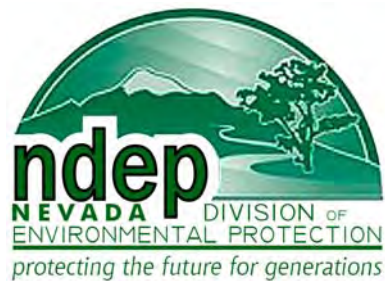


**Evaluation of  
Hydrogeologic Zone Connectivity  
Through Tritium and Stable Isotope  
Sampling and Analysis  
BMI Common Areas (Eastside)  
Clark County, Nevada**

**April 21, 2010**

**Submitted to:**



**Prepared for:**



***Daniel B. Stephens & Associates, Inc.***

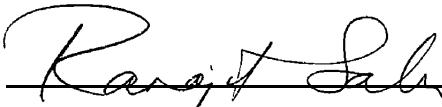
5951 Encina Road, Suite 208 • Goleta, California 93117



### **Responsible CEM for this Project**

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances.

  
\_\_\_\_\_  
April 21, 2010  
Stephen J. Cullen, Ph.D., C.E.M. (No. 1839)  
Daniel B. Stephens & Associates, Inc.

  
\_\_\_\_\_  
April 21, 2010  
Dr. Ranajit Sahu, C.E.M. (No. EM-1699)  
BRC Project Manager

### **Individuals Who Provided Technical Input to this Document**

  
\_\_\_\_\_  
April 21, 2010  
John J. Dodge, P.G.  
Daniel B. Stephens & Associates, Inc.





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## **1. Introduction**

During the planning of aquifer testing activities by Daniel B. Stephens & Associates, Inc. (DBS&A), the need to evaluate the connectivity between the BMI Common Areas, Eastside (the Site) water-bearing zones became apparent. Accordingly, pursuant to the aquifer testing work plan (DBS&A, 2007), DBS&A and Basic Remediation Company (BRC) conducted sampling and analysis of tritium and stable isotopes to address the connectivity between the three designated water-bearing zones at the Site: the Shallow Zone, the Middle Zone, and the Deep Zone (NDEP, 2009). This report presents the sampling data and interpretations regarding zone connectivity and addresses comments from the Nevada Division of Environmental Protection (NDEP) (Appendix A), dated April 24, 2009, regarding BRC's technical memorandum dated March 26, 2009, entitled *Tritium and Stable Isotope Sampling & Analysis, and Evaluation of Hydrogeologic Zone Connectivity, BMI Common Areas (Eastside), Clark County, Nevada*.





## **2. Background**

The study area is located near the BMI Industrial Complex in Clark County, Nevada, approximately 13 miles southeast of Las Vegas and 2 miles northeast of the City of Henderson's downtown (Figure 1). Physiographically, the Site is situated approximately 2 miles west of the River Mountains and 1 mile north of the McCullough Range. As shown in Figure 1, the surface topography in the vicinity of the Site slopes in a westerly to northwesterly direction from the River Mountains and in a northerly to northeasterly direction from the McCullough Range. At the Site, the surface topography slopes in a northerly direction toward Las Vegas Wash.

Over the past 65 years, numerous private and public entities have owned, leased, or operated facilities on the original 5,000 acres and have engaged in a wide range of commercial and other activities, including the manufacturing of chemicals and metals. Historically, a network of ditches, canals, flumes, and unlined ponds was used for the disposal of aqueous waste from the original magnesium plant and, later, other industrial plants and the municipality adjacent to it. The Site as described herein encompasses approximately 2,287 acres of the original 5,000-acre deed referred to as the Eastside Area (Figure 2).

### **2.1 Geology**

The depositional environment of the various strata encountered beneath the Site has been characterized through drilling and sampling of numerous borings installed during previous investigations. The Site is located on alluvial fan sediments, with a surface that slopes to the north-northeast, toward Las Vegas Wash, at a gradient of approximately 0.02. The uppermost two geologic formations encountered at the Site are the focus of this report:

- The uppermost unit is composed of relatively coarse-grained Quaternary alluvial sediments.
- These alluvial sediments are underlain by lacustrine sediments known as the Muddy Creek Formation (TMCf). For the most part, the lacustrine TMCf is comprised of silts





and clays, although a coarser facies was noted in the southwest portion of the site (Section 2.2.2).

These geologic units are described in Sections 2.1.1 and 2.2.2.

### **2.1.1 Quaternary Alluvium**

The uppermost strata beneath the Site consist primarily of alluvial sands and gravels of Quaternary age (Carlsen et al., 1991) and are mapped and referred to as Quaternary alluvium (Qal). The alluvial fan deposits are composed of volcanic materials that were shed from various nearby mountains and then coalesced in the Las Vegas Valley. The Qal is typically on the order of 50 feet thick at the Site, with a maximum thickness of 65 feet noted to the southwest of the Southern rapid infiltration basins (RIBs). The variations of the thickness of the Qal are, in part, a result of the non-uniform contact between the Qal and the underlying TMCf. The Qal is not present in localized areas of the northernmost portion of the Site, where it was removed as a result of previous gravel mining. Such areas where excavation has occurred previously (such as Tuscany Village or the Weston Hills development) have since been backfilled to allow for residential development.

Whereas the original surface of the Qal prior to development was a nominally planar surface that, as a whole, dipped gently to the north, the contact between the Qal and the underlying TMCf is not a planar surface. The unconformity between these two geologic units is a result of erosion of the TMCf prior to the deposition of the alluvial sediments that comprise the Qal. As the TMCf was eroded, broad channels were incised into its surface and were subsequently filled with the alluvium, resulting in the development of several paleochannels of varying depths and width. BRC et al. (2006) have interpreted that two paleochannels originating to the east and west of the Southern RIBs join at the southern end of the former location of the historical spray wheel to form one paleochannel that runs north beneath the Northern RIBs and then northeasterly to the Las Vegas Wash.

As indicated by the borelog data, the structural surface of the TMCf also exhibits a topographic gradient to the north-northeast. However, the TMCf topography does not appear to be so deeply incised that the current flow of groundwater is controlled by paleochannel features. The degree to which these paleochannels act as preferential pathway(s) for groundwater flow and





contaminant migration is presently uncertain and is most likely a function of the amount and location of groundwater present.

Plate 1 is a structure contour of the top of the TMCf (base of the Qal) based on the evaluation of geophysical surveys and logs as later refined by the interpretation of more than 500 boring logs. The plate details the irregular nature of the topographic surface of the TMCf, as well as the presence of the three dominant paleochannels that trend north-northeast toward the Las Vegas Wash. As depicted in Plate 1, the data demonstrate that two of the three paleochannels originate from off-site in the southern portion of the study area and then extend generally northward to the Site's Western Hook and No-Build sub-areas. BRC understands that work is ongoing by TIMET regarding the occurrence of any paleochannels in the southwest portion of the Site. As this information becomes available, the conceptual site model will be revised as necessary.

### **2.1.2 Tertiary Muddy Creek Formation**

The TMCf underlies much of the Las Vegas Valley and is more than 2,000 feet thick in places. At the Site, this unit is encountered beneath the Qal, where an unconformity separates the two geologic units. The depth to the top of the TMCf ranges from approximately 27 feet below ground surface (ft bgs) at well MCF-11 to approximately 65 ft bgs southwest of the Southern RIBs. At the Site, the TMCf was encountered to the maximum explored depth of 430 ft bgs. The TMCf is typically fine-grained (sandy silt and clayey silt), although thin layers (interbeds or "stringers") with increased sand content are encountered sporadically.

A coarser-grained facies of the TMCf occurs off-site and in the southwest portion of the study area (at well MCF-27, for example). The proportion of coarser-grained sediments in the upper portion of the TMCf decreases to the north beneath the Site. This more permeable TMCf facies is interpreted as being caused by an influx of slightly coarser alluvial deposits into the older lacustrine depositional environment. One possible ramification of the presence of these coarser TMCf sediments near the southwestern border of the Site is that they may serve as a potential pathway for chemicals to migrate into the TMCf.





## 2.2 Hydrogeology

The uppermost water-bearing zone at the Site is identified as the Shallow Zone. Shallow Zone groundwater is unconfined and occurs in both the Qal and the upper portion of the TMCf (referred to as the Upper Muddy Creek Formation [UMCf]). In the eastern portion of the Site, the Qal is dry and Shallow Zone groundwater is first encountered in the UMCf. Shallow Zone groundwater generally flows in a northerly direction toward Las Vegas Wash, but Shallow Zone groundwater in the UMCf has a north-northwesterly flow component along the southeastern Site boundary. Shallow Zone groundwater is continuous across the Site, but there are areas where some Shallow Zone wells are dry. To distinguish between unconfined groundwater occurring in the two lithologies, the Shallow Zone is further divided into Layer 1 (Qal only) and Layer 2 (TMCf only).

Below the Shallow Zone, deeper groundwater occurs in sporadically encountered lenses in the Middle Zone, designated between approximately 90 and 270 ft bgs.

Deep Zone groundwater is generally continuous across the Site and is characterized with wells screened below 270 ft bgs to a maximum nominal depth of 400 feet bgs. Groundwater elevation data from the last several rounds of groundwater monitoring (2006, 2007, 2008, 2009) show that Deep Zone groundwater is confined, and the potentiometric surface of Deep Zone groundwater is oriented generally north toward Las Vegas Wash (MWH, 2008). A January 2009 NDEP-produced document entitled *Hydrogeologic and Lithologic Nomenclature Unification* (NDEP, 2009) defines the rationale behind the definitions of the Shallow, Middle, and Deep Zones at the Site and at adjacent properties.





### **3. Historical Groundwater Characterization Activities**

As previously reported to NDEP, BRC has conducted many investigation activities to collect data upon which to base an evaluation of the connectivity between the Site water-bearing zones. During investigations conducted in 2004, BRC and its consultants:

- Advanced 13 exploratory borings to a depth of approximately 400 ft bgs.
- Conducted geophysical logging of the 13 borings to a depth of approximately 400 ft bgs.
- Drilled 50 additional boreholes at 27 locations throughout the Site using mud rotary, hollow-stem auger, and rotary sonic drilling methods.
- Collected continuous core soil samples from 3 of the 400-foot mud-rotary borings (locations 1, 4, and 6) and from all of the boreholes drilled with the rotary sonic drilling method (18 locations).
- Collected 94 saturated soil samples and 12 in-situ groundwater samples from the various water-bearing zones at the Site for fast turnaround analysis of perchlorate using U.S. Environmental Protection Agency (EPA) method 314.0.
- Installed 44 groundwater monitor wells, including 8 wells in the Qal and 27 wells in the UMCf.

Since 2004, BRC has conducted the following activities:

- Reported on five groundwater monitoring events conducted between April to June 2006 and April to July 2008. The first monitoring event included collection and reporting of water elevations for 104 wells and water sample chemical analytic results for 53 wells. The monitoring scope has increased over the course of the five monitoring events. The fifth monitoring event included collection and reporting of water elevations for 155 wells and water sample chemical analytic results for 106 wells. A sixth round of sampling was completed in August and September of 2009.





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*Daniel B. Stephens & Associates, Inc.*

- Conducted and reported on an aquifer testing program conducted at the Site.
- Installed numerous monitoring wells at upgradient and downgradient property boundary locations at the Site.
- Conducted analytic and numerical groundwater modeling.





## 4. Technical Approach

BRC and DBS&A have evaluated methods to assess the hydraulic connectivity of the Site water-bearing zones. This section discusses the rationale that provides the basis for using tritium and stable isotopes to evaluate Site water-bearing zone connectivity.

### 4.1 Injected Tracers

BRC and DBS&A do not believe that the use of injected tracer testing to directly assess the connectivity of the three water-bearing zones (or even the connectivity of the UMCf with groundwater in the Qal) is practical for two main reasons:

- The travel time for a conservative tracer introduced in the upper portion of the UMCf to migrate upward into the Qal where it could potentially be observed in a monitor well is at least on the order of several years and quite possibly much longer.
- Due to what are expected to be heterogeneous and unidentified specific flow paths for tracer migration, appropriate target sampling location(s) are, as a practical matter, unknowable.

The following calculation illustrates what BRC believes is the main problem with using tracer injection to evaluate saturated zone connectivity at the Site.

The 2004 groundwater well measurement data indicated that vertical hydraulic gradients were upward at most locations but downward in some, and ranged in magnitude from approximately 0.018 to 0.180. Assuming that the increased sand content of the Middle Zone lenses has an overall hydraulic conductivity of  $1 \times 10^{-4}$  centimeters per second (cm/s) and an effective porosity of 30 percent, the average groundwater velocity can be estimated using Darcy's Law:

$$v = \frac{Ki}{n_e}$$

where  $v$  = average groundwater pore velocity (cm/s)





$K$  = saturated hydraulic conductivity (cm/s)

$i$  = gradient (unitless, L/L)

$n_e$  = effective porosity (unitless,  $L^3/L^3$ )

$L$  = travel distance

Using a gradient of 0.018 (MWH, 2008), the calculated average pore velocity would be:

$$v = 6 \times 10^{-6} \text{ cm/s} = 0.017 \text{ ft/d}$$

Assuming this average pore velocity, it would take a tracer about 5 years to travel 30 feet in the vertical direction, assuming that no other retardation factors apply. Although other assumed values could be applied in the travel time calculation, BRC believes that the main constraint will be the average hydraulic conductivity of the intervening materials between the tracer release point and the target reception point. The  $1 \times 10^{-4}$ -cm/s value was selected to be on the expected high end of possibilities; the actual hydraulic conductivity may be lower, perhaps by 10 to 100 times.

Furthermore, the sporadic nature of the UMCf sand lenses indicates that a straight-line path is not realistic and that the path is instead tortuous and longer, possibly much longer, than accounted for in the above analysis (i.e., the actual flow path is not likely to be only 30 feet). This greater length would increase the tracer travel time even more. Although it is theoretically possible to reduce expected tracer travel times by inducing a higher hydraulic gradient by pumping or injection, BRC does not believe that this approach is appropriate because there is a significant likelihood that flow pathways would be opened where none existed prior to creation of the induced gradient, and the results of such a study would therefore not be representative of the flow regime observed at the Site.

In addition to the travel time problem, insufficient data are currently available (and are not likely to be reasonably attainable) to characterize the location of the point of intersection of the Middle Zone sand lenses with either the overlying Shallow Zone or the underlying Deep Zone. Therefore, it is not possible to confidently identify the proper location for a monitor well to capture the tracer as it discharges from the Middle Zone into either the Shallow Zone or the Deep Zone.





## **4.2 Historical Tracers**

Use of historical tracers is a promising approach for application at the Site. Historical tracers result from human activities or events in the past, such as contaminant spills or atmospheric nuclear testing ( $^3\text{H}$  and  $^{36}\text{Cl}$ ). Known industrial chemical contaminants at the Site from previous operational activities, such as perchlorate and tetrachloroethylene (PCE), are evaluated in this report, together with groundwater elevation data, to provide qualitative evidence of connectivity, or lack thereof, between the three Site water-bearing zones. Total dissolved solids (TDS) distribution is also evaluated. However, uncertainties with respect to source location, concentration, timing of chemical release, and the non-conservative behavior of some chemicals makes it difficult to use this information to quantify the connectivity in terms of the flux of groundwater between water-bearing zones.

The presence of an event marker, such as bomb tritium, in groundwater can provide evidence that a component of that water recharged during a particular time period. Because of tritium's short half-life (12.32 years), the use of bomb tritium as a hydrologic tracer is relatively temporary. Before significant amounts of tritium were injected into the atmosphere through nuclear activities in the 1950s and 1960s, precipitation had an estimated natural background of approximately 5 to 10 tritium units (TU) (Illinois Environmental Protection Agency, 1997). Radioactive decay of the tritium in any water recharged before the 1950s would therefore leave no detectable tritium today. Tritium content in precipitation in North America since the advent of atmospheric nuclear bomb testing in 1952 reached an atmospheric high in approximately 1963, and has diminished significantly since that time to the present atmospheric levels. In the southern hemisphere, the bomb pulse has already decayed to within 15 TU of natural background. Over 20 years ago, Bentley et al. (1986) reported that bomb tritium will be difficult to detect in 10 to 20 years.

The actual tritium content varies widely with location (Illinois Environmental Protection Agency, 1997). The Santa Maria, California and the Albuquerque, New Mexico stations have tritium monitoring stations with some of the longest monitoring records in the U.S. (Figures 3 and 4, respectively). Santa Maria is located approximately 400 miles west-southwest of the Site; Albuquerque is located approximately 490 miles east-southeast of the Site. At Santa Maria, peak atmospheric tritium concentrations of about 1,300 TU were recorded from 1962 through





early 1964, but by late 1964, tritium concentrations had diminished to less than 400 TU. Today, atmospheric background levels in the northern hemisphere are between about 5 and 30 TU (IAEA/WMO, 2006).

For 1976, the last year of record at Santa Maria, the average tritium atmospheric content from nine Santa Maria reporting stations was 15.33 TU (IAEA, 2009). Albuquerque, New Mexico reported a mean atmospheric tritium content of 7.3 TU from 12 reporting stations in 2001. These data are in agreement with the statement by the IAEA (2009) that, "Atmospheric tritium concentrations have been decreasing over the last 30 years and are currently almost at their low, natural levels, making tritium less useful as a hydrological tracer."

While tritium was chemically analyzed and evaluated for the Site monitoring wells sampled, the evaluation is qualitative and based on the absence or presence of tritium. Nonetheless, it provides an additional useful line of evidence in the interpretation of the source and fate and transport of chemicals at the Site.

### **4.3 Stable Isotopes**

Stable isotopes were sampled as an alternative means of evaluating the connectivity between the three water-bearing zones and to potentially gain insight as to the origin of the water in the individual zones.

In an atom of any element, the atomic number is used to represent the number of protons in a nucleus. Because the chemical properties of an element are primarily determined by the number of protons in the atom, the atomic number characterizes the element. In the uncharged state, the number of positively charged protons is equal to the number of negatively charged electrons. More subtle differences in physical behavior result from differing numbers of uncharged neutrons that may exist in the nuclei of atoms of a given element.

The sum of the number of protons and neutrons in an atomic nucleus is the nuclear mass number. The atomic mass number is an approximation of the atomic mass.





An isotope is a variation of an element produced by differences in the number of neutrons in the nucleus of the element; hence, isotopes of an element have different masses. In the most stable and abundant nuclides of the light elements (i.e., elements with relatively low atomic masses), the numbers of protons and neutrons are equal (Mook, 2006). In the case of hydrogen, one single proton ( $^1\text{H}$ ) is also stable. Unstable atoms can be caused by an excess of protons or neutrons. Examples include tritium ( $^3\text{H}$ ) and carbon-14 ( $^{14}\text{C}$ ). On the other hand, for light elements a slight excess of neutrons does not necessarily result in instability. For example, there are two stable isotopes of hydrogen,  $^1\text{H}$  and  $^2\text{H}$ , and three stable isotopes of oxygen,  $^{16}\text{O}$ ,  $^{17}\text{O}$ , and  $^{18}\text{O}$ . The probability of forming nuclei with unequal numbers of protons and neutrons is smaller, and the natural concentrations of those isotopes are thus smaller as well (Mook, 2006). Therefore, the majority of water molecules ( $\text{H}_2\text{O}$ ) contain only atoms of  $^1\text{H}$  and  $^{16}\text{O}$ ; only a fraction contain other isotopes.

The chemical and some physical properties of the isotopes of one element are not exactly equal, resulting in slightly different chemical and physical properties brought about by mass differences of the atomic nuclei (Mook, 2006). In general, heavier isotopic molecules have lower mobility caused by lower diffusion velocity and lower frequency of collision with other molecules (Mook, 2006). The heavier isotopic molecules can also have higher binding energy which, for example, can result in a lower vapor pressure and thus a lower tendency to evaporate from the liquid phase and a higher tendency to condense from the vapor phase (Mook, 2006).

Considering this isotopic mass difference at the molecular level, the two stable, or non-radioactive, isotopes of hydrogen— $^1\text{H}$  (protium [H]) and  $^2\text{H}$  (deuterium [D])—and the three stable isotopes of oxygen— $^{16}\text{O}$ ,  $^{17}\text{O}$ , and  $^{18}\text{O}$ —form part of the water molecule. Forces that drive the hydrologic cycle will tend to impart measureable differences in the abundance of stable isotopes in water at different locations and different times. Thus, analyses of their concentrations in groundwater can be used to trace movement of water in the subsurface.

Laboratory analyses can determine the ratio of isotopes in a water sample. For the Site sample analyses, the isotopic ratios of  $^{18}\text{O}/^{16}\text{O}$  and  $^2\text{H}/^1\text{H}$  (D/H) were interpreted. The isotope ratio from a Site sample was compared to the isotopic ratio of a reference material called Vienna Standard Mean Ocean Water (VSMOW). The comparison is made by means of the parameter  $\delta$ , defined





by Fetter (1988) for isotope ratios of oxygen and hydrogen (expressed in parts per thousand [‰]) as:

$$\delta^{18}\text{O} (\text{‰}) = \left[ \frac{\left( \frac{{}^{18}\text{O}}{{}^{16}\text{O}} \right)_{\text{sample}}}{\left( \frac{{}^{18}\text{O}}{{}^{16}\text{O}} \right)_{\text{VSMOW}}} - 1 \right] 10^3$$

$$\delta^2\text{H} (\text{‰}) = \left[ \frac{\left( \frac{{}^2\text{H}}{{}^1\text{H}} \right)_{\text{sample}}}{\left( \frac{{}^2\text{H}}{{}^1\text{H}} \right)_{\text{VSMOW}}} - 1 \right] 10^3$$

It is well established that the isotopic composition of precipitation at a particular location will vary seasonally and with individual storms (Mook, 2006). The isotopic composition of precipitation will also vary among locations depending upon climate and elevation. Nevertheless, the composition of all precipitation generally falls on a straight line plot of  $\delta^2\text{H}$  versus  $\delta^{18}\text{O}$ . This line is called the Global Meteoric Water Line (GMWL).

After liquid water is formed from vapor (as in precipitation), the isotopic ratios of  $^{18}\text{O}$  and  $^2\text{H}$  do not change and are locked into the water molecule except when a body of water is exposed to either (1) geothermal heating or (2) evaporation, such as from ponds or lakes in dry climates. The stable isotope concentration of the precipitation can be modified subsequent to precipitation; this modified signature of the soil water can be used to reveal the origin of the water.

Evaporation of soil water or evaporation from a free water surface leads to an increase in the concentration of the stable isotopes  $^2\text{H}$  and  $^{18}\text{O}$  in the residual water, since the lighter isotopes  $^1\text{H}$  and  $^{16}\text{O}$  are preferentially lost during evaporation as vapor. This physical process is known as fractionation. When water evaporates, the heavier atoms or molecules tend to remain behind in the liquid phase, thus leading to enrichment in the concentration (fractionation) of the heavier isotopes in the residual liquid, as the lighter isotopes preferentially fractionate into the vapor phase.

Another process that can change the stable isotope signature of a parcel of water is a rock-water interaction such as exchange with water in hydrated minerals. For example, evaporites





such as gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) are hydrated by the highly fractionated water from which they precipitated, and dissolution of the mineral or exchange of water with the mineral will release this fractionated water into more recently recharged water and shift its isotopic signature in proportion to the mixing.

In geothermal systems, significant isotope exchange of hydrogen and oxygen occurs between rock and water, due to membrane filtration through layers of semipermeable clays as well as hydration or dehydration of secondary minerals. Water that is heated geothermally becomes relatively enriched in  $^{18}\text{O}$  due to the water coming into equilibrium with elevated concentrations of that isotope in minerals. Hydrogen is not similarly affected (Mook, 2006).





## 5. Site Investigation

During the fifth quarterly groundwater monitoring and sampling performed during April through July 2008, groundwater samples were collected from the three water-bearing zones at the Site and analyzed for tritium and stable isotopes. During the groundwater monitoring and sampling performed in August and September 2009 at the Site, additional samples were collected from the Deep Zone. No additional samples were collected for tritium analysis during this event. The results of the laboratory analyses were used to determine if the isotopic character of the water in the three water-bearing zones could be differentiated on the basis of their isotopic signature and to assess the connectivity between the three site water-bearing zones.

The laboratory analyses for stable isotopes of hydrogen and oxygen were conducted by Isotech Laboratories, Inc., in Champaign, Illinois; a copy of their report is provided in Appendix B.

### 5.1 Tritium and Isotope Sample Collection

Between April 22 and July 18, 2008 groundwater samples were collected by Converse Consultants and analyzed as part of a groundwater monitoring event conducted by MWH Americas, Inc (MWH). MWH reported those data in a report entitled, *Fifth Round Groundwater Monitoring Report (April - July 2008), BMI Common Areas (Eastside), Clark County, Nevada*. Samples were collected and analyzed for the following constituents:

- $\delta^{18}\text{O}$  (reported as the ratio of stable isotopes of oxygen [ $^{18}\text{O}$  to  $^{16}\text{O}$ ] relative to the VSMOW ratio)
- $\delta^2\text{H}$  (reported as the ratio of stable isotopes of hydrogen ( $^2\text{H}$  [deuterium] to  $^1\text{H}$  [protium]) relative to the VSMOW ratio)
- Tritium ( $^3\text{H}$ ) (radioactive isotope of hydrogen)

The samples were collected from the following monitoring wells (Figure 5):





- *Northern Site Area (near Las Vegas Wash):* Wells AA-08 (Shallow Zone), MCF-08B-R (Middle Zone), and MCF-17A (Deep Zone)
- *Northern Site Area (upgradient of northern RIBs):* Wells MCF-05 (Middle Zone) and MCF-20A (Deep Zone) (Shallow Zone Well DM-5 was proposed but not sampled due to lack of water.)
- *Middle Site Area (near high perchlorate and TDS detections):* Wells MCF-16C (Shallow Zone), MCF-16B (Middle Zone), and MCF-16A (Deep Zone)
- *Southern Site Area (near plants sites):* Wells AA-01 (Shallow Zone), MCF-02B (Middle Zone), and MCF-01A (Deep Zone)

Between August 21 and September 29, 2009, additional groundwater samples were collected by Converse Consultants, Inc. (Converse) and analyzed for stable isotopes. This sampling event focused on deep wells and those data are reported here for the first time. The samples from the 2009 monitoring event were collected from the following monitoring wells:

- *MCF-02A:* Located at the southern end of the Site, approximately 1,830 feet north-northwest of the intersection of Boulder Highway and Lake Mead Drive
- *MCF-06A-R:* Located at the north-central edge of the Site, on the boundary with the Weston Hill property
- *MCF-18A:* Located approximately 390 feet west-northwest of the northwest corner of the City of Henderson Northern RIBs
- *MCF-18A (FD):* Field duplicate collected from monitoring well MCF-18A
- *MCF-29A:* Located at the northwestern corner of the Weston Hills property, immediately south of Las Vegas Wash





- *MCF-31A*: Located adjacent to the north-central boundary of the Tuscany Village property
- *MCF-30A*: Located approximately 460 feet east of the northwest corner of the Tuscany Village property, south of the C channel

## **5.2 Isotope Results**

The results of the stable isotope and tritium laboratory analyses are summarized in Table 1. The analytical results of stable isotope sampling ( $\delta^2\text{H}$  versus  $\delta^{18}\text{O}$ ) are also plotted in Figure 6, along with results of the tritium ( $^3\text{H}$ ) sample analyses. The isotopic values from these samples are co-plotted with the Global Meteoric Water Line (GMWL) which, as discussed in Section 4.3, is defined by the annual average stable isotope composition of precipitation at locations around the globe.

The range of  $\delta^2\text{H}$  values measured in the Site samples generally fell within the range of expected  $\delta^2\text{H}$  VSMOW values for temperate zone precipitation:  $-60$  to  $-95$  ‰ (Mook, 2006). Likewise, the range of  $\delta^{18}\text{O}$  values measured in the Site samples generally fell within the range of expected  $\delta^{18}\text{O}$  VSMOW values for temperate zone precipitation:  $-2$  to  $-15$  ‰ (Mook, 2006). The stable isotope concentrations in most of the Deep Zone wells are relatively high and indicate a source of water that has been strongly fractionated, based on values plotting to the right of the GMWL by shifts in  $\delta^{18}\text{O}$  of approximately 6 to 11‰ and the clustering of the values along a line with a slope of approximately 3.3 (Figure 6). This behavior is discussed in more detail in Section 5.3.2.

## **5.3 Data Interpretation**

### **5.3.1 Tritium**

Three Shallow Zone monitoring well samples were tested for tritium during the April through July 2008 sampling event. Two of the samples (AA-08 and AA-01) were collected from wells screened in the Qal and contained tritium above the detection limit (1 TU) with activities of 5.18 and 9.88 TU, respectively. These sample results represent water that has recharged relatively





recently. Theoretically, this water could have recharged any time since the 1950s or 1960s when atmospheric levels of tritium were much higher, and the tritium concentrations in the subsurface were then subsequently reduced to present levels by radioactive decay and possibly mixing with older groundwater.

However, Site data from aquifer testing indicates that water travel velocities within the Qal are relatively fast. For example, pumping tests conducted at well AA-08 yielded an average horizontal hydraulic conductivity (Kh) value of 510 feet per day (ft/d) at this location (Kleinfelder, 2007). This Kh value is the highest measured at the Eastside Area. Using a groundwater gradient (i) estimated from the April through July 2008 sampling event (MWH, 2008) (0.022 foot per foot near well AA-08) and an estimate for soil porosity (n) of 0.25, average groundwater velocity (v) in the vicinity of well AA-08 can be estimated:

$$v = (Kh * i) / n = (510 \text{ ft/d}) (0.022) / (0.25) = 45 \text{ ft/d}$$

Based on this computed velocity and a travel distance of approximately 8,000 feet between the Southern RIBs and the Northern RIBs, groundwater traverses the distance in an average travel time of 178 days, or 0.49 year. This short average travel time, when compared to a tritium half life of 12.42 years, leads to a conclusion that water containing bomb tritium would have flushed from the system faster than it could have decayed to the currently observed levels. Therefore, the most likely explanation is that the tritium concentrations in the samples collected from the Qal represent water with a component that has recharged relatively recently, within approximately the last decade.

All other samples were collected from wells screened in the UMCf and contained no tritium above a detection limit of 1 TU. As indicated in Section 4.2, the pre-bomb atmospheric tritium level was on the order of 5 to 10 TU. While recognizing that the amount of data is limited, the tritium data are consistent with previous Site soil physical hydraulic data, post-purging well recovery data, and aquifer test data, all of which demonstrate that there is a significant permeability contrast between the Qal and UMCf, that is, the permeability of the UMCf is significantly lower (orders of magnitude lower) than the overlying Qal. Both of the samples collected from the Shallow Zone wells completed in the Qal contain tritium at levels that are within the range of current background.





The rest of the samples were below the tritium detection limit and were collected from wells having various screened interval depths within the UMCf. These data suggest one of two scenarios:

- Groundwater within the UMCf is on the order of at least 37 years old (assuming that three tritium decay half-lives are required to reduce atmospheric [assumed for this calculation to average 7.5 TU] background concentrations of tritium to below the detection limit of 1 TU).
- Vertical gradients (discussed below), have caused younger groundwater to mix with older groundwater, resulting in diluted concentrations below the detection limit. For example, monitoring well MCF-16C is partially screened in the UMCf at the relatively shallow depth interval of 53 to 73 ft bgs. The water level in 2009 was 3.06 feet above the contact, such that the greater part of the saturated zone in contact with the screened interval was in the UMCf. One of the strongest upward gradients at the Site has been measured between the Middle Zone and the Shallow Zone at Location 16. Shallow Zone water impacted by tritium at atmospheric concentrations that was mixed with enough water from a deeper zone in which tritium is below the detection limit could conceivably yield a sample result of nondetect for tritium. Appendix C presents the compiled historical groundwater elevation data for monitoring wells representative of the three defined water-bearing zones at the Site, along with the historical record of the direction and magnitude of the vertical gradient between the three defined water-bearing zones. Figure C-1 shows the paired monitoring well locations for which data are presented.

This latter scenario is unlikely because the relatively low UMCf permeability would tend to limit the flux of water that would contribute to mixing between waters in the Qal and those from the UMCf. An estimate of flux from the UMCf was completed with the numerical flow model recently completed for the Eastside Area (for the current period [2007] simulation) (DBS&A, 2009). Simulated flow from the UMCf (shallow, model layer 2) to the Qal is 21,558 cubic feet per day (ft<sup>3</sup>/d). The total Qal lateral outflow to Las Vegas Wash gravels is 293,589 ft<sup>3</sup>/d (this does not include outflow at pumping wells). The fraction of Qal flow to the wash gravels that is attributable to the UMCf flux is therefore 21,558 / 293,589 or 7 percent (assuming complete mixing).





Using the value of 7 percent and assuming complete mixing, the resulting ratio of Qal water to UMCf water would be 13.3 to 1. Using the highest detected concentration of tritium in the Qal water (9.88 TU) at the mixing ratio of 13.3 to 1 would result in a diluted tritium concentration of 9.83 TU, only slightly different from the originally considered concentration. Thus, mixing of younger Qal water with older UMCf water (of lower tritium content) is expected to have very little effect on the tritium concentration of sampled Qal waters.

### **5.3.2 Stable Isotopes**

#### **5.3.2.1 2008 Sampling**

With the exception of the samples collected from monitoring wells MCF-05 and MCF-20A, the plot of  $\delta^2\text{H}$  as a function of  $\delta^{18}\text{O}$  forms a generally straight line subparallel to the GMWL.

The April 22 and July 18, 2008 samples collected from monitoring wells MCF-05 and MCF-20A are isotopically heavier than, and distinct from, the other samples collected in 2008. Well MCF-20A is a Deep Zone well that has a screened interval from 360 to 380 ft bgs. Well MCF-05 is screened at a relatively deep depth interval within the Middle Zone at 221 to 231 ft bgs. These two wells are located in the vicinity of the focus of high TDS concentrations that were reported for samples from the Deep Zone and the Middle Zone by MWH (2008).

The data represent one line of evidence that the elevated TDS in this area of the Deep and Middle Zones is the result of groundwater that is in contact with a paleo-evaporitic deposit.

#### **5.3.2.2 2009 Sampling**

In order to further evaluate groundwater quality, to determine whether other wells with the conceptualized influence of the paleo-evaporitic deposit exhibit isotopic fractionation, and to estimate the extent of influence of the paleo-evaporitic deposit, six additional Deep Zone wells were sampled between August 25 and September 29, 2009. In the stable isotope plot of  $\delta^2\text{H}$  as a function of  $\delta^{18}\text{O}$  illustrated in Figure 6, all of these samples except for MCF-02A plotted below the GMWL and to the right of the  $\delta^{18}\text{O}$  analytic values for MCF-05 and MCF-20-A. This indicates that these well samples, anticipated to be affected by the postulated paleo-evaporitic deposit, have undergone isotopic fractionation and are enriched in the heavier isotopes,  $^{18}\text{O}$  and  $^2\text{H}$ . These data lend further support to the interpretation that the elevated TDS in this area





of the Deep and Middle Zones is the result of groundwater that is in contact with a paleo-evaporitic deposit.

#### 5.3.2.3 Spatial Analysis

Spatial analysis was also performed to determine if the area of the Deep Zone that is influenced by dissolution of salts from the paleo-evaporitic deposit could be estimated. Figure 7 presents posted results of the  $\delta^{18}\text{O}$  laboratory analyses for each well sampled, including combined data from both the 2008 and 2009 sampling events, along with isoconcentration contours of the  $\delta^{18}\text{O}$  data. The contoured interpretation indicates that the area of greatest fractionation, and therefore enrichment of the Deep Zone groundwater by  $^{18}\text{O}$ , is focused at and north of the northern BRC boundary, with the main portion of the influenced area beneath the Weston Hills and Tuscany Village developments.

Similarly, Figure 8 presents posted results of the  $\delta^2\text{H}$  laboratory analyses for each well sampled during the 2008 and 2009 sampling events, as well as isoconcentration contours of the  $\delta^2\text{H}$  data. Again, the contoured interpretation indicates that the area of greatest fractionation, and therefore enrichment of the Deep Zone groundwater by  $^{18}\text{O}$ , is focused at and north of the northern BRC boundary, with the main portion of the influenced area beneath the Weston Hills and Tuscany Village developments, as well as the City of Henderson Northern RIBs.

Both isoconcentration plots of the spatial distribution of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  laboratory analytic results are consistent with the interpretation that water in this area has been isotopically fractionated and that there is a concentrated Deep Zone area of  $^{18}\text{O}$ - and  $^2\text{H}$ -enriched groundwater (Figures 7 and 8).

#### 5.3.2.4 Global Meteoric Water Line

A generally valid relationship between  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  values of precipitation from various parts of the world is represented by the equation:

$$\delta^2\text{H} = (8) (\delta^{18}\text{O}) + 10\text{‰ SMOW} \quad (\text{Mook, 2006})$$

A refinement of the equation following the introduction of the VSMOW standard and the collection of additional samples was stated by Rozanski et al. (1993) as follows:





$$\delta^2\text{H} = (8.13) (\delta^{18}\text{O}) + 10.8\text{‰ VSMOW}$$

This relationship, referred to as the Global Meteoric Water Line (GMWL) (Section 4.3), is plotted on Figure 9. As indicated by the above linear equations, the GMWL has a slope of approximately 8 (Figure 9). The changes to  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  in a water body that occur during the process of evaporation have been calculated and presented in scientific literature. As evaporation proceeds, the residual water departs from the GMWL along a line with a slope typically between 3 and 5, with lower slopes corresponding to lower relative humidities (Clark and Fritz, 1999). Though the evaporative process varies by climatic condition, under tropical conditions (and with no mixing of the water or perturbations other than evaporation), the resulting ratio has been calculated as:

$$\frac{\Delta^2\delta}{\Delta^{18}\delta} = 4.5 \pm 0.5 \quad (\text{Mook, 2006})$$

Plots of evaporative lines with slopes of 4 and 5 are presented in Figure 9 for comparative purposes.

For the Site isotopic data collected, a trend of the Deep Zone sample data indicated a clear departure from the GMWL, consistent with a trend that is caused by evaporation. Linear regression was conducted on the  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  values obtained from all the Deep Zone wells sampled in both 2008 and 2009. The resulting best-fit linear equation ( $\delta^2\text{H} = 3.3(\delta^{18}\text{O}) - 54$ ;  $R^2 = 0.97$ ) confirmed the recognition of that trend. The plot of the regressed line, which has a slope of approximately 3.3, is shown in Figure 6. This slope departure from the GMWL is consistent with the fractionation of the sampled water by evaporation during a previous paleoclimatic time period, presumably of Tertiary age (the same age as the TMCf, ended approximately 2.6 million years before present).

#### 5.3.2.5 Isoconcentration Plots

Appendix D provides isoconcentration plots (Figures D-1 through D-18) created with 2009 data for selected parameters evaluated in past monitoring reports (arsenic, hexavalent chromium, perchlorate, radium 226+228, PCE, and TDS). As depicted in the TDS figures (D-16 through D-18), the area of elevated TDS is focused in an area at and north of the northern boundary of





the Site. This area of TDS impacts is coincident with the area of enriched  $^2\text{H}$  and  $^{18}\text{O}$ . The isoconcentration plots of the distribution of groundwater with enriched  $^{18}\text{O}$  and  $^2\text{H}$  (Figures 7 and 8) show a focused region of heavy isotope enrichment in the same area that is characterized by elevated TDS. This coincident occurrence is consistent with and indicative of an area that is the focus of evaporite deposits.

#### 5.3.2.6 Gypsum Deposits

Significant presence of salts has also been observed at the depth of interest in the geologic column and in the area influenced by elevated groundwater TDS and enriched  $^2\text{H}$  and  $^{18}\text{O}$ . For example, boring logs MCF-06A-R, MCF-20A, MCF-28A (weak reaction to HCl), MCF-29A (strong reaction to HCl), MCF-30A (strong reaction to HCl), and MCF-31A (strong reaction to HCl) are all located within the area of influence of  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  enrichment (GES, 2008, 2009). All of these borings had an abundant presence of gypsum crystals ( $\text{CaSO}_4 \bullet 2\text{H}_2\text{O}$ ), as noted in the boring logs. Figure 10 presents a photograph of sample gypsum crystals collected from Deep Zone boring Location 16. In addition, some boring logs note gypsum “ghosts,” where euhedral crystals have dissolved in situ, leaving behind a mold of the original crystal form in the UMCf clay matrix.

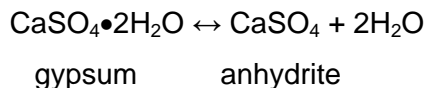
#### 5.3.2.7 Calcite Deposits

Nearer to the center of the  $^2\text{H}$  and  $^{18}\text{O}$  enrichment area and the elevated TDS area, reaction to HCl (as noted in the borelogs based upon on-site field screening tests) in layers within the screened intervals was generally greater. At more distal areas of influence by isotope fractionation and elevated groundwater TDS, reaction to HCl in layers within the screened interval was generally weaker. Reaction to HCl is a commonly used field screening tool to test for the presence of calcium carbonate ( $\text{CaCO}_3$ ), also sometimes referred to as calcite, lime, or caliche, depending on its genesis and morphology. The concurrent presence of  $\text{CaCO}_3$  with  $\text{CaSO}_4 \bullet 2\text{H}_2\text{O}$  would be expected in an evaporitic deposit.

#### 5.3.2.8 Evaporite Mineral Weathering and Dissolution

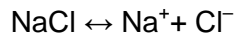
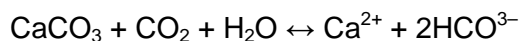
Based on the observance of gypsum crystals and the positive screening tests for  $\text{CaCO}_3$  during borehole drilling and sampling, it is likely that the high TDS in the Deep Zone groundwater is caused by the mineral weathering and dissolution of salts including, among others,  $\text{CaSO}_4 \bullet 2\text{H}_2\text{O}$ ,  $\text{CaCO}_3$ , NaCl, and  $\text{MgSO}_4$ . An example of weathering would be the formation of gypsum by the addition of water ( $\text{H}_2\text{O}$ ) to anhydrite ( $\text{CaSO}_4$ ):





A marked increase in volume accompanies the reaction of anhydrite to gypsum. If this takes place within a rock, physical disintegration can occur (Birkeland, 1976).

Examples of dissolution of an evaporite mineral deposit are the dissolution of calcium carbonate, sodium chloride, and magnesium sulfate, as respectively shown below:



The rate of dissolution of salts is dependent upon pH, temperature, and in the case of  $\text{CaCO}_3$ , the partial pressure of  $\text{CO}_2$ . The pH of the wells in the Deep Zone of the area of high TDS concentrations, as measured during the April through July 2008 monitoring event is generally slightly acid (e.g., 6.7 to 6.8 in monitoring wells MCF-6A-R, MCF-18A, and MCF-20A) to slightly alkaline (e.g., 7.3 to 7.5 in monitoring wells MCF-8A and MCF-17A).

The solubilities of the above-mentioned compounds at 25°C (Craft, 2005) are:

- Magnesium Sulfate ( $\text{MgSO}_4$ ): 757,000-948,000 mg/L  
(depending on the degree of hydration)
- Sodium chloride ( $\text{NaCl}$ ): 360,000 mg/L
- Calcium sulfate ( $\text{CaSO}_4$ ): 2,100-2,400 mg/L  
(depending on the degree of hydration)
- Calcium carbonate ( $\text{CaCO}_3$ ): 14 mg/L

Under saturated solution conditions the combination of these evaporite salts, primarily magnesium sulfate and sodium chloride, can account for the Deep Zone TDS concentrations





that have been observed at and north of the northern Site boundary. Plots of common general cations (calcium, magnesium, sodium, and potassium) shown as a function of the common general anions (bicarbonate, carbonate, sulfate, and chloride) for Site Deep Zone groundwater samples are presented in Appendix E. Two of these plots, for  $\text{MgSO}_4$  and  $\text{NaCl}$ , stand out as unique. In both cases, the plots of the cations fall nearly along a 1:1 line as compared to the respective anions, indicating that the groundwater is nearly saturated with respect to these soluble salts. Both of these salts are commonly associated with evaporite deposits.

General water chemistry data from the area of greatest fractionation and enrichment of the Deep Zone groundwater by  $^{18}\text{O}$  and  $^2\text{H}$  were plotted in Stiff diagrams (Appendix F). As discussed in Section 5.3.2.10, the resulting diagrams are consistent with groundwater that contains dissolved salts dominated by the cations magnesium and sodium (and to a lesser extent, calcium) and the anions sulfate and chloride.

#### 5.3.2.9 Examples of Groundwater Salinization from Evaporite Deposits

The phenomenon of water salinization by encounter with evaporite deposits has been observed before in southern Nevada. For example Lake Mead, where it is impounded behind Hoover Dam, overlies deposits of gypsiferous sediments (evaporite deposits), and dissolution of this gypsum substantially increases the salinity of the Colorado River (Bohn et al., 1979).

#### 5.3.2.10 Stiff Diagrams

Stiff diagrams illustrating the general water chemistry of groundwater samples collected from the Shallow, Middle, and Deep water-bearing zones are presented in Appendix F. A comparison of Stiff diagrams between water-bearing zones indicates that groundwater in all three zones is generally enriched in chloride and sulfate anions.

Shallow Zone groundwater samples generally exhibit no dominant cation. Several exceptions, wells AA-UW-4, AA-UW-3, COH-2A, and WMW5.58SS, are slightly enriched with sodium cation. In the Middle Zone, wells COH-1, MCF-02B, MCF-05, MCF-08B, MCF-24B, MCF-28B, MCF-29B, and MCF-31B are relatively depleted of calcium and relatively enriched with magnesium and sodium. In the Deep Zone, wells MCF-3A, MCF-12A, MCF-18A, MCF-20A, and NCF-25A are dominated by sodium cations, while wells MCF-06A, MCF-07A, MCF-21A, and MCF-24A are dominated by magnesium and sodium cations.





The Stiff diagram data and plots (Appendix F), when examined alone, reveal no information regarding whether the dissolved salts are sourced from an evaporite deposit or from an anthropogenic source. The data are consistent with groundwater that contains dissolved salts dominated by the cations magnesium and sodium (and to a lesser extent, calcium), and the anions sulfate and chloride. Differences between dominant cations in the Shallow versus the Middle and Deep water-bearing zones are likely due to differences in the geologic source material through which groundwater is flowing.

#### *5.3.2.11 Modern Day Analogues*

Present-day examples exist of lakes in closed basins where the buildup of TDS is equivalent to that observed in this area of the Deep Zone. Primarily, these example lakes exist in closed topographic basins with no discharges by surface streams or seepage, and with a groundwater gradient toward a lake or playa. These are the settings in which evaporite deposits readily form. For example, the Great Salt Lake in Utah had measured salinity of 276,000 parts per million (ppm) in 1932, Owens Lake in California had measured salinity of 213,700 ppm in 1905, and the Dead Sea in Palestine has a salinity level of 220,000 ppm (van der Leeden et al., 1990).

#### *5.3.2.12 Plants Area Impacts vs. Natural Evaporite Deposits*

The interpretation that the relatively high TDS concentrations observed in the Deep Zone are due to groundwater intersecting a paleo-evaporite deposit and dissolving salts (Section 5.3.2.8) is contrasted with an alternative hypothesis that postulates that high TDS process waters from historical Plants Area operations were disposed in the BMI Evaporation Ponds and subsequently infiltrated and percolated into the Deep Zone where it is now detected. Several observations that are inconsistent with this hypothesis are consistent with the interpretation that considers evaporitic deposits as the source of high TDS in the Deep Zone. These are:

- Shallow Zone TDS and perchlorate concentrations indicate the presence of these compounds in the vicinity of monitoring well MCF-16C. Darcy's Law was used to make a simple calculation of the average travel time from Location 16 to Location 20 within the Deep Zone. The calculation is simplified and does not account for dispersion or potential preferred pathways. It assumes a gradient of 0.037 ft/ft, a Deep Zone hydraulic conductivity of  $1 \times 10^{-4}$  cm/s, a porosity of 0.30, and a travel distance (L) of 3,980 feet (the distance between Locations 16 and 20). Based on this calculation, the average travel time from Location 16 to Location 20 would be approximately 312 years, with a





velocity (v) of 12.8 feet per year. Even given this long travel time, this calculation is highly conservative in that it does not account for the vertical travel time from the evaporation pond bottoms to the Deep Zone, a nominal distance of 350 feet through the low-permeability sediments of the UMCf.

A more complete calculation, incorporating dispersion, was also conducted. An analytic solution of advection dispersion was used (Fetter, 1999):

$$C = \frac{C_o}{2} \left[ \operatorname{erfc} \left( \frac{L - vt}{2\sqrt{Dt}} \right) \right] \quad \text{Eq. 1}$$

where  $C_o$  = the input concentration

$\operatorname{erfc}$  = complementary error function

$D$  = dispersion coefficient.

The dispersion coefficient was calculated as a function of the travel distance and velocity, as given by Fetter (2001):

$$D = 0.83 \cdot (\log L)^{2.414} \cdot v \quad \text{Eq. 2}$$

The resulting breakthrough curve, showing normalized concentration ( $C/C_o$ ) versus time, is provided in Figure 11. The first arrival is greater than 200 years, and the mean arrival time is 312 years.

- Based on review of the 2009 sampling data (report in preparation), other chemicals coincident with the high-TDS area in the Shallow Zone (e.g., hexavalent chromium and perchlorate) do not have a similar distribution in the Deep Zone, suggesting that the Deep Zone high TDS concentrations are not related to the Shallow Zone high TDS concentrations at Locations 6 and 16. PCE was also detected in Shallow Zone wells in the southwestern portion of the Site and not in any Deep Zone wells, again suggesting the lack of downward flow and transport from the Shallow Zone to the Deep Zone. Comparison of water quality between the Shallow and Deep Zones Stiff diagrams (Appendix F) suggests that the Shallow Zone has water quality that contrasts with the Middle and Deep Zones, as described in Section 5.3.2.10.





- Vertical gradient evaluations (Appendix C) suggest that there is a general upward gradient, with groundwater movement from the Deep Zone to the Middle and Shallow Zones. The movement of a TDS plume from the Evaporation Pond bottoms to the Deep Zone at any historical time would have likely had to overcome the upward vertical gradient. It is recognized, however, that the gradient is downward at Locations 6 and 3. The gradient is variable between the Shallow Zone and the Middle Zone, but also generally upward. Significantly, however, the gradient is downward in selected locations on the northern portion of the Site (excluding the western portion of the Western Hook).
- Migration in the Deep Zone from upgradient off-site source(s) is indicated for hexavalent chromium (Cr(VI)). This is consistent with the hypothesis that the BMI Plants Area impacts are loading the coarse-grained facies of the UMCf (UMCf–cg) where this unit is present to the south of the Eastside Area.

For example, a simplified calculation of average travel time (t) in the UMCf–cg (not accounting for longitudinal dispersion, which would reduce the value of t) can be completed with the following estimates:

- Kh of the UMCf–cg assumed to be within the range of modeled values for the Qal (100 ft/d) (DBS&A, 2009)
- Gradient (i) assumed to be on the order of 0.02 ft/ft
- Porosity of 0.30
- Travel distance (L) of approximately 5,000 feet (approximate distance between the Plants area and well AA-27 where Cr(VI) has been detected [MWH, 2008]).

Based on this calculation, the travel time from the plants area to AA-27 would be approximately:

- $t = L / v$
- $v = (Kh * i) / n = (100 \text{ ft/d} \times 0.02) / 0.3 = \text{approximately } 7 \text{ ft/d}$
- $t = (5,000 \text{ feet}) / (7 \text{ ft/d}) = 714 \text{ days} = \text{approximately } 2 \text{ years}$





The more complex calculation incorporating dispersion that was used for Deep Zone travel time from Location 16 to Location 20 (Equations 1 and 2) was also conducted. The resulting breakthrough curve, showing normalized concentration ( $C / C_o$ ) versus time, is given in Figure 12. The first arrival time is greater than 1 year, and the mean arrival time is approximately 2 years, consistent with the Darcy's law calculation given above.

### **5.3.3 Vertical Gradients**

Vertical gradients, as measured in the five recent Eastside monitoring events, have been generally upward. A summary table of vertical gradient data, including adjustments made for difference in groundwater density between water bearing zones and adjustments made to account for variable position on the potentiometric surface, is presented in Appendix C.

This generally upward gradient condition is consistent with the position of the Site at the relatively distal end of two coalescing alluvial deposits from the River Mountains and McCullough Range. In general, high-energy alluvial sediments are deposited near their source, resulting in a geologic profile dominated by coarser-textured soils that are conducive to downward recharge of precipitation and mountain runoff. At more distal locations, it is common to encounter lower-energy alluvial sediments that result in a geologic profile dominated by finer-textured soils. The distal portions of alluvial deposits often comprise pressure zones where confining or semiconfining zones exist. Water in these zones is often laterally recharged at depth, resulting in pressure buildup that is sustained by the head of water created in the upslope vertical recharge zones. The geologic aspects of this are discussed in Section 5.3.4.3.

At the Site, there are isolated locations where downward gradients exist. For example, the 2009 monitoring event elevation data (MWH, 2008) indicate a downward gradient between the Shallow Zone and the Middle Zone at Location 12 (0.011); the gradient between the Shallow Zone and Deep Zone at Location 12 is upward (0.060). A downward gradient was also calculated between the Middle Zone and the Deep Zone at Location 28 (0.217); well elevation data for the Shallow Zone at this location were not available to make a comparison. A slight downward gradient was also calculated between the Shallow Zone and the Deep Zone at Location 7 (0.007); the direction of gradient has alternated between up and down at this location in previous monitoring events. Historically, downward vertical gradients have been measured at





Location 6 (groundwater elevation was not measured in 2009; previous 2007 vertical gradient was 0.043), which is immediately adjacent to the site of a former gravel mining enterprise where most of the Qal had been removed at one time, exposing the UMCf at that location.

#### **5.3.4 Anthropogenic Chemical Impacts**

The distributions in groundwater of chemicals produced by, or as byproducts of, mine processing, manufacturing, and waste disposal activities provide an indication of the connectivity of water-bearing zones. Chemicals that have been evaluated based on concentrations detected in the 2009 monitoring event (MWH, 2008) include those also discussed in prior groundwater monitoring reports: arsenic (As), hexavalent chromium (Cr(VI)), perchlorate, TDS, PCE, and radium 226+228 (Ra226+228).

##### **5.3.4.1 Total Cr and Cr(VI)**

Cr(VI) has been detected at elevated concentrations in Shallow Zone, Middle Zone, and Deep Zone groundwater. Appendix G presents isoconcentration plots of the compiled Cr(VI) results from groundwater samples collected during various recent groundwater monitoring events conducted at the Site and its vicinity (Figures G-1 through G-4). The data indicate that the Shallow Zone Cr(VI) appears to be derived, at least in part, from an off-site source(s), as evidenced by concentrations as high as 22,100 micrograms per liter ( $\mu\text{g/L}$ ) (well M-89) in Shallow Zone Layer 1 to the west, on the Tronox site. Cr(VI) concentrations in Layer 2 Shallow Zone wells are also high (35,000  $\mu\text{g/L}$  in well M-36) on the Tronox site. These high concentrations at the Tronox Site appear to be a source of elevated Cr(VI) groundwater concentrations in both layers on the southern end of the BRC Eastside property. Cr(VI) was much lower in Shallow Zone well samples collected on the southern end of the BRC Eastside property, with concentrations ranging from nondetect ( $<3 \mu\text{g/L}$  in AA-UW1) to 30  $\mu\text{g/L}$  (AA-UW3). Prior soil sampling detected Cr(VI) in Eastside soil samples at relatively low concentrations and only at the upgradient well locations AA-UW-1 (0.25 mg/kg at 60 feet), AA-UW-3 (0.4 mg/kg at 30 feet), and AA-UW-4 (0.22 mg/kg at 10 feet) (ERM, 2009).

Cr(VI) concentrations reported for wells screened in the Middle Zone are generally less than those in the Shallow Zone but are still elevated. Middle Zone multilevel monitoring well CMT-204 (located on the Tronox site, screened interval from 119.5 to 120 ft bgs) had a reported CR (VI) concentration of 1,700  $\mu\text{g/L}$ .





Cr(VI) concentration data for the Deep Zone are very limited. Well MW-08 on the POSSM site had a detected Cr(VI) concentration of 7.7 µg/L, and detections were reported for wells beneath the southern portion of the BRC Eastside property at MCF-27 (34 µg/L) and upgradient well MCF-3A (38 µg/L). No data are available for the Deep Zone beneath the Tronox site, representing a gap in the data needed to fully understand the elevated concentrations of Cr(VI) in the Deep Zone beneath the BRC Eastside property.

Total Cr groundwater sample concentrations from the Site and vicinity have a similar distribution to that of Cr(VI) in the Shallow Zone layers and the Middle Zone. Figures G-5 through G-8 (Appendix G) present isoconcentration plots of the compiled total Cr results for groundwater samples collected during various recent groundwater monitoring events conducted at the Site and its vicinity.

For the Deep Zone, slightly more total Cr data are available than Cr(VI) data. MW-08 had a concentration of 4,300 µg/L. Total Cr concentrations in the TR series of wells on the western border of the Tronox property ranged from 10 µg/L (TR-7) to 46 µg/L (TR-12). No total Cr data for the Deep Zone are available from the Plants Area for locations east of the western Tronox border, representing a gap in the data needed to fully understand the elevated concentrations of total Cr in the Deep Zone beneath the BRC Eastside property. Total Cr detections in the Deep Zone wells along the southern border of the BRC Eastside property range from nondetect (MCF-01A) to 108 µg/L (MCF-03A).

The data indicate that a significant source of Cr(VI) and total Cr exists in the Plants Area to the west and somewhat south of the BRC Eastside property. It appears likely that Cr(VI) has migrated from this source area to the Deep Zone groundwater on the BRC Eastside property. However, the data gaps discussed above need to be addressed and filled in order to increase the certainty of this interpretation. The data do not indicate or support a conclusion that Cr(VI) has migrated vertically on the BRC Eastside Property from the Shallow Zone Layer 1 through the Middle Zone and to the Deep Zone.

#### *5.3.4.2 Perchlorate*

Perchlorate was detected at elevated concentrations in the Shallow Zone. The data indicate that the Shallow Zone perchlorate appears to be derived, at least in part, from an off-site





source(s) to the west (concentrations as high as 500,000 µg/L in monitoring well PC-28). On-site concentrations are as high as 15,000 µg/L (monitoring well BEC-6).

Perchlorate concentrations in the Middle Zone are generally significantly less than those in the Shallow Zone. Notable detections in the Middle Zone include monitoring wells MCF-06B (5,580 µg/L), MCF-12C (430 µg/L), and MCF-03B (93.3 µg/L) (all detected during the April through July 2008 monitoring event). Perchlorate was also detected in well MCF-01B (672 µg/L) during the same round of monitoring, but this appears to be attributable to an off-site source to the southwest.

Though perchlorate was not analyzed for samples from several locations, the data that were produced indicate that there were few and low detections of perchlorate in the Deep Zone. During the 2009 monitoring event perchlorate was detected in Deep Zone wells MCF-01A (0.17 µg/L), MCF-27 (0.79 µg/L), MCF-12A (0.049 µg/L), MCF-31A (5.7 µg/L), MCF-18A (6.1 µg/L); MCF-28A (17 µg/L), and MCF-18A (6.1 µg/L) (except for MCF-28A, all of these detections had J qualifiers, indicating that the reported values are estimated). In the 2009 event, lower laboratory detection levels were reported than ever before, with some detections reported in parts per trillion range. These detections have focused concern on field sampling protocols and, based on historical concentration trends, the potential that these low detected concentrations could be potential field sampling aberrations. BRC will perform a complete review of the sampling logs and, as a result, may present a revised analysis of these data.

#### *5.3.4.3 Total Dissolved Solids*

TDS in the Shallow Zone generally mimicked the distribution of perchlorate in the Shallow Zone. The data indicate that the Shallow Zone elevated TDS appears to be sourced, at least in part, from an off-site source(s) to the west, where concentrations as high as 11,000 mg/L (monitoring well PC-67) were detected, and potentially from the eastern portion of the Upper Ponds area on the Site where monitoring well MCF-16C had a locally elevated concentration of 11,500 mg/L.

TDS at depth, however, shows a different distribution than perchlorate. TDS concentrations in the northern area of the Middle Zone were as high as 180,000 mg/L at monitoring well MCF-05. In the Deep Zone TDS concentrations are also locally high in the northern area of the Deep





Zone. The highest concentrations were noted in wells MCF-31A (185,000 mg/L) and MCF-06A (178,000 mg/L).

These elevated concentrations prompted further investigation using stable isotope techniques. This area of high TDS concentrations is interpreted as being caused by a separate source of salts, where groundwater has encountered paleo-evaporite deposits in the Deep Zone. As detailed in Section 5.3.2.6, boring logs showed the presence of paleo-evaporite deposits in the Deep Zone in this area. The presence of these deposits is consistent with the interpretation that the Site is located in the distal portion of the regional alluvial system.

Malmberg (1965) states that the most reliable data on the character of the TMCf in the Las Vegas Valley are deep well logs showing that the formation consists of sand, silt, clay, gravel, and evaporite. Bell and Smith (1980) have mapped several facies of the TMCf where exposed at the surface in the Site vicinity. They have mapped the occurrence of a fine-grained facies of the TMCf (TMCf-fg), a coarse-grained facies (TMCf-cg), and the TMCf undifferentiated between the coarse- and fine-grained facies. (Bell and Smith identify the coarse-grained facies as Tmcc, the fine-grained facies as Tmcf, and the undifferentiated coarse-grained and fine-grained facies as Tmcu.) The mapped extent of the surface exposures, along with logs of borings from the Site and BMI Plants Area, indicate that the frequency of encountering the TMCf-cg in boring logs increases in locations closer to the mountains.

In addition to the presence of Quaternary alluvial fans, the data and literature indicate that the source of lacustrine sediments that resulted in the TMCf was Tertiary alluvial deposition. The coarser, higher energy material was deposited closer to the Tertiary mountains (the River and McCullough ranges) that aggraded laterally and ultimately produced the finer Tertiary lacustrine deposits (including evaporites) at locations more distal from the sediment source. This explains the spatial distribution of the coarse-grained facies of the TMCf and the formation of recharge zones near the mountains and pressure zones at distal locations. Figure 13 reproduces Malmberg's (1965) interpretation of the effect of this depositional environment on the regional hydrogeology of the Las Vegas Valley.





#### 5.3.4.4 PCE

PCE is generally at low to nondetectable concentrations in the Shallow Zone. Well AA-20 has a low concentration (5.1 µg/L), only slightly above the maximum contaminant level (MCL) for PCE. One exception, well AA-01 (54 µg/L) appears to indicate an off-site source to the south-southwest. Both the Middle Zone and Deep Zone well samples were below the detection limit (< 1 µg/L) for PCE.

A localized area of elevated Ra 226+228 activity in the Shallow Zone was observed in the vicinity of wells MCF-06B (16.1 picocuries per liter [pCi/L]) and DBMW-12 (12.7 pCi/L). Middle Zone wells were generally below the MCL of 5 pCi/L with the exception of MCF-16B (9.35 pCi/L). Deep Zone wells showed localized impacts above the MCL. Notable Ra 226+228 detections in the Deep Zone included MCF-28A (40.4 pCi/L), MCF-08A (9.92 pCi/L), MCF-24A (8.1 pCi/L), MCF-21A (28.4 pCi/L), and MCF-16A (16.1 pCi/L).





## **6. Summary**

Evaluation of the data indicates that only limited or incidental connectivity exists between the three water-bearing zones at the Site.

Analysis of tritium samples indicates that the water in the Shallow Zone (Qal) is younger than water in the Middle or Deep Zones. Stable isotope analyses indicate that the elevated TDS in the Deep Zone is not sourced at the surface, but rather is present because of deep, isolated groundwater encountering and dissolving natural paleo-evaporite deposits. The Stiff diagram evaluations are consistent with this and indicate that the general chemistry of water in the Shallow Zone is contrasted from that in the Middle and Deep Zones.

Vertical gradients between the Shallow and Deep Zones at the Site are generally upward, with a localized area of downward gradient at Location 6. (Location 6 is immediately adjacent to the site of a former gravel mining enterprise where most of the Qal had been removed at one time, exposing the UMCf at that location). Though no data are available to assess historical vertical gradients, it is expected that similar gradient conditions would have existed in the past, based on the Site location as a pressure zone in a mixed alluvial fan and lacustrine depositional environment.

Chemical impacts to the Shallow Zone on the BRC Eastside Property appear to be independent of those in the underlying Deep Zone and vice versa. The Middle Zone wells appear to variously have impacts influenced by those in both the Shallow and Deep Zones. Though Shallow Zone TDS and perchlorate chemical distribution signatures were very similar, the respective impacts were much different in the Deep Zone. These data indicate an origin for the Deep Zone TDS other than migration from the Shallow Zone.

It is interpreted that the Shallow Zone and the Deep Zone are largely isolated from one another at the Site. However, there could be limited and incidental connection between the Shallow Zone and the Deep Zone via the Middle Zone. The large depth interval and generally low permeability of the Middle Zone together serve to greatly modulate and buffer hydraulic variation and chemical transport between the Shallow and the Deep Zones.





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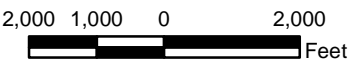
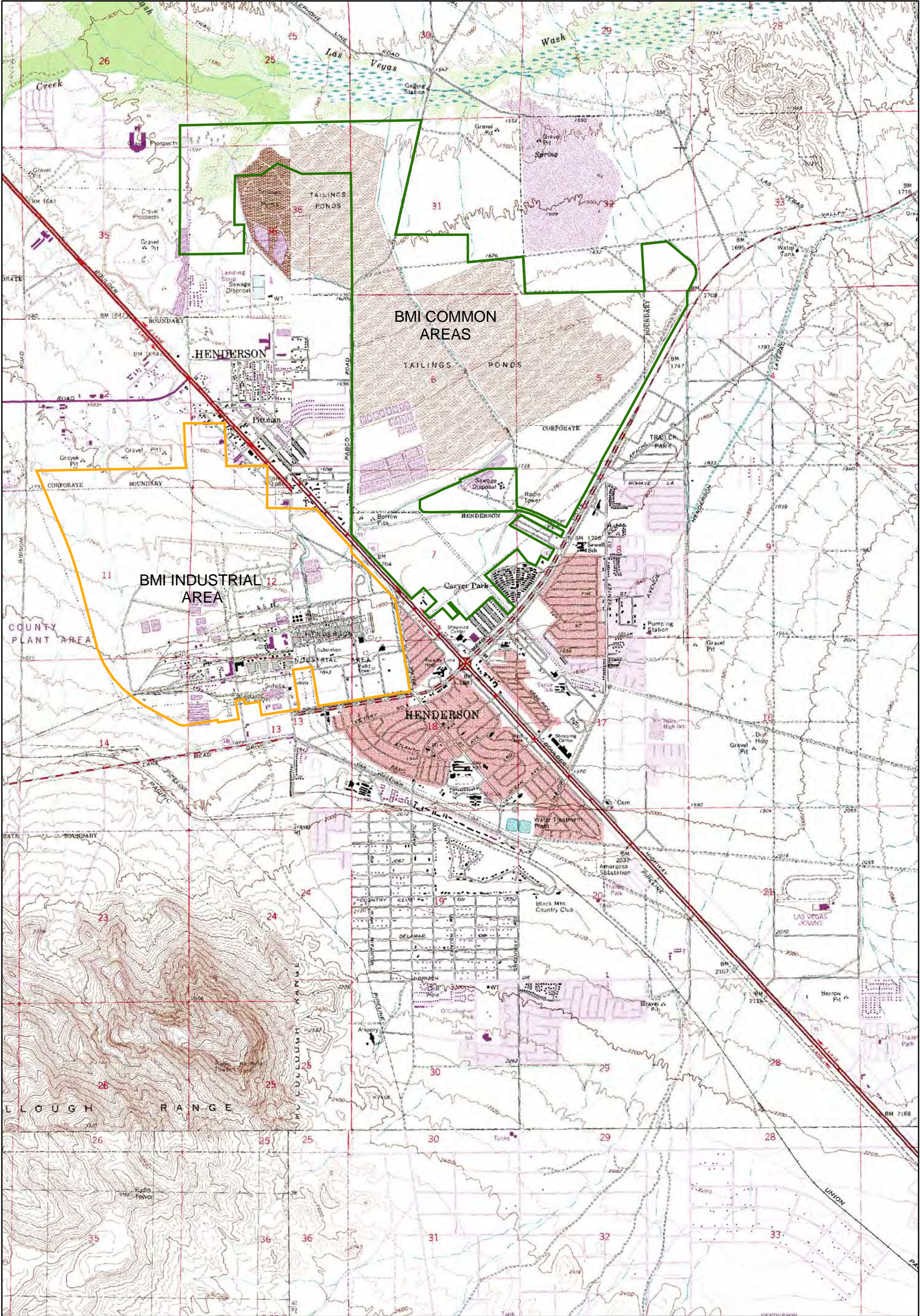
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## Figures





BMI Site  
Henderson, Nevada

FIGURE 1

SITE LOCATION AND  
TOPOGRAPHIC MAP



Nevada-Clark Co. 7.5 Minute Series (Topographic)  
Henderson, Nevada SE, Boulder City NW, and Sloan NE Quadrangles


Prepared by:  
MKJ

Date  
09/28/06


JOB No. 1881262  
FILE: GIS/BRC/BKGD\_FIGURE1.MXD





  
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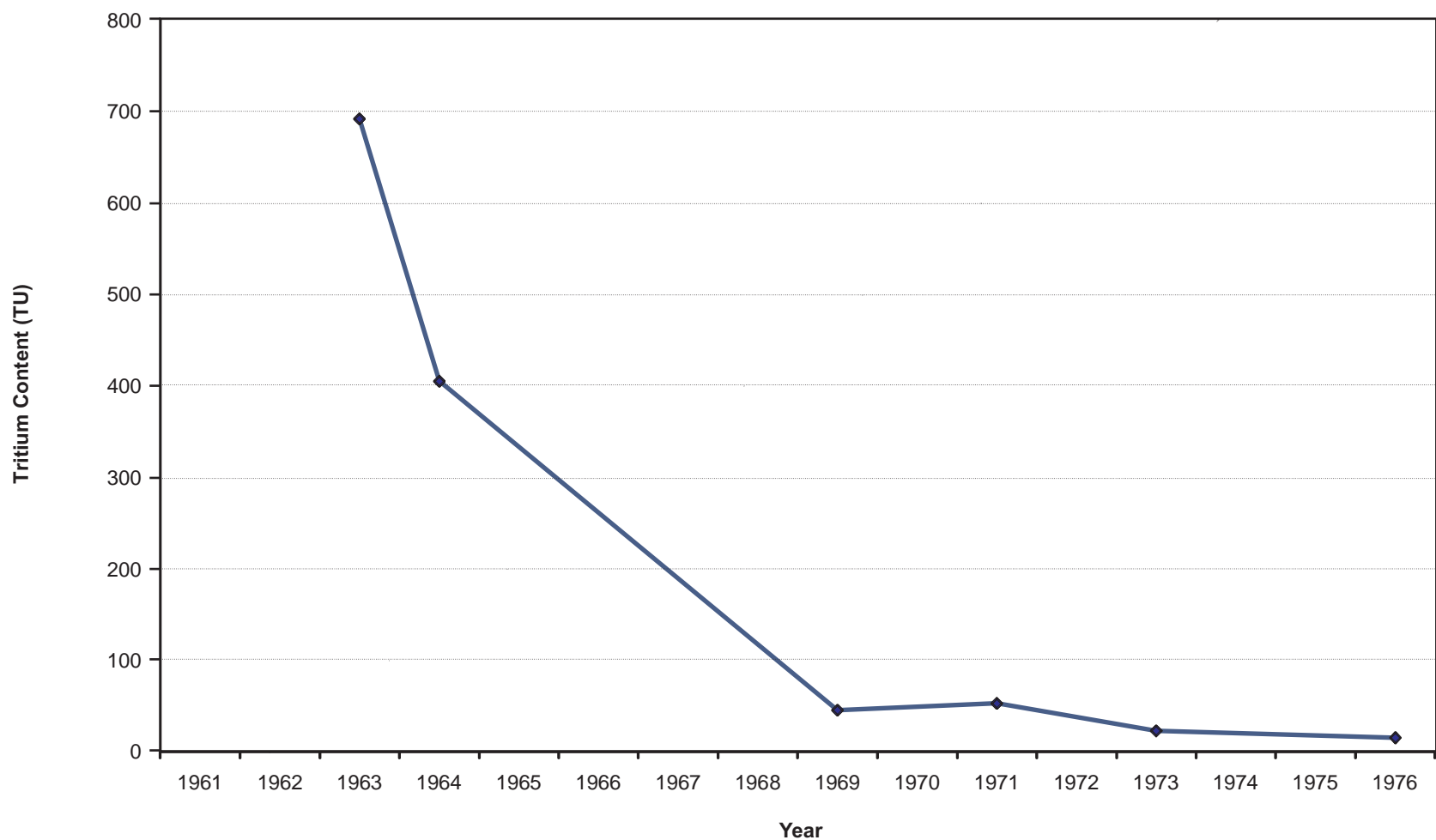
2,000 Feet

**Explanation**  

Site boundary

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE 2 AERIAL PHOTOGRAPH SEPTEMBER 2003	
Prepared by: DWR (DBS&A)	 Date: 09-08-06





BMI Common Areas (Eastside)  
Henderson, Nevada


**FIGURE 3**  
**Atmospheric Tritium Content**  
**Santa Maria, California**  
**1961-1976**



*Daniel B. Stephens  
& Associates, Inc.*



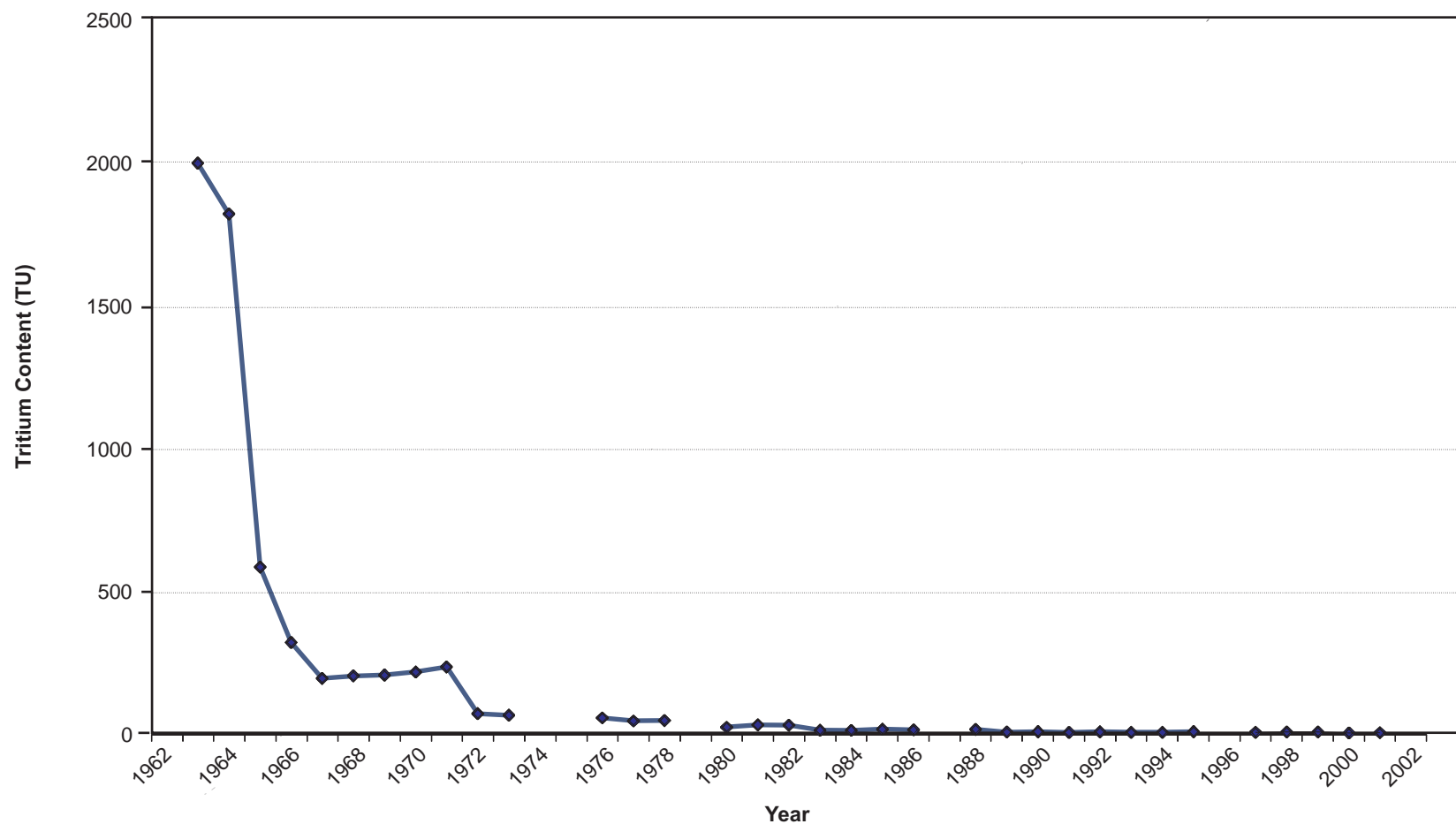
**Basic Remediation**  
COMPANY

Prepared by:  
 **DBS&A** CRS

Date  
04-08-10

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VDR\_DRAWINGS/FIG4\_ATMOSPHERIC\_TRITIUM\_CONTENT\_





BMI Common Areas (Eastside)  
Henderson, Nevada


**FIGURE 4**  
**Atmospheric Tritium Content**  
**Albuquerque, New Mexico**  
**1963-2001**



*Daniel B. Stephens  
& Associates, Inc.*



**Basic Remediation**  
COMPANY

Prepared by:  
 DBS&A CRS

Date  
04-08-10

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VDR\_DRAWINGS/FIG4\_ATMOSPHERIC\_TRITIUM\_CONTENT\_  
ALBUQUERQUE\_1963-2001.CDR














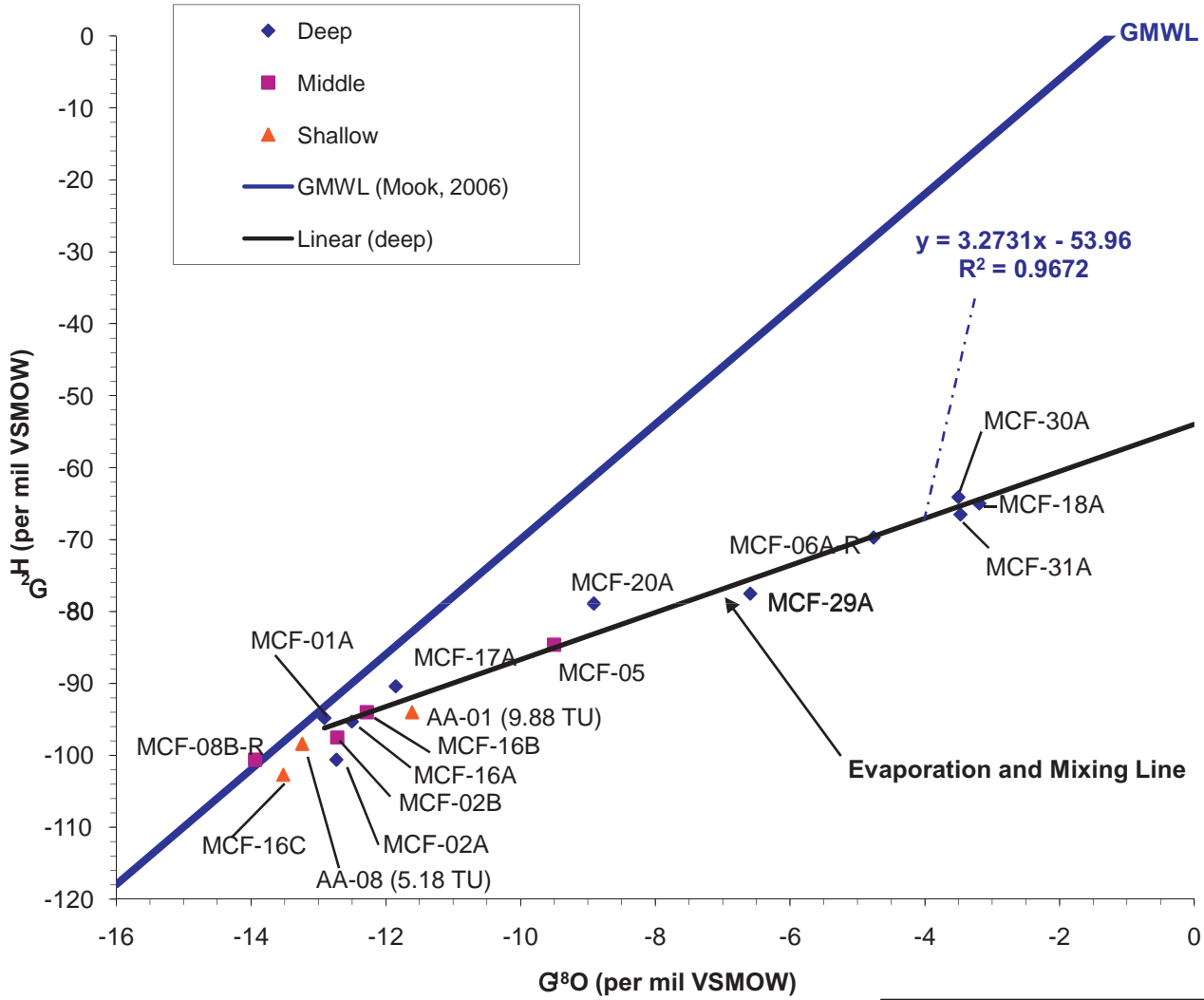
Explanation	
	Shallow Zone monitoring well
	Middle Zone monitoring well
	Deep Zone monitoring well
	Abandoned Shallow Zone monitoring well
	Abandoned Middle Zone monitoring well
	Abandoned Deep Zone monitoring well
	Site boundary
	Gravel pit circa 1976.
	Source: Aerial photograph dated 1976
	Las Vegas Wash
	Street

FIGURE 5  
Monitoring Well Locations



S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
Mg\_2009\_DEEP.MXD 906121





**Note:** 1. GMWL = Global meteoric water line  
 2. VSMOW = Vienna Standard Mean Ocean Water  
 3. Data from groundwater samples collected April and July 2008 and August and September 2009

BMI Common Areas (Eastside)  
 Henderson, Nevada

**FIGURE 6**  
 Groundwater Samples  
 Stable Isotope Analytic  
 Results and GMWL



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 & Associates, Inc.



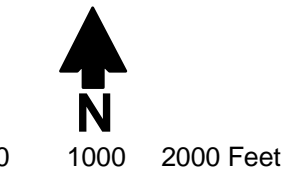
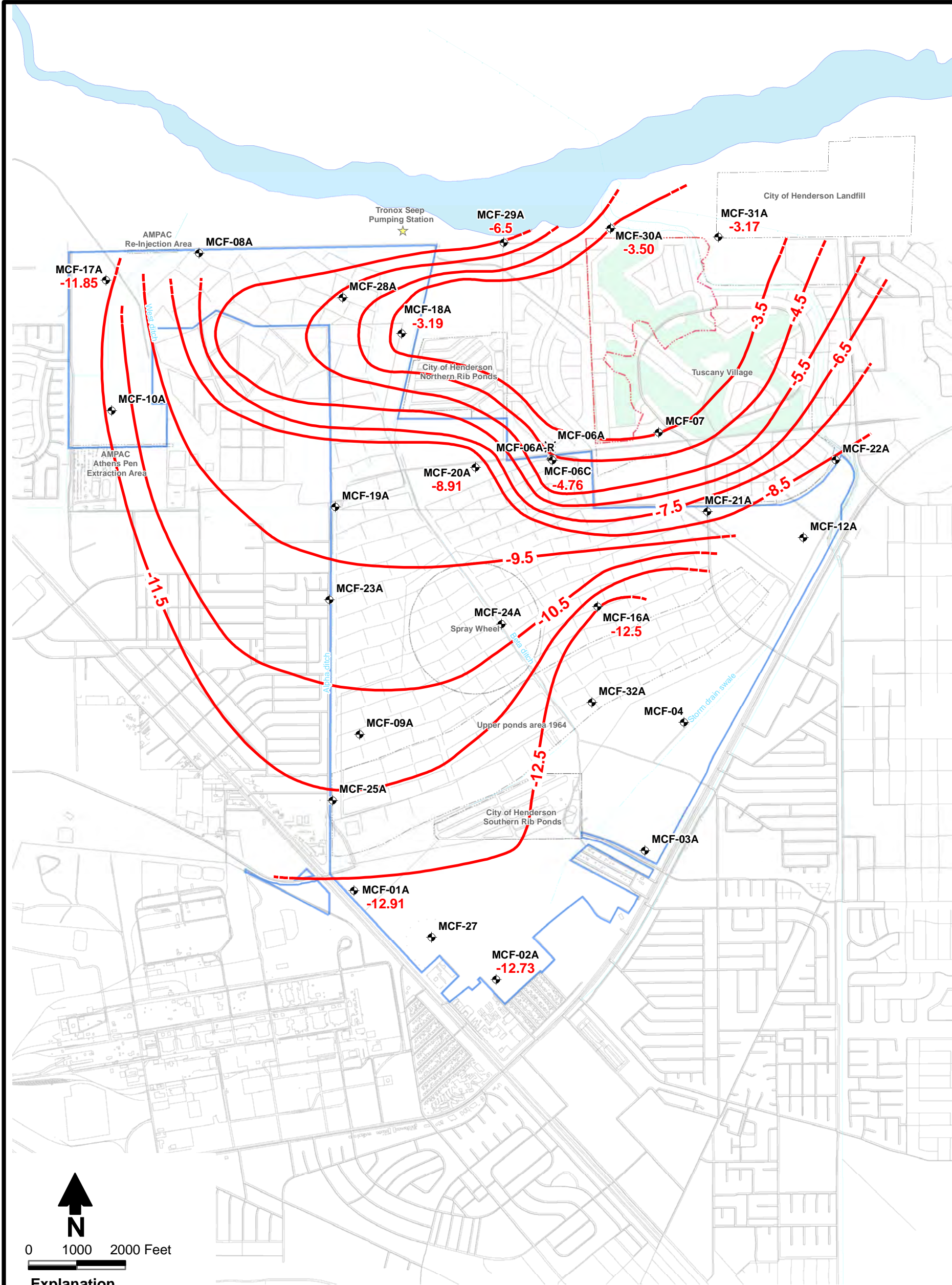
Basic Remediation  
 COMPANY

Prepared by:  
 DBS&A CRS

Date  
 04-08-10

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 VDR\_DRAWINGS/FIG7\_GW\_ISOTOPE\_ANALYTIC\_RESULTS.CDR



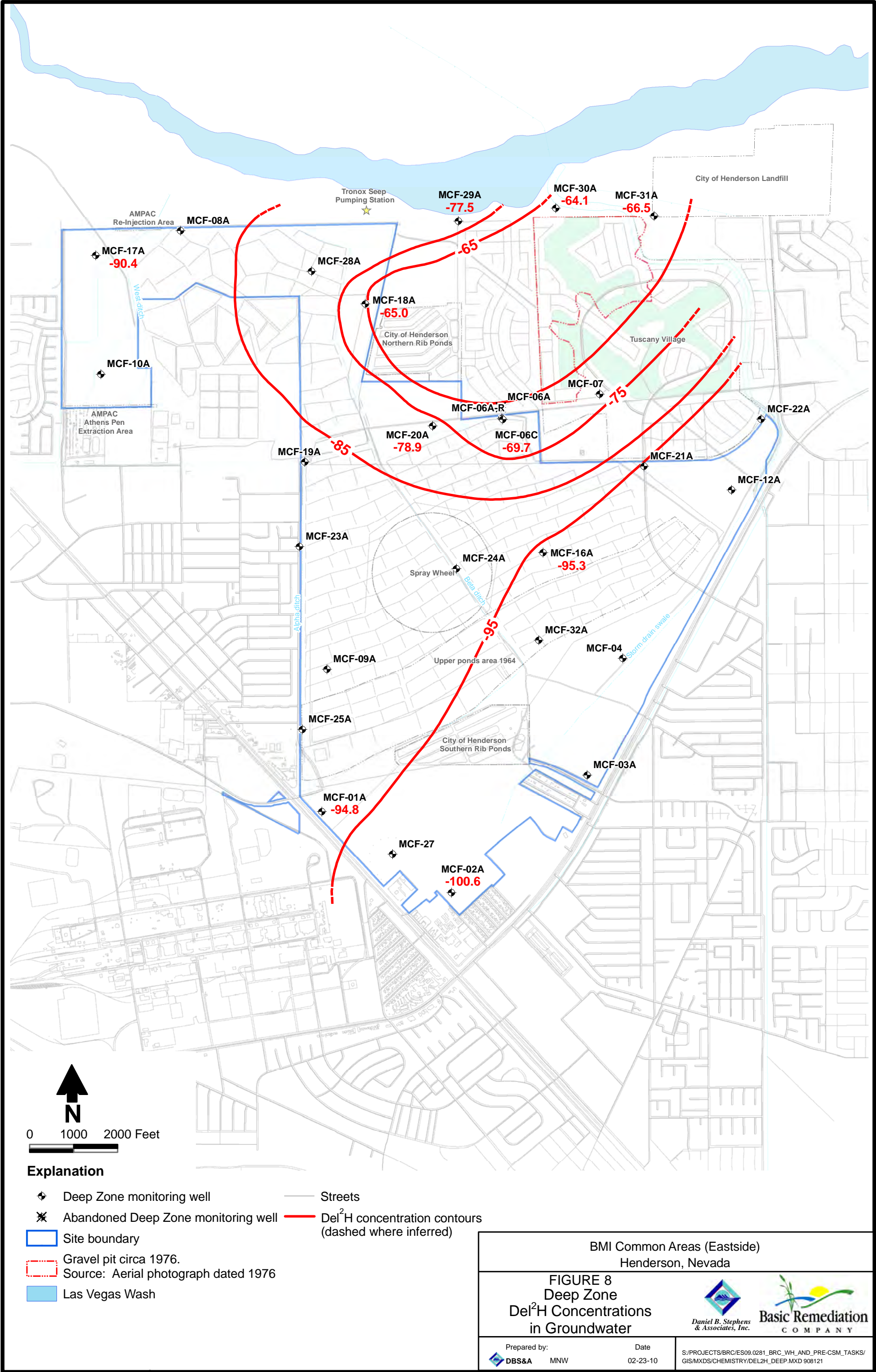


Explanation

- Deep Zone monitoring well
- Abandoned Deep Zone monitoring well
- Site boundary
- Gravel pit circa 1976.
- Source: Aerial photograph dated 1976
- Las Vegas Wash
- Streets
- $\text{Del}^{18}\text{O}$  concentration contours (dashed where inferred)

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE 7 Deep Zone $\text{Del}^{18}\text{O}$ Concentrations in Groundwater	
Prepared by: DBS&A MNW	Date 02-23-10
S:/PROJECTS/BRC/ES09.0281_BRC_WH_AND_PRE-CSM_TASKS/GIS/MXDS/CHEMISTRY/DEL2_H_DEEP.MXD 907121	








**Source:** Mook, 2006

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE 9  
Relationship of  $^{18}\text{O}$  and  $^2\text{H}$   
Variations in Natural Waters



Prepared by:  
 **DBS&A**      CRS

Date  
04-08-10

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VDR\_DRAWINGS/FIG07\_RELATIONSHIP\_OF\_O&H\_MOOK.CDR





**Note:** Example of gypsum crystals commonly encountered in the northern portion of the Site. These nominally 3 to 4 inch crystals were collected from location 16 at 225 ft bgs.

BMI Common Areas (Eastside)  
Henderson, Nevada


FIGURE 10  
Example of Gypsum Crystals



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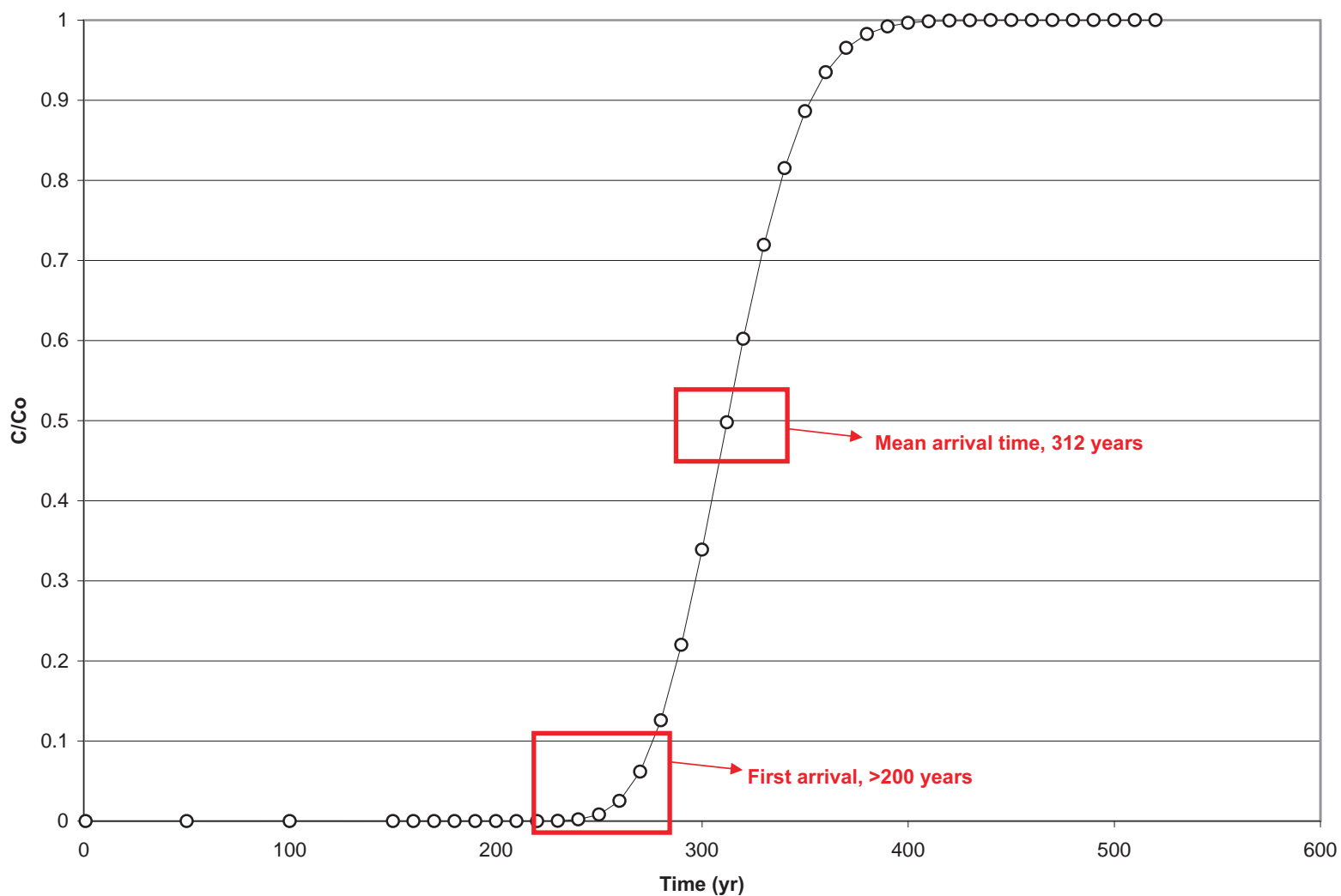
Basic Remediation  
COMPANY

Prepared by:  
 DBS&A CRS

Date  
04-08-10

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VDR\_DRAWINGS/FIG12\_GYPSUM\_CRYSTALS.CDR





BMI Common Areas (Eastside)  
Henderson, Nevada

**FIGURE 11**  
First Arrival and Mean Travel Time  
Location 16 to Location 20  
(Deep Zone)



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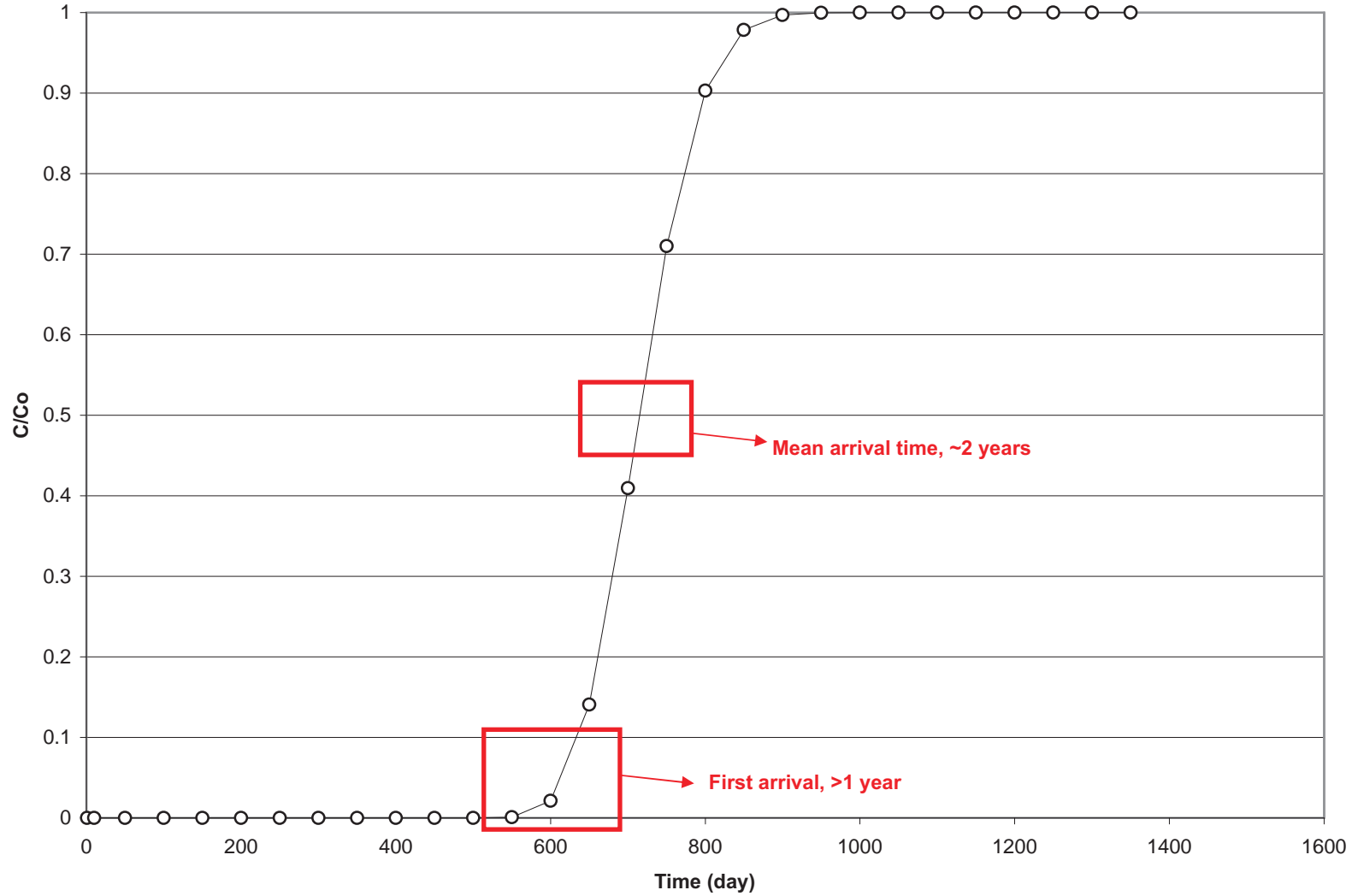


Prepared by:  
 DBS&A CRS

Date  
04-08-10

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VDR\_DRAWINGS/Fig13\_First\_arrival\_and\_mean\_travel\_  
time\_deep\_zone.cdr





BMI Common Areas (Eastside)  
Henderson, Nevada

**FIGURE 12**  
First Arrival and Mean Travel Time  
Plants Area to AA-27  
(Shallow Zone)



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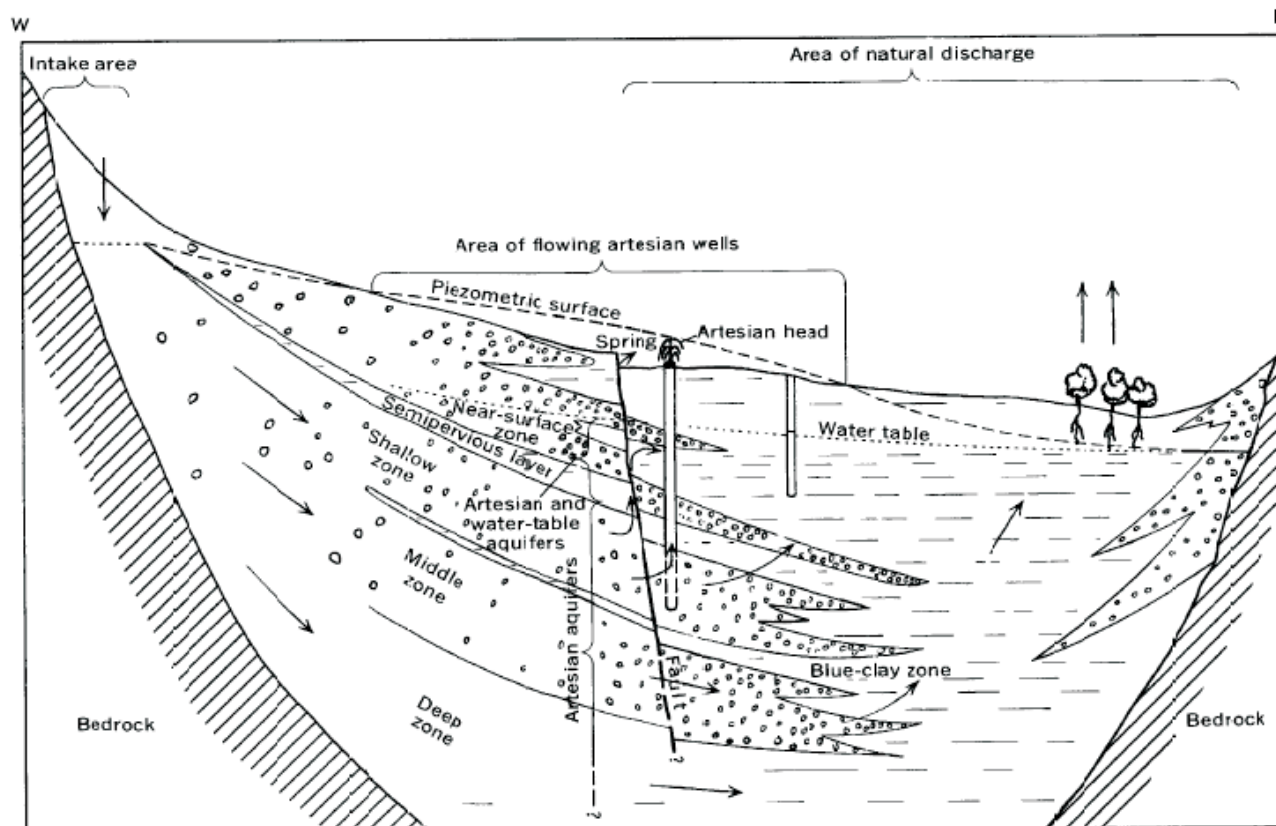
Basic Remediation  
COMPANY

Prepared by:  
DBS&A CRS

Date  
04-08-10

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VDR\_DRAWINGS/Fig14\_First\_arrival\_and\_mean\_travel\_  
time\_shallow\_zone.cdr





Malmberg (1965) interpretation of the presence of recharge and discharge zones in the Las Vegas Valley.

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE 13  
Regional Hydrogeology  
Las Vegas Valley



Daniel B. Stephens  
& Associates, Inc.



Basic Remediation  
COMPANY

Prepared by:  
DBS&A CRS

Date  
04-08-10

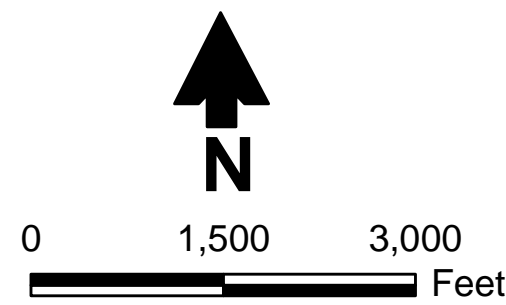
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VRDRAWINGS/fig\_Z\_solubility\_plots.cdr



**Plate**



S:\PROJECTS\BRC\ES09\0281\_BRC\_VH\_AND\_PRE-CSM\_TASKS\GIS\MXDS\REPORTS\FIG03\_TOP\_MUDDY\_CREEK\_12-17-09\_D-SIZE.MXD 9/12/21



Updated 12-17-09  
Explanation

- New data point used in contouring (2008/2009)
- Data point used in contouring (2006)
- Site boundary
- Top of Muddy Creek Formation contour (ft msl)
- - - Paleochannels (dashed where inferred)
- Las Vegas wash



BMI Common Areas (Eastside) Henderson, Nevada	
Plate 1 TOPOGRAPHIC SURFACE OF THE MUDDY CREEK FORMATION	
Prepared by: DBSA	Date: 02-23-10
CRF	S:\PROJECTS\BRC\ES09\0281_BRC_VH_AND_PRE-CSM_TASKS\GIS\MXDS\CHEMISTRY\fig_2009_DEEP.MXD 9/12/21



**Table**





Daniel B. Stephens & Associates, Inc.

**Table 1. Isotopic Data Results Summary  
BMI Common Areas (Eastside) Groundwater Sampling  
April–July 2008 and August–September 2009**

Location	Well	Water Bearing Zone	Screen Interval (ft bgs)		Date	Delta-D <sup>a</sup> (‰)	Delta-O <sup>b</sup> (‰)	Tritium (TU)
			Top	Bottom				
Western Hook	AA-08	Shallow	5	35	5/16/2008	−98.4	−13.24	5.18
	MCF-08B-R	Middle	116.5	136.5	7/23/2008	−100.6	−13.94	< 1
	MCF-17A	Deep	367	387	7/21/2008	−90.4	−11.85	< 1
East of Spray Wheel	MCF-16C	Shallow	53	73	5/19/2008	−102.7	−13.52	< 1
	MCF-16B	Middle	283.7	313.7	5/19/2008	−94	−12.28	< 1
	MCF-16A	Deep	364.5	384.5	5/19/2008	−95.3	−12.5	< 1
Near Pittman lateral	MCF-05	Middle	221	231	4/30/2008	−84.6	−9.5	< 1
	MCF-20A	Deep	360	380	7/18/2008	−78.9	−8.91	< 1
Southwestern Site boundary	AA-01	Shallow	29	49	4/22/2008	−94	−11.61	9.88
Southern Site boundary	MCF-02B	Middle	215	235	4/24/2008	−97.5	−12.72	< 1
Southwestern Site boundary	MCF-01A	Deep	335	355	4/28/2008	−94.8	−12.91	< 1
Southern Site boundary	MCF-02A	Deep	360	380	8/25/2009	−100.6	−12.73	NA
North Central Site boundary	MCF-06A-R	Deep	353	373	9/25/2009	−69.7	−4.76	NA
390 ft W-NW of COH RIBs	MCF-18A	Deep	380	400	9/25/2009	−65.0	−3.19	NA
390 ft W-NW of COH RIBs	MCF-18A (FD)	Deep	380	400	9/25/2009	−65.9	−3.52	NA
NW corner, Weston Hills property	MCF-29A	Deep	259.5	379.5	10/1/2009	−77.5	−6.59	NA
North central boundary of Tuscany	MCF-31A	Deep	361	381	10/1/2009	−66.5	−3.47	NA
NW corner of the Tuscany Village	MCF-30A	Deep	350	370	10/8/2009	−64.1	−3.50	NA
NW corner of the Tuscany Village	MCF-30A (ms/msd)	Deep	350	370	10/8/2009	−65.6	−3.59	NA

<sup>a</sup> Delta-<sup>2</sup>H – Stable Isotopes of Hydrogen (Deuterium [<sup>2</sup>H] to Protium [<sup>1</sup>H])

<sup>b</sup> Delta-<sup>18</sup>O – Stable Isotopes of oxygen (<sup>18</sup>O/<sup>16</sup>O)

ft bgs = Feet below ground surface

‰ = Per mil relative to VSMOW

TU = Tritium unit (1 TU is equivalent to approximately 3.19 picoCuries per liter)

< = Analyte detected below reporting limit shown

NA = Not analyzed



**Appendix A**  
**Response to Comments**



**Response to Nevada Division of Environmental Protection (NDEP) Comments, dated February 11, 2010, to *Evaluation of Hydraulic Zone Connectivity through Tritium and Stable Isotope Sampling and Analysis*, dated December 29, 2009, NDEP Facility ID# H-000688**

1. Section 5.1, page (pg) 16, it would be helpful to note that Converse collected the samples for BRC.

**Response:** A reference to Converse Consultant's role in groundwater sample collection has been inserted in Section 5.1.

2. Section 5.3.2.6, pg 23, NDEP has the following comments:
  - a. A plot that should provide support to this discussion would be to graph Ca (meq/L) [y-axis] versus SO<sub>4</sub> (meq/L) [x-axis]. Add a line for 1:1 ratio at various concentrations of Ca meq/L and SO<sub>4</sub> meq/L which would represent the solubility of the mineral. Data points above the line would be enriched with Ca and data points below the line would be enriched with SO<sub>4</sub>. Data points that fall about the line would be indicative of gypsum dissolution.

**Response:** This discussion has been added to the revised report as Section 5.3.2.8, Evaporite Mineral Weathering and Dissolution

- b. It is also noted that this discussion does not appear to agree with the Stiff diagrams in Figure E-3. Please explain.

**Response:** The discussion has been revised and a discussion added to point out the consistency between the Stiff diagrams and the revised discussion on mineral weathering and dissolution.

3. Section 5.3.2.7, pg 24, please strike "Piper" from the heading and within this section as Piper diagrams are not presented herein.

**Response:** The word "Piper" has been struck.

4. Section 5.3.2.9, pg 27, 3<sup>rd</sup> bullet on page. Please expand the explanation as how the off-site upgradient source is indicated. It would also be helpful to show chemical concentration contours to support this discussion. Figure D-6 does not present any data from the off-site sources and hence it is difficult to support BRC's hypothesis. NDEP understands that the Tronox facility is the primary source of hexavalent chromium in groundwater, however, the data needs to be presented for clarity.

**Response:** The text has been revised to address how an upgradient source is indicated. Figures that support this discussion and present data from upgradient source areas have been added.



5. Section 5.3.4, pg 29, last paragraph on page, it is noted that if the BMI plant site is or was a potential source for Cr(VI), then the ponds that received waste water from the site could be a potential source as well. Please see comment above requesting a figure to support BRC's hypothesis.

**Response:** See response to Comment 4.

6. Section 5.3.4, pg 30, top of page, BRC states "Exceptions are MCF-27 (34 µg/L), where an off-site source to the south appears to be indicated, and upgradient well MCF-3A (38 µg/L)." It is noted that the potential source could also be to the southwest of these wells. The figures requested above would help to clarify this issue.

**Response:** See response to Comment 4.

7. Section 5.3.4, pg 30, last paragraph on page, please specify when the review discussed in this paragraph will be completed.

**Response:** BRC is planning to provide a comprehensive review of the data and sampling protocols in the forthcoming Conceptual Site Model report.

8. Section 5.3.4, pg 31, 3<sup>rd</sup> paragraph on page, BRC states "This is consistent with the interpretation that the Site is located in the distal portion of the regional alluvial system." Please clarify and discuss what the TMCf evaporitic deposits have to do with the alluvial system.

**Response:** The discussion in Section 5.3.4 has been appended to provide citations and discussion that describes the TMCf evaporite deposits as a lacustrine facies deposited as the result of basinward alluvial deposition and aggradation.

9. Figure 6, please remove field duplicate and MS/MSD from the graph and re-compute the  $R^2$  value.

**Response:** The field duplicate and MS/MSD data have been removed from the graph and the  $R^2$  value recomputed.

#### Appendix D

10. Figures D-6 and D-9, NDEP is not certain contours are justified on these figures given the paucity of the detected data.

**Response:** The contours have been removed.

11. Figures D-16 and D-18, NDEP appreciates and acknowledges the value of posting wells when the CAB qualifier indicates R-CAB & TDS.



***Response:*** Comment noted.

#### Appendix E

12. The figures must include the CAB qualification status. Also, please note that analyses with R – CAB & TDS must not be used for plots.

***Response:*** The CAB qualification status has been included on the revised plots.



***Responses to Nevada Division of Environmental Protection (NDEP) Comments, dated April 24, 2009,  
to Tritium and Stable Isotope Sampling and Analysis, and Evaluation of Hydrogeologic Zone  
Connectivity, BMI Common Areas (Eastside), Clark County, Nevada, dated March 26, 2009  
NDEP Facility ID# H-000688***

1. General, where previous data, figures and tables are referenced, please reproduce and include as appendix materials (as feasible). Additionally, this document (once finalized and approved) should be incorporated in the conceptual site model (CSM) update expected in the summer of 2009.

***Response:*** In the revised document, applicable reference materials will be included in an appendix. Also, this document will be incorporated into the CSM as noted.

2. Page 11, first paragraph, please include referenced Quaternary alluvium (Qal) water travel velocity and residence time calculations.

***Response:*** These calculations will be included in the revised document.

3. Page 11, second paragraph, NDEP concurs that the amount of data presented for tritium analysis is limited, however, NDEP is unsure that additional data will provide commensurate value.

***Response:*** Comment noted.

4. Page 11, number 2, BRC should also consider discussing (and presenting) information relating to vertical gradients at the Site.

***Response:*** Vertical gradient information will be included in the revised document and the CSM.

5. Page 12, first paragraph, please provide mass flux/mixing calculations to support assertion of limited flux and mixing of Qal and Upper Muddy Creek formation (UMCf) waters.

***Response:*** These calculations will be included in the revised document.

6. Page 12, third paragraph, NDEP concurs that the isotopically heavier signature of MCF-05 and MCF-20A may support the concept that the source of high total dissolved solids (TDS) in these locations is evaporitic deposits, however, the logical process appears to be incomplete, please expand. For example, has the evaporitic deposit been characterized in terms of nature and extent? Have the mineral(s) of the deposit been identified? What are the basic geochemical reactions and kinetics, related to observed water chemistry? Do other wells screened within the conceptualized deposit exhibit isotope fractionation? Conversely, are the wells which plot on the "Local Meteoric Water Line" located within the same conceptual deposit? Can this theory be supported using Piper and Stiff diagrams?



**Response:** The CSM will include hydrogeologic cross-sections that illustrate the lateral and vertical extent of the evaporite deposits, to the extent known. The deposits have been characterized in boring logs as gypsum-bearing sediments. The observed water chemistry, as it relates to the evaporite deposits rich in gypsum ( $\text{CaSO}_4$ ), will be evaluated in the CSM. A discussion of evaporite dissolution will be included. The CSM will evaluate the spatial distribution of the conceptualized evaporite deposit relative to wells that plot on the Local Meteoric Water Line.

The April 28, 2009 Eastside groundwater sampling plan includes supplemental isotope sampling to further evaluate groundwater quality. Piper and Stiff diagrams will be used to evaluate if groundwater sampled from wells installed within the interpreted evaporite deposit have a unique geochemical signature. This evaluation will be presented in the CSM.

7. Page 12, number 1, the advective travel time calculation is presented as being conservative; NDEP has several exceptions with this statement as follows:
- The logical starting point for such transport calculation should be the former TIMET Spray Wheel or TIMET ponds rather than location 16 as these appear to be the primary potential Site source for water and TDS.

**Response:** A revised transport calculation, with the former TIMET Spray Wheel of the TIMET ponds as the starting point, will be evaluated and presented if appropriate . in the CSM. In any case, this issue will be discussed.

- The calculation does not account for dispersion, and only provides an average seepage velocity rather than a more conservative “toe” travel time for solutes.

**Response:** Dispersion will be input into the revised calculation.

- The calculation does not account for preferential pathways; NDEP has observed boring cores from various locations at the Site, and has observed a natural cleavage plane especially in the presence of “evaporite” crystals within boring cores. Preferential pathways may also be present due to heterogeneity. Also, vertical preferential pathways, such as soil macro-structures, may dominate flow and transport, especially through media which has resided below paleosurfaces.

**Response:** As part of the calculation to be presented in the CSM, BRC will evaluate the evidence and potential for preferential flow pathways in both horizontal and vertical directions.

8. Page 13, number 2, as noted above, please include the referenced chemical maps as appendix material.

**Response:** As discussed in the response to Comment No.1 above, in the revised document, applicable reference materials will be included in an appendix.



9. Page 13, number 3, please discuss if the previous water quality data been quality control checked using standard operating procedures (SOPs) (e.g.: cation anion balance checks) and flagged accordingly. BRC should also discuss if the data is usable. Please include the most pertinent Piper and Stiff diagrams as appendix material.

**Response:** Cation anion balance checks have been completed for the data from each BRC groundwater monitoring event. The results of the CAB checks are currently in review with the laboratory to determine why some analyses do not meet the 5% balance criteria. The results of the CAB analysis, and revised Piper and Stiff diagrams, if needed, will be included in the revised document.

10. Page 13, number 4, BRC assumes that the present-time observed general upward gradient was also the historical case. Please consider the degree of hydraulic gradient reversal which would be induced via TIMET Spray Wheel, evaporation pond, and rapid infiltration basin infiltration and mounding. Please account for density-driven flow in your consideration.

**Response:** This task is underway in preparation for inclusion in the CSM.

11. Page 13, number 5, the assertion of hexavalent chromium migration within the Deep Zone appears to be inconsistent with travel time calculations presented in page 12, number 1. Please support this assertion with similar calculations.

**Response:** The coarse-grained facies of the TMC (TMCcg) is interpreted to be present to the south of the Eastside site, that is, sand lenses within the TMCcg are anticipated to be facilitating contaminant transport in this area. The CSM will discuss this concept in detail. As applicable, the revised isotope tech memo will include a revised calculation to demonstrate the anticipated travel time in the TMCcg.

12. Page 14, Anthropogenic Chemical Impacts, the NDEP has the following comments:

- a. Iso-concentration maps need to be included with this discussion.

**Response:** Iso-concentration maps from the 5th round monitoring event will be included as an appendix to the revised document.

- b. BRC refers to the elevated arsenic detection limits as a limiting factor. It appears that this document will need to be revisited after the next round of sampling when usable data is gathered.

**Response:** Additional arsenic sampling has been proposed in the Eastside groundwater sampling plan, dated April 28, 2009. The new data will be incorporated into the interpretation of the isotopic data for the Eastside area as well as the overall Eastside CSM.



13. Page 15, first paragraph, hexavalent chromium concentrations are noted to have been present in the Middle and Deep Zones. What is the current conceptual model for these occurrences? Are soil analytical data available that can support or refute hexavalent chromium as an anthropogenic tracer?

**Response:** The current hypothesis for the CrVI conceptual model is that sand lenses in the TMCcg are facilitating transport from the offsite area. This concept will be described in detail in the CSM along with supporting data. Soil data for CrVI will be reviewed for the revised isotope tech memo to evaluate if anthropogenic sources are present in the Eastside area.

14. Page 15, second paragraph, perchlorate concentrations are stated to have been “essentially” not detected in the Deep Zone. Does this mean that detections were made? If so, what is the current conceptual model for these occurrences? BRC also states that perchlorate was not analyzed for several locations; since perchlorate is among the most relevant anthropogenic tracers for the Site, please sample for perchlorate at all Middle and Deep Zone locations, including those of the most recent round of well installations. Also, please insure the use of the lowest possible laboratory detection limit. As discussed with BRC previously, it may be necessary to utilize a different analytical method to gather meaningful data.

**Response:** In the 5th round groundwater sampling event, perchlorate was detected in Western Hook area deep well MCF-10A at 2.38 J. Additional perchlorate sampling and analysis with a different laboratory method has been proposed in the April 28, 2009 Eastside groundwater sampling plan. The new data will be incorporated into the interpretation of the isotopic data for the Eastside area as well as the overall Eastside CSM.

15. Page 16, Summary, second paragraph, as noted previously by NDEP, it appears that most of the data used to generate the referenced Piper and Stiff diagrams is unusable. This issue will need to be revisited once usable data is collected.

**Response:** Please see the response to Comment No.9 above.

16. Page 16, fifth paragraph, the relationship between the former gravel mining operation, and the localized area of downward gradient at Location 6, is unclear. Please explain.

**Response:** Currently there is no clear relationship that is evident between the former mine and the gradient at Location 6. This information is included in the document as a matter of completeness. If a relationship is determined to be present it will be detailed in the revised document and in the CSM.



## **Appendix B**

### **Laboratory Reports**



## Water Analysis

Lab Number: 172091

Job Number: 12040

Submitter Sample Name: MCF-29A

Submitter Sample ID:

Submitter Job #: 06-43226-07

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: 1 Liter Plastic Bottle

Sample Collected: 9/29/2009

Results Reported: 10/15/2009

Delta D of water ----- -77.5 per mil relative to VSMOW

Delta O-18 of water ----- -6.59 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



## Water Analysis

Lab Number: 172092 Job Number: 12040

Submitter Sample Name: MCF-31A

Submitter Sample ID:

Submitter Job #: 06-43226-07

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: 1 Liter Plastic Bottle

Sample Collected: 9/29/2009 Results Reported: 10/15/2009

Delta D of water -----	-66.5 per mil relative to VSMOW
Delta O-18 of water -----	-3.47 per mil relative to VSMOW
Tritium content of water -----	na
Delta C-13 of DIC -----	na
Carbon-14 content of DIC -----	na
Delta N-15 of nitrate -----	na
Delta O-18 of nitrate -----	na
Delta S-34 of sulfate -----	na
Delta O-18 of sulfate -----	na

Remarks:



## Water Analysis

Lab Number: 172516

Job Number: 12066

Submitter Sample Name: MCF-30A

Submitter Sample ID:

Submitter Job #: 06-43226-07

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: 1 Liter Plastic Bottle

Sample Collected: 10/05/2009

Results Reported: 10/15/2009

Delta D of water ----- -64.1 per mil relative to VSMOW

Delta O-18 of water ----- -3.51 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



## Water Analysis

Lab Number: 172517 Job Number: 12066

Submitter Sample Name: MCF-30A (ms/msd)

Submitter Sample ID:

Submitter Job #: 06-43226-07

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: 1 Liter Plastic Bottle

Sample Collected: 10/05/2009 Results Reported: 10/15/2009

Delta D of water -----	-65.6 per mil relative to VSMOW
Delta O-18 of water -----	-3.59 per mil relative to VSMOW
Tritium content of water -----	na
Delta C-13 of DIC -----	na
Carbon-14 content of DIC -----	na
Delta N-15 of nitrate -----	na
Delta O-18 of nitrate -----	na
Delta S-34 of sulfate -----	na
Delta O-18 of sulfate -----	na

Remarks:



## Water Analysis

Lab Number: 169383

Job Number: 11869

Submitter Sample Name: MCF-02A

Submitter Sample ID:

Submitter Job #: 06-43226-07

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: Plastic Bottle

Sample Collected: 8/21/2009

Results Reported: 9/01/2009

Delta D of water ----- -100.6 per mil relative to VSMOW

Delta O-18 of water ----- -12.73 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



## Water Analysis

Lab Number: 171282

Job Number: 11991

Submitter Sample Name: MCF-06A-R

Submitter Sample ID:

Submitter Job #:

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: Plastic Bottle

Sample Collected: 9/21/2009

Results Reported: 10/01/2009

Delta D of water ----- -69.7 per mil relative to VSMOW

Delta O-18 of water ----- -4.76 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



## Water Analysis

Lab Number: 171283

Job Number: 11991

Submitter Sample Name: MCF-18A

Submitter Sample ID:

Submitter Job #:

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: Plastic Bottle

Sample Collected: 9/21/2009

Results Reported: 10/01/2009

Delta D of water ----- -65.0 per mil relative to VSMOW

Delta O-18 of water ----- -3.19 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



## Water Analysis

Lab Number: 171284

Job Number: 11991

Submitter Sample Name: MCF-18A (FD)

Submitter Sample ID:

Submitter Job #:

Company: GEL Laboratories, LLC

Field or Site: BMI Commons Area (Eastside)

Location:

Depth/Formation:

Container Type: Plastic Bottle

Sample Collected: 9/21/2009

Results Reported: 10/01/2009

Delta D of water ----- -65.9 per mil relative to VSMOW

Delta O-18 of water ----- -3.52 per mil relative to VSMOW

Tritium content of water ----- na

Delta C-13 of DIC ----- na

Carbon-14 content of DIC ----- na

Delta N-15 of nitrate ----- na

Delta O-18 of nitrate ----- na

Delta S-34 of sulfate ----- na

Delta O-18 of sulfate ----- na

Remarks:



# Isotech Water Data

Job 12066

BMI Commons Area (Eastside)

Isotech Lab No.	Sample Name	Analysis Date	$\delta D\ H_2O$ ‰	$\delta^{18}O\ H_2O$ ‰
172516	MCF-30A	10/8/2009	-64.1	-3.50
172517	MCF-30A (ms/msd)	10/8/2009	-65.6	-3.59



# Isotech Water Data

Job 11991

BMI Commons Area (Eastside)

Isotech Lab No.	Sample Name	Analysis Date	$\delta\text{D H}_2\text{O}$ ‰	$\delta^{18}\text{O H}_2\text{O}$ ‰
171282	MCF-06A-R	9/25/2009	-69.7	-4.76
171283	MCF-18A	9/25/2009	-65.0	-3.19
171284	MCF-18A (FD)	9/25/2009	-65.9	-3.52



# Isotech Water Data

Job 11869

BMI Commons Area (Eastside)

Isotech	Sample	Analysis	$\delta\text{D H}_2\text{O}$	$\delta^{18}\text{O H}_2\text{O}$
Lab No.	Name	Date	‰	‰
169383	MCF-02A	8/25/2009	-100.6	-12.73



# Isotech Water Data

Job 12040

BMI Commons Area (Eastside)

Isotech Lab No.	Sample Name	Analysis Date	$\delta D$ H <sub>2</sub> O ‰	$\delta^{18}O$ H <sub>2</sub> O ‰
172091	MCF-29A	10/1/2009	-77.5	-6.59
172092	MCF-31A	10/1/2009	-66.5	-3.47



## **Appendix C**

### **Vertical Gradient Data**



Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

Deep/Shallow Well Pairs

Deep Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundwater Elevation (ft AMSL) (hi)	GW Elevation Date Measured	Groundwater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head, (ft AMSL) (hf)	Shallow Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundw ater Elevation (ft AMSL) (hi)	GW Elevation Date Measured	Groundw ater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head (ft AMSL) (hf)
MCF-01A	335	355	1754.44	1409.44	1720.21	7/25/04	--	--	--	--	--	AA-01	29	49	1754.93	1715.93	1712.03	4/8/04	--	--	--	--	--
MCF-01A	335	355	1754.44	1409.44	1723.51	4/18/06	3570	05/30/06	27.72	0.999	1723.20	AA-01	29	49	1754.93	1715.93	1712.35	4/18/06	3430	04/26/06	25.01	1.000	1712.35
MCF-01A	335	355	1754.44	1409.44	1726.61	7/27/06	4020	08/07/06	26.39	0.997	1725.66	AA-01	29	49	1754.93	1715.93	1711.69	7/27/06	3930	08/01/06	24.84	1.000	1711.69
MCF-01A	335	355	1754.44	1409.44	1727.87	10/16/06	4060	10/24/06	26.01	1.000	1727.87	AA-01	29	49	1754.93	1715.93	1711.50	10/16/06	3310	10/18/06	23.88	1.000	1711.50
MCF-01A	335	355	1754.44	1409.44	1726.47	1/22/07	3930	02/02/07	23.4	1.000	1726.47	AA-01	29	49	1754.93	1715.93	1711.45	1/22/07	3730	01/25/07	24	1.000	1711.45
MCF-01A	335	355	1754.44	1409.44	1716.51	8/6/09	3900	08/14/09	26.8	1.000	1716.51	AA-01	29	49	1754.93	1715.93	1707.20	8/6/09	3800	08/14/09	24.9	1.000	1707.20
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	4/7/04	--	--	--	--	--	AA-08	5	35	1578.46	1558.46	1566.82	6/7/04	--	--	--	--	--
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	4/21/06	110000	06/07/06	24.59	1.082	(a)	AA-08	5	35	1578.46	1558.46	1567.69	4/21/06	5070	05/25/06	23.48	1.001	1567.70
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	7/26/06	113000	08/23/06	23.8	1.084	(a)	AA-08	5	35	1578.46	1558.46	1565.47	7/26/06	4390	08/14/06	23.3	1.001	1565.48
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	10/17/06	113000	11/10/06	25.73	1.084	(a)	AA-08	5	35	1578.46	1558.46	1568.82	10/17/06	4640	11/01/06	23.65	1.001	1568.83
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	1/23/07	116000	02/08/07	22.5	1.087	(a)	AA-08	5	35	1578.46	1558.46	1568.72	1/23/07	4700	02/08/07	23.4	1.001	1568.73
MCF-08A	350	370	1579.02	1219.02	ARTESIAN	8/4/09	99800	09/06/09	26.49	1.073		AA-08	5	35	1578.46	1558.46	1565.58	8/4/09	3500	08/20/09	26.25	0.999	1565.57
MCF-10A	365	385	1613.32	1238.32	1613.06	4/14/04	--	--	--	--	--	AA-10	10	40	1612.54	1587.54	1595.91	7/9/04	--	--	--	--	--
MCF-10A	365	385	1613.32	1238.32	ARTESIAN	4/21/06	8080	05/31/06	24.96	1.003	(a)	AA-10	10	40	1612.54	1587.54	1596.04	4/21/06	4880	05/12/06	23.36	1.001	1596.05
MCF-10A	365	385	1613.32	1238.32	1601.56	7/27/06	6800	08/21/06	24.3	1.002	1602.29	AA-10	10	40	1612.54	1587.54	1596.97	7/27/06	4720	08/11/06	23.2	1.001	1596.98
MCF-10A	365	385	1613.32	1238.32	1607.46	10/17/06	7700	11/14/06	25.01	1.003	1608.57	AA-10	10	40	1612.54	1587.54	1596.75	10/17/06	4770	10/27/06	22.63	1.001	1596.76
MCF-10A	365	385	1613.32	1238.32	1612.18	1/23/07	7270	02/16/08	22.51	1.003	1613.30	AA-10	10	40	1612.54	1587.54	1596.89	1/23/07	4560	02/05/07	22.9	1.001	1596.90
MCF-10A	365	385	1613.32	1238.32	ARTESIAN	8/3/09	4200	09/06/09	25.3	1.000	(a)	AA-10	10	40	1612.54	1587.54	1595.05	8/3/09	4110	08/19/09	23.6	1.001	1595.06
MCF-12A	349.5	369.5	1713.68	1354.18	1658.06	7/22/04	--	--	--	--	--	MCF-12B	64	84	1712.74	1638.74	1648.18	6/5/04	--	--	--	--	--
MCF-12A	349.5	369.5	1713.68	1354.18	1661.03	4/27/06	5950	05/18/06	28.13	1.003	1661.95	MCF-12B	64	84	1712.74	1638.74	1649.08	4/27/06	2630	05/23/06	25.14	0.999	1649.07
MCF-12A	349.5	369.5	1713.68	1354.18	1661.21	7/27/06	5900	08/10/06	25.6	1.001	1661.52	MCF-12B	64	84	1712.74	1638.74	1648.33	7/27/06	2520	08/09/06	26.7	0.999	1648.32
MCF-12A	349.5	369.5	1713.68	1354.18	1661.36	10/16/06	7580	01/25/00	24.64	1.003	1662.28	MCF-12B	64	84	1712.74	1638.74	1648.20	10/16/06	2620	11/08/06	24.54	0.999	1648.19
MCF-12A	349.5	369.5	1713.68	1354.18	1661.54	1/24/07	6320	01/24/00	24.8	1.002	1662.15	MCF-12B	64	84	1712.74	1638.74	1647.75	1/24/07	2760	02/15/07	21.19	1.000	1647.75
MCF-12A	349.5	369.5	1713.68	1354.18	1663.63	8/6/09	7300	09/06/09	28.73	1.002	1664.25	MCF-12B	64	84	1712.74	1638.74	1646.79	8/6/09	2900	08/25/09	30.04	0.998	1646.77
MCF-16A	364.5	384.5	1689.67	1315.17	1661.98	4/6/04	--	--	--	--	--	MCF-16C	53	73	1689.88	1626.88	1629.98	6/11/04	--	--	--	--	--
MCF-16A	364.5	384.5	1689.67	1315.17	1643.84	4/20/06	81800	05/18/06	25.74	1.059	1663.23	MCF-16C	53	73	1689.88	1626.88	1626.23	4/20/06	8150	05/22/06	23.3	1.004	1626.23
MCF-16A	364.5	384.5	1689.67	1315.17	1643.62	7/26/06	83800	08/21/06	24.0	1.061	1663.66	MCF-16C	53	73	1689.88	1626.88	1625.88	7/26/06	8190	08/16/06	25.8	1.003	1625.88
MCF-16A	364.5	384.5	1689.67	1315.17	1643.84	10/17/06	86400	11/06/06	24.14	1.063	1664.55	MCF-16C	53	73	1689.88	1626.88	1625.66	10/17/06	7010	11/06/06	23.53	1.003	1625.66
MCF-16A	364.5	384.5	1689.67	1315.17	1644.13	1/22/07	88300	02/16/07	23.2	1.065	1665.51	MCF-16C	53	73	1689.88	1626.88	1625.51	1/22/07	6480	02/20/07	22.3	1.003	1625.51
MCF-16A	364.5	384.5	1689.67	1315.17	1644.98	8/5/09	78800	2009	26.50	1.056	1663.45	MCF-16C	53	73	1689.88	1626.88	1625.04	8/5/09	11500	--	25.1	1.005	1625.03
MCF-27	361.5	381.5	1787.03	1415.53	1763.48	7/14/04	--	--	--	--	--	AA-27	61.5	81.5	1786.85	1715.35	1729.98	7/13/04	--	--	--	--	--
MCF-27	361.5	381.5	1787.03	1415.53	1773.50	4/20/06	1460	05/19/06	26.42	0.998	1772.78	AA-27	61.5	81.5	1786.85	1715.35	1723.58	4/19/06	4080	04/27/06	24.97	1.000	1723.58
MCF-27	361.5	381.5	1787.03	1415.53	1774.28	7/26/06	1260	08/02/06	25.58	0.998	1773.56	AA-27	61.5	81.5	1786.85	1715.35	1722.66	7/26/06	4240	08/02/06	24.65	1.000	1722.66
MCF-27	361.5	381.5	1787.03	1415.53	1774.88	10/16/06	1170	10/20/06	25.41	0.998	1774.16	AA-27	61.5	81.5	1786.85	1715.35	1722.61	10/16/06	4220	10/19/06	24.67	1.000	1722.61
MCF-27	361.5	381.5	1787.03	1415.53	1775.27	1/22/07	968	02/20/07	24.3	0.998	1774.55	AA-27	61.5	81.5	1786.85	1715.35	1722.46	1/22/07	4340	02/02/07	24.9	1.000	1722.46
MCF-27	361.5	381.5	1787.03	1415.53	1779.58	8/6/09	600	09/25/09	26.7	0.997	1778.49	AA-27	61.5	81.5	1786.85	1715.35	1721.27	8/6/09	3300	09/03/09	40.7	0.994	1721.23
MCF-06A	373.5	393.5	1588.80	1205.3	1563.27	4/16/04	--	--	--	--	--	MCF-06C	44	59	1630.42	1578.92	1584.17	7/15/04	--	--	--	--	--
MCF-06A	373.5	393.5	1588.80	1205.3	1519.38	4/20/06	186000	05/30/06	26.27	1.144	1564.61	MCF-06C	44	59	1630.42	1578.92	1580.63	4/20/06	47600	05/22/06	24.09	1.033	1580.69
MCF-06A	373.5	393.5	1588.80	1205.3	1509.54	7/27/06	185000	08/21/06	25.1	1.143	1553.05	MCF-06C	44	59	1630.42	1578.92	1579.38	7/26/06	6280	08/08/06	23.97	1.002	1579.38
MCF-06A	373.5	393.5	1588.80	1205.3	1512.00	10/16/06	205000	11/13/06	23.44	1.162	1561.68	MCF-06C	44	59	1630.42	1578.92	1578.93	10/17/06	6720	10/30/06	23.57	1.002	1578.93
MCF-06A	373.5	393.5	1588.80	1205.3	1515.31	1/23/07	191000	02/23/07	20.4	1.151	1562.12	MCF-06C	44	59	1630.42	1578.92	1578.09	1/23/07	6980	02/01/07	22.3	1.003	1578.09
MCF-06A	373.5	393.5	1588.80	1205.3	(c)	8/6/09	--	--	--	--	--	MCF-06C	44	59	1630.42	1578.92	1575.81	8/3/09	6200	09/17/09	25.2	1.002	1575.80
MCF-07	350	370	1610.07	1250.07	1524.30	7/24/04	--	--	--	--	--	AA-07	30	50	1610.12	1570.12	1570.81	7/23/04	--	--	--	--	--
MCF-07	350	370	1610.07	1250.07	(b)	5/24/06	--	--	--	--	--	AA-07	30	50	1610.12	1570.12	1572.10	5/24/06	2030	06/06/06	23.99	0.999	1572.10
MCF-07	350	370	1610.07	1250.07	1523.04	8/30/06	174000	08/30/06	25.0	1.134	1559.62	AA-07	30	50	1610.12	1570.12	1572.05	7/27/06	1990	08/16/06	23.58	0.999	1572.05
MCF-07	350	370	1610.07	1250.07	1532.33	10/16/06	182000	11/10/06	24.29	1.141	1572.13	AA-07	30	50	1610.12	1570.12	1571.99	10/16/06	2120	11/03/06	23.63	0.999	1571.99
MCF-07	350	370	1610.07	1250.07	1530.38	1/23/07	193000	02/23/07	23.8	1.151	1572.71	AA-07	30	50	1610.12	1570.12	1572.01	1/23/07	2170	02/26/07	23.3	0.999	1572.01
MCF-07	350	370	1610.07	1250.07	1533.56	8/6/09	166000	09/17/09	25.4	1.127	1569.56	AA-07	30	50	1610.12	1570.12	1571.84	8/6/09	2500	08/14/09	24.4	0.999	1571.84
MCF-09A	270	290	1694.26	1414.26	1667.29	4/18/04	--	--	--	--	--	AA-09	30	65	1694.11								



Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

Deep Well	Shallow Well	Uncorrected for Groundwater Density			Corrected for Groundwater Density			Corrected for Equipotential Surface (lateral distance between wells)						
		Point Water Head Delta (ft)	Point Water Head Deep/Shallow Vertical Gradient (ft/ft)	Point Water Head Vertical Flow Direction	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Deep/Shallow Vertical Gradient (ft/ft)	Vertical Flow Direction	Horizontal Gradient	Distance Between Wells Along Gradient	Well Name	Revised GW Elevation/Head	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Deep/Shallow Vertical Gradient (ft/ft)	Fresh Head Vertical Flow Direction
MCF-01A	AA-01	-8.18	0.03	UP	--	--	--	--	--	--	--	--	--	--
MCF-01A	AA-01	-11.16	0.04	UP	-10.85	0.04	UP	0.0165	8	AA-01	1712.22	-10.98	0.04	UP
MCF-01A	AA-01	-14.92	0.05	UP	-13.97	0.05	UP	0.0137	5	AA-01	1711.62	-14.04	0.05	UP
MCF-01A	AA-01	-16.37	0.05	UP	-16.37	0.05	UP	0.0086	8	AA-01	1711.43	-16.44	0.05	UP
MCF-01A	AA-01	-15.02	0.05	UP	-15.02	0.05	UP	0.0093	10	AA-01	1711.36	-15.11	0.05	UP
MCF-01A	AA-01	-9.31	0.03	UP	-9.31	0.03	UP	0.0208	4	AA-01	1707.12	-9.39	0.03	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	-	(a)	(a)	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-08A	AA-08	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-10A	AA-10	-17.15	0.05	UP	--	--	--	--	--	--	--	--	--	--
MCF-10A	AA-10	(a)	(a)	UP	(a)	(a)	UP	0.0070	-12	AA-10	1596.13	(a)	(a)	UP
MCF-10A	AA-10	-4.59	0.01	UP	-5.31	0.02	UP	0.0138	-28	AA-10	1597.37	-4.92	0.01	UP
MCF-10A	AA-10	-10.71	0.03	UP	-11.81	0.03	UP	0.0105	0	AA-10	1596.76	-11.81	0.03	UP
MCF-10A	AA-10	-15.29	0.04	UP	-16.40	0.05	UP	0.0133	0	AA-10	1596.90	-16.40	0.05	UP
MCF-10A	AA-10	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-12A	MCF-12B	-9.88	0.03	UP	--	--	--	--	--	--	--	--	--	--
MCF-12A	MCF-12B	-11.95	0.04	UP	-12.88	0.05	UP	0.0168	-17	MCF-12B	1649.36	-12.60	0.04	UP
MCF-12A	MCF-12B	-12.88	0.05	UP	-13.20	0.05	UP	0.0821	-17	MCF-12B	1649.72	-11.80	0.04	UP
MCF-12A	MCF-12B	-13.16	0.05	UP	-14.09	0.05	UP	0.0118	-16.5	MCF-12B	1648.38	-13.90	0.05	UP
MCF-12A	MCF-12B	-13.79	0.05	UP	-14.40	0.05	UP	0.0254	-17	MCF-12B	1648.18	-13.97	0.05	UP
MCF-12A	MCF-12B	-16.84	0.06	UP	-17.47	0.06	UP	0.0227	-17	MCF-12B	1647.17	-17.08	0.06	UP
MCF-16A	MCF-16C	-32.00	0.10	UP	--	--	--	--	--	--	--	--	--	--
MCF-16A	MCF-16C	-17.61	0.06	UP	-37.00	0.12	UP	0.0181	28	MCF-16C	1625.72	-37.51	0.12	UP
MCF-16A	MCF-16C	-17.74	0.06	UP	-37.78	0.12	UP	0.0261	13	MCF-16C	1625.54	-38.12	0.12	UP
MCF-16A	MCF-16C	-18.18	0.06	UP	-38.89	0.12	UP	0.0134	21	MCF-16C	1625.37	-39.17	0.13	UP
MCF-16A	MCF-16C	-18.62	0.06	UP	-40.01	0.13	UP	0.0157	22	MCF-16C	1625.16	-40.35	0.13	UP
MCF-16A	MCF-16C	-19.94	0.06	UP	-38.42	0.12	UP	0.02	-27.87	MCF-16C	1625.64	-37.81	0.12	UP
MCF-27	AA-27	-33.50	0.11	UP	--	--	--	--	--	--	--	--	--	--
MCF-27	AA-27	-49.92	0.17	UP	-49.20	0.16	UP	0.0112	-14	AA-27	1723.74	-49.05	0.16	UP
MCF-27	AA-27	-51.62	0.17	UP	-50.90	0.17	UP	0.0142	-9	AA-27	1722.79	-50.77	0.17	UP
MCF-27	AA-27	-52.27	0.17	UP	-51.55	0.17	UP	0.0093	-14.5	AA-27	1722.74	-51.42	0.17	UP
MCF-27	AA-27	-52.81	0.18	UP	-52.09	0.17	UP	0.0107	-14.5	AA-27	1722.61	-51.94	0.17	UP
MCF-27	AA-27	-58.31	0.19	UP	-57.25	0.19	UP	0.0313	-9.3	AA-27	1721.53	-56.96	0.19	UP
MCF-06A	MCF-06C	20.90	-0.06	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-06A	MCF-06C	61.25	-0.16	DOWN	16.08	-0.04	DOWN	0.0214		MCF-06C	1580.69	16.08	-0.04	DOWN
MCF-06A	MCF-06C	69.84	-0.19	DOWN	26.33	-0.07	DOWN	0.0074		MCF-06C	1579.38	26.33	-0.07	DOWN
MCF-06A	MCF-06C	66.93	-0.18	DOWN	17.25	-0.05	DOWN	0.0078		MCF-06C	1578.93	17.25	-0.05	DOWN
MCF-06A	MCF-06C	62.78	-0.17	DOWN	15.97	-0.04	DOWN	0.0086		MCF-06C	1578.09	15.97	-0.04	DOWN
MCF-06A	MCF-06C	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)		(c)	(c)	(c)	
MCF-07	AA-07	46.51	-0.15	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-07	AA-07	(b)	(b)		(b)	(b)	(b)	--	--	--	--	(b)	(b)	(b)
MCF-07	AA-07	49.01	-0.15	DOWN	12.43	-0.04	DOWN	0.0102	15	AA-07	1571.89	12.28	-0.04	DOWN
MCF-07	AA-07	39.66	-0.12	DOWN	-0.14	0.0004	UP	0.0134	4.5	AA-07	1571.93	-0.20	0.00	UP
MCF-07	AA-07	41.63	-0.13	DOWN	-0.70	0.0022	UP	0.0188	7.5	AA-07	1571.87	-0.84	0.00	UP
MCF-07	AA-07	38.28	-0.12	DOWN	2.28	-0.0071	DOWN	0.0167	10.7	AA-07	1571.66	2.10	-0.01	DOWN
MCF-09A	AA-09	-3.83	0.02	UP	--	--	--	--	--	--	--	--	--	--
MCF-09A	AA-09	1.80	-0.01	DOWN	--	--	--	0.0157	-14	AA-09	1659.38	-0.22	0.00	UP
MCF-09A	AA-09	1.44	-0.01	DOWN	-2.18	0.01	UP	0.0196	-19	AA-09	1659.04	-1.81	0.01	UP
MCF-09A	AA-09	1.05	-0.005	DOWN	-3.06	0.01	UP	0.0118	-18	AA-09	1658.59	-2.85	0.01	UP
MCF-09A	AA-09	1.30	-0.01	DOWN	-3.20	0.01	UP	0.0222	-15	AA-09	1658.84	-3.20	0.01	UP
MCF-09A	AA-09	1.53	-0.01	DOWN				0.0227	-17.89	AA-09	1658.34	-1.19	0.01	UP
MCF-19A	DBMW-2	(c)	(c)	(c)	(c)	(c)	(c)	--	--	--	--	(c)	(c)	(c)
MCF-19A	DBMW-2	(c)	(c)	(c)	(c)	(c)	(c)							
MCF-28A	PC-56	--	--	--	--	--	--	0.0046	22	PC-56	--	--	--	--
MCF-29A	HMW-08	-19.17	--	UP	--	--	--	0.0227	-15	HMW-08	--	--	--	--
MCF-30A	AA-30	-9.92	0.029	UP	-57.10	(c)	(c)	0.0625	13	AA-30	1512.24	-57.90	0.17	UP
MCF-31A	MW-4	-25.60	(c)	UP	-77.11	(c)	(c)	0.0132	3	MW-4	1498.58	-77.14	0.23	UP
MCF-32A	BEC-6	-38.76	--	UP	--	--	--	0.0192	-17	BEC-6	--	--	--	--



Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

Middle/Shallow Well Pairs

Middle Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundwater Elevation (ft AMSL) (hi)	Date Measured	Groundwater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head, Hf (ft AMSL) (h(f))	Shallow Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundwater Elevation (ft AMSL) (hi)		Groundwater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head, Hf (ft AMSL)
																		Date Measured					
BEC-9	44	59	--	--	1570.98	7/27/06	6020	08/02/06	22.8	1.002	--	AA-19	22	42.0	1639.88	1607.88	1,601.02	7/26/06	--	--	--	--	--
BEC-9	44	59	--	--	1570.20	10/16/06	5120	10/19/06	23.51	1.001	--	AA-19	22	42.0	1639.88	1607.88	1,599.85	10/17/06	--	--	--	--	--
BEC-9	44	59	--	--	1569.15	1/22/07	5900	01/29/07	22.6	1.002	--	AA-19	22	42.0	1639.88	1607.88	1,598.54	1/22/07	--	--	--	--	--
BEC-9	44	59	--	--	1564.88	8/4/09	5300	08/25/09	27.26	1.000	--	AA-19	22	42.0	1639.88	1607.88	Dry	8/3/09	--	--	--	--	--
MCF-10B	84	104	1612.38	1518.38	1597.87	7/9/04	--	--	--	--	--	AA-10	10	40	1612.38	1587.38	1595.91	7/9/04	--	--	--	--	--
MCF-10B	84	104	1612.38	1518.38	1597.92	4/21/06	2050	05/18/06	24.35	0.999	1597.84	AA-10	10	40	1612.38	1587.38	1596.04	4/21/06	4880	05/01/06	23.36	1.001	1596.05
MCF-10B	84	104	1612.38	1518.38	1598.08	7/27/06	2030	08/15/06	23.75	0.999	1598.00	AA-10	10	40	1612.38	1587.38	1596.97	7/27/06	4610	08/11/06	23.2	1.001	1596.98
MCF-10B	84	104	1612.38	1518.38	1598.81	10/17/06	2050	11/10/06	23.67	0.999	1598.73	AA-10	10	40	1612.38	1587.38	1596.75	10/17/06	4770	10/23/06	22.63	1.001	1596.76
MCF-10B	84	104	1612.38	1518.38	1598.85	1/23/07	2150	02/27/07	23.0	0.999	1598.77	AA-10	10	40	1612.38	1587.38	1596.89	1/23/07	4560	01/26/07	22.9	1.001	1596.90
MCF-10B	84	104	1612.38	1518.38	1597.75	8/3/09	2200	08/25/09	23.9	0.999	1597.67	AA-10	10	40	1612.38	1587.38	1595.05	8/3/09	4110	08/19/09	23.6	1.001	1595.06
MCF-11	93.5	103.5	1657.75	1559.25	1632.13	7/13/04	--	--	--	--	--	AA-11	9	29	1658.00	1639	1632.84	4/15/04	--	--	--	--	--
MCF-11	93.5	103.5	1657.75	1559.25	1630.82	4/20/06	3470	05/16/08	25.11	1.000	1630.82	AA-11	9	29	1658.00	1639	1630.62	4/20/06	--	--	--	--	--
MCF-11	93.5	103.5	1657.75	1559.25	1630.12	7/26/06	3250	08/16/08	24.4	1.000	1630.12	AA-11	9	29	1658.00	1639	1629.96	7/26/06	--	--	--	--	--
MCF-11	93.5	103.5	1657.75	1559.25	1629.89	10/17/06	3350	10/27/08	24.01	0.999	1629.82	AA-11	9	29	1658.00	1639	1629.74	10/17/06	--	--	--	--	--
MCF-11	93.5	103.5	1657.75	1559.25	1630.11	1/23/07	3520	02/23/07	23.7	1.000	1630.11	AA-11	9	29	1658.00	1639	1629.87	1/23/07	--	--	--	--	--
MCF-11	93.5	103.5	1657.75	1559.25	1629.47	8/3/09	2700	08/20/09	25.0	0.999	1629.40	AA-11	9	29	1658.00	1639	1629.32	8/3/09	--	--	--	--	--
MCF-12C	155	175	1713.03	1548.03	1647.56	7/21/04	--	--	--	--	--	MCF-12B	64	84	1712.74	1638.74	1648.18	6/5/04	--	--	--	--	--
MCF-12C	155	175	1713.03	1548.03	1648.68	4/27/06	1690	05/22/06	24.97	0.998	1648.48	MCF-12B	64	84	1712.74	1638.74	1649.08	4/27/06	2630	05/23/06	25.14	0.999	1649.07
MCF-12C	155	175	1713.03	1548.03	1647.97	7/27/06	1820	08/10/06	25.3	0.998	1647.77	MCF-12B	64	84	1712.74	1638.74	1648.33	7/27/06	2520	08/09/06	26.7	0.999	1648.32
MCF-12C	155	175	1713.03	1548.03	1647.76	10/16/06	2010	11/03/06	24.35	0.999	1647.66	MCF-12B	64	84	1712.74	1638.74	1648.20	10/16/06	2620	11/08/06	24.54	0.999	1648.19
MCF-12C	155	175	1713.03	1548.03	1647.28	1/24/07	2100	02/22/07	21.7	0.999	1647.18	MCF-12B	64	84	1712.74	1638.74	1647.75	1/24/07	2760	02/15/07	21.19	1.000	1647.75
MCF-12C	155	175	1713.03	1548.03	1646.25	8/6/09	1000	08/25/09	29.14	0.997	1645.96	MCF-12B	64	84	1712.74	1638.74	1646.79	8/6/09	2900	08/25/09	30.04	0.998	1646.77
MCF-16B	283.7	313.7	1689.67	1390.97	1628.46	7/23/04	--	--	--	--	--	MCF-16C	53	73	1689.88	1626.88	1629.98	6/11/04	--	--	--	--	--
MCF-16B	283.7	313.7	1689.67	1390.97	1626.55	4/20/06	64800	05/01/06	25.83	1.046	1637.39	MCF-16C	53	73	1689.88	1626.88	1626.23	4/20/06	8150	05/22/06	23.3	1.004	1626.23
MCF-16B	283.7	313.7	1689.67	1390.97	1627.11	7/26/06	70000	08/23/06	24.31	1.050	1638.92	MCF-16C	53	73	1689.88	1626.88	1625.88	7/26/06	8190	08/16/06	25.8	1.003	1625.88
MCF-16B	283.7	313.7	1689.67	1390.97	1626.95	10/17/06	72200	11/06/06	23.34	1.052	1639.22	MCF-16C	53	73	1689.88	1626.88	1625.66	10/17/06	7010	11/06/06	23.53	1.003	1625.66
MCF-16B	283.7	313.7	1689.67	1390.97	1626.83	1/22/07	74400	02/20/07	19.50	1.055	1639.80	MCF-16C	53	73	1689.88	1626.88	1625.51	1/22/07	6480	02/20/07	22.3	1.003	1625.51
MCF-16B	283.7	313.7	1689.67	1390.97	1628.37	8/5/09	64300	--	24.4	1.045	1639.05	MCF-16C	53	73	1689.88	1626.88	1625.04	8/5/09	11500	--	25.10	1.005	1625.03
MCF-1B	55	85	1753.95	1683.95	1713.88	6/7/04	--	--	--	--	--	AA-01	29	49	1754.96	1715.96	1712.03	4/8/04	--	--	--	--	--
MCF-1B	55	85	1753.95	1683.95	1712.16	4/18/06	2000	05/11/06	24.89	0.999	1712.13	AA-01	29	49	1754.96	1715.96	1712.35	4/18/06	3430	04/26/06	25.01	1.000	1712.35
MCF-1B	55	85	1753.95	1683.95	1711.50	7/27/06	2070	07/31/06	25.89	0.998	1711.44	AA-01	29	49	1754.96	1715.96	1711.69	7/27/06	3930	08/01/06	24.84	1.000	1711.69
MCF-1B	55	85	1753.95	1683.95	1711.34	10/16/06	1980	11/06/06	23.67	0.999	1711.31	AA-01	29	49	1754.96	1715.96	1711.50	10/16/06	3310	10/18/06	23.88	1.000	1711.50
MCF-1B	55	85	1753.95	1683.95	1711.28	1/22/07	1830	02/14/06	23.93	0.999	1711.25	AA-01	29	49	1754.96	1715.96	1711.45	1/22/07	3730	01/25/07	24	1.000	1711.45
MCF-1B	55	85	1753.95	1683.95	1709.23	8/6/09	1990	08/12/09	25.7	0.998	1709.18	AA-01	29	49	1754.96	1715.96	1707.20	8/6/09	3800	08/14/09	24.9	1.000	1707.20
MCF-6B	67	82	1630.40	1555.9	1590.58	7/16/04	--	--	--	--	--	MCF-06C	44	59	1630.42	1578.92	1584.17	7/15/04	--	--	--	--	--
MCF-6B	67	82	1630.40	1555.9	1581.18	4/20/06	31400	05/18/06															



Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

		Uncorrected for Groundwater Density			Corrected for Groundwater Density			Corrected for Equipotential Surface						
Middle Well	Shallow Well	Point Water Head Delta (ft AMSL)	Point Water Head Intermediate/Shallow Vertical Gradient (ft/ft)	Point Water Head Vertical Flow Direction	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Intermediate/Shallow Vertical Gradient (ft/ft)	Fresh Head Vertical Flow Direction	Horizontal Gradient	Distance Between Wells Along Gradient	Well Name	Revised GW Elevation/Head	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Intermediate/Shallow Vertical Gradient (ft/ft)	Fresh Head Vertical Flow Direction
BEC-9	AA-19	30.04	--	DOWN	--	--	--	--	--	--	--	--	--	--
BEC-9	AA-19	29.65	--	DOWN	--	--	--	--	--	--	--	--	--	--
BEC-9	AA-19	29.39	--	DOWN	--	--	--	--	--	--	--	--	--	--
BEC-9	AA-19	--	--	--	--	--	--							
MCF-10B	AA-10	-1.96	0.03	UP	--	--	--	--	--	--	--	--	--	--
MCF-10B	AA-10	-1.88	0.03	UP	-1.79	0.03	UP	0.0070	-12	AA-10	1596.13	-1.71	0.02	UP
MCF-10B	AA-10	-1.11	0.02	UP	-1.02	0.01	UP	0.0138	-19	AA-10	1597.24	-0.76	0.01	UP
MCF-10B	AA-10	-2.06	0.03	UP	-1.97	0.03	UP	0.0105	-4	AA-10	1596.80	-1.93	0.03	UP
MCF-10B	AA-10	-1.96	0.03	UP	-1.87	0.03	UP	0.0133	-8	AA-10	1597.01	-1.76	0.03	UP
MCF-10B	AA-10	-2.70	0.04	UP				0.0096	-16.8	AA-10	1595.22	-2.45	0.04	UP
MCF-11	AA-11	0.71	-0.01	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-11	AA-11	-0.20	0.00	UP	--	--	--	0.0118	-6	AA-11	1630.69	-0.07	0.001	UP
MCF-11	AA-11	-0.16	0.00	UP	--	--	--	0.0168	-6	AA-11	1630.06	-0.10	0.001	UP
MCF-11	AA-11	-0.15	0.00	UP	--	--	--	0.0235	-6	AA-11	1629.88	-0.14	0.002	UP
MCF-11	AA-11	-0.24	0.00	UP	--	--	--	0.0157	-4	AA-11	1629.93	-0.06	0.001	UP
MCF-11	AA-11	-0.15	0.00	UP	--	--	--	0.0125	-3.69	AA-11	1629.37	-0.05	0.001	UP
MCF-12C	MCF-12B	0.62	-0.01	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-12C	MCF-12B	0.40	0.00	DOWN	0.59	-0.01	DOWN	0.0168	-10	MCF-12B	1649.24	0.76	-0.01	DOWN
MCF-12C	MCF-12B	0.36	0.00	DOWN	0.55	-0.01	DOWN	0.0821	-8	MCF-12B	1648.98	1.21	-0.01	DOWN
MCF-12C	MCF-12B	0.44	0.00	DOWN	0.53	-0.01	DOWN	0.0118	-9	MCF-12B	1648.30	0.64	-0.01	DOWN
MCF-12C	MCF-12B	0.47	-0.01	DOWN	0.57	-0.01	DOWN	0.0254	-10	MCF-12B	1648.00	0.82	-0.01	DOWN
MCF-12C	MCF-12B	0.54	-0.01	DOWN	0.82	-0.01	DOWN	0.0227	-8.6	MCF-12B	1646.97	1.01	-0.01	DOWN
MCF-16B	MCF-16C	1.52	-0.01	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-16B	MCF-16C	-0.32	0.00	UP	-11.16	0.05	UP	0.0181	13	MCF-16C	1625.99	-11.39	0.05	UP
MCF-16B	MCF-16C	-1.23	0.01	UP	-13.04	0.06	UP	0.0261	6	MCF-16C	1625.72	-13.20	0.06	UP
MCF-16B	MCF-16C	-1.29	0.01	UP	-13.56	0.06	UP	0.0134	12	MCF-16C	1625.49	-13.73	0.06	UP
MCF-16B	MCF-16C	-1.32	0.01	UP	-14.30	0.06	UP	0.0157	11	MCF-16C	1625.33	-14.47	0.06	UP
MCF-16B	MCF-16C	-3.33	0.01	UP	-14.02	0.06	UP	0.0217	-13.93	MCF-16C	1625.33	-13.72	0.06	UP
MCF-1B	AA-01	-1.85	0.06	UP	--	--	--	--	--	--	--	--	--	--
MCF-1B	AA-01	0.19	-0.01	DOWN	0.22	-0.01	DOWN	0.0165	24.8	AA-01	1711.94	-0.19	0.01	UP
MCF-1B	AA-01	0.19	-0.01	DOWN	0.25	-0.01	DOWN	0.0137	14	AA-01	1711.50	0.05	0.00	DOWN
MCF-1B	AA-01	0.16	0.00	DOWN	0.19	-0.01	DOWN	0.0086	21	AA-01	1711.32	0.01	0.00	DOWN
MCF-1B	AA-01	0.17	-0.01	DOWN	0.20	-0.01	DOWN	0.0093	24.9	AA-01	1711.22	-0.03	0.00	UP
MCF-1B	AA-01	-2.03	0.06	UP	-1.98	0.06	UP	0.0208	24.9	AA-01	1706.68	-2.50	0.08	UP
MCF-6B	MCF-06C	-6.41	0.28	UP	--	--	--	--	--	--	--	--	--	--
MCF-6B	MCF-06C	-0.55	0.02	UP	-1.02	0.04	UP	0.0214	4	MCF-06C	1580.60	-1.11	0.05	UP
MCF-6B	MCF-06C	-0.87	0.04	UP	-1.53	0.07	UP	0.0074	0	MCF-06C	1579.38	-1.53	0.07	UP
MCF-6B	MCF-06C	-0.99	0.04	UP	-1.61	0.07	UP	0.0078	3	MCF-06C	1578.91	-1.64	0.07	UP
MCF-6B	MCF-06C	-0.70	0.03	UP	-1.37	0.06	UP	0.0086	6	MCF-06C	1578.04	-1.42	0.06	UP
MCF-6B	MCF-06C	-1.16	0.05	UP	-1.19	0.05	UP	0.0068	0	MCF-06C	1575.80	-1.19	0.05	UP
MCF-8B	AA-08	-3.77	0.04	UP	--	--	--	--	--	--	--	--	--	--
MCF-8B	AA-08	-10.74	0.10	UP	-12.94	0.13	UP	0.0124	9	AA-08	1567.59	-13.05	0.13	UP
MCF-8B	AA-08	-11.42	0.11	UP	-13.47	0.13	UP	0.0138	6	AA-08	1565.39	-13.55	0.13	UP
MCF-8B	AA-08	-8.72	0.09	UP	-10.90	0.11	UP	0.0105	10	AA-08	1568.73	-11.00	0.11	UP
MCF-8B	AA-08	-9.87	0.10	UP	-12.19	0.12	UP	0.0105	8	AA-08	1568.65	-12.27	0.12	UP
MCF-8B	AA-08	(c)	(c)	(c)	--	--	--	--	--	--	--	--	--	--
MCF-9B	AA-09	0.03	0.00	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-9B	AA-09	-0.98	0.01	UP	-0.97	0.01	UP	0.0157	7	AA-09	1659.06	-1.08	0.02	UP
MCF-9B	AA-09	-0.75	0.01	UP	-0.64	0.01	UP	0.0196	2	AA-09	1658.62	-0.68	0.01	UP
MCF-9B	AA-09	-0.86	0.01	UP	-0.84	0.01	UP	0.0118	5	AA-09	1658.31	-0.90	0.01	UP
MCF-9B	AA-09	-0.61	0.01	UP	-0.71	0.01	UP	0.0235	8	AA-09	1658.32	-0.89	0.01	UP
MCF-9B	AA-09	0.33	0.00	DOWN	-1.24	0.02	UP	0.0227	2.56	AA-09	1657.87	-1.30	0.02	UP
MCF-28B	PC-56	--	--	--	--	--	--	0.0046	31	PC-56	--	--	--	--
MCF-29B	HMW-08	-7.83	-0.01	UP	--	--	--	0.0227	-26	HMW-08	--	--	--	--
MCF-30B	AA-30	-0.02	0.00	UP	-17.26	0.13	UP	0.0625	26	AA-30	1511.44	-18.86	0.14	UP
MCF-31B	MW-4	42.38	-0.23	DOWN	--	--	--	0.0132	4	MW-4	1498.56	--	--	--
MCF-32B	BEC-6	-5.52	#VALUE!	UP	--	--	--	0.0192	-14	BEC-6	--	--	--	--



Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

Deep/Middle Well Pairs

Deep Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundwater Elevation (ft AMSL) (hi)	GW Elevation Date Measured	Groundwater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head, Hf (ft AMSL) (hlf)	Middle Well	Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Ground Surface elevation (ft AMSL)	Screen Midpoint (ft AMSL) (zi)	Groundw ater Elevation (ft AMSL) (hi)	GW Elevation Date Measured	Groundw ater TDS (mg/L)	TDS Date Measured	Groundwater Temperature (C)	GW Density (g/cm^3) (pi)	Fresh Water Head, Hf (ft AMSL)
MCF-10A	365	385	1613.32	1238.32	1613.06	4/14/04	--	--	--	--	--	MCF-10B	84	104	1612.38	1518.38	1597.87	7/9/04	--	--	--	--	--
MCF-10A	365	385	1613.32	1238.32	ARTESIAN	4/21/06	8080	05/31/06	24.96	1.003	--	MCF-10B	84	104	1612.38	1518.38	1597.92	4/21/06	2050	05/18/06	24.35	0.999	1597.84
MCF-10A	365	385	1613.32	1238.32	1601.56	7/27/06	6800	08/15/06	24.3	1.002	1602.29	MCF-10B	84	104	1612.38	1518.38	1598.08	7/27/06	2030	08/15/06	23.75	0.999	1598.00
MCF-10A	365	385	1613.32	1238.32	1607.46	10/17/06	7700	11/10/06	25.01	1.003	1608.57	MCF-10B	84	104	1612.38	1518.38	1598.81	10/17/06	2050	11/10/06	23.67	0.999	1598.73
MCF-10A	365	385	1613.32	1238.32	1612.18	1/23/07	7270	02/27/06	22.51	1.003	1613.30	MCF-10B	84	104	1612.38	1518.38	1598.85	1/23/07	2150	02/27/07	23.0	0.999	1598.77
MCF-10A	365	385	1613.32	1238.32	ARTESIAN	8/3/09	4200	09/06/09	25.3	1.000	--	MCF-10B	84	104	1612.38	1518.38	1597.75	8/3/09	2200	08/25/09	23.9	0.999	1597.67
MCF-12A	349.5	369.5	1713.68	1354.18	1658.06	7/22/04	--	--	--	--	--	MCF-12C	155	175	1713.03	1548.03	1647.56	7/21/04	--	--	--	--	--
MCF-12A	349.5	369.5	1713.68	1354.18	1661.03	4/27/06	5950	05/18/06	28.13	1.003	1661.95	MCF-12C	155	175	1713.03	1548.03	1648.68	4/27/06	1690	05/22/06	24.97	0.998	1648.48
MCF-12A	349.5	369.5	1713.68	1354.18	1661.21	7/27/06	5900	08/10/06	25.6	1.001	1661.52	MCF-12C	155	175	1713.03	1548.03	1647.97	7/27/06	1820	08/10/06	25.3	0.998	1647.77
MCF-12A	349.5	369.5	1713.68	1354.18	1661.36	10/16/06	7580	11/10/06	24.64	1.003	1662.28	MCF-12C	155	175	1713.03	1548.03	1647.76	10/16/06	2010	11/03/06	24.35	0.999	1647.66
MCF-12A	349.5	369.5	1713.68	1354.18	1661.54	1/24/07	6320	02/23/07	24.8	1.002	1662.15	MCF-12C	155	175	1713.03	1548.03	1647.28	1/24/07	2100	02/22/07	21.7	0.999	1647.18
MCF-12A	349.5	369.5	1713.68	1354.18	1663.63	8/6/09	7300	09/06/09	28.73	1.002	1664.25	MCF-12C	155	175	1713.03	1548.03	1646.25	8/6/09	1000	08/25/09	29.14	0.997	1645.96
MCF-16A	364.5	384.5	1689.67	1315.17	1661.98	4/6/04	--	--	--	--	--	MCF-16B	283.7	313.7	1689.75	1391.05	1628.46	7/23/04	--	--	--	--	--
MCF-16A	364.5	384.5	1689.67	1315.17	1643.84	4/20/06	81800	05/18/06	25.74	1.059	1663.23	MCF-16B	283.7	313.7	1689.75	1391.05	1626.55	4/20/06	64800	05/01/06	25.83	1.046	1637.38
MCF-16A	364.5	384.5	1689.67	1315.17	1643.62	7/26/06	83800	08/21/06	24.0	1.061	1663.66	MCF-16B	283.7	313.7	1689.75	1391.05	1627.11	7/26/06	70000	08/23/06	24.31	1.050	1638.91
MCF-16A	364.5	384.5	1689.67	1315.17	1643.84	10/17/06	86400	11/06/06	24.14	1.063	1664.55	MCF-16B	283.7	313.7	1689.75	1391.05	1626.95	10/17/06	72200	11/06/06	23.34	1.052	1639.22
MCF-16A	364.5	384.5	1689.67	1315.17	1644.13	1/22/07	88300	02/16/07	23.2	1.065	1665.51	MCF-16B	283.7	313.7	1689.75	1391.05	1626.83	1/22/07	74400	02/20/07	19.50	1.055	1639.80
MCF-16A	364.5	384.5	1689.67	1315.17	1644.98	8/5/09	78800	--	28.50	1.055	1663.12	MCF-16B	283.7	313.7	1689.75	1391.05	1628.37	8/5/09	64300	--	24.4	1.045	1639.05
MCF-1A	335	355	1754.44	1409.44	1720.21	7/25/04	--	--	--	--	--	MCF-1B	55	85	1753.95	1683.95	1713.88	6/7/04	--	--	--	--	--
MCF-1A	335	355	1754.44	1409.44	1723.51	4/18/06	3570	05/30/06	27.72	0.999	1723.20	MCF-1B	55	85	1753.95	1683.95	1712.16	4/18/06	2000	05/11/06	24.89	0.999	1712.13
MCF-1A	335	355	1754.44	1409.44	1726.61	7/27/06	4020	08/07/06	26.39	0.997	1725.66	MCF-1B	55	85	1753.95	1683.95	1711.50	7/27/06	2070	07/31/06	25.89	0.998	1711.44
MCF-1A	335	355	1754.44	1409.44	1727.87	10/16/06	4060	10/24/06	26.01	1.000	1727.87	MCF-1B	55	85	1753.95	1683.95	1711.34	10/16/06	1980	11/06/06	23.67	0.999	1711.31
MCF-1A	335	355	1754.44	1409.44	1726.47	1/22/07	3930	02/02/07	23.4	1.000	1726.47	MCF-1B	55	85	1753.95	1683.95	1711.28	1/22/07	1830	02/14/06	23.93	0.999	1711.25
MCF-1A	335	355	1754.44	1409.44	1716.51	8/6/09	3900	08/14/09	26.8	1.000	1716.51	MCF-1B	55	85	1753.95	1683.95	1709.23	8/6/09	1990	08/12/09	25.7	0.998	1709.18
MCF-2A	360	380	1816.44	1446.44	1770.22	3/24/04	--	--	--	--	--	MCF-2B	215	235	1816.36	1591.36	1751.83	7/8/04	--	--	--	--	--
MCF-2A	360	380	1816.44	1446.44	1775.11	4/18/06	494	05/10/06	26.55	0.997	1774.12	MCF-2B	215	235	1816.36	1591.36	1757.25	4/20/06	622	05/05/06	26.92	0.997	1756.75
MCF-2A	360	380	1816.44	1446.44	1775.80	7/27/06	560	08/04/06	26.66	0.997	1774.81	MCF-2B	215	235	1816.36	1591.36	1757.40	7/27/06	620	08/21/06	26.2	0.997	1756.90
MCF-2A	360	380	1816.44	1446.44	1776.48	10/16/06	492	11/07/06	25.68	0.997	1775.49	MCF-2B	215	235	1816.36	1591.36	1757.62	10/16/06	650	11/03/06	26.76	0.997	1757.12
MCF-2A	360	380	1816.44	1446.44	1776.98	1/22/07	623	02/15/07	25.54	0.997	1775.99	MCF-2B	215	235	1816.36	1591.36	1757.59	1/22/07	638	02/20/07	25.3	0.997	1757.09
MCF-2A	360	380	1816.44	1446.44	1781.50	8/6/09	1100	08/25/09	26.2	0.998	1780.83	MCF-2B	215	235	1816.36	1591.36	1758.12	8/6/09	2200	08/25/09	26.6	0.998	1757.79
MCF-3A	364	384	1783.23	1409.23	1732.71	2/25/04	--	--	--	--	--	MCF-3B	57	77	1783.46	1716.46	1741.72	7/9/04	--	--	--	--	--
MCF-3A	364	384	1783.23	1409.23	1736.73	4/20/06	694	06/07/06	26.0	0.997	1735.75	MCF-3B	57	77	1783.46	1716.46	1742.02	4/20/06	2590	05/12/06	24.75	0.999	1741.99
MCF-3A	364	384	1783.23	1409.23	1737.12	7/27/06	631	08/14/06	25.09	0.998	1736.46	MCF-3B	57	77	1783.46	1716.46	1741.80	7/27/06	2450	08/16/06	24.68	0.999	1741.77
MCF-3A	364	384	1783.23	1409.23	1737.57	10/16/06	627	11/02/06	24.21	0.998	1736.91	MCF-3B	57	77	1783.46	1716.46	1741.56	10/16/06	2490	11/03/06	24.86	0.999	1741.53
MCF-3A	364	384	1783.23	1409.23	1737.81	1/22/07	640	02/27/07	21.8	0.998	1737.15	MCF-3B	57	77	1783.46	1716.46	1741.61	1/22/07	2610	02/20/07	24.2	0.999	1741.58
MCF-3A	364	384	1783.23	1409.23	1742.00	8/6/09	700	08/19/09	25.6	0.997	1741.00	MCF-3B	57	77	1783.46	1716.46	1740.67	8/6/09	1900	08/20/09	26.4	0.998	1740.62
MCF-6A	373.5	393.5	1588.80	1205.3	1563.27	4/16/04	--	--	--	--	--	MCF-6B	67	82	1630.40	1555.9	1590.58	7/16/04	--	--	--	--	--
MCF-6A	373.5	393.5	1588.80	1205.3	1519.38	4/20/06	186000	05/30/06	26.27	1.144	1564.61	MCF-6B	67	82	1630.40	1555.9	1581.18	4/20/06	31400	05/18/06	24.38	1.021	1581.71
MCF-6A	373.5	393.5	1588.80	1205.3	1509.54	7/27/06	185000	08/21/06	25.1	1.143	1553.05	MCF-6B	67	82	1630.40	1555.9	1580.25	7/26/06	39700	08/09/06	24.02	1.027	1580.91
MCF-6A	373.5	393.5	1588.80	1205.3	1512.00	10/16/06	205000	11/13/06	23.44	1.162	1561.68	MCF-6B	67	82	1630.40	1555.9	1579.92	10/17/06	38200	10/31/06	25.63	1.026	1580.54
MCF-6A	373.5	393.5	1588.80	1205.3	1515.31	1/23/07	191000	02/23/07	20.4	1.151	1562.12	MCF-6B	67	82	1630.40	1555.9	1578.79	1/23/07	39700	02/01/06	19.3	1.029	1579.45
MCF-6A	373.5	393.5	1588.80	1205.3	(c)	8/6/09	--	--	--	--	--	MCF-6B	67	82	1630.40	1555.9	1576.97	8/3/09	11500	09/06/09	26.6	1.001	1576.99
MCF-8A	350	370	1579.02	1219.02	ARTESIAN	4/7/04	--	--	--	--	--	MCF-8B	107.5	137.5	1578.43	1455.93	1570.59	6/9/04	--	--	--	--	--
MCF-8A	350	370	1579.02	1219.02	ARTESIAN	4/21/06	110000	06/07/06	24.59	1.082	--	MCF-8B	107.5	137.5	1578.43	1455.93	1578.43	4/21/06	27100	05/23/06	23.45	1.018	1580.64
MCF-8A	350	370	1579.02	1219.02	ARTESIAN	7/26/06	113000	08/23/06	23.8	1.084	--	MCF-8B	107.5	137.5	1578.43	1455.93	1576.89	7/26/06	26200	08/23/06	23.87	1.017	1578.95
MCF-8A	350	370	1579.02	1219.02	ARTESIAN	10/17/06	113000	11/10/06	25.73	1.084	--	MCF-8B											

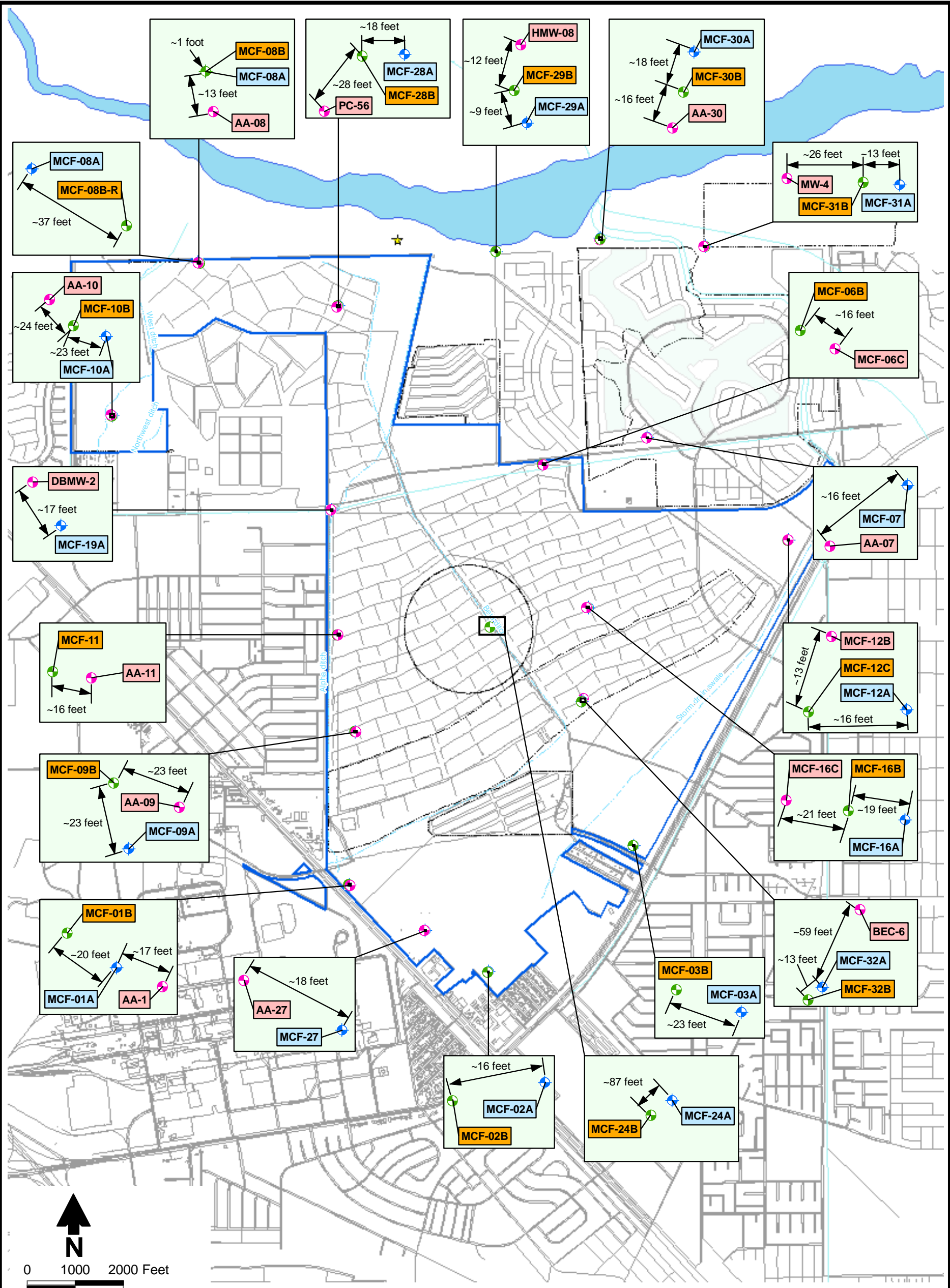


Appendix C. Summary of Vertical Gradient Data  
BRC Common Areas - Eastside (updated for 2009 Data)

Deep Well	Middle Well	Uncorrected for Groundwater Density			Corrected for Groundwater Density			Corrected for Equipotential Surface						
		Point Water Head Delta (ft AMSL)	Point Water Head Deep/Intermediate Vertical Gradient (ft/ft)	Point Water Head Vertical Flow Direction	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Deep/Intermediate Vertical Gradient (ft/ft)	Fresh Water Head Vertical Flow Direction	Horizontal Gradient	Distance Between Wells Along Gradient	Well Name	Revised GW Elevation/Head	Fresh Water Head Delta (ft AMSL)	Fresh Water Head Deep/Intermediate Vertical Gradient (ft/ft)	Fresh Head Vertical Flow Direction
MCF-10A	MCF-10B	-15.19	0.05	UP	--	--	--	--	--	--	--			
MCF-10A	MCF-10B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-10A	MCF-10B	-3.48	0.01	UP	-4.29	0.02	UP	0.0118	-10	MCF-10A	1602.40	-4.40	0.02	UP
MCF-10A	MCF-10B	-8.65	0.03	UP	-9.84	0.04	UP	0.0047	-7	MCF-10A	1608.60	-9.87	0.04	UP
MCF-10A	MCF-10B	-13.33	0.05	UP	-14.53	0.05	UP	0.0118	-6	MCF-10A	1613.37	-14.60	0.05	UP
MCF-10A	MCF-10B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-12A	MCF-12C	-10.50	0.05	UP	--	--	--	--	--	--	--	--	--	--
MCF-12A	MCF-12C	-12.35	0.06	UP	-13.47	0.07	UP	0.0181	7.5	MCF-12A	1661.81	-13.34	0.07	UP
MCF-12A	MCF-12C	-13.24	0.07	UP	-13.75	0.07	UP	0.0261	7	MCF-12A	1661.33	-13.56	0.07	UP
MCF-12A	MCF-12C	-13.60	0.07	UP	-14.62	0.08	UP	0.0118	6	MCF-12A	1662.21	-14.55	0.08	UP
MCF-12A	MCF-12C	-14.26	0.07	UP	-14.97	0.08	UP	0.0376	7	MCF-12A	1661.89	-14.71	0.08	UP
MCF-12A	MCF-12C	-17.38	0.09	UP	-18.29	0.09	UP	0.0500	1	MCF-12A	1664.22	-18.26	0.09	UP
MCF-16A	MCF-16B	-33.52	0.44	UP	--	--	--	--	--	--	--	--	--	--
MCF-16A	MCF-16B	-17.29	0.23	UP	-25.15	0.33	UP	0.0357	19.6	MCF-16A	1662.53	-25.15	0.33	UP
MCF-16A	MCF-16B	-16.51	0.22	UP	-24.74	0.33	UP	0.0186	9	MCF-16A	1663.49	-24.58	0.32	UP
MCF-16A	MCF-16B	-16.89	0.22	UP	-25.33	0.33	UP	0.0235	10	MCF-16A	1664.31	-25.09	0.33	UP
MCF-16A	MCF-16B	-17.30	0.23	UP	-25.32	0.33	UP	0.0308	12.8	MCF-16A	1665.12	-25.32	0.33	UP
MCF-16A	MCF-16B	-16.61	0.22	UP	-23.66	0.31	UP	0.0357	11.40	MCF-16A	1662.71	-23.66	0.31	UP
MCF-1A	MCF-1B	-6.33	0.02	UP	--	--	--	--	--	--	--	--	--	--
MCF-1A	MCF-1B	-11.35	0.04	UP	-11.06	0.04	UP	0.0157	20	MCF-1A	1722.88	-10.75	0.04	UP
MCF-1A	MCF-1B	-15.11	0.06	UP	-14.21	0.05	UP	0.0261	18	MCF-1A	1725.19	-13.74	0.05	UP
MCF-1A	MCF-1B	-16.53	0.06	UP	-16.56	0.06	UP	0.0188	19	MCF-1A	1727.51	-16.20	0.06	UP
MCF-1A	MCF-1B	-15.19	0.06	UP	-15.22	0.06	UP	0.0314	15	MCF-1A	1726.00	-14.75	0.05	UP
MCF-1A	MCF-1B	-7.28	0.03	UP	-7.33	0.03	UP	0.0128	11.77	MCF-1A	1716.36	-7.18	0.03	UP
MCF-2A	MCF-2B	-18.39	0.13	UP	--	--	--	--	--	--	--	--	--	--
MCF-2A	MCF-2B	-17.86	0.12	UP	-17.37	0.12	UP	0.0196	-4.5	MCF-2A	1774.21	-17.46	0.12	UP
MCF-2A	MCF-2B	-18.40	0.13	UP	-17.91	0.12	UP	0.0038	-9	MCF-2A	1774.85	-17.94	0.12	UP
MCF-2A	MCF-2B	-18.86	0.13	UP	-18.37	0.13	UP	0.0152	-12	MCF-2A	1775.67	-18.55	0.13	UP
MCF-2A	MCF-2B	-19.39	0.13	UP	-18.90	0.13	UP	0.0103	-12	MCF-2A	1776.11	-19.02	0.13	UP
MCF-2A	MCF-2B	-23.38	0.16	UP	-23.04	0.16	UP	0.0250	-12.16	MCF-2A	1781.13	-23.35	0.16	UP
MCF-3A	MCF-3B	9.01	-0.03	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-3A	MCF-3B	5.29	-0.02	DOWN	6.35	-0.02	DOWN	0.0108	9.7	MCF-3A	1735.64	6.35	-0.02	DOWN
MCF-3A	MCF-3B	4.68	-0.02	DOWN	5.31	-0.02	DOWN	0.0102	4	MCF-3A	1736.42	5.35	-0.02	DOWN
MCF-3A	MCF-3B	3.99	-0.01	DOWN	4.62	-0.02	DOWN	0.0078	8	MCF-3A	1736.85	4.68	-0.02	DOWN
MCF-3A	MCF-3B	3.80	-0.01	DOWN	4.55	-0.01	DOWN	0.0091	13.2	MCF-3A	1737.03	4.55	-0.01	DOWN
MCF-3A	MCF-3B	-1.33	0.00	UP	-0.23	0.00	UP	0.0132	11.5	MCF-3A	1740.85	-0.23	0.001	UP
MCF-6A	MCF-6B	27.31	-0.08	DOWN	--	--	--	--	--	--	--	--	--	--
MCF-6A	MCF-6B	61.80	-0.18	DOWN	17.10	-0.05	DOWN	--	--	--	--	--	--	--
MCF-6A	MCF-6B	70.71	-0.20	DOWN	27.86	-0.08	DOWN	--	--	--	--	--	--	--
MCF-6A	MCF-6B	67.92	-0.19	DOWN	18.86	-0.05	DOWN	--	--	--	--	--	--	--
MCF-6A	MCF-6B	63.48	-0.18	DOWN	17.33	-0.05	DOWN	--	--	--	--	--	--	--
MCF-6A	MCF-6B	(c)	(c)	(c)										
MCF-8A	MCF-8B	(a)	(a)	UP	--	--	--	--	--	--	--	--	--	--
MCF-8A	MCF-8B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-8A	MCF-8B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-8A	MCF-8B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-8A	MCF-8B	(a)	(a)	UP	(a)	(a)	UP	--	--	--	--	(a)	(a)	UP
MCF-8A	MCF-8B	(a)	(a)	UP										
MCF-8A	MCF-8B-R	(c)	(c)	(c)	(c)	(c)	(c)	--	--	--	--	(c)	(c)	(c)
MCF-8A	MCF-8B-R	(c)	(c)	(c)										
MCF-9A	MCF-9B	-3.86	0.02	UP	--	--	--	--	--	--	--	--	--	--
MCF-9A	MCF-9B	2.78	-0.02	DOWN	--	--	--	0.0235	23	MCF-9A	1656.82	3.32	-0.02	DOWN
MCF-9A	MCF-9B	2.19	-0.01	DOWN	-1.54	0.01	UP	0.0147	23	MCF-9A	1660.51	-1.20	0.01	UP
MCF-9A	MCF-9B	1.91	-0.01	DOWN	-2.22	0.01	UP	0.0235	22	MCF-9A	1660.91	-1.70	0.01	UP
MCF-9A	MCF-9B	1.91	-0.01	DOWN	-2.87	0.02	UP	0.0078	23	MCF-9A	1661.86	-2.69	0.02	UP
MCF-9A	MCF-9B	1.20	-0.01	DOWN	-2.11	0.01	UP	0.0263	21.72	MCF-9A	1658.96	-1.54	0.01	UP
MCF-24A	MCF-24B	(c)	(c)	(c)	(c)	(c)	(c)	0.04	-3	MCF-24A	--	(c)	(c)	(c)
MCF-28A	MCF-28B	41.01	-0.21	DOWN	42.89	-0.22	DOWN	0.02	0	MCF-28A	1530.46	42.89	-0.22	DOWN
MCF-29A	MCF-29B	-11.34	0.06	UP	(c)	(c)	(c)	0.00	-6	MCF-29A	1585.73	-56.04	0.28	UP
MCF-30A	MCF-30B	-9.90	0.05	UP	-39.83	0.19	UP	0.01	-8	MCF-30A	1570.19	-39.88	0.19	UP
MCF-31A	MCF-31B	-67.98	0.46	UP	(c)	(c)	(c)	0.02	14	MCF-31A	1575.49	-119.28	0.81	UP
MCF-32A	MCF-32B	-33.24	0.16	UP	(c)	(c)	(c)	0.03	-1	MCF-32A	1696.68	-33.37	0.16	UP

-- - Well not sampled or parameter data not available/not applicable.  
(a) - Water level was artesian when observed. Numerical value not measured.  
(b) - No data recorded for well MCF-07 in May 2006.  
(c) - One well in the pair was recently installed. Water levels not yet stabilized after well development. Value will be calculated once water level measurement is completed.  
Groundwater density (pi) values calculated from TDS and temperature data at [http://www.earthwardconsulting.com/density\\_calculator.htm](http://www.earthwardconsulting.com/density_calculator.htm).





Explanation

- MCF-16C Shallow zone well
- MCF-16B Middle zone well
- MCF-16A Deep zone well
- Site AOC3 boundary

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE C-1  
EASTSIDE AREA VERTICAL  
GRADIENT WELLS



Prepared by:  
 DBS&A CRS

Date  
12-21-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/REPORTS/  
EASTSIDE\_VERTICAL\_GRADIENT\_WELLS.MXD 907121



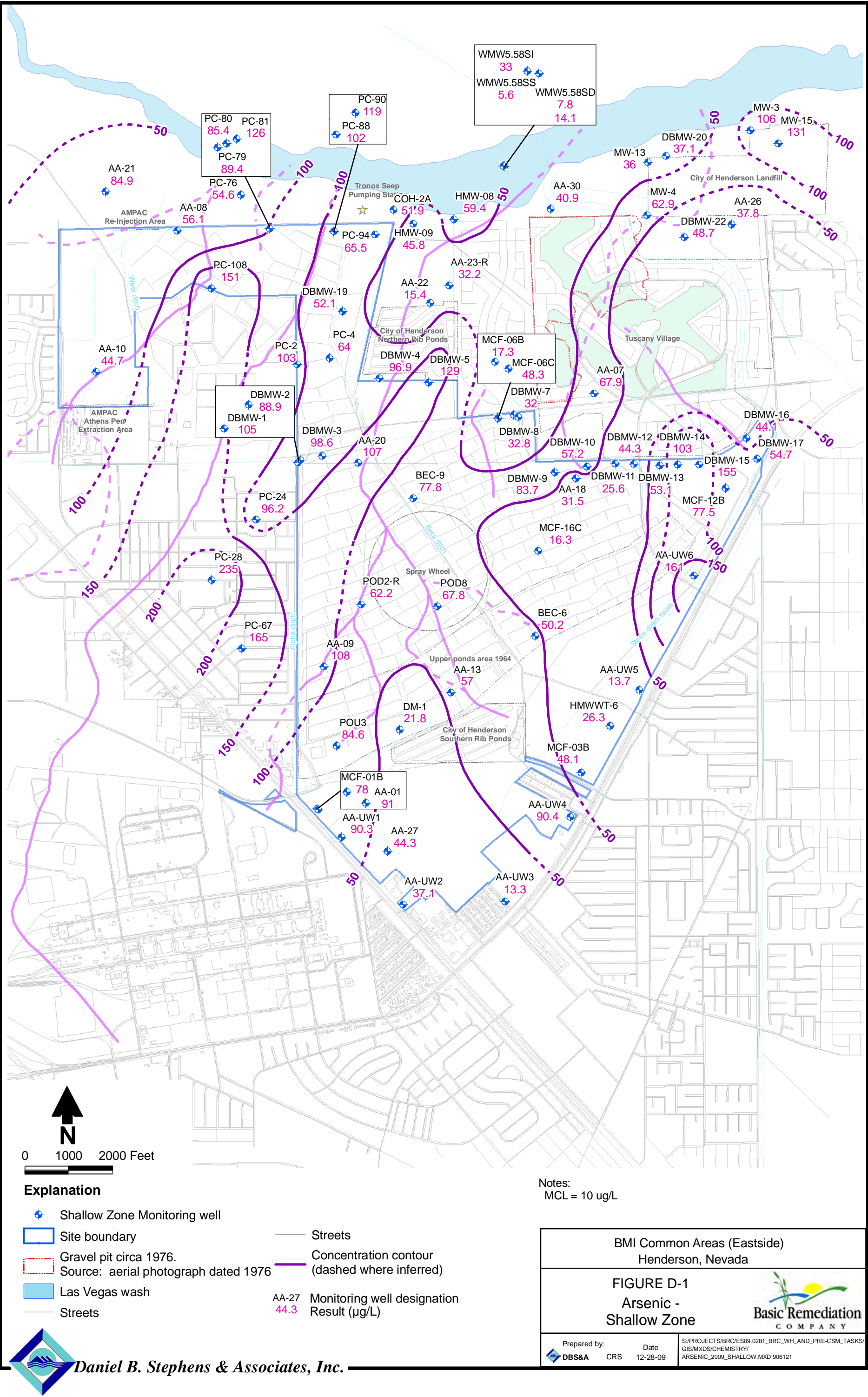
Daniel B. Stephens & Associates, Inc.





## **Appendix D**

### **Isoconcentration Plots (Shallow/Middle/Deep Zone)**

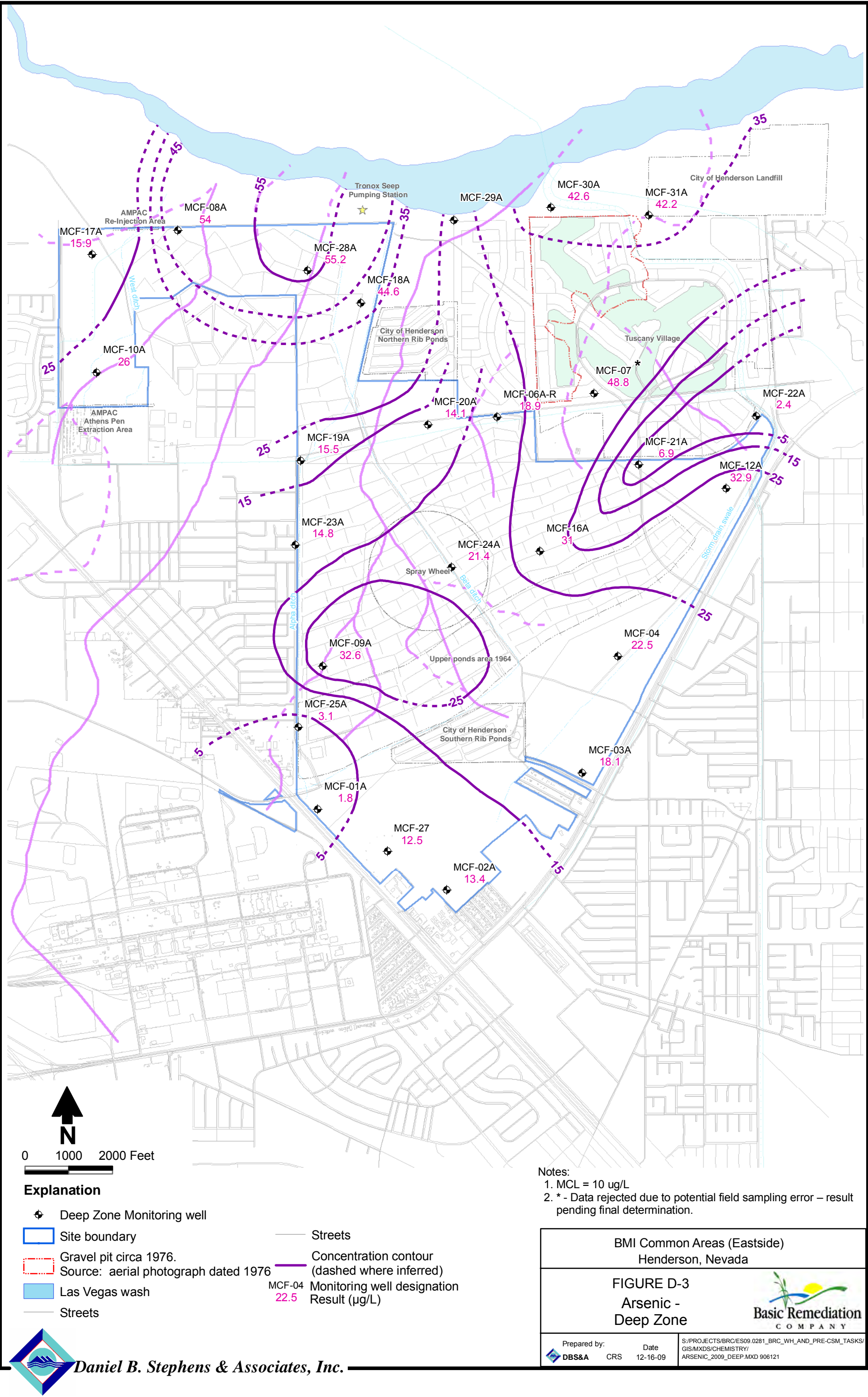




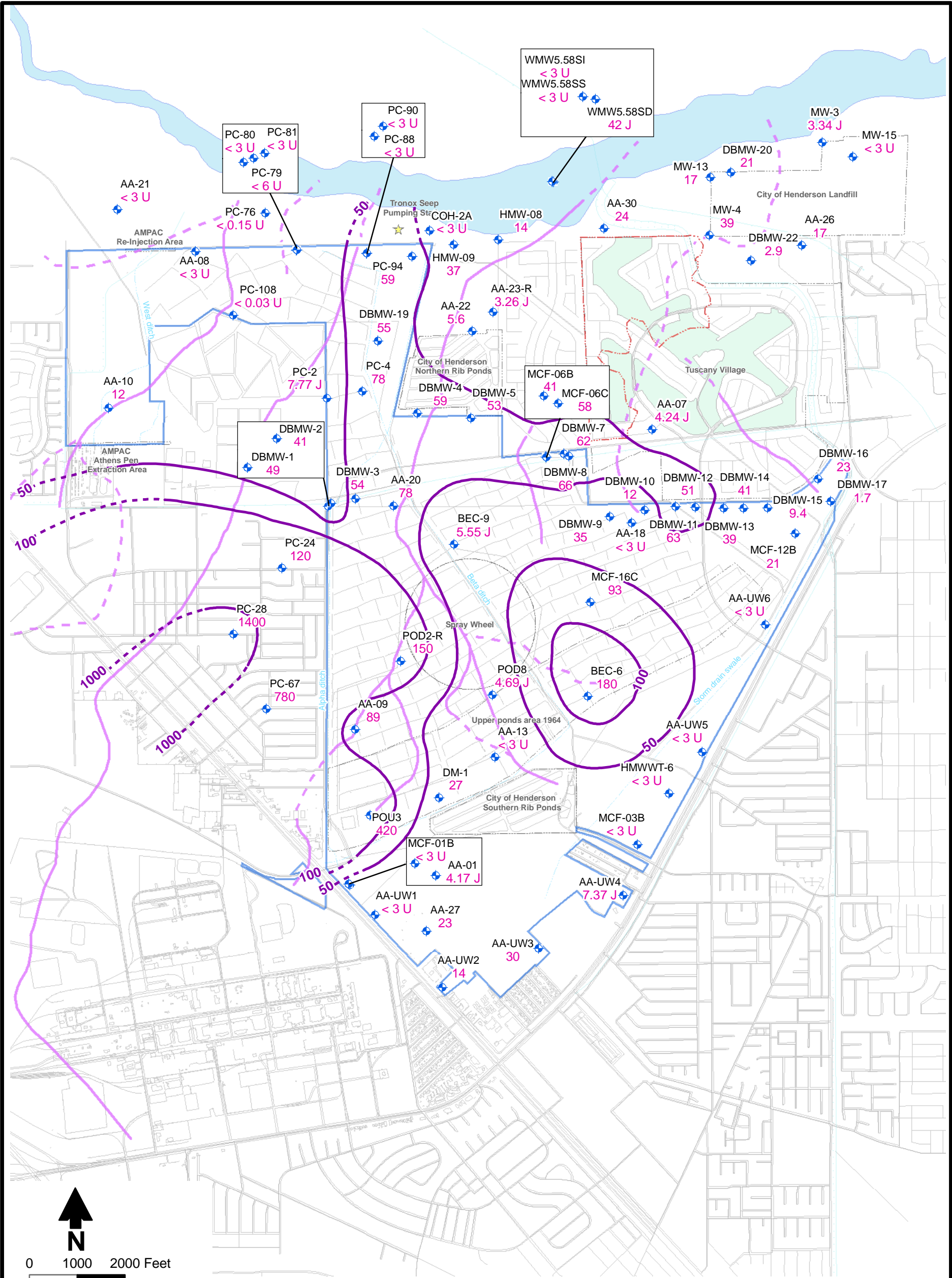


<p>BMI Common Areas (Eastside) Henderson, Nevada</p>		
<p>FIGURE D-2 Arsenic - Middle Zone</p>		
<p>Prepared by:  <b>DBS&amp;A</b></p>	<p>Date <b>CRS</b> 12-28-09</p>	<p>S:\PROJECTS\BRC\ES09.0281_BRC_WH_AND_PRE-CSM_TASKS\GIS\MXDS\CHEMISTRY\ARSENIC_2009_MIDDLE.MXD 906121</p>









Notes:  
MCL for total chromium = 100 ug/L

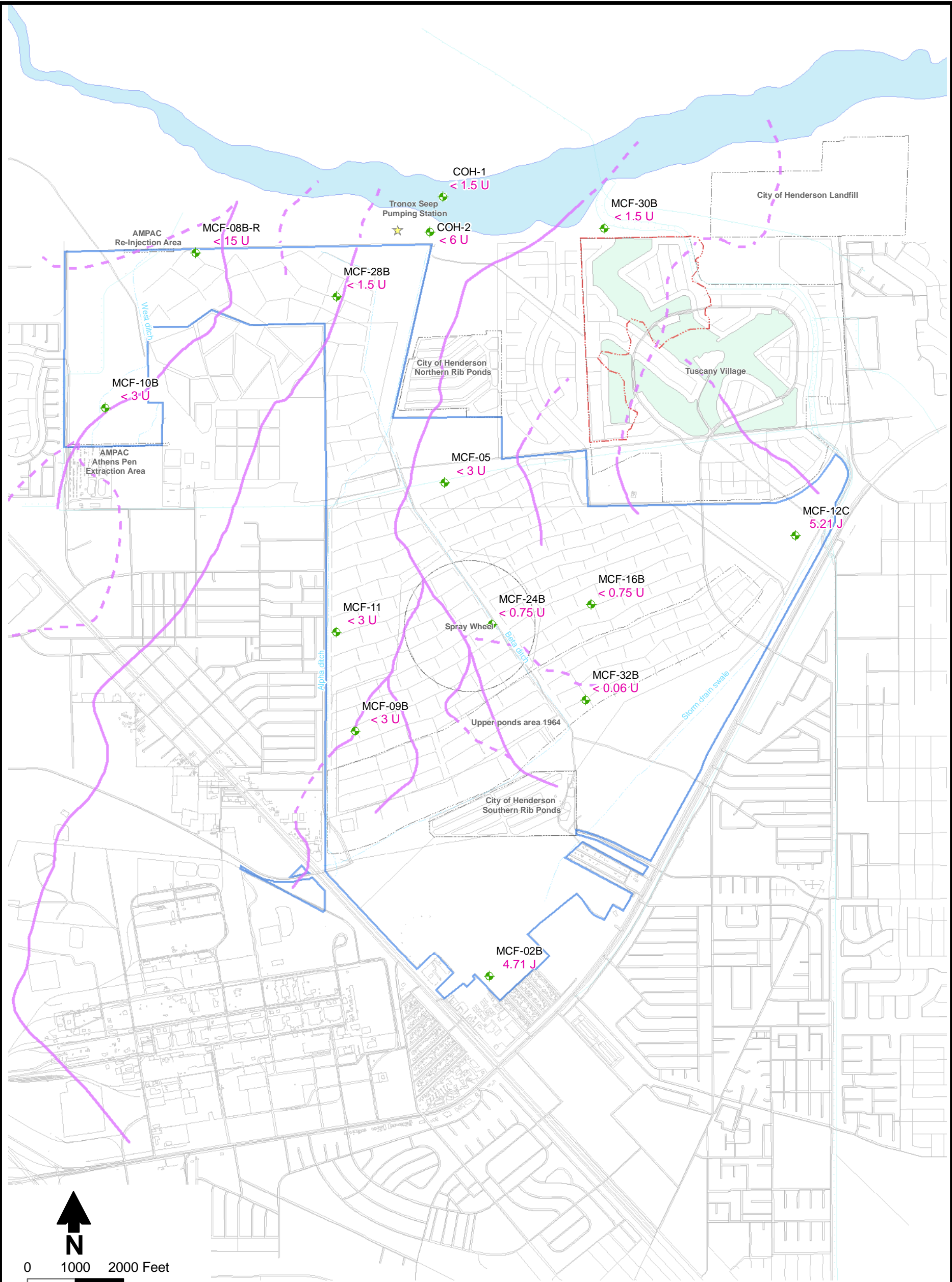
Explanation

- Shallow Zone Monitoring well
- Site boundary
- Gravel pit circa 1976.  
Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- Concentration contour  
(dashed where inferred)
- Monitoring well designation  
Result (µg/L)

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE D-4 Hexavalent Chromium (Cr VI) - Shallow Zone	
Prepared by: DBS&A CRS	Date 12-18-09
S:\PROJECTS\BRC\ES09.0281_BRC_WH_AND_PRE-CSM_TASKS\GIS\MXDS\CHEMISTRY\CRVI_2009_SHALLOW.MXD 906121	







Notes:  
MCL for total chromium = 100 ug/L

Explanation

- Middle Zone Monitoring well
- Site boundary
- Gravel pit circa 1976. Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- MCF-09B Monitoring well designation
- MCF-09B Result (µg/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-5  
Hexavalent Chromium (Cr VI) -  
Middle Zone



Prepared by:  
DBS&A CRS

Date

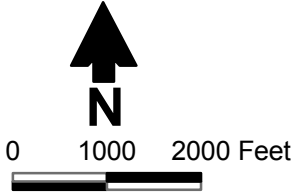
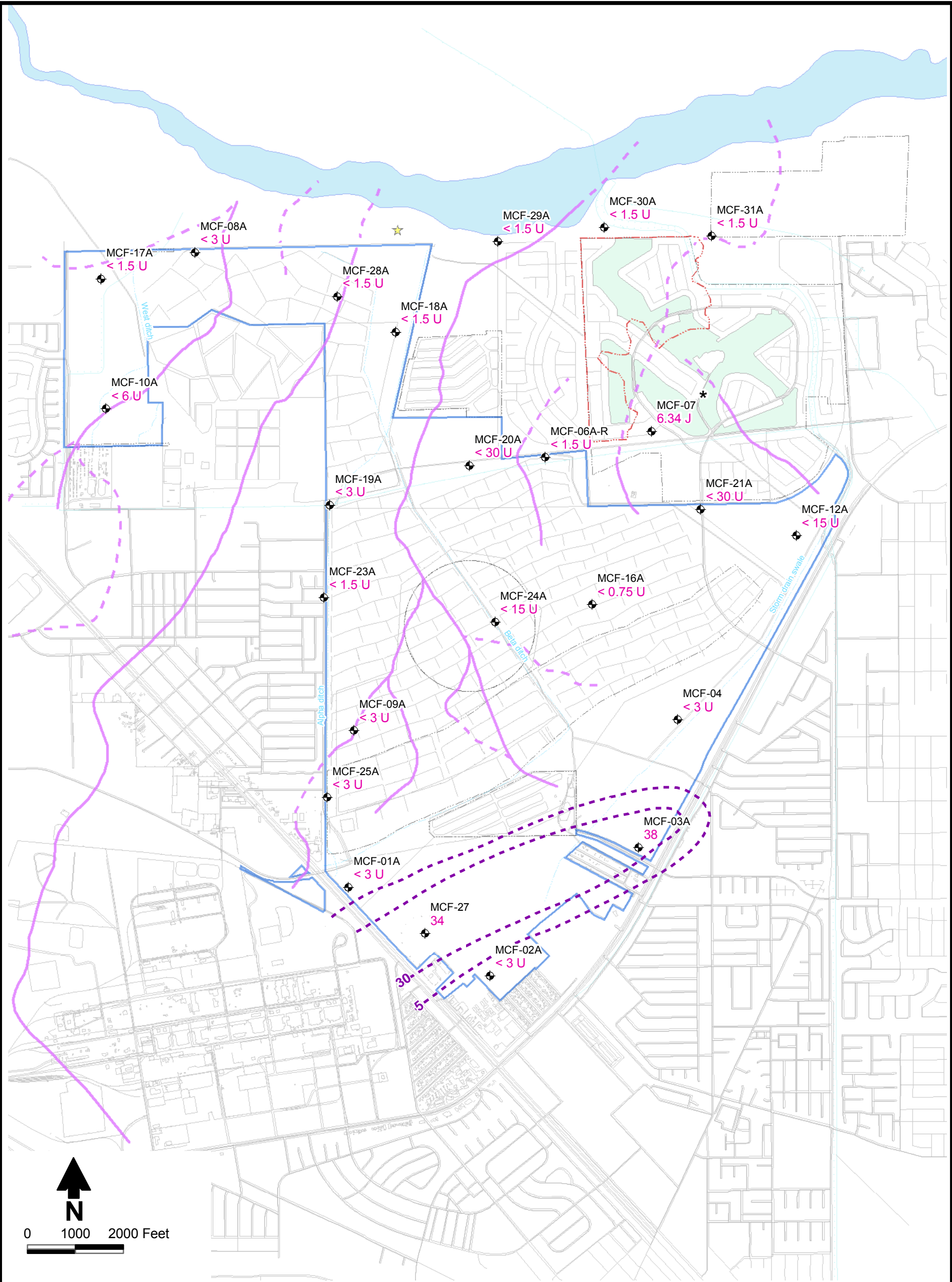
12-16-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
CRVI\_2009\_MIDDLE.MXD 906121



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**Explanation**

- Deep zone monitoring well
- Site boundary
- Gravel pit circa 1976.
- Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Concentration contour (dashed where inferred)
- MCF-24A Monitoring well designation < 15 U Result (µg/L)

- Notes:
1. MCL for total chromium = 100 ug/L
  2. \* - Data rejected due to potential field sampling error – result pending final determination.

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-6  
Hexavalent Chromium (Cr VI) -  
Deep Zone



Prepared by:  
DBS&A CRS

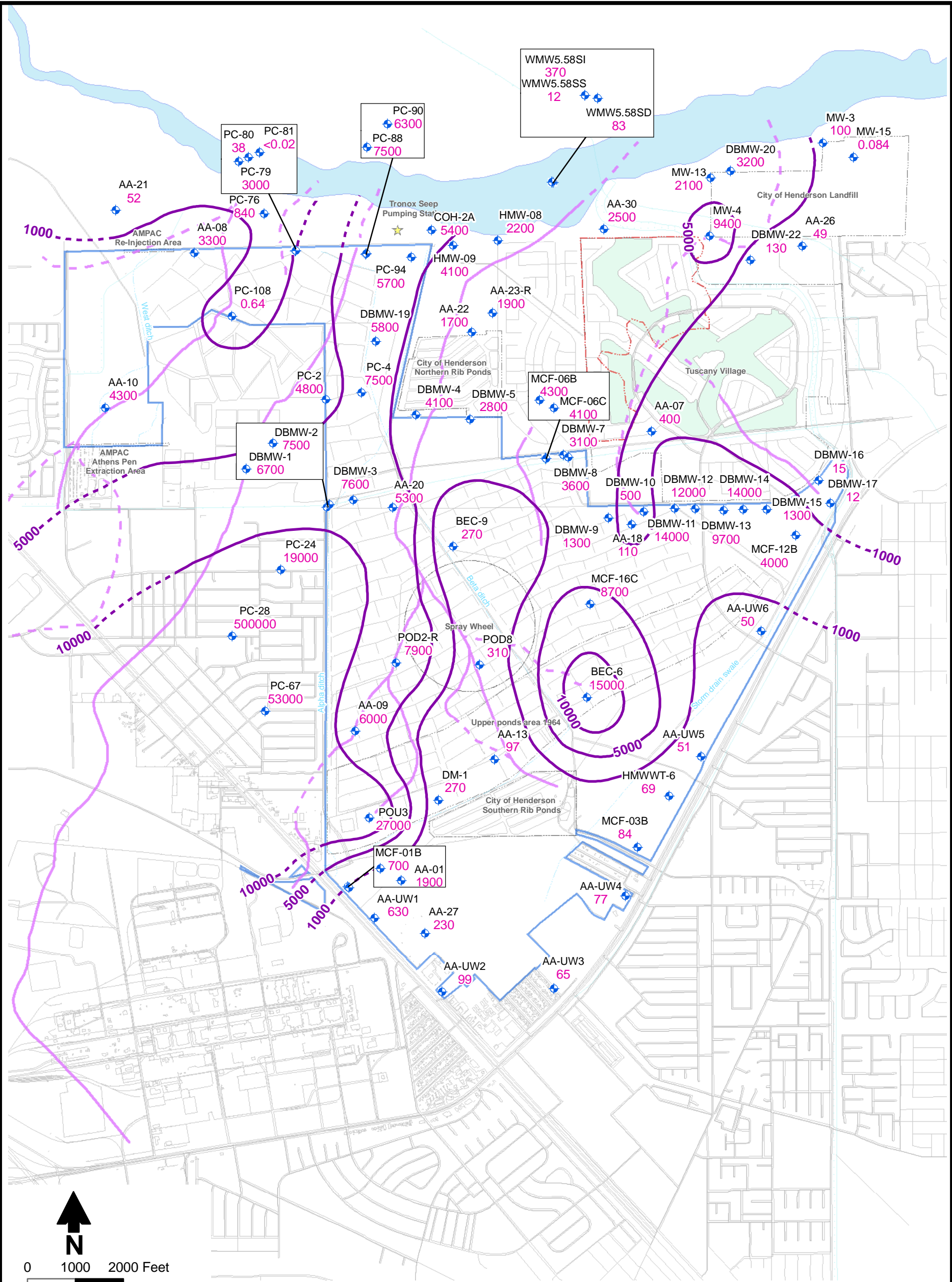
Date  
12-28-09

S:\PROJECTS\BRC\ES09.0281\_BRC\_WH\_AND\_Pre\_CSM\_tasks/  
GIS\MXD\SCHEMISTRY\CVI\_DEEP.MXD 905011



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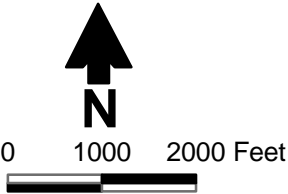
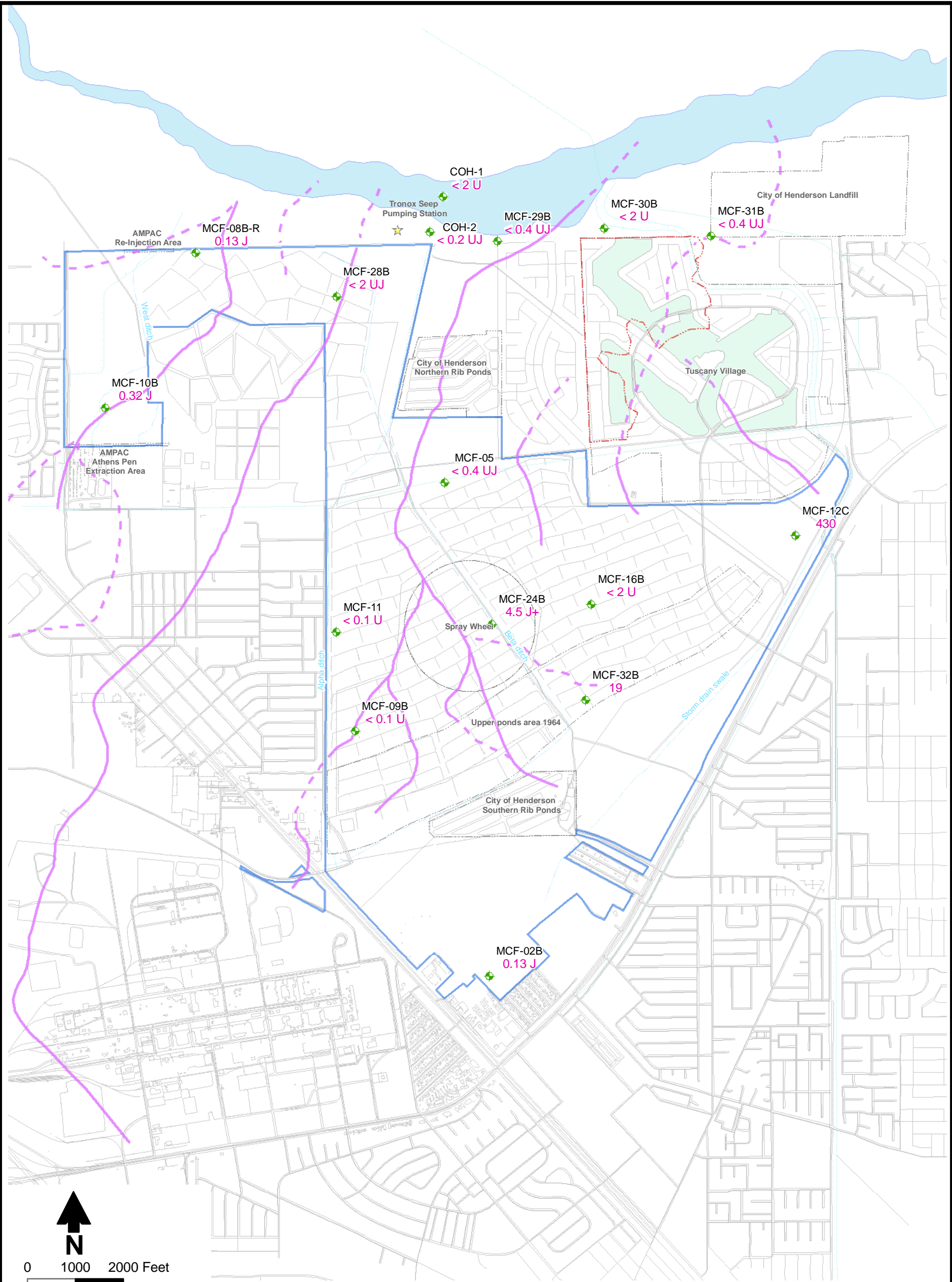




Notes:  
1. NDEP Provisional AL = 18 ug/L  
2. USEPA Drinking Water Equivalent Level (DWEL) = 24.5 ug/L

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE D-7 Perchlorate - Shallow Zone	
Prepared by: DBS&A CRS	Date 12-18-09
S:/PROJECTS/BRC/ES09.0281_BRC_WH_AND_PRE-CSM_TASKS/ GIS/MXDS/CHEMISTRY/ PERCHL_2009_SHALLOW.MXD 906121	





Explanation

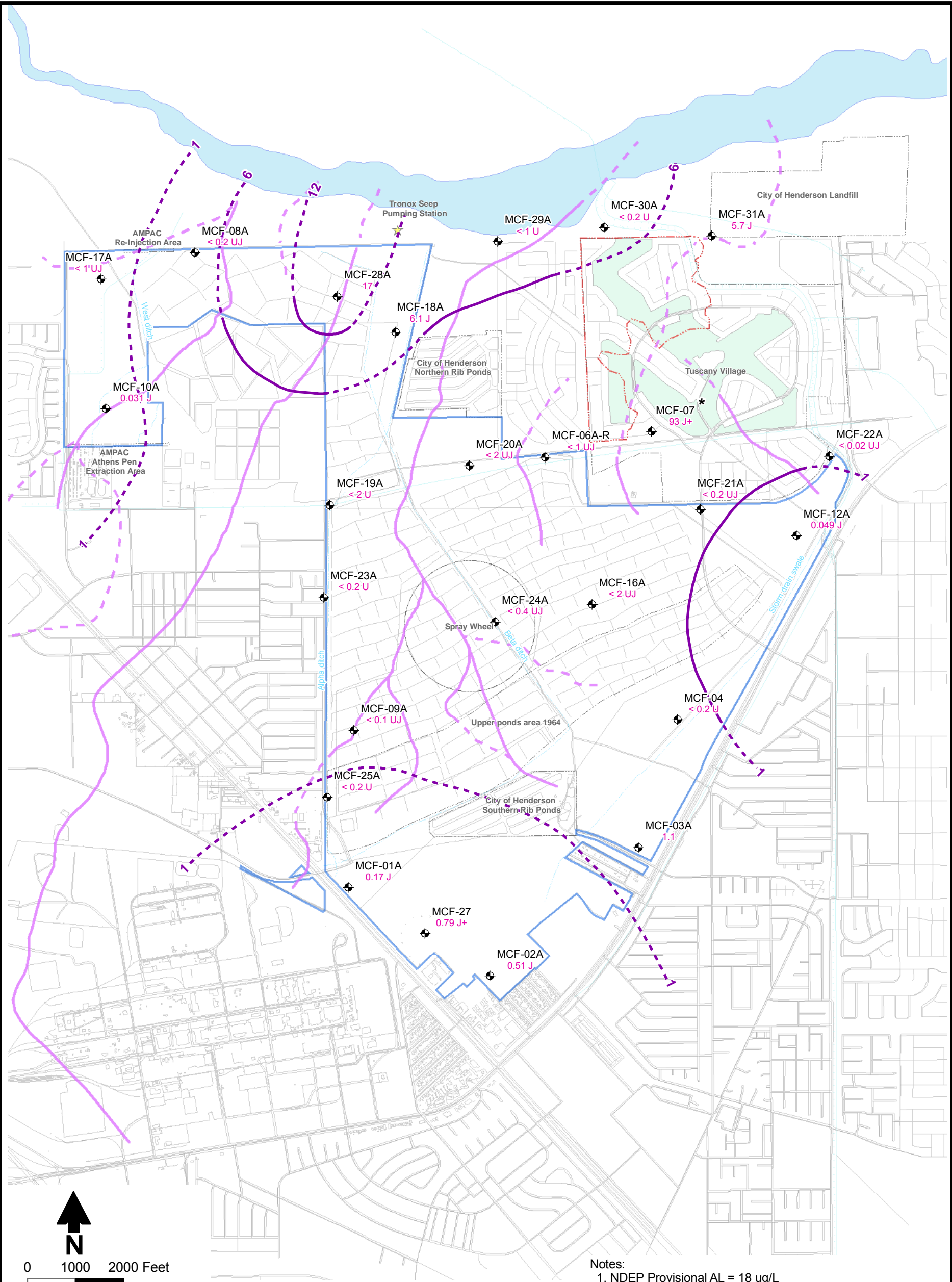
- Middle Zone Monitoring well
- Site boundary
- Gravel pit circa 1976. Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- MCF-09B Monitoring well designation
- Result (µg/L)

- Notes:
- NDEP Provisional AL = 18 ug/L
  - USEPA Drinking Water Equivalent Level (DWEL) = 24.5 ug/L

BMI Common Areas (Eastside) Henderson, Nevada		
<b>FIGURE D-8</b> <b>Perchlorate -</b> <b>Middle Zone</b>		
Prepared by: DBS&A	CRS	Date 12-16-09
S:/PROJECTS/BRC/ES09.0281_BRC_WH_AND_PRE-CSM_TASKS/ GIS/MXDS/CHEMISTRY/ PERCHL_2009_MIDDLE.MXD 906121		







- Notes:
1. NDEP Provisional AL = 18 ug/L
  2. USEPA Drinking Water Equivalent Level (DWEL) = 24.5 ug/L
  3. \* - Data rejected due to potential field sampling error – result pending final determination.

Explanation

- Deep Zone Monitoring well
- Site boundary
- Gravel pit circa 1976. Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- Concentration contour (dashed where inferred)
- Monitoring well designation Result (µg/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-9  
Perchlorate -  
Deep Zone



Prepared by:  
DBS&A CRS

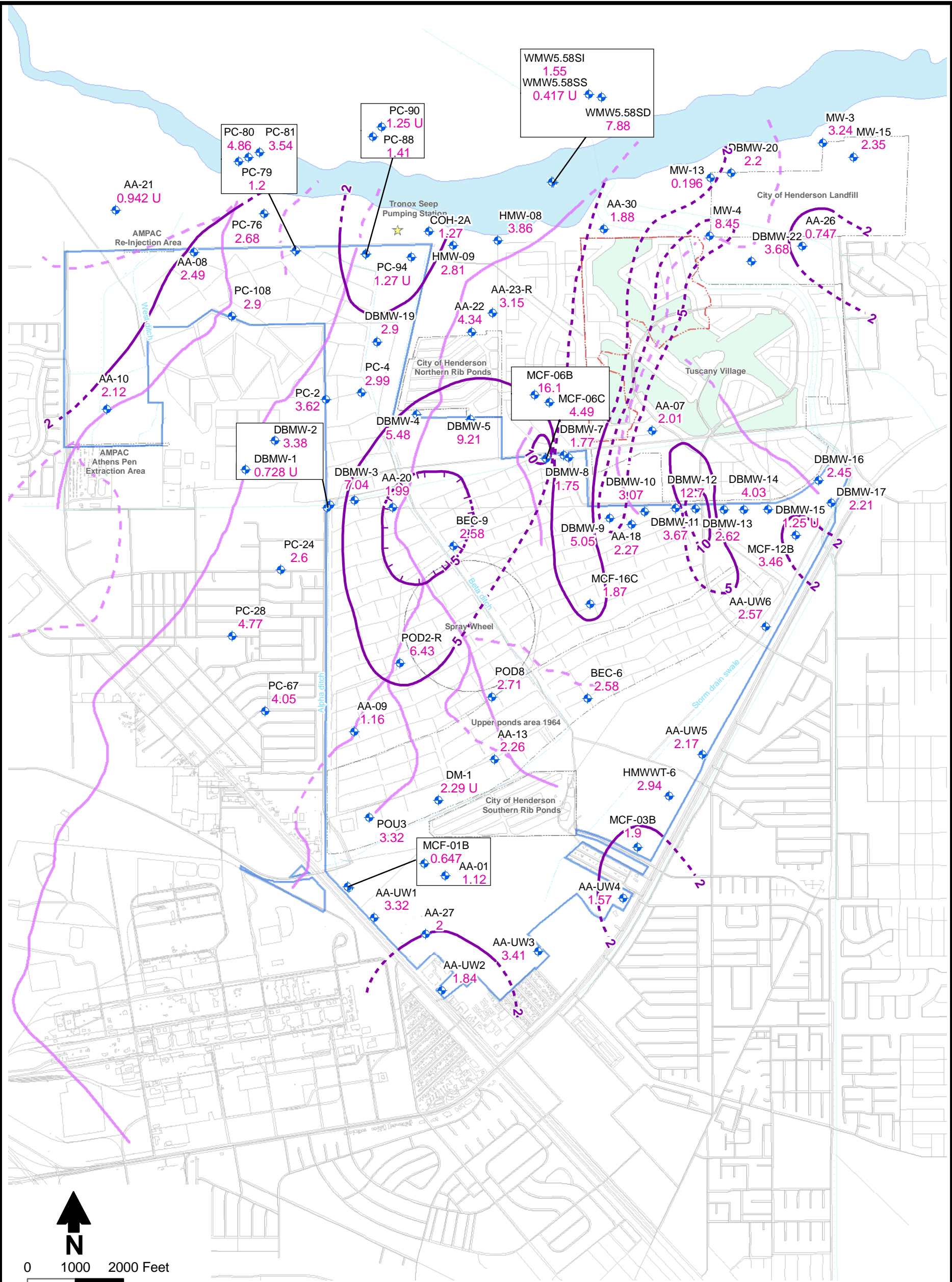
Date  
12-21-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
PERCHL\_2009\_DEEP.MXD 906121



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Notes:  
MCL = 5.0 pCi/L

Explanation

- Shallow Zone Monitoring well
- Site boundary
- Gravel pit circa 1976.  
Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- Concentration contour  
(dashed where inferred)
- Monitoring well designation  
Result (pCi/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-10  
Radium 226+228 -  
Shallow Zone



Prepared by:  
DBS&A CRS

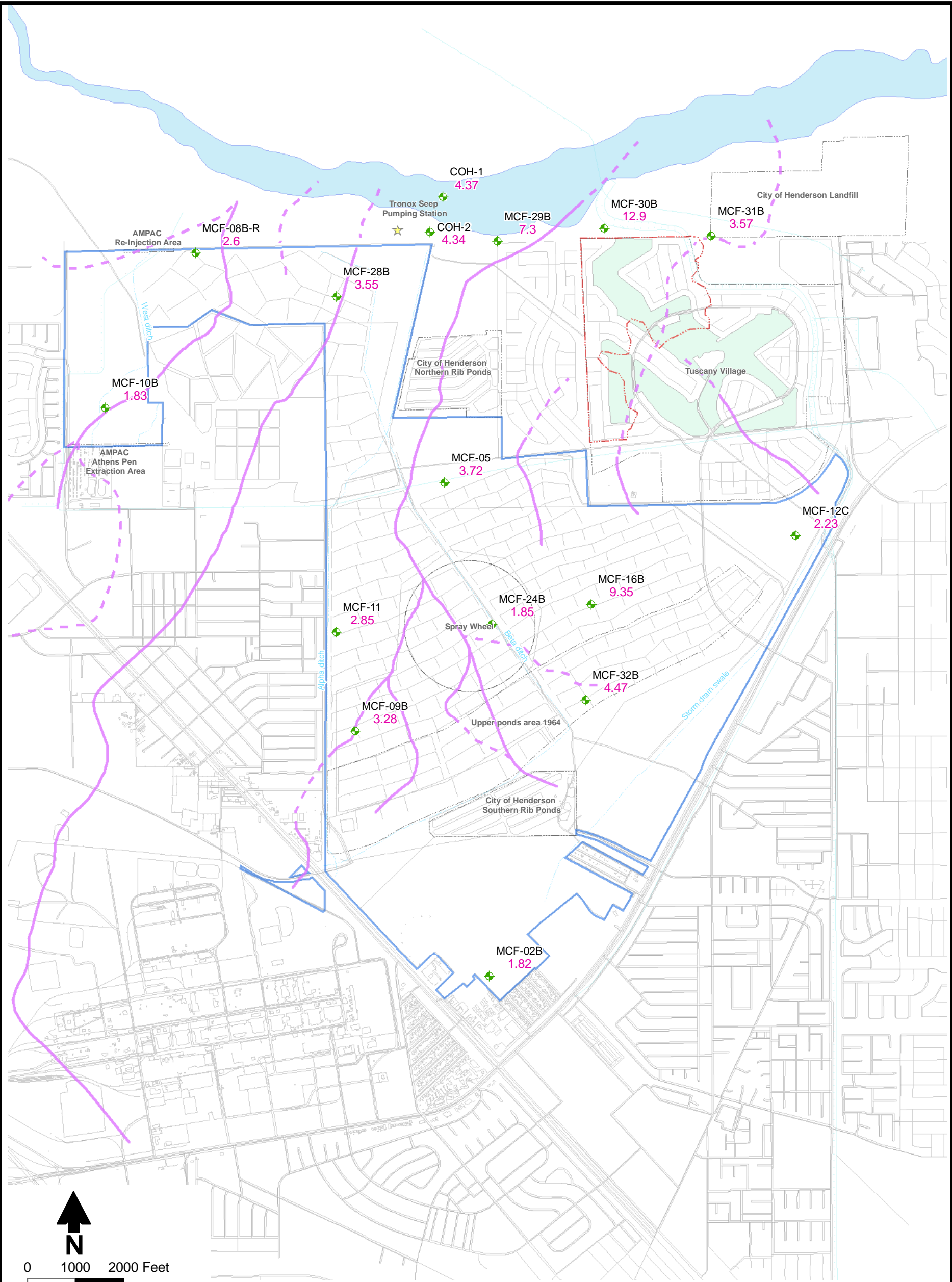
Date  
12-18-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_VH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/  
CHEMISTRY/RA226\_228\_2009\_SHALLOW.MXD 907121



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Explanation

- Middle Zone Monitoring well
- Site boundary
- Gravel pit circa 1976.  
Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- MCF-09B Monitoring well designation  
3.28 Result (pCi/L)

Notes:  
MCL = 5.0 pCi/L

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-11  
Radium 226+228 -  
Middle Zone



Prepared by:  
DBS&A CRS

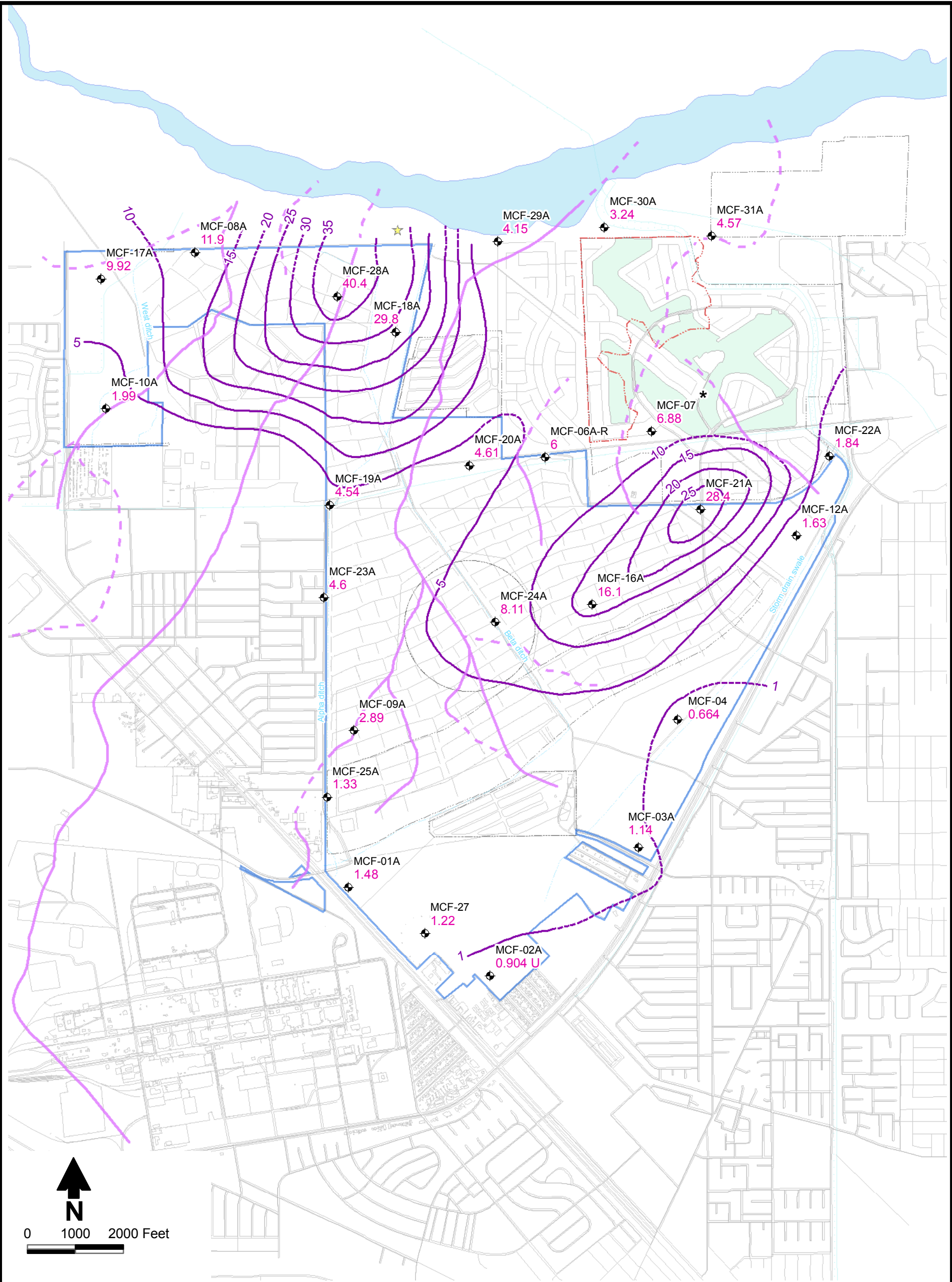
Date  
12-16-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/  
CHEMISTRY/RA226\_228\_2009\_MIDDLE.MXD 907121



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Notes:  
1. MCL = 5.0 pCi/L  
2. \* - Data rejected due to potential field sampling error – result pending final determination.

**Explanation**

- Deep zone monitoring well
- Site boundary
- Gravel pit circa 1976.
- Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Concentration contour (dashed where inferred)
- MCF-24A Monitoring well designation Result (pCi/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-12  
Radium 226+228 -  
Deep Zone



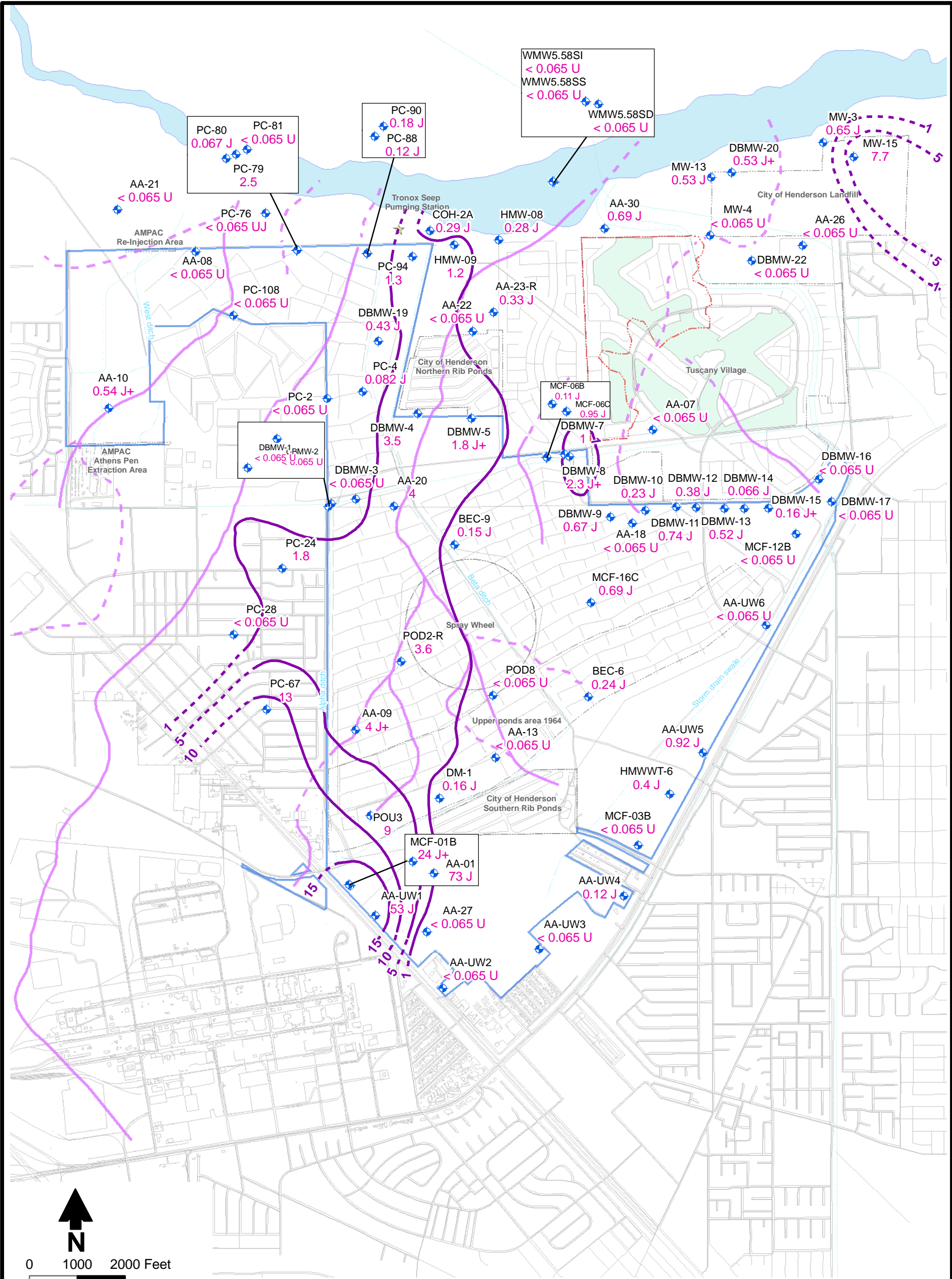
Prepared by: DBS&A CRS Date: 12-28-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_Pre\_CSM\_tasks/GIS/MXDS/CHEMISTRY/Ra226+228\_DEEP.MXD 905011



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Explanation

- Shallow Zone Monitoring well
- Site boundary
- Gravel pit circa 1976. Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- Concentration contour (dashed where inferred)
- AA-27 Monitoring well designation < 0.065 U Result (µg/L)

Notes:  
MCL = 5.0 ug/L

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-13  
Tetrachloroethene (PCE) -  
Shallow Zone



Prepared by:  
DBS&A CRS

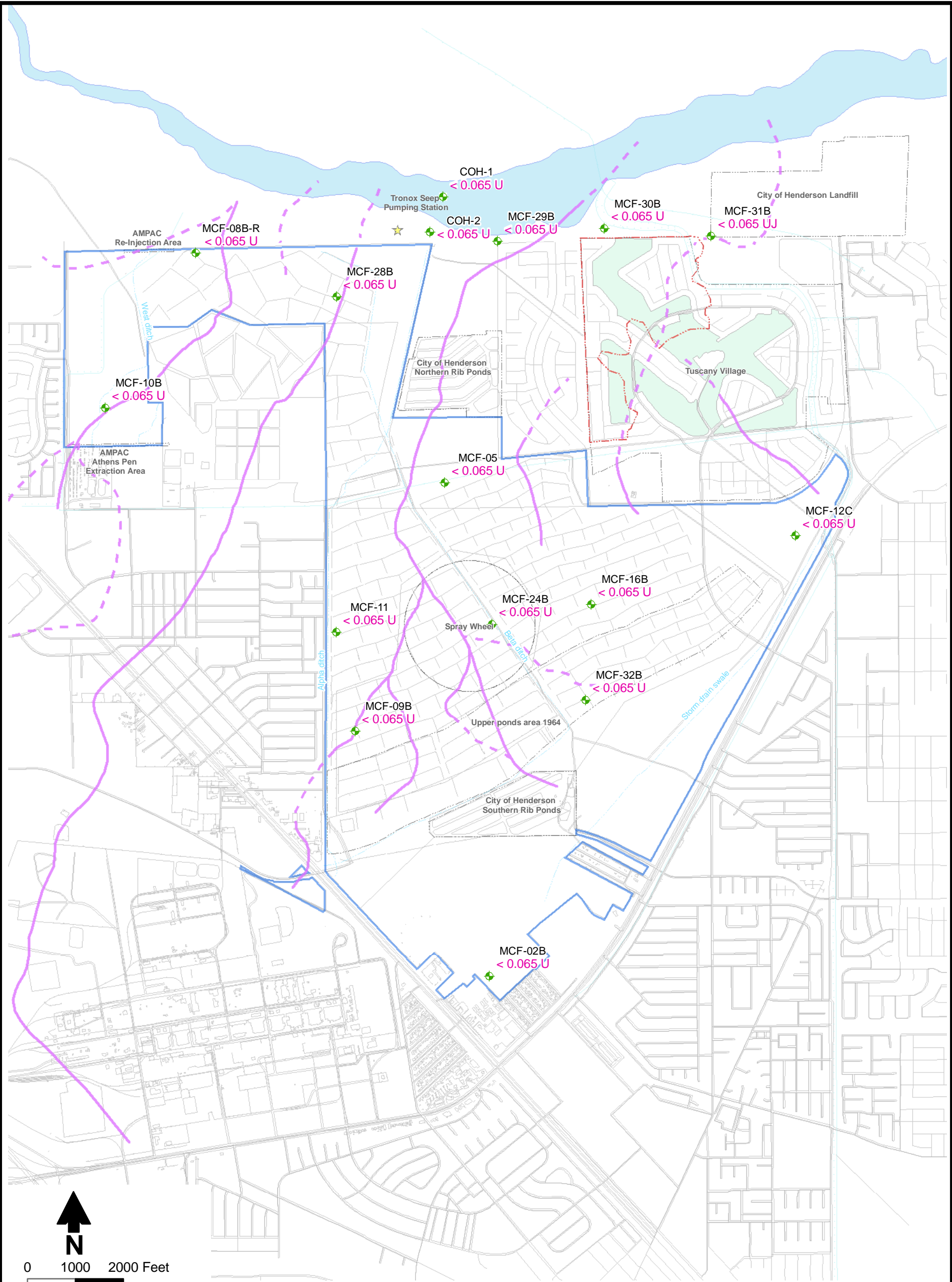
Date  
12-18-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_VH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
PCE\_2009\_SHALLOW.MXD 906121



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Notes:  
MCL = 5.0 ug/L

Explanation

- Middle Zone Monitoring well
- Site boundary
- Gravel pit circa 1976.  
Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- MCF-09B Monitoring well designation
- < 0.065 U Result (µg/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-14  
Tetrachloroethene (PCE) -  
Middle Zone



Prepared by:  
 DBS&A CRS

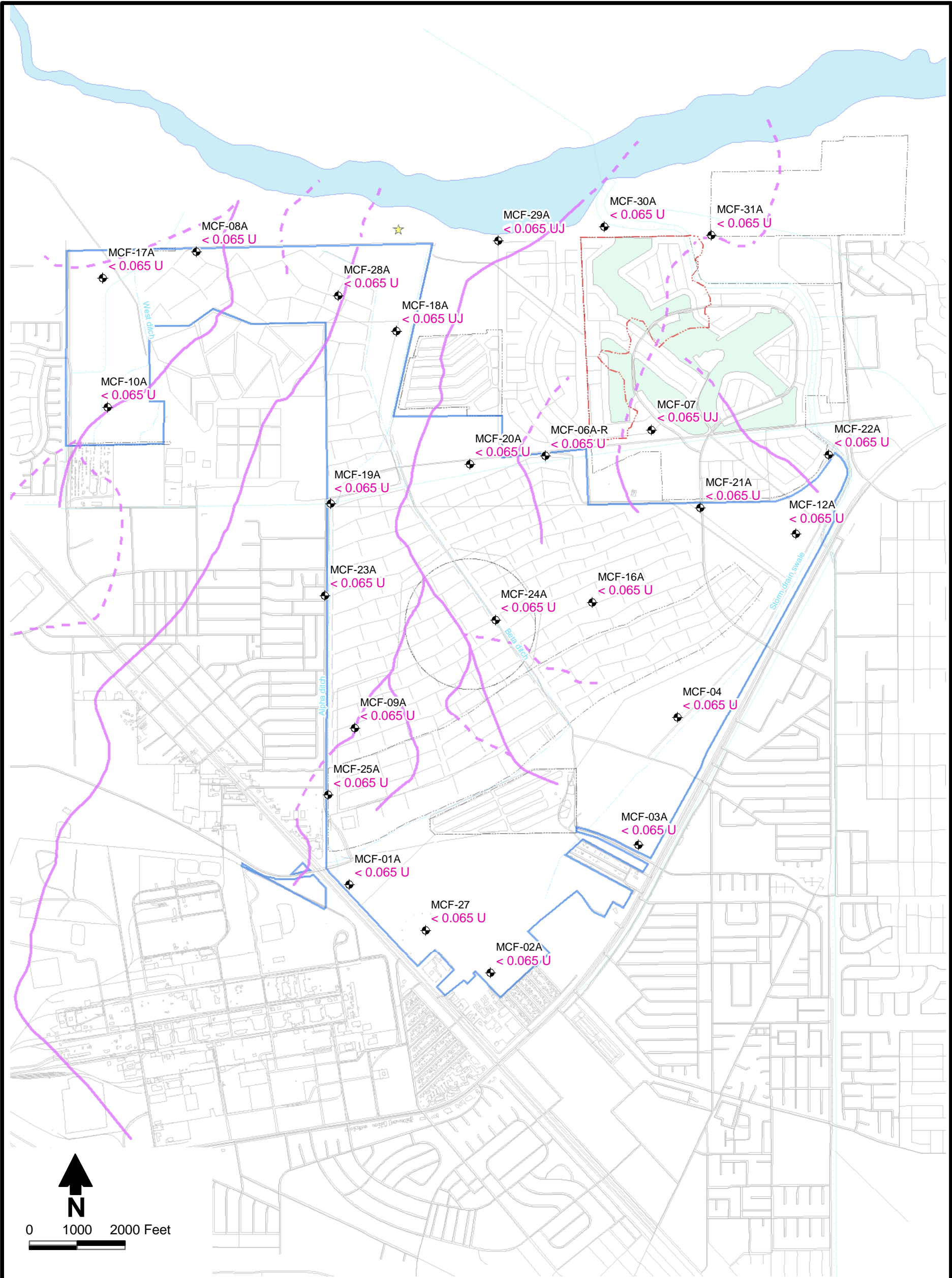
Date  
12-16-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_VH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
PCE\_2009\_MIDDLE.MXD 906121



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Notes:  
MCL = 5.0 ug/L

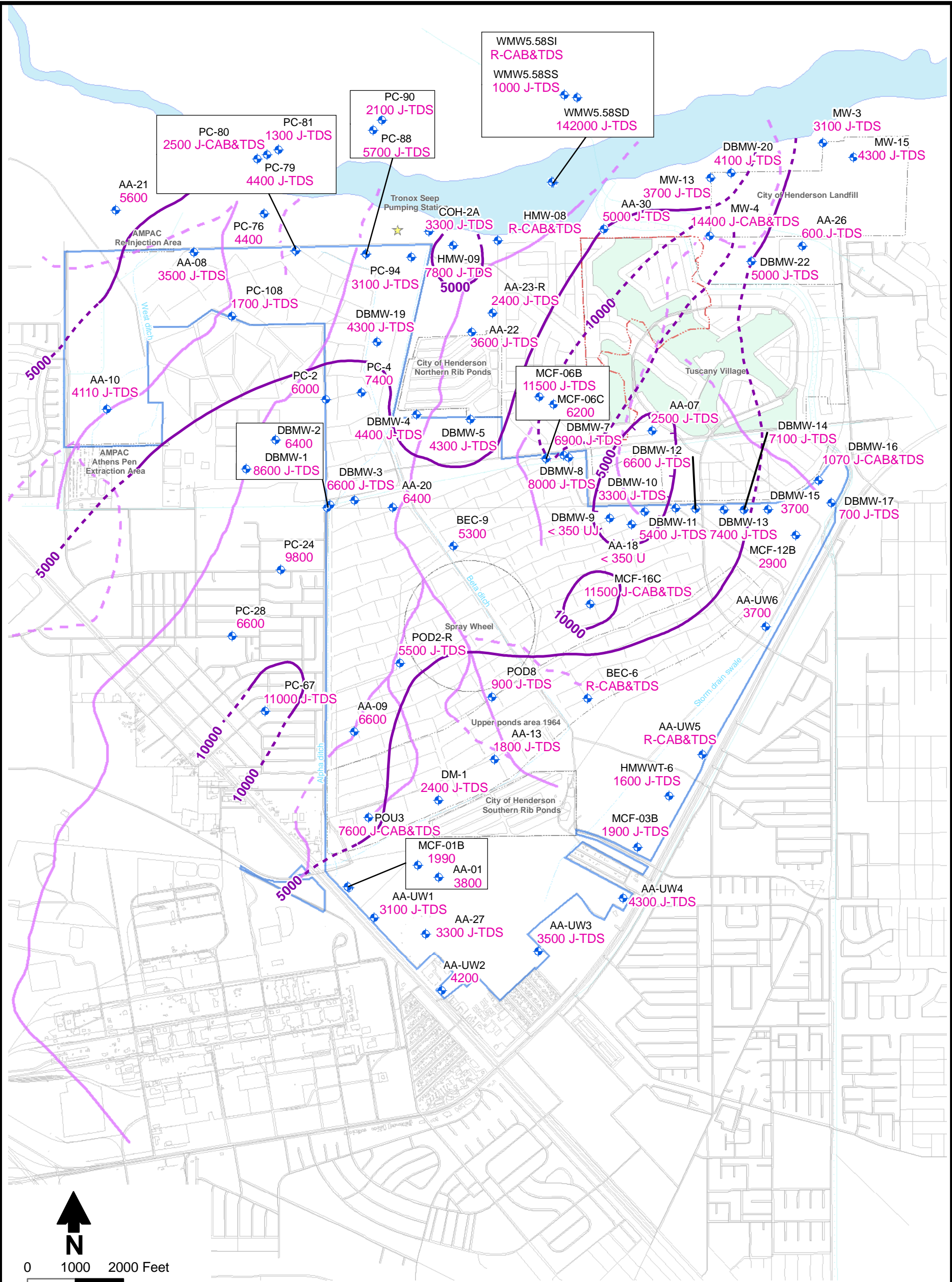
Explanation

- Deep zone monitoring well
- Site boundary
- Gravel pit circa 1976.
- Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- MCF-24A Monitoring well designation
- < 0.065 U Result (µg/L)

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE D-15 Tetrachloroethene (PCE) - Deep Zone	
Prepared by: DBS&A CRS	Date 12-14-09
S:/PROJECTS/BRC/ES09.0281_BRC_WH_AND_Pre_CSM_tasks/ GIS/MXDS/CHEMISTRY/PCE_DEEP.MXD 905011	







Notes:  
USEPA MCL = 500 mg/L

Explanation

- Shallow Zone Monitoring well
- Site boundary
- Gravel pit circa 1976.  
Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- Concentration contour  
(dashed where inferred)
- Monitoring well designation  
Result (mg/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE D-16  
Total Dissolved Solids (TDS) -  
Shallow Zone

Basic Remediation  
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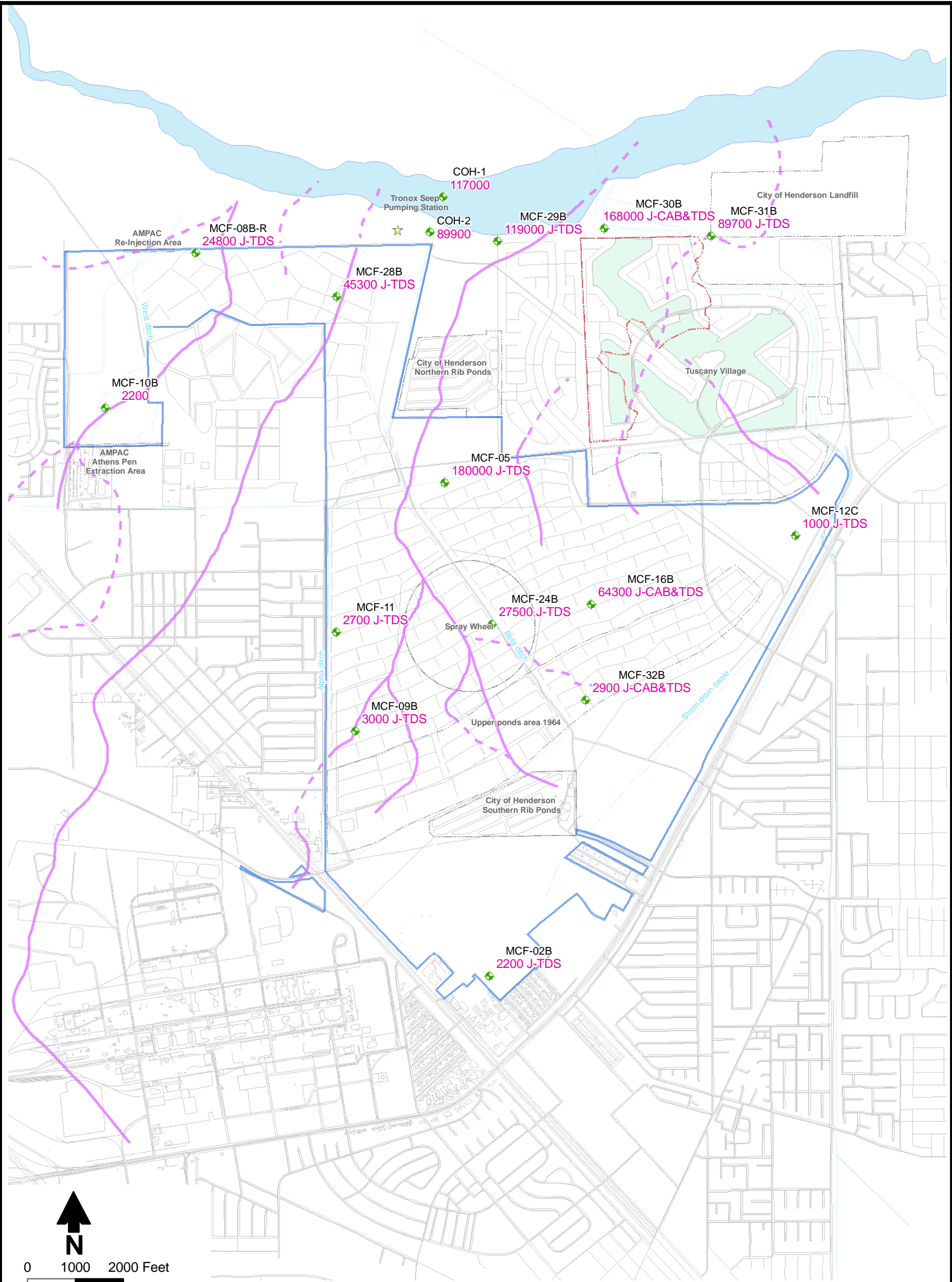
Prepared by:  
DBS&A CRS

Date  
12-18-09

S:/PROJECTS/BRC/ES09.0281\_BRC\_VH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
TDS\_2009\_SHALLOW.MXD 906121








Notes:  
USEPA MCL = 500 mg/L

Explanation

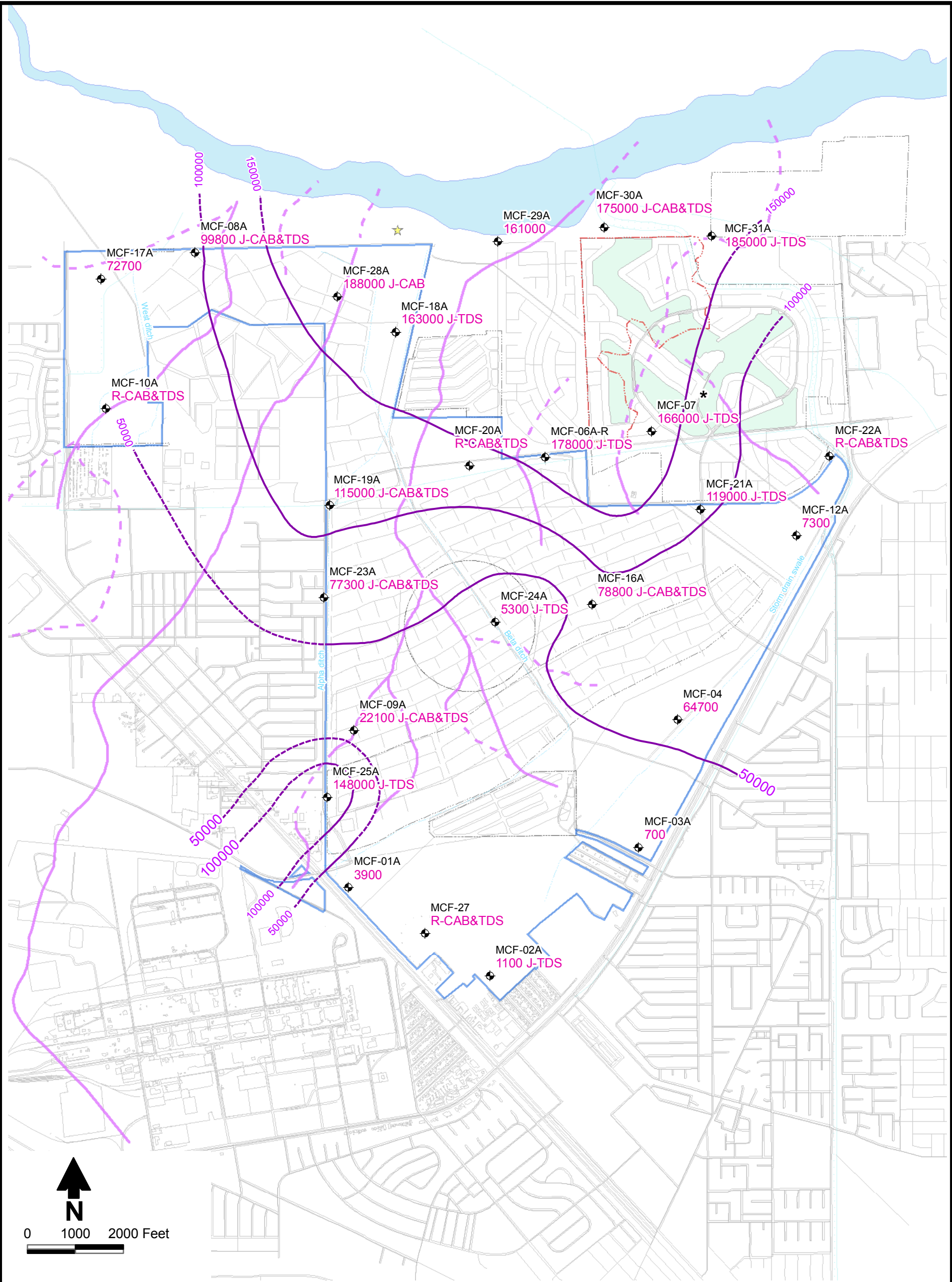
- Middle Zone Monitoring well
- Site boundary
- Gravel pit circa 1976. Source: aerial photograph dated 1976
- Las Vegas wash
- Streets
- Streets
- MCF-09B 3000 J-TDS Monitoring well designation Result (mg/L)

BMI Common Areas (Eastside) Henderson, Nevada	
FIGURE D-17 Total Dissolved Solids (TDS) - Middle Zone	
Prepared by: DBS&A CRS	Date 12-16-09
S:/PROJECTS/BRC/ES09.0281_BRC_VH_AND_PRE-CSM_TASKS/ GIS/MXDS/CHEMISTRY/ TDS_2009_MIDDLE.MXD 906121	



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Notes:  
1. USEPA MCL = 500 mg/L  
2. \* - Data rejected due to potential field sampling error – result pending final determination.

BMI Common Areas (Eastside) Henderson, Nevada		
FIGURE D-18 Total Dissolved Solids (TDS) - Deep Zone		
Prepared by: DBS&A	CRS	Date 12-28-09
S:\PROJECTS\BRC\ES09.0281_BRC_WH_AND_PRE-CSM_TASKS\GIS\MXDS\CHEMISTRY\TDS_DEEP.MXD 905011		

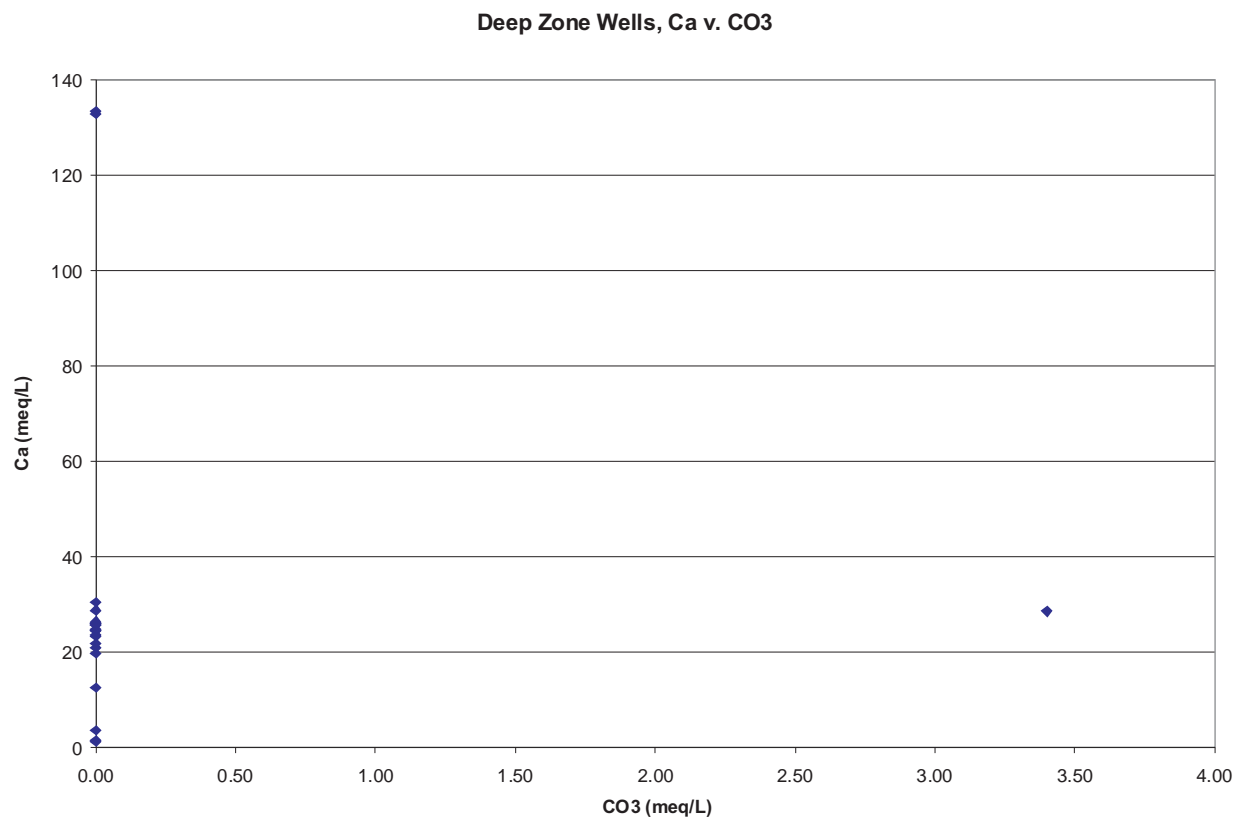
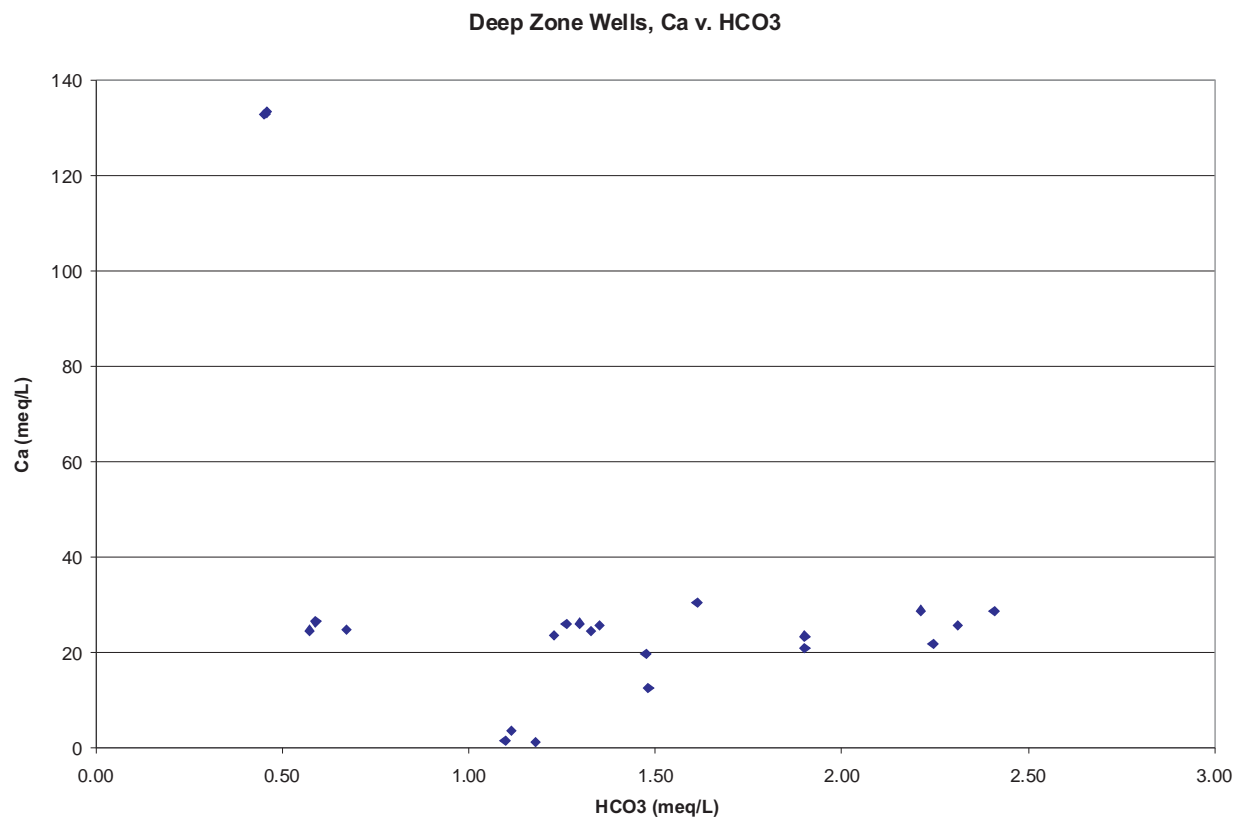




## **Appendix E**

### **Cation/Anion Plots**






**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-1  
Cation/Anion Plots

  
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COMPANY**

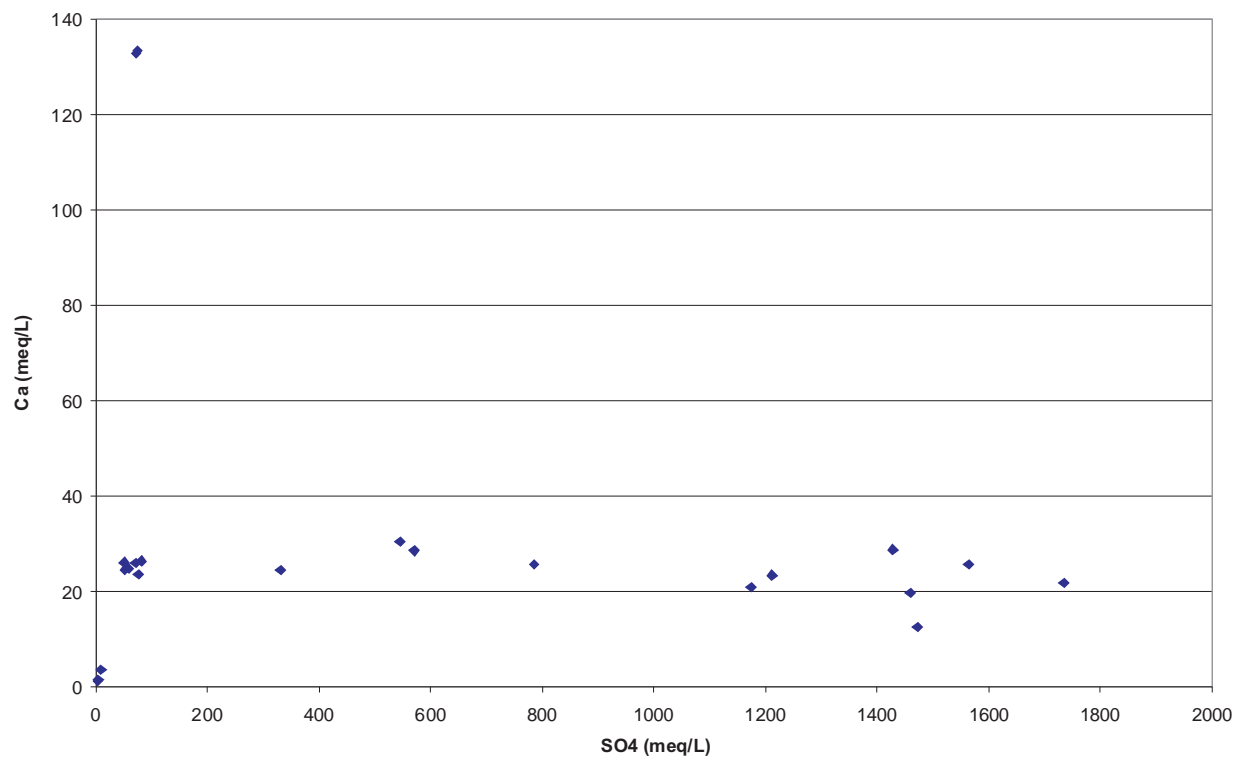
Prepared by:  
 **DBS&A** CRS

Date  
04-08-10

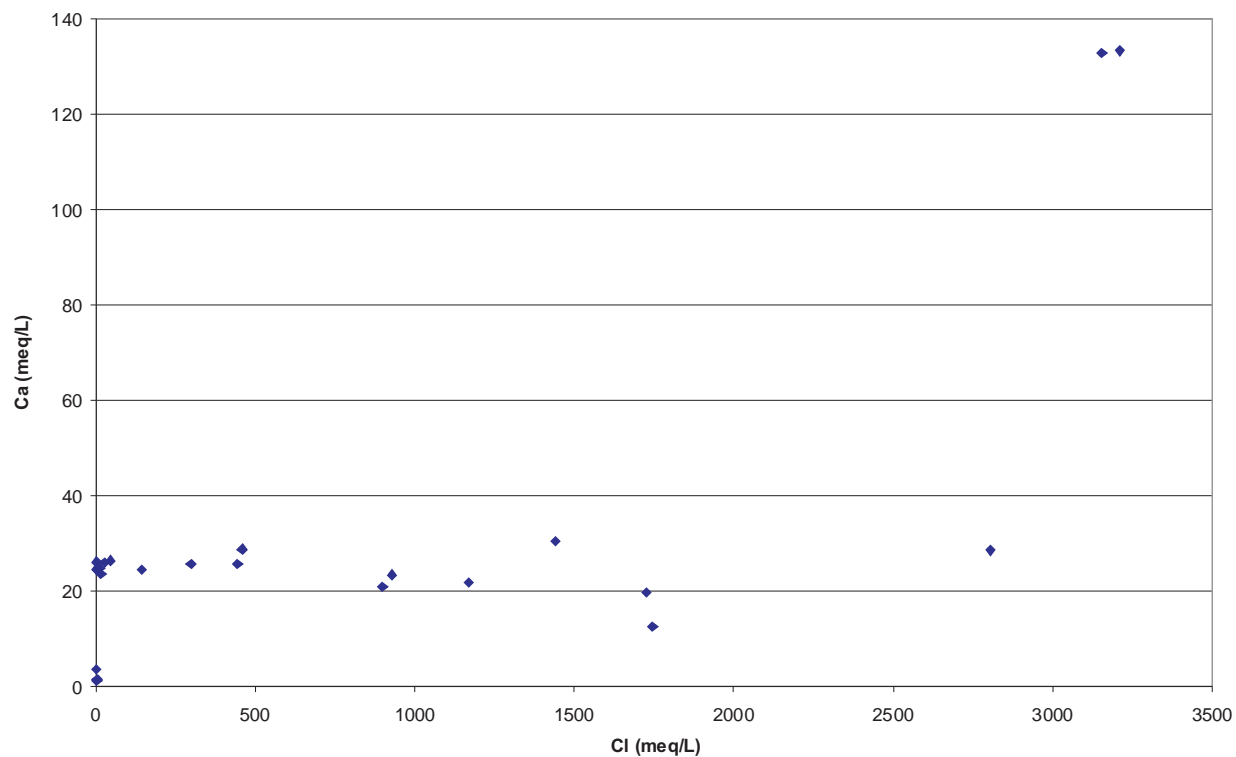
S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
VDR\_DRAWINGS/FIG2\_solubility\_plots.CDR



Deep Zone Wells, Ca v. SO4



Deep Zone Wells, Ca v. Cl




**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-2  
Cation/Anion Plots

  
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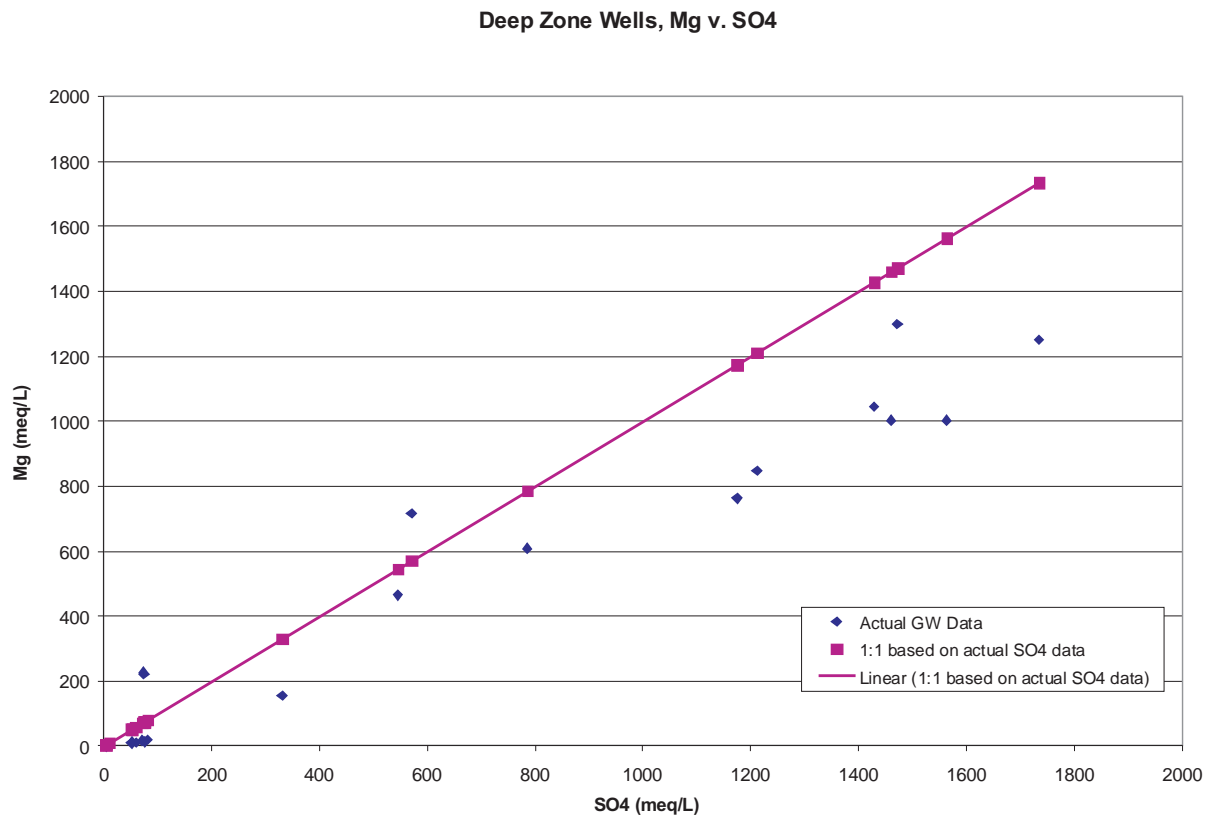
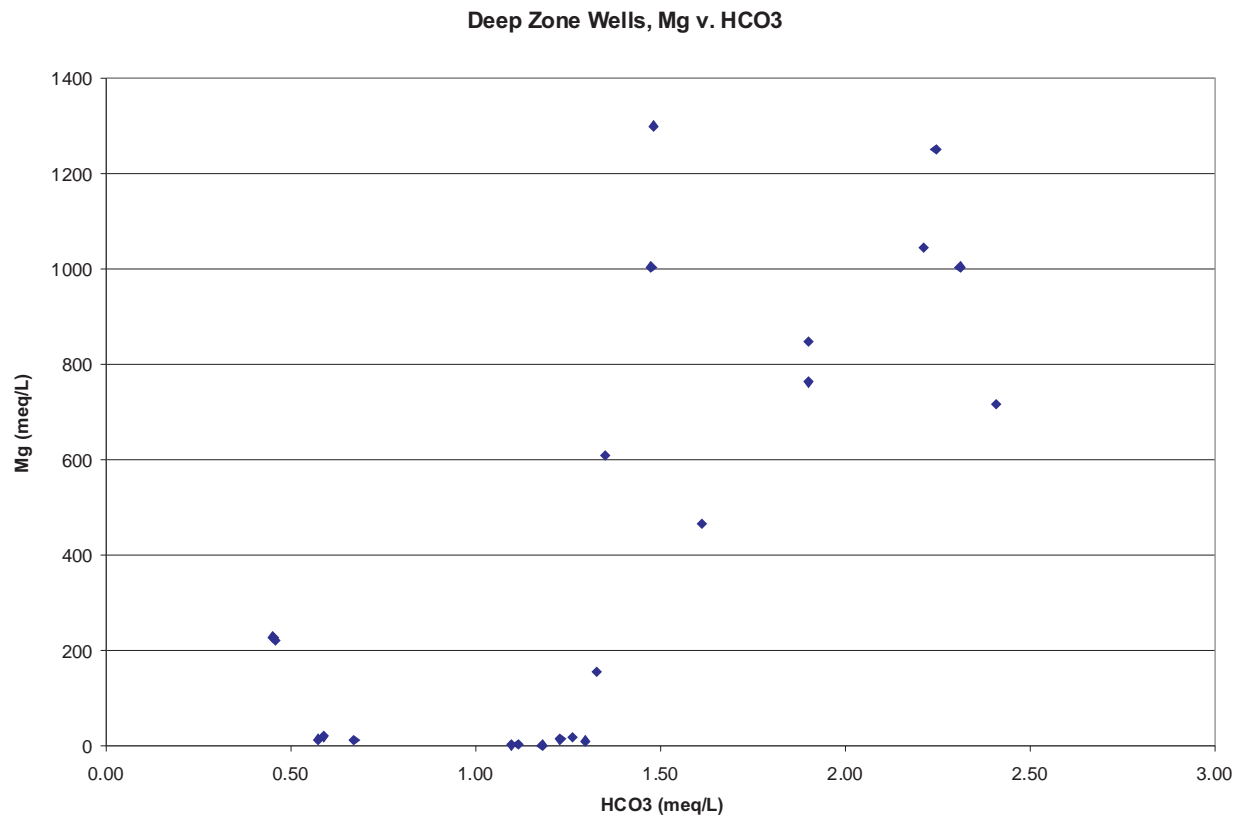
  
Basic Remediation  
COMPANY

Prepared by:  
 DBS&A CRS

Date  
04-08-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
VDR\_DRAWINGS/FIG2\_solubility\_plots.CDR






**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-3  
Cation/Anion Plots

  
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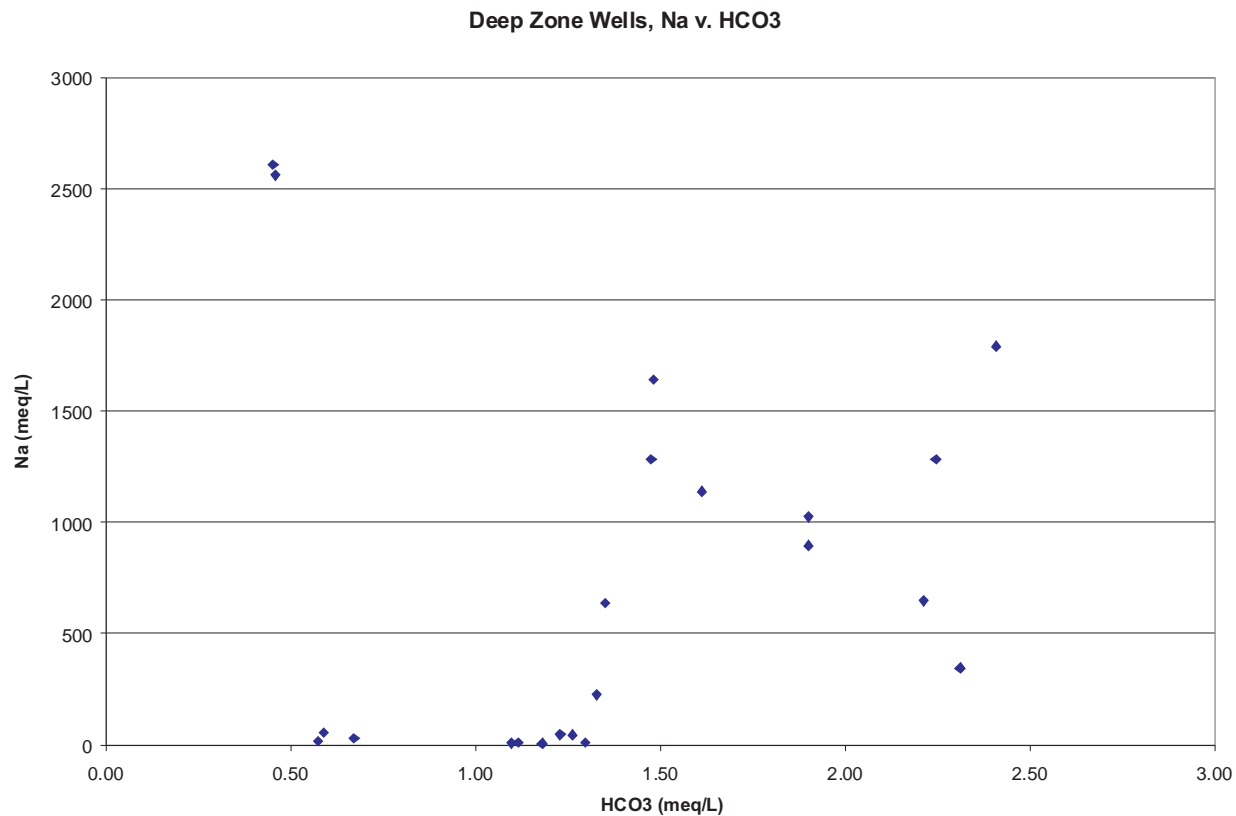
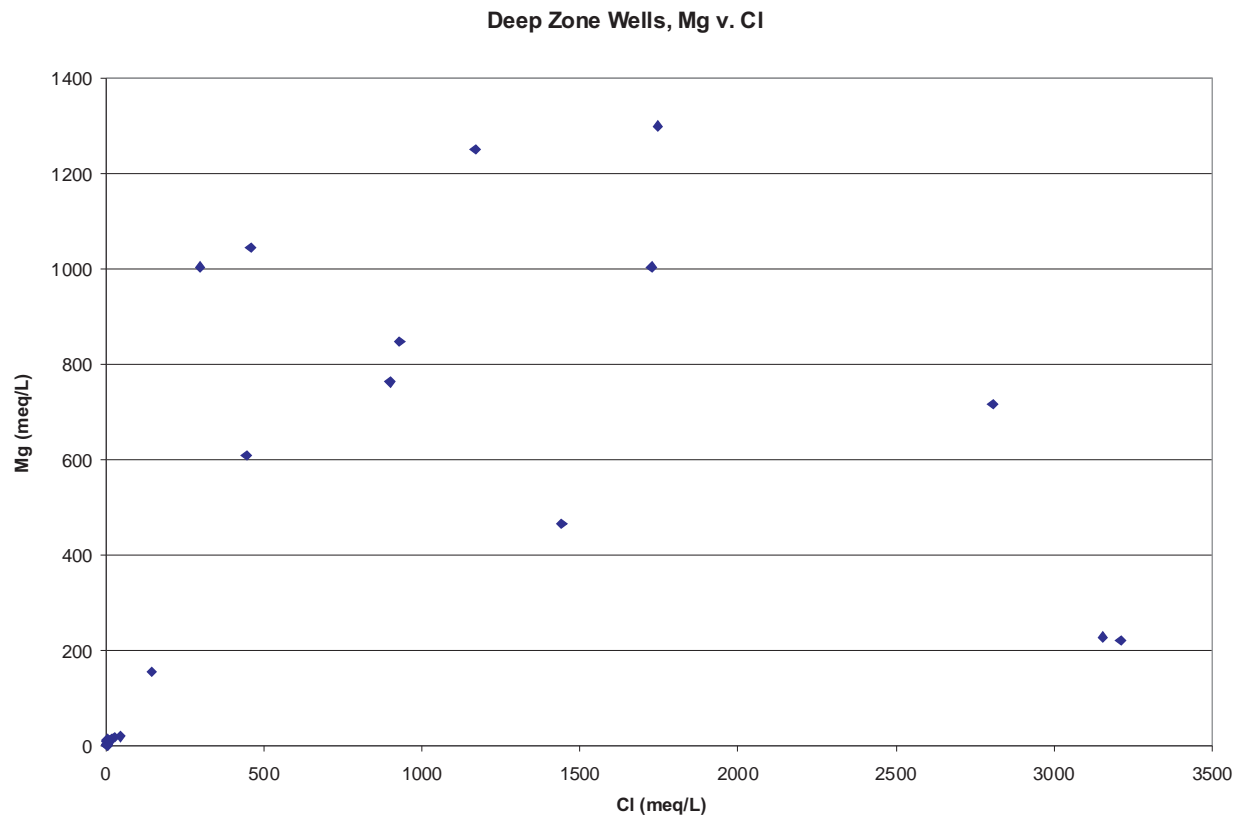
  
**Basic Remediation  
COMPANY**

Prepared by:  
 **DBS&A**    CRS

Date  
04-08-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
VDR\_DRAWINGS/FIGZ\_solubility\_plots.CDR






**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-4  
Cation/Anion Plots

  
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Prepared by:  
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04-08-10

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VDR\_DRAWINGS/FIGZ\_solubility\_plots.CDR



A scatter plot showing the relationship between Sulfate (SO4) concentration in meq/L on the x-axis and Sodium (Na) concentration in meq/L on the y-axis. The x-axis ranges from 0 to 2000 with major ticks every 200 units. The y-axis ranges from 0 to 3000 with major ticks every 500 units. There are 15 data points plotted as blue diamonds. The points are widely scattered, indicating a weak or no linear correlation between the two variables. Most points are clustered at lower concentrations, with a few outliers at higher SO4 values.

SO4 (meq/L)	Na (meq/L)
10	10
40	20
50	30
60	40
70	50
80	60
90	70
100	80
110	90
120	100
130	110
140	120
150	130
160	140
170	150
180	160
190	170
200	180
210	190
220	200
230	210
240	220
250	230
260	240
270	250
280	260
290	270
300	280
310	290
320	300
330	310
340	320
350	330
360	340
370	350
380	360
390	370
400	380
410	390
420	400
430	410
440	420
450	430
460	440
470	450
480	460
490	470
500	480
510	490
520	500
530	510
540	520
550	530
560	540
570	550
580	560
590	570
600	580
610	590
620	600
630	610
640	620
650	630
660	640
670	650
680	660
690	670
700	680
710	690
720	700
730	710
740	720
750	730
760	740
770	750
780	760
790	770
800	780
810	790
820	800
830	810
840	820
850	830
860	840
870	850
880	860
890	870
900	880
910	890
920	900
930	910
940	920
950	930
960	940
970	950
980	960
990	970
1000	980
1010	990
1020	1000
1030	1010
1040	1020
1050	1030
1060	1040
1070	1050
1080	1060
1090	1070
1100	1080
1110	1090
1120	1100
1130	1110
1140	1120
1150	1130
1160	1140
1170	1150
1180	1160
1190	1170
1200	1180
1210	1190
1220	1200
1230	1210
1240	1220
1250	1230
1260	1240
1270	1250
1280	1260
1290	1270
1300	1280
1310	1290
1320	1300
1330	1310
1340	1320
1350	1330
1360	1340
1370	1350
1380	1360
1390	1370
1400	1380
1410	1390
1420	1400
1430	1410
1440	1420
1450	1430
1460	1440
1470	1450
1480	1460
1490	1470
1500	1480
1510	1490
1520	1500
1530	1510
1540	1520
1550	1530
1560	1540
1570	1550
1580	1560
1590	1570
1600	1580
1610	1590
1620	1600
1630	1610
1640	1620
1650	1630
1660	1640
1670	1650
1680	1660
1690	1670
1700	1680
1710	1690
1720	1700
1730	1710
1740	1720
1750	1730
1760	1740
1770	1750
1780	1760
1	

This scatter plot displays the relationship between Chloride (Cl) and Sodium (Na) concentrations in groundwater. The x-axis represents Cl (meq/L) and the y-axis represents Na (meq/L), both ranging from 0 to 3500. The plot includes three data series: Actual GW Data (blue diamonds), a 1:1 line based on SO4 data (magenta squares), and a linear regression line based on SO4 data (magenta line). The data points generally follow the 1:1 line, indicating a strong positive correlation between Cl and Na concentrations.

Cl (meq/L)	Na (meq/L)	Data Type
0	0	Actual GW Data
0	0	1:1 line based on SO4 data
100	100	Actual GW Data
100	100	1:1 line based on SO4 data
200	200	Actual GW Data
200	200	1:1 line based on SO4 data
300	300	Actual GW Data
300	300	1:1 line based on SO4 data
400	400	Actual GW Data
400	400	1:1 line based on SO4 data
500	500	Actual GW Data
500	500	1:1 line based on SO4 data
900	900	Actual GW Data
900	900	1:1 line based on SO4 data
1000	1000	Actual GW Data
1000	1000	1:1 line based on SO4 data
1200	1200	Actual GW Data
1200	1200	1:1 line based on SO4 data
1500	1500	Actual GW Data
1500	1500	1:1 line based on SO4 data
1700	1700	Actual GW Data
1700	1700	1:1 line based on SO4 data
2800	2800	Actual GW Data
2800	2800	1:1 line based on SO4 data
3200	3200	Actual GW Data
3200	3200	1:1 line based on SO4 data

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-5  
Cation/Anion Plots

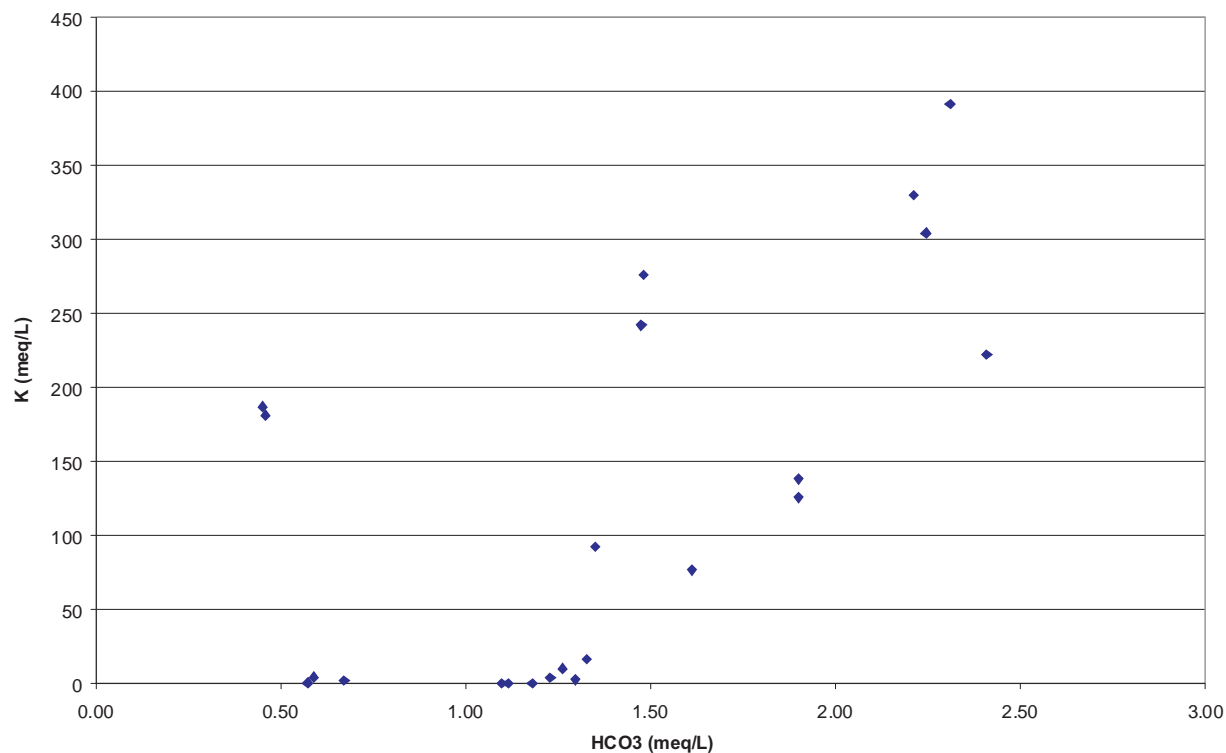


**Basic Remediation**  
COMPANY

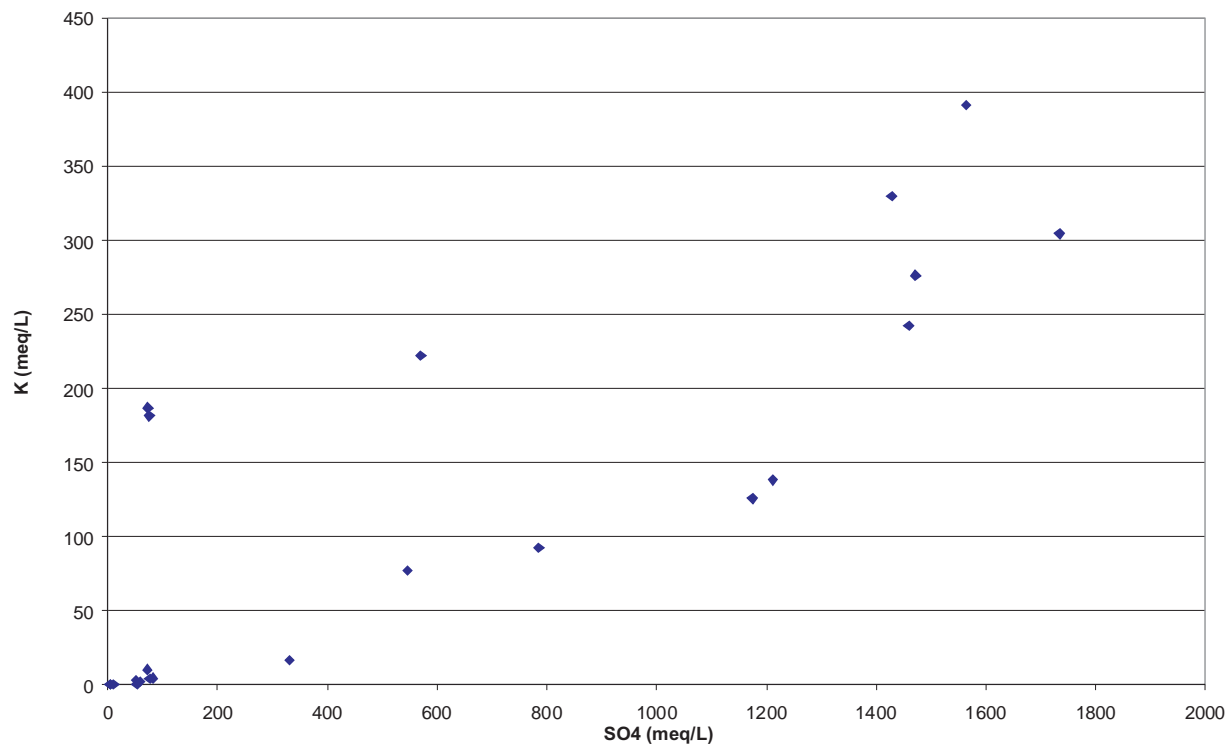
S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
VDR\_DRAWINGS\FIGZ\_solubility\_plots.CDR



Deep Zone Wells, K v. HCO<sub>3</sub>



Deep Zone Wells, K v. SO<sub>4</sub>



**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE E-6  
Cation/Anion Plots



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COMPANY

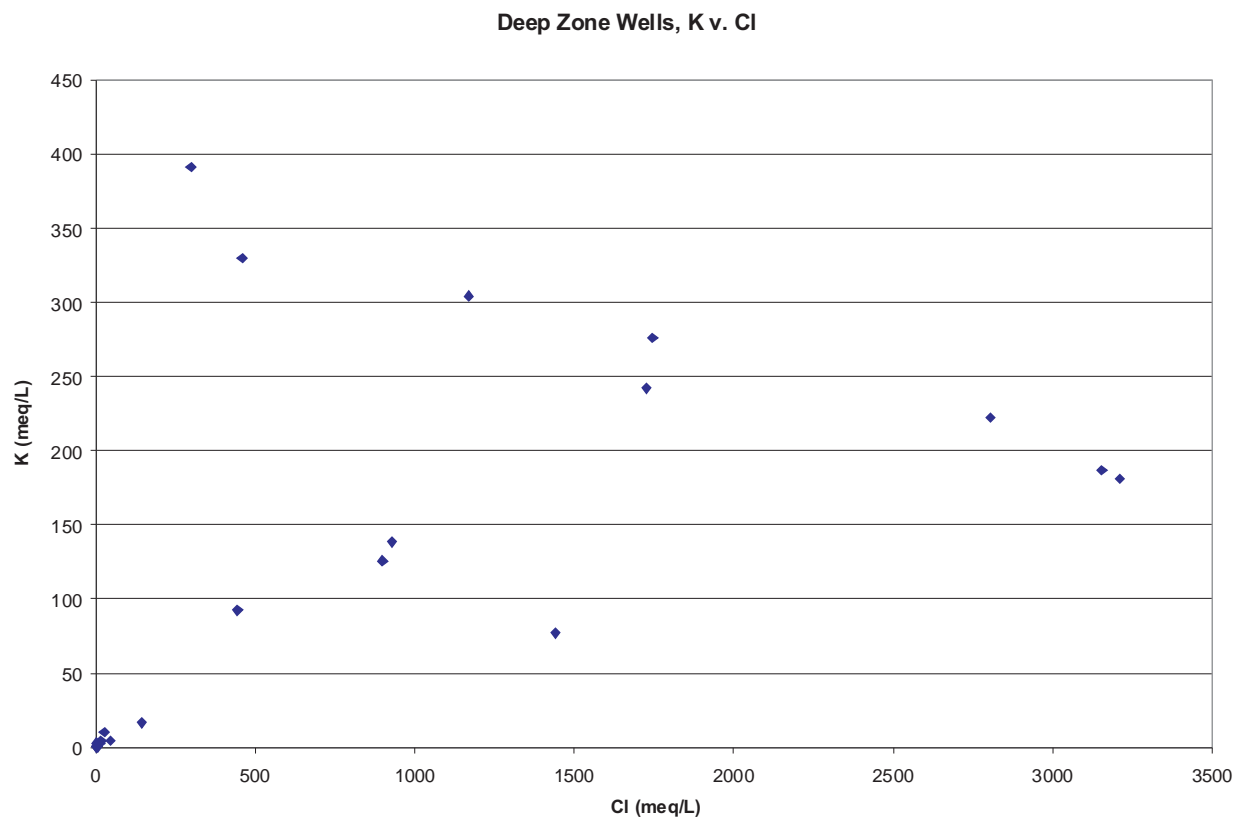


Prepared by:  
DBS&A CRS

Date  
04-08-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
VDR\_DRAWINGS/FIGZ\_solubility\_plots.CDR





**Note:** Data from groundwater samples collected August to October, 2009 in the Deep Zone

BMI Common Areas (Eastside)  
Henderson, Nevada

**FIGURE E-7**  
**Cation/Anion Plot**



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**Basic Remediation**  
C O M P A N Y



Prepared by:  
**DBS&A** CRS

Date  
04-08-10

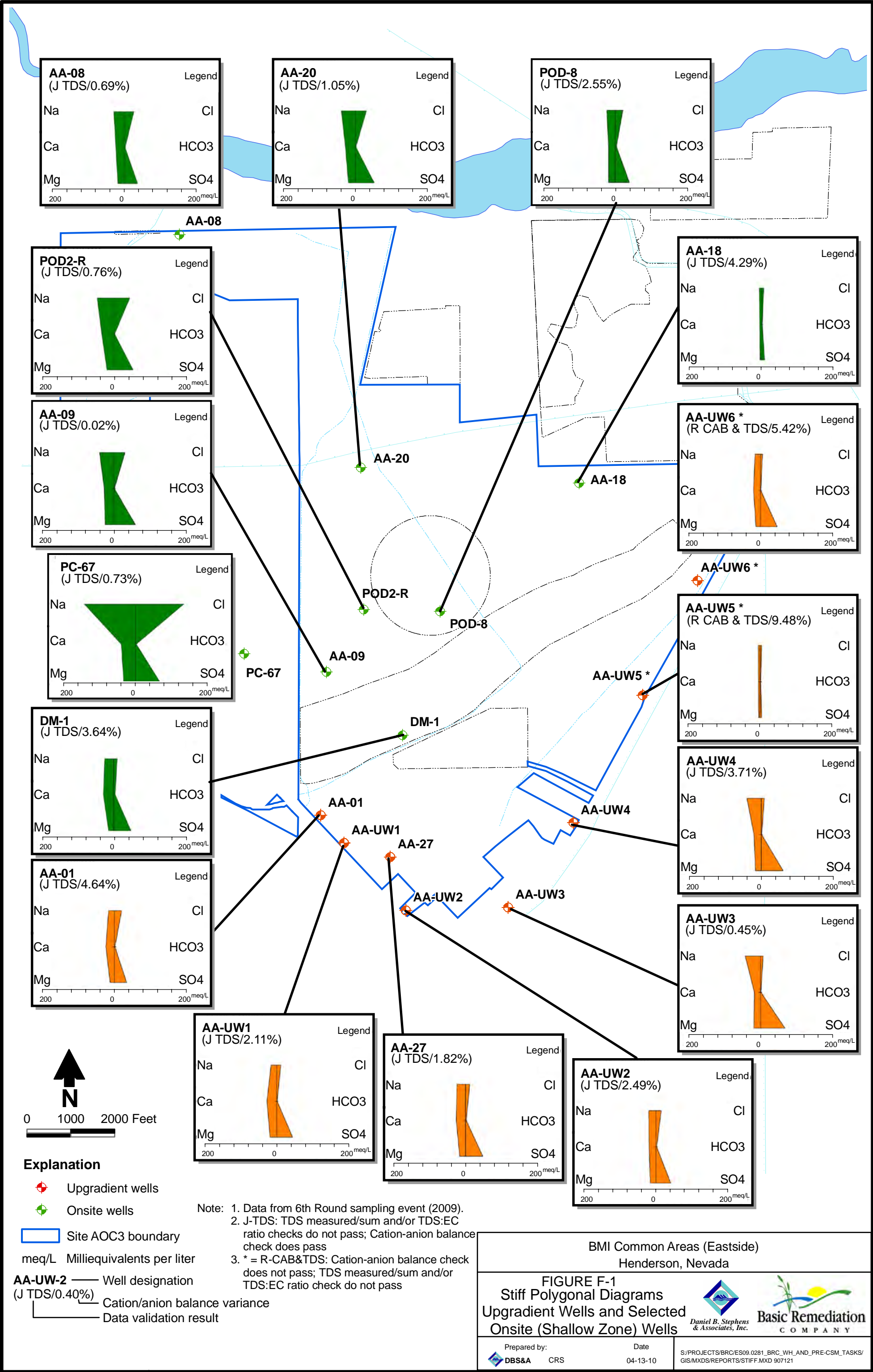
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VDR\_DRAWINGS/FIGZ\_solubility\_plots.CDR



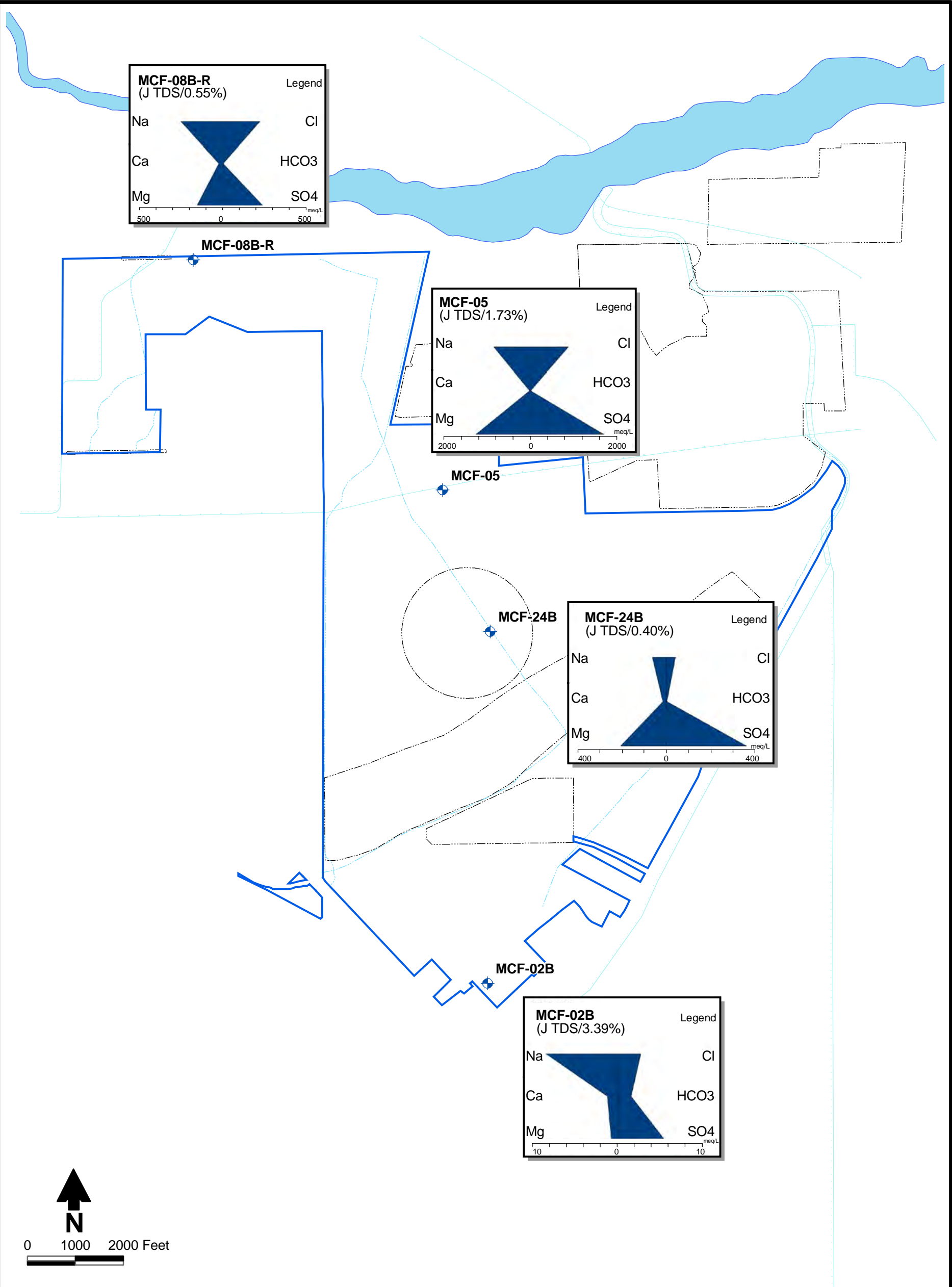
## **Appendix F**

### **Stiff Diagrams (Shallow/Middle/Deep Zone)**









**Explanation**

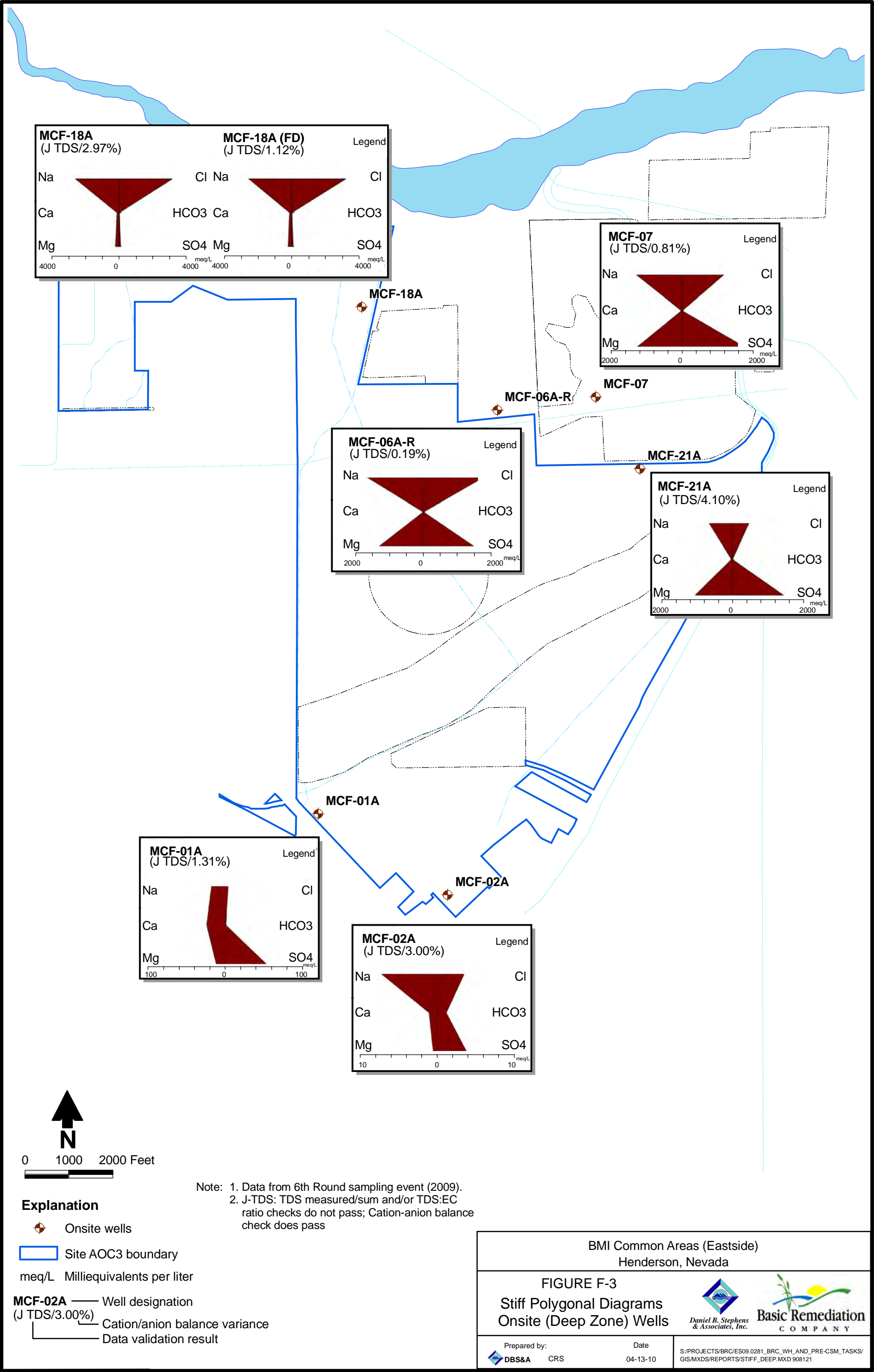
- Onsite wells
- Site AOC3 boundary
- meq/L Milliequivalents per liter

**MCF-02B** — Well designation  
(J TDS/3.39%) — Cation/anion balance variance  
— Data validation result

Note: 1. Data from 6th Round sampling event (2009).  
2. J-TDS: TDS measured/sum and/or TDS:EC ratio checks do not pass; Cation-anion balance check does pass

BMI Common Areas (Eastside) Henderson, Nevada		
FIGURE F-2 Stiff Polygonal Diagrams Onsite (Middle Zone) Wells		
Prepared by: DBS&A CRS	Date 04-13-10	 
S:/PROJECTS/BRC/ES09.0281_BRC_WH_AND_PRE-CSM_TASKS/GIS/MXDS/REPORTS/STIFF_MID.MXD 908121		







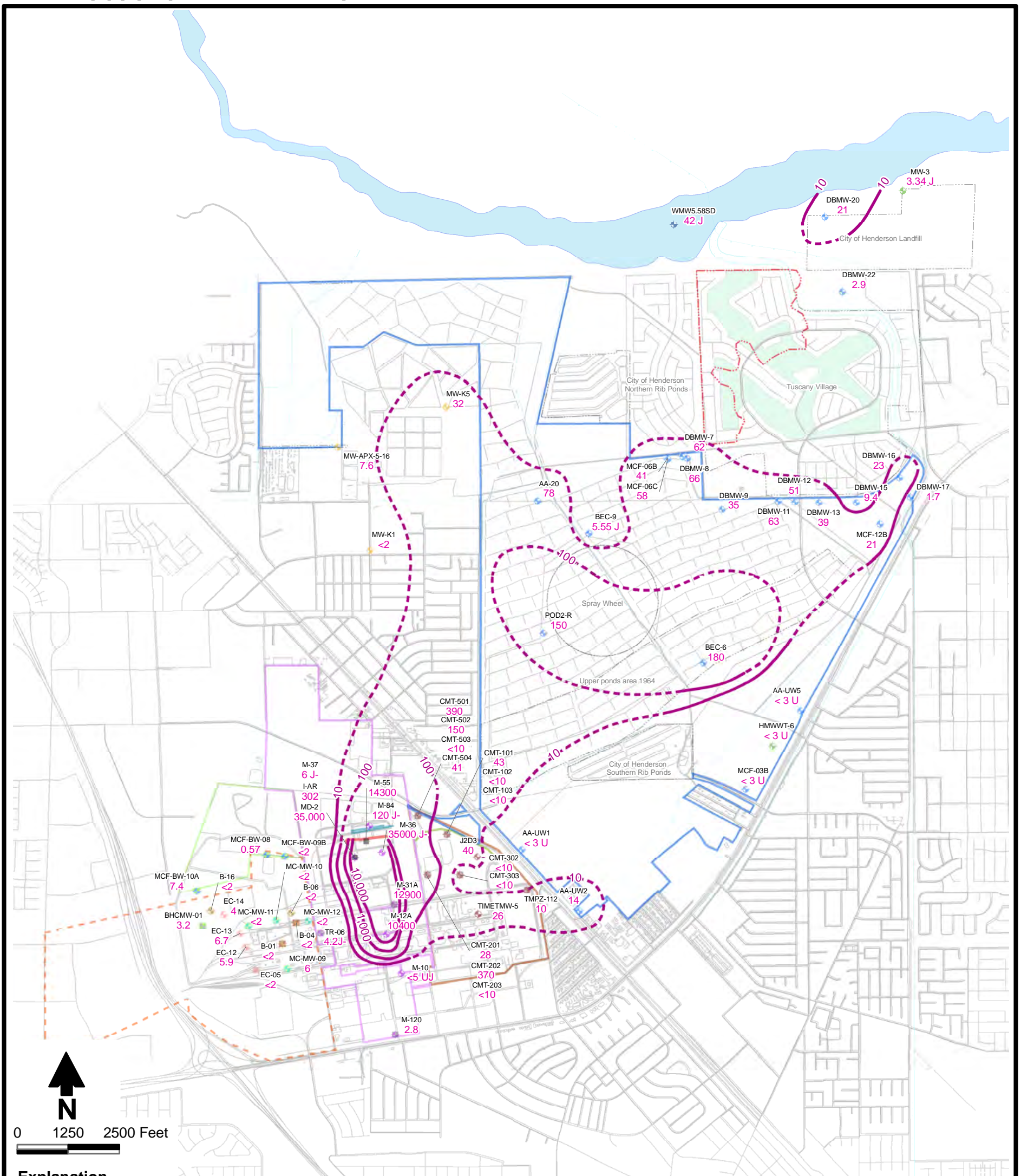
## **Appendix G**

### **Regional Isoconcentration Plots Total and Hexavalent Chromium**


















S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_LAYER1\_VER2.MXD 016040

















### Explanation

## Well Site - Date of Data

- |                                                                                                                       |                                                                                                     |
|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
|  Site not known - 2006             |  Olin - 2007     |
|  Site not known - 2007             |  Stauffer - 2007 |
|  Site not known - 2009             |  Stauffer - 2009 |
|  AMPAC - 2006                      |  TIMET - 2008    |
|  BRC - 2007                        |  TIMET - 2009    |
|  BRC - 2009                        |  Tronox - 2007   |
|  U.S. Bureau of Reclamation - 2009 |  Tronox - 2009   |
|  City of Henderson, Nevada - 2009  |                                                                                                     |
|  Montrose - 2006                   |                                                                                                     |
|  Montrose - 2007                   |                                                                                                     |

-  Site boundary
- Gravel pit circa 1976.
-  Source: Aerial photograph dated 1976
-  TIMET boundary
-  Tronox boundary
-  POSSM (The Companies)
-  Site AOC3 boundary
-  Las Vegas Wash


-  TIMET proposed slurry wall  
 Sept 2008  
 Tronox groundwater  
 recharge trench  
 Tronox slurry wall  
 Street  
 Concentration contour  
 (dashed where inferred)  
 M-120  
 2.8 Monitoring well designation  
 Result (ug/L)

Notes:  
1. No Cr(VI) data available for AMPAC

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE G-2  
Cr(VI) Layer 2  
Shallow Zone

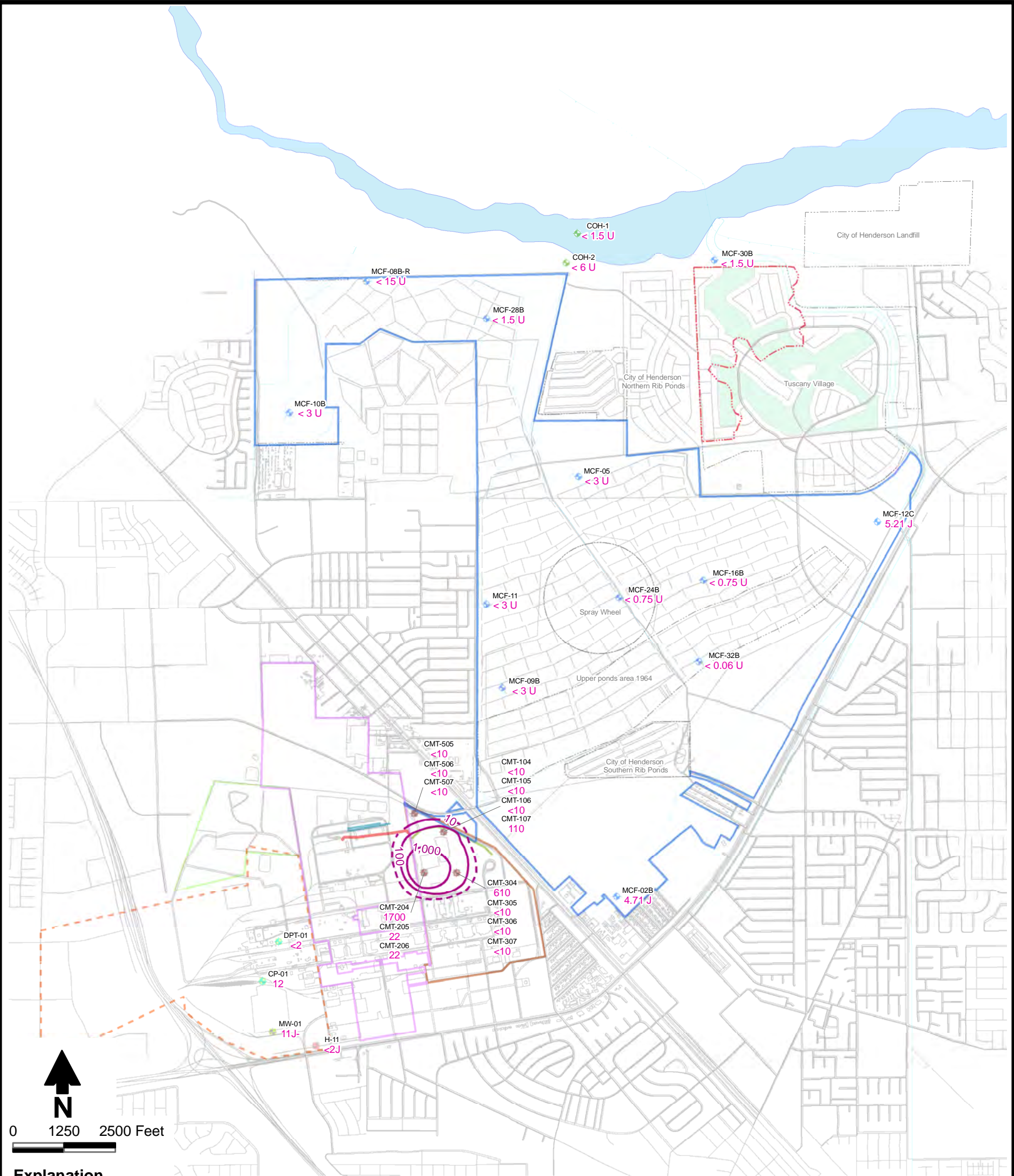


Prepared by:  
 **DBS&A**      CRS

Date  
04-16-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_LAYER2.MXD 016040





Explanation

Well Site - Date of Data

- Site not known - 2007
- BRC - 2009
- City of Henderson, Nevada - 2009
- Montrose - 2006
- Stauffer - 2007
- TIMET - 2008

- Site boundary
- Gravel pit circa 1976.
- Source: Aerial photograph dated 1976
- TIMET boundary
- Tronox boundary
- POSSM (The Companies)
- Site AOC3 boundary
- Las Vegas Wash

- TIMET proposed slurry wall Sept 2008
- Tronox groundwater recharge trench
- Tronox slurry wall
- Street
- Concentration contour (dashed where inferred)
- Monitoring well designation Result (ug/L)

Notes:

- No Cr(VI) data available for AMPAC

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE G-3  
Cr(VI)  
Middle Zone

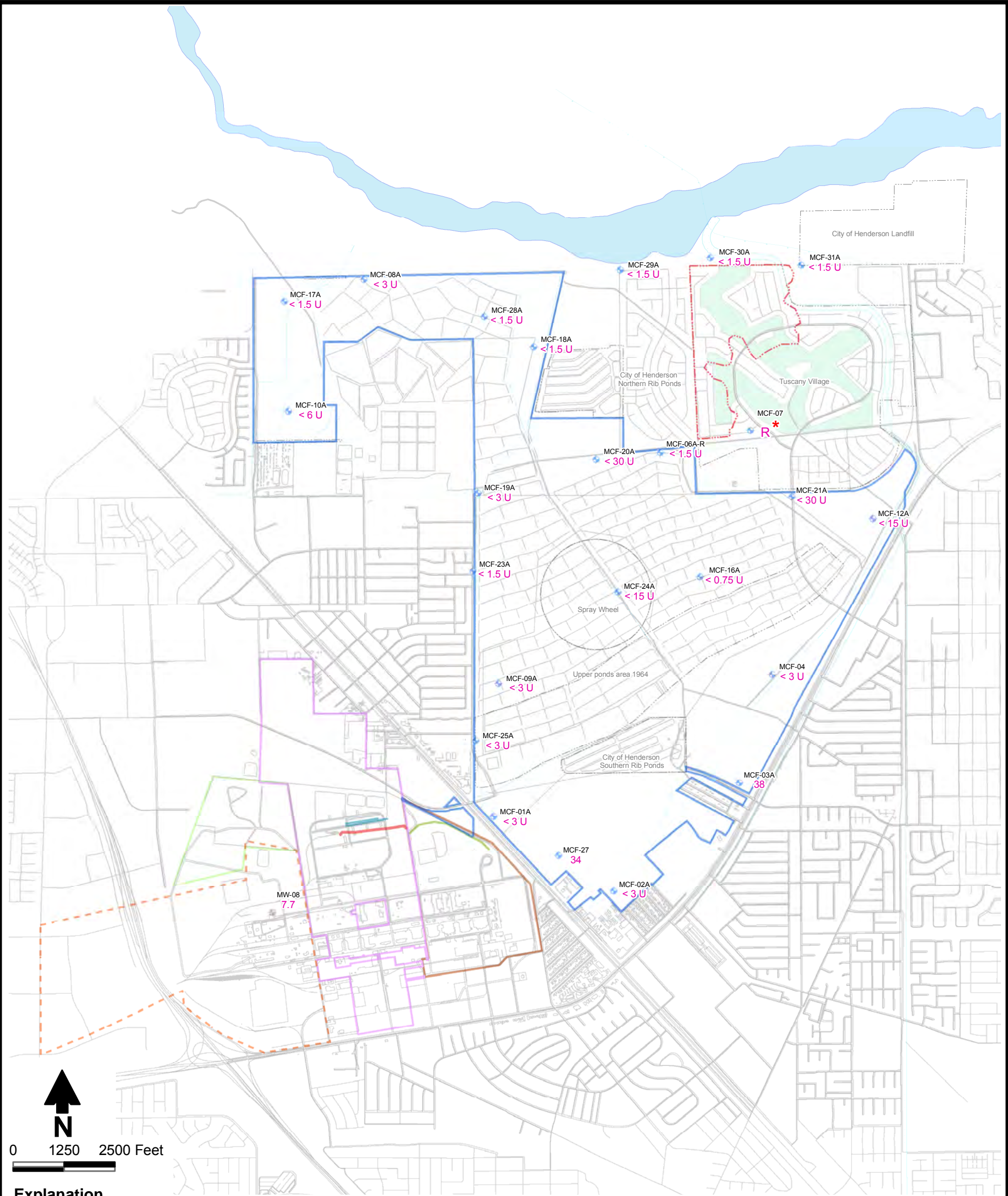


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DBS&A CRS

Date  
04-16-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_MIDDLE.MXD 016040





Explanation

Well Site - Date of Data

- Site not known - 2006
- BRC - 2009
- Site boundary
- Gravel pit circa 1976.
- Source: Aerial photograph dated 1976
- TIMET boundary
- Tronox boundary
- POSSM (The Companies)
- Site AOC3 boundary
- Las Vegas Wash

- TIMET proposed slurry wall Sept 2008
- Tronox groundwater recharge trench
- Tronox slurry wall
- Street
- Concentration contour (dashed where inferred)
- Monitoring well designation Result (ug/L)

Notes:

- No Cr(VI) data available for AMPAC
- \* - Data rejected due to potential field sampling error – result pending final determination.

BMI Common Areas (Eastside)  
Henderson, Nevada

FIGURE G-4  
Cr(VI)  
Deep Zone



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Date  
04-15-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_LAYER1\_VER2.MXD 016040



See note B

M-71 5100

I-V 21000

I-J 3200

CLD1-R 380

M-68 1100

CLD2-R 420

M-67 6500

M-61 1500

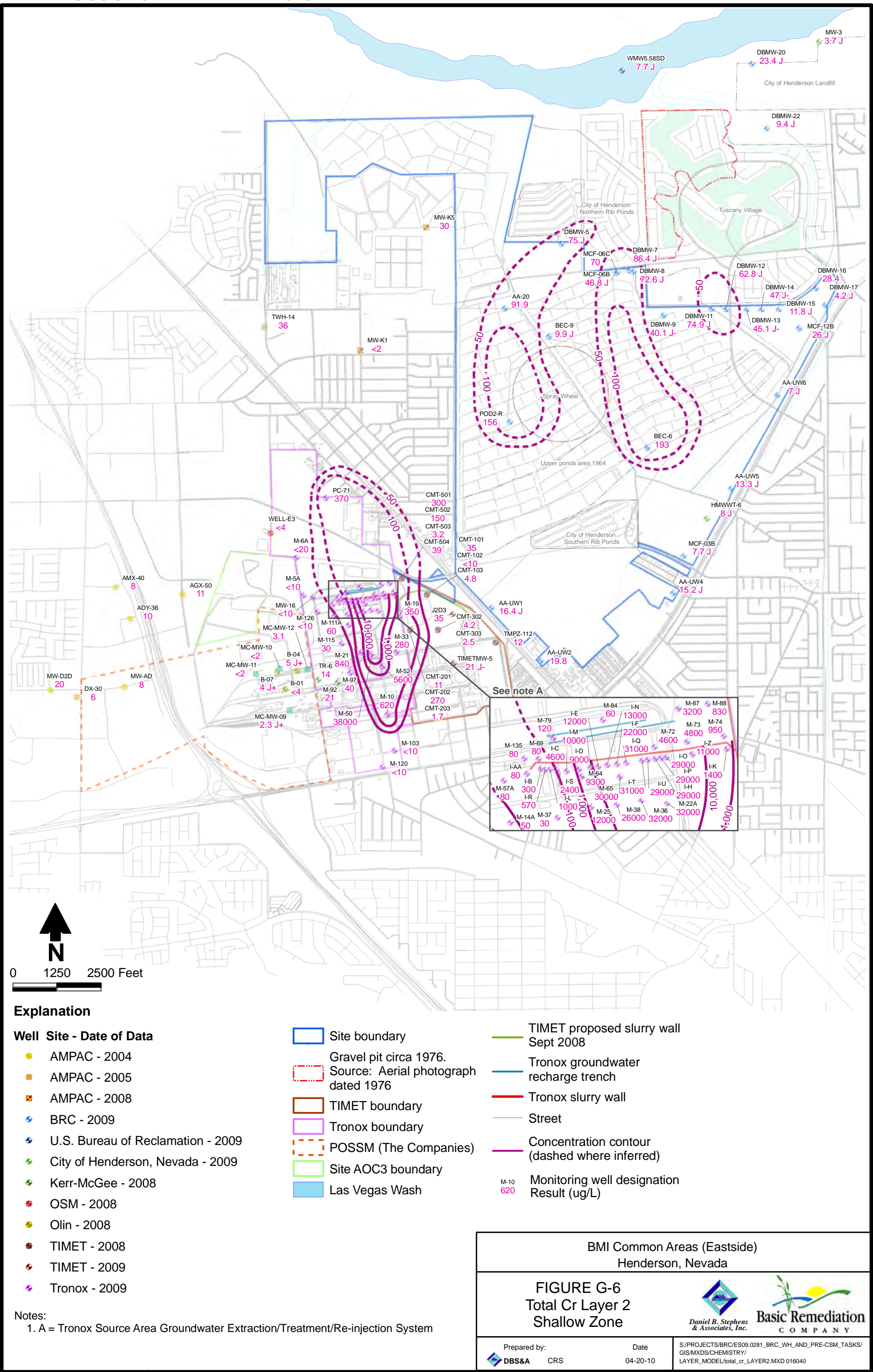
M-70 550

I-H 20000

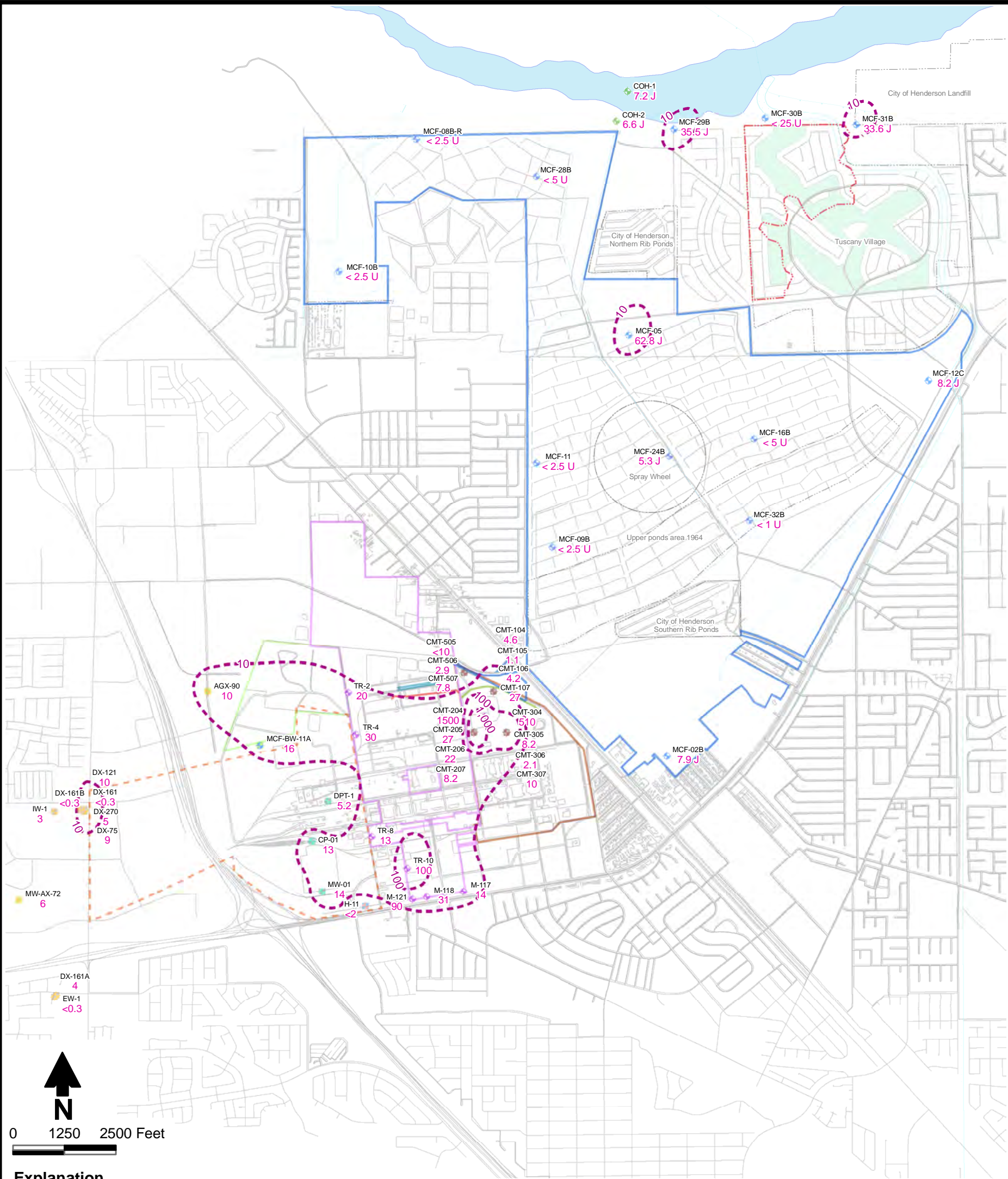
M-66 31000

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_LAYER1.MXD 016040









Explanation

Well Site - Date of Data

- AMPAC - 2004
- AMPAC - 2005
- BRC - 2008
- BRC - 2009
- City of Henderson, Nevada - 2009
- Kerr-McGee - 2008
- Montrose - 2008
- Stauffer - 2008
- TIMET - 2008
- Tronox - 2009

- Site boundary
- Gravel pit circa 1976. Source: Aerial photograph dated 1976
- TIMET boundary
- Tronox boundary
- POSSM (The Companies)
- Site AOC3 boundary
- Las Vegas Wash

- TIMET proposed slurry wall Sept 2008
- Tronox groundwater recharge trench
- Tronox slurry wall
- Street
- Concentration contour (dashed where inferred)
- Monitoring well designation Result (ug/L)

BMI Common Areas (Eastside)  
Henderson, Nevada

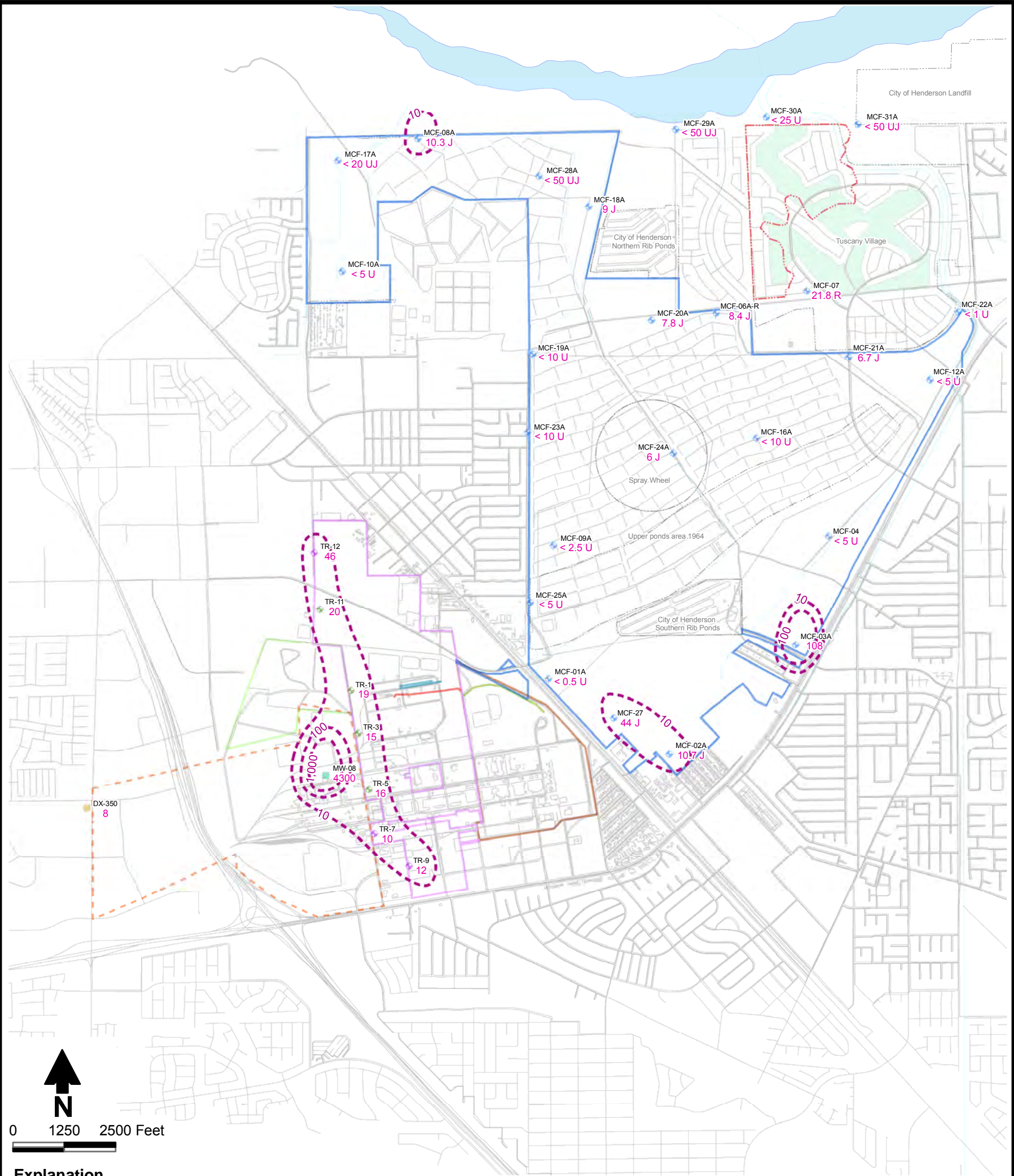
FIGURE G-7  
Total Cr  
Middle Zone



Prepared by: DBS&A CRS Date: 04-20-10

S:\PROJECTS\BRC\ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS\GIS\MXDS\CHEMISTRY\ LAYER\_MODEL\total\_cr\_middle.MXD 016040





**Explanation**

**Well Site - Date of Data**

- AMPAC - 2005
- BRC - 2009
- Kerr-McGee - 2008
- Montrose - 2008
- Tronox - 2009

- Site boundary
- Gravel pit circa 1976. Source: Aerial photograph dated 1976
- TIMET boundary
- Tronox boundary
- POSSM (The Companies)
- Site AOC3 boundary
- Las Vegas Wash

- TIMET proposed slurry wall Sept 2008
- Tronox groundwater recharge trench
- Tronox slurry wall
- Street
- Concentration contour (dashed where inferred)
- Monitoring well designation Result (ug/L)

**Notes:**

- \* - Data rejected due to potential field sampling error – result pending final determination.

BMI Common Areas (Eastside)  
Henderson, Nevada

**FIGURE G-8**  
**Total Cr**  
**Deep Zone**



Prepared by:  
DBS&A CRS

Date  
04-20-10

S:/PROJECTS/BRC/ES09.0281\_BRC\_WH\_AND\_PRE-CSM\_TASKS/  
GIS/MXDS/CHEMISTRY/  
LAYER\_MODEL/total\_cr\_LAYER1.MXD 016040