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

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NDEP — Nevada Division of Environmental Protection — protecting the future for generations

Prepared for:

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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 30, 2008

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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. The scope of work for this technical memorandum was approved by Basic Remediation Company (BRC) and Nevada Division of Environmental Protection (NDEP) as part of the *Groundwater Modeling Work Plan for BMI Upper and Lower Ponds Area* (DBS&A, 2006). This document has also been revised to address comments received from NDEP dated March 28, 2008 (Appendix A).

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 that will be used in the model. The source/sink estimates will continue to be refined during model development as additional information is obtained regarding off-site properties and Site conditions. For each section that involves a boundary condition assignment in the numerical model, the relevant MODFLOW simulation packages that may be applied are listed.

2. Historical Scenario

2.1 Groundwater Inflows (Sources)

2.1.1 Lateral Groundwater Inflow

Lateral groundwater flow circa 1968 was calculated using a 1972 groundwater flow map from Westphal and Nork (1972) that depicts the shallow water-bearing zone at the Site (Appendix B). 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, so that 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 (TMCf) (Section 5) along the model domain perimeter. This 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 following Darcy's Law, incorporating estimates for i, area (A), and estimated maximum and minimum horizontal hydraulic conductivity values (K_h) from Kleinfelder (2007a, 2007b) according to the following equation:

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

The values used in each calculation and the resulting Q values are shown in Table 1. Total lateral inflow (averaged) from the Qal is estimated at 1.13 cubic foot per second (cfs). A similar calculation was prepared for lateral flow in the water-bearing zone within TMCf along the model domain perimeter (Table 2). Total lateral inflow (averaged) from the TMCf is estimated at 0.14 cfs.

Lateral groundwater inflow will be simulated using the MODFLOW-SURFACT Well package or, for some locations, by prescribing hydraulic head.

2.1.2 Ditch Seepage

Seepage (S) from the alpha ditch, the beta ditch, the western ditch, and the northwestern ditch was estimated based on the length (L) and width (W) of each ditch and the estimated infiltration capacity (saturated vertical hydraulic conductivity [K_v]):

$$S\ (ft^3/d) = L\ (ft) \times W\ (ft) \times K_v\ (ft/d)$$

Ditch length and width estimates were obtained from a 1968 aerial photograph of the Site area (Appendices C and D). Values for minimum and maximum K_v were obtained from core data reported by Kleinfelder (2007a, 2007b). The resultant seepage values are presented in Table 3. Total averaged ditch seepage is estimated at 1.89 cfs.

For reference, Westphal and Nork (1972) estimated ditch and pond seepage at the adjacent BMI complex (“plants” area) at 1 cfs. This value represents a smaller pond area and a shorter ditch segment than the areas and lengths used in the Eastside area estimates.

Ditch seepage will be incorporated in the model using either the MODFLOW-SURFACT Recharge or Well package.

2.1.3 Seepage from Stormwater Swale

The stormwater swale runs along the southern Site boundary, heads northeast parallel to Lake Mead Parkway, then turns northwest toward the Las Vegas Wash. Seepage from the swale was estimated based on the length and width of the swale and an estimated infiltration capacity (saturated K_v). Swale length and width estimates were obtained from a 1968 aerial photograph of the Site area (Appendix C). Minimum and maximum K_v values were obtained from Kleinfelder (2007a, 2007b). Average swale seepage is estimated at 0.78 cfs

In the 1968 aerial photograph, the swale widens, appears to shallow, and distributes its flow over a broad fan area for the last approximately 5,500 feet of its length. From the 1968 aerial photograph, the fan area is estimated to be approximately 600 feet wide, thus covering approximately 33 acres. Discharge and seepage from this fan will be accounted for, as appropriate, during modeling.

Seepage from the stormwater swale will be incorporated in the model using either the MODFLOW-SURFACT Recharge or Well package. In addition, if simulated water levels are sufficiently high, an outflow boundary condition will be applied to the swale using the MODFLOW Drain package to allow for groundwater outflow to the swale.

2.1.4 Wastewater/Effluent Pond Seepage (Upper and Lower Ponds)

As discussed in the groundwater modeling work plan (DBS&A, 2006), historical seepage rates for the wastewater ponds (Table 3) were obtained from the modeling report prepared by Westphal and Nork (1972). 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.

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 inflow data. A final value of 2.25 cfs was assigned by Westphal and Nork (1972) to the lower ponds area; this value is used in this water balance. For the 48-acre upper ponds area, the infiltration rate of 11.20 cfs calculated by Westphal and Nork (1972) will be used in the initial water balance.

In addition, it is expected, based on prior analytical modeling completed by BRC, that the value of 11.20 cfs will be reduced significantly during the model calibration process. Evaporation rates used by Westphal and Nork were derived from Boulder City data, which are lower than the 30-year recorded average of evaporation from the Las Vegas area. Westphal and Nork also point out that flows from the plants area were reduced after their study was completed. The estimated total pond (upper plus lower) seepage of 13.45 cfs was reduced by 50 percent to achieve a net zero sum of sources and sinks in the initial historical water balance.

Wastewater/effluent pond seepage will be incorporated in the model using the MODFLOW-SURFACT Recharge Seepage Face (RSF4) package or the Well package.

2.1.5 Las Vegas Wash Seepage to Alluvium

Upon detailed consideration of the Las Vegas Wash hydrogeologic environment, the northern boundary of the groundwater flow model domain was moved south to the approximate location of the contact between the Qal and the Las Vegas Wash alluvium/gravel (Appendix B). At this location, a third-type boundary condition (e.g. MODFLOW General Head Boundary [GHB] package) will be used to simulate groundwater outflow from the model domain into the wash gravel, which essentially acts as a drain for the aquifer system to the south.

The boundary head applied will be the approximate average water level within the wash (current and predictive scenarios) or the estimated historical water level within the wash gravel/alluvium if there is no surface water (historical scenario). The conductance term will be estimated based on the thickness of the wash gravel/alluvium and its estimated hydraulic conductivity.

This approach avoids many of the potential complexities associated with extending the model domain to the center of the wash without sacrificing or compromising the objectives of the model. This approach is consistent with the model objectives; the model is not intended to provide a detailed simulation framework of groundwater flow or solute transport within the Las Vegas Wash.

As a result of this domain boundary change, this parameter (Las Vegas Wash seepage to Qal) is located outside of the model domain and is thus not included in the water balance.

2.1.6 Recharge from Precipitation/Storm Flow

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

In arid settings, recharge from precipitation is typically a small percentage of annual precipitation. Based on values from Scanlon et al. (2006) (Appendix E), recharge as a percentage of annual precipitation for the Site area was estimated to be between 0.1 percent and 5 percent. Recharge is thus estimated to be between 0.0048 inch and 0.24 inch per year.

Where on-site ponds impounded precipitation or storm flow, estimates of average storm frequencies will be used to estimate the volume of water impounded. The volume estimate will be used to evaluate potentially significant additional recharge from the ponds.

Recharge from precipitation and storm flow will be incorporated in the model using either the MODFLOW-SURFACT Recharge or Well package.

2.1.7 Inflow from Tertiary Muddy Creek Formation

Deep monitoring wells were not present at the Site during the historical scenario time frame, so inflow from the TMCf cannot be calculated from Site data. Westphal and Nork (1972) assumed that flow from low-yield sediments (i.e., TMCf) was negligible. Shallow/deep well pairs are now present at the Site and inflow from the lower TMCf can be calculated for the current scenario (Section 3.1).

The TMCf inflow calculated for the current scenario (Section 3.1.7) was used also for the historical scenario (Table 4); however, a larger Site area of downward vertical flow was assumed for the historical scenario calculations, because the former Eastside ponds were operating during the historical scenario time frame.

The current groundwater elevation data indicate that three well pairs have a downward vertical head gradient (Table 4). Based on the locations and distribution of these well pairs within the central portion of the model domain, downward flow for the current scenario (Section 3.1) was roughly estimated to be present in approximately 25 percent of the model domain area. Inflow for the current scenario is thus assumed to occur over the remaining 75 percent of the model domain area.

A range of values for areas of upflow (and downflow) will be considered during numerical model development. Operation of the BMI ponds during the historical scenario time frame may also have resulted in groundwater mounding in the alluvium that may have caused some variation in the direction of vertical groundwater flow between the TMCf and the alluvium. This will also be considered during modeling.

Because the former ponds were operating during the historical scenario time frame, downward vertical flow from the Qal to the TMCf is assumed to have occurred over a somewhat larger area under the historical scenario than in the current scenario. In the absence of quantitative data to use in this estimate, the area of downward flow in the historical scenario was roughly estimated at approximately 40 percent of the model domain (Table 4). Inflow (upward) in the historical scenario is thus assumed to occur over the remaining 60 percent of the model domain area. Historical inflow (upward) from the TMCf was estimated at 30.88 cfs (Table 5).

A range of areas of upward flow will be considered during modeling. The calculations estimate that upward vertical flow (inflow) from the TMCf for the historical scenario was less than inflow from the TMCf in the current scenario (Table 4).

Inflow to the bottom of the model domain from the deep TMCf will most likely be simulated using the MODFLOW-SURFACT GHB package or possibly the Well package.

2.2 Groundwater Outflows (Sinks)

2.2.1 Lateral Groundwater Outflow

Lateral groundwater outflow for the historical scenario was calculated for the Qal in the same manner as lateral groundwater inflow (Section 2.1). The calculation used 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 toward Las Vegas Wash along the northern model domain boundary (Table 1). Lateral outflow from the Qal was estimated at 14.99 cfs.

A similar calculation was prepared for lateral flow in the water-bearing zone within the TMCf along the model domain perimeter (Table 2). Lateral outflow from the TMCf was estimated at 0.27 cfs.

Lateral groundwater outflow from the model domain will be simulated using the MODFLOW-SURFACT GHB or possibly the Well package.

2.2.2 Outflow to Tertiary Muddy Creek Formation (Vertical Leakage)

Outflow to the TMCf can be estimated in the same manner as inflow from the TMCf (comparing shallow with deep groundwater elevations from adjacent shallow/deep monitoring well pairs [Section 2.1.7]). However, because deep monitoring wells were not present at the Site during the historical scenario time frame, historical values for this parameter cannot be directly calculated. Instead, the input parameters for TMCf outflow in the current scenario were used for the historical scenario calculations, with downward flow again assumed to occur over a larger area in the past due to pond operation. Thus, downward vertical outflow to the TMCf for the historical scenario was again estimated to exceed downward vertical outflow to the TMCf for the current scenario (Table 3). Historical downward vertical outflow to the TMCf was estimated at 23.55 cfs.

Vertical groundwater outflow to the deep TMCf will be simulated using either the MODFLOW-SURFACT GHB or Well package.

2.2.3 Tronox Seep

McGinley & Associates (2003) reports that flow from the seep (the “Tronox Seep”) north of the City of Henderson Water Reclamation facility (COH WRF) was routinely measured at more than 300 gallons per minute (gpm), or 0.67 cfs. This value will be used as the best available estimate for the historical pre-pumping seep flow rate. The Tronox Seep is located at the northern model domain boundary. As a result, this feature is anticipated to be modeled as a sink contributing to outflow from the model domain. Groundwater outflow from the seep will be simulated using the MODFLOW-SURFACT Drain package.

2.2.4 Seeps to North of Upper Ponds Area

No known information is available to describe the historical seep areas that are visible on the 1968 aerial photograph of the area (Appendix C. Recent data reported in 2006 indicate that seeps near the Weston Hills property flowed between 16 and approximately 178 gpm in an excavation completed for a stormwater drainage channel trench (Converse, 2006).

With an estimate of historical seep area, a calculated evaporation rate can be used to evaluate groundwater loss from the model domain due to evaporation at the seep areas.

Based on a review of the 1968 aerial photograph (Appendix C), the seep areas covered approximately 149 acres within the model domain. Using a pan evaporation rate of 119.40 inches per year (in/yr) reported for the Las Vegas area (Oregon Climate Service, 2008), the seep area loss to evaporation is estimated at:

$$149 \text{ acres} \times 119.40 \text{ in/yr} = 2.05 \text{ cfs}$$

This estimate assumes that overland seep flow out of the model domain does not occur. The photograph in Appendix C and other aerial photographs of the area taken around 1968 provide no evidence indicating that overland seep flow out of the model domain is occurring.

Groundwater outflow from the seep area north of the Upper Ponds will be simulated using the MODFLOW-SURFACT Drain package.

2.2.5 Seeps along Las Vegas Wash

No known information is available to describe historical seep areas along Las Vegas Wash. In addition, because seep areas within the wash are located outside of the model domain, this parameter will not be included in the water balance.

For reference, McGinley & Associates (2003) describe some surface water flow in the eastern wash area. Based on an estimated seep area of approximately 15 acres (one-tenth of the historical seep area discussed in Section 2.2.4) and using the same pan evaporation rate calculation shown in Section 2.2.4, this area corresponds to an evaporative loss of approximately 0.21 cfs. This estimate assumes that overland seep flow out of the model domain does not occur.

2.2.6 Phreatophyte Evapotranspiration

An estimate of salt cedar (*Tamarisk ramosissima Ledeb.*) coverage for the Site area was completed in 2006 (Devitt, 2006) using aerial photographs from the fall of 2005. The evapotranspiration (ET) values estimated by Devitt (2006) for the Site area were used to estimate historical ET for the larger model domain area, based on comparing the salt cedar coverage evident in a 1968 aerial photograph of the model domain area with the Site salt cedar coverage measured by Devitt (2006) (assuming salt cedar stands of uniform density). According to Baum (1978), the depth of salt cedar roots is typically on the order of 30 meters (98.4 feet), which is deeper than the Site water levels reported by Westphal and Nork (1972). Thus, groundwater depth was not a restriction to salt cedar growth at the Site.

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

- 7.54 acres near Alpha Ditch: 75 centimeters per year (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

The model domain area (5,800 acres) is larger than the 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 salt cedar coverage. An ET value of 75 cm/yr was assigned to this area.

Salt cedar 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 percent of the coverage in 2006, or approximately 10 acres. To calculate historical ET, the range of ET values (38 to 119 cm/yr) estimated by Devitt (2006) was used over the 10-acre area estimated for 1968. ET by phreatophytes will be simulated using the MODFLOW -SURFACT ET package.

3. Current Scenario

3.1 Groundwater Inflows (Sources)

3.1.1 Lateral Groundwater Flow

Lateral groundwater flow for the current scenario was estimated using the same method described in Section 2.1 for the historical scenario. A 2007 groundwater flow map (MWH, 2007) for the shallow water-bearing zone was used for the estimate, the results of which are shown in Table 1. Current lateral inflow from the Qal is estimated at 0.40 cfs, which is lower than the historical value of 1.13 cfs. This decrease is interpreted to be due to lower current groundwater levels and a corresponding reduced thickness of saturated Qal. Lateral groundwater inflow will be simulated using the MODFLOW-SURFACT Well package or, for some locations, by prescribing hydraulic head.

3.1.2 City Effluent Disposal Basin Recharge

The City of Henderson currently operates three effluent disposal basins: P2 rapid infiltration basins (southern RIBs), Pabco Road (northern RIBs), and the birding preserve. Recharge (seepage) for the P2 RIBs, the birding preserve, and the Pabco Road RIBs was estimated by McGinley & Associates (2003) to be a total of 4.8 cfs. This value accounts for an evaporative loss estimated at 8.2 ft/yr (98 in/yr) by Shevenell (1996) (McGinley & Associates, 2003). A higher pan evaporation rate of 116 in/yr (WRCC, 2008) is more conservative and may be applied for the ponds area. Seepage from the RIBs/preserve will be incorporated in the model using either the MODFLOW-SURFACT RSF4 package or the Well package.

3.1.3 TIMET Pond Seepage

For the current scenario, seepage from the TIMET ponds is assumed to be negligible, as these ponds are lined and no longer in use. For reference, however, a seepage rate can be calculated using a K_v estimate for the 211-acre ponds that is comparable to a landfill liner (10^{-7} centimeters per second or 2.83×10^{-4} ft/d):

$$S\ (ft^3/d) = Area\ (ft^2) \times K_v\ (ft/d)$$

$$S\ (ft^3/d) = 211\ acres \times 2.83 \times 10^{-4}\ ft/d = 3.02 \times 10^{-2}\ cfs$$

If recharge from the TIMET ponds is considered in the simulation, it will be incorporated using the MODFLOW-SURFACT Well package.

3.1.4 Tronox Groundwater Infiltration Trenches

Tronox operates three facilities: (1) an on-site pumping system (i.e., within the Tronox plant site) with groundwater infiltration trenches, (2) the "Athens Road" groundwater extraction system on Galleria Drive, and (3) the Tronox Seep area groundwater extraction system (Tronox, 2007).

The on-site system at the Tronox plant site is located outside of the model domain and will not be included in the water balance. The remaining features, however, are sinks within the model domain and are addressed in Section 3.2.3 and Section 3.2.4.

3.1.5 Las Vegas Wash Seepage to Alluvium

As discussed in Section 2.1.5, this parameter is located outside of the model domain and will not be included in the water balance.

3.1.6 Recharge from Precipitation/Storm Flow

This parameter is considered to be the same as the value estimated for the historical scenario (Section 2.1.6) and will be incorporated in the model in the same manner.

3.1.7 Inflow from Tertiary Muddy Creek Formation (Vertical Leakage)

As discussed in Section 2.1.7, an estimate for inflow from the TMCf can be obtained by comparing shallow and deep groundwater elevations from adjacent shallow/deep monitoring well pairs. Because shallow/deep well pairs are now present at the Site, inflow from the lower TMCf can be calculated for the current scenario (Table 3). Hydraulic gradient was calculated as the difference in head between the paired wells over the vertical distance between the midpoints of the screens in the two wells. Values for minimum and maximum K_v were obtained from

Kleinfelder (2007a, 2007b). Inflow from the TMCf in the current scenario was estimated at 27.57 cfs. Inflow to the bottom of the model domain from the deep TMCf will most likely be simulated using the MODFLOW-SURFACT GHB package or possibly the Well package.

3.1.8 Seepage from Neighborhoods/Developed Areas

Seepage from the developed areas surrounding the Site can be calculated using an engineering estimate of typical leakage from water distribution and sewer systems. SWRB (1962) estimated for the Los Angeles area that unaccounted-for water (exfiltration) makes up approximately 20 percent of supplied volume. That is, approximately 20 percent of supplied water returns to groundwater.

This value will be used with the City of Henderson meter records (if available) or estimates of neighborhood use and pipes/drains (Appendix F) 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.

A supplemental estimate of seepage from landscaped areas was also completed, using an estimate of hardscape/landscape (permeable and impermeable surfaces) in the area and a reference range of values for turf grass consumptive use. Permeable softscape was estimated at 2,035 acres. Consumptive use of turf grass in the Phoenix area, which has a similar climate, was determined to range from 0.05 to 0.25 inch per day (University of Arizona, 2003).

A general estimate of the leaching fraction required to prevent salt from building up in the root zone (when water leaches out of the root zone) and becoming recharge is 25 percent of the estimated annual consumptive use for turf grass (U.S. Salinity Laboratory, 1954). Based on this percentage, seepage (recharge) from grass-landscaped areas would range from approximately 0.0125 to 0.0625 inch per day. This range of rates, applied over 2,035 acres of softscape in the model domain, yields a seepage estimate of 0.00878 cfs (approximately 0.01 cfs).

BRC previously estimated a value of 0.01 inch per day for infiltration from golf course watering and a value of 0.003 inch per day for infiltration from residential sources (BRC, 2003). This range of seepage values will be evaluated for permeable areas within the model domain, which will be estimated based on the current plan for Site redevelopment (Appendix G).

Seepage from neighborhoods and developed areas will be incorporated in the model using the MODFLOW-SURFACT Well package.

3.1.9 Golf Course Irrigation Return Flow

Seepage from golf course irrigation will be calculated based on an estimate of the area of hardscape/landscape (permeable and impermeable surfaces) on the golf course property (if available) and a reference range of values for turf grass consumptive use.

Using the calculation from Section 3.1.8, seepage (recharge) from irrigated grass areas would range from approximately 0.125 to 0.0625 inch per day (potentially higher for higher-quality grass [University of Arizona, 2003]). This range of values will be applied to the estimated area of permeable/impermeable golf course areas within the model domain, which will be estimated based on golf course maps during numerical model domain construction. A current estimate of turf grass coverage on golf course grounds 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 is expected to be minimal due to evaporation. BRC previously estimated a value of 0.01 inch per day for infiltration from golf course watering (BRC, 2003) and this value will be considered during modeling.

Golf course irrigation return flow was estimated at 0.000617 cfs. This parameter will be incorporated in the model using the MODFLOW-SURFACT Well package.

3.2 Groundwater Outflows (Sinks)

3.2.1 Lateral Groundwater Outflow

Lateral groundwater outflow was calculated using the methodology described for lateral groundwater inflow from the Qal (Section 2.1.1). Outflow was estimated as shallow Qal groundwater flow toward Las Vegas Wash along the northern model domain boundary

(Table 1). A similar calculation was prepared for lateral flow in the water-bearing zone within the TMCf along the model domain perimeter (Table 2). Lateral outflow from the Qal is estimated at 16.10 cfs and lateral outflow from the TMCf is estimated at 0.10 cfs.

3.2.2 Outflow to Tertiary Muddy Creek Formation (Vertical Leakage)

Outflow to the TMCf can be estimated using the same method used to calculate inflow from the TMCf (Section 3.1.7): by comparing shallow with deep groundwater elevations from adjacent shallow/deep monitoring well pairs. Because shallow/deep well pairs are now present at the Site, outflow to the lower TMCf can be calculated for the current scenario (Table 3). Hydraulic gradient was calculated as the difference in head between paired wells over the vertical distance between the midpoints of the screens in the two wells. Values for minimum and maximum K_v were obtained from Kleinfelder (2007a, 2007b). Outflow to the TMCf (downward vertical leakage) is estimated at 14.74 cfs.

Vertical groundwater outflow to the deep TMCf will be simulated using either the MODFLOW-SURFACT GHB or Well package

3.2.3 Tronox Seep Groundwater Extraction

Pumping rates at the Tronox Seep well field from October 2002 through March 2003 varied between approximately 324 gpm and 584 gpm (McGinley & Associates, 2003). Tronox (2007) reported a more recent (June 2007) rate of 673.7 gpm. Extracted groundwater from the seep area is pumped south to the on-site treatment area and then redirected north in a pipeline that empties into the Las Vegas Wash (Tronox, 2007).

The range of 324 to 673.7 gpm was averaged to obtain a value of 1.11 cfs for this parameter. Groundwater outflow due to pumping will be simulated using the MODFLOW-SURFACT Well package.

3.2.4 Tronox Pumping at Athens Road Well Field

The Athens Road well field was reported by Tronox (2007) to be operating at 258.5 gpm. Thus, this sink is assigned a value of 258.5 gpm, or 0.58 cfs, in the water balance. Extracted groundwater from the Athens Road area is pumped south to the on-site treatment area and then redirected north in a pipeline that empties into the Las Vegas Wash (Tronox, 2007). Groundwater outflow due to pumping will be simulated using the MODFLOW-SURFACT Well package.

3.2.5 Phreatophyte Evapotranspiration

Although salt cedar was removed from the Site in November and December 2007 (BRC, 2008), phreatophyte ET for the current scenario will be based on 2006 conditions (before the salt cedar removal). The range of ET values from Devitt (2006) (38 to 119 cm/yr) was applied to salt cedar coverage on-site and off-site within the model domain (estimated at 40 acres total) to arrive at an estimate of 0.36 cfs. ET by salt cedar will be simulated using the MODFLOW-SURFACT ET package.

3.2.6 Tuscany French Drains/Infiltration Gallery

A groundwater collection drain and infiltration gallery was installed at the Tuscany property for groundwater seep control (NDEP, 2008). Nuisance groundwater is collected by a main subsurface trunk line and laterals. The water is then directed to an infiltration gallery. These features are within the model domain, but there is a net zero balance of groundwater extraction and infiltration. As a result, this parameter will not be included in the water balance.

4. Future Scenario

4.1 Groundwater Inflows (Sources)

Several of the groundwater inflow parameters are not currently anticipated to change substantially in the future scenario and will thus be assigned the same value as used for the current scenario. Minor potential changes to the parameters listed below will be evaluated, as appropriate, during model development:

- Recharge from precipitation/storm flow. This parameter may change based on increased hardscape added with new development, or stormwater capture and channeling to recharge basins through storm drains.

- Inflow from lower TMCf. This parameter will vary as heads in the Qal and in the TMCf 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 groundwater head changes.

4.1.1 City Effluent Disposal Basin Recharge

All city RIBs will be discontinued in the near future (BRC, 2008). The city bird viewing preserve (wastewater treatment plant [WWTP] #3 ponds), however, is permitted for 9.5 million gallons per day of influent flow and will remain in service (NDEP, 2006).

If city discharge doubles in the future scenario based on new property development, then recharge from the WWTP #3 ponds would presumably also increase. Accordingly, the prior estimate of 4.8 cfs for the RIBs and the preserve (Section 3.1.2) was approximately doubled to obtain an estimated value of 10 cfs for WWTP #3 recharge under the future scenario.

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

4.1.2 Seepage from Developed Areas

Seepage from the surrounding developed areas will be based on adjusting the value for the current scenario to account for anticipated new construction, new hardscape, and new pipe leakage (Appendix F), as appropriate. The current plan for future Site development is included as Appendix G. The developed areas will be estimated and delineated during numerical model construction. This parameter is currently estimated at 0.001 cfs. Additional data from the City of Henderson or other sources, if available, will be used to constrain this parameter estimate.

4.2 Groundwater Outflows (Sinks)

Several outflow parameters are not currently anticipated to change under the future scenario and are thus assigned the same value as for the current scenario. The fractional changes listed below will be evaluated, as appropriate, during model development:

- Lateral groundwater outflow. This value may vary as simulated heads in the Qal change.

- Outflow to the TMCf. This parameter will vary as heads in the Qal and in the TMCf change.

- Tronox pumping at the seep area and the Athens Road well field. These pumping rates may be modified in the future based on capture system performance.

- Phreatophyte ET. This parameter will be set to zero because salt cedar has been removed from the Site; however, it may change based on salt cedar regrowth. In addition, small areas of salt cedar may be present at off-site areas that are within the model domain.

5. Structure Contour Map Update, Tertiary Muddy Creek Formation

The TMCf structure contour map was updated with new data from 2007 borings completed in the northeast area, in the flux line area, and at the deep background soil boring locations. This updated TMCf structure contour, shown in Figure 1, will be used in the groundwater flow model to represent the lower surface of the Qal at the Site.

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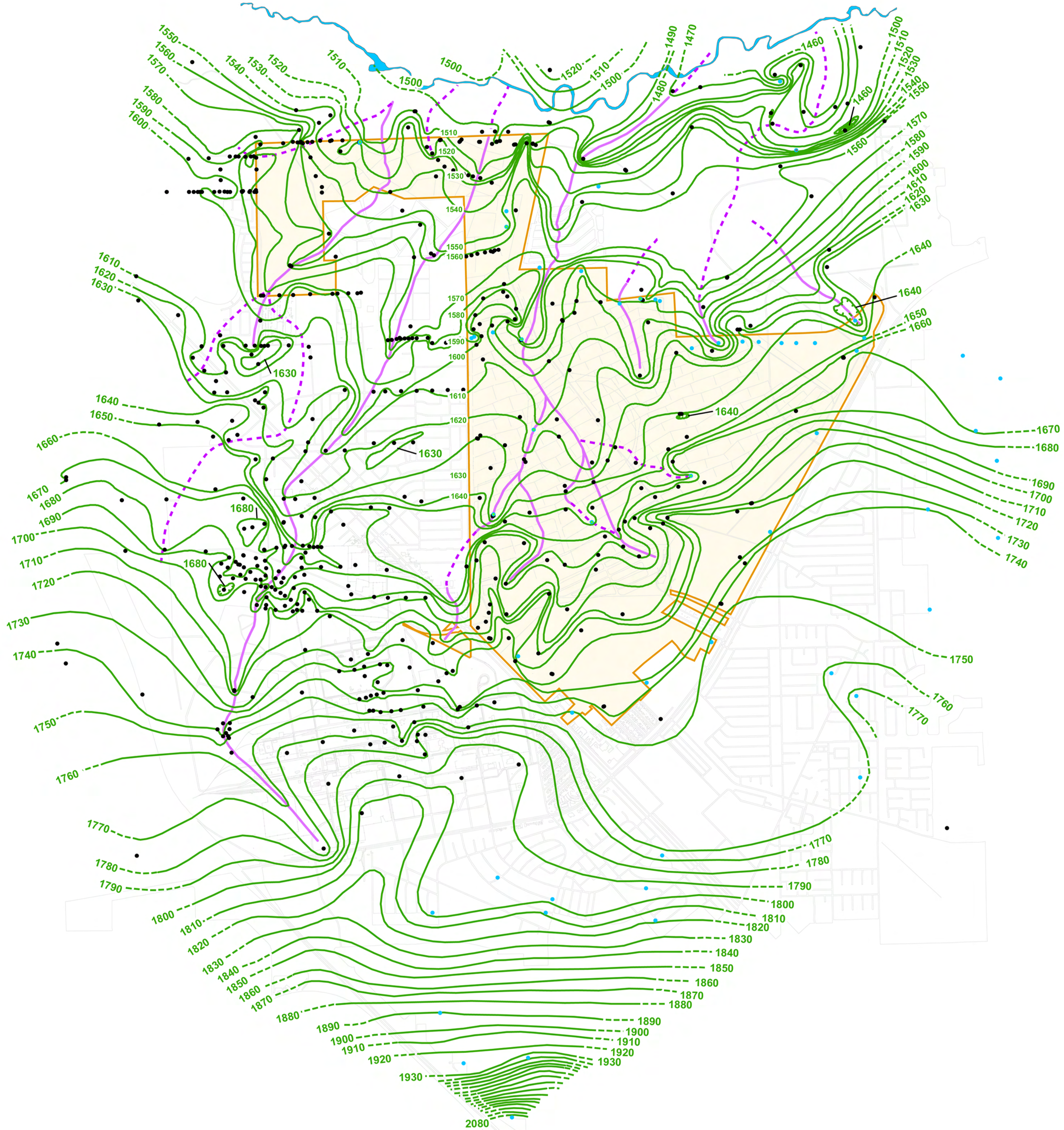
Figure



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)

S:/PROJECTS/BRC/ES04.0212_BRC_COMMONS_AREA/GIS/MXDS/TOP_MUDDY_CREEK_04-25-08_D-SIZE.MXD

Daniel B. Stephens & Associates, Inc.

BMI Common Areas (Eastside)
Henderson, Nevada

TOPOGRAPHIC SURFACE OF THE MUDDY CREEK FORMATION

Basic Remediation Company

Prepared by: CRF (DBS&A) Date: 4-25-08

Figure 1

Tables

Table 1. Lateral Groundwater Inflow and Outflow, Quaternary Alluvium

Domain Boundary	Length of Qal Water-Bearing Zone (ft)	Water-Bearing Zone Thickness (ft)	Polygonal Flow Area Below Water (ft^2)	K_h (ft/d)		i (ft/ft)	Q (ft^3/d)		Q (cfs)	
				Minimum	Maximum		Minimum	Maximum	Minimum	Maximum
Historical Scenario										
Inflow										
L1-southwest	1,905	14	17,145	0.18	12.53	0.011	34	2,363	3.93×10^{-4}	2.74×10^{-2}
	571	14	7,994	0.18	12.53	0.011	16	1,102	1.83×10^{-4}	1.28×10^{-2}
	762	14	5,334	0.18	12.53	0.011	11	735	1.22×10^{-4}	8.51×10^{-3}
	762	4	1,524	0.18	12.53	0.011	3	210	3.49×10^{-5}	2.43×10^{-3}
	762	4	3,048	0.18	12.53	0.011	6	420	6.99×10^{-5}	4.86×10^{-3}
	286	3	429	0.18	12.53	0.011	1	59	9.83×10^{-6}	6.84×10^{-4}
L2-southwest (dry)	0	0	---	---	---	---	0	0	0	0
L3-southwest	853	18	7,677	0.18	12.53	0.011	15	1,058	1.76×10^{-4}	1.22×10^{-2}
L4-southwest	190	19	3,610	0.18	12.53	0.011	7	498	8.27×10^{-5}	5.76×10^{-3}
	1,043	19	13,559	0.18	12.53	0.011	27	1,869	3.11×10^{-4}	2.16×10^{-2}
	237	7	830	0.18	12.53	0.011	2	114	1.90×10^{-5}	1.32×10^{-3}
	474	2	474	0.18	12.53	0.011	1	65	1.09×10^{-5}	7.56×10^{-4}
L5-south	267	16	2,136	0.18	12.53	0.011	4	294	4.90×10^{-5}	3.41×10^{-3}
	933	27	20,060	0.18	12.53	0.011	40	2,765	4.60×10^{-4}	3.20×10^{-2}
	1,067	27	28,809	0.18	12.53	0.011	57	3,971	6.60×10^{-4}	4.60×10^{-2}
	1,267	27	17,105	0.18	12.53	0.011	34	2,358	3.92×10^{-4}	2.73×10^{-2}
L6-south (dry)	0	0	---	---	---	---	0	0	0	0
L7-southeast (dry)	0	0	---	---	---	---	0	0	0	0

K_h = Horizontal hydraulic conductivity
i = Hydraulic gradient
Q = Groundwater flow
cfs = Cubic feet per second
Qal = Quaternary alluvium
--- = Data not applicable

Table 1. Lateral Groundwater Inflow and Outflow, Quaternary Alluvium

Domain Boundary	Length of Qal Water-Bearing Zone (ft)	Water-Bearing Zone Thickness (ft)	Polygonal Flow Area Below Water (ft^2)	K_h (ft/d)		i (ft/ft)	Q (ft^3/d)		Q (cfs)	
				Minimum	Maximum		Minimum	Maximum	Minimum	Maximum
Historical Scenario (cont.)										
Inflow (cont.)										
L8-southeast	1,518	20	15,180	0.18	12.53	0.011	30	2,092	3.48×10^{-4}	2.42×10^{-2}
	3,035	40	91,050	0.18	12.53	0.012	197	13,690	2.28×10^{-3}	1.58×10^{-1}
	1,518	40	51,612	0.18	12.53	0.023	214	14,874	2.47×10^{-3}	1.72×10^{-1}
L9-southeast	528	34	16,368	0.05	510	0.015	12	125,215	1.42×10^{-4}	1.45×10^{0}
	396	42	15,048	0.05	41.42	0.011	8	6,856	9.58×10^{-5}	7.94×10^{-2}
	826	42	29,736	0.05	41.42	0.011	16	13,548	1.89×10^{-4}	1.57×10^{-1}
						Total Lateral Inflow	734	194,157	8.50×10^{-3}	2.25
Outflow										
L10-west	7,120	74	438,419	0.07	510	0.0008	25	178,875	2.84×10^{-4}	2.07×10^{0}
L11-east	2,607	44	105,584	0.07	510	0.013	96	700,019	1.11×10^{-3}	8.10×10^{0}
	702	58	33,345	0.07	510	0.013	30	221,077	3.51×10^{-4}	2.56×10^{0}
	3,811	60	224,849	0.07	510	0.013	205	1,490,749	2.37×10^{-3}	1.73×10^{1}
						Total Lateral Outflow	356	2,590,720	4.12×10^{-3}	29.99
Current / Future Scenario										
Inflow										
L1-southeast	2,340	10	11,700	0.18	12.53	0.011	23.17	1,613	2.68×10^{-4}	1.87×10^{-2}
	203	3	300	0.18	12.53	0.011	0.59	41	6.88×10^{-6}	4.79×10^{-4}
L2-southeast	208	3	300	0.18	12.53	0.012	0.65	45	7.5×10^{-6}	5.22×10^{-4}
L3-southeast (dry)	0	0	---	---	---	---	0	0	0	0

K_h = Horizontal hydraulic conductivity
i = Hydraulic gradient
Q = Groundwater flow
cfs = Cubic feet per second
Qal = Quaternary alluvium
--- = Data not applicable

Table 1. Lateral Groundwater Inflow and Outflow, Quaternary Alluvium

Domain Boundary	Length of Qal Water-Bearing Zone (ft)	Water-Bearing Zone Thickness (ft)	Polygonal Flow Area Below Water (ft^2)	K_h (ft/d)		i (ft/ft)	Q (ft^3/d)		Q (cfs)	
				Minimum	Maximum		Minimum	Maximum	Minimum	Maximum
Current / Future Scenario (cont.)										
Inflow (cont.)										
L4-southeast (dry)	0	0	---	---	---	---	0	0	0	0
L5-southwest	1,900	29	28,500	0.05	41.42	0.014	19.95	16,527	2.31×10^{-4}	1.91×10^{-1}
	1,200	33	37,200	0.05	41.42	0.014	26.04	21,572	3.01×10^{-4}	2.50×10^{-1}
	600	30	15,300	0.05	41.42	0.014	10.71	8,872	1.24×10^{-4}	1.03×10^{-1}
	1,400	23	28,000	0.05	41.42	0.014	19.60	16,237	2.27×10^{-4}	1.88×10^{-1}
L6-west (dry)	0	0	---	---	---	---	0	0	0	0
L7-southwest	86	20	1,200	0.05	41.42	0.014	0.84	696	9.72×10^{-6}	8.05×10^{-3}
	24	8	200	0.05	41.42	0.014	0.14	116	1.62×10^{-6}	1.34×10^{-3}
	73	40	1,800	0.05	41.42	0.014	1.26	1,044	1.46×10^{-5}	1.21×10^{-2}
	293	40	2,900	0.05	41.42	0.014	2.03	1,682	2.35×10^{-5}	1.95×10^{-2}
						Total Lateral Inflow	104.98	68,443.26	1.22×10^{-3}	0.79
Outflow										
L8-west	620	54	33,500	0.07	510	0.015	35.18	256,275	4.07×10^{-4}	2.97
	6,500	54	273,000	0.07	510	0.015	286.65	2,088,450	3.32×10^{-3}	24.17
L9-east	2,400	30	48,000	0.07	510	0.013	43.68	318,240	5.06×10^{-4}	3.68
	900	30	18,000	0.07	510	0.013	16.38	119,340	1.90×10^{-4}	1.38
						Total Lateral Outflow	381.89	2,782,305	4.42×10^{-3}	32.20

K_h = Horizontal hydraulic conductivity
i = Hydraulic gradient
Q = Groundwater flow
cfs = Cubic feet per second
Qal = Quaternary alluvium
--- = Data not applicable

Table 2. Lateral Groundwater Inflow and Outflow, Tertiary Muddy Creek Formation
Page 1 of 2

Domain Boundary	Length of TMCf Water-Bearing Zone (ft)	Specified Zone Thickness (ft)	Polygonal Flow Area Below Water (ft^2)	K_h (ft/d)		i (ft/ft)	Q (ft^3/d)		Q (cfs)	
				Minimum	Maximum		Minimum	Maximum	Minimum	Maximum
Historical Scenario										
Inflow										
L1-southwest	5,069	50	248,313	0.18	1.5	0.011	491.66	4,097	5.69×10^{-3}	4.74×10^{-2}
L2-southwest	486	50	20,412	0.18	1.5	0.011	40.42	337	4.68×10^{-4}	3.90×10^{-3}
L3-southwest	2,473	50	121,729	0.18	1.5	0.011	241.02	2,009	2.79×10^{-3}	2.32×10^{-2}
L4-southwest	2,700	50	133,250	0.18	1.5	0.011	263.84	2,199	3.05×10^{-3}	2.54×10^{-2}
L5-south	2,920	50	142,788	0.18	1.5	0.011	282.72	2,356	3.27×10^{-3}	2.73×10^{-2}
L6-south	2,747	50	131,567	0.18	1.5	0.011	260.50	2,171	3.02×10^{-3}	2.51×10^{-2}
L7-southeast	2,418	50	95,754	0.18	1.5	0.011	189.59	1,580	2.19×10^{-3}	1.83×10^{-2}
L8-southeast	8,726	50	412,996	0.18	1.5	0.012	892.07	7,434	1.03×10^{-2}	8.60×10^{-2}
L9-southeast	982	50	49,100	0.18	1.5	0.011	97.22	810	1.13×10^{-3}	9.38×10^{-3}
					Total Lateral Inflow		2,569.45	21,412	2.97×10^{-2}	2.48×10^{-1}
Outflow										
L10-West	7,120	50	356,000	0.0007	5.1	0.013	3.24	23,603	3.75×10^{-5}	2.73×10^{-1}
L11-East	7,120	50	356,000	0.0007	5.1	0.013	3.24	23,603	3.75×10^{-5}	2.73×10^{-1}
					Total Lateral Outflow		6.48	47,206	7.50×10^{-5}	5.46×10^{-1}

K_h = Horizontal hydraulic conductivity
i = Hydraulic gradient
Q = Groundwater flow
cfs = Cubic feet per second
TMCf = Tertiary Muddy Creek formation

Table 2. Lateral Groundwater Inflow and Outflow, Tertiary Muddy Creek Formation

Domain Boundary	Length of TMCf Water-Bearing Zone (ft)	Specified Zone Thickness (ft)	Polygonal Flow Area Below Water (ft^2)	K_h (ft/d)		i (ft/ft)	Q (ft^3/d)		Q (cfs)	
				Minimum	Maximum		Minimum	Maximum	Minimum	Maximum
Current / Future Scenario										
Inflow										
L1-southeast	6,700	50	335,000	0.18	1.5	0.011	663.30	5,528	7.68×10^{-3}	6.40×10^{-2}
L2-southeast	7,990	50	264,196	0.18	1.5	0.012	570.66	4,756	6.60×10^{-3}	5.50×10^{-2}
L3-southeast	907	50	26,846	0.18	1.5	0.012	57.99	483	6.71×10^{-4}	5.59×10^{-3}
L4-southeast	907	50	52,001	0.18	1.5	0.012	112.32	936	1.30×10^{-3}	1.08×10^{-2}
L5-southwest	6,920	50	329,982	0.18	1.5	0.014	831.55	6,930	9.62×10^{-3}	8.02×10^{-2}
L6-west	4,230	50	166,683	0.18	1.5	0.014	420.04	3,500	4.86×10^{-3}	4.05×10^{-2}
L7-southwest	550	50	26,344	0.18	1.5	0.014	66.39	553	7.68×10^{-4}	6.40×10^{-3}
						Total Lateral Inflow	1,890.70	15,756	2.19×10^{-2}	1.82×10^{-1}
Outflow										
L8-West	7,120	50	356,000	0.18	1.5	0.015	961.20	8,010	1.11×10^{-2}	9.27×10^{-2}
L9-East	7,120	50	356,000	0.18	1.5	0.013	833.04	6,942	9.64×10^{-3}	8.03×10^{-2}
						Total Lateral Outflow	1,794.24	14,952	2.08×10^{-2}	1.73×10^{-1}

K_h = Horizontal hydraulic conductivity
i = Hydraulic gradient
Q = Groundwater flow
cfs = Cubic feet per second
TMCf = Tertiary Muddy Creek formation

Table 3. Seepage from Ditches, Stormwater Swale, and Ponds

Seepage Type	Estimated Length[a] (ft)	Estimated Width (ft)	Kv[b] (ft/d)		S (ft^3/d)		S (cfs)	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Historical scenario								
Ditch seepage (15 acres)								
Alpha	14,000	15	7.94×10^{-5}	0.496	17	104,160	1.93×10^{-4}	1.2
Beta	18,000	15	7.94×10^{-5}	0.496	21	133,920	2.48×10^{-4}	1.6
Western	7,500	15	7.94×10^{-5}	0.496	9	55,800	1.03×10^{-4}	0.6
Northwestern	4,500	15	7.94×10^{-5}	0.496	5	33,480	6.20×10^{-5}	0.4
Ditch seepage subtotal								3.8
Stormwater swale (6 acres)	18,000	15	7.94×10^{-5}	0.496	21	133,920	2.48×10^{-4}	1.6
Total ditch/swale seepage					74	461,280	9.0×10^{-4}	5.4
Wastewater/effluent pond seepage[c]								
Upper ponds (48 acres)	---	---	---	---	967,680	967,680	11.2	11.2
Lower ponds (12 acres)	---	---	---	---	194,400	194,400	2.25	2.25
Current/future scenarios								
Ditch, swale and pond seepage (total)	0[d]	0	0	0	0	0	0	0

[a] Lengths are estimated unless otherwise noted
[b] Values are from Kleinfelder (2007a, 2007b)
[c] Values are from Westphal and Nork (1972)
[d] Measured length

K_v = Vertical hydraulic conductivity
S = Seepage
cfs = Cubic feet per second
--- = Data not applicable

Table 4. Tertiary Muddy Creek Formation Inflow and Outflow (Vertical Leakage)

Deep Well	Screen Interval (ft)	Screen midpoint (ft)	Jan-07 Groundwater Elevation (ft msl)	Shallow Well	Screen Interval (ft)	Screen midpoint (ft)	Jan-07 Groundwater Elevation (ft msl)	Jan-07 Groundwater Elevation Delta (ft msl)	Shallow/ Deep Vertical Gradient (ft/ft)	Vertical Flow Direction	K_v (ft/d)		Approximate Site Area of Upward Gradient		Inflow/Outflow TMCf to Qal (ft^3/d)		Inflow/Outflow TMCf to Qal (cfs)	
											Minimum	Maximum	%	ft^2	Minimum	Maximum	Minimum	Maximum
Historical Scenario																		
Inflow																		
MCF-01A	335-355	345	1,726.47	AA-01	29-49	39	1,711.45	–15.02	0.05	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	3.8×10^{1}	462,154	4.4×10^{-4}	5
MCF-08A	350-370	360	1,581.24	AA-08	5-35	20	1,568.72	–12.52	0.04	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	2.8×10^{1}	346,708	3.3×10^{-4}	4
MCF-10A	365-385	375	1,612.18	AA-10	10-40	25	1,596.89	–15.29	0.04	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	3.4×10^{1}	411,318	3.9×10^{-4}	5
MCF-12A	349.5-369.5	359.5	1,661.54	MCF-12B	64-84	74	1,647.75	–13.79	0.05	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	3.7×10^{1}	454,775	4.3×10^{-4}	5
MCF-16A	364.5-384.6	374.5	1,644.13	MCF-16C	53-73	63	1,625.51	–18.62	0.06	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	4.6×10^{1}	562,808	5.3×10^{-4}	7
MCF-27	361.5-381.5	371.5	1,775.27	AA-27	61.5-81.5	71.5	1,722.46	–52.81	0.18	Up	7.71×10^{-5}	9.41×10^{-1}	10.0	10,005,732	1.4×10^{2}	1,657,423	1.6×10^{-3}	19
												Total Inflow	60.0	60,034,392	319	3,895,187	3.7×10^{-3}	45
Outflow																		
MCF-06A	373.5-393.5	383.5	1,515.31	MCF-06C	44-59	51.50	1,578.09	62.78	0.19	Down	7.71×10^{-5}	9.41×10^{-1}	13.3	13,307,624	1.9×10^{2}	2,367,955	2.2×10^{-3}	27
MCF-07	350-370	360	1,530.38	AA-07	30-50	40	1,572.01	41.63	0.13	Down	7.71×10^{-5}	9.41×10^{-1}	13.3	13,337,641	1.3×10^{2}	1,632,770	1.5×10^{-3}	19
MCF-09A	270-290	280	1,657.18	AA-09	30-65	47.50	1,658.46	1.28	0.01	Down	7.71×10^{-5}	9.41×10^{-1}	13.3	13,337,641	5.7×10^{0}	69,096	6.6×10^{-5}	1
												Total Outflow	40.0	39,982,905	333	4,069,821	3.9×10^{-3}	47
Current Scenario																		
Inflow																		
MCF-01A	335-355	345	1,726.47	AA-01	29-49	39	1,711.45	–15.02	0.05	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	4.7×10^{1}	577,693	5.5×10^{-4}	7
MCF-08A	350-370	360	1,581.24	AA-08	5-35	20	1,568.72	–12.52	0.04	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	3.6×10^{1}	433,385	4.1×10^{-4}	5
MCF-10A	365-385	375	1,612.18	AA-10	10-40	25	1,596.89	–15.29	0.04	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	4.2×10^{1}	514,148	4.9×10^{-4}	6
MCF-12A	349.5-369.5	359.5	1,661.54	MCF-12B	64-84	74	1,647.75	–13.79	0.05	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	4.7×10^{1}	568,469	5.4×10^{-4}	7
MCF-16A	364.5-384.6	374.5	1,644.13	MCF-16C	53-73	63	1,625.51	–18.62	0.06	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	5.8×10^{1}	703,510	6.7×10^{-4}	8
MCF-27	361.5-381.5	371.5	1,775.27	AA-27	61.5-81.5	71.5	1,722.46	–52.81	0.18	Up	7.71×10^{-5}	9.41×10^{-1}	12.5	12,507,165	1.7×10^{2}	2,071,779	2.0×10^{-3}	24
												Total Inflow	75.0	75,042,990	399	4,868,983	4.6×10^{-3}	56
Outflow																		
MCF-06A	373.5-393.5	383.5	1,515.31	MCF-06C	44-59	51.50	1,578.09	62.78	0.19	Down	7.71×10^{-5}	9.41×10^{-1}	8.3	8,334,775	1.2×10^{2}	1,483,087	1.4×10^{-3}	17
MCF-07	350-370	360	1,530.38	AA-07	30-50	40	1,572.01	41.63	0.13	Down	7.71×10^{-5}	9.41×10^{-1}	8.3	8,334,775	8.4×10^{1}	1,020,328	9.7×10^{-4}	12
MCF-09A	270-290	280	1,657.18	AA-09	30-65	47.50	1,658.46	1.28	0.01	Down	7.71×10^{-5}	9.41×10^{-1}	8.3	8,304,758	3.5×10^{0}	43,023	4.1×10^{-5}	0
												Total Outflow	25.0	24,974,307	209	2,546,439	2.4×10^{-3}	29

ft msl = Feet above mean sea level
K_v = Vertical hydraulic conductivity
TMCf = Tertiary Muddy Creek formation
Qal = Quaternary alluvium

Table 5. Summary of Sources/Sinks and Water Balance

Source/Sink		Estimation/Calculation Method(s)	Estimated Flow Rate (cfs)				Data Quality Ranking [b]
			Minimum	Maximum	Average	Average Balanced [a]	
Historical scenario							
Groundwater inflows (sources)							
Lateral groundwater inflow, Qal		Flow direction and head in Qal and TMCf around model domain based on 1972 flow map from Westphal and Nork (1972)	8.50×10^{-3}	2.2	1.13	1.13	1
Lateral groundwater inflow, TMCf		Flow direction and head in Qal and TMCf around model domain based on 1972 flow map from Westphal and Nork (1972)	2.97×10^{-2}	2.48×10^{-1}	0.14	0.14	1
Ditch seepage	Alpha	Ditch dimensions and K_v	1.93×10^{-4}	1.2	0.60	0.60	1
	Beta	Ditch dimensions and K_v	2.48×10^{-4}	1.6	0.78	0.78	1
	Western	Ditch dimensions and K_v	1.03×10^{-4}	0.6	0.32	0.32	1
	Northwestern	Ditch dimensions and K_v	6.20×10^{-5}	0.4	0.19	0.19	1
Stormwater swale		Swale dimensions and K_v	2.48×10^{-4}	1.6	0.78	0.78	1
Upper and lower ponds		Values from Westphal and Nork (1972), reduced per head/infiltration calculation	13.45	13.45	13.45	**6.73**	1
Las Vegas Wash seepage to alluvium		Not included in model domain	0	0	0.00	0.00	
Recharge from precipitation/storm flow		Literature value as percentage of precipitation from Scanlon et al. (2006); Pond impounding to be evaluated; 5,800-acre domain area (0.0048 to 0.24 ac-in/yr)	3.20×10^{-3}	1.60×10^{-1}	0.08	0.08	2
Inflow from TMCf (upward vertical leakage)		Upflow estimate from vertical heads in TMCf around model domain	3.69×10^{-3}	45.08	22.54	30.88	1
		Total Sources, Historical	13	67	40.01	41.63	

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Source/Sink	Estimation/Calculation Method(s)	Estimated Flow Rate (cfs)				Data Quality Ranking [b]
		Minimum	Maximum	Average	Average Balanced [a]	
Historical scenario (cont.)						
Groundwater outflows (sinks)						
Lateral groundwater outflow, Qal	Head in Qal and TMCf groundwater flowing to wash from 1972 flow map (Westphal and Nork, 1972)	4.12×10^{-3}	29.99	14.99	14.99	1
Lateral groundwater outflow, TMCf	Head in Qal and TMCf groundwater flowing to wash from 1972 flow map from Westphal and Nork (1972)	7.50×10^{-5}	5.46×10^{-1}	0.27	0.27	1
Outflow to TMCf (downward vertical leakage)	Downflow estimate from vertical heads in TMCf around model domain using 2007 data with ponds assumed to be active	3.86×10^{-3}	47	23.55	23.55	1
Tronox Seep	Value cited by McGinley & Associates (2003) (300 gpm) for historical flow	0.67	0.67	0.67	0.67	1
Seeps to north of Upper Ponds area visible on 1968 aerial photograph	Seep area estimate and pan evaporation rate (Section 2.2.4)	2.05	2.05	2.05	2.05	2
Seeps along Las Vegas Wash	Not included in model domain	0.00	0.00	0.00	0.00	2
Phreatophyte ET	ET rates from Devitt (2006) (38 to 119 ac-in/yr) applied to historical salt cedar coverage (10 acres)	0.044	0.137	9.04×10^{-2}	0.09	2
	Total Sinks, Historical	3	80	41.63	41.63	
	Water Balance (sources – sinks), Historical	11	–14	–1.62	0.00	

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Source/Sink	Estimation/Calculation Method(s)	Estimated Flow Rate (cfs)				Data Quality Ranking [b]
		Minimum	Maximum	Average	Average Balanced [a]	
Current scenario						
Groundwater inflows (sources)						
Lateral groundwater inflow, Qal	Flow direction and head in Qal and TMCf around model domain based on 2007 flow map	1.22×10^{-3}	7.92×10^{-1}	0.40	0.40	1
Lateral groundwater inflow, TMCf	Head in Qal and TMCf groundwater flowing to wash based on 1972 flow map from Westphal and Nork (1972)	2.19×10^{-2}	1.82×10^{-1}	0.10	0.10	1
City effluent pond seepage (RIBs + birding preserve)	Value cited by McGinley & Associates (2003)	4.8	4.8	4.80	4.80	2
BMI complex pond seepage	Set to zero (ponds inactive plus outside of model domain)	0	0	0.00	0.00	1
TIMET pond seepage	Although ponds not in use, value estimated based on landfill liner K_v of 1×10^{-7} cm/s	3.02×10^{-2}	3.02×10^{-2}	0.03	0.03	2
Tronox on-site groundwater infiltration trenches	Not included in model domain	0	0	0.00	0.00	1
Las Vegas Wash seepage to alluvium	Not included in model domain	0	0	0.00	0.00	
Recharge from precipitation/storm flow	Literature value as percentage of precipitation from Scanlon et al. (2006); Pond impounding to be evaluated (same as historical scenario)	3.20×10^{-3}	1.60×10^{-1}	8.17×10^{-2}	0.08	2
Inflow from TMCf (upward vertical leakage)	Upflow estimate from vertical heads in TMCf around model domain using 2007 data (ponds inactive)	4.62×10^{-3}	56	28.18	**27.57**	1

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Table 5. Summary of Sources/Sinks and Water Balance
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Source/Sink	Estimation/Calculation Method(s)	Estimated Flow Rate (cfs)				Data Quality Ranking [b]
		Minimum	Maximum	Average	Average Balanced [a]	
Current scenario (cont.)						
Groundwater inflows (sources) (cont.)						
Seepage from developed areas	Softscape coverage (2,035 acres) and consumptive use (0.0125 to 0.0625 in/d) calculation	2.93×10^{-3}	1.46×10^{-2}	8.78×10^{-3}	8.78×10^{-3}	2
Golf course irrigation return flow	Literature value for pipe leakage (SWRB, 1972) and pipe length estimates; Hardscape coverage and consumptive use calculation; Golf course records if available	2.06×10^{-4}	1.03×10^{-3}	6.17×10^{-4}	6.17×10^{-4}	2
	Total sources, current	5	62	33.60	32.99	
Groundwater outflows (sinks)						
Lateral groundwater outflow, Qal	Flow direction and head in Qal and TMCf around model domain based on 2007 flow map	4.42×10^{-3}	32.20	16.10	16.10	1
Lateral groundwater outflow, TMCf	Head in Qal and TMCf groundwater flowing to wash from 1972 flow map from Westphal and Nork (1972)	2.08×10^{-2}	1.73×10^{-1}	0.10	0.10	1
Outflow to TMCf (downward vertical leakage)	Downflow estimate from vertical heads in TMCf around model domain using 2007 data (ponds inactive)	2.41×10^{-3}	29	14.74	14.74	1
Tronox Seep pumping	Values from McGinley & Associates (2003) and Tronox (2007) (324 to 674 gpm)	0.72	1.50	1.11	1.11	1
Tronox pumping at Athens Road well field	Value from Tronox (2007) (258.5 gpm)	0.58	0.58	0.58	0.58	1

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Table 5. Summary of Sources/Sinks and Water Balance
Page 5 of 6

Source/Sink	Estimation/Calculation Method(s)	Estimated Flow Rate (cfs) Minimum	Maximum	Average	Average Balanced [a]	Data Quality Ranking [b]
Current scenario (cont.)						
Groundwater outflows (sinks) (cont.)						
Phreatophyte ET	ET rates from Devitt (2006) (38 to 119 ac-in/yr) applied to 2006 salt cedar coverage within domain (30 acres [Devitt, 2006] plus estimated 10 additional acres in domain = 40-acre total)	1.75×10^{-1}	5.48×10^{-1}	0.36	0.36	
Tuscany Hills french drains/infiltration gallery	Groundwater redistribution, net zero balance	0	0	0.00	0.00	1
	Total Sinks, Current	1	64	32.99	32.99	
	Water Balance (sources – sinks), Current	3	–2	0.61	0.00	
Future scenario						
Groundwater inflows (sources)						
Lateral groundwater inflow, Qal	Same as current scenario	1.22×10^{-3}	7.92×10^{-1}	0.40	0.40	1
Lateral groundwater inflow, TMCf	Same as current scenario	2.19×10^{-2}	1.82×10^{-1}	0.10	0.10	1
City effluent pond seepage (birding preserve only)	Estimated value for bird preserve lagoons (WWTP #3) based on rate estimated by McGinley & Associates (2003)	10	10	10.00	10.00	2
Infiltration of treated groundwater at Athens Road well field	Not included in model domain	0	0	0.00	0.00	1
Las Vegas Wash seepage to alluvium	Not included in model domain	0	0	0.00	0.00	
Recharge from precipitation/storm flow	Same as current scenario	3.20×10^{-3}	0.16	0.08	0.08	2
Inflow from TMCf (upward vertical leakage)	Same as current scenario	4.62×10^{-3}	56.35	28.18	**22.10**	1

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Table 5. Summary of Sources/Sinks and Water Balance

Source/Sink	Estimation/Calculation Method(s)	Estimated Flow Rate (cfs) Minimum	Maximum	Average	Average Balanced [a]	Data Quality Ranking [b]
Future scenario (cont.)						
Groundwater inflows (sources) (cont.)						
Seepage from developed areas	Estimated at current scenario x 4 for new future development (softscape = 232 acres or 40% of model domain)	1.17×10^{-2}	5.86×10^{-2}	3.51×10^{-2}	3.51×10^{-2}	2
Golf course irrigation return flow	Same as current scenario	2.06×10^{-4}	1.03×10^{-3}	6.17×10^{-4}	6.17×10^{-4}	2
	Total sources, future	10	68	38.80	32.72	
Groundwater outflows (sinks)						
Lateral groundwater outflow, Qal	Same as current scenario	4.42×10^{-3}	32.20	16.10	16.10	1
Lateral groundwater outflow, TMCf	Same as current scenario	2.08×10^{-2}	1.73×10^{-1}	0.10	0.10	1
Outflow to TMCf (downward vertical leakage)	Same as current scenario	2.41×10^{-3}	29.47	14.74	14.74	1
Tronox Seep pumping	Same as current scenario	0.72	1.50	1.11	1.11	1
Tronox pumping at Athens Road well field	Same as current scenario	0.57	0.57	0.58	0.58	1
Tuscany Hills french drains/infiltration gallery	Groundwater redistribution, net zero balance	0	0	0.00	0.00	
Phreatophyte ET	ET rates from Devitt (2006) (38 to 119 ac-in/yr) applied to future estimated salt cedar coverage of 10 acres total	0.044	0.137	0.09	0.09	2
	Total sinks, future	1	64	32.71	32.71	
	Water balance (sources – sinks), future	9	3	6.08	0.00	

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Appendix A

Response to NDEP Comments Dated March 28, 2008

Appendix A. Responses to Nevada Division of Environmental Protection (NDEP) Comments, dated March 28, 2008, to *Technical Memorandum: Sources/Sinks and Input Parameters for Groundwater Flow Model,* dated March 4, 2008, NDEP Facility ID# H-000688.

1. General comment, in general, the water budget as presented in the text and Tables 1, 2, 3, and 4 is well organized and thought out. The water budget provides a good first step in developing a conceptual understanding of the inflows and outflows from the area to be modeled.

Response: *Comment noted and appreciated.*

2. General comment, please edit all references to KMC to be Tronox, as appropriate.

Response: *The requested edit has been made in the revised technical memorandum.*

3. General comment, throughout the report information is provided for reference but no information (*i.e.*, numbers or results) is supplied to give the reference meaning. Refer to specific comments below.

Response: *Calculated values will be cited in the revised technical memorandum.*

4. General comment, although not intended to be part of this document there is a potential issue that remains to be addressed that involves the horizontal discretization; perhaps this is part of what was intended in Section 4.1.2 and discussed below.

Response: *It is BRC's belief that the proposed horizontal discretization of approximately 1 acre proposed in the Groundwater Modeling Work Plan is appropriate, as indicated in a conference call with NDEP. However, BRC will address additional or continuing NDEP concerns and suggestions if necessary. Section 4.1.2 of the technical memorandum is not intended to adjust horizontal discretization; the intent of the work described in Section 4.1.2 is to determine the relative areas of land cover types that lie within a given grid cell and to adjust input values (e.g., recharge) appropriately.*

5. General comment, a brief statement regarding the potential boundary type assignments (e.g., General Head Boundary) for each hydrologic component, in each respective section, would be useful, including uncommon MODFLOW packages (e.g., River Package, Drain, etc.).

Response: *The technical memorandum has been revised, in a number of separate locations, to address this comment.*

6. General comment, presented source and sink values vary widely in terms of quality, as well as magnitude. Ranking each source/sink in Table 4, with respect to quality may help to guide model progression and calibration. Values that were derived from field observations or sample results may be considered of high quality, versus estimates calculated from empirical models, etc.

Response: *As requested, the sources and sinks in the water balance table (now Table 5) have been approximately ranked according to data quality, based on how the value was derived (observed/measured vs. calculated/estimated).*

7. General comment, some comments regarding model assumptions, or presentation of information, are specified for Section 2 (historical scenario), however, are implied for consideration of similar water budget components and treatment in Sections 3 and 4 (current and historical scenarios).

Response: *Comment noted. As appropriate, model assumptions will be clarified for each scenario in the revised technical memorandum.*

8. List of Attachments, please note that attachment number six was not included in the list.

Response: *Attachment six will be included in the revised Tech Memo. (Attachment six [the current plan for future site development, referred to as Appendix G in the revised technical memorandum] was included as the last page in the PDF submittal but it was erroneously not included in the list of attachments.)*

9. Section 2.1.1, page 2, 1st paragraph, referred segments L1, L2 etc should be labeled on Attachment 1. Or ideally, a map and cross section showing the model domain, and indicating each model boundary "reach" assignment (boundary condition type and values).

Response: *The revised technical memorandum includes a figure (second page of Appendix B) illustrating referenced segments L1, L2, etc., as requested. Final model boundaries and boundary condition types will be presented in the modeling report.*

10. Section 2.1.1, page 3, 1st sentence. BRC states "The values used in each calculation and the resulting Q values are shown in Table 1." BRC should present the results from their calculations.

Response: *Referenced values will be presented in the text of the revised technical memorandum as requested.*

11. Table 1 and other tables report a relatively wide range of max/min values (often 2 to 4 orders-of-magnitude), due to the wide range of hydraulic conductivity (K) values. For consideration, a kriged map of K may be useful to generate a "best estimate" K for each boundary segment, versus the average values used in Table 4. Otherwise, the use of geometric mean Ks may produce substantially different results.

Response: *A wide range of K values varying over orders of magnitude is expected and reflective of the hydrogeologic conditions at the Site. The data density is not sufficient, nor is the distribution of data appropriate, to develop a reliable kriged map of K values. For example, kriging will not adequately account for changes in K expected to occur in conjunction with changes in geology (e.g., paleochannel versus inter-channel regions). Geometric means were calculated for the range of K values; however, the total values for the sources and sinks did not balance as well as the averaged values used in the water balance (larger adjustments were needed to achieve a balance). As a result, the original averaged values were considered more applicable and are retained in the tables.*

12. Section 2.1.2, page 3, 1st and 2nd paragraph. BRC states "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." Comment the same as above; without providing results here, the reference to Westphal and Nork has little meaning.

Response: *The referenced values will be presented in the text of the revised technical memorandum.*

13. Section 2.1.2, page 3. It is noted that total ditch seepage exceeds lateral inward flow by an order of magnitude, and exceeds pond seepage by a factor of two. Please explain if this is this the expected result, with regards to the CSM. Tighter qualification and control for this parameter may provide the most benefit for the model.

Response: *See response to comment 14. K_v values and widths have been re-examined for the ditches and drainage swale. The resulting comparison of total ditch seepage, lateral inward flow, and pond seepage is now more realistic. Recent groundwater monitoring data have demonstrated significant monitoring well water level sensitivity to RIB use. In other words, when the RIBs are filled and in use, the well water levels rise. It is presumed that the same correlation would have historically applied to the unlined effluent ponds. Further, the revised seepage values now correlate better with the respective feature acreage.*

14. Section 2.1.3, page 4, last paragraph of the section. BRC states "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)." The NDEP recalls that BRC earlier developed an analytical model that indicated that this was not possible in that heads required to inject this volume of water would have been above ground surface. Please explain if something has changed that makes this more feasible now.

Response: *BRC appreciates this comment, and NDEP is correct. We believe that when the model is constructed and calibrated, it will be necessary to use upper pond seepage rates significantly lower than those provided in Westphal and Nork (1972). However, Westphal and Nork (1972) is one of the few detailed historical references, so information from the report has been considered in the technical memorandum, with adjustments to follow if and as required. For example, certain conditions can be incorporated into the numerical model that could not be simulated in the analytical model, so it is possible, or even likely, that the ultimate rates of simulated infiltration will be different (and possibly greater) than those determined in the analytical modeling.*

15. Section 2.1.4, page 4. Has BRC investigated the invert elevation of the swale and compared this to the mounding estimated? Is it possible that the swale acted as a drain due to its depth and close proximity to the Upper Ponds? Special attention should be paid to initial model heads in that vicinity with respect to the bottom of the swale, which is greater than 25 feet below grade in some locations.

Response: *In addition to consideration of the drainage swale as a periodic seepage source, BRC proposes to treat the swale as a drain boundary in the model, so that groundwater can exit the top layer of the model to the swale if simulated water levels are greater than the base elevation of the swale.*

16. Section 2.1.5, page 4. Unless there are hydraulic heads in Qal monitoring wells measured below the stage of the Wash, seepage to the alluvium (as a source) is not a viable term. Also, this calculation assumed a unit vertical gradient (essentially purely vertical flow), which is highly unlikely between the wash and Qal groundwater. The Las Vegas Wash is considered the hydraulic low for the model domain, and is correctly represented as a sink in Section 2.2.1. If Qal/gravels of the LV Wash (i.e., below the active channels) are included within the model domain, then the Wash as a source should be calculated as lateral inflow along the axis of the Wash only. Please consider if this area is addressed adequately in Section 2.1.1.

Response: *Upon detailed consideration of this and other comments (e.g. Comments 17, 25 and 33), BRC proposes to adjust the northern boundary of the groundwater flow model to occur at the approximate location of the contact between the Qal and the Las Vegas Wash alluvium/gravel. At this location, a third-type boundary condition (e.g. MODFLOW GHB package) would be used to simulate groundwater outflow from the model domain into the wash gravel, which essentially acts as a drain for the aquifer system to the south that lies beneath BRC. The boundary head applied will be the approximate average water level within the wash (current and predictive scenarios) or the estimated historical water level within the wash gravel/alluvium if there is no surface water (historical scenario). The conductance term will be estimated based on the thickness of the wash gravel/alluvium and its estimated hydraulic conductivity. The technical memorandum has been updated to provide an estimate of this boundary outflow term. This approach avoids many of the potential complexities associated with extending the model domain to the center of the wash as reflected in NDEP's comments, and is consistent with BRC's stated approach that the groundwater flow model is not intended to provide a detailed simulation framework of groundwater flow or solute transport within the Las Vegas Wash.*

17. Section 2.1.5, page 5. BRC states "…wash seepage could be calculated using head differential between the wash surface water and groundwater…". Depending on the MODFLOW package used to simulate this boundary, and the wash stage values used, this boundary could be simulated as alternating source and sink along its length. When inputting these head results to drive a transport model, care must be taken to insure that the code correctly conserves mass (i.e., that mass leaving the model domain along a wash gaining reach is also simulated to re-enter the model domain along a downstream wash losing reach).

Response: *See response to Comment 16; by adjusting our simulation approach and boundary conceptualization for the northern portion of the model, this potential complexity is eliminated.*

18. Section 2.1.6. It is noted that precipitation represents about 1/10 of one percent of the total historical sources. The values for this component of the hydrologic budget is low based on magnitude and quality (empirically derived).

Response: *Comment noted.*

19. Section 2.1.6, 3rd paragraph, page 5. BRC states "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)." Please explain this reference context. Also, please explain why the Boulder City pan evaporation rate was chosen versus Las Vegas (which is significantly less).

Response: *The reference to pan evaporation rates was removed from this section in the revised technical memorandum. Boulder City data (readily available during preparation of the draft technical memorandum) have been replaced with Las Vegas area data in Sections 2.2.4 and 2.2.5 regarding seeps.*

20. Section 2.1.7. The treatment of leakage between the Qal and TMC does not appear to consider areas of zero flux, but is rather treated in all areas as either a source or sink. Is this appropriate? As presented, this source term is among the largest (along with ditch seepage); it is therefore among the most important to qualify and control. Please explain if there is enough (current) data to krig and class the vertical gradient. This type of approach may yield substantially different results.

Response: *There are currently nine shallow/deep well pairs at the site where vertical head data can be measured at the same location (Table 3). These data show that heads are either up or down and appear representative of site conditions. Currently no data indicate that areas of zero flux are present at the Site. The existing data are not dense enough (or regularly aligned enough) for high-quality kriging. The magnitude of upward vertical leakage from the TMC to the Qal appears appropriate based on currently available data.*

21. Section 2.2.1. BRC states "A similar calculation will be prepared for lateral flow … within TMC..". Unless the TMC is being explicitly simulated (i.e., a separate model layer), then

this is not a viable budget term. Any contribution from the TMC will be handled as vertical leakage.

Response: *The new Table 2 presents the lateral flow calculations for the upper portion of the TMCf. Vertical leakage calculations were completed using deep zone TMCf wells (Table 4). As originally stated in the Groundwater Modeling Work Plan, BRC does propose to simulate the upper portion of the TMCf (approximately the upper 20 to 30 feet) as a second model layer, in addition to the Qal.*

22. Section 2.2.3. McGinley and Associates 2003 values represent remediation engineering-modified conditions (i.e., Athens Road and seep area pumping, RIB infiltration, etc.). Please discuss if historical conditions would differ substantially. If so, a different range of values for seep flow might be considered.

Response: *There are no available historical data to evaluate whether or not the historical conditions are different than those cited in McGinley and Associates (2003). These parameters can be adjusted if data or credible estimates become available.*

23. Section 2.2.4, 1st paragraph, page 8. BRC states "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." This assumes that there was no overland flow from the seep area. This is okay if supported by aerial photograph examination. Specific attention should be paid to model head calibration in this area.

Response: *Comment noted. Aerial photographs were examined, and no evidence of overland flow out of the model domain appears to be present in the photos. Head calibration will also be carefully completed for this seep area during the numerical modeling phase of the project.*

24. Section 2.2.4, please note that NDEP provided quantified data regarding seep flows at the Weston Hills property. This should be incorporated into the revised document

Response: *Information from Converse (2006) regarding seep flow in an excavation near Weston Hills has been added to the revised technical memorandum Section 2.2.4 for reference.*

25. Section 2.2.5. Please note that McGinley and Associates 2003 did not refer to any seeps in the eastern wash fault zone.

Response: *The draft technical memorandum presented an initial estimate of seep area based on the eastern wash area described in McGinley and Associates (2003). Section 2.2.5 in the draft was referring to the following text in the McGinley and Associates document (Section 1.1, third paragraph):* "Groundwater flowing through the wash encounters a series of fault structures at the east end of the subject study area, daylights, and combines with surface water flow…" *The document also states (Section 2.2, page 4),* "Primary groundwater outflow from the system is conceptualized as discharge to the Wash channel at the fault zone on the east side of the site."

However, the characterization of wash flow in Section 1.1 is not referenced and does not appear to be supported by data presented in the document. In addition, historical aerial photographs do not appear useful for seep flow estimates in the wash area (surface flow and seep flow is not readily discernible). As a result, the value for historical seep flow in the wash, for the purposes of the water balance, will be set to zero unless historical seep data is available for use in the water balance. In addition, wash seep areas are outside of the revised model domain (see response to Comment 16) and will not be included in the water balance.

26. Section 2.2.6. Please discuss how deep saltcedar roots typically extend. Also, please discuss the areal coverage for saltcedar. Please note that this ET coverage should not be applied to areas where groundwater is measured or simulated to be beyond the root zone. Might this hydrologic component may be used better as a modifier for precipitation?

Response: *According to Baum (1978), salt cedar roots extend up to 30 meters below grade (98.4 feet). This depth is greater than the historical depth to water data presented by Westphal and Nork (1972) (Appendix C). Thus, groundwater did not limit salt cedar growth or areal coverage at the Site (discussed in Section 2.2.6 of the revised technical memorandum).*

27. Section 3.1.1, page 10. BRC states "The estimated value for lateral groundwater flow is presented in Table 1." Please provide a summary number in the text and refer the reader to the Table for more detail.

Response: *The cited values will be presented in the text of the revised technical memorandum.*

28. Section 3.1.3. BRC states "Seepage from … ponds… is assumed to be negligible." Other negligible values are also presented herein. NDEP recommends calculating and presenting some value here.

Response: *An estimated value for TIMET pond seepage is presented in the revised Section 3.1.3 and Table 5.*

29. Section 3.1.4, page 11. Please obtain the information from Tronox.

Response: *The Tronox on-site infiltration trenches (and on-site groundwater extraction system) are not included in the model domain, so this feature has been removed from the water balance. The Tronox groundwater extraction systems at Athens Road and at the Tronox Seep area are within the model domain and remain in the water balance. The technical memorandum has been revised to clarify these features.*

30. Section 3.1.4, please note that the injection trenches are at the Tronox Plant Site not at Athens Road.

Response: *Comment noted; the technical memorandum has been revised to clarify this feature. See also response to Comment 29.*

31. Section 3.1.8, 2nd paragraph, page 12. BRC states "Cheong (1991) estimated that unaccounted for water (exfiltration) accounts for approximately 20 to 30% of supplied volume." This issue was previously discussed and NDEP provided a reference that was perhaps a bit closer geographically if not climatically. Based on the Report of Referee (SWRB, 1962) the Upper Los Angeles River Area (ULARA) Watermaster assumes that 20% of the delivered water in Burbank, Glendale, and San Fernando is returned to the groundwater system. Also, BRC developed an analysis of potential leakage from municipal water supply and waste water infrastructure; please discuss how this number compares.

Response: *The ULARA reference is cited in the revised technical memorandum with information from the BRC leakage analysis completed in 2003.*

32. Section 3.2.6, 1st paragraph, page 15. BRC states "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…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." This section appears a bit confusing, is the water discharged to surface water, if so, then the water would be discharged from the model. Also, this information should be readily available from the NDEP's Bureau of Water Pollution Control.

Response: *The operation of the Tuscany drains and infiltration gallery has been clarified with information from NDEP, and this information has been added to the revised technical memorandum.*

33. Section 4.1, 1st bullet, page 16. BRC states "Las Vegas Wash Seepage to Alluvium. This parameter may change as heads in the Qal and in the wash change." What about the planned changes in discharge to Las Vegas Wash by the various municipalities. Over time the total surface water flow in the wash will be significantly less than it is at this time.

Response: *Comment acknowledged. The Las Vegas Wash is outside of the revised model domain and will not be included in the water balance (see response to Comment 16).*

34. Section 4.1.1, please note that all of the City of Henderson RIBs are going out of service in the near future (except the Birding Preserve). This information and the pertinent flow rates can be obtained from the City.

Response: *The text has been revised to clarify that the RIBs will not be used in the future and the estimated value applies only to the birding preserve lagoons. For reference, a flow rate into the lagoons (9.5 mgd) was obtained from an NDEP fact sheet discussing the preserve and this information has been added to the revised technical memorandum.*

35. Section 4.1.2, 1st paragraph, page 17. BRC states "These areas will be estimated and delineated during numerical model domain construction." There are two issues in regards to this statement: 1) the NDEP understood that the model domain was previously established, and 2) the model domain previously mapped needs to be evaluated. Perhaps the latter is what is/was intended herein.

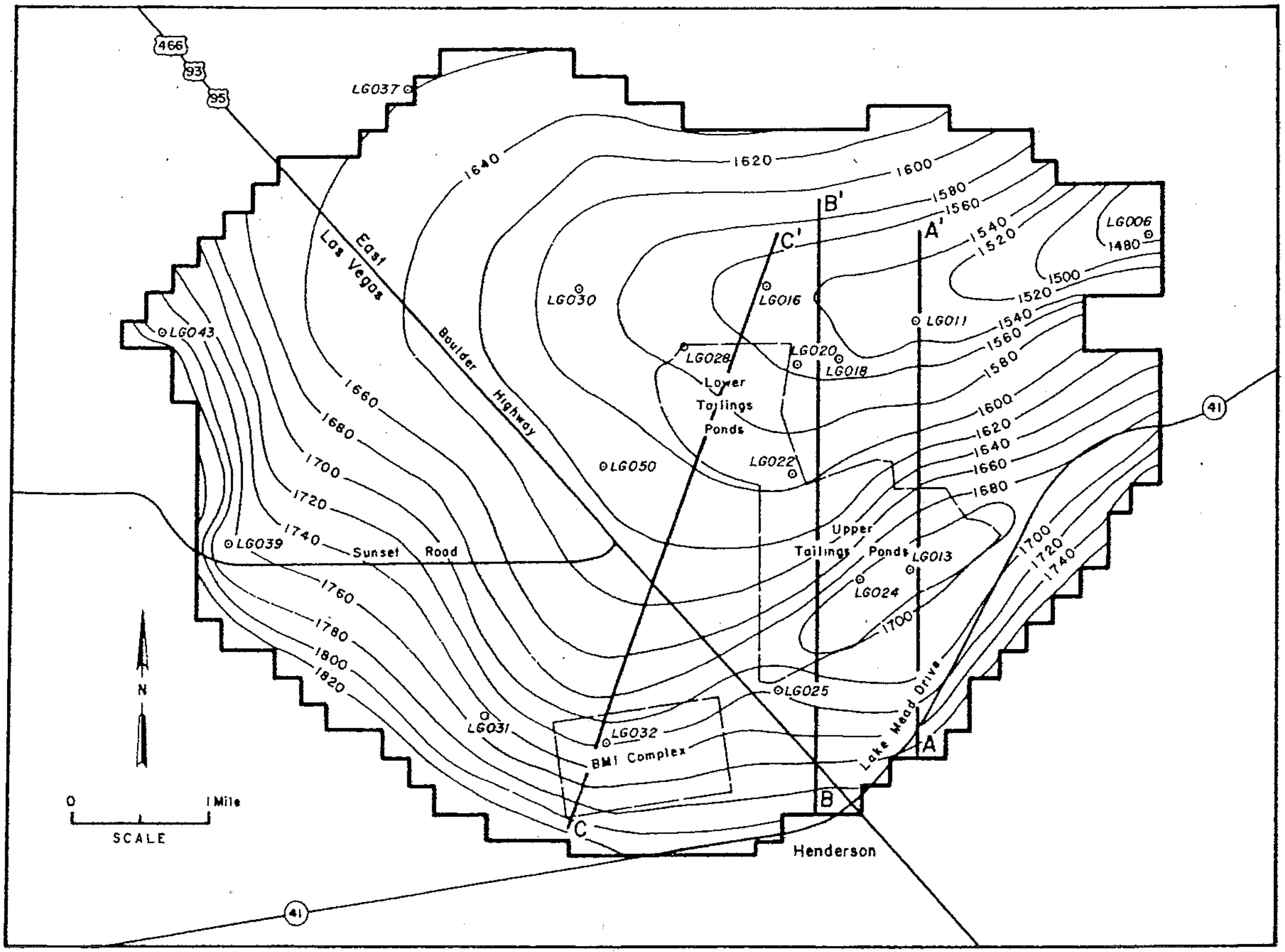
Response: *The referenced statement does not refer to changes in the proposed modeling domain; it refers only to the process of determining various areas associated with certain land use or cover type in the future and to the incorporation of the anticipated changes into appropriate model inputs such as recharge. The word "domain" has been deleted from the technical memorandum avoid confusion caused by this statement.*

36. Tables 1 through 4 were reviewed and are attached for information purposes. Based on the NDEP's understanding of the hydrogeologic setting, adjustments were made to Table 4, *e.g.*, discharge from Las Vegas Wash to groundwater was removed from the water balance. These adjustments are not intended to be an NDEP recommended water budget. Rather, the NDEP recommends that BRC further evaluates the water budget and obtains information from the City of Henderson, Tronox, etc. and refine the analysis.

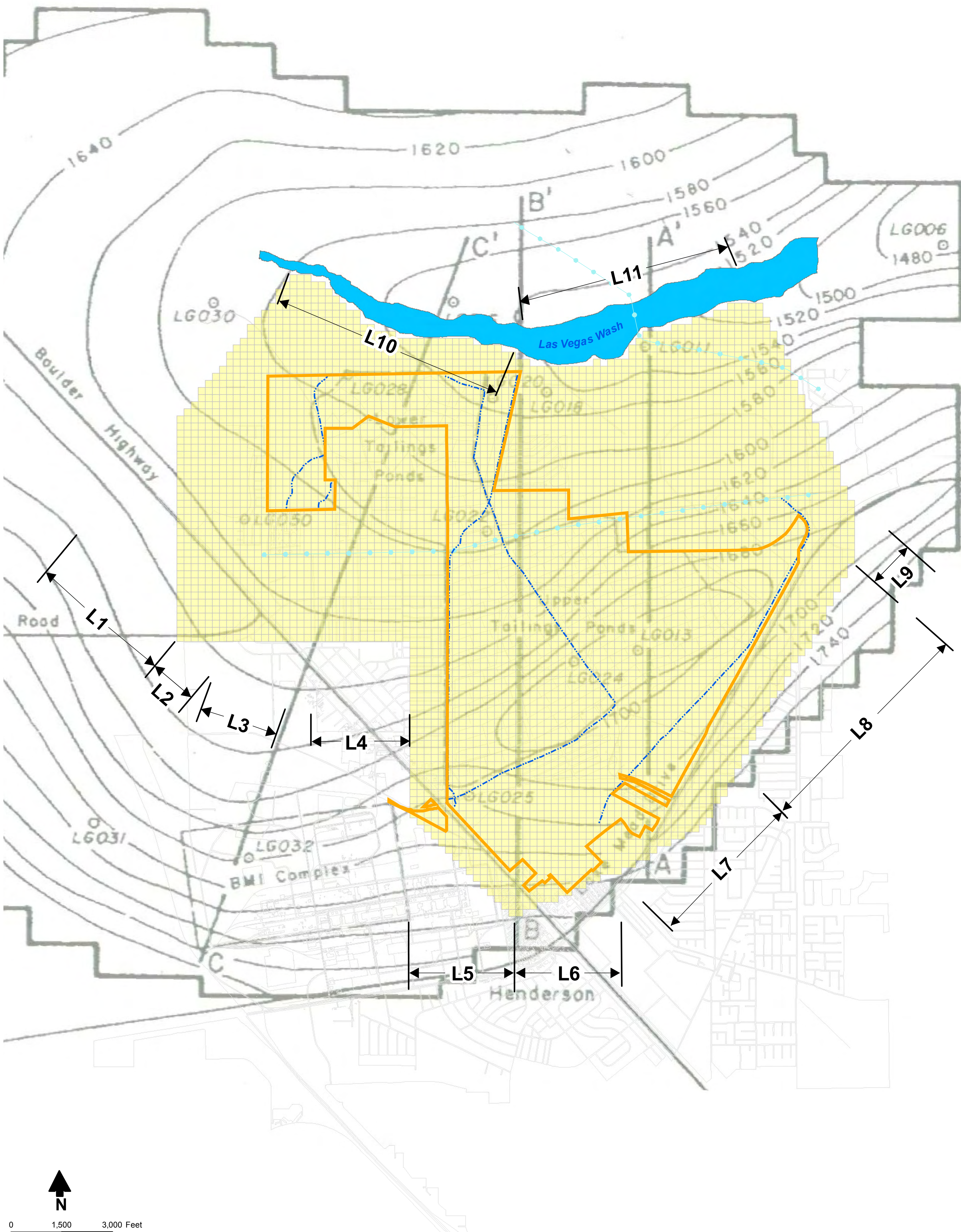
Response: *Comment noted - a refined analysis is included in the revised technical memorandum.*

Appendix B

Groundwater Flow Map
(Westphal and Nork, 1972)


466
93
95
East Las Vegas
Boulder Highway
LG037
LG030
LG016
LG011
LG006
LG043
LG028
LG020
LG018
LG022
LG050
LG039
LG013
LG024
LG025
LG031
LG032
Lower Tailings Ponds
Upper Tailings Ponds
BMI Complex
Sunset Road
Lake Mead Drive
Henderson
41
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/ES07.0252_BRC_GROUNDWATER_MODELING/GIS/MXDS/HISTORICAL_CONTOURS_WITH_PROP_MODEL_DOMAIN.MXD



Explanation

- Monitoring well
- Ditches
- Laterals
- Water level contour (dashed where inferred)
- Site AOC3 boundary
- Site boundary
- Active model domain
- L1 Lateral inflow boundary

BMI Common Areas (Eastside)
Henderson, Nevada

HISTORICAL CONTOURS WITH PROPOSED MODEL DOMAIN

Basic Remediation Company

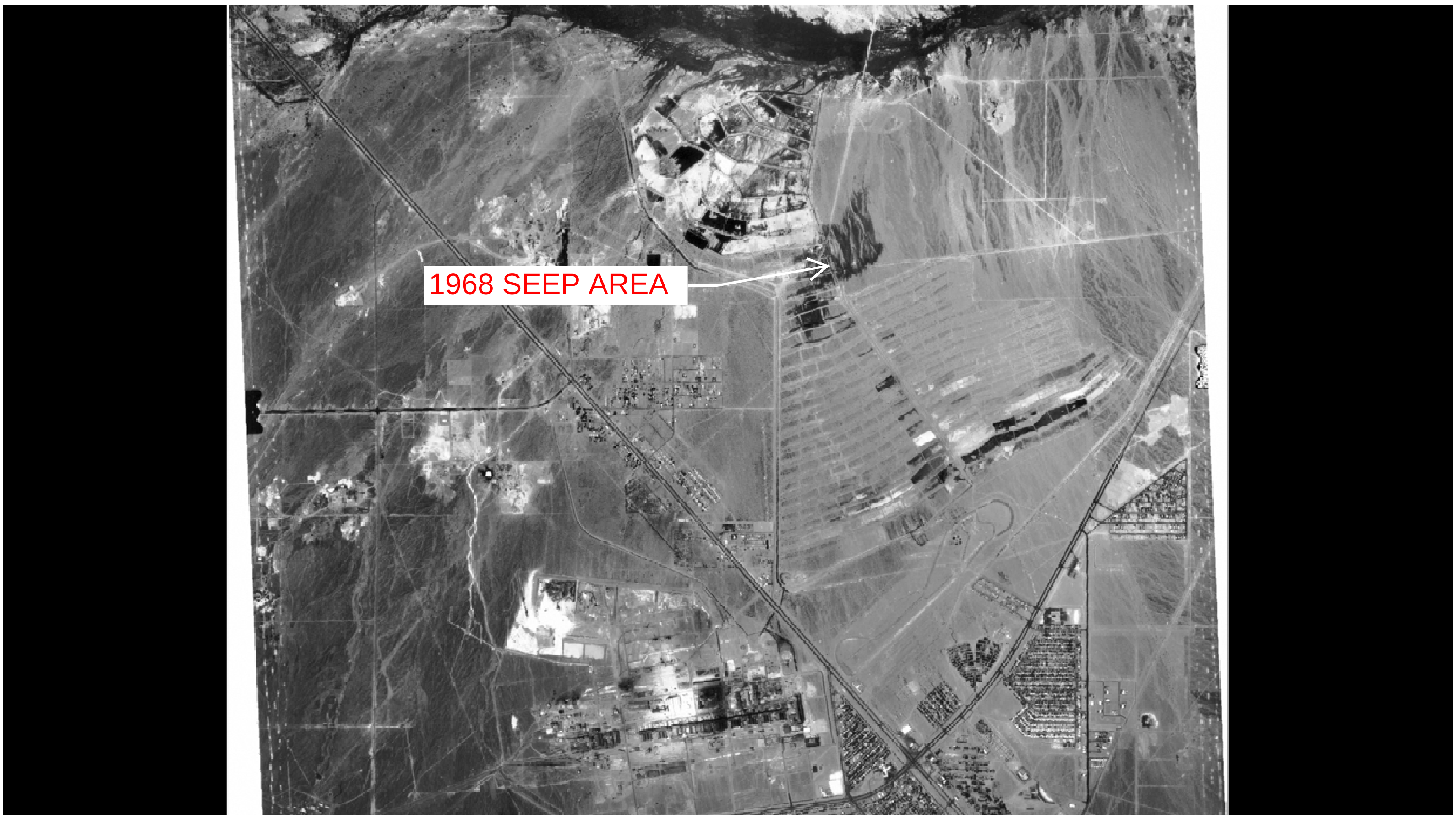
Prepared by: HMM (DBS&A)

Date: 4-21-08

Daniel B. Stephens & Associates, Inc.

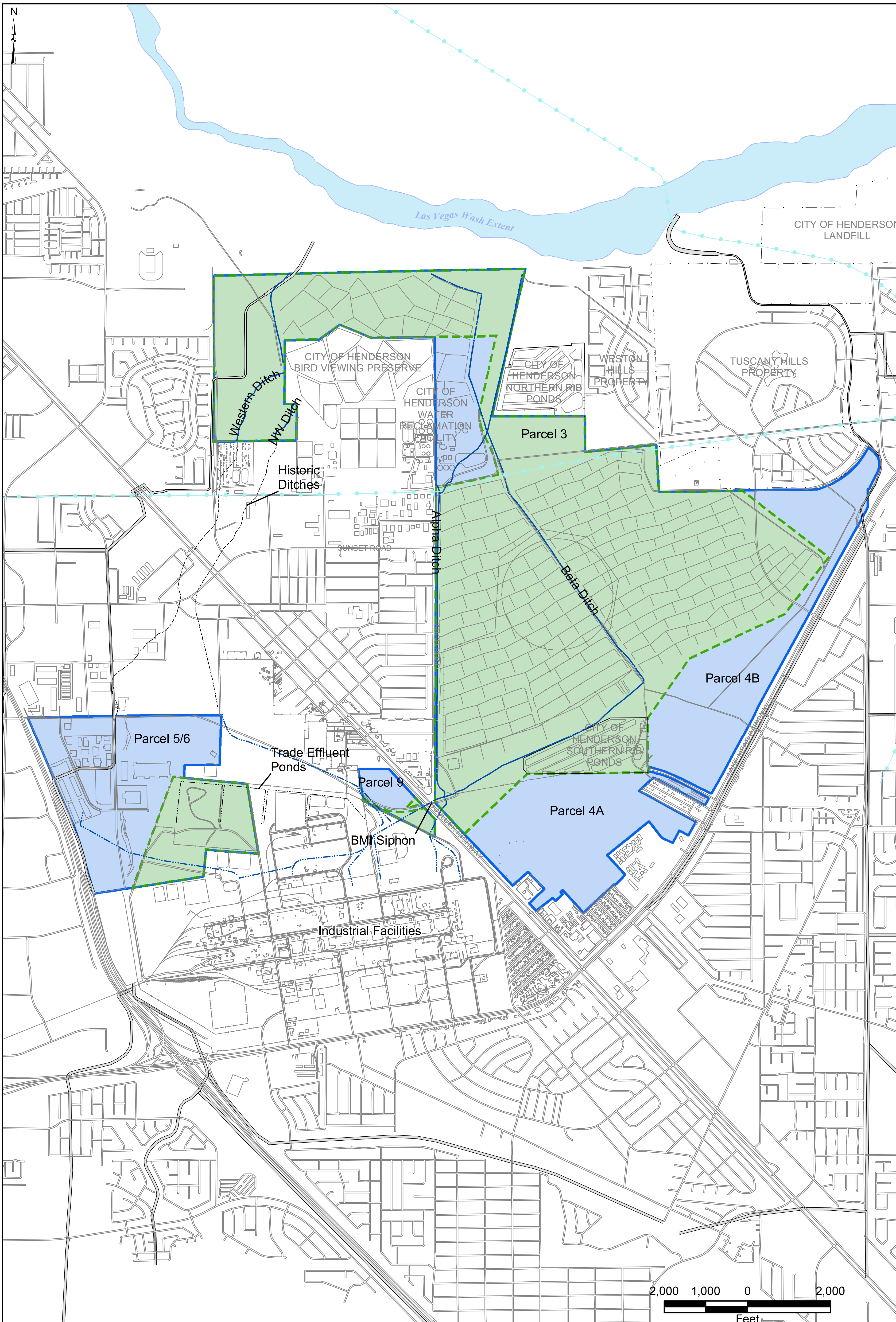
Appendix C

1968 Aerial Photograph of Site Area


1968 SEEP AREA

Appendix D

Project Map
(with Ditches)



- Site Soil Boundary
- Site AOC3 Boundary

BMI Common Areas
Clark County, Nevada

FIGURE 1-3

PROJECT MAP

Basic Remediation COMPANY

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

Appendix E

Literature Recharge Values
(Scanlon et al., 2006)

HYDROLOGICAL PROCESSES
Hydrol. Process. **20**, 3335–3370 (2006)
Published online in Wiley InterScience
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Global synthesis of groundwater recharge in semiarid and arid regions

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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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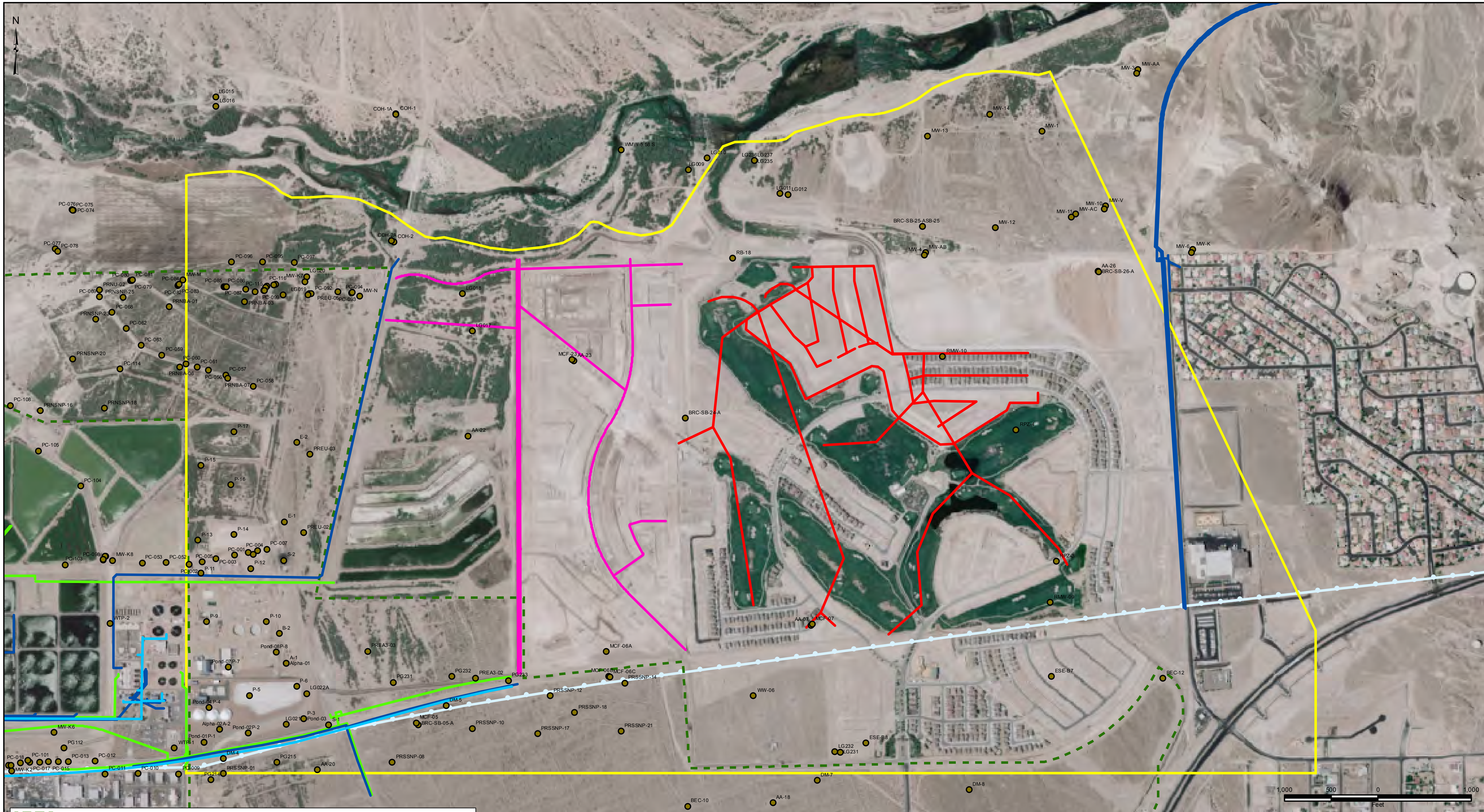
Appendix F

Subdrains and Pipes in Tuscany/Weston Hills Area



- 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

Source: Modified from MWH by DBS&A

Date 4/22/08

FILE: S:\Projects\BRC\ES04.0212_BRC_Commons_Area\Adobe Acrobat PDF\John_Dodge_4-22-08\Subdrains_and_pipes.pdf

Appendix G

Future Development Plan