Technical Memorandum:
Sources/Sinks and Input Parameters for
Groundwater Flow Model
BMI Common Areas
Eastside Area

Submitted to:

March 4, 2008

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

Prepared for:

Basic Remediation COMPANY

Daniel B. Stephens & Associates, Inc.
260 Newport Center Drive • Newport Beach, California 92660

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.

March 4, 2008

Stephen J. Cullen, Ph.D., C.E.M. (No. 1839, Exp. 11/12/07)
Daniel B. Stephens & Associates, Inc.

March 4, 2008

Dr. Ranajit Sahu, C.E.M. (No. EM-1699, Exp. 10/07/2007)
BRC Project Manager

Individuals Who Provided Technical Input to this Document

March 4, 2008

John J. Dodge, P.G.
Daniel B. Stephens & Associates, Inc.

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1. Introduction and Objectives

This technical memorandum summarizes the water balance sources and sinks/input parameters for the numerical groundwater flow model currently being prepared for the Eastside Area of the Basic Management, Incorporated (BMI) Common Areas/Complex (the "Site") in Clark County, Nevada.

This scope of work for this technical memorandum has previously been approved by Basic Remediation Company (BRC) and Nevada Division of Environmental Protection (NDEP) as a part of the Groundwater Modeling Work Plan for BMI Upper and Lower Ponds Area (DBSA, 2006).

The scope of work consists of presenting the methodology and preliminary calculations, estimates, and information sources and references that were used to develop values for groundwater inflows (sources) and groundwater outflows (sinks) in three scenarios:

- Historical Scenario (c. 1968)
- Current Scenario
- Future Scenario

This technical memorandum presents the methodology used in parameter estimation and preliminary values for each input parameter. However, the source/sink estimates will continue to be refined during model development as additional information is obtained regarding offsite properties and Site conditions.

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2. Historical Scenario

2.1 Groundwater Inflows (Sources)

2.1.1 Lateral Groundwater Inflow - Historical Scenario

This parameter was calculated by using a 1972 groundwater flow map from Westphal and Nork (1972) depicting the shallow water-bearing zone at the Site (Attachment 1). The flow map was superimposed over the groundwater flow model domain and the domain perimeter (boundary) was divided into segments (L1, L2, etc.) based on flow direction. Groundwater flow intercepts each domain segment at the same angle. A line drawn perpendicular to the groundwater flow direction defines the maximum horizontal length of the water-bearing zone at each perimeter segment.

Groundwater elevation data from the 1972 map were compared to the elevation of the Tertiary Muddy Creek Formation (TMC) (Section 5) along the model domain perimeter. The comparison was made to estimate the vertical thickness of the water-bearing zone within the Quaternary alluvium (Qal) around the perimeter of the model domain. Water-bearing zone thickness and length were used to estimate the vertical, two-dimensional area that borders the model perimeter. Lateral groundwater inflow passes horizontally through this polygonal area into the model domain.

The 1972 groundwater flow map was also used to estimate the various historical hydraulic gradients (I) around the model domain. Groundwater flow (Q) into each vertical area along the domain perimeter was then calculated with Darcy's Law incorporating estimates for I, area (A), and estimated horizontal hydraulic conductivity (K_h). Maximum and minimum K_h values were obtained from the 2007 Site aquifer testing program (Kleinfelder, 2007). Thus, lateral flow was estimated by:

$$Q \text{ (cubic feet per day [ft}^3\text{/d])} = K_h \text{ (ft/d)} \times I \text{ (ft/ft)} \times \text{area (ft}^2\text{)}$$

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The values used in each calculation and the resulting Q values are shown in Table 1. A similar calculation will be prepared for lateral flow in the water-bearing zone within TMC along the model domain perimeter.

2.1.2 Ditch Seepage - Historical Scenario

Seepage (S, ft3/d) from the alpha ditch, the beta ditch, the western ditch, and the northwestern ditch were estimated based on length and width of each ditch and estimated infiltration capacity (saturated vertical hydraulic conductivity, K_V):

$$S\ (ft^3/d) = \text{length (ft)} \times \text{width (ft)} \times K_V\ (ft/d)$$

Ditch length and width estimates were obtained from a 1968 aerial photograph of the Site area (Attachment 2, 3). Values for minimum and maximum K_V were obtained from core data reported in the 2007 aquifer testing report (Kleinfelder, 2007). The resultant seepage values are presented in Table 2.

For reference, Westphal and Nork (1972) estimated ditch and pond seepage at 1 cubic foot per second (cfs) at the Site.

2.1.3 Wastewater/Effluent Pond Seepage (Upper and Lower Ponds) - Historical Scenario

As discussed in the groundwater modeling work plan (DBSA, 2006), historical seepage rates for the wastewater ponds were obtained from the modeling report prepared by Westphal and Nork (1972) (Table 2).

A rate of 0.019 feet per hour (ft/hr) was empirically estimated for one of the lower ponds from a 26-hour weir infiltration experiment conducted in 1971 (Westphal and Nork 1972). This value was extrapolated by Westphal and Nork (1972) across the entire 12.5-acre lower ponds area to derive a value of 2.85 cfs for total lower ponds infiltration.

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For comparison and verification, this value was later re-estimated by Westphal and Nork (1972) at 2.15 cfs using 5 months of lower pond in-flow data. A final value of 2.25 cfs was assigned by Westphal and Nork (1972) to the lower ponds area

For the 48-acre upper ponds area, the infiltration rate that will be used was calculated by Westphal and Nork (1972) at 11.20 cfs (Table 2).

2.1.4 Seepage from Stormwater Swale - Historical Scenario

The stormwater swale runs along the southern Site boundary, heads northeast parallel to Lake Mead Parkway, then turns northwest towards the Las Vegas Wash. Seepage from the swale was estimated based on the length and width of the swale and an estimate of infiltration capacity (saturated K_V). Swale length and width estimates were obtained from a 1968 aerial photograph of the Site area. Values for minimum and maximum K_V were obtained from the 2007 aquifer testing report (Kleinfelder, 2007). Swale seepage values are listed in Table 2.

In the 1968 aerial photograph, the swale widens, appears to shallow, and distributes its flow over a broad fan area over approximately the last 5,500 feet of its length. From the 1968 aerial photograph, the fan area is estimated to be approximately 600 feet wide. The fan thus covers approximately 33 acres. This fan discharge and seepage will be accounted for, as appropriate, during numerical model domain preparation.

2.1.5 Las Vegas Wash Seepage to Alluvium - Historical Scenario

Seepage from the Las Vegas Wash to alluvium was estimated based on the length and width of the wash channel and an estimate of infiltration capacity (saturated K_h) (similar to a seepage calculation for a ditch)

An estimated channel width of approximately 50 feet was estimated from the 1968 aerial photograph. The channel length along the model domain is approximately 14,200 feet. Values for maximum and minimum K_h were obtained from the 2007 aquifer testing report (Kleinfelder,

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2007) (slug and pumping test results from wells in the Qal and the TMC were averaged). The resultant seepage value are listed in Table 2.

Alternatively, wash seepage could be calculated using head differential between the wash surface water and groundwater. This alternative method will be evaluated during model development. Values from McGinley & Associates (2003) will also be considered and compared to calculated values.

2.1.6 Recharge From Precipitation/Storm Flow - Historical Scenario

Precipitation values for the Las Vegas Area were obtained from the Western Regional Climate Center-Desert Research Institute (WRCDC, 2008). Precipitation in this area averages approximately 0.4 inches per month or 4.8 inches per year (WRCDC, 2008).

Recharge from precipitation is typically a small percentage of annual precipitation in arid settings. Recharge as a percentage of annual precipitation is estimated for the Site area between 0.1% and 5% based on values from Scanlon et al (2006) (Attachment 4). Recharge is thus estimated to be between 0.0048 inches and 0.24 inches per year.

For reference only, pan evaporation rates for the Boulder City area (10 miles southeast of the Site) were measured at 116 inches per year between 1931 and 2004 (WRCDC, 2008).

In Site areas where ponds were constructed that resulted in impounding of water, estimates of average storm frequencies will be used during modeling to further estimate the volume of water impounded by the constructed ponds. The volume estimate will be used to evaluate potentially significant additional recharge from the ponds.

2.1.7 Inflow From Tertiary Muddy Creek Formation - Historical Scenario

Deep monitoring wells were not present at the Site in the historical scenario so this parameter can not be calculated from Site data. Westphal and Nork (1972) assumed flow was negligible from low yield sediments (i.e. TMC). Shallow/deep well pairs are now present at the Site and inflow from the lower TMC can be calculated for the Current Scenario (Section 3.1).

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The calculated value for TMC inflow in the Current Scenario was utilized for the Historical Scenario (Table 3) but a larger Site area of downward vertical flow was utilized in the Historical Scenario calculations. A larger Site area was assumed because the BMI effluent disposal ponds were operating during the Historical Scenario.

Because the BMI ponds were operating during the Historical Scenario, groundwater mounding in the alluvium may have caused some variation in the direction of vertical groundwater flow between the TMC and the alluvium.

The current groundwater elevation data indicate that three well pairs have a downward vertical head gradient (Table 3). Based on the location and distribution of these well pairs within the central portion of the model domain, downward flow is roughly estimated to be present at approximately 25% of the model domain area in the Current Scenario (Section 3.1) (the ponds are no longer operating). Inflow in the Current Scenario is thus assumed to occur over the remaining 75% of the model domain area. These values were used to approximate inflow from the TMC in the Historical Scenario. A range of values for areas of upflow (and downflow) will be considered during numerical model development.

Because the ponds were operating in the Historical Scenario, downward vertical flow from the Qal to the TMC is thus assumed to have occurred over a somewhat larger area in the Historical Scenario. In the absence of quantitative data to utilize for this estimate, the area of downward flow in the Historical Scenario is currently roughly estimated at approximately 40% of the model domain (Table 3). Inflow in the Historical Scenario is thus assumed to occur over the remaining 60% of the model domain area.

A smaller area of upward vertical flow was used with the remaining input parameters for the Current Scenario to estimate inflow from the TMC in the Historical Scenario. A range of areas of upward flow will be utilized during modeling.

The calculations estimate that upward vertical flow (inflow) from TMC in the Historical Scenario was less than inflow from the TMC in the Current Scenario (Table 3).

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2.2 Groundwater Outflows (Sinks)

2.2.1 Lateral Groundwater Outflow - Historical Scenario

This parameter was calculated for the Qal in the same manner as lateral groundwater inflow (Section 2.1) using the 1972 groundwater flow map from Westphal and Nork (1972) that depicts the shallow water-bearing zone at the Site. The flow map was superimposed over the groundwater flow model domain and the northern domain boundary near the Las Vegas Wash was divided into two segments (east and west). Outflow was estimated as shallow Qal groundwater flow towards Las Vegas Wash along the northern model domain boundary (Table 1). A similar calculation will be prepared for lateral flow in the water-bearing zone within TMC along the model domain perimeter.

2.2.2 Outflow to Tertiary Muddy Creek Formation - Historical Scenario

An estimate for this parameter can be obtained in the same manner as inflow from the TMC (comparing shallow with deep groundwater elevations from adjacent shallow/deep monitoring well pairs). However, because deep monitoring wells were not present at the Site in the Historical Scenario, this parameter can not be directly calculated. The input parameters for TMC outflow in the current scenario was utilized for the Historical Scenario calculations, however, downward flow was assumed to occur over a larger area in the past due to pond operation. Downward vertical outflow to the TMC in the Historical Scenario is estimated to exceed downward vertical outflow to the TMC in the Current Scenario (Table 3).

2.2.3 Tronox Seep - Historical Scenario

McGinley & Associates (2003) reports that the Tronox Seep flow was routinely gauged in excess of 300 gpm. This value will be used as the best available estimate for the historical pre-pumping seep flow rate.

For reference, pumping rates at the seep area from October 2002 through March 2003 varied between approximately 324 gpm and 584 gpm (McGinley & Associates, 2003). KMC (2007) reported a more recent rate of 674 gpm for June 2007.

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2.2.4 Seeps to north of Upper Ponds Area visible on 1968 Aerial Photo - Historical Scenario

No known information is available to describe these seep areas. However, with an estimate of seep area, an evaporation rate calculation can be used to evaluate groundwater loss from the model domain due to evaporation at the seep areas.

Based on review of the 1968 aerial photograph (Attachment 2), the seep areas covered approximately 149 acres within the model domain. Using the pan evaporation rate of 116 inches per year reported for the Boulder City area (10 miles southeast of the Site) (WRCDC, 2008), the seep area loss to evaporation is estimated at:

(149 acres) x (116 inches/year) =

(9.3e+008 square inches) x (116 inches/year) =

1.0e+11 cubic inches/year =

5.8e+7 ft3/year =

1.8 cfs.

2.2.5 Seeps along Las Vegas Wash - Historical Scenario

No known information is available to describe these seep areas. Seeps along the Las Vegas Wash, in the eastern wash fault zone area discussed by McGinley & Associates (2003), are estimated to cover approximately 15 acres (one tenth of the historical seep area discussed in Section 2.2.4). Using the same pan evaporation rate calculation that is shown in Section 2.2.4, this area corresponds to a evaporative loss of approximately 0.18 cfs.

2.2.6 Phreatophyte Evapotranspiration - Historical Scenario

An estimate of saltcedar (*Tamarisk ramosissima Ledeb.*) coverage for the Site area was completed in 2006 (Devitt, 2006) using aerial photographs from fall 2005. The ET values estimated by Devitt (2006) for the Site area were then used to estimate historical evapotranspiration (ET) for the larger model domain area.

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A historical ET estimate was calculated based on comparing saltcedar coverage evident in a 1968 aerial photograph of the model domain area with the Site saltcedar coverage measured by Devitt (2006) (assuming saltcedar stands of uniform density).

Devitt (2006) estimated the following areas and ET rates:

- 7.54 acres near Alpha Ditch - 75 cm/yr
- 5.34 additional acres near Alpha Ditch - 56 cm/yr
- 2.73 acres near Beta Ditch - 38 cm/yr
- 10.95 total acres as “islands” east of Henderson Treatment Plant - 75 cm/yr
- 4.21 acres south of Las Vegas Wash - 119 cm/yr

However, the model domain area (5,800 acres) is larger than the Site area (2,297 acres) surveyed by Devitt (2006). Based on a review of a September 1, 2005 aerial photograph (Terraserver, 2008), the larger model domain area is estimated to add an additional 10 acres of saltcedar coverage. An ET value of 75 cm/yr was assigned to this area.

Saltcedar coverage in 1968 appears to be much less extensive than in 2006 based on aerial photograph review. Coverage in 1968 within the model domain is estimated to be approximately 25% of the coverage in 2006 or a total of approximately 10 acres. The range of ET values (38 to 119 cm/yr) estimated by Devitt (2006) will be used over the 10-acre area estimated for 1968 to calculate historical ET.

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3. Current Scenario

3.1 Groundwater Inflows (Sources)

3.1.1 Lateral Groundwater Flow - Current Scenario

This parameter was estimated using the same method described above in Section 2.1 for the historical scenario. A 2007 groundwater flow map (MWH, 2007) for the shallow water-bearing zone was utilized for the estimate. The estimated value for lateral groundwater flow is presented in Table 1.

3.1.2 City Effluent Disposal Basin Recharge - Current Scenario

The City of Henderson currently operates three effluent disposal basins: P2 rapid infiltration basins (southern RIBs), Pabco (northern RIBs, and the birding preserve (McGinley & Associates, 2003). A seepage estimate for these three city effluent disposal basins was obtained from McGinley and Associates (2003).

Recharge (seepage) for the P2 RIBs, the birding preserve, and the Pabco Road RIBs was estimated by McGinley and Associates (2003) at a total of 4.8 cfs. This value accounts for an evaporative loss estimated at 8.2 ft/year (98 inches per year) from Shevenell (1996) (McGinley and Associates, 2003). A higher pan evaporation rate of 116 inches per year (WCDC, 2008) is more conservative and may be applied for the ponds area.

3.1.3 TIMET Pond Seepage - Current Scenario

These ponds are lined and are no longer in use. Seepage from the TIMET ponds in the current scenario is assumed to be negligible.

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3.1.4 Infiltration of Treated Groundwater at Athens Road Well Field - Current Scenario

The Athens Road well field was reported by KMC (2007) to be operating at 258 gpm. The infiltration rate of treated groundwater in the recharge trenches was not specifically addressed in KMC (2007) so the infiltration rate was assumed to equal the pumping rate. Thus, the well field infiltration rate was estimated at 258 gpm or 0.57 cfs.

3.1.5 Las Vegas Wash Seepage to Alluvium - Current Scenario

Seepage from the Las Vegas Wash to alluvium for the Current Scenario was estimated based on the average length and width of the wash channel and an estimate of infiltration capacity (saturated hydraulic conductivity) (similar to a seepage calculation for a ditch).

An estimated channel width of approximately 50 feet was estimated from Figure 2 from McGinley & Associates (2003) that shows a delineated wash channel. Thus, seepage was estimated as:

$$S\ (ft3/d) = L\ (ft) \times W\ (ft) \times K_V\ (ft/d)$$

The calculations for this parameter are shown in Table 1 with the estimated seepage values.

This value will be utilized, where appropriate in the numerical flow model to characterize wash seepage. Alternatively, wash seepage could be calculated using head differential between the wash surface water and groundwater. This alternative method will be evaluated during model development. Values from McGinley & Associates (2003) will also be considered during model development.

3.1.6 Recharge from Precipitation/Storm Flow - Current Scenario

This parameter is considered to be the same as the value estimated for the Historical Scenario.

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3.1.7 Inflow from Tertiary Muddy Creek Formation - Current Scenario

As discussed in Section 2 above, an estimate for this parameter can be obtained by comparing shallow with deep groundwater elevations from adjacent shallow/deep monitoring well pairs. Hydraulic gradient was calculated as the difference in head between the well pairs over the vertical distance between the mid-points of the screens in the two wells. Values for minimum and maximum K_V were obtained from core data reported in the 2007 aquifer testing report (Kleinfelder, 2007).

Shallow/deep well pairs are present at the Site and inflow from the lower TMC can be calculated for the Current Scenario (Table 3). The calculations estimate that inflow (upward vertical flow) from the TMC in the Current Scenario is greater than upward inflow in the Historical Scenario (Table 3). This is interpreted to be due to the former operation of the BMI ponds.

3.1.8 Seepage from Neighborhoods/Developed Areas - Current Scenario

This parameter was estimated by referencing an engineering estimate of typical leakage from water distribution and sewer systems.

Cheong (1991) estimated that unaccounted for water (exfiltration) accounts for approximately 20 to 30% of supplied volume. This value will be used with the City meter records (if available) or estimates of neighborhood use to determine the seepage value. Average per capita water use records can also be used with census records of population to develop an estimate of supplied water.

If available, seepage estimates will be constrained by the City of Henderson diversion and return flow records. Current information regarding piping in the Tuscany and Weston Hills areas will also be considered (Attachment 5).

A supplemental estimate for seepage from landscaped area was also completed with an estimate of hardscape/landscape (permeable and impermeable surfaces) and a reference range of values for turf grass consumptive use. Consumptive use is water that is not returned to an approved community sanitary sewer for treatment. Such water includes, but is not limited to,

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septic tanks, turf irrigation with potable water, and other, similar uses (Las Vegas Valley Water District, 2008). Consumptive use of turf grass in the Phoenix area was determined to range from 0.05 to 0.25 inches per day (U of A , 2008).

Twenty five percent of the estimated annual consumptive use for turf grass can be used as a general estimate of the leaching fraction required to prevent salt buildup in the root zone (water leached out of the root zone) and becoming recharge (US Salinity Laboratory, 1954). Using this reference, then seepage (recharge) from grass landscaped areas would range from approximately 0.0125 to 0.0625 inches per day. This value will be used over an estimated area of permeable/impermeable areas within the model domain. An estimate of permeable/impermeable areas within the model domain will be completed with city maps during numerical model domain construction. A current conservative estimate of turf grass coverage within the model domain is 30 acres.

3.1.9 Golf Course Irrigation Return Flow - Current Scenario

An estimate for seepage from golf course irrigation will be completed with an estimate of hardscape/landscape (permeable and impermeable surfaces) for the golf course property (if available) and a reference range of values for turf grass consumptive use (same calculation as in Section 3.1.8 above).

Using the calculation from Section 3.1.8, seepage (recharge) from irrigated grass areas would range from approximately 0.125 to 0.0625 inches per day. This value may be higher for higher-quality grass (U of A, 2008).

This value will be used over an estimated area of permeable/impermeable areas within the model domain. An estimate of permeable/impermeable areas within the model domain will be completed with golf course maps during numerical model domain construction. A current estimate of turf grass coverage within the model domain is 143 acres.

If available, these seepage estimates will be constrained by metered records of golf course water use. Return flow from irrigation, however, is expected to be minimal due to evaporation.

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3.2 Groundwater Outflows (Sinks)

3.2.1 Lateral Groundwater Outflow - Current Scenario

This parameter was calculated using the same methodology that was completed for lateral groundwater inflow from the Qal (Section 2.1). Outflow was estimated as shallow Qal groundwater flow into Las Vegas Wash along the northern model domain boundary (Table 1). A similar calculation will be prepared for lateral flow in the water-bearing zone within TMC along the model domain perimeter.

3.2.2 Outflow to Tertiary Muddy Creek Formation - Current Scenario

An estimate for this parameter can be obtained with the same method used to calculate inflow from the TMC: by comparing shallow with deep groundwater elevations from adjacent shallow/deep monitoring well pairs. Hydraulic gradient is calculated as the difference in head between the well pairs over the vertical distance between the mid-points of the screens in the two wells. Values for minimum and maximum K_V were obtained from core data reported in the 2007 aquifer testing report (Kleinfelder, 2007). Shallow/deep well pairs are present at the Site, and outflow to the lower TMC can be calculated for the Current Scenario (Table 3).

The calculations estimate that outflow to the TMC (downward vertical flow) in the Current Scenario is less than inflow in the Current Scenario (upward vertical flow) (Table 3).

3.2.3 Tronox Seep - Current Scenario

Pumping rates at the Tronox seep well field from October 2002 through March 2003 varied between approximately 324 gpm and 584 gpm (McGinley & Associates, 1993). KMC (2007) reported a more recent rate of 674 gpm for June 2007. Thus, a range of 324-674 gpm will be used for this parameter.

3.2.4 Tronox Pumping at Athens Road Well Field - Current Scenario

The Athens Road well field was reported by KMC (2007) to be operating at 258 gpm. Thus, the well field pumping rate was assigned a value of 258 gpm or 0.57 cfs.

3.2.5 Phreatophyte Evapotranspiration - Current Scenario

Saltcedar was removed from the Site in November and December 2007 (BRC, 2008). However, the Current Scenario will be based approximately on 2006 conditions for some parameters. Thus, the range of ET values from Devitt (2006) (38 to 119 cm/yr) will be used for the model. Saltcedar coverage and ET for areas offsite but within the model domain will be accounted for.

3.2.6 Tuscany Hills French Drains - Current Scenario

Only limited information is currently available concerning this parameter. The current understanding of the drains is that they remove groundwater from under Tuscany and redistribute the water to another location within the model domain. This redistribution will be taken into account during numerical model domain construction, however, the net result in the water balance will be zero. Operational information from Tuscany, if available, will be requested for review and use to characterize the drains. For example, Tuscany may periodically discharge to the nearby C-1 channel. As a result, additional data may be needed to further evaluate the potential outflow and sensitivity of this parameter.

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4. Future Scenario

4.1 Groundwater Inflows (Sources)

The following parameters are not currently anticipated to change substantially in the Future Scenario and will be assigned the same value as in the Current Scenario. Minor potential changes to the parameters listed below will be evaluated, as appropriate, during model development:

- Infiltration of Treated Groundwater at Athens Road Well Field
- Las Vegas Wash Seepage to Alluvium. This parameter may change as heads in the Qal and in the wash change.
- Recharge from Precipitation/Storm Flow. This parameter may change based on increased hardscape added with new development, or storm water capture and channeling to recharge basins via storm drains.
- Inflow from Lower Muddy Creek Formation. This parameter will vary as heads in the Qal and in the TMC change.
- Golf Course Irrigation Return Flow. This parameter may change as irrigation practices change with new development, potential new hardscape, or pipe leakage.
- Lateral Groundwater Flow. This parameter will vary as heads in the Qal change.

4.1.1 City Effluent Disposal Basin (RIBs) Recharge - Future Scenario

As discussed above in Section 2, the City of Henderson currently operates three effluent disposal basins: P2 rapid infiltration basins (RIBs), Pabco RIBs, and the birding preserve (McGinley & Associates, 2003). An estimate for current city effluent disposal basin seepage was obtained from McGinley and Associates (2003). Recharge (seepage) for the P2 RIBs, the birding preserve, and the Pabco Road RIBs was estimated at a total of 4.8 cfs. This value accounts for an evaporative loss estimated at 8.2 ft/year from Shevenell (1996) (McGinley and Associates, 2003). The Pabco RIBs will be discontinued in the future (BRC, 2008). If city discharge doubles in the Future Scenario, based on new property development, then recharge from these sources would increase to approximately 10 cfs even without the Pabco RIBs operating. A value of 10 cfs is currently assigned for recharge at these sources. Additional data from the City of Henderson will be utilized, if available, to constrain this parameter estimate.

4.1.2 Seepage from Neighborhoods/Developed Areas - Future Scenario

This parameter will be based on adjusting the value for the Current Scenario for anticipated new construction, new hardscape, and new pipe leakage as appropriate. The current plan for future site development is included as Attachment 6. These areas will be estimated and delineated during numerical model domain construction.

Additional data from the City of Henderson will be utilized, if available, to constrain this parameter estimate.

4.2 Groundwater Outflows (Sinks) - Future Scenario

The following parameters are not currently anticipated to change in the Future Scenario and are assigned the same value as in the Current Scenario. The fractional changes listed below will be evaluated, as appropriate, during model development:

- Lateral Groundwater Outflow. This parameter will vary as heads in the Qal change.
- Outflow to Tertiary Muddy Creek Formation. This parameter will vary as heads in the Qal and in the TMC change.
- Tronox Pumping at Athens Road Well Field. This system pumping rate may be modified in the future based on performance.
- Tuscany Hills French Drains.
- Phreatophyte evapotranspiration. This parameter will be set to zero because saltcedar has been removed from the Site, however, it may change based on saltcedar re-growth. In addition, small areas of saltcedar may be present at areas offsite but still within the model domain. Saltcedar coverage in this scenario is currently estimated at 10% of the Current Scenario (40 acres) or 4 acres. The ET values from Devitt (2006) were used with this estimated coverage area to calculate this parameter (Table 4).

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5. Structure Contour Map Update - Tertiary Muddy Creek Formation

The Tertiary Muddy Creek formation structure contour map is being updated with new data from 2007 borings completed in the northeast area, the flux line area, and at the deep background soil boring locations. The TMC structure contour will be used in the groundwater flow model to represent the lower surface of the Quaternary alluvium (Qal) at the Site.

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Tables

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Table 1. Lateral Groundwater Inflow and Outflow

Historical Scenario

		Water-bearing	Polygonal	Kh	Kh		Q	Q	Q	Q
Domain	**Length**	**zone thickness**	**Flow Area**	**minimum**	**maximum**	**i**	**minimum**	**maximum**	**minimum**	**maximum**
Boundary	**(ft)**	**(ft)**	**below**	**(ft/d)**	**(ft/d)**	**(ft/ft)**	**(ft3/d)**	**(ft3/d)**	**(ft3/s)**	**(ft3/s)**
			Water (ft2)							
Inflow to Qal										
L1-southwest	1905	14	17,145	0.18	12.53	0.011	34	2,363	3.93E-04	2.74E-02
L1-southwest	571	14	7,994	0.18	12.53	0.011	16	1,102	1.83E-04	1.28E-02
L1-southwest	762	14	5,334	0.18	12.53	0.011	11	735	1.22E-04	8.51E-03
L1-southwest	762	4	1,524	0.18	12.53	0.011	3	210	3.49E-05	2.43E-03
L1-southwest	762	4	3,048	0.18	12.53	0.011	6	420	6.99E-05	4.86E-03
L1-southwest	286	3	429	0.18	12.53	0.011	1	59	9.83E-06	6.84E-04
L2-southwest	0	0		--	--	--	0	0	0	0
L3-southwest	853	18	7,677	0.18	12.53	0.011	15	1,058	1.76E-04	1.22E-02
L4-southwest	190	19	3,610	0.18	12.53	0.011	7	498	8.27E-05	5.76E-03
L4-southwest	1043	19	13,559	0.18	12.53	0.011	27	1,869	3.11E-04	2.16E-02
L4-southwest	237	7	830	0.18	12.53	0.011	2	114	1.90E-05	1.32E-03
L4-southwest	474	2	474	0.18	12.53	0.011	1	65	1.09E-05	7.56E-04
L5-south	267	16	2,136	0.18	12.53	0.011	4	294	4.90E-05	3.41E-03
L5-south	933	27	20,060	0.18	12.53	0.011	40	2,765	4.60E-04	3.20E-02
L5-south	1067	27	28,809	0.18	12.53	0.011	57	3,971	6.60E-04	4.60E-02
L5-south	1267	27	17,105	0.18	12.53	0.011	34	2,358	3.92E-04	2.73E-02
L6-south	0	0		--	--	--	0	0	0	0
L7-southeast	0	0		--	--	--	0	0	0	0
L8-southeast	1518	20	15,180	0.18	12.53	0.011	30	2,092	3.48E-04	2.42E-02
L8-southeast	3035	40	91,050	0.18	12.53	0.012	197	13,690	2.28E-03	1.58E-01
L8-southeast	1518	40	51,612	0.18	12.53	0.023	214	14,874	2.47E-03	1.72E-01
L9-southeast	528	34	16,368	0.05	510	0.015	12	125,215	1.42E-04	1.45E+00
L9-southeast	396	42	15,048	0.05	41.42	0.011	8	6,856	9.58E-05	7.94E-02
L9-southeast	826	42	29,736	0.05	41.42	0.011	16	13,548	1.89E-04	1.57E-01
					Total Lateral Inflow:		734	194,157	8.50E-03	2.25
Outflow to Las Vegas Wash										
L10-'West	7120	74	438,419	0.07	510	0.0008	25	178,875	2.84E-04	2.07031194
L11-East	2607	44	105,584	0.07	510	0.013	96	700,019	1.11E-03	8.10206719
L11-East	702	58	33,345	0.07	510	0.013	30	221,077	3.51E-04	2.55876563
L11-East	3811	60	224,849	0.07	510	0.013	205	1,490,749	2.37E-03	17.2540378
					Total Lateral Outflow:		356	2,590,720	4.12E-03	29.99

Current Scenario

	Length of Qal	Maximum	Polygonal							
	Water-bearing	**Water-bearing**	**Flow Area**	**Kh**	**Kh**		**Q**	**Q**	**Q**	**Q**
Domain	**Zone**	**zone thickness**	**below**	**minimum**	**maximum**	**i**	**minimum**	**maximum**	**minimum**	**maximum**
Boundary	**(ft)**	**(ft)**	**Water (ft2)**	**(ft/d)**	**(ft/d)**	**(ft/ft)**	**(ft3/d)**	**(ft3/d)**	**(ft3/s)**	**(ft3/s)**
Inflow to Qal										
L1-southeast	2340	10	11,700	0.18	12.53	0.011	23.17	1,613	2.68E-04	1.87E-02
L1-southeast	203	3	300	0.18	12.53	0.011	0.59	41	6.88E-06	4.79E-04
L2-southeast	208	3	300	0.18	12.53	0.012	0.65	45	7.50E-06	5.22E-04
L3-southeast	0	0		--	--	--	0	0	0	0
L4-southeast	0	0		--	--	--	0	0	0	0
L5-southwest	1900	29	28,500	0.05	41.42	0.014	19.95	16,527	2.31E-04	1.91E-01
L5-southwest	1200	33	37,200	0.05	41.42	0.014	26.04	21,572	3.01E-04	2.50E-01
L5-southwest	600	30	15,300	0.05	41.42	0.014	10.71	8,872	1.24E-04	1.03E-01
L5-southwest	1400	23	28,000	0.05	41.42	0.014	19.60	16,237	2.27E-04	1.88E-01
L6-west	0	0		--	--	--	0	0	0	0
L7-southwest	86	20	1,200	0.05	41.42	0.014	0.84	696	9.72E-06	8.05E-03
L7-southwest	24	8	200	0.05	41.42	0.014	0.14	116	1.62E-06	1.34E-03
L7-southwest	73	40	1,800	0.05	41.42	0.014	1.26	1,044	1.46E-05	1.21E-02
L7-southwest	293	40	2,900	0.05	41.42	0.014	2.03	1,682	2.35E-05	1.95E-02
					Total Lateral Inflow:		104.98	68443.26	1.22E-03	0.79
Outflow to Las Vegas Wash										
L8-West	620	54	33,500	0.07	510	0.015	35.18	256,275	4.07E-04	2.97
L8-West	6500	54	273,000	0.07	510	0.015	286.65	2,088,450	3.32E-03	24.17
L9-East	2400	30	48,000	0.07	510	0.013	43.68	318,240	5.06E-04	3.68
L9-East	900	30	18,000	0.07	510	0.013	16.38	119,340	1.90E-04	1.38
					Total Lateral Outflow:		381.89	2,782,305	4.42E-03	32.20

Note: Future scenario is the same as the current scenario.

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Table 2. Seepage from Ditches, Stormwater Swale, Ponds and Las Vegas Wash

Historical Scenario

	estimated	estimated	minimum	maximum	minimum	maximum	minimum	maximum
Ditch Seepage	length (ft)	width (ft)	Kv (ft/d)	Kv (ft/d)	S (ft3/d)	S (ft3/d)	S (ft3/s)	S (ft3/s)
Alpha	14,000	30	7.94E-05	0.496	33	208,320	3.86E-04	2.4
Beta	18,000	30	7.94E-05	0.496	43	267,840	4.96E-04	3.1
Western	7,500	15	7.94E-05	4.49	9	505,125	1.03E-04	5.8
Northwestern	4,500	15	7.94E-05	4.49	5	303,075	6.20E-05	3.5
Stormwater Swale	18,000	10	7.94E-05	4.49	14	808,200	1.65E-04	9.4
				Total Seepage:	105	2,092,560	1.E-03	24
Wastewater/Effluent Pond Seepage (Westphal and Nork, 1972)								
Upper Ponds	--	--	--	--	967,680	967,680	11.2	11.2
Lower Ponds	--	--	--	--	194,400	194,400	2.25	2.25
	measured	estimated	minimum	maximum	minimum	maximum	minimum	maximum
	length (ft)	width (ft)	Kv (ft/d)	Kv (ft/d)	S (ft3/d)	S (ft3/d)	S (ft3/s)	S (ft3/s)
Las Vegas Wash Seepage to Alluvium	14,200	100	7.94E-05	0.496	113	704,320	0.0013	8.2

Current/Future Scenarios	measured	estimated	minimum	maximum	minimum	maximum	minimum	maximum
	length (ft)	width (ft)	Kv (ft/d)	Kv (ft/d)	S (ft3/d)	S (ft3/d)	S (ft3/s)	S (ft3/s)
Ditch, Swale and Pond Seepage (total)	0	0	0	0	0	0	0	0
Las Vegas Wash Seepage to Alluvium	14,200	100	7.94E-05	0.496	113	704,320	0.0013	8.2

K values from Kleinfelder (2007)

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Table 3. Tertiary Muddy Creek Formation Inflow and Outflow

Historical Scenario

Deep Well	Screen Interval ft	Screen midpoint ft	Groundwater Elevation famsl Jan-07	Shallow Well	Screen Interval ft	Screen midpoint ft	Groundwater Elevation famsl Jan-07	Groundwater Elevation delta famsl Jan-07	Shallow/Deep Vertical Gradient ft/ft	Vertical Flow Direction	minimum Kv ft/d	maximum Kv ft/d	approximate Site area of upward gradient %	approximate Site area of upward gradient ft2	minimum Inflow TMC to Qal ft3/d	maximum Inflow TMC to Qal ft3/d	minimum Inflow TMC to Qal ft3/s	maximum Inflow TMC to Qal ft3/s
MCF-01A	335-355	345	1726.47	AA-01	29-49	39	1711.45	-15.02	0.05	UP	7.71E-05	9.41E-01	10.0%	10,005,732	3.8E+01	462,154	4.4E-04	5
MCF-08A	350-370	360	1581.24	AA-08	5-35	20	1568.72	-12.52	0.04	UP	7.71E-05	9.41E-01	10.0%	10,005,732	2.8E+01	346,708	3.3E-04	4
MCF-10A	365-385	375	1612.18	AA-10	10-40	25	1596.89	-15.29	0.04	UP	7.71E-05	9.41E-01	10.0%	10,005,732	3.4E+01	411,318	3.9E-04	5
MCF-12A	349.5-369.5	359.5	1661.54	MCF-12B	64-84	74	1647.75	-13.79	0.05	UP	7.71E-05	9.41E-01	10.0%	10,005,732	3.7E+01	454,775	4.3E-04	5
MCF-16A	364.5-384.6	374.5	1644.13	MCF-16C	53-73	63	1625.51	-18.62	0.06	UP	7.71E-05	9.41E-01	10.0%	10,005,732	4.6E+01	562,808	5.3E-04	7
MCF-27	361.5-381.5	371.5	1775.27	AA-27	61.5-81.5	71.5	1722.46	-52.81	0.18	UP	7.71E-05	9.41E-01	10.0%	10,005,732	1.4E+02	1,657,423	1.6E-03	19
												Total Inflow:	60.0%	60,034,392	319	3,895,187	3.7E-03	45
															minimum Outflow TMC to Qal ft3/d	maximum Outflow TMC to Qal ft3/d	minimum Outflow TMC to Qal ft3/s	maximum Outflow TMC to Qal ft3/s
MCF-06A	373.5-393.5	383.5	1515.31	MCF-06C	44-59	51.50	1578.09	62.78	0.19	DOWN	7.71E-05	9.41E-01	13.3%	13,307,624	1.9E+02	2,367,955	2.2E-03	27
MCF-07	350-370	360	1530.38	AA-07	30-50	40	1572.01	41.63	0.13	DOWN	7.71E-05	9.41E-01	13.3%	13,337,641	1.3E+02	1,632,770	1.5E-03	19
MCF-09A	270-290	280	1657.18	AA-09	30-65	47.50	1658.46	1.28	0.01	DOWN	7.71E-05	9.41E-01	13.3%	13,337,641	5.7E+00	69,096	6.6E-05	1
												Total Outflow:	40.0%	39,982,905	333	4,069,821	3.9E-03	47

Current Scenario

Deep Well	Screen Interval ft	Screen midpoint ft	Groundwater Elevation famsl Jan-07	Shallow Well	Screen Interval ft	Screen midpoint ft	Groundwater Elevation famsl Jan-07	Groundwater Elevation delta famsl Jan-07	Shallow/Deep Vertical Gradient ft/ft	Vertical Flow Direction	minimum Kv ft/d	maximum Kv ft/d	approximate Site area of upward gradient %	approximate Site area of upward gradient ft2	minimum Inflow TMC to Qal ft3/d	maximum Inflow TMC to Qal ft3/d	minimum Inflow TMC to Qal ft3/s	maximum Inflow TMC to Qal ft3/s
MCF-01A	335-355	345	1726.47	AA-01	29-49	39	1711.45	-15.02	0.05	UP	7.71E-05	9.41E-01	12.5%	12,507,165	4.7E+01	577,693	5.5E-04	7
MCF-08A	350-370	360	1581.24	AA-08	5-35	20	1568.72	-12.52	0.04	UP	7.71E-05	9.41E-01	12.5%	12,507,165	3.6E+01	433,385	4.1E-04	5
MCF-10A	365-385	375	1612.18	AA-10	10-40	25	1596.89	-15.29	0.04	UP	7.71E-05	9.41E-01	12.5%	12,507,165	4.2E+01	514,148	4.9E-04	6
MCF-12A	349.5-369.5	359.5	1661.54	MCF-12B	64-84	74	1647.75	-13.79	0.05	UP	7.71E-05	9.41E-01	12.5%	12,507,165	4.7E+01	568,469	5.4E-04	7
MCF-16A	364.5-384.6	374.5	1644.13	MCF-16C	53-73	63	1625.51	-18.62	0.06	UP	7.71E-05	9.41E-01	12.5%	12,507,165	5.8E+01	703,510	6.7E-04	8
MCF-27	361.5-381.5	371.5	1775.27	AA-27	61.5-81.5	71.5	1722.46	-52.81	0.18	UP	7.71E-05	9.41E-01	12.5%	12,507,165	1.7E+02	2,071,779	2.0E-03	24
												Total Inflow:	75.0%	75,042,990	399	4,868,983	4.6E-03	56
MCF-06A	373.5-393.5	383.5	1515.31	MCF-06C	44-59	51.50	1578.09	62.78	0.19	DOWN	7.71E-05	9.41E-01	8.3%	8,334,775	1.2E+02	1,483,087	1.4E-03	17
MCF-07	350-370	360	1530.38	AA-07	30-50	40	1572.01	41.63	0.13	DOWN	7.71E-05	9.41E-01	8.3%	8,334,775	8.4E+01	1,020,328	9.7E-04	12
MCF-09A	270-290	280	1657.18	AA-09	30-65	47.50	1658.46	1.28	0.01	DOWN	7.71E-05	9.41E-01	8.3%	8,304,758	3.5E+00	43,023	4.1E-05	0
												Total Outflow:	25.0%	24,974,307	209	2,546,439	2.4E-03	29

kv data for TMC cores from Kleinfelder (2007)
-- - data not applicable
Future scenario assumed to be same as current scenario.

Table 4. Summary of Sources/Sinks and Water Balance

<u>Scenario</u>		Estimation/Calculation Method	Estimated Minimum Value	Estimated Maximum Value	Estimated Average Value	Average Values Balanced
Historical						
			cfs	cfs	cfs	cfs
Groundwater Inflows (sources)-Historical						
	Lateral groundwater inflow-Qal	flow direction and head in Qal and TMC around model domain with 1972 flow map from Westphal and Nork (1972)	8.50E-03	2.2	1.13	1.13
	Ditch seepage					
	Alpha	ditch dimensions and Kv	3.86E-04	2.4	1.21	1.21
	Beta	ditch dimensions and Kv	4.96E-04	3.1	1.55	1.55
	Western	ditch dimensions and Kv	1.03E-04	5.8	2.92	2.92
	Northwestern	ditch dimensions and Kv	6.20E-05	3.5	1.75	1.75
	Stormwater swale	swale dimensions and Kv	1.65E-04	9.4	4.68	4.68
	Upper and Lower Ponds	Values from Westphal and Nork (1972)	13.45	13.5	13.45	13.45
	Las Vegas Wash seepage to alluvium	wash channel dimensions and kv; or, vertical head differentials	0.0013	8.2	4.08	4.08
	Recharge from precipitation/storm flow	Literature value as % of precipitation from Scanlon et al (2006); pond impounding to be evaluated; 5,800 ac domain area (0.0048-0.24 in-ac/yr)	3.20E-03	1.60E-01	0.08	0.08
	inflow from Tertiary Muddy Creek Formation-vertical	upflow estimate from vertical heads in TMC around model domain	3.69E-03	45.08	22.54	22.54
		Total Sources-Historical:	13	93	53.39	53.39
Groundwater Outflows (sinks)-Historical						
	Lateral groundwater outflow	Head in Qal and TMC groundwater flowing to wash from 1972 flow map from Westphal and Nork (1972)	4.12E-03	29.99	14.99	14.99
	Outflow to Tertiary Muddy Creek Formation	downflow estimate from vertical heads in TMC around model domain using 2007 data with active ponds assumed	3.86E-03	47	23.55	35.65
	Tronox Seep	Value cited in McGinley & Associates (2003) (300 gpm)	0.67	0.67	0.67	0.67
	Seeps to north of Upper Ponds Area visible on 1968 aerial photo	Seep area estimate and pan evaporation rate (see text)	1.8	1.8	1.80	1.80
	Seeps along Las Vegas Wash	Seep area estimate and pan evaporation rate (see text)	0.18	0.18	0.18	0.18
	Phreatophyte evapotranspiration	ET rates from Devitt (2006) applied to historical saltcedar coverage (38-119 in-ac/yr)-10 ac	0.044	0.137	9.04E-02	0.09
		Total Sinks-Historical:	3	80	41.29	53.39
		Water Balance (Sources-Sinks)-Historical:	11	13	12.10	0.00

Table 4. Summary of Sources/Sinks and Water Balance

Scenario		Estimation/Calculation Method	Estimated Minimum	Estimated Maximum	Estimated Average	Average Values
Current						
Groundwater Inflows (sources)-Current						
	Lateral groundwater inflow	flow direction and head in Qal and TMC around model domain with 2007 flow map	1.22E-03	7.92E-01	0.40	0.40
	City effluent pond seepage (RIBs + birding p.)	Value cited in McGinley & Associates (2003)	4.8	4.8	4.80	4.80
	BMI pond seepage	Set to zero (ponds inactive)	0	0	0.00	0.00
	TIMET pond seepage	Set to zero (ponds lined); impounding to be evaluated	0	0	0.00	0.00
	Infiltration of treated groundwater at Athens Road Well Field	System pumping rate set to trench infiltration rate (KMC, 2005)	0.57	0.57	0.57	0.57
	Las Vegas Wash seepage to alluvium	wash channel dimensions and kv; or, vertical head differentials	0.0013	8.15	4.08	4.08
	Recharge from precipitation/storm flow	Literature value as % of precipitation from Scanlon et al (2006); pond impounding to be evaluated (same as Historical Scenario)	3.20E-03	1.60E-01	8.17E-02	0.08
	Inflow from Tertiary Muddy Creek Formation	upflow estimate from vertical heads in TMC around model domain using 2007 data (ponds inactive)	4.62E-03	56	28.18	28.18
	Seepage from neighborhoods/developed areas	Literature value for supply loss (20-30%) (Cheong, 1991), softscape coverage and consumptive use calculation; City records if available; 58 ac of softscape (10% of 5,800 ac domain); 0.0125-0.0625 in/day	8.35E-05	4.17E-04	2.50E-04	2.50E-04
	Golf course irrigation return flow	Literature value for pipe leakage (Cheong, 1991) and pipe length estimates; hardscape coverage and consumptive use calculation; golf course records if available; currently:	2.06E-04	1.03E-03	6.17E-04	6.17E-04
		Total Sources-Current:	5	71	38.11	38.11
Groundwater Outflows (sinks)-Current						
	Lateral groundwater outflow	flow direction and head in Qal and TMC around model domain with 2007 flow map	4.42E-03	32.20	16.10	16.10
	Outflow to Tertiary Muddy Creek Formation	downflow estimate from vertical heads in TMC around model domain using 2007 data (ponds inactive)	2.41E-03	29	14.74	19.97
	Tronox seep	Values from McGinley & Associates (2003) and KMC (2007) (324-674 gpm)	0.70	1.50	1.10	1.10
	Tronox pumping at Athens Road Well Field	Value from KMC (2007) (258 gpm)	0.57	0.57	0.57	0.57
	Phreatophyte evapotranspiration	ET rates from Devitt (2006) (38-119 in-ac/yr) applied to 2006 saltcedar coverage in domain (Devitt Site area of 30 ac + estimated 10 ac additional in domain= 40 ac total)	1.75E-01	5.48E-01	0.36	0.36
	Tuscany Hills french drains	groundwater redistribution-net zero balance	0	0	0.00	0.00
		Total Sinks-Current:	1	64	32.87	38.10
		Water Balance (Sources-Sinks)-Current:	4	7	5.23	0.00

Table 4. Summary of Sources/Sinks and Water Balance

Scenario		Estimation/Calculation Method	Estimated Minimum	Estimated Maximum	Estimated Average	Average Values
Future						
Groundwater Inflows (sources)-Future						
	Lateral groundwater inflow	Same as Current Scenario	1.22E-03	7.92E-01	0.40	0.40
	City effluent pond seepage (N.RIBs + birding p.)	Value for Current Scenario doubled for new development (w/o Pabco RIBs)	10	10	9.60	9.60
	Infiltration of treated groundwater at Athens Rd Well Field	Same as Current Scenario	0.57	0.57	0.57	0.57
	Las Vegas Wash seepage to alluvium	Same as Current Scenario	0.0013	8.1519	4.08	4.08
	Recharge from precipitation/storm flow	Same as Current Scenario	3.20E-03	0.16	0.08	0.08
	Inflow from Tertiary Muddy Creek Formation	Same as Current Scenario	4.62E-03	56.35	28.18	28.18
	Seepage from neighborhoods/developed areas	Estimated at Current Scenario x 4 for new future development (softscape = 232 ac or 40% of domain)	3.34E-04	1.67E-03	1.00E-03	1.00E-03
	Golf course irrigation return flow	Same as Current Scenario	2.06E-04	1.03E-03	6.17E-04	6.17E-04
		Total Sources-Future:	10	76	42.91	42.91
Groundwater Outflows (sinks)-Future						
	Lateral groundwater outflow	Same as Current Scenario	4.42E-03	32.20	16.10	21.26
	Outflow to Tertiary Muddy Creek Formation	Same as Current Scenario	2.41E-03	29.47	14.74	19.89
	Tronox Seep	Same as Current Scenario	0.70	1.50	1.10	1.10
	Tronox pumping at Athens Road Well Field	Same as Current Scenario	0.57	0.57	0.57	0.57
	Tuscany Hills french drains	groundwater redistribution-net zero balance	0	0	0.00	0.00
	Phreatophyte Evapotranspiration	ET rates from Devitt (2006) (38-119 in-ac/yr) applied to future estimated saltcedar coverage of 10 ac total	0.044	0.137	0.09	0.09
		Total Sinks-Future:	1	64	32.60	42.91
		Water Balance (Sources-Sinks)-Future:	9	12	10.30	0.00

Figure

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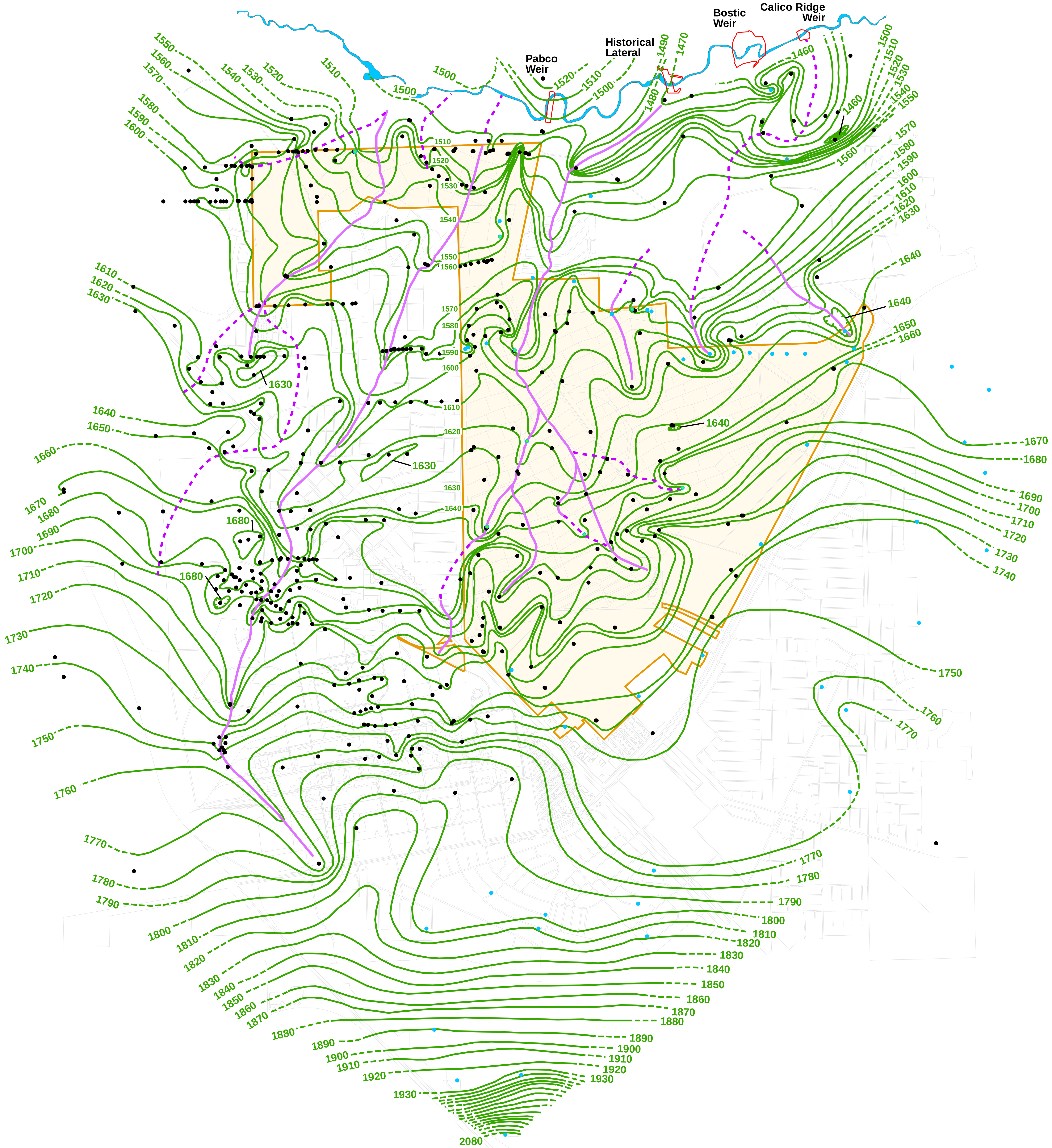

Note:
Although work is ongoing to further delineate the paleochannels, the channels depicted are based on currently available data.

N

0 1,500 3,000 Feet

Explanation

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

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BMI Common Areas (Eastside)
Henderson, Nevada

TOPOGRAPHIC SURFACE OF THE MUDDY CREEK FORMATION

Basic Remediation Company

Prepared by: CRF (DBS&A) Date: 2-20-08

Daniel B. Stephens & Associates, Inc.

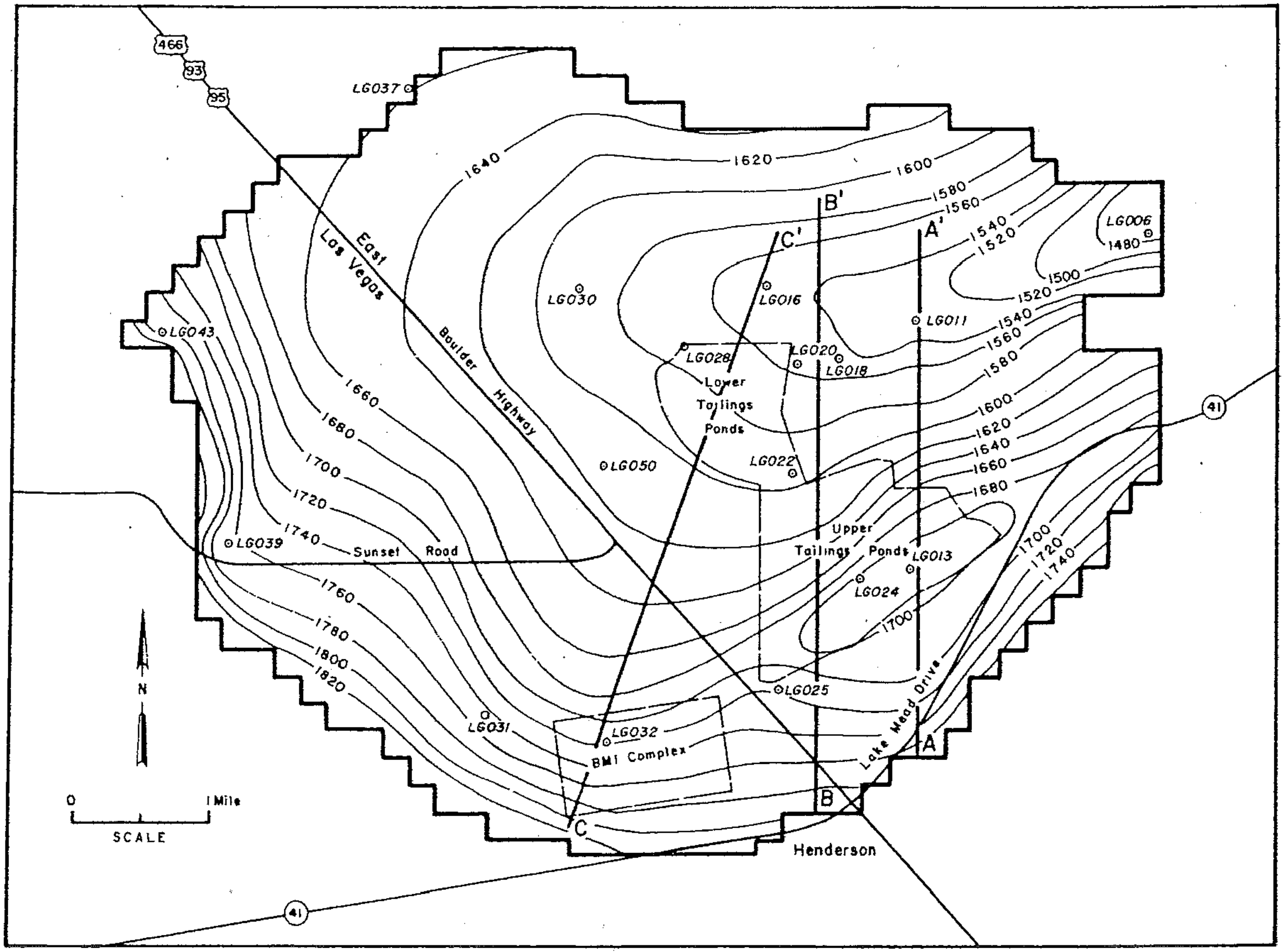
S:/PROJECTS/BRC/BRC/ES04.0212_BRC_COMMONS_AREA/GIS/MXDS/REFERENCE_WORKING_ONLY/TOP_MUDDY_CREEK_02-12-08_D-SIZE.MXD

Attachments

DRAFT

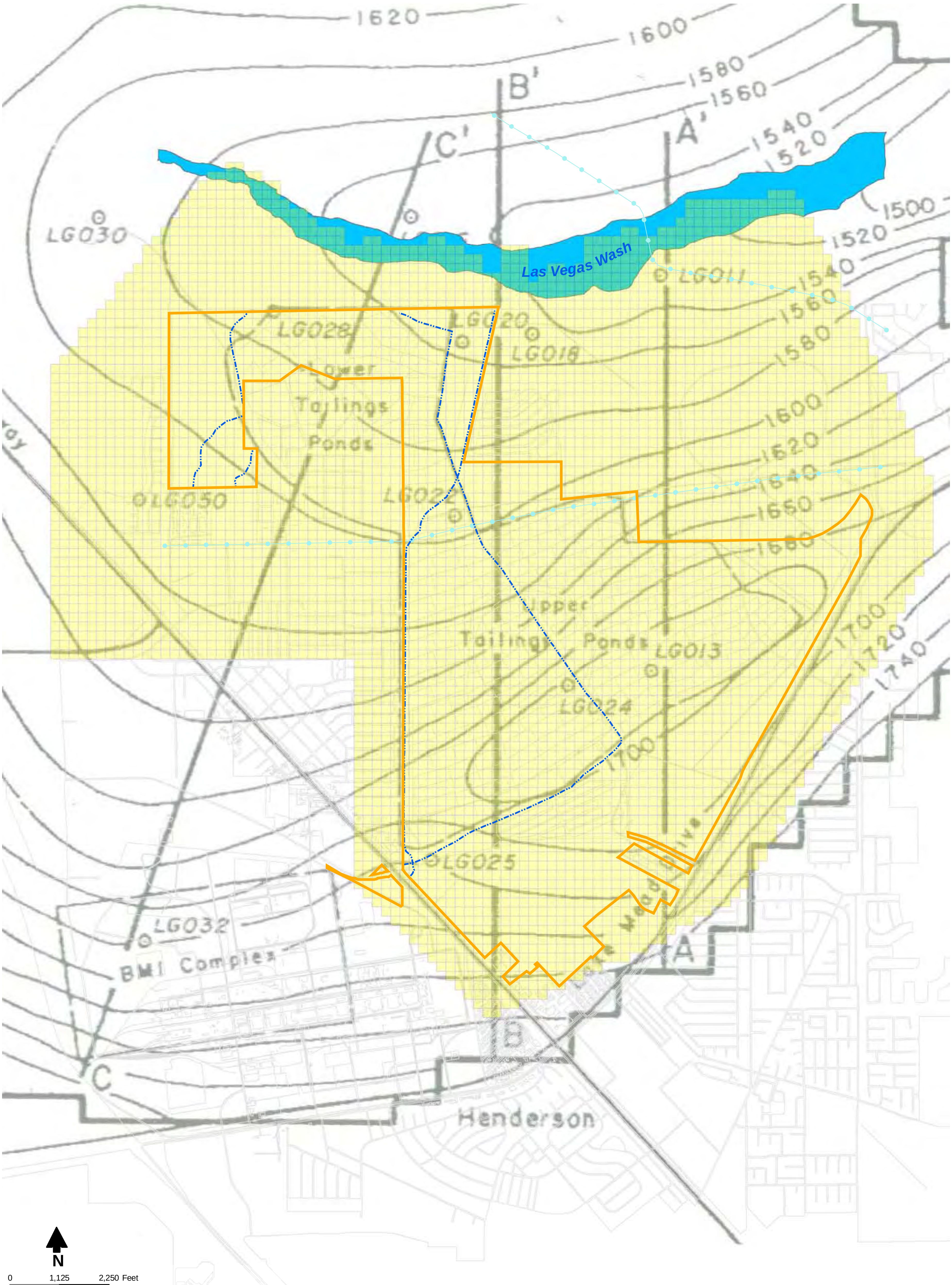
Attachment 1

DRAFT



466
93
95
East Las Vegas
Boulder Highway
Sunset Road
Lake Mead Drive
Henderson
41
Lower Tailings Ponds
Upper Tailings Ponds
BMI Complex
LG037
LG030
LG016
LG011
LG006
LG043
LG028
LG020
LG018
LG050
LG022
LG039
LG013
LG024
LG025
LG031
LG032
A
A'
B
B'
C
C'
1480
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
N
0
1 Mile
SCALE

S:/PROJECTS/BRC/ES04.0212_BRC_COMMONS_AREA/GIS/MXDS/HISTORIC_CONTOURS_MODEL_DOMAINMXD 805210



Explanation

- Monitoring well
- Ditches
- Laterals
- Water level contour (dashed where inferred)
- Site AOC3 boundary
- Site boundary
- Active model domain

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BMI Common Areas (Eastside)
Henderson, Nevada

HISTORICAL CONTOURS WITH PROPOSED MODEL DOMAIN

Basic Remediation Company

Prepared by: HMM (DBS&A) Date: 2-7-08

Daniel B. Stephens & Associates, Inc.

Attachment 2

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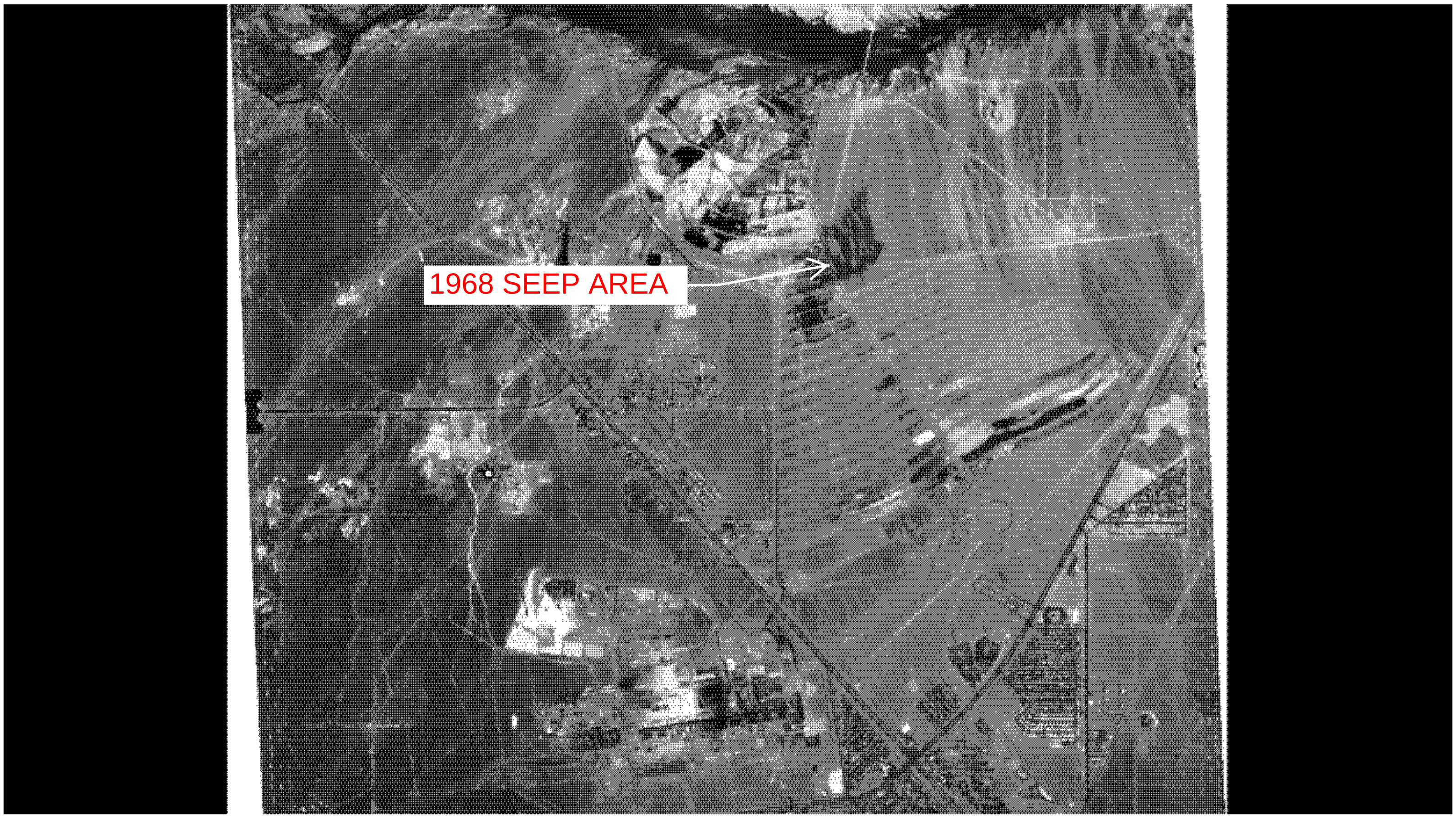
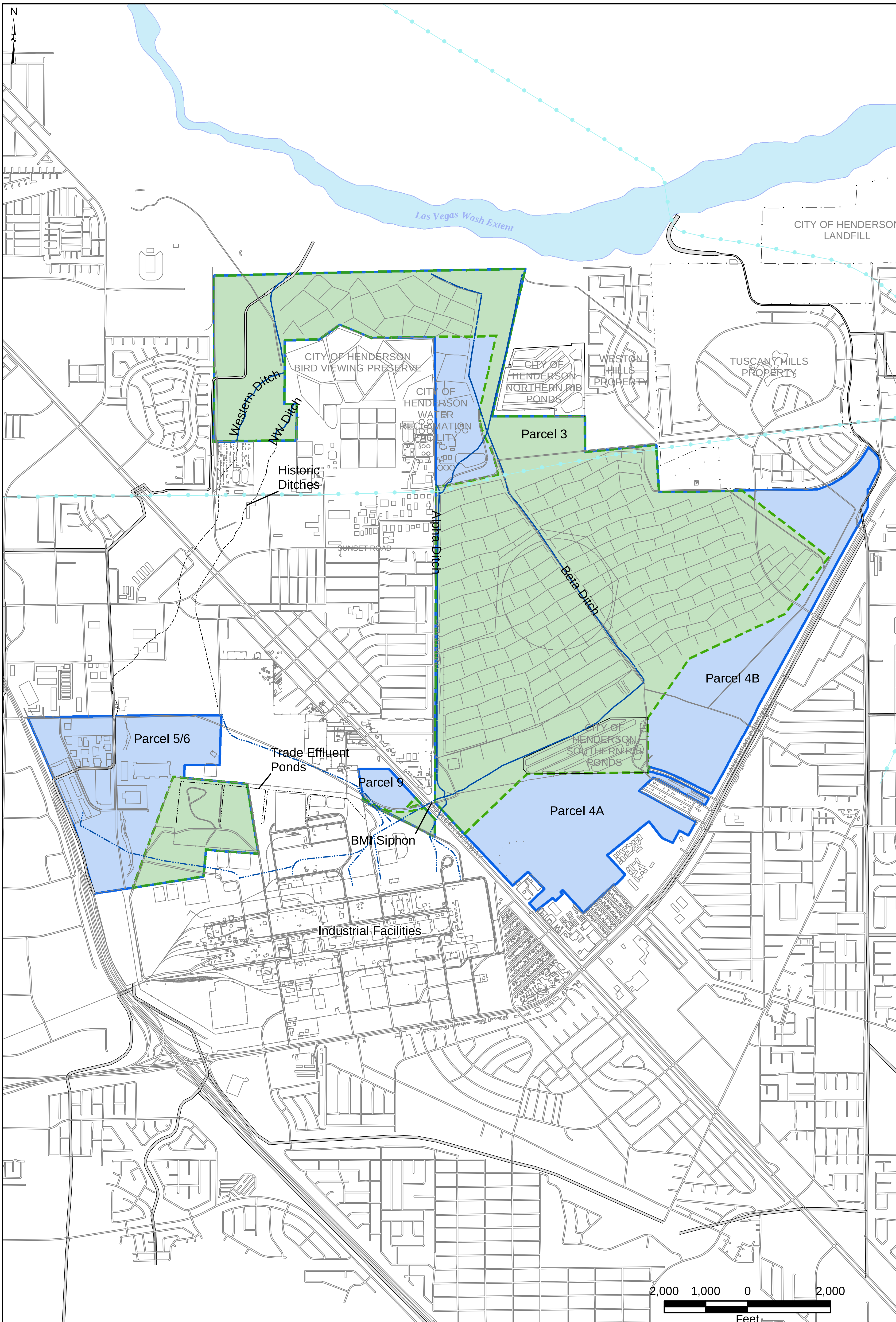

1968 SEEP AREA

Attachment 3

DRAFT



BMI Common Areas
Clark County, Nevada

FIGURE 1-3

PROJECT MAP

Basic Remediation Company

- Site Soil Boundary
- Site AOC3 Boundary

Prepared by: MWH MKJ | Date 07/28/06 | JOB No. 1881425 | FILE: GIS/BRC/FIGURE_1-3.MXD

Attachment 4

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HYDROLOGICAL PROCESSES
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Published online in Wiley InterScience
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Global synthesis of groundwater recharge in semiarid and arid regions

Bridget R. Scanlon,[1]* Kelley E. Keese,[1] Alan L. Flint,[2] Lorraine E. Flint,[2] Cheikh B. Gaye,[3] W. Michael Edmunds[4] and Ian Simmers[5]

[1] *The University of Texas at Austin, Bureau of Economic Geology, Jackson School of Geosciences, Austin, TX, 78713-8924, USA*
[2] *US Geological Survey, Sacramento, California 95819-6129, USA*
[3] *Université Cheikh Anta Diop, Département de Géologie, Dakar, Senégal*
[4] *Oxford Center for Water Research, Oxford University Center for the Environment, Oxford OX1 3QY, UK*
[5] *Vrije Universiteit, Faculty of Earth- and Life Sciences, Amsterdam, The Netherlands*

Abstract:

Global synthesis of the findings from ~140 recharge study areas in semiarid and arid regions provides important information on recharge rates, controls, and processes, which are critical for sustainable water development. Water resource evaluation, dryland salinity assessment (Australia), and radioactive waste disposal (US) are among the primary goals of many of these recharge studies. The chloride mass balance (CMB) technique is widely used to estimate recharge. Average recharge rates estimated over large areas (40–374 000 km^2) range from 0·2 to 35 mm year^{-1}, representing 0·1–5% of long-term average annual precipitation. Extreme local variability in recharge, with rates up to ~720 m year^{-1}, results from focussed recharge beneath ephemeral streams and lakes and preferential flow mostly in fractured systems. System response to climate variability and land use/land cover (LU/LC) changes is archived in unsaturated zone tracer profiles and in groundwater level fluctuations. Inter-annual climate variability related to El Niño Southern Oscillation (ENSO) results in up to three times higher recharge in regions within the SW US during periods of frequent El Niños (1977–1998) relative to periods dominated by La Niñas (1941–1957). Enhanced recharge related to ENSO is also documented in Argentina. Climate variability at decadal to century scales recorded in chloride profiles in Africa results in recharge rates of 30 mm year^{-1} during the Sahel drought (1970–1986) to 150 mm year^{-1} during non-drought periods. Variations in climate at millennial scales in the SW US changed systems from recharge during the Pleistocene glacial period ($\geq$10 000 years ago) to discharge during the Holocene semiarid period. LU/LC changes such as deforestation in Australia increased recharge up to about 2 orders of magnitude. Changes from natural grassland and shrublands to dryland (rain-fed) agriculture altered systems from discharge (evapotranspiration, ET) to recharge in the SW US. The impact of LU change was much greater than climate variability in Niger (Africa), where replacement of savanna by crops increased recharge by about an order of magnitude even during severe droughts. Sensitivity of recharge to LU/LC changes suggests that recharge may be controlled through management of LU. In irrigated areas, recharge varies from 10 to 485 mm year^{-1}, representing 1–25% of irrigation plus precipitation. However, irrigation pumpage in groundwater-fed irrigated areas greatly exceeds recharge rates, resulting in groundwater mining. Increased recharge related to cultivation has mobilized salts that accumulated in the unsaturated zone over millennia, resulting in widespread groundwater and surface water contamination, particularly in Australia. The synthesis of recharge rates provided in this study contains valuable information for developing sustainable groundwater resource programmes within the context of climate variability and LU/LC change. Copyright © 2006 John Wiley & Sons, Ltd.

KEY WORDS groundwater recharge; water resources; climate variability; land use/land cover change

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* Correspondence to: Bridget R. Scanlon, The University of Texas at Austin, Bureau of Economic Geology, Jackson School of Geosciences, Austin, TX, 78713-8924, USA. E-mail: bridget.scanlon@beg.utexas.edu

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Attachment 5

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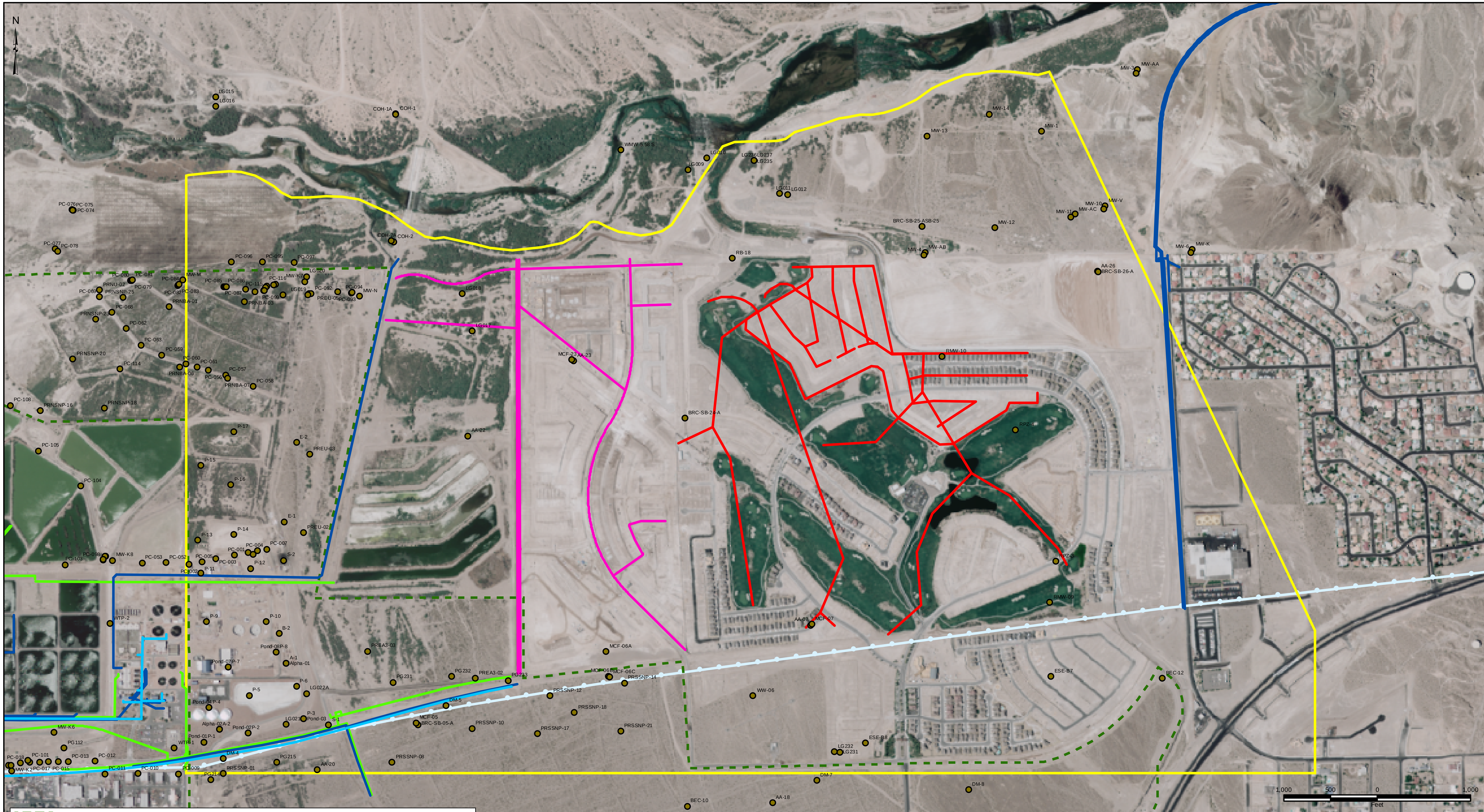

AOC3 Boundary Line
Groundwater Modeling Area of Interest
Pittman Lateral
Boring Logs Index Locations
Tuscany Hills Subdrains
Weston Hills Subdrains
CoH Reuse Pipes
CoH Sewer Pipes
CoH Water Pipes

BMI Common Areas (Eastside)
Clark County, Nevada

SUBDRAINS AND PIPES

Basic Remediation COMPANY

Prepared by:		Date	
MWH	MKJ	11/21/06	JOB No. 1881425 FILE: GIS/BRC/GW_MODEL/AOI.MXD

Attachment 6

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