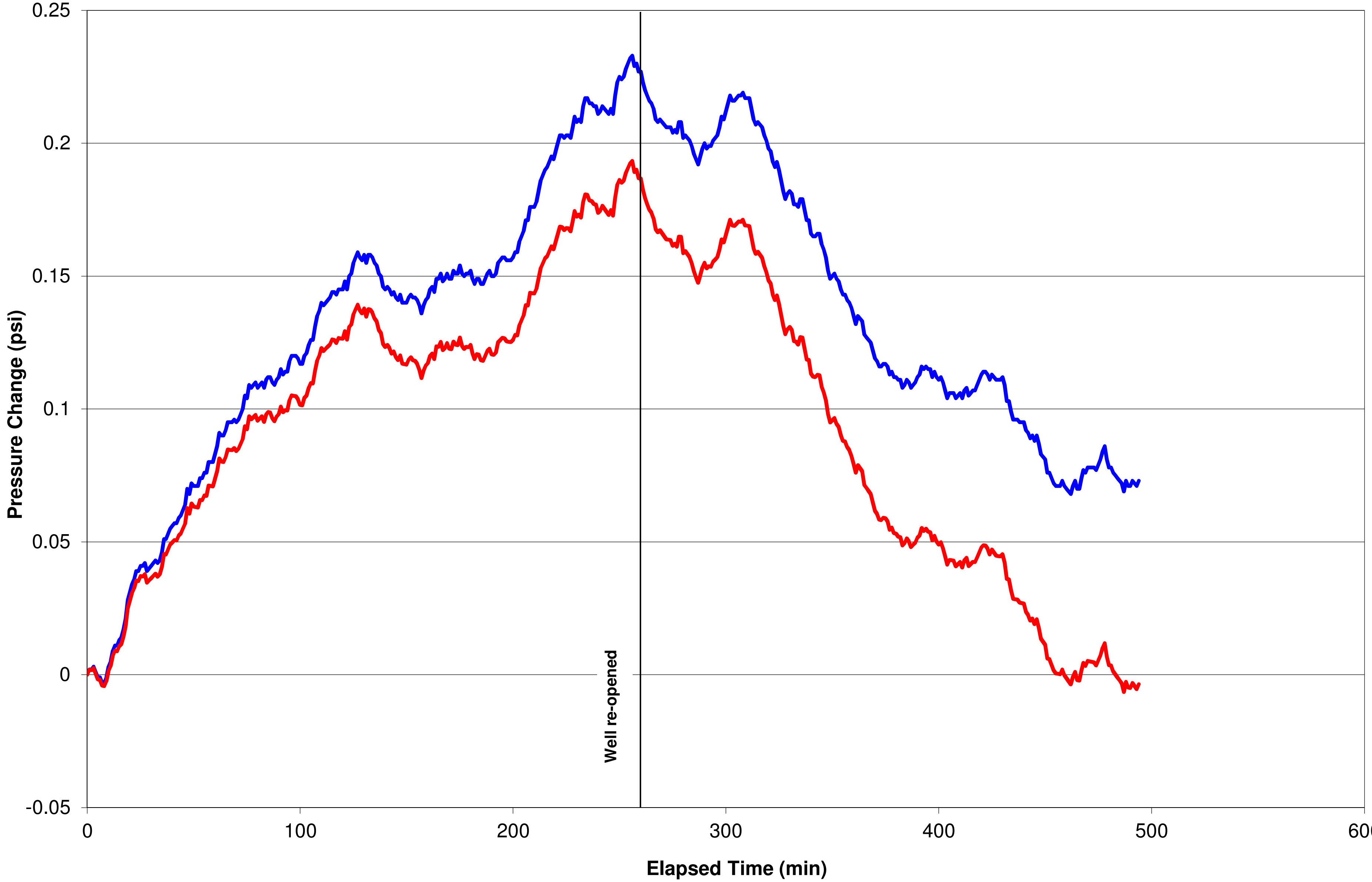
HYDRO GEO CHEM, INC.

PRESSURE CHANGE AT GW7024 SHALLOW PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009028	28



HYDRO GEO CHEM, INC.	RAW AND DE-TRENDED PRESSURE CHANGE AT CGW575-15-10 DURING SHUT-IN TEST					
	Approved SJS	Date 3/6/15	Author GEM	Date 11/11/14	File Name 2013009029	Figure 29

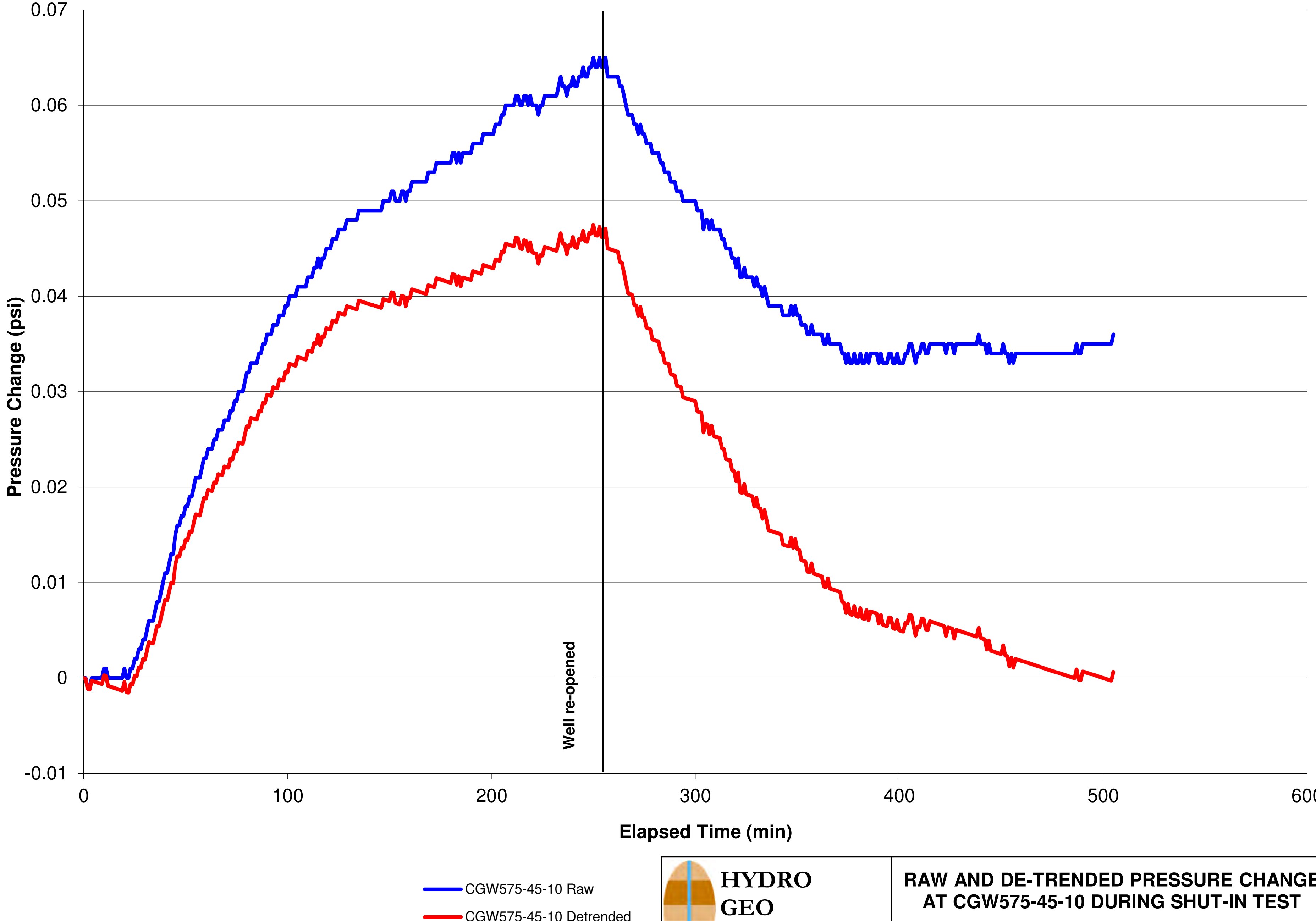


HYDRO GEO CHEM, INC.

RAW AND DE-TRENDED PRESSURE CHANGE AT CGW575-15-100 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009030	30

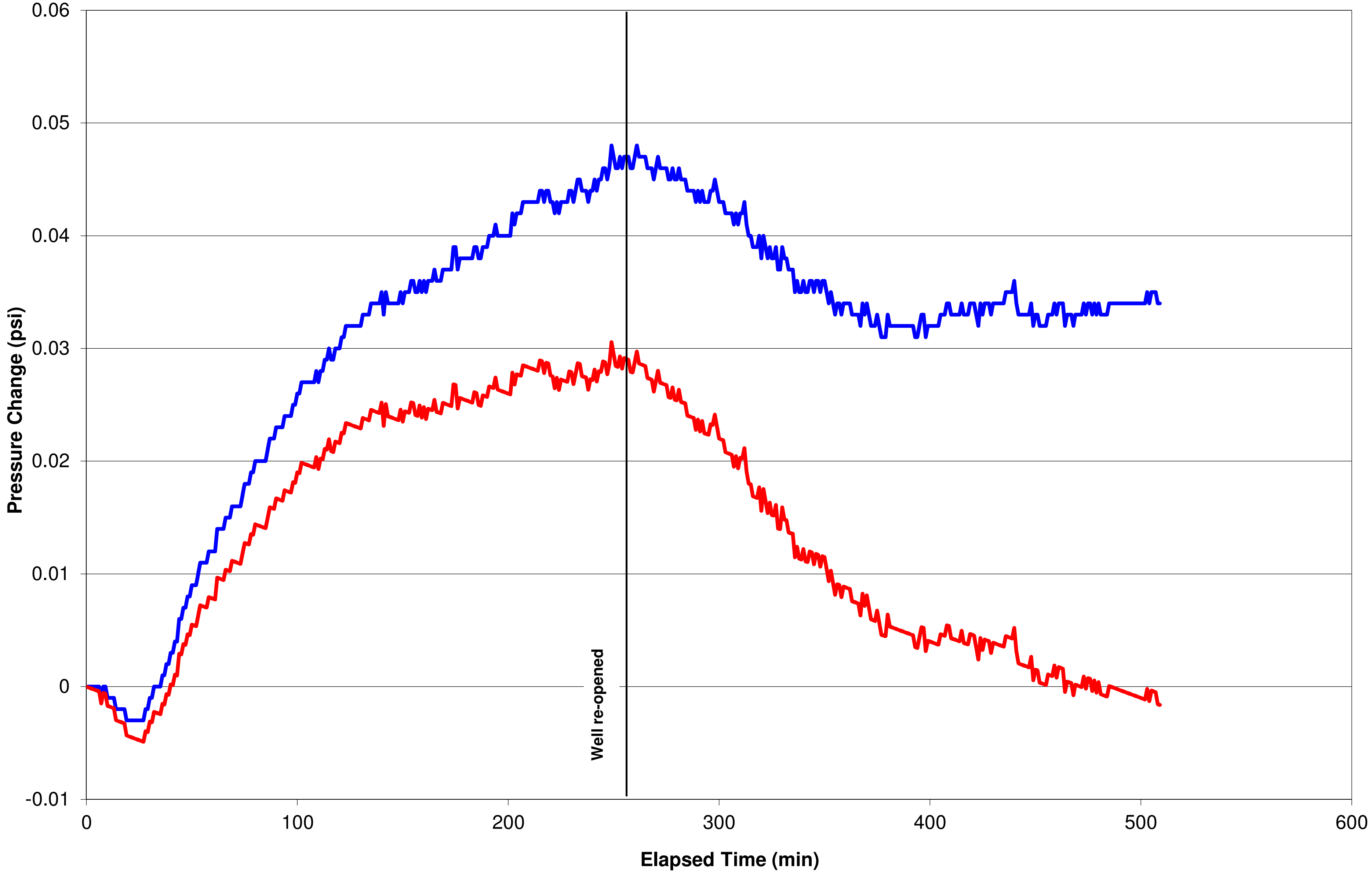
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\9_Figures29thru33.xls: Figure 30



HYDRO GEO CHEM, INC.

RAW AND DE-TRENDED PRESSURE CHANGE AT CGW575-45-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009031	31

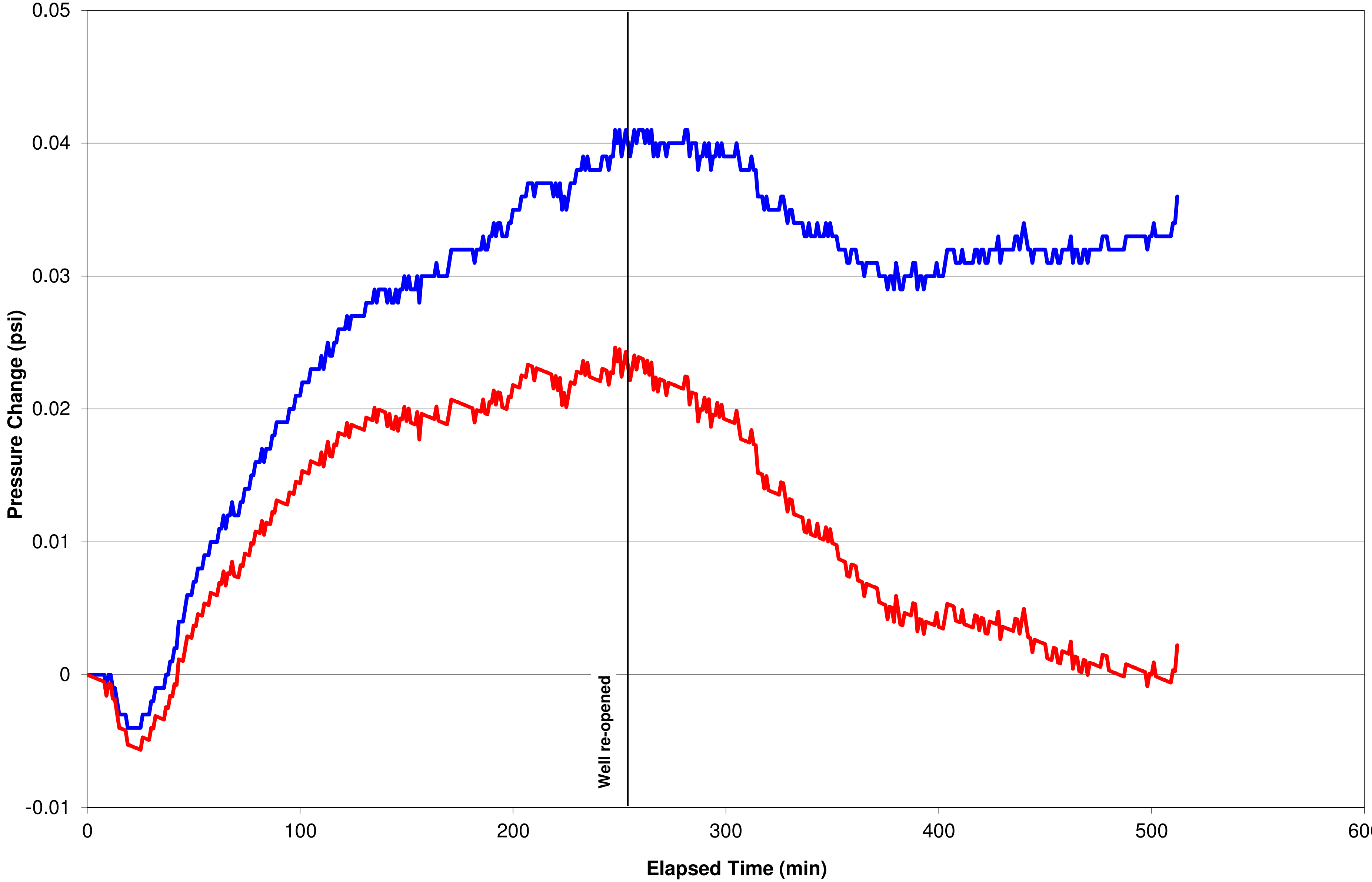


HYDRO GEO CHEM, INC.

RAW AND DE-TRENDED PRESSURE CHANGE CGW575-75-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009032	32

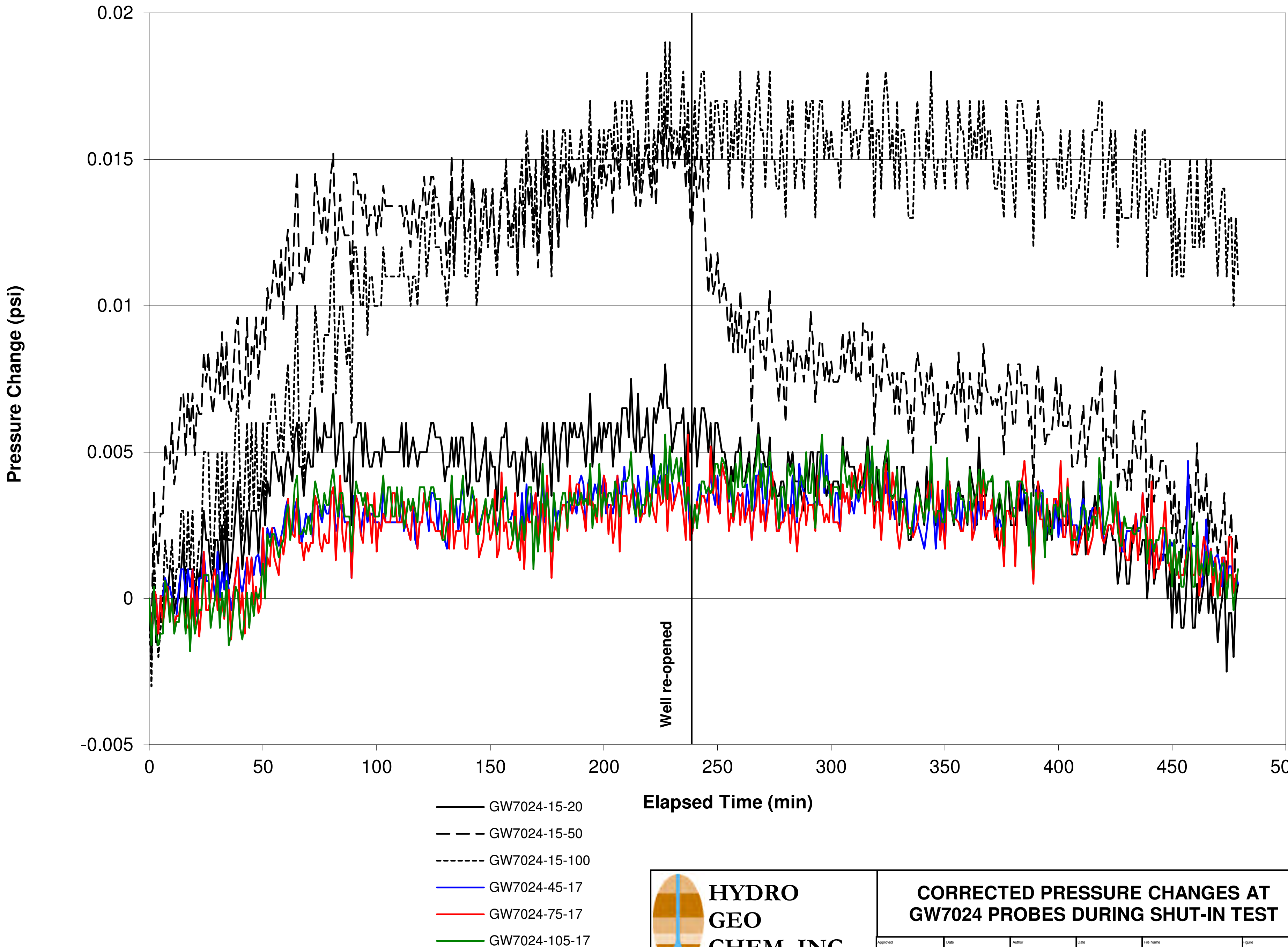
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\9_Figures29thru33.xls: Figure 32



HYDRO GEO CHEM, INC.

RAW AND DE-TRENDED PRESSURE CHANGE AT CGW575-105-10 DURING SHUT-IN TEST

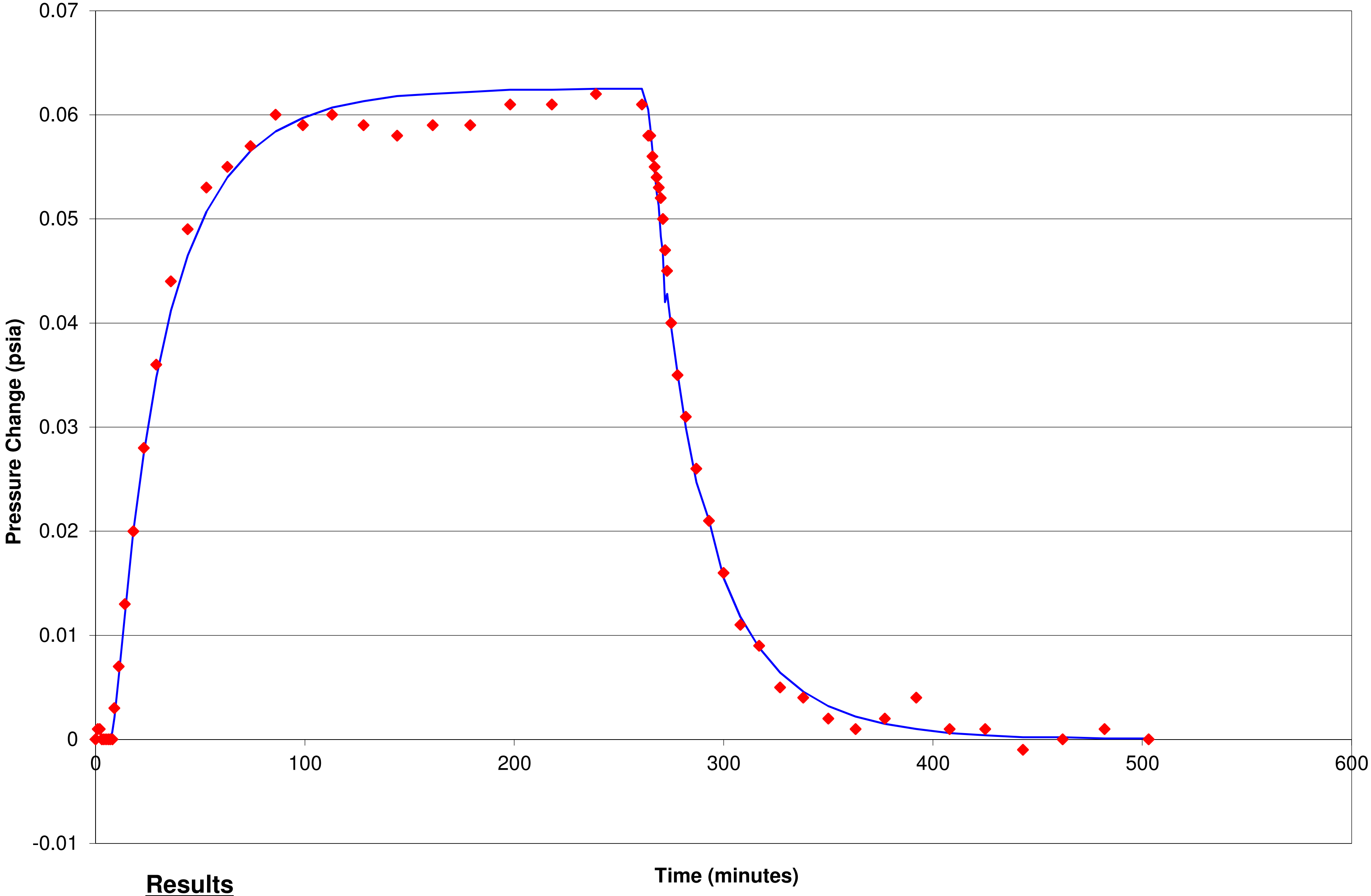
Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009033	33



HYDRO GEO CHEM, INC.

CORRECTED PRESSURE CHANGES AT GW7024 PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009034	34

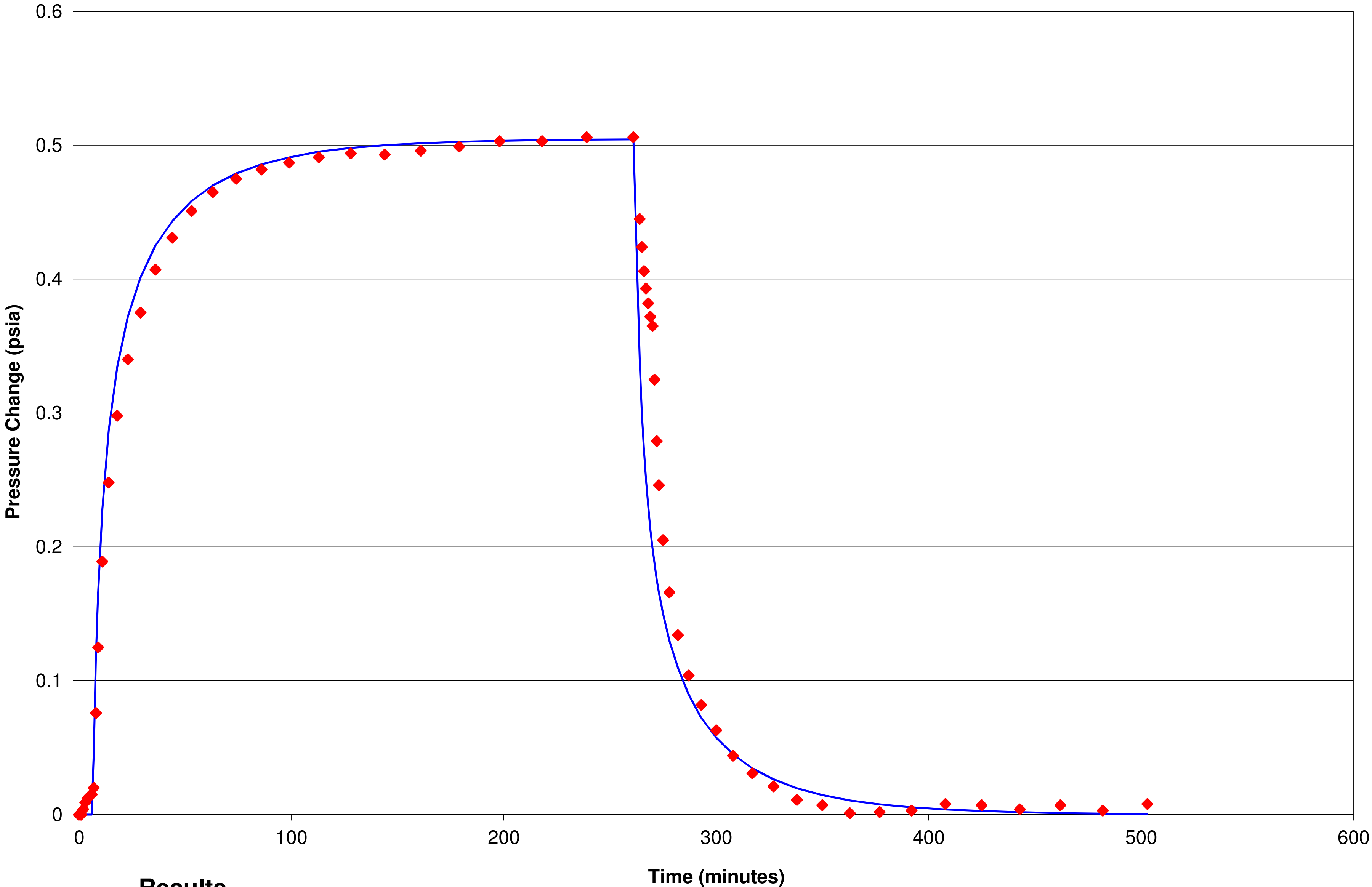


Results
horizontal gas permeability = 10.0 darcies
vertical gas permeability = 1.38 darcies
confining layer permeability = 0.155 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009035	35



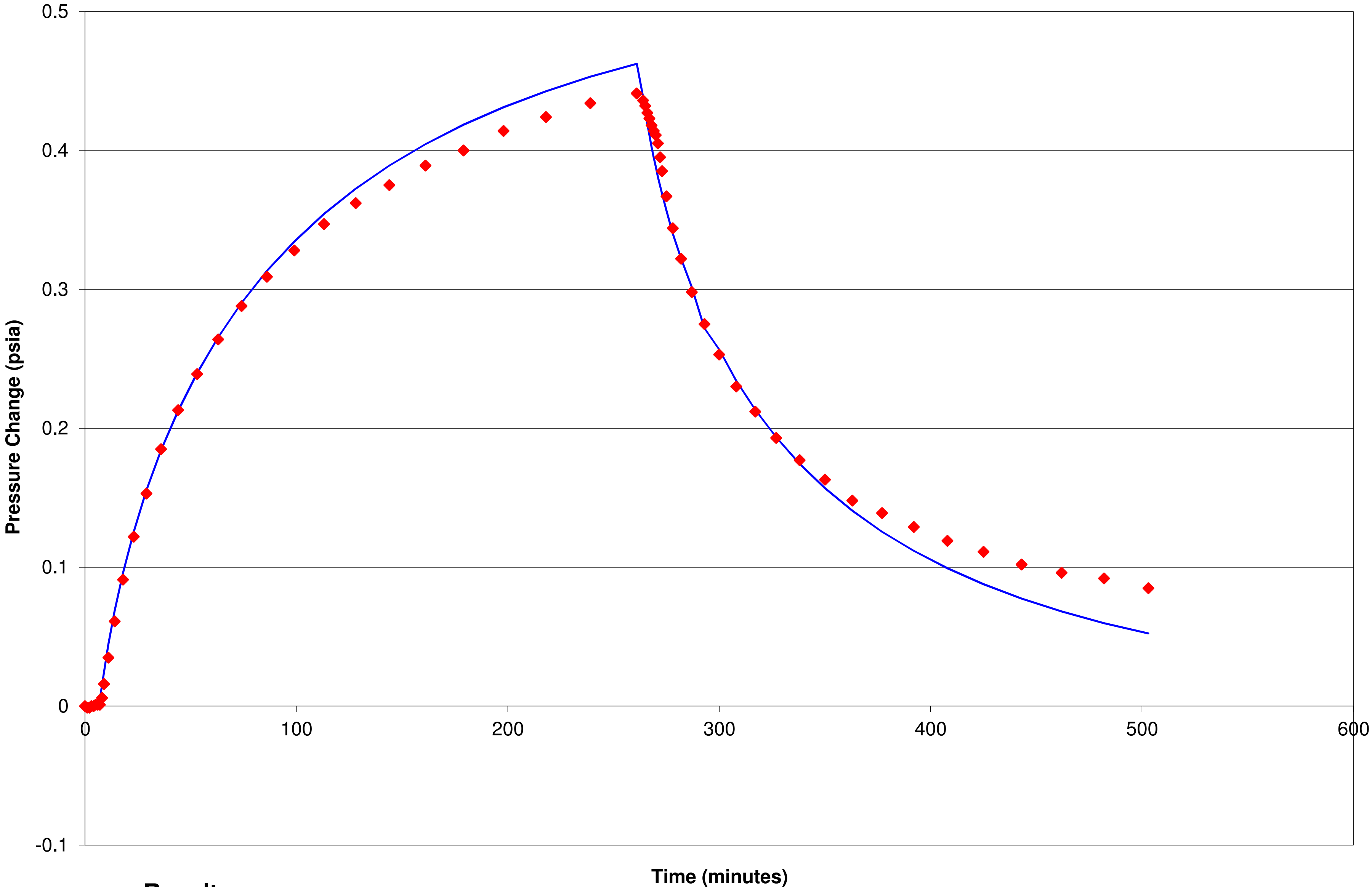
Results

horizontal gas permeability = 4.0 darcies
vertical gas permeability = 1.4 darcies
confining layer permeability = 0.12 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-35 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009036	36



Results

horizontal gas permeability = 3.2 darcies
vertical gas permeability = 0.028 darcies
confining layer permeability = 0.02 darcies
gas porosity = 0.20

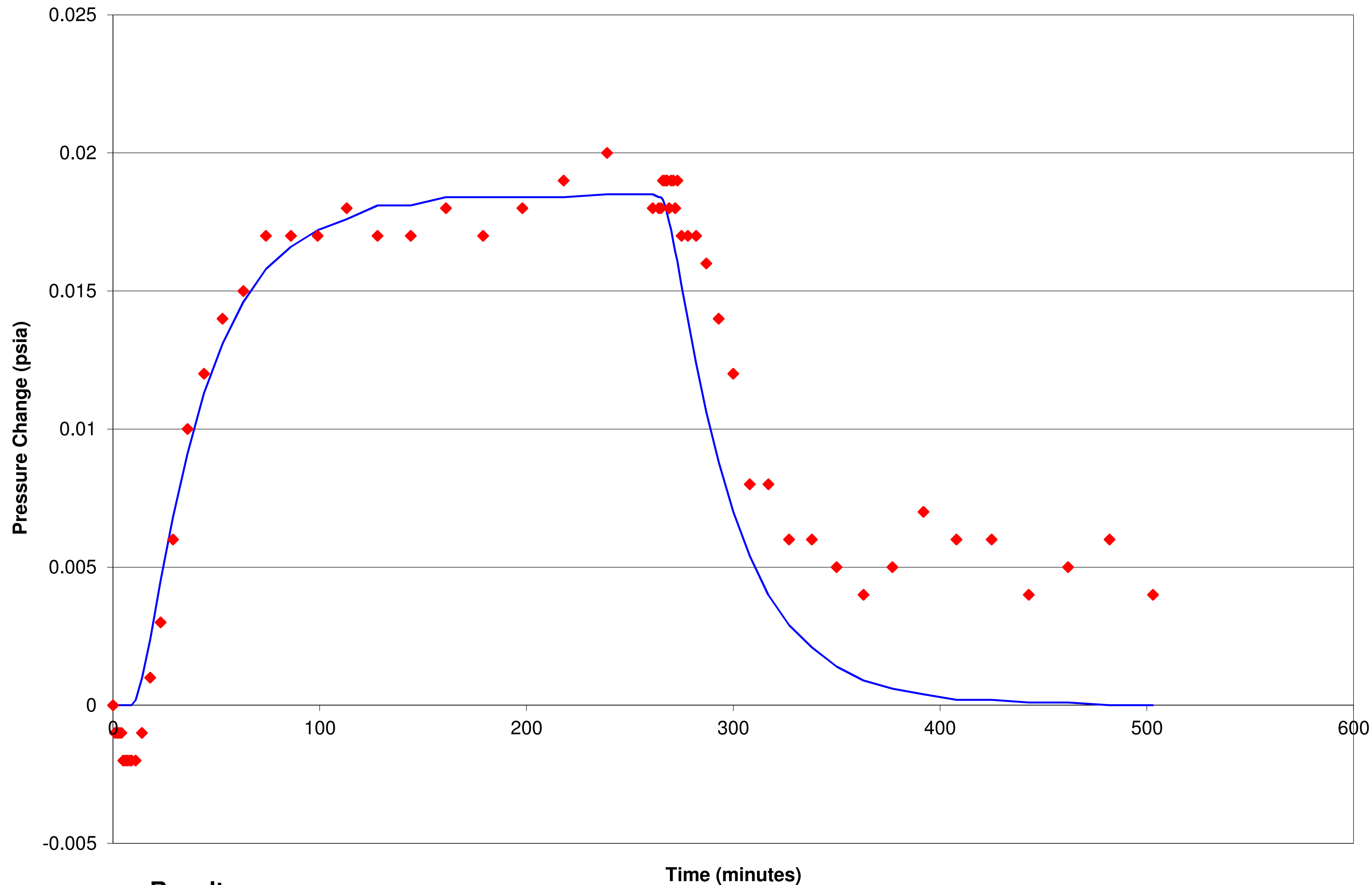
Observed
Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-70 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009037	37

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\11_Figures35thru41.xls: Figure 37



Results

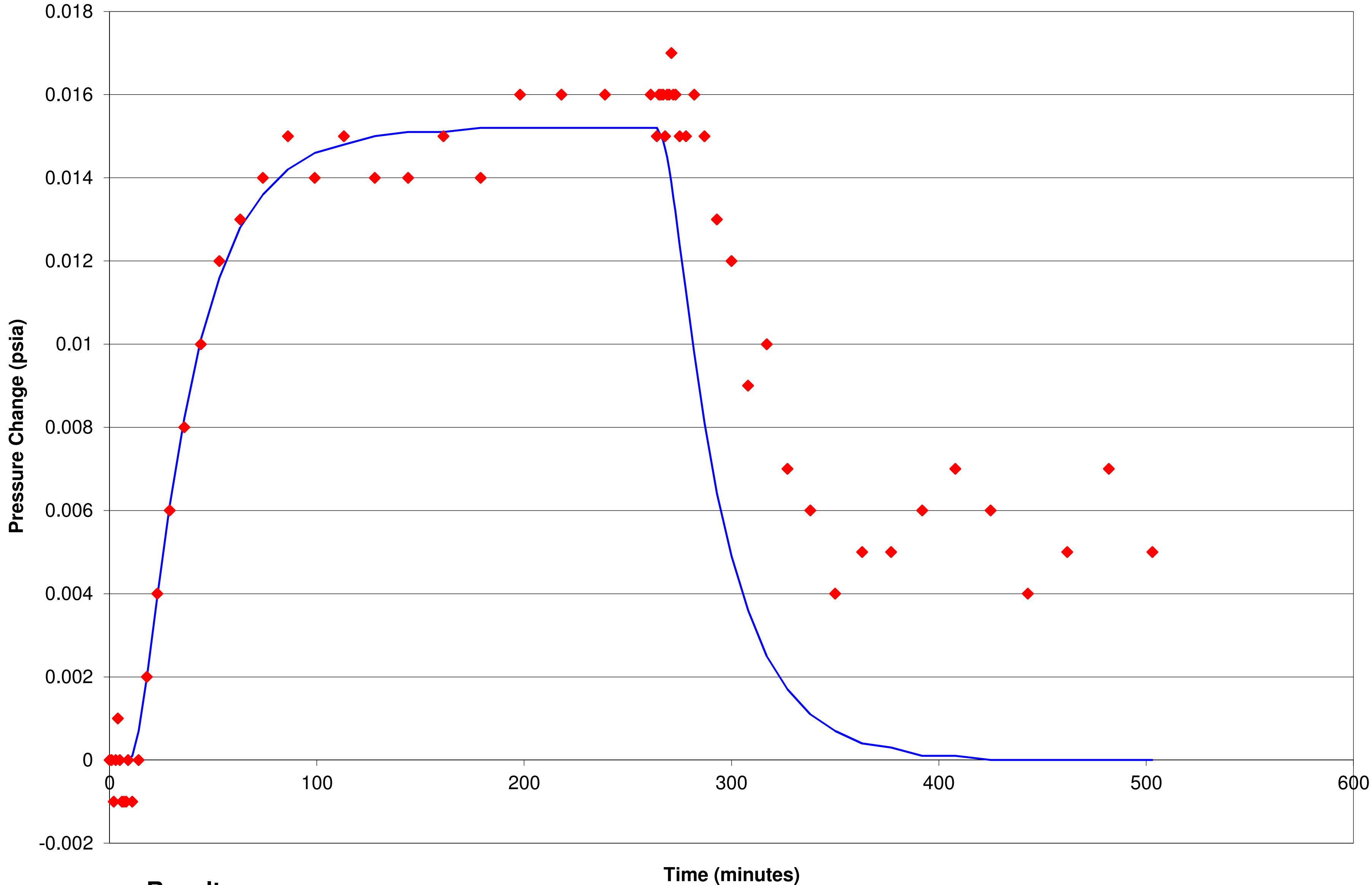
horizontal gas permeability = 12.0 darcies
vertical gas permeability = 0.488 darcies
confining layer permeability = 0.183 darcies
gas porosity = 0.25

Observed
Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-45-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009036	38



Results

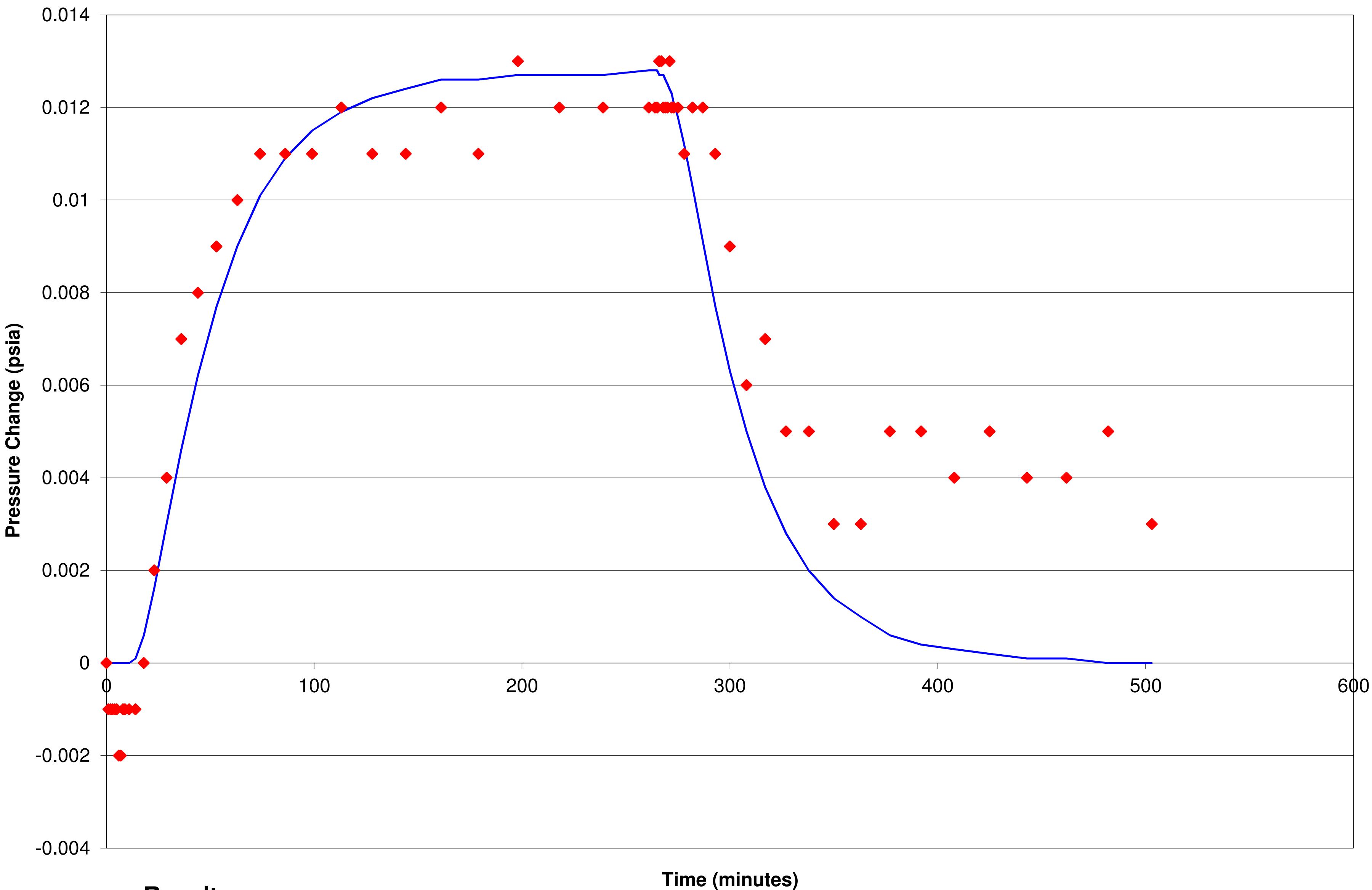
horizontal gas permeability = 12.0 darcies
vertical gas permeability = 0.695 darcies
confining layer permeability = 0.227 darcies
gas porosity = 0.25

◆ Observed
— Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-75-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009039	39

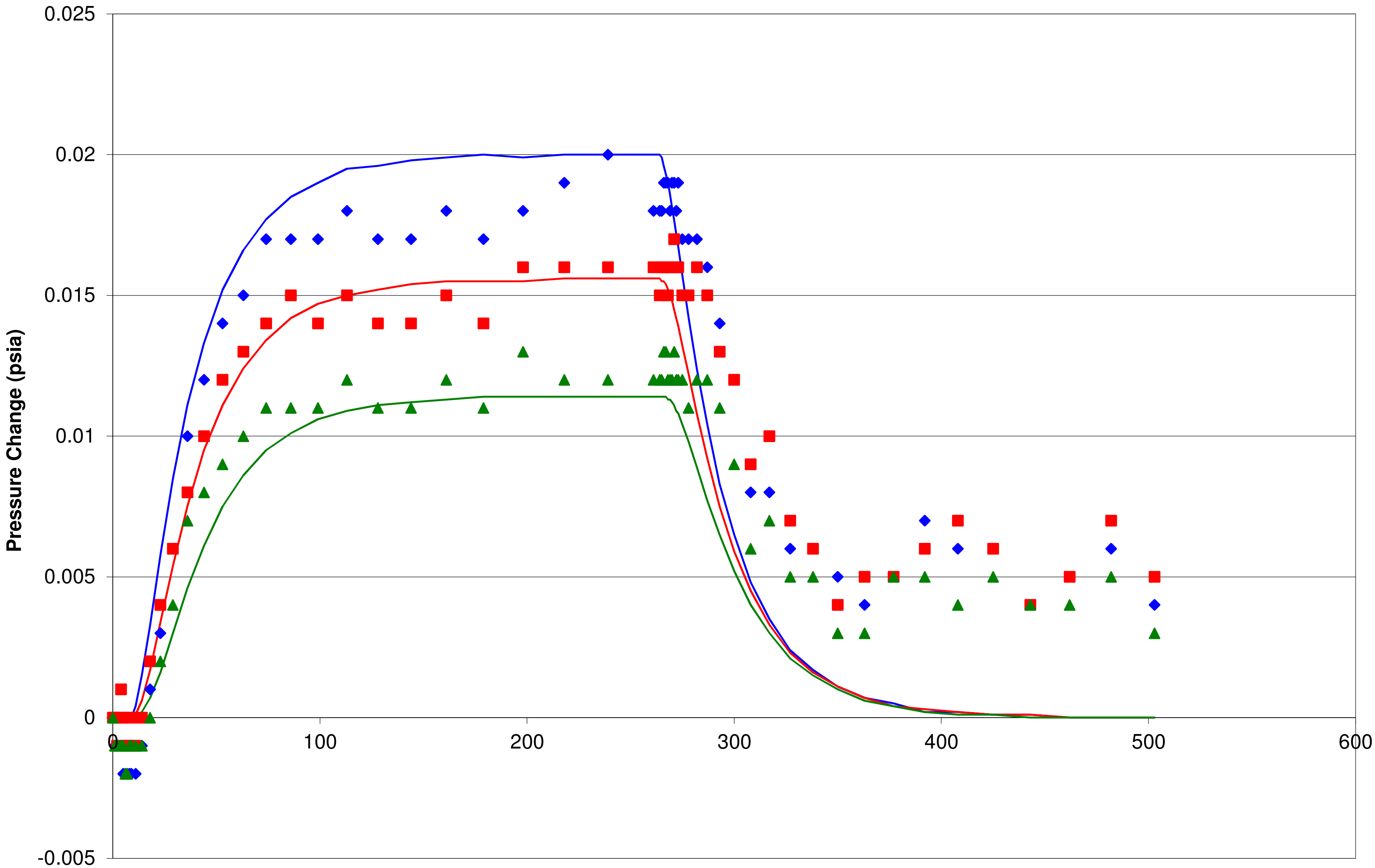


Results

horizontal gas permeability = 12.0 darcies
vertical gas permeability = 0.561 darcies
confining layer permeability = 0.177 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.	MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-105-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)					
Approved SJS	Date 3/6/15	Author GEM	Date 11/11/14	File Name 2013009040	Figure 40	

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\11_Figures35thru41.xls: Figure 40



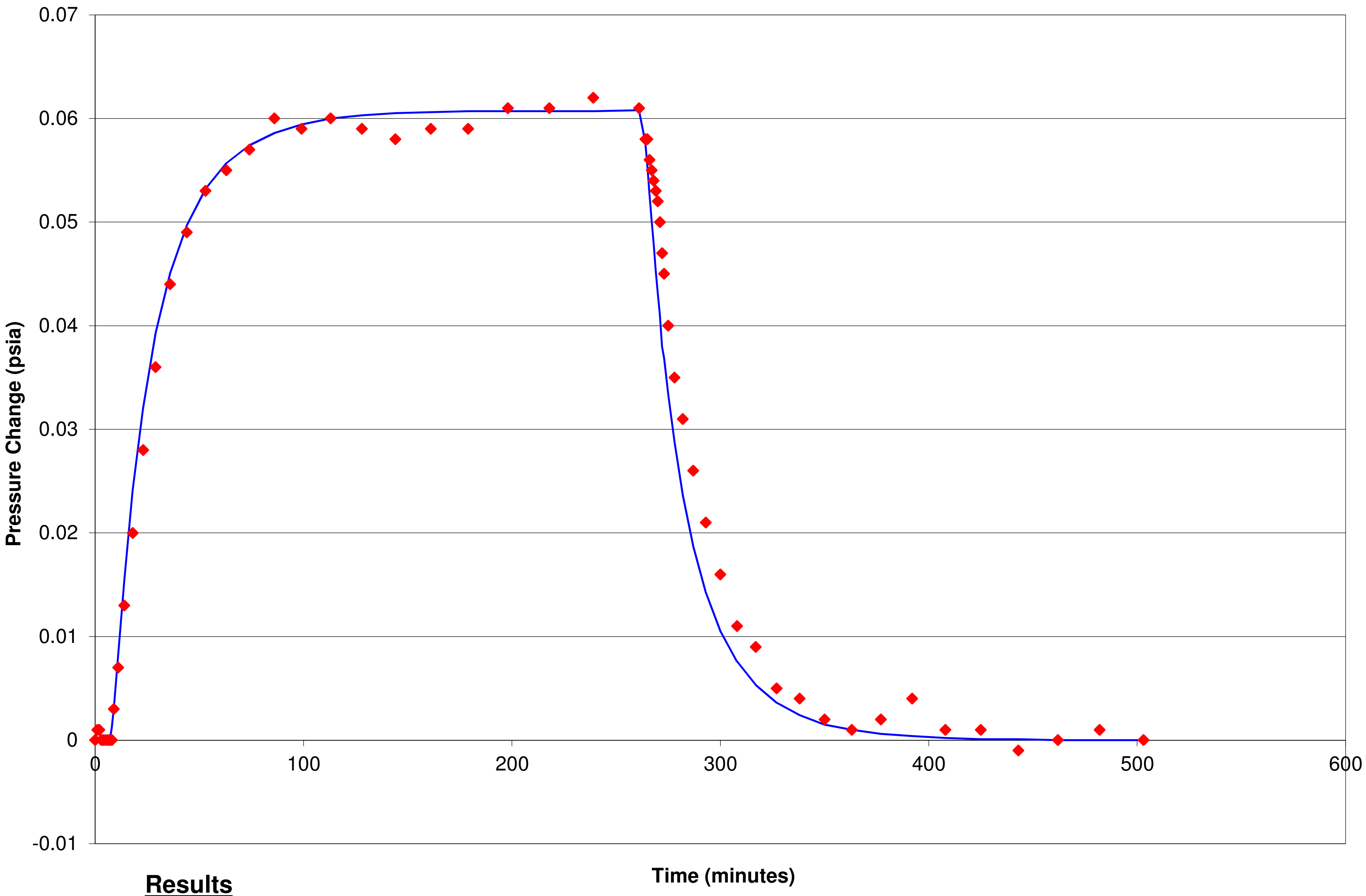
Results

horizontal gas permeability = 12.0 darcies
vertical gas permeability = 0.595 darcies
confining layer permeability = 0.20 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740 DISTAL SHALLOW PROBES DURING SHUT-IN TEST
(ASSUMING EXTRACTION RATE OF 110 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009041	41



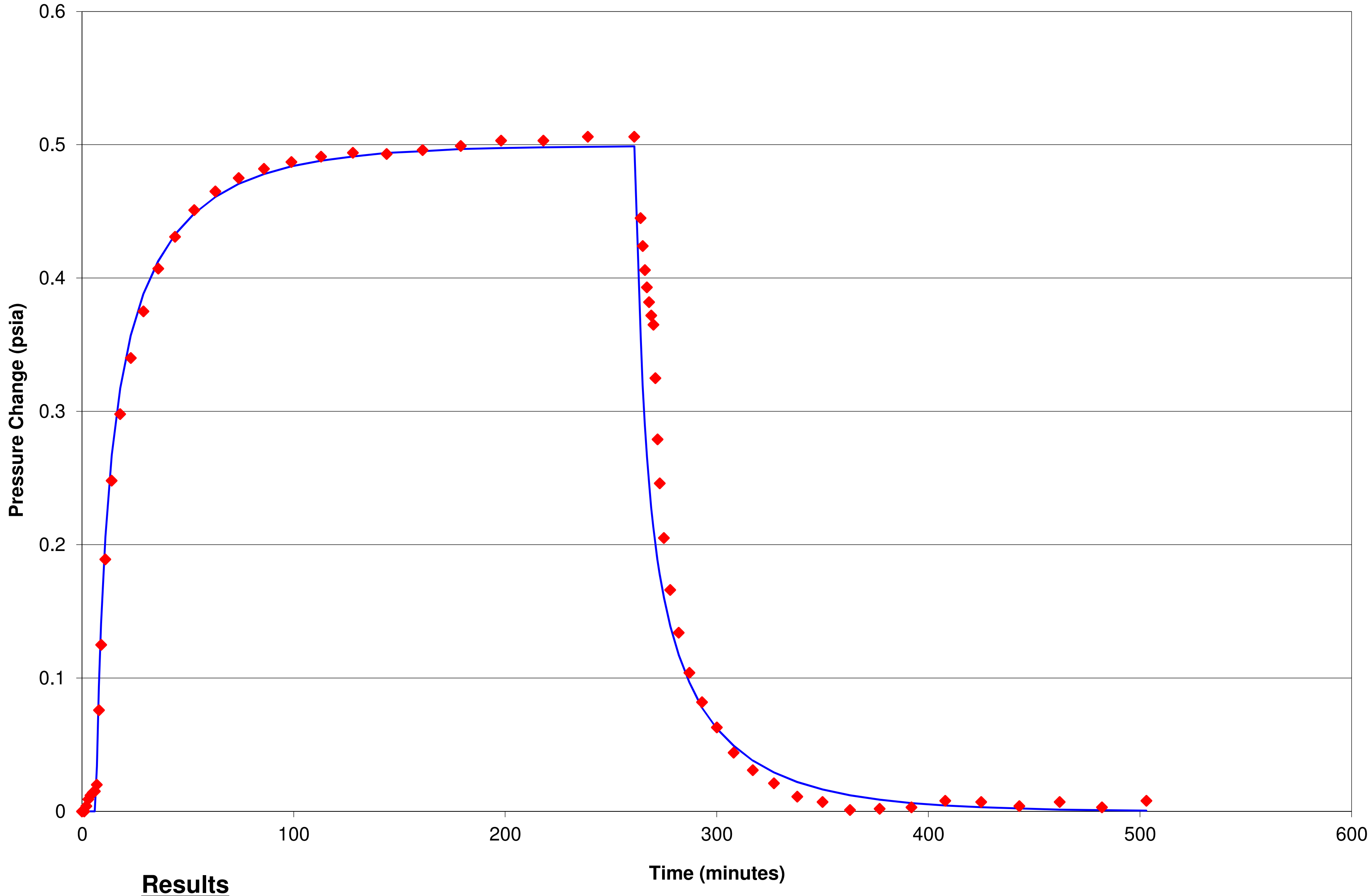
Results

horizontal gas permeability = 5.0 darcies
vertical gas permeability = 1.05 darcies
confining layer permeability = 0.12 darcies
gas porosity = 0.15

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009042	42



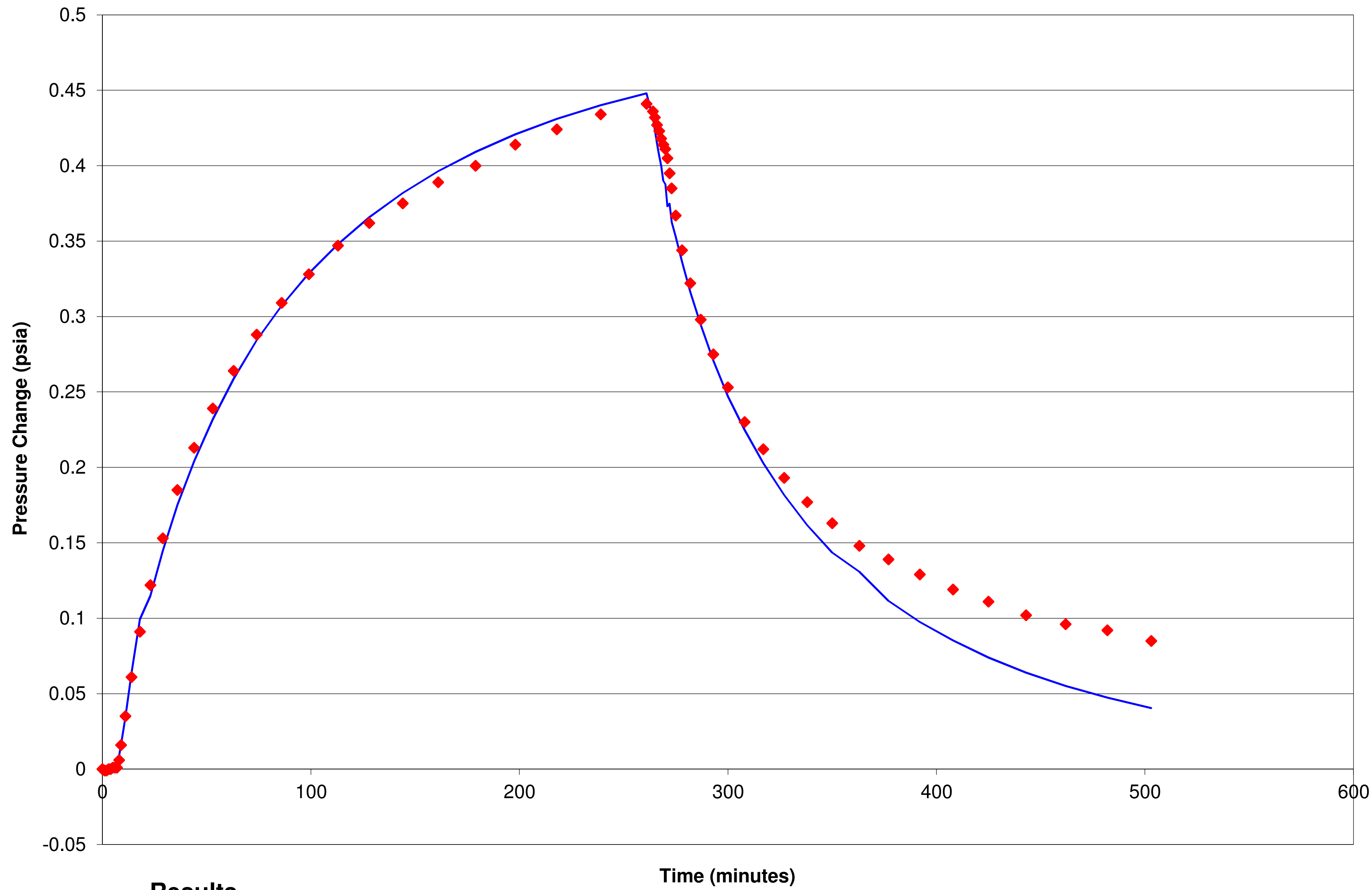
Results

horizontal gas permeability = 1.9 darcies
vertical gas permeability = 0.7 darcies
confining layer permeability = 0.07 darcies
gas porosity = 0.15

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-35 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009043	43



Results

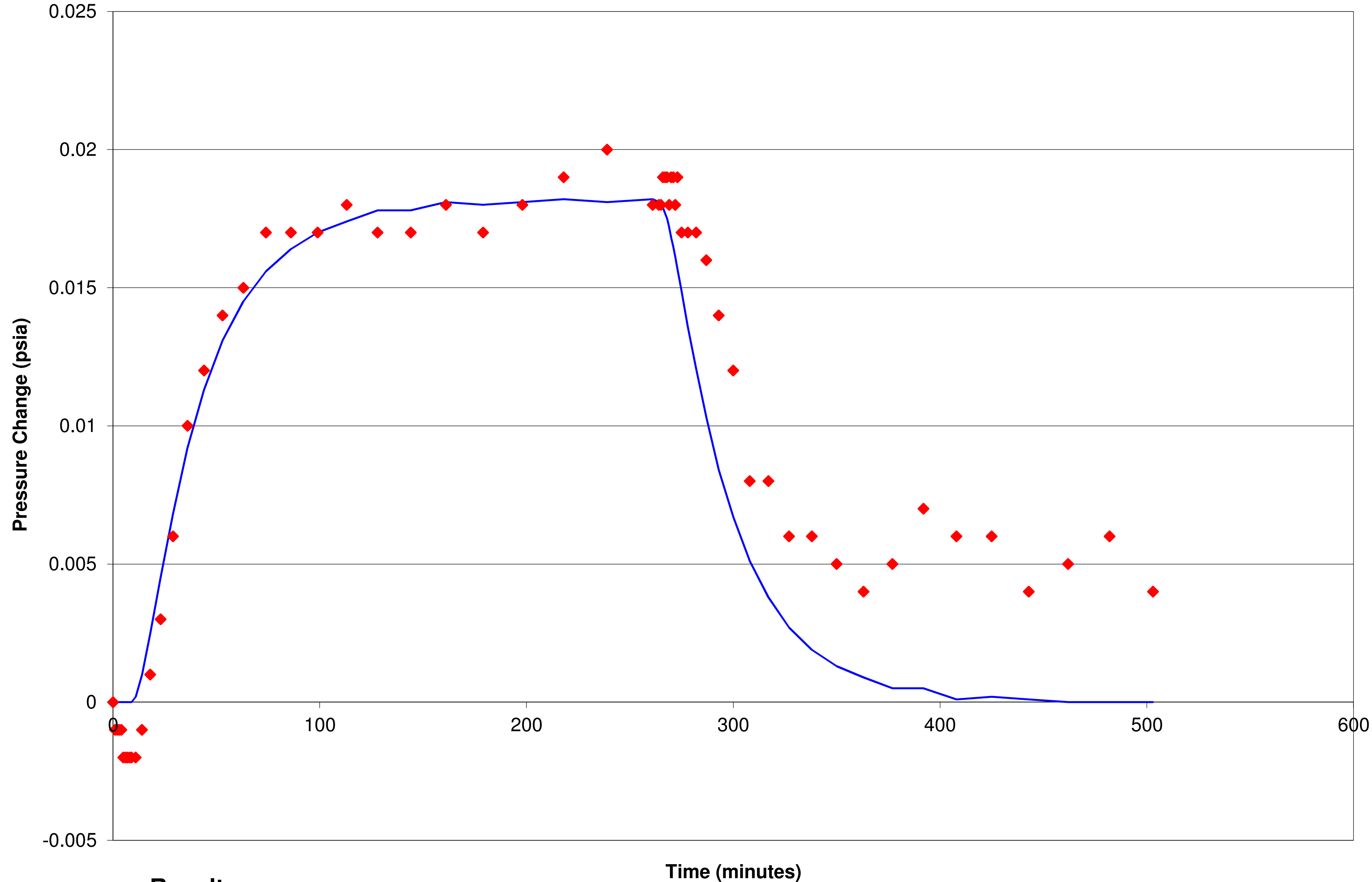
horizontal gas permeability = 1.4 darcies
vertical gas permeability = 0.019 darcies
confining layer permeability = 0.02 darcies
gas porosity = 0.15

◆ Observed
— Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-15-70 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009044	44



Results

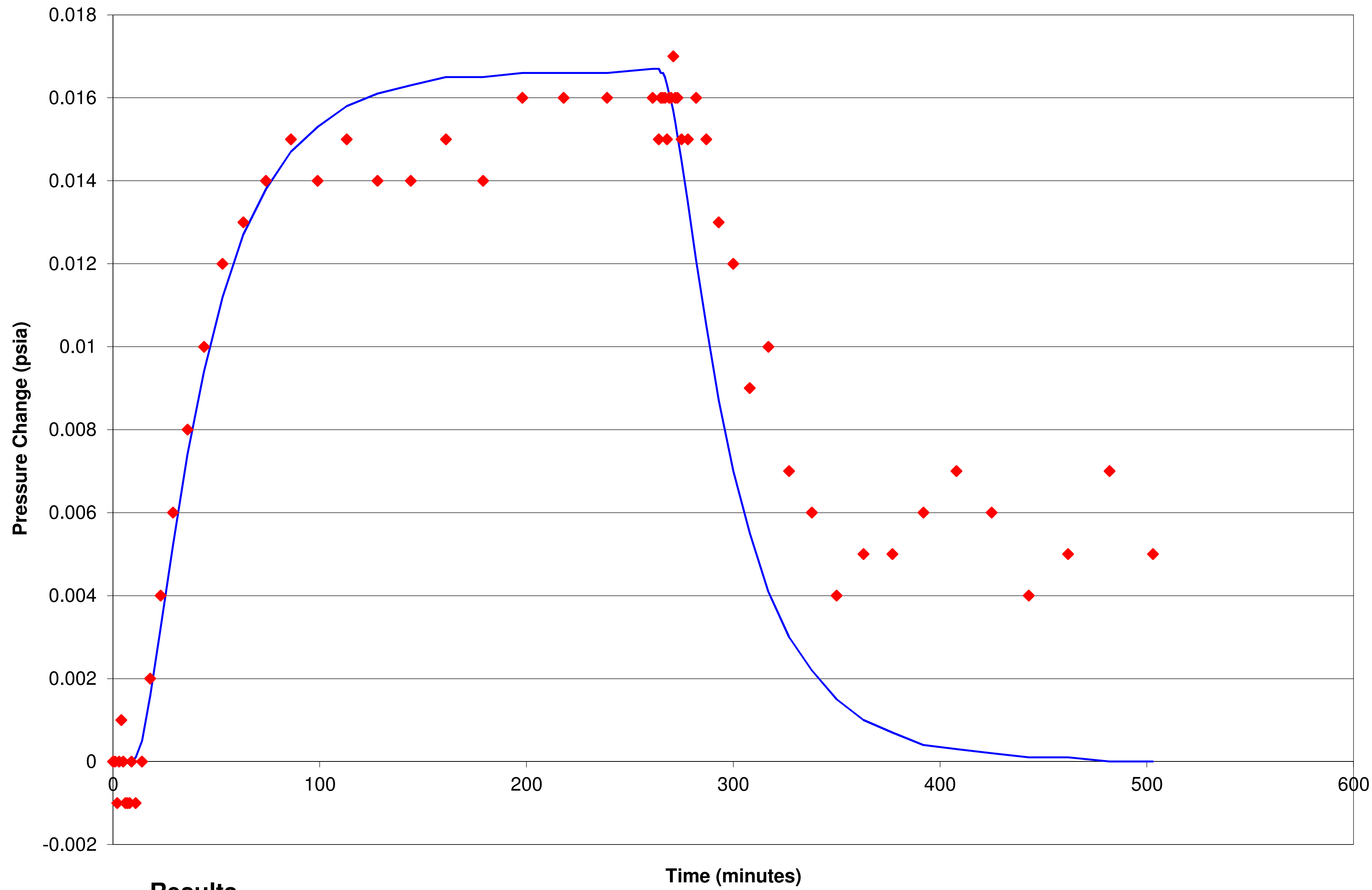
horizontal gas permeability = 6.32 darcies
vertical gas permeability = 0.316 darcies
confining layer permeability = 0.111 darcies
gas porosity = 0.15

Observed
Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-45-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009045	45



Results

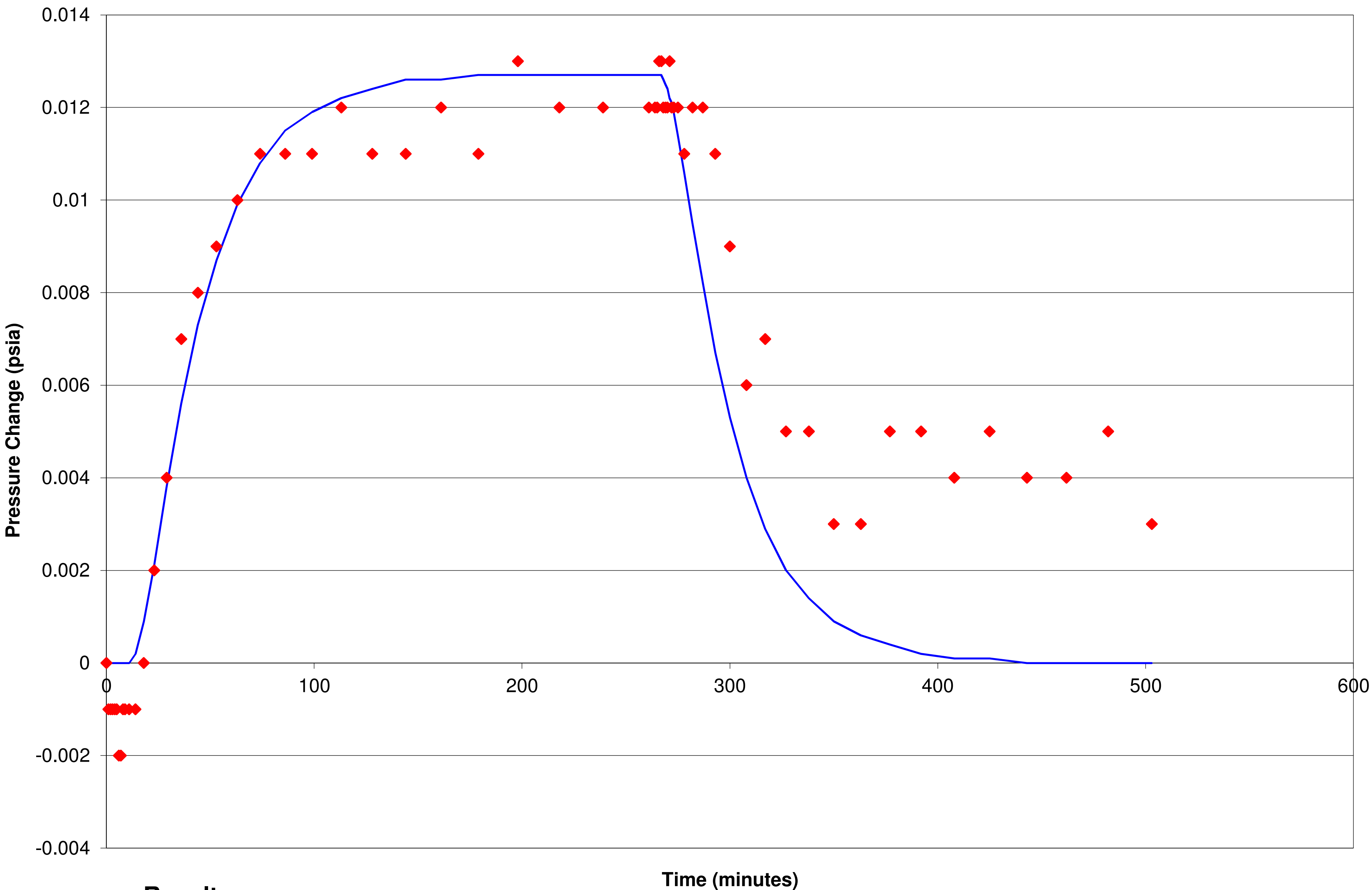
horizontal gas permeability = 6.3 darcies
vertical gas permeability = 0.299 darcies
confining layer permeability = 0.092 darcies
gas porosity = 0.13

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-75-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009046	46

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\12_Figures42thru48.xls: Figure 46



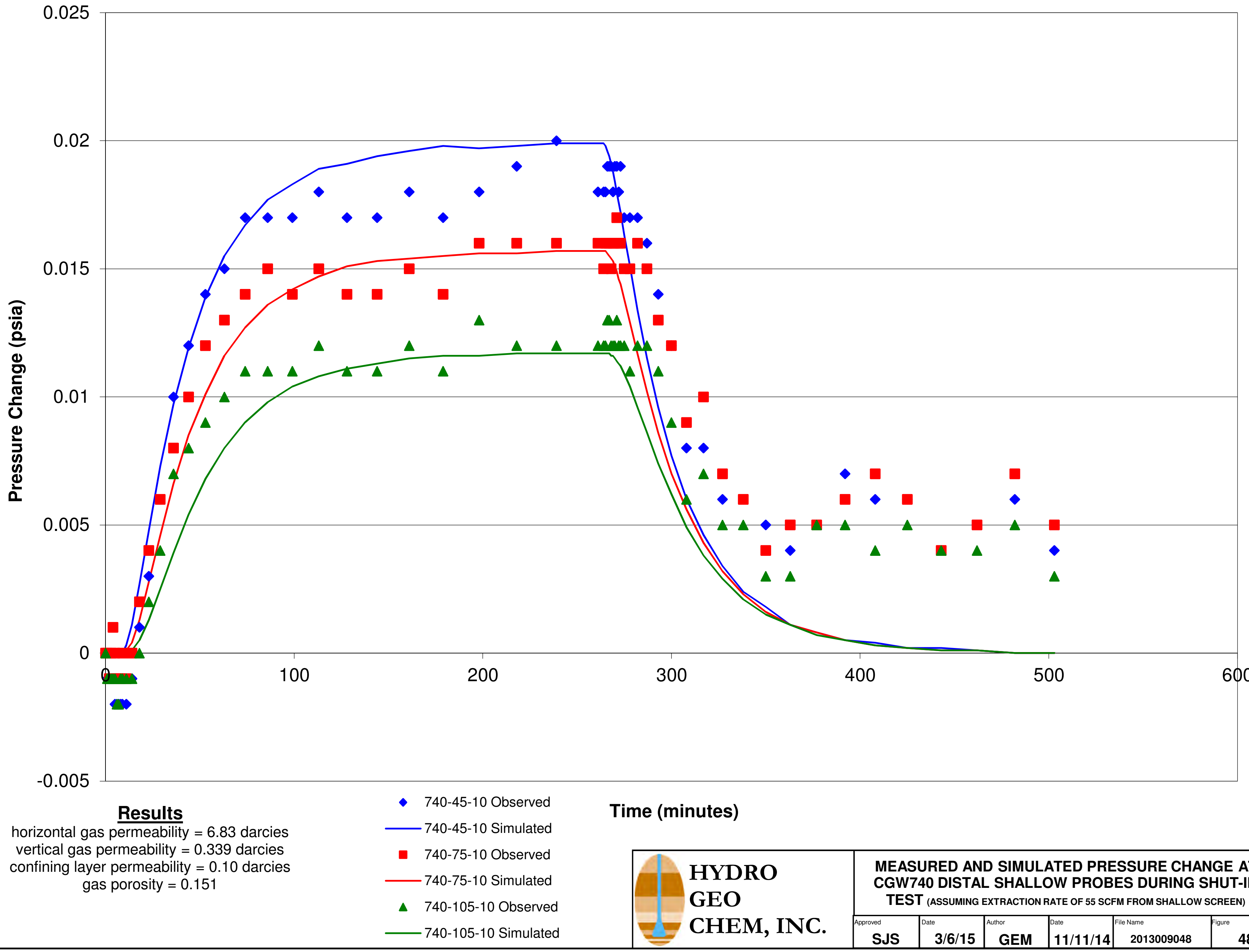
Results

horizontal gas permeability = 6.0 darcies
vertical gas permeability = 0.419 darcies
confining layer permeability = 0.108 darcies
gas porosity = 0.13

Observed
Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740-105-10 DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)					
Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009047	47



Results

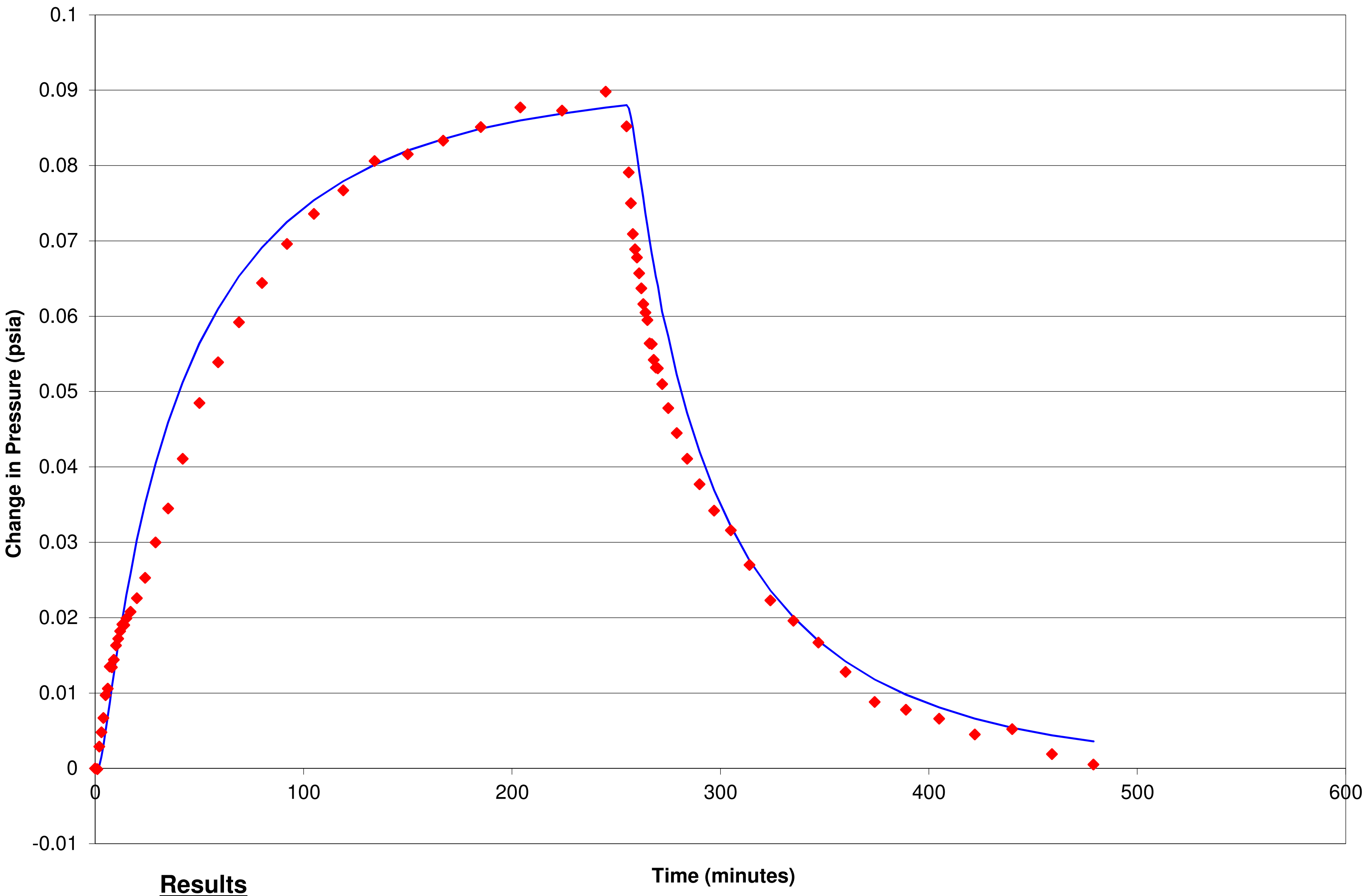
horizontal gas permeability = 6.83 darcies
vertical gas permeability = 0.339 darcies
confining layer permeability = 0.10 darcies
gas porosity = 0.151

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW740 DISTAL SHALLOW PROBES DURING SHUT-IN TEST (ASSUMING EXTRACTION RATE OF 55 SCFM FROM SHALLOW SCREEN)

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009048	48

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\12_Figures42thru48.xls: Figure 48



Results

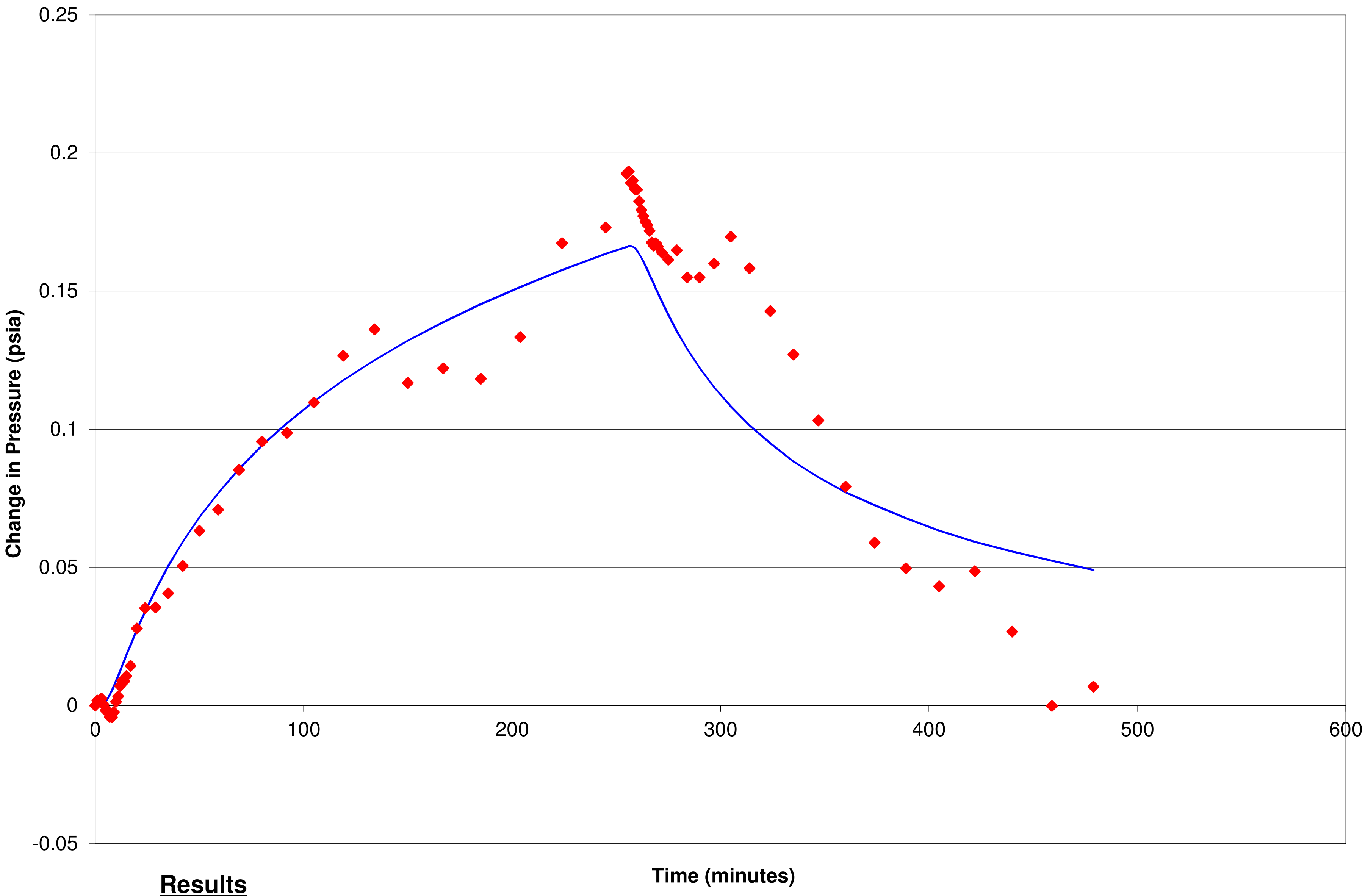
horizontal gas permeability = 4.50 darcies
vertical gas permeability = 2.50 darcies
confining layer permeability = 0.254 darcies
gas porosity = 0.22

Observed — Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575-15-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009049	49



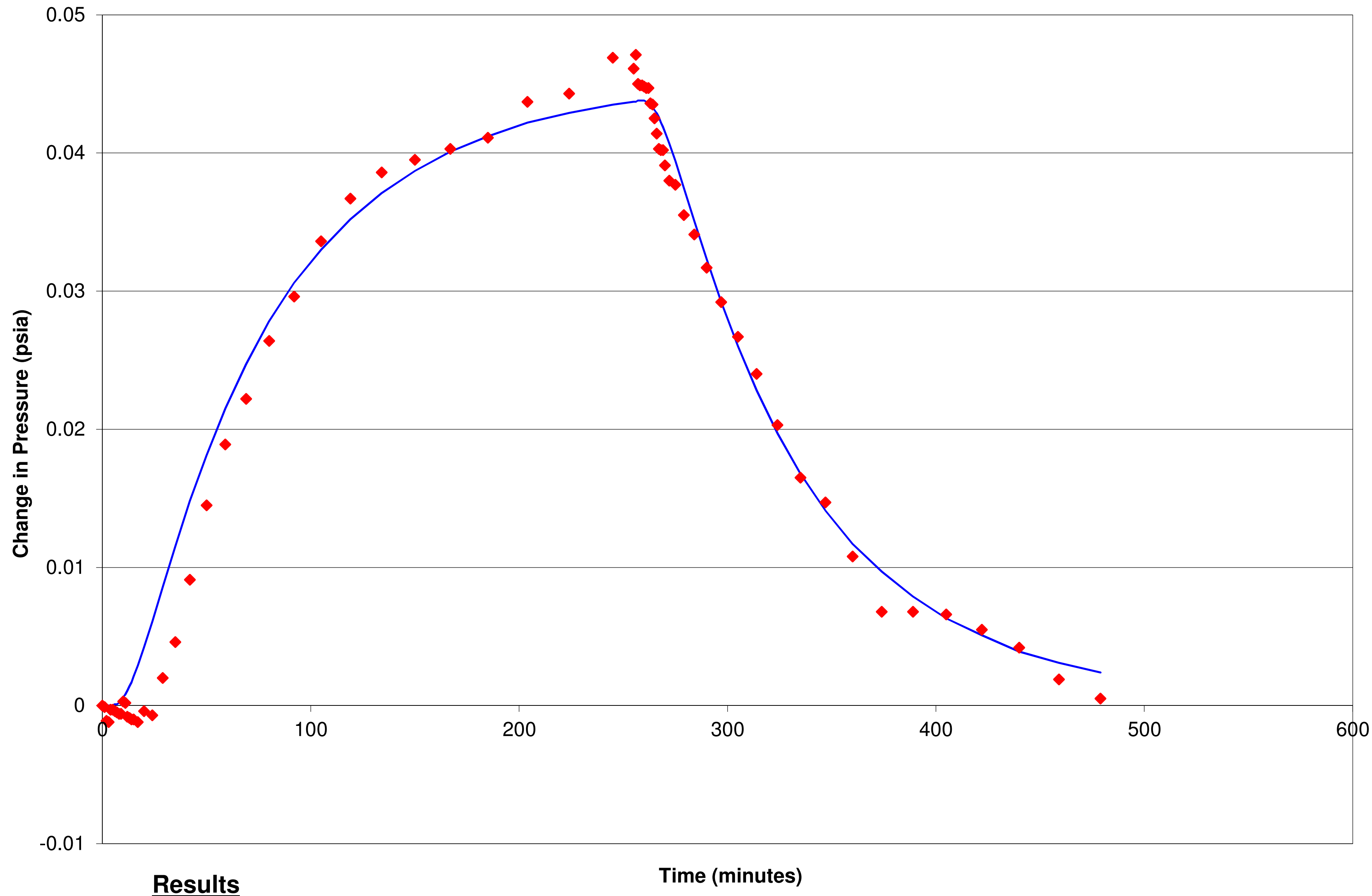
Results

horizontal gas permeability = 4.20 darcies
vertical gas permeability = 0.032 darcies
confining layer permeability = 0.0214 darcies
gas porosity = 3.50

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575-15-100 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009050	50



Results

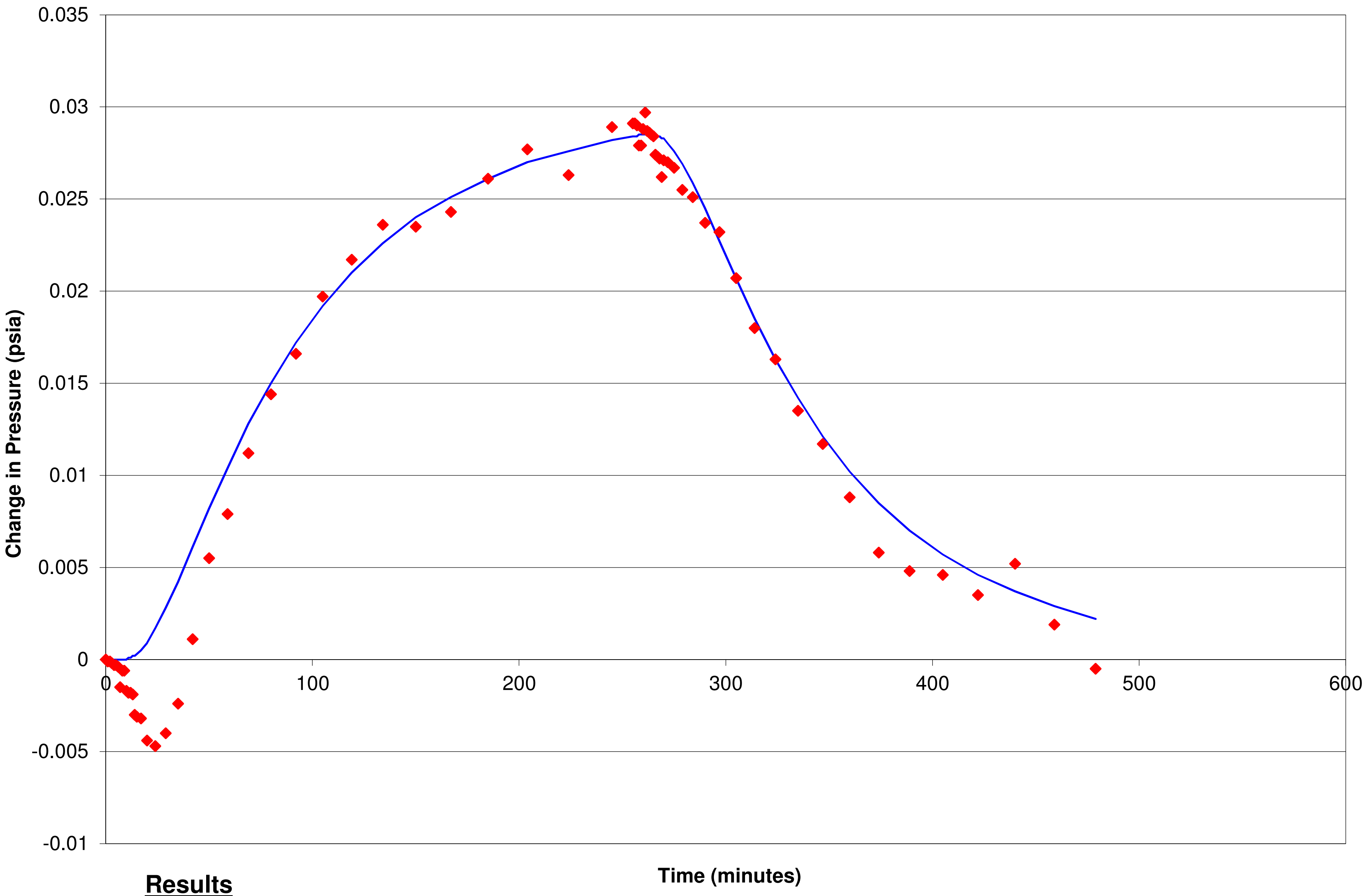
horizontal gas permeability = 3.00 darcies
vertical gas permeability = 0.839 darcies
confining layer permeability = 0.387 darcies
gas porosity = 0.25

◆ Observed — Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575-45-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009051	51



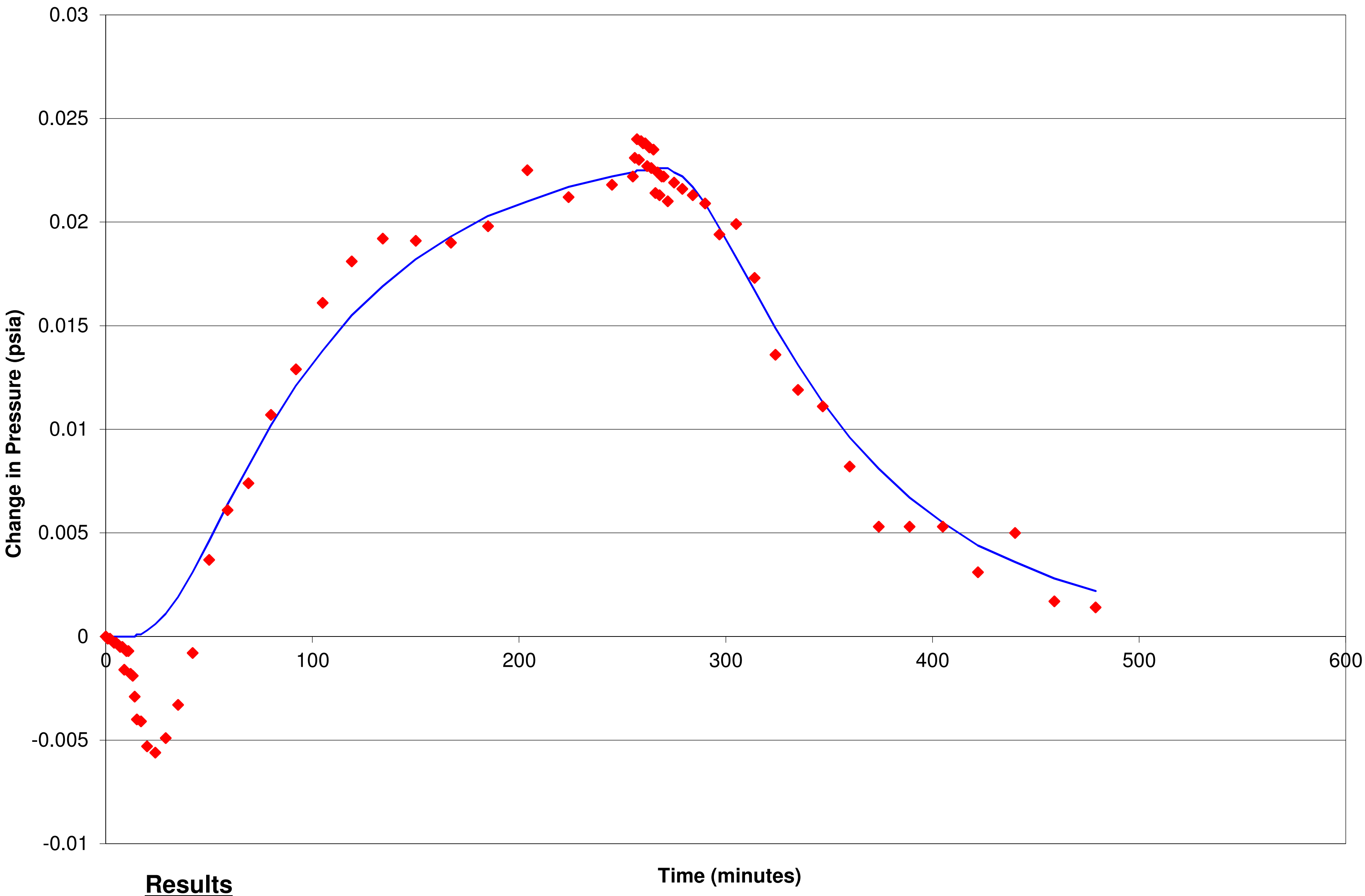
Results

horizontal gas permeability = 3.00 darcies
vertical gas permeability = 0.839 darcies
confining layer permeability = 0.387 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575-75-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009052	52

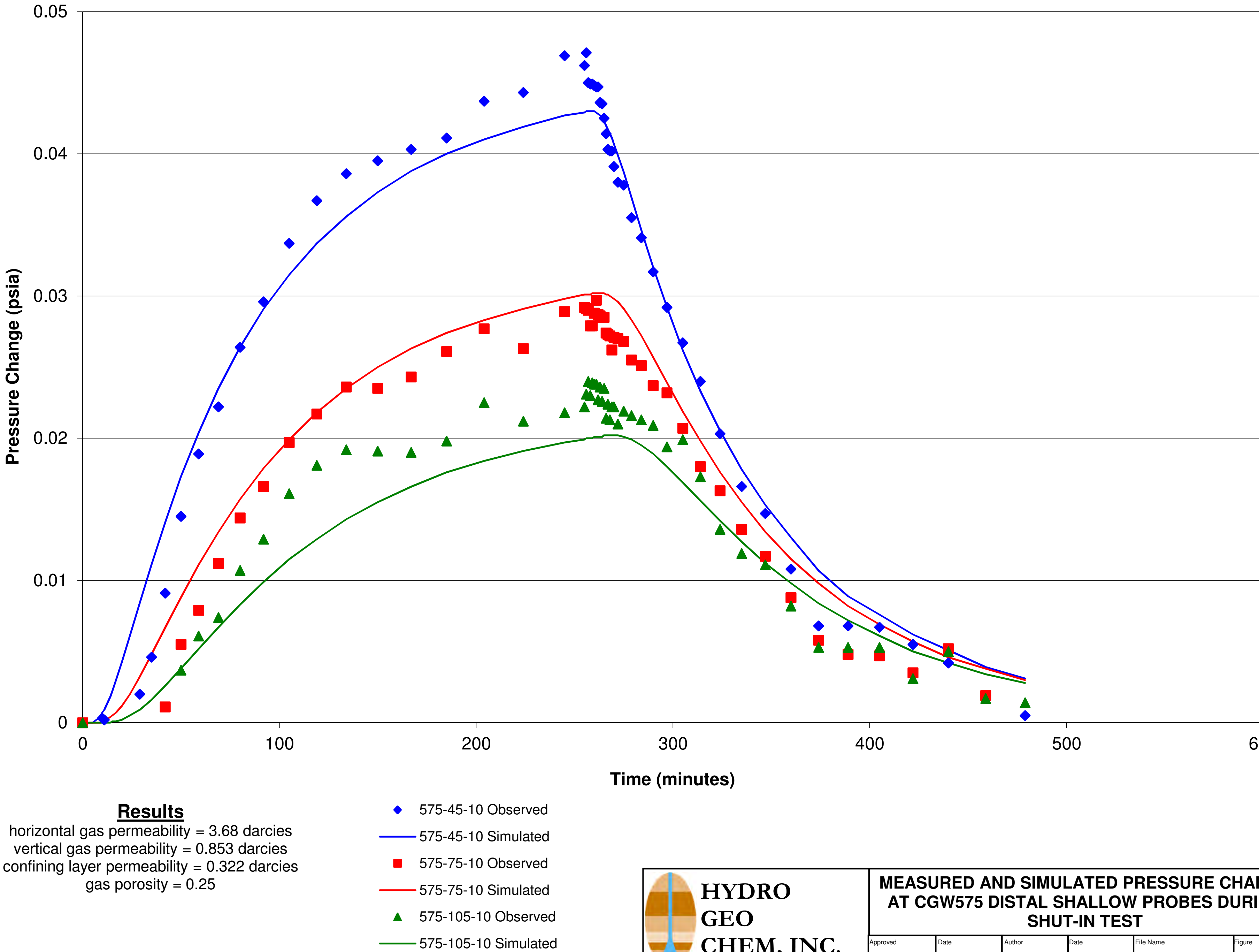


Results
horizontal gas permeability = 2.94 darcies
vertical gas permeability = 2.0 darcies
confining layer permeability = 0.377 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575-105-10 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009053	53



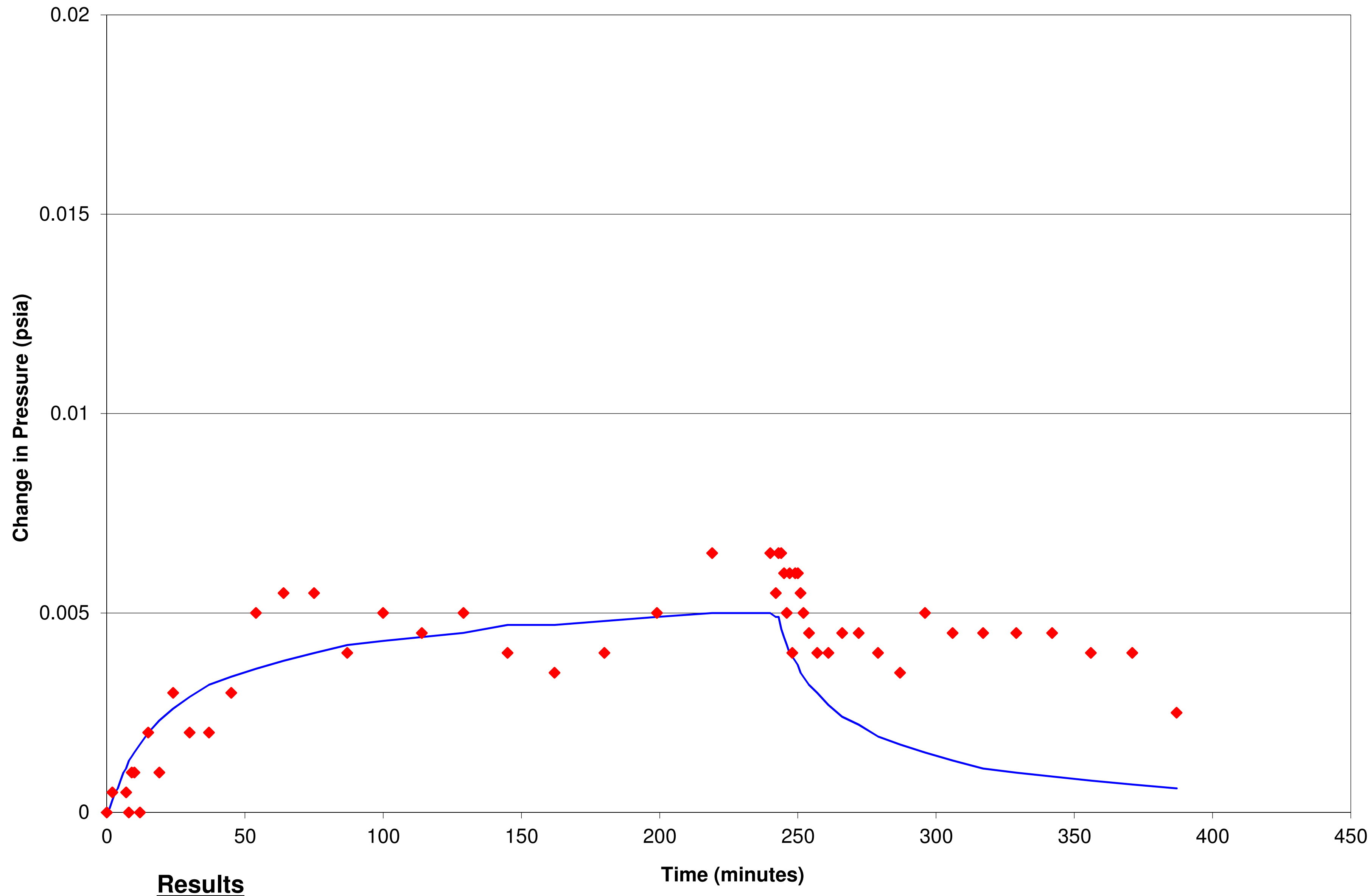
Results

horizontal gas permeability = 3.68 darcies
vertical gas permeability = 0.853 darcies
confining layer permeability = 0.322 darcies
gas porosity = 0.25

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT CGW575 DISTAL SHALLOW PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009054	54



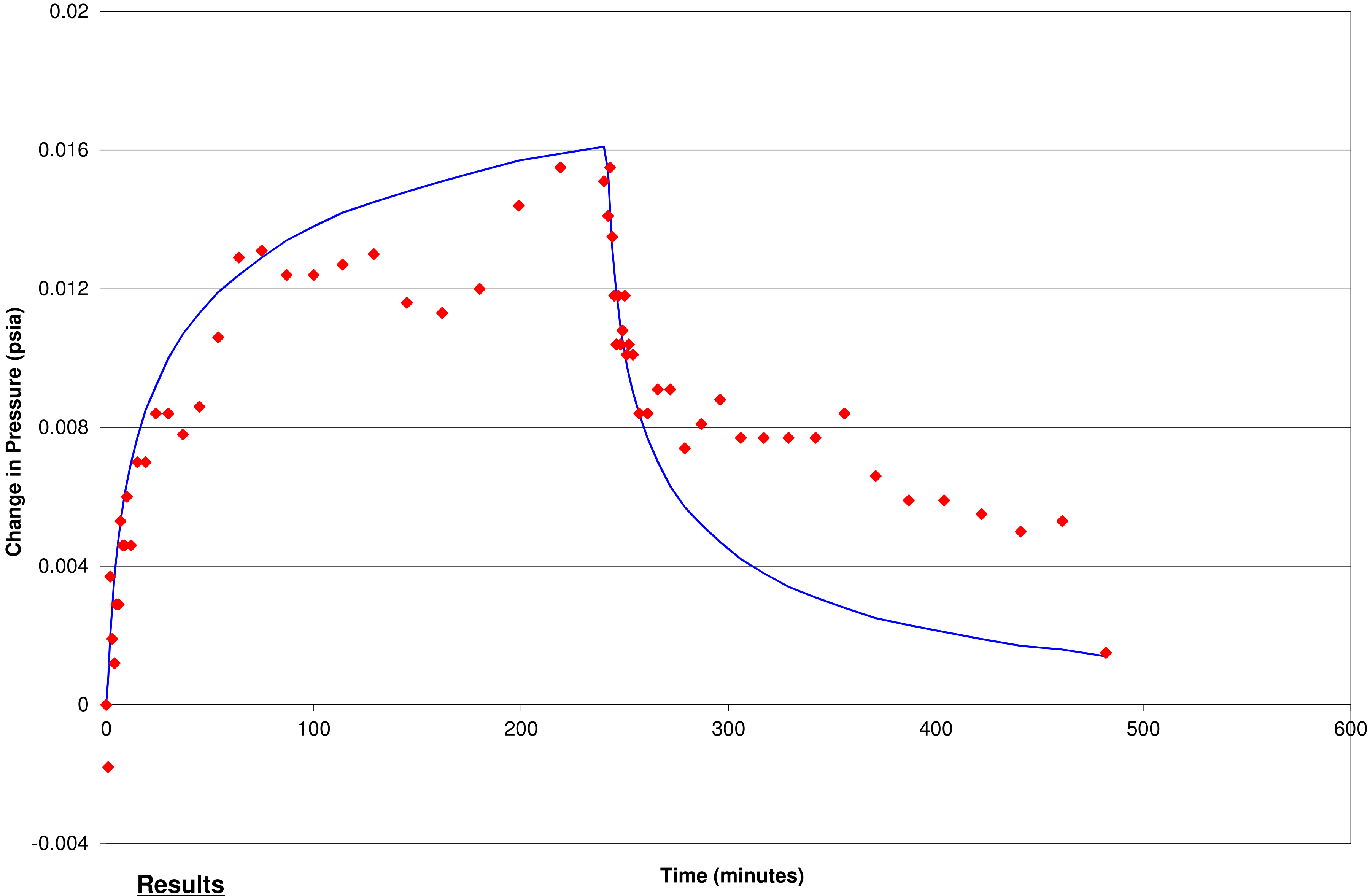
Results

horizontal gas permeability = 100.0 darcies
vertical gas permeability = 6.0 darcies
confining layer permeability = 0.5 darcies
gas porosity = 0.5

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-15-20 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009055	55



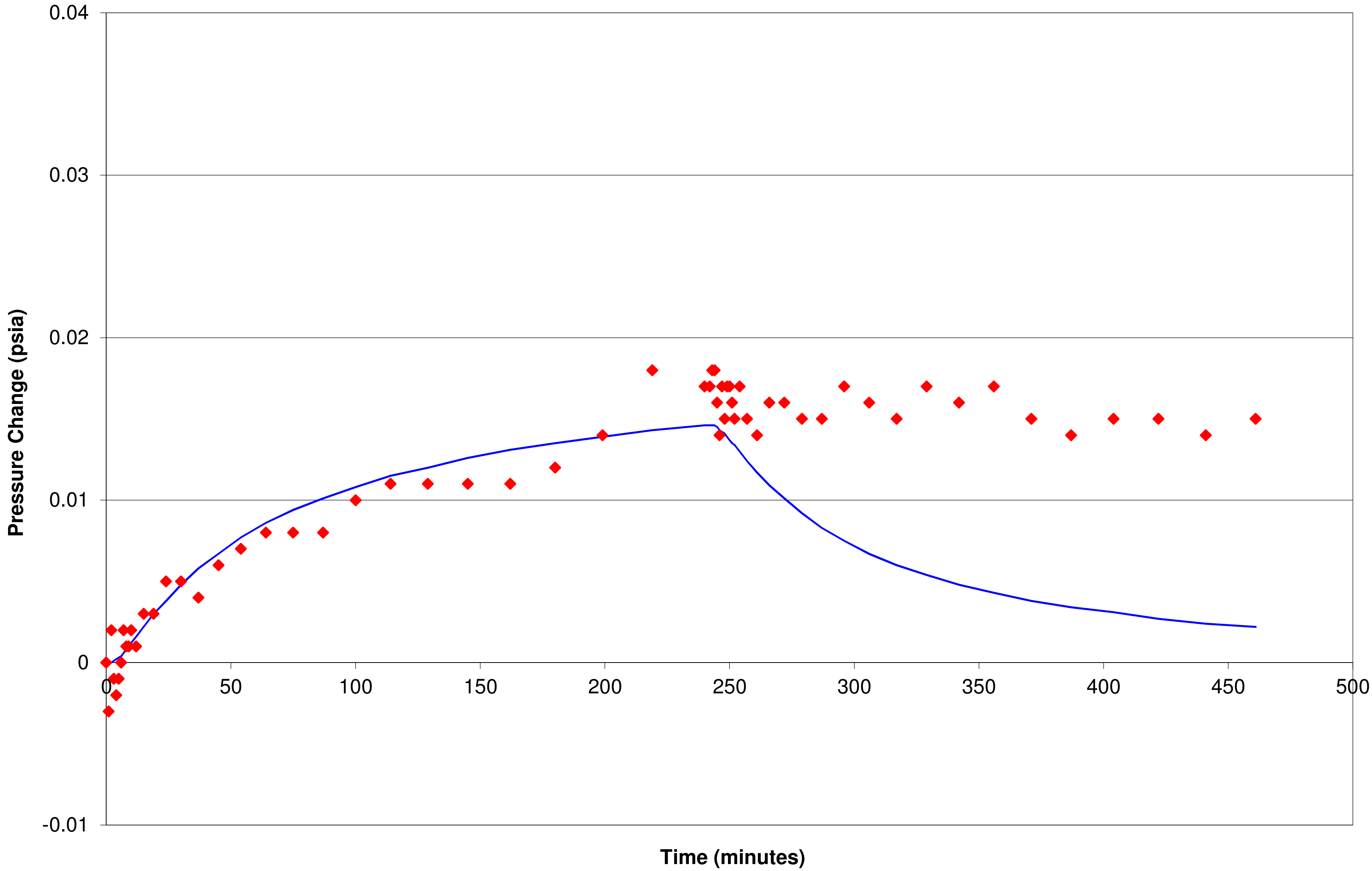
Results

horizontal gas permeability = 80.0 darcies
vertical gas permeability = 1.0 darcies
confining layer permeability = 0.5 darcies
gas porosity = 5.0*

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-15-50 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009056	56



Results

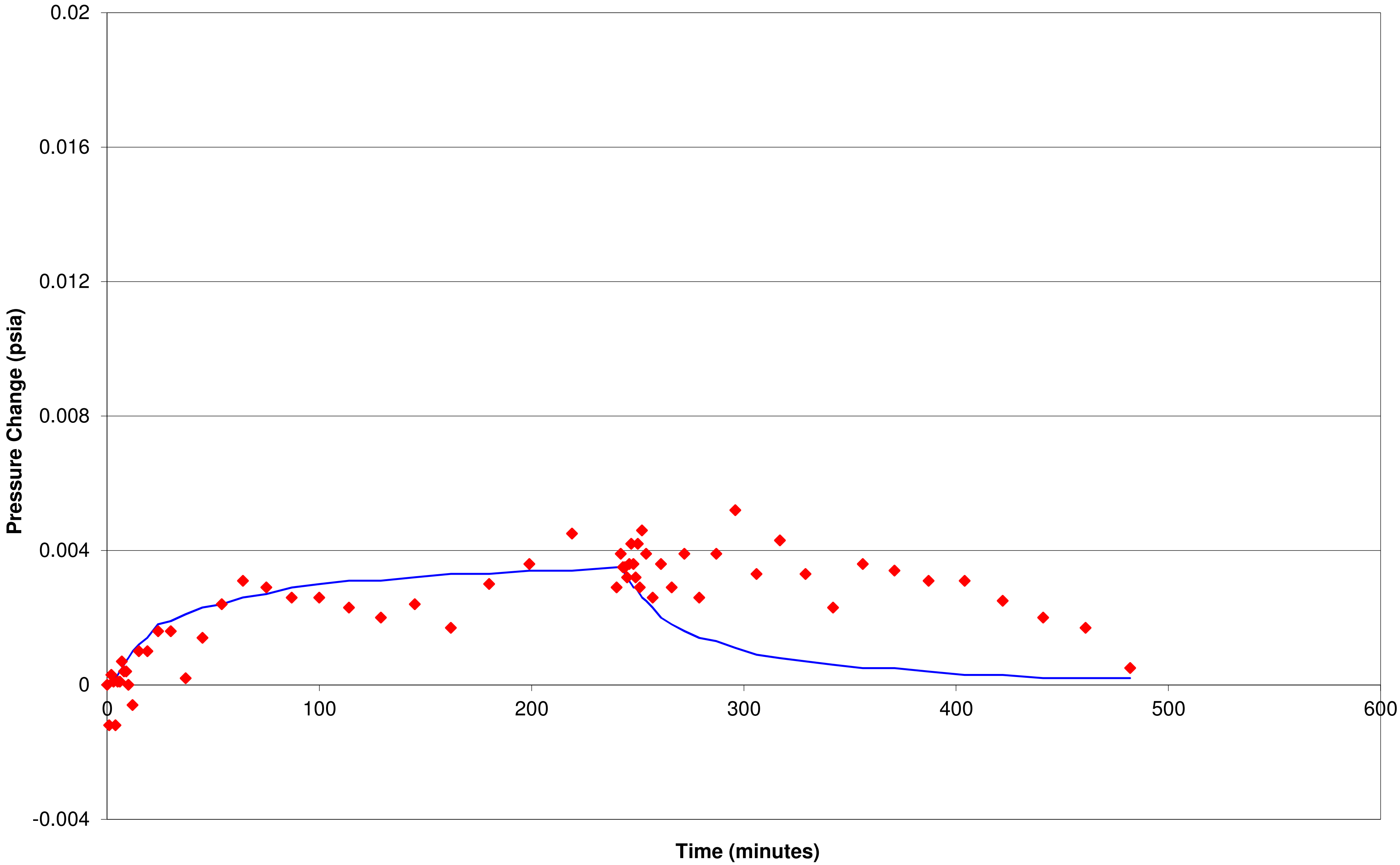
horizontal gas permeability = 25.0 darcies
vertical gas permeability = 1.0 darcies
confining layer permeability = 0.2 darcies
gas porosity = 0.35

Observed
Simulated

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-15-100 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009057	57



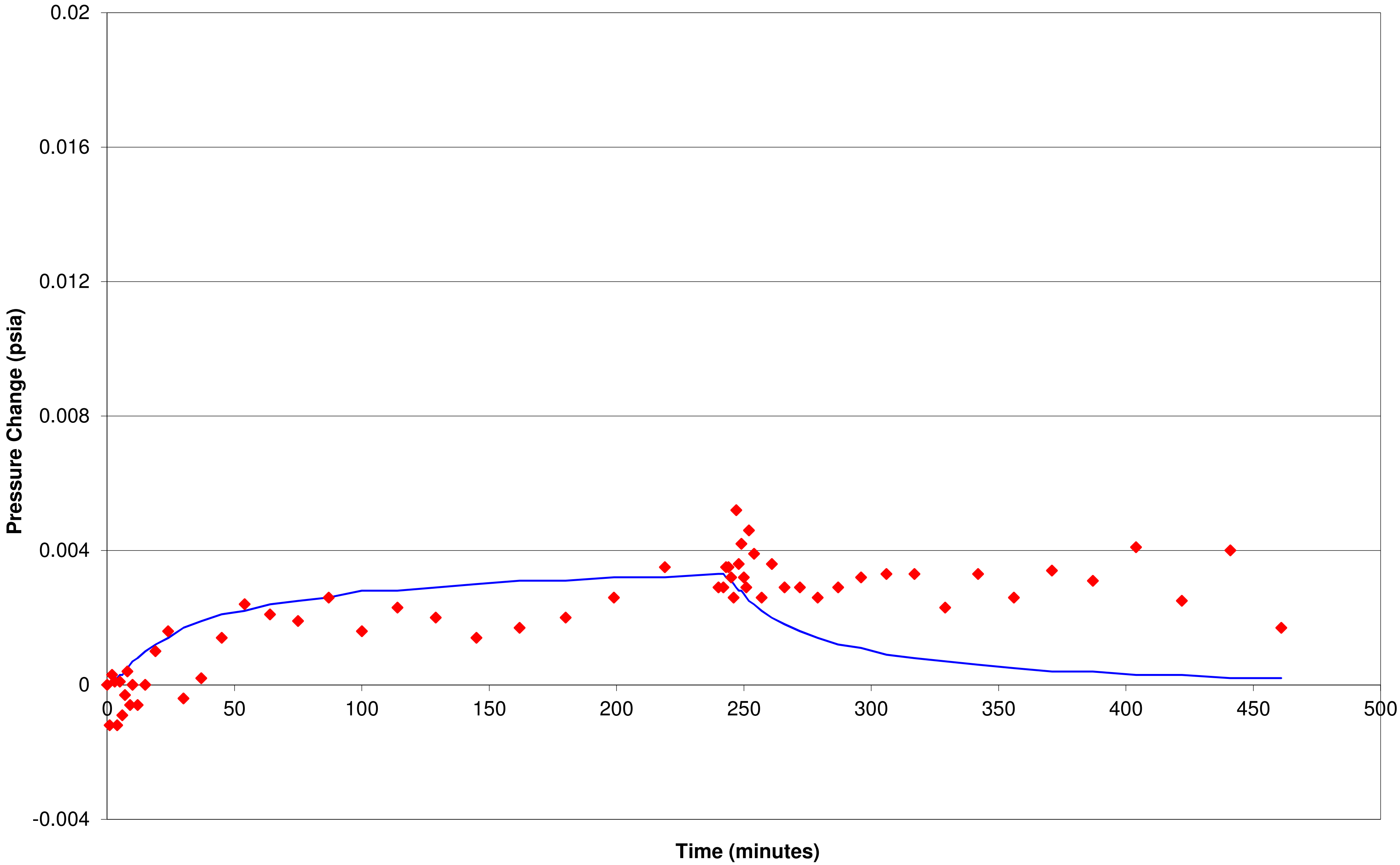
Results

horizontal gas permeability = 120.0 darcies
vertical gas permeability = 4.0 darcies
confining layer permeability = 0.5 darcies
gas porosity = 0.4

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-45-17 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009058	58

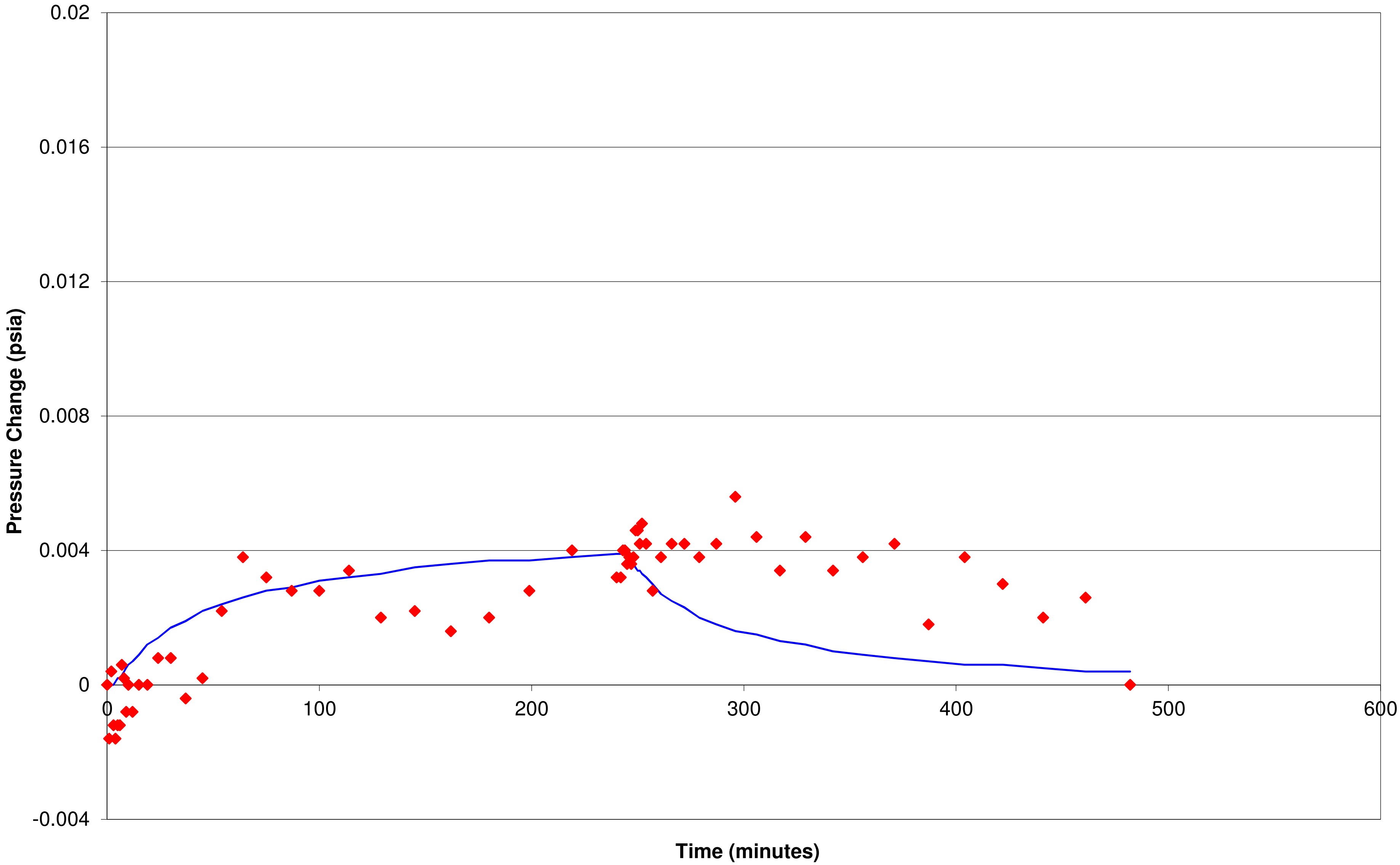


Results
horizontal gas permeability = 120.0 darcies
vertical gas permeability = 4.0 darcies
confining layer permeability = 0.5 darcies
gas porosity = 0.4

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-75-17 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009059	59



Results

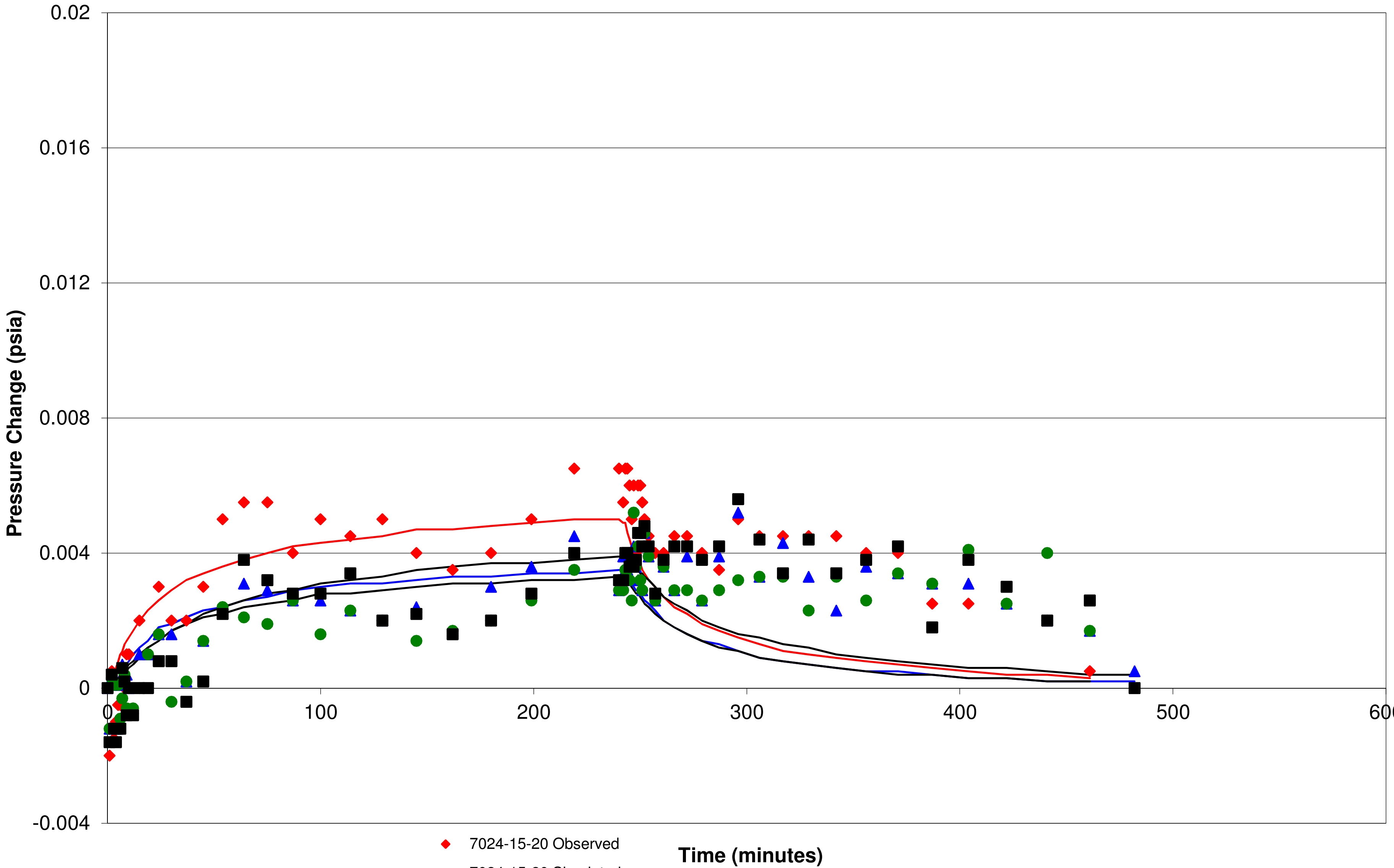
horizontal gas permeability = 100.0 darcies
vertical gas permeability = 4.0 darcies
confining layer permeability = 0.3 darcies
gas porosity = 0.4

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024-105-17 DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009060	60

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\14_Figures55thru61.xls: Figure 60



Results

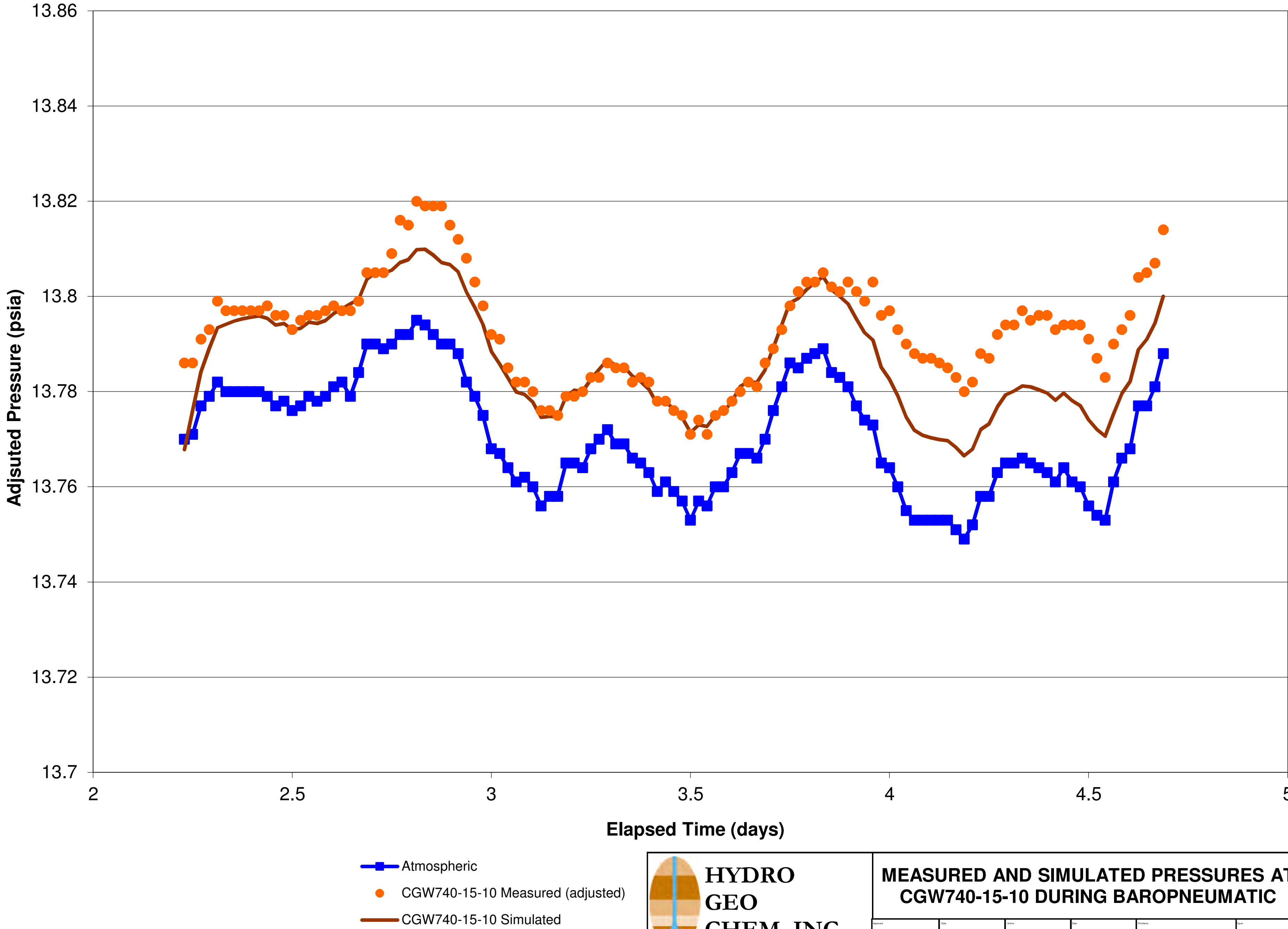
horizontal gas permeability = 130.0 darcies
vertical gas permeability = 6.0 darcies
confining layer permeability = 0.5 darcies
gas porosity = 0.49

HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURE CHANGE AT GW7024 SHALLOW PROBES DURING SHUT-IN TEST

Approved	Date	Author	Date	File Name	Figure
SJS	3/6/15	GEM	11/11/14	2013009061	61

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\14_Figures55thru61.xls: Figure 61

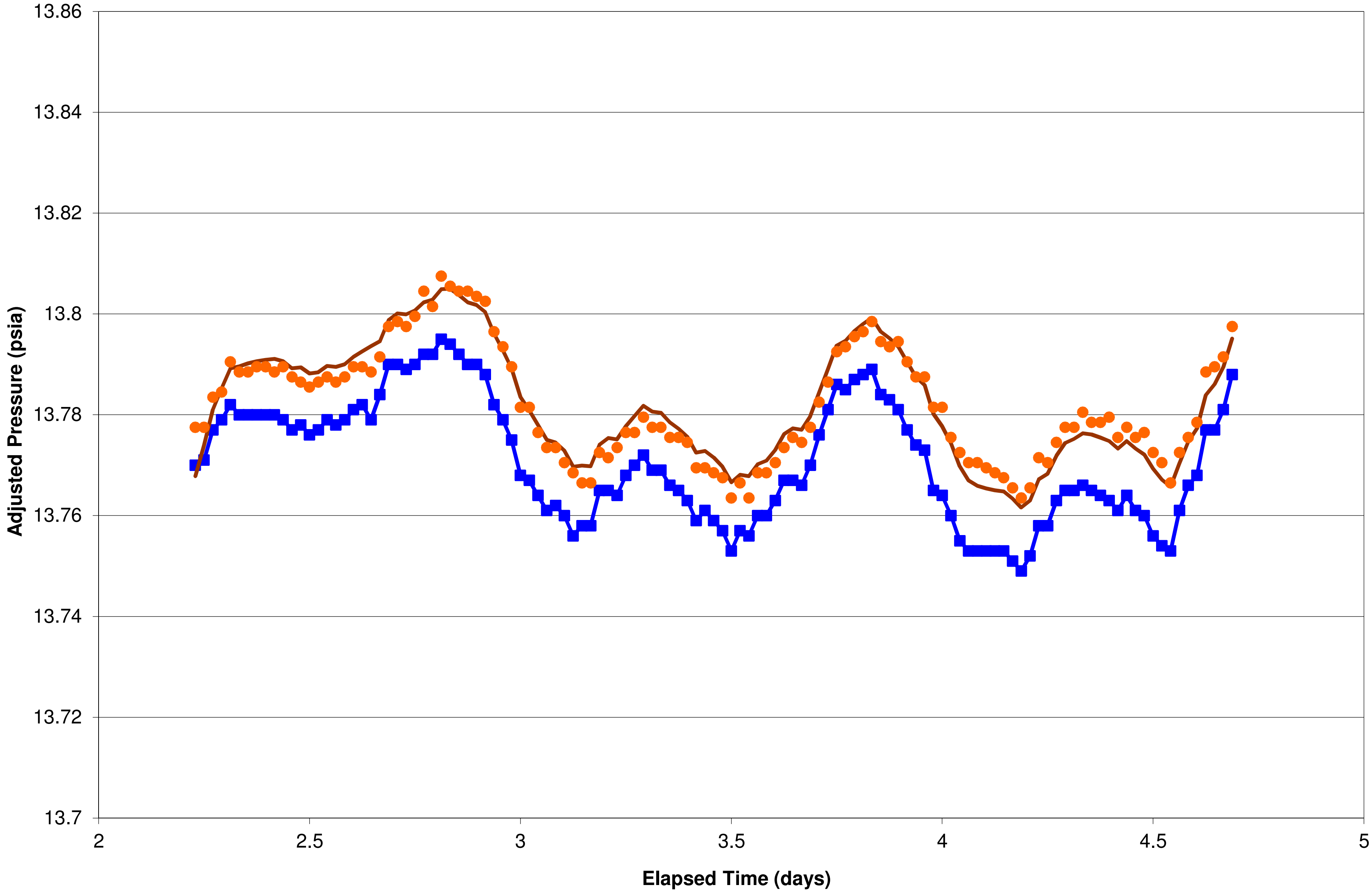


HYDRO
GEO
CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW740-15-10 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009062	62

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\15_Figures62thru65.xls: Figure 62

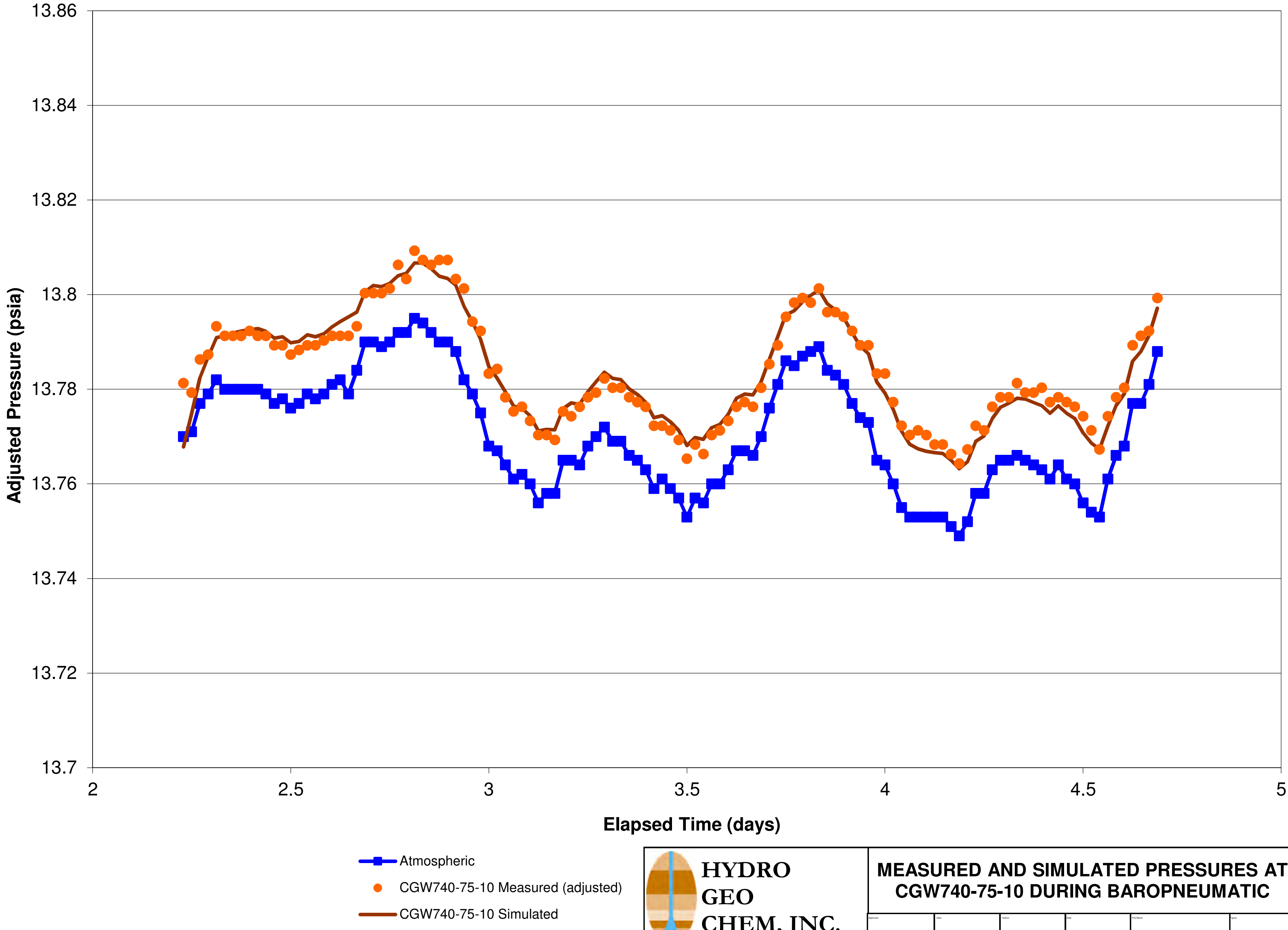


HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW740-45-10 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009063	63

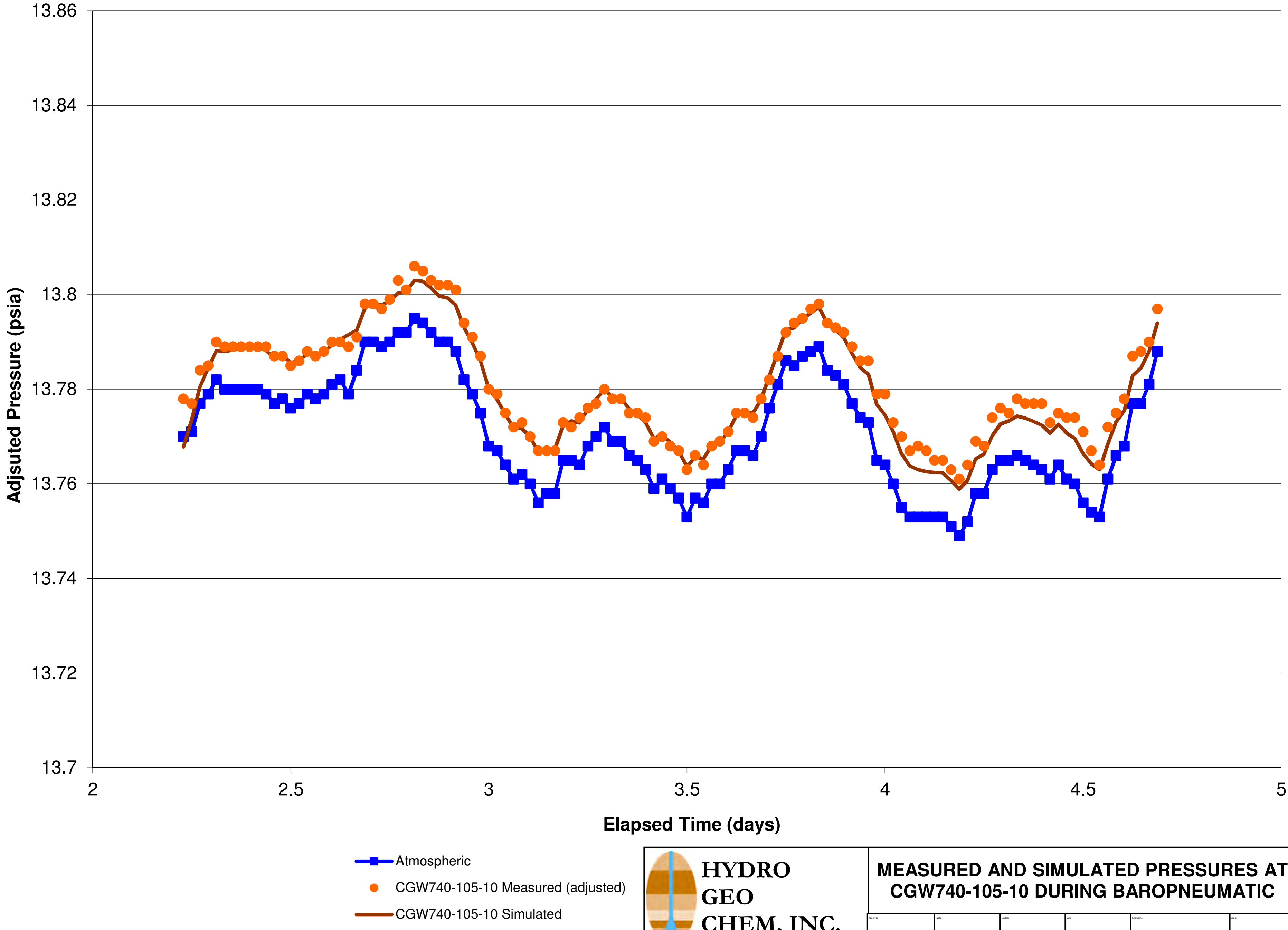
H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\15_Figures62thru65.xls: Figure 63



HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW740-75-10 DURING BAROPNEUMATIC

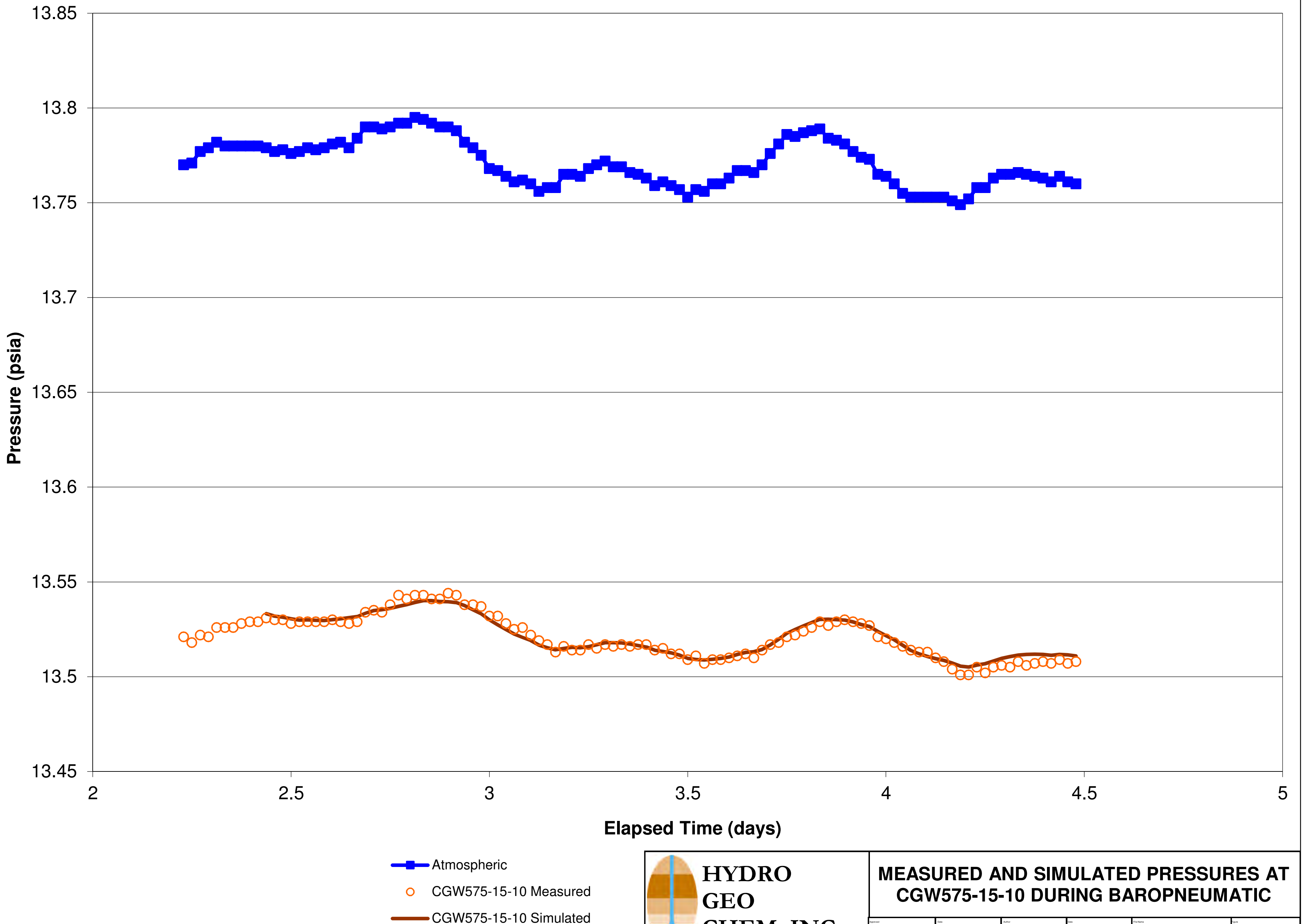
SJS	3/6/15	GEM	11/11/14	2013009064	64



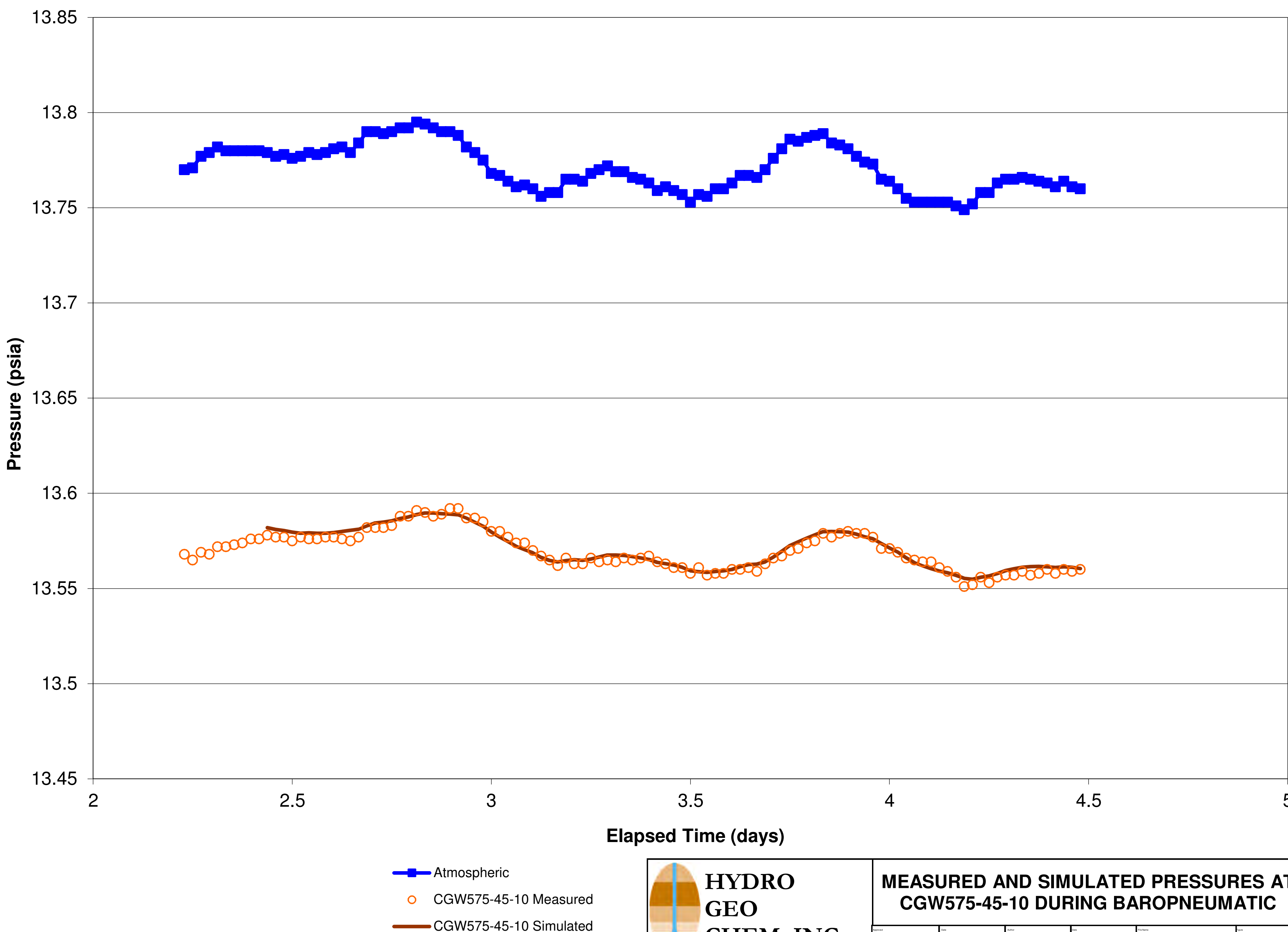
HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW740-105-10 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009065	65



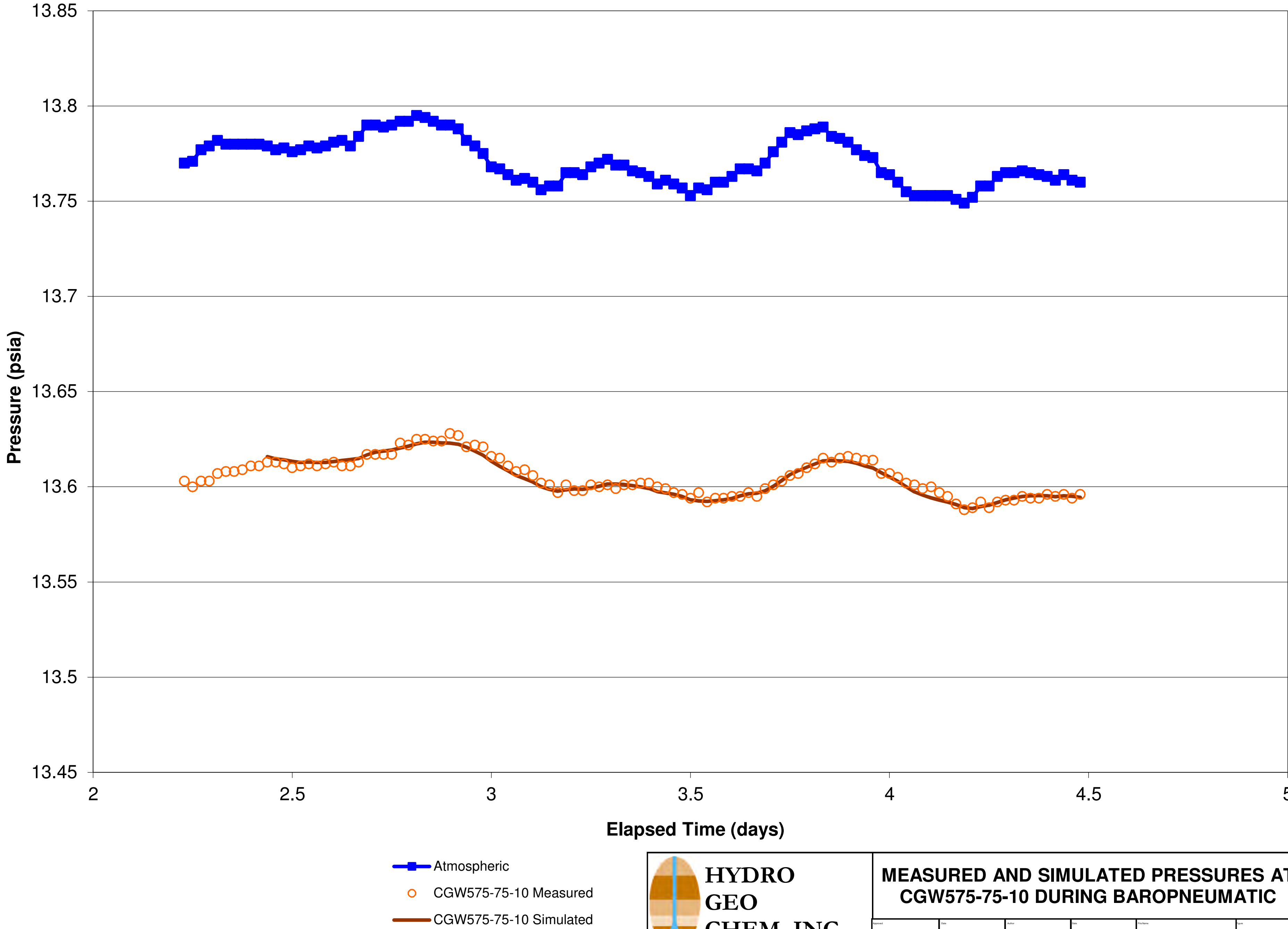
HYDRO GEO CHEM, INC.	MEASURED AND SIMULATED PRESSURES AT CGW575-15-10 DURING BAROPNEUMATIC					
	SJS	3/6/15	GEM	11/11/14	2013009066	66



HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW575-45-10 DURING BAROPNEUMATIC

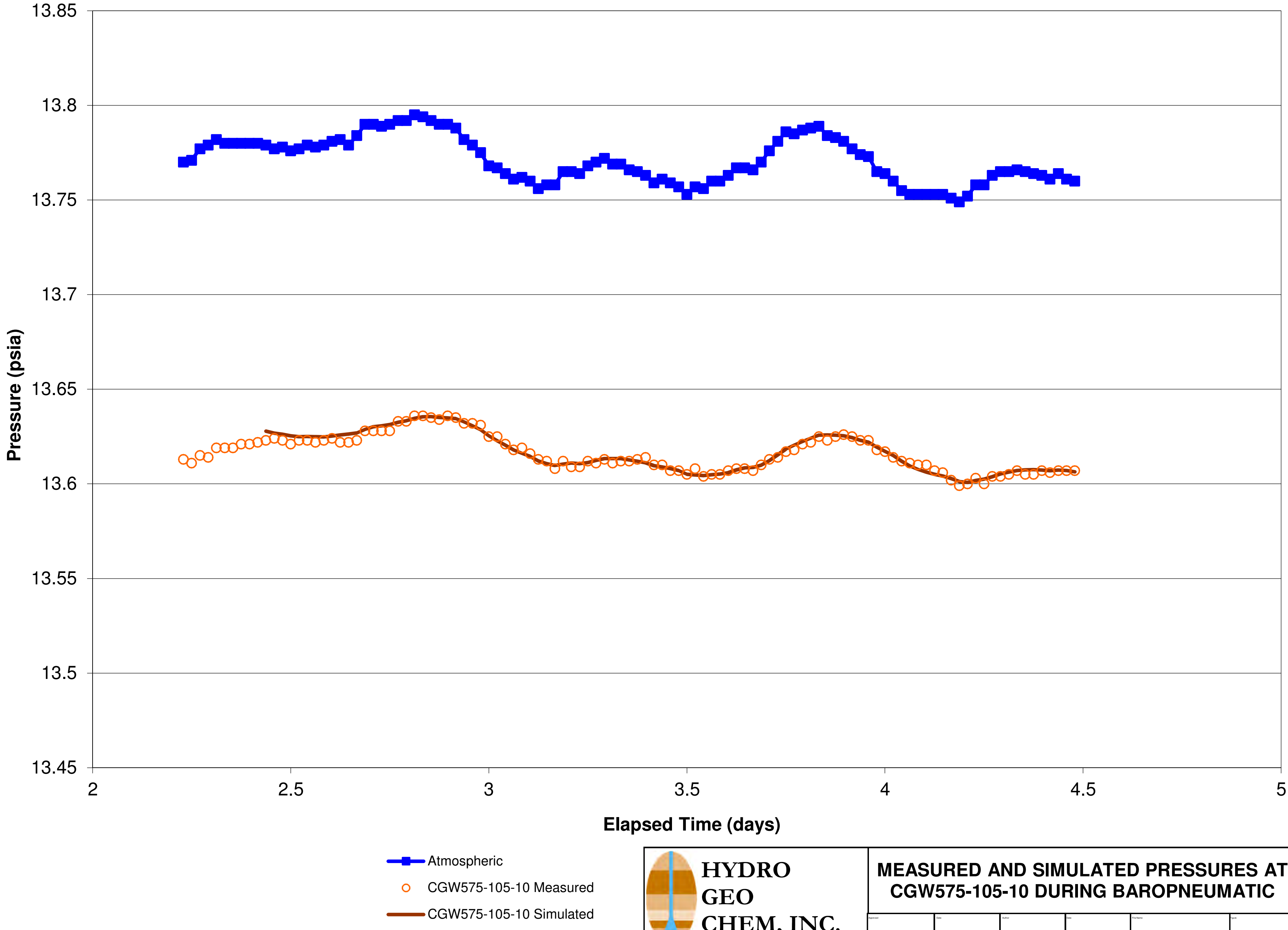
SJS	3/6/15	GEM	11/11/14	2013009067	67



HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW575-75-10 DURING BAROPNEUMATIC

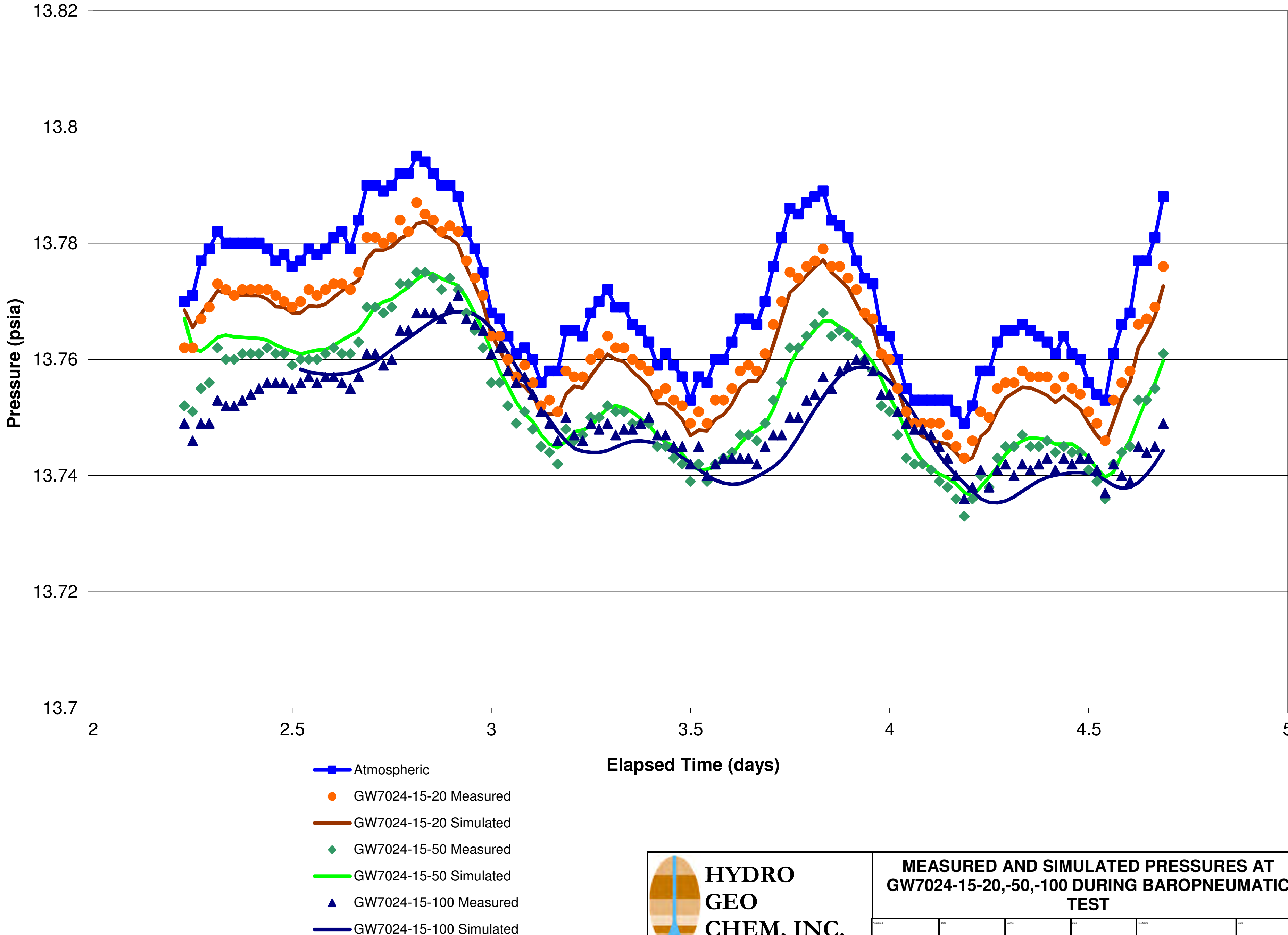
SJS	3/6/15	GEM	11/11/14	2013009068	68



HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT CGW575-105-10 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009069	69

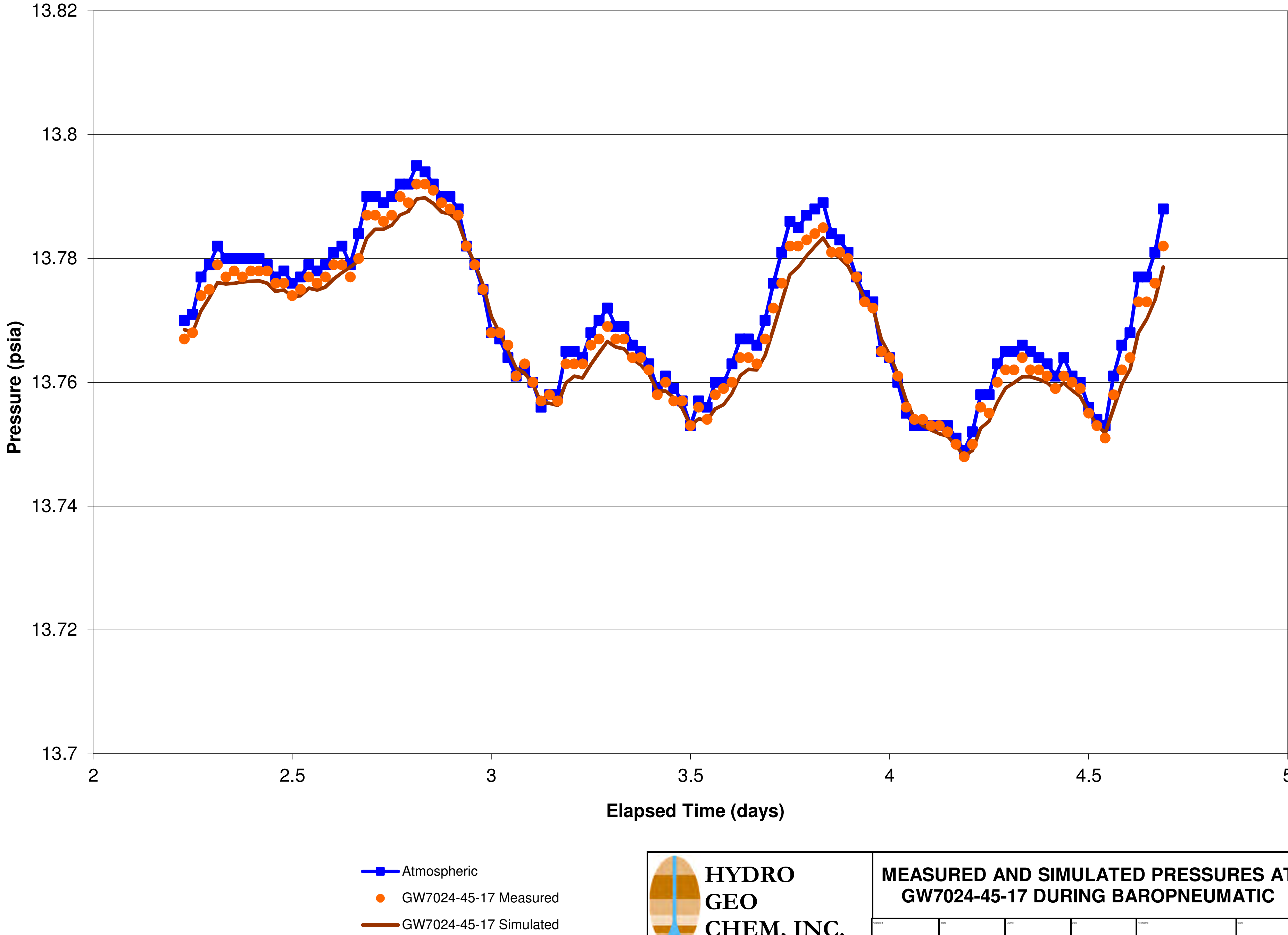


HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT GW7024-15-20,-50,-100 DURING BAROPNEUMATIC TEST

SJS	3/6/15	GEM	11/11/14	2013009070	70

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\17_Figures70thru73.xls: Figure 70

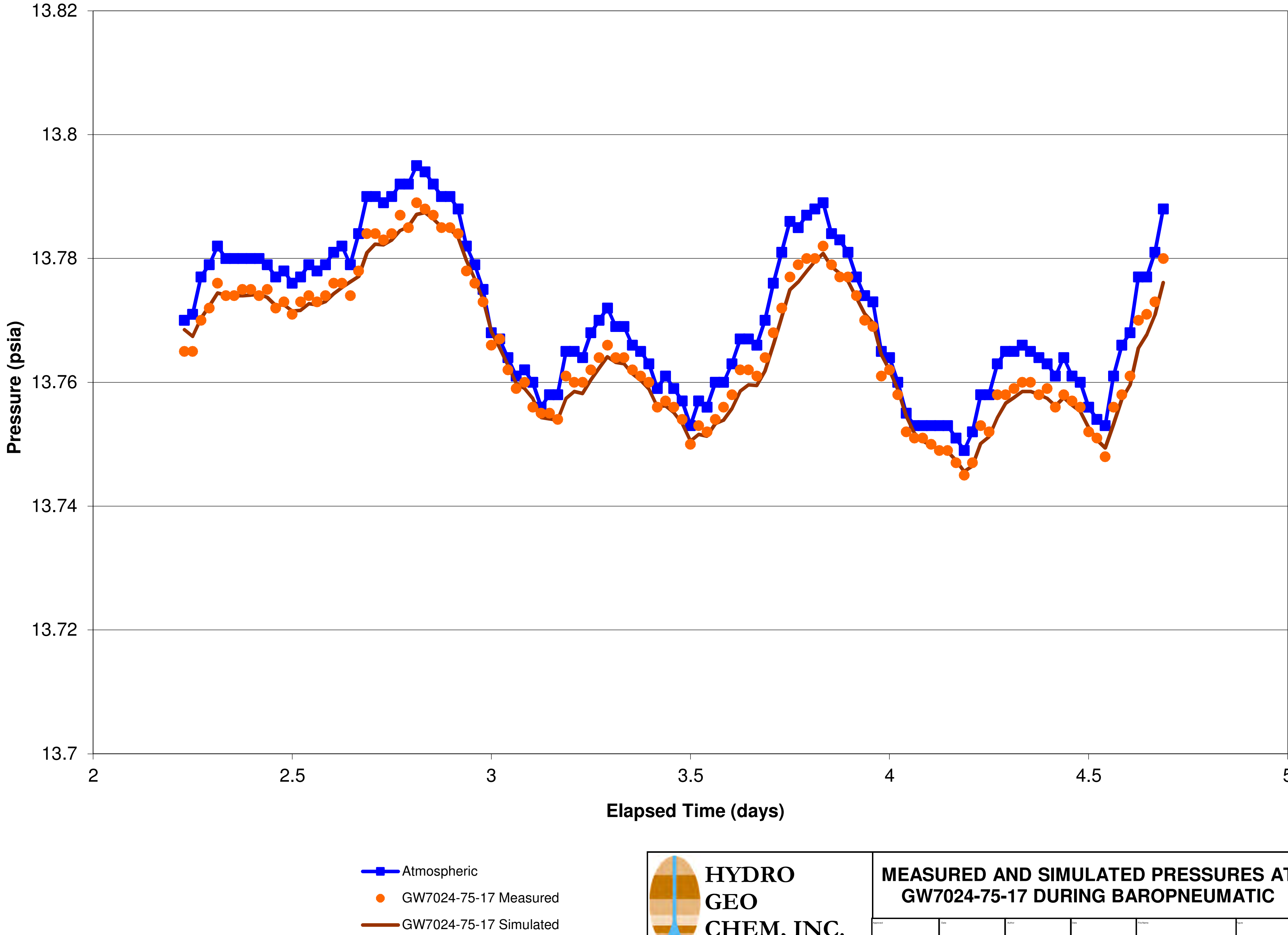


HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT GW7024-45-17 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009071	71

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\17_Figures70thru73.xls: Figure 71

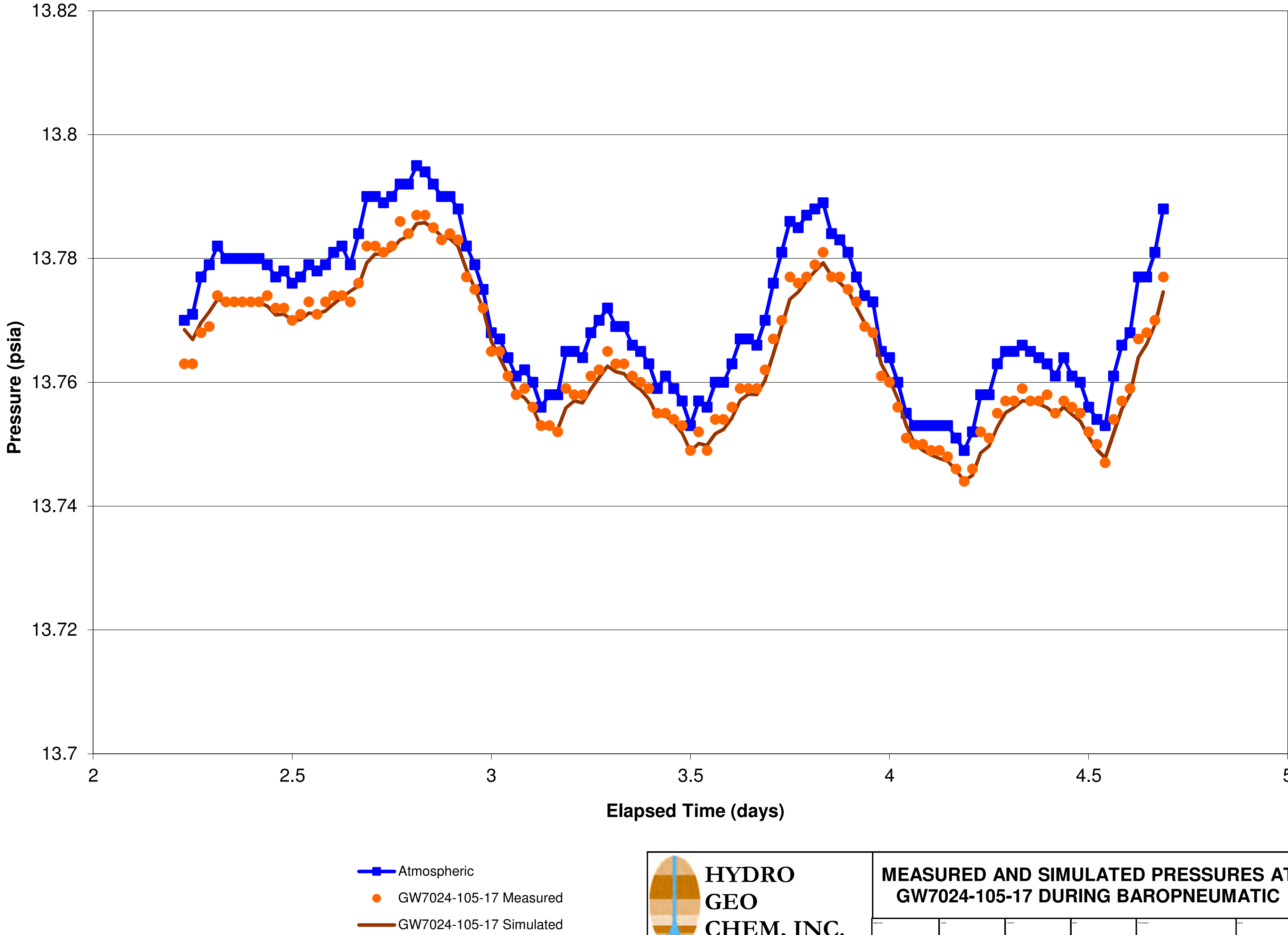


HYDRO GEO CHEM, INC.

MEASURED AND SIMULATED PRESSURES AT GW7024-75-17 DURING BAROPNEUMATIC

SJS	3/6/15	GEM	11/11/14	2013009072	72

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\17_Figures70thru73.xls: Figure 72



HYDRO GEO CHEM, INC.	MEASURED AND SIMULATED PRESSURES AT GW7024-105-17 DURING BAROPNEUMATIC					
	SJS	3/6/15	GEM	11/11/14	2013009073	73

H:\2013009.00 SCAQMD Sunshine Canyon LF\report\Figures\17_Figures70thru73.xls: Figure 73

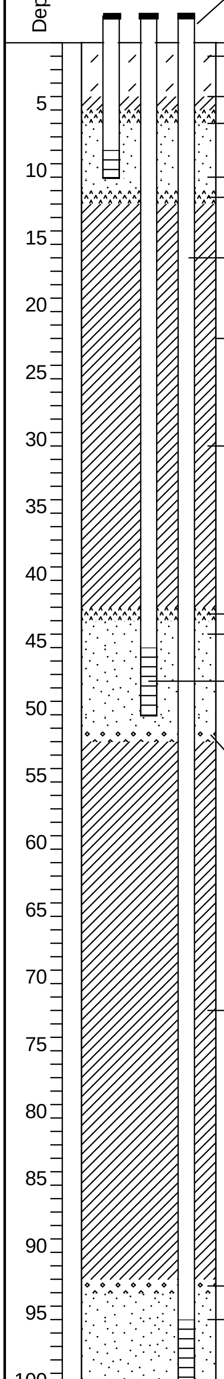
APPENDIX A

TEST PROBE CONSTRUCTION SCHEMATICS AND BORING LOGS

Project: Sunshine Landfill | **Boring:** CGW-575-15 | Pg. 1 of 1

Drilling Co:	Tetra Tech - W. Romanowski	Drilling Method:	Auger	Date Started:	6/24/14
Location:	15' from pumping well	Sampler:	W. Thompson	Date Completed:	6/25/14
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	WT

WELL COMPLETION



Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
0–6		Silt - dark yellowish brown (10YR4/4); trace gravel to 1" max diameter, subangular to rounded; sand fraction is fine grained; soft texture; non-plastic; damp
6		Refuse - very dark grayish brown (10YR3/1); primarily household waste mixed with silt; highly degraded
		unable to determine exact cover soil and refuse lift contact due to the augering process; damp; very strong acidic odor
52		very dark gray to black (10YR3/1 to 10YR2/1); very degraded; humic like texture; homogenous; very strong acidic odor; damp
100		Total depth 100' bls

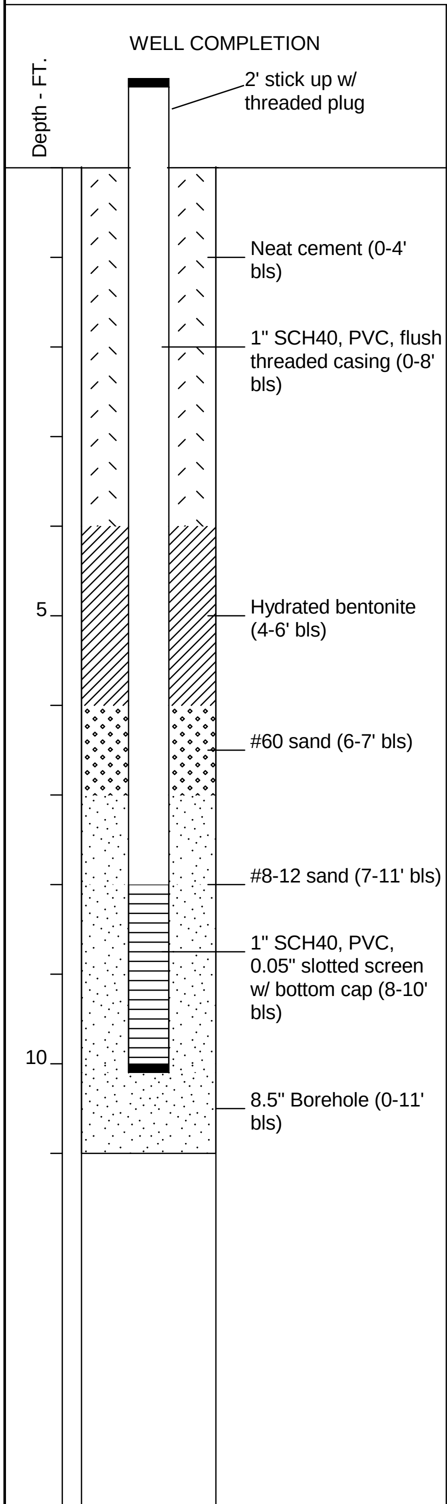
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of CGW-575-15

Approved	Date	Revised	Date	Reference:	FIG.
SS	9/24/14	BV	9/22/14		

Project: Sunshine Landfill | Boring: **CGW-575-45** | Pg. 1 of 1

Drilling Co:	Tetra Tech - W. Romanowski	Drilling Method:	Auger	Date Started:	6/25/14
Location:	45' from pumping well	Sampler:	W. Thompson	Date Completed:	6/25/14
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	WT



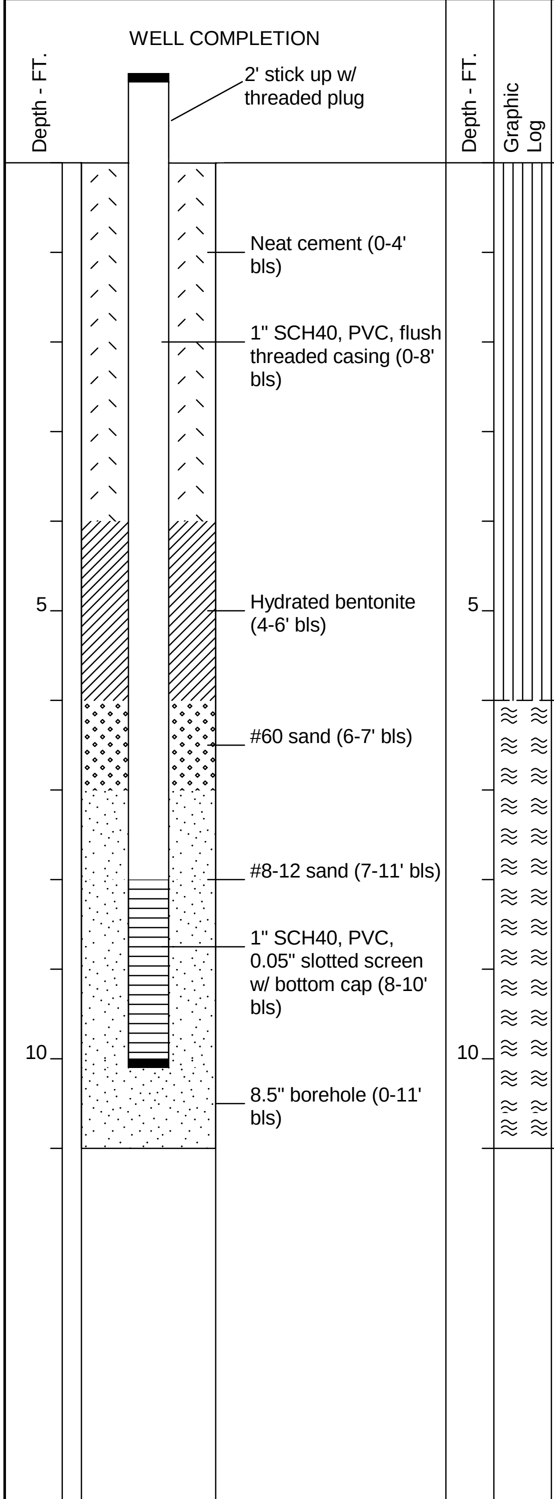
Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
0–6		Silt - dark gray (10YR4/1); trace gravel to 1" max diameter, subangular to rounded; minor sand fraction is fine grained; soft gritty texture; damp at 2' bls
6–11		Refuse - primarily household waste paper, plastic, wood fibers, etc.; fairly well preserved at top gradually becoming more degraded with depth
11		Total depth 11' bls

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of CGW-575-45

Approved	Date	Revised	Date	Reference:	FIG.
SS	9/24/14	BV	9/22/14		

Project:	**Sunshine Landfill**		Boring:	**CGW-575-75**	Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/25/14**
Location:	**75' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/25/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**



DESCRIPTION
(see lithologic log for details)

Silt - dark gray (10YR4/1); trace gravel to 1" max diameter, subangular to rounded; sand fraction is fine grained; soft gritty texture; nonplastic; damp at 2' bls

Refuse - primarily household waste paper, plastic, metal, wood fibers, etc.; fairly well perserved at top gradually becoming more degraded with depth; strong acidic odor; damp

Total depth 11' bls

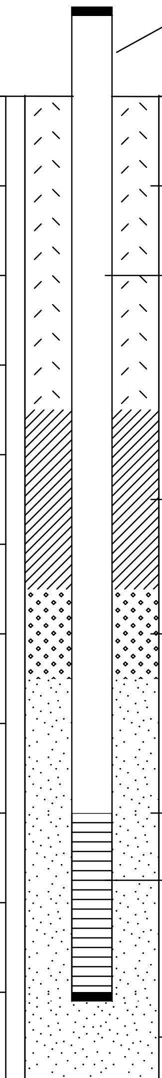
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of CGW-575-75

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**		Boring:	**CGW-575-105**	Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/26/14**
Location:	**105' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/26/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION



Depth - FT.	Well completion	Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
	2' stick up w/ threaded plug			
0–5	Neat cement (0-3.5' bls); 1" SCH40, PVC, flush threaded casing (0-9' bls); Hydrated bentonite (3.5-5.5' bls)	0–5		Silt - very dark grayish brown (10YR3/2); trace gravel to 1" max diameter, subangular to rounded; sand fraction is fine grained; soft gritty texture; damp at 2' bls
5–11	#60 sand (5.5-6.5' bls); #8-12 sand (6.5-11' bls); 1" SCH40, PVC, 0.05" slotted screen w/ bottom cap (8-10' bls); 8.5" borehole (0-11' bls)	5–11		Refuse - primarily household waste paper, plastic, metal, glass, etc.; well preserved at top gradually becoming more degraded with depth to a fiberous humic like mulch
				Total depth 11' bls

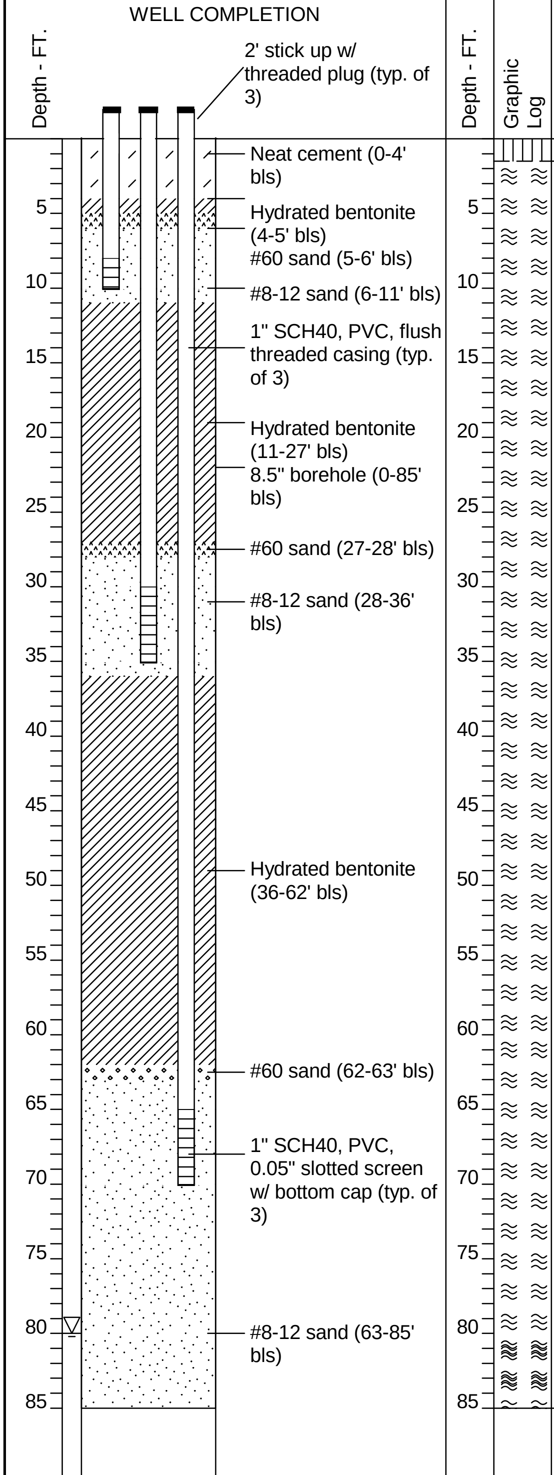
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of CGW-575-105

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**			Boring:	**CGW-740-15** Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/26/14**
Location:	**15' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/26/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION



DESCRIPTION
(see lithologic log for details)

Silt - yellowish brown (10YR5/4); trace gravel to 3" max diameter, angular; few cobbles to 8" max diameter; sand fraction is fine grained; soft gritty texture; non-plastic; slightly damp

Refuse - primarily household waste paper, plastic, metal, glass, etc.; fairly well preserved; strong acidic odor

highly degraded to a black fiberous humic like mulch; strong acidic odor

water encountered at ~80' bls

Total depth 85' bls

HGC-WELL-IUC SUNSHINE LANDFILL.GPJ NEWPROJ.GDT 10/10/14

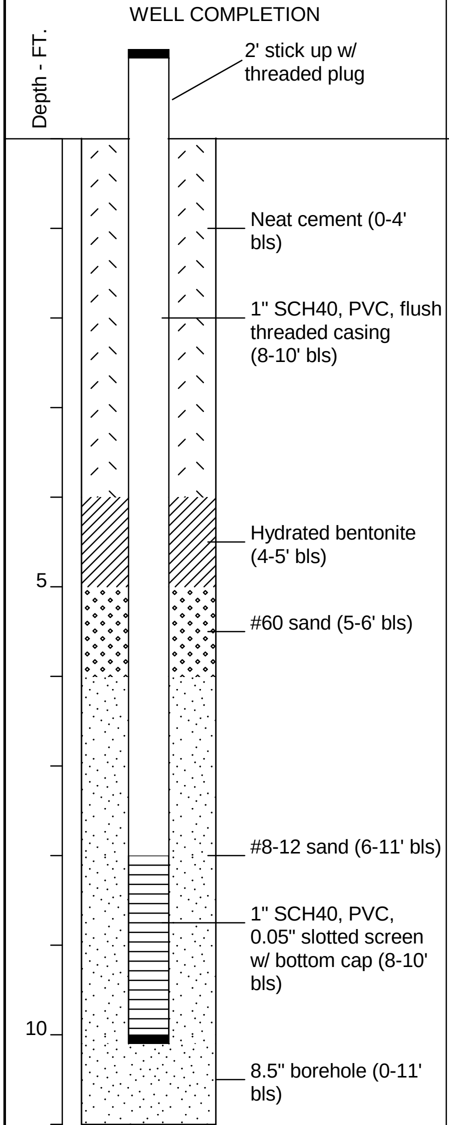
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of CGW-740-15

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**			**Boring:**	**CGW-740-45** Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/27/14**
Location:	**45' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/27/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION



Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
0		Silt - yellowish brown (10YR5/4); trace gravel to 2" max diameter, subangular to rounded; sand fraction is fine grained; soft gritty texture; non-plastic; slightly damp
		Refuse - primarily household waste paper, plastic, metal, glass, etc.; fairly well preserved; strong acidic odor
5		
10		
		Total depth 11' bls

HYDRO GEO CHEM, INC.

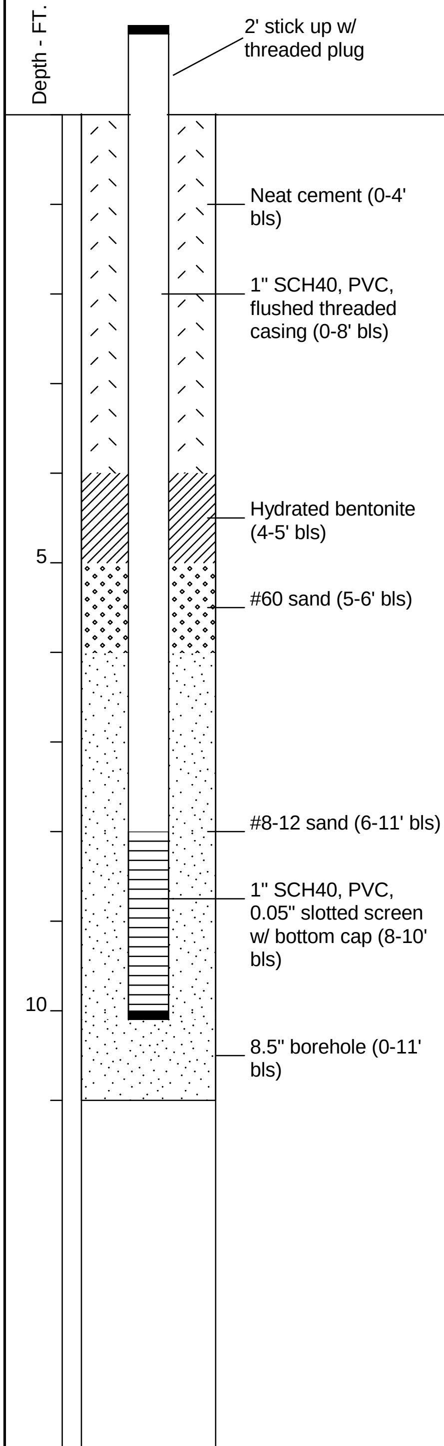
Lithologic Log and Well Construction Details of CGW-740-45

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project: Sunshine Landfill | Boring: **CGW-740-75** | Pg. 1 of 1

Drilling Co:	Tetra Tech - W. Romanowski	Drilling Method:	Auger	Date Started:	6/27/14
Location:	75' from pumping well	Sampler:	W. Thompson	Date Completed:	6/27/14
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	WT

WELL COMPLETION



Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
0–1.5		Silt - yellowish brown (10YR4/4); trace gravel to 2" max diameter; sand fraction is fine grained; soft texture; damp
1.5–11		Refuse - primarily household waste paper, plastic, metals, glass, etc.; fairly well preserved; strong acidic odor; damp
11		Total depth 11' bls

HYDRO GEO CHEM, INC.

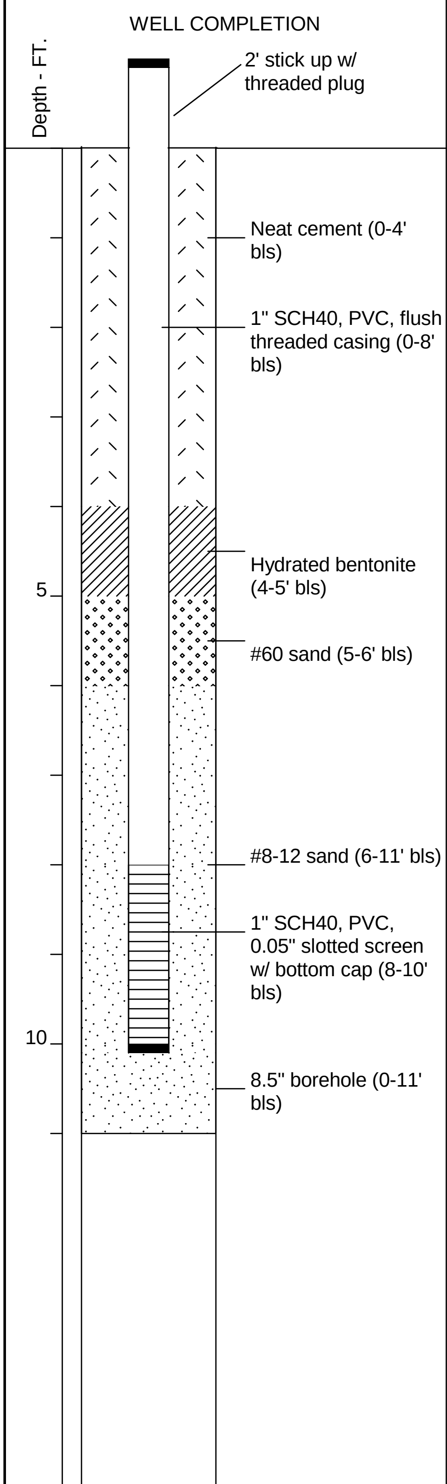
Lithologic Log and Well Construction Details of CGW-740-75

Approved	Date	Revised	Date	Reference:	FIG.
SS	9/24/14	BV	9/22/14		

HGC-WELL-IUC SUNSHINE LANDFILL.GPJ NEWPROJ.GDT 9/24/14

Project: Sunshine Landfill — Boring: **CGW-740-105** — Pg. 1 of 1

Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/27/14**
Location:	**105' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/27/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**



Depth - FT.	Graphic Log	DESCRIPTION (see lithologic log for details)
0–3		Silt - yellowish brown (10YR5/4); trace gravel to 2" max diameter, angular to subrounded; sand fraction is fine grained; soft texture; damp
3–11	≈ ≈	Refuse - primarily household waste paper, plastic, metal, glass, etc.; well preserved; strong acidic odor
11		Total depth 11' bls

HYDRO GEO CHEM, INC.

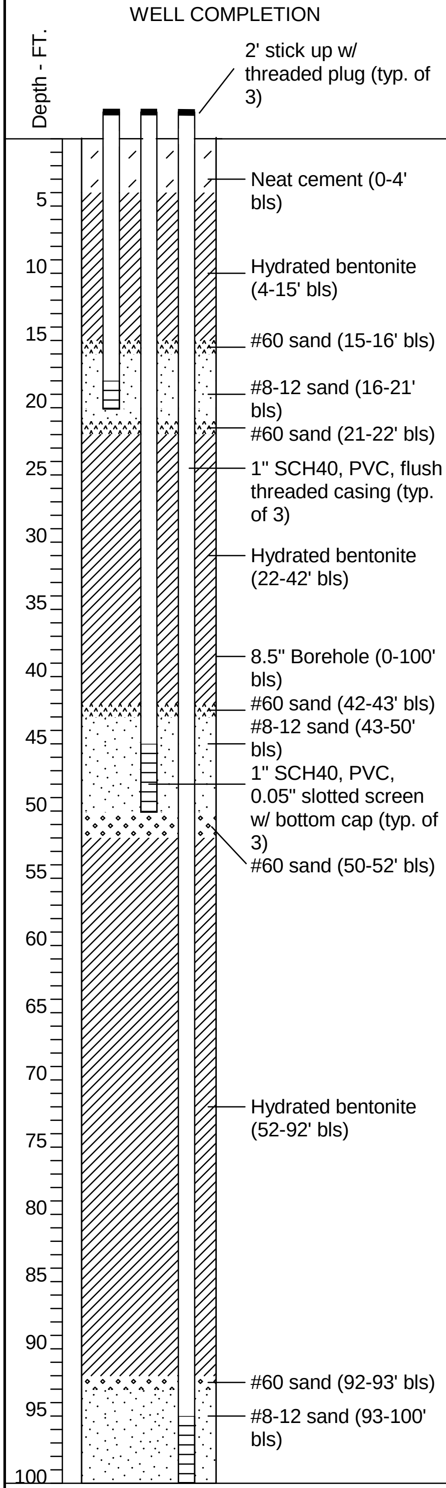
Lithologic Log and Well Construction Details of CGW-740-105

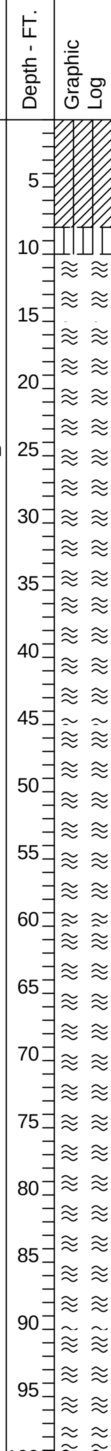
Approved	Date	Revised	Date	Reference:	FIG.
SS	9/24/14	BV	9/22/14		

HGC-WELL-IUC SUNSHINE LANDFILL.GPJ NEWPROJ.GDT 9/24/14

Project:	**Sunshine Landfill**		Boring:	**GW-7024-15**	Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/23/14**
Location:	**15' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/24/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:	________	Meas. Pt. Elev:	________	Reviewed by:	**WT**

WELL COMPLETION





DESCRIPTION
(see lithologic log for details)

Sandy Silty Clay - dark grayish brown (10YR4/2); gravel clasts to 1.5" max diameter, subangular to rounded; sand fraction medium to fine grained; cohesive; soft texture; slightly plastic; damp

Sandy Silt - dark grayish brown (10YR4/2); sand fraction is very fine grained; non plastic; cohesive; soft gritty texture; damp

Refuse - primarily household waste paper, plastic, metal, glass, etc.; moderately degraded; very strong acidic odor

Silt and Refuse Mix - very dark gray (10YR3/1); primarily wood fibers mixed with small amounts of refuse; moderately compacted; strong acidic odor

well degraded; strong sour acidic odor; damp

degraded to a compost like material with a loam like texture

decomposed refuse; black (10YR2/1); fiberous; damp

very sour acidic odor

Total depth 101.8' bls

HGC-WELL-IUC SUNSHINE LANDFILL.GPJ NEWPROJ.GDT 9/24/14

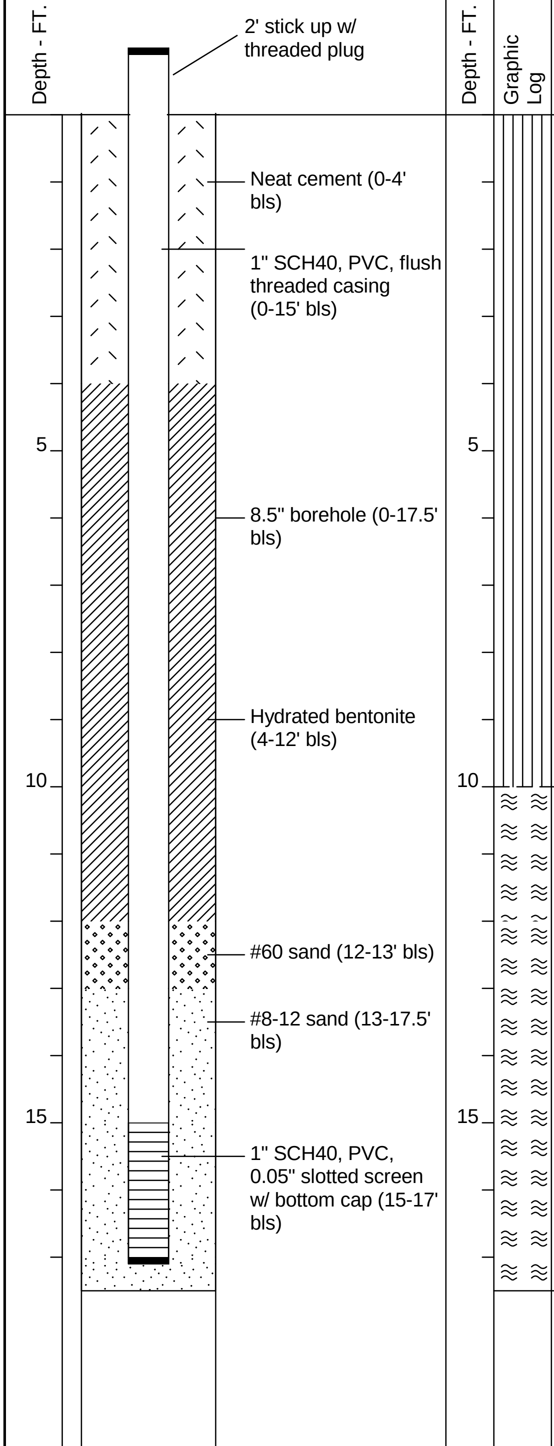
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of GW-7024-15

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**			Boring:	**GW-7024-45** Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/24/14**
Location:	**45' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/24/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION



DESCRIPTION
(see lithologic log for details)

Sandy Silt - yellowish brown (10YR5/4); some gravel clasts to 2" max diameter, subangular to rounded; sand fraction is primarily fine grained; soft texture; damp

Refuse - primarily household waste paper, wood chips and fibers, mixed with above cover material

olive brown (2.5Y4/3); fairly well degraded; fiberous humic like mulch; dry; very strong acidic odor

Total depth 17.5' bls

HYDRO GEO CHEM, INC.

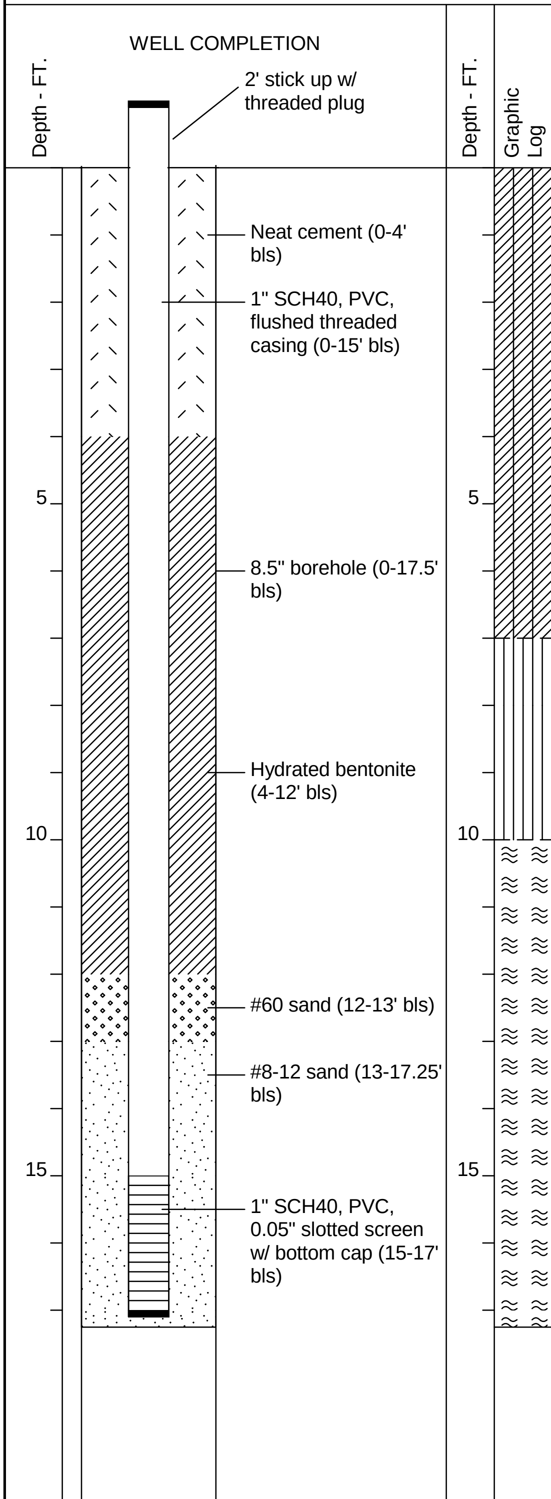
Lithologic Log and Well Construction Details of GW-7024-45

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**		Boring:	**GW-7024-75**	Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/24/14**
Location:	**75' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/24/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION

DESCRIPTION
(see lithologic log for details)



Sandy Silty Clay - olive brown (2.5Y5/3); some gravel to 1.5" max diameter, subangular to rounded; sand fraction is course to fine grained; cohesive; slightly plastic; soft texture; damp

Silt with Sand - dark yellowish brown (10YR4/4); sand fraction is fine grained; slightly cohesive; soft texture; damp

very dark gray (10YR5/3)

Refuse - dark gray (10YR4/1); well degraded fiberous material; strong acidic odor

Total depth 17.25' bls

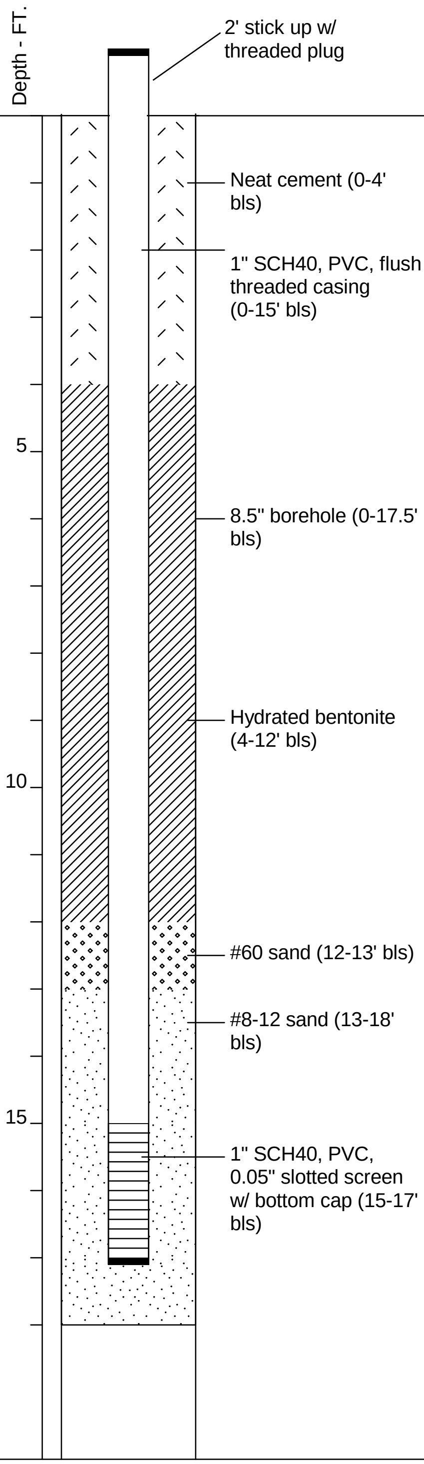
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of GW-7024-75

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

Project:	**Sunshine Landfill**			Boring: **GW-7024-105**	Pg. 1 of 1
Drilling Co:	**Tetra Tech - W. Romanowski**	Drilling Method:	**Auger**	Date Started:	**6/24/14**
Location:	**105' from pumping well**	Sampler:	**W. Thompson**	Date Completed:	**6/24/14**
		Desc. of Meas Pt:	**Land Surface Elev.**	Logged by:	**W.Thompson**
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	**WT**

WELL COMPLETION



Depth - FT.	DESCRIPTION (see lithologic log for details)
0–10	Silt with Sand- yellowish brown (10YR3/4); some gravel to 1" max diameter, subangular to rounded; sand fraction is primarily fine grained; soft gritty texture; damp at 2' bls
10–18	Refuse - very dark gray (10YR3/1); degraded fiberous material; strong acidic odor; damp
18	Total depth 18' bls

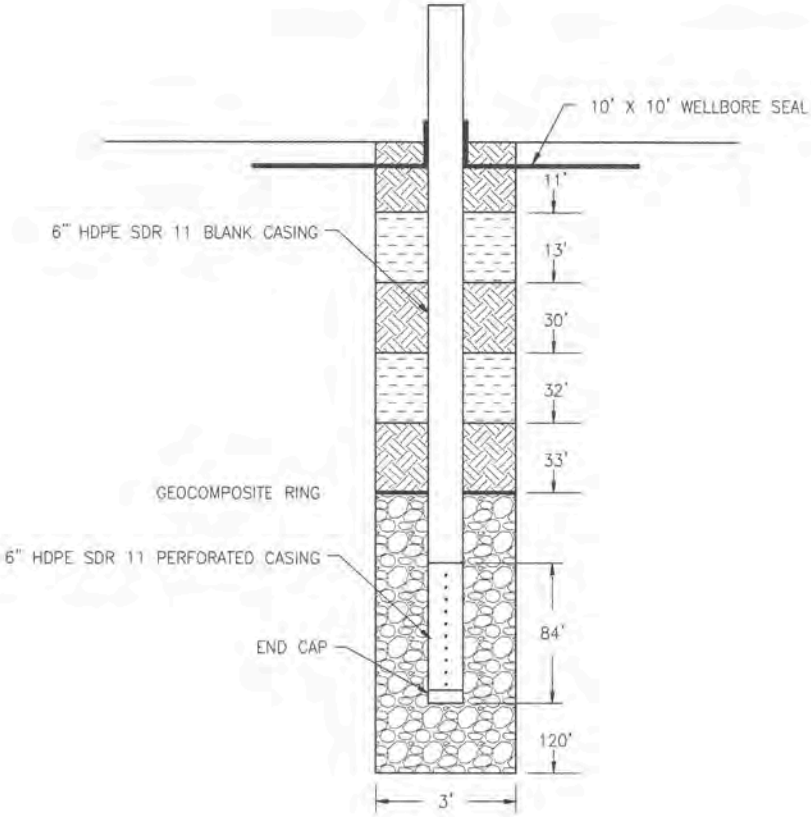
HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of GW-7024-105

Approved	Date	Revised	Date	Reference:	FIG.
SS	**9/24/14**	**BV**	**9/22/14**		

APPENDIX B

CONSTRUCTION SCHEMATICS FOR LFGCS WELLS CGW740, CGW575, AND GW7024

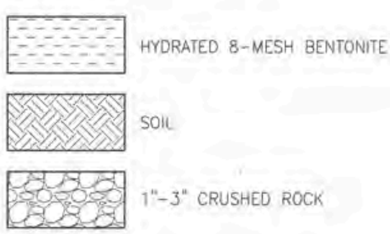


WELL PW-75

WELL DATA

WELL ID	NORTHING	EASTING	SURVEYED LANDFILL SURFACE ELEVATION	ESTIMATED LANDFILL BOTTOM ELEVATION	ESTIMATED DEPTH TO LANDFILL BOTTOM	APPROXIMATE COVER DEPTH	CONSTRUCTION DATE
PW-75	4233772	4130454	1874.4	1682.9	191.5'	13'	9/19/11

LEGEND

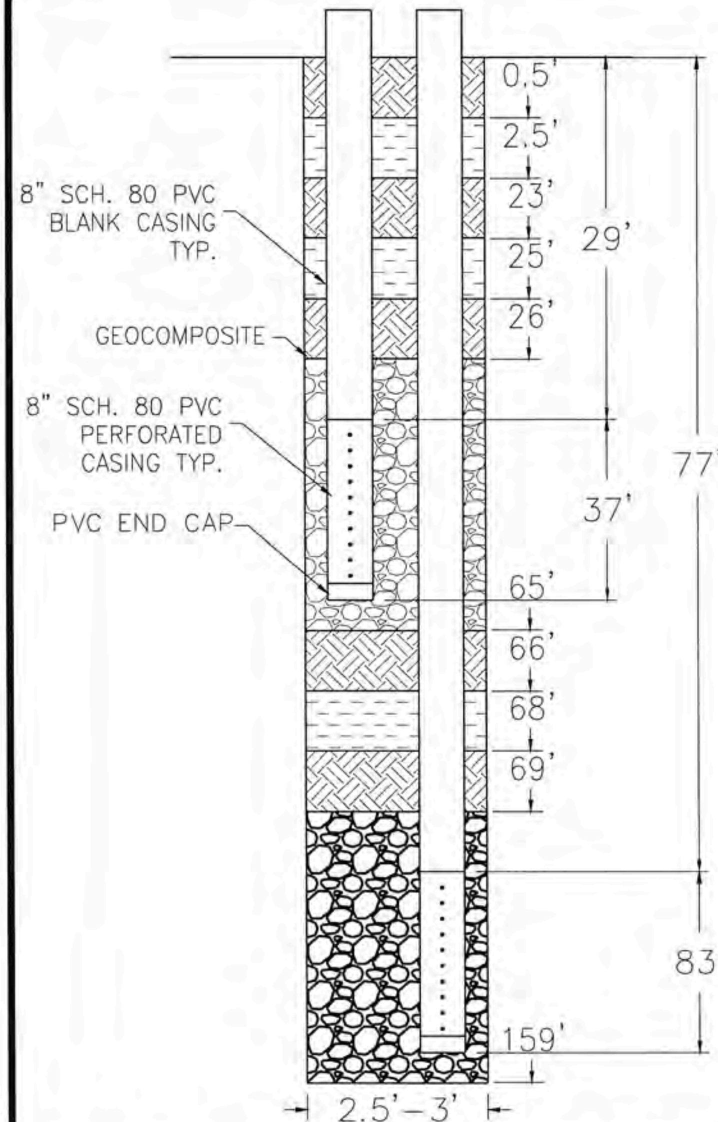


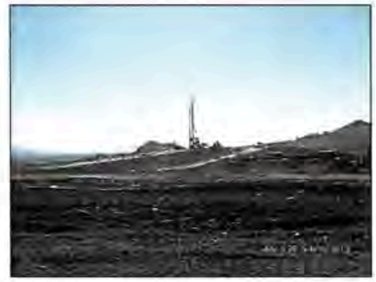
WELL CONSTRUCTION LOG
SUNSHINE CANYON LANDFILL
LFG WELLS - 2011

REPUBLIC SERVICES

GAS management services

CORONA, CA
951 317 0808




WELL SITE


DRILL CUTTINGS AT 100'


DRILL CUTTINGS AT 159'

NOTE: WASTE WAS MODERATELY TO HIGHLY DECOMPOSED. WET WASTE WAS ENCOUNTERED AT 110' AND 30" BUCKET WAS USED TO COMPLETE THE BORING. REFUSAL AT 159'.

AS BUILT DATA

WELL ID: CGW740DS
CONSTRUCTION DATE: 11/6/13
NORTHING: 4232452
EASTING: 4132224
SURFACE ELEVATION: 1781.94
APPROXIMATE COVER DEPTH: 1.0'
BOOT SEAL: YES
IRON GRATE: YES

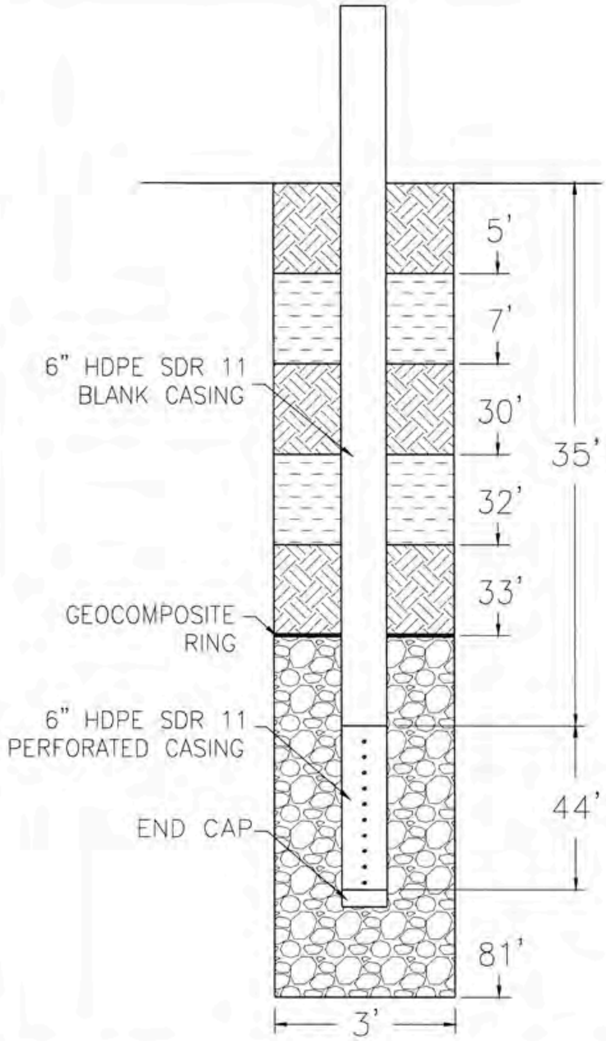
LEGEND

HYDRATED 8-MESH BENTONITE
SOIL
1"-3" CRUSHED ROCK

WELL CONSTRUCTION LOG
SUNSHINE CANYON LANDFILL
11 WELLS AUGUST 2013

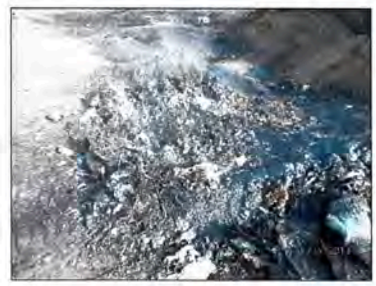
REPUBLIC SERVICES

GAS management services inc.
CORONA, CA
951 317 0808



WELL SITE

DRILL CUTTINGS AT 40'



DRILL CUTTINGS AT 81'

NOTE: WASTE WAS MODERATELY TO HIGHLY DECOMPOSED. NO WATER WAS ENCOUNTERED.

AS BUILT DATA
WELL ID: GW 7024
CONSTRUCTION DATE: 11/15/13
NORTHING: 4229789
EASTING: 4131812
SURFACE ELEVATION: 1919.00
APPROXIMATE COVER DEPTH: 7'
BOOT SEAL: YES
IRON GRATE: YES

LEGEND
HYDRATED 8-MESH BENTONITE
SOIL
1"-3" CRUSHED ROCK

WELL CONSTRUCTION LOG SUNSHINE CANYON LANDFILL 83 WELLS NOVEMBER 2013	DTE BIOMASS ENERGY	GAS management services inc. CORONA, CA 951 317 0808

APPENDIX C

EXTRACTION WELLS GAS QUALITY MONITORING DATA

TABLE C.1
Gas Quality Monitoring Data for GW-7024, CGW-740S/D and CGW-575
6/27/2014 through 7/1/2014

Well ID	Date and Time	% CH_4	% CO_2	% O_2	Balance %
GW-7024	6/27/2014 17:07	26.1	31.1	0	42.8
	6/27/2014 17:08	26.1	31.1	0	42.8
	6/27/2014 17:09	26.1	31.1	0	42.8
	6/27/2014 17:10	26.1	31.1	0	42.8
	6/27/2014 17:12	26.1	31.1	0	42.8
	6/28/2014 10:29	21.2	28.7	0	50.1
	6/30/2014 9:17	17.7	26.8	0	55.5
	6/30/2014 12:53	18.3	26.9	0	54.8
	6/30/2014 12:56	18.3	26.9	0	54.8
	6/30/2014 12:58	18.3	26.9	0	54.8
	6/30/2014 16:23	20.8	27.7	0	51.5
	6/30/2014 16:24	20.8	27.7	0	51.5
	7/1/2014 9:30	16.7	26	0.4	56.9
	7/1/2014 9:33	16.7	26	0.4	56.9
	7/1/2014 9:35	16	24.9	5.1	54
	7/1/2014 16:01	19.1	26.8	0	54.1
	7/1/2014 16:02	19.1	26.8	0	54.1
	7/1/2014 17:23	20.3	26.9	0	52.8
	7/1/2014 17:24	20.3	26.9	0	52.8
CGW-740S	6/28/2014 11:06	45.2	52.2	0	2.6
	6/30/2014 9:56	42.9	51.5	0	5.6
	6/30/2014 13:37	42.9	49.4	0.7	7
	6/30/2014 13:40	42.9	49.4	0.7	7
	6/30/2014 17:09	46.5	50.7	0	2.8
	6/30/2014 17:11	46.5	50.7	0	2.8
	6/30/2014 17:12	46.5	50.7	0	2.8
	7/1/2014 10:58	44.4	50.1	0	5.5
	7/1/2014 16:38	44.9	49.9	0	5.2
	7/1/2014 16:39	44.9	49.9	0	5.2
	7/1/2014 16:40	44.9	49.9	0	5.2
	7/1/2014 16:43	46.3	49.9	0	3.8
CGW-740D	6/28/2014 11:11	52.2	45.3	0.2	2.3
	6/30/2014 10:02	49.8	44.1	0.8	5.3
	6/30/2014 10:03	49.8	44.1	0.8	5.3
	6/30/2014 13:45	52.3	44.6	0	3.1
	6/30/2014 13:46	52.3	44.6	0	3.1
	6/30/2014 17:17	52.9	44.1	0	3
	6/30/2014 17:18	52.9	44.1	0	3
	7/1/2014 11:01	53.1	44.1	0	2.8
	7/1/2014 11:02	53.1	44.1	0	2.8
	7/1/2014 16:46	50.5	41.3	1.4	6.8
CGW-575	6/27/2014 18:10	50.6	38.7	0	10.7
	6/28/2014 10:48	48.2	38.5	0	13.3
	6/28/2014 10:49	48.2	38.5	0	13.3
	6/30/2014 9:37	45.8	38	0	16.2
	6/30/2014 13:20	46.5	38	0	15.5
	6/30/2014 13:23	46.5	38	0	15.5
	6/30/2014 16:48	47	37.5	0	15.5
	6/30/2014 16:49	47	37.5	0	15.5
	7/1/2014 10:21	44.7	37.5	0	17.8
	7/1/2014 16:26	45.1	37.2	0	17.7
	7/1/2014 16:27	45.1	37.2	0	17.7
	7/1/2014 17:05	46.1	37	0	16.9

Note:

Data recorded using LandTec GEM2000 Landfill Gas Analyzer.

TABLE C.2
Fractional Volumetric Concentrations of Major Gas Components in Air

Air Gas Component		Fraction in Air	
N_2		0.78079	
O_2		0.20946	
Argon		0.00934	
CO_2*		0.00039	
SUM		0.99998	
Balance-Gas Fraction	(N_2 + Argon)	0.79013	0.79013
Balance Gas:O_2 ratio	(N_2 + Argon):O_2	3.77222	3.77409
N_2:O_2 ratio	(N_2/O_2)	3.72763	3.72763

Note:

* *CO_2 volumetric fraction calculated from atmospheric measurements at Mauna Loa Observatory 2015*

TABLE C.3
Averaged GW-7024 Fractional Volumetric Concentrations and Estimated Percent Air Intrusion 6/27/2014 through 7/1/2014

Date and Time	Fraction CH_4	Fraction CO_2	Fraction O_2	Fraction Balance Gas	Well Balance Gas/ Air Balance Gas	Estimated % Air Intrusion
6/27/2014 17:07	0.261	0.311	0	0.428	0.548	54.8
6/27/2014 17:08	0.261	0.311	0	0.428	0.548	54.8
6/27/2014 17:09	0.261	0.311	0	0.428	0.548	54.8
6/27/2014 17:10	0.261	0.311	0	0.428	0.548	54.8
6/27/2014 17:12	0.261	0.311	0	0.428	0.548	54.8
6/28/2014 10:29	0.212	0.287	0	0.501	0.642	64.2
6/30/2014 9:17	0.177	0.268	0	0.555	0.711	71.1
6/30/2014 12:53	0.183	0.269	0	0.548	0.702	70.2
6/30/2014 12:56	0.183	0.269	0	0.548	0.702	70.2
6/30/2014 12:58	0.183	0.269	0	0.548	0.702	70.2
6/30/2014 16:23	0.208	0.277	0	0.515	0.660	66.0
6/30/2014 16:24	0.208	0.277	0	0.515	0.660	66.0
7/1/2014 9:30	0.167	0.26	0.004	0.569	0.729	72.9
7/1/2014 9:33	0.167	0.26	0.004	0.569	0.729	72.9
7/1/2014 9:35	0.16	0.249	0.051	0.54	0.692	69.2
7/1/2014 16:01	0.191	0.268	0	0.541	0.693	69.3
7/1/2014 16:02	0.191	0.268	0	0.541	0.693	69.3
7/1/2014 17:23	0.203	0.269	0	0.528	0.676	67.6
7/1/2014 17:24	0.203	0.269	0	0.528	0.676	67.6
Average:				0.510	0.653	65.3

TABLE C.4
Averaged CGW-740S Fractional Volumetric Concentrations and Estimated Percent Air Intrusion 6/27/2014 through 7/1/2014

Date and Time	Fraction CH_4	Fraction CO_2	Fraction O_2	Fraction Balance Gas	Well Balance Gas/ Air Balance Gas	Estimated % Air Intrusion
6/28/2014 11:06	0.452	0.522	0	0.026	0.033	3.3
6/30/2014 9:56	0.429	0.515	0	0.056	0.072	7.2
6/30/2014 13:37	0.429	0.494	0.007	0.07	0.090	9.0
6/30/2014 13:40	0.429	0.494	0.007	0.07	0.090	9.0
6/30/2014 17:09	0.465	0.507	0	0.028	0.036	3.6
6/30/2014 17:11	0.465	0.507	0	0.028	0.036	3.6
6/30/2014 17:12	0.465	0.507	0	0.028	0.036	3.6
7/1/2014 10:58	0.444	0.501	0	0.055	0.070	7.0
7/1/2014 16:38	0.449	0.499	0	0.052	0.067	6.7
7/1/2014 16:39	0.449	0.499	0	0.052	0.067	6.7
7/1/2014 16:40	0.449	0.499	0	0.052	0.067	6.7
7/1/2014 16:43	0.463	0.499	0	0.038	0.049	4.9
Average:				0.046	0.059	5.9

TABLE C.5
Averaged CGW-740D Fractional Volumetric Concentrations and Estimated Percent Air Intrusion 6/27/2014 through 7/1/2014

Date and Time	Fraction CH_4	Fraction CO_2	Fraction O_2	Fraction Balance Gas	Well Balance Gas/ Air Balance Gas	Estimated % Air Intrusion
6/28/2014 11:11	0.522	0.453	0.002	0.023	0.029	2.9
6/30/2014 10:02	0.498	0.441	0.008	0.053	0.068	6.8
6/30/2014 10:03	0.498	0.441	0.008	0.053	0.068	6.8
6/30/2014 13:45	0.523	0.446	0	0.031	0.040	4.0
6/30/2014 13:46	0.523	0.446	0	0.031	0.040	4.0
6/30/2014 17:17	0.529	0.441	0	0.03	0.038	3.8
6/30/2014 17:18	0.529	0.441	0	0.03	0.038	3.8
7/1/2014 11:01	0.531	0.441	0	0.028	0.036	3.6
7/1/2014 11:02	0.531	0.441	0	0.028	0.036	3.6
7/1/2014 16:46	0.505	0.413	0.014	0.068	0.087	8.7
Average:				0.038	0.048	4.8

TABLE C.6
Averaged CGW-575 Fractional Volumetric Concentrations and Estimated Percent Air Intrusion 6/27/2014 through 7/1/2014

Date and Time	Fraction CH_4	Fraction CO_2	Fraction O_2	Fraction Balance Gas	Well Balance Gas/ Air Balance Gas	Estimated % Air Intrusion
6/27/2014 18:10	0.506	0.387	0	0.107	0.137	13.7
6/28/2014 10:48	0.482	0.385	0	0.133	0.170	17.0
6/28/2014 10:49	0.482	0.385	0	0.133	0.170	17.0
6/30/2014 9:37	0.458	0.38	0	0.162	0.207	20.7
6/30/2014 13:20	0.465	0.38	0	0.155	0.199	19.9
6/30/2014 13:23	0.465	0.38	0	0.155	0.199	19.9
6/30/2014 16:48	0.47	0.375	0	0.155	0.199	19.9
6/30/2014 16:49	0.47	0.375	0	0.155	0.199	19.9
7/1/2014 10:21	0.447	0.375	0	0.178	0.228	22.8
7/1/2014 16:26	0.451	0.372	0	0.177	0.227	22.7
7/1/2014 16:27	0.451	0.372	0	0.177	0.227	22.7
7/1/2014 17:05	0.461	0.37	0	0.169	0.216	21.6
Average:				0.155	0.198	19.8

APPENDIX D

NWCI COVER TREATMENTS

Appendix D: ADC and Alternative Intermediate Cover Recommendations by New Waste Concepts (NWCI)[1]

General Comments: NWCI sprayable cover materials create no VOC's during the evaporation process, are not additive to liquids in the landfill because they pass the paint filter test, are not flammable even though cellulose is a major component in the daily cover, and pass regulatory TCLP tests. **HydraGuard 21** and **42** are hydrophobic products and therefore resist the penetration of liquids. When used alone or in addition with other cover materials, the seal created will break up into pieces when run over by a compactor and therefore not create a barrier to the flow of gas or liquids within the landfill. All NWCI products have passed multiple environmental testing with regards to regulatory requirements.

HydraGuard 21 can be used alone as an intermediate cover: **HydraGuard 21** or **42** would be sprayed at a ratio of 1 gallon of **HydraGuard** to 8 gallons of water. Thus, 500 gallons of **HydraGuard** mixes with 4,000 gallons of water, making a 4500 gallon batch. This quantity of **HydraGuard** mix will cover a 152,460 square feet or 3.5 acres. 500 gallons ($5.95 per gallon) will cost $2,975.00 (product comes in 275 gallon flexible containers), or $0.0195 per square foot. Expected longevity is 3-6 months. Sandy soils will allow deeper penetration and may require application rates that can increase the cost to $0.023 per square foot.

Alternative Daily Cover Recommendations

<u>ProGuard SB2</u> – This is the recommended product for ADC. It is a cellulose and polymer based coating that will degrade after application within about 14-30 days. It is an evaporative coating that dries as the liquids that are held by the polymer evaporate. It is a flexible coating that supresses VOCs and odors, controls dust, and inhibits blowing litter. This product mixes easily with water and becomes viscous slurry, adhering well to all substrates. The quality of the polymers allows for spraying in a light rain event.

Product Mixture: 50 pound powder Chemical/Polymer bags mixed with 50-pound Cellulose/Mulch bags.
Example batch mix: 900-gallon capacity machine:

- Add 750 – 800 gallons of water
- Add 7 Cellulose/Mulch bags – mix until completely wetted out
- Add 1 Chemical/Polymer bag (**ProGuard SB2 –** cost is $120 per 50 # bag)

Approximate coverage per batch at ¼ inch (900 gallon machine):
22,000 – 25,000 sq. ft.
Cost: One (1) cent or less per sq. ft.

Heavy Rain Event Mixture: Add additional chemical bags to the above mix. The number of bags depends on the size of the machine, but based upon the above size machine, add three **ConCover 180** bags (cost is $34 per 50# bag) and 20 gallons of **HydraGuard 21** ($5.95 per gallon).

[1] This description of NWCI products and application was submitted by Milton F Knight, CEO of NWCI (WWW.NWCI.com)

Alternative Intermediate Cover Recommendations

Products Sprayed Over the Waste without Soil Covering: These products are designed for longer duration (up to 6 months) and assume the operator will be placing new waste over the treated area within this time period. The cover is thicker and more durable because the solids content is three times that of the daily cover blend and it has a higher bentonite clay component.

ConCover SW – This product provides for suppression of VOCs, odors, gases and, because of the bentonite clay component, provides for resistance to infiltration of water. This material is also an evaporative coating, which dries to a cover layer after being sprayed. Mixing is very similar to **ProGuard SB2** creating a thick slurry when mixed with water. The slurry is sprayed over MSW, soils and other landfill mediums to a thickness of ¼ inch. This material will adhere well to slopes, and is suitable for in-place GCCS and new cell construction without damaging liners or newly constructed surfaces. Because of its viscosity this material requires the use of a gear pump or progressing cavity pump. The slurry is applied from a cannon and will spray distances of up to 100 feet. Durability is good in moderate rains. May need minimal touch up over a period of 6 months.

Product Mixture: 50 pound powder Chemical/Polymer bags mixed with 50- pound Cellulose/Mulch bags.
Example batch mix: 900-gallon capacity machine:

- Add 700 gallons of water
- Add 5 Cellulose/Mulch bags – mix until completely wetted out
- Add 7 Chemical/Polymer bags – **ConCover SW** (cost is $68 per 50# bag)

Approximate coverage per batch at ¼ inch (900 gallon machine):
9,000 – 10,000 sq. ft.

Cost: Five (5) cents or less per sq. ft.

Heavy Rain Event Mixture: This product is good in moderate rains, but durability is improved by adding additional Chemical bags and Liquid Chemistry to the above Product Mixture. The number of bags depends on the size of the machine. Based upon the above size machine add three **ConCover 180** bags (cost is $34 per 50# bag) and 20 gallons of **HydraGuard 21** ($5.95 per gallon)

Alternative Gas Suppressing Cover Materials Used for Spraying Over Soil: These hydrophobic materials are designed to shed water and congeal soil particles using glues and acrylic polymers to generate an impermeable layer. Material has been used in monofil landfills where waste going into the monofil is reactive to water or liquids, creating odors and heat. **HydraGuard 21** was specifically designed and tested to provide run off of liquids from the surface.

Best results require a smooth surface, achieved using a smooth roll vibrating compactor. Surfaces are coated until a donut like glaze occurs.

<u>HydraGuard 21</u> – Composed of acrylic polymers, glues and cross-linked chemistries. Product comes in 5-gallon pails or 275-gallon flexible containers (Totes). The product creates an impermeable surface, which restricts the flow of water and gases. The product holds both soil particles and the sprayable cover materials (**ProGuard SB2**, **ConCover SW** and **ConCover 180**) together making them less permeable and increasing their durability.

Depending upon the permeability of the soil, **HydraGuard** will penetrate about 9-10 inches of soil.

Product Mixture & Application: 1 gallon of **HydraGuard** to 8 gallons of water (previously noted on page 1). If using a large water truck (4500-gallon water truck), add 500 gallons of **HydraGuard 21** to 4000 gallons of water. Apply the mixed product topically over the compacted soils using a truck-mounted cannon .

Coverage: Approximate coverage for a 4,500-gallon batch: 3.5 acres (150,000 ft^2.)

Cost: Typical **HydraGuard** application costs for this dilution ratio are less than two (2) cents per sq. ft. Durability of **HydraGuard** treated cover soils is generally 1-6 months with moderate reapplication needed in areas showing signs of wear.

<u>Other Long Term Cover Products Sprayed Over the Waste with or without Soil Covering</u>: These products are designed for longer duration (up to 12-36 months)

ConCover 180 and HydraGuard Combination: Typical costs of the **HydraGuard + ConCover 180** spray cover (the most durable mixed treatment) is 12-14 cents per sq. ft. Durability of the **HydraGuard + ConCover 180** application is 1-3 years, with moderate reapplication needed in areas showing signs of wear.

ConCover SW and HydraGuard Combination: Typical costs of the **HydraGuard + ConCover SW** spray cover (the intermediate durability mixed treatment) is approximately 6-8 cents per sq. ft. Durability of the mixed **HydraGuard + ConCoverSW** application is approximately 0.5 -1.5 years, again with moderate reapplication needed in areas showing signs of wear.

Equipment:

Water Truck with Spray Cannon and Dust Control Spray Nozzles: **(HydraGuard 21 or 42)**
A standard water truck with a cannon can apply this product

CAPS EL 3300 Gallon Machine: Capacity to cover over an acre per batch.
This machine can apply all products
Lease: $6,800 per month
Purchase:
Used and Refurbished: $70-$80,000
New: ~$130,000
Freight to Los Angeles, California: $11,500 (actual pricing)

Truckload shipment of Cover materials: Estimated $5,500

Contact Information:

Milton F. Knight
New Waste Concepts Inc. – 26624 Glenwood Road, Perrysburg, Ohio 43551
Cellular phone: 419-466-3283 office phone: 419-872-2190 email: mfknight@nwci.com

You asked that I recommend a piece of equipment that can provide the application methodology for both products. To have a machine that can do both, you will need a CAPS EL series machine which is a machine with a diesel engine, a larger tank which has mechanical agitation and which is connected to a positive displacement pump. We typically recommend that when you are covering areas as large as an acre you use the 3300 gallon machine to minimize the number of loads you have to mix each day. I have set forth below a photo of the type of machine, as well as photos of the machines being towed in a landfill.

The following is a photo of the CAPS 3300 gallon machine.

The following photo is of the 3300 gallon machine in the state of Washington at Whiteford remediation of radioactively contaminated sediment.

The following photo shows how the equipment is towed in a landfill.

Hopefully this will fully explain the process and the equipment.

The following cannon can be mounted on a water truck or Bowser at the landfill:

Valew Electric Water Cannon

Cab mounted - Remotely controlled