

Attachment A

Further Evaluation of Soil Leaching to Groundwater

1.0 Introduction

The Nevada Division of Environmental Protection (NDEP) developed Basic Comparison Levels (BCLs) for use at the BMI Complex and Common Areas in Henderson Nevada (NDEP, 2009). The BCLs were generated as a technical screening tool to assist users in risk assessment components such as the evaluation of data usability, determination of extent of contamination, identifying chemicals of potential concern, and identifying preliminary remediation goals (NDEP, 2009). The User's Guide and Background Technical Document (NDEP, 2009) provides leaching-based BCLs (LBCLs) for organic and inorganic chemicals and eight radionuclides. These LBCLs are developed specifically for the soil leaching to groundwater migration pathway, and for certain constituents, are lower than BCLs for other potential exposure pathways (*e.g.*, direct contact via inhalation, dermal contact, or ingestion of soil). The LBCLs in NDEP, 2009 were calculated based on the United States Environmental Protection Agency (U.S. EPA) Soil Screening Guidance (U.S. EPA, 1996a) default values for soil physical properties. Also consistent with U.S. EPA (U.S. EPA, 1996a), LBCL values were presented in the NDEP, 2009 guidance for dilution attenuation factor (DAF) values of 1 and 20.

The purpose for this guidance is to provide a rationale and methodology for further evaluation of the soil leaching to groundwater pathway using the soil-water partition (SWP) equation with site-specific parameters, unsaturated zone fate-and-transport models, and the synthetic precipitation leaching procedure (SPLP) (U.S. EPA, 1994). Proper use of these methods with adequate site-specific data result in site-specific estimates of soil concentrations (leaching-based site-specific levels [LSSLs] considered to be protective of the leaching-to-groundwater pathway for the site under evaluation. In the course of implementing the methods outlined in this guidance, the NDEP recommends the following progression:

1. LBCLs (NDEP, 2009) which employs a simple linear equilibrium equation with generic default values (U.S. EPA, 1996a and 1996b) for input parameters to the SWP equation with site-specific data;
2. LSSLs which substitute site-specific data for the conservative, default input values;
3. Unsaturated zone fate-and-transport modeling, also, employing site-specific data; and
4. SPLP testing as required to support either the SWP equation or unsaturated zone fate-and-transport modeling.

Each one of the methods is detailed in separate Sections below. The SWP equation can be modified using site-specific soil physical and chemical parameters and the dilution attenuation factor (DAF) calculation can be adjusted for local precipitation and/or recharge conditions. Unsaturated zone fate-and-transport models can be used to account for contaminant distribution in the unsaturated zone, attenuation processes including sorption, volatilization, degradation, cation exchange, hydrolysis, and metal complex formation. The NDEP has adopted SESOIL as the default unsaturated zone fate-

and-transport model. The SPLP is another method that may be used to evaluate impact to groundwater from on-site soils.

Please note that Basic Remediation Company (BRC), Montrose Chemical Corp of CA, Olin Corporation; Pioneer Companies, Inc., Stauffer Management Co, LLC, Titanium Metals Corporation, and Tronox, LLC are referred to herein collectively as “the Companies.”

1.1 Limitations of Guidance

In the process of developing guidance for the soil leaching-to-groundwater pathway for use at the BMI Complex and Common Areas in Henderson, Nevada the NDEP reviewed the U.S. EPA Soil Screening Guidance and Technical Background Document (U.S. EPA, 1996a and 1996b) and guidance documents from five states including the Hawai’i Department of Health (2007), Minnesota Pollution Control Agency (1998), Michigan Department of Environmental Quality (2004), New Jersey Department of Environmental Protection (2008a, 2008b, and 2008c), Ohio Environmental Protection Agency (2002), and Wisconsin Department of Natural Resources (2003).

The SWP equation approach assumes that the soil column is contaminated from land surface to the water table. The SESOIL model and SPLP tests are to be used where there is uncontaminated soil between the source area and water table and therefore should not be used in areas where there is known contamination between the source area and the water table. There are areas within the BMI Complex and Common Areas where there are documented releases from above-ground or underground sources that have documented impacts to groundwater. This guidance may not be applicable for these areas and this matter should be discussed with the NDEP. This guidance attempts to identify the key issues associated with the use of unsaturated zone models and leaching tests for developing LSSLs protective of groundwater.

The NDEP recognizes that contaminant fate and transport in the unsaturated zone is complex. Thus, the NDEP recommends that the Companies review the appropriate references before employing these methods at the BMI Complex and Common Areas.

This guidance is designed for use at the BMI Complex and Common Areas in Henderson, Nevada. The applicability of this guidance should be verified prior to use at any other site. NDEP also reserves the right to change this guidance at any time without public notice. The guidance set out in this document is not final NDEP action. It is neither intended to nor can it be relied upon to create any rights enforceable by a party in litigation with the state of Nevada.

2.0 SWP Equation

The U.S. EPA (U.S. EPA, 1996a) SWP equation calculates the concentration of contaminant that may remain in soil so that the aqueous phase concentration of a contaminant will not exceed a risk-based groundwater concentration (RBGC) such as non-zero MCLGs, MCLs, or other risk-based screening levels. The migration of contaminants from soil to groundwater is modeled in two steps: (1) release of contaminant in soil leachate; and (2) transport of the contaminant through the soil to groundwater (U.S. EPA, 1996b). The SWP equation assumes that contaminants in soil exist in equilibrium between the soil matrix (sorbed), aqueous (soil pore water), and vapor (soil gas) phases.

A dilution attenuation factor (DAF) is included in the equation because soil water becomes diluted once it enters groundwater. However, the SWP equation does not account for attenuation process such as degradation, cation exchange, hydrolysis, and metal complexation (*i.e.*, biological or chemical degradation) during transport through the unsaturated soil zone. Further discussion of the simplifying assumptions for the migration to groundwater pathway is provided in the Soil Screening Guidance Technical Background Document (U.S. EPA, 1996b).

2.1 SWP Equation with Site-Specific Parameters

LSSLs for the BMI Complex and Common Areas may be calculated by replacing the LBCL default input parameters (Table 1) in the SWP equation with site-specific soil physical and chemical properties. The default DAF may be adjusted on a site-specific basis by modifying several input parameters.

The use of site data to modify default input parameters in the SWP equation will likely generate higher LSSLs that are still protective of groundwater for a given site. Some input parameters will have a greater effect on raising the LSSL than others. In particular, higher groundwater flow rates, lower infiltration rates, and for metals higher soil pH will have the greatest effect on increasing the LSSL when using this method.

2.1.1 Soil-Water Partition Equation for Inorganic Contaminants

$$C_t = RBCG \times DAF \left(K_d + \frac{\theta_w + \theta_a H'}{\rho_b} \right) \quad \text{Equation 1}$$

Input parameter descriptions and NDEP approved default values for the SWP equation (U.S. EPA, 1996a) are listed in Table 1.

The K_d values for metals are affected by a variety of soil and groundwater conditions including, but not limited to: pH, oxidation-reduction conditions, iron oxide content, soil organic matter content, cation exchange capacity, and major ion chemistry (U.S. EPA, 1996b). U.S. EPA Soil Screening Guidance (1996a) provides pH-specific K_d coefficients for a selected listed of metals including silver (Ag), barium (Ba), beryllium (Be), cadmium (Cd), chromium⁺³ (Cr⁺³), copper (Cu), mercury (Hg), nickel (Ni), and zinc (Zn). Site-specific soil pH measurements should be used to select appropriate K_d values for these metals. K_d values derived by the U.S. EPA MINTEQ2 modeling and empirical relationships for selected metals can be located in the Soil Screening Guidance (U.S. EPA, 1996a) and Technical Background Document (U.S. EPA, 1996b). The conceptualization, measurement, and use of the K_d coefficient and geochemical aqueous solution and sorbent properties that are most important in controlling adsorption behavior of selected contaminants is discussed in a two volume report by the U.S. EPA (1999a and 1999b). Volume II of this series presents K_d values for cadmium (Cd), cesium (Ce), chromium (Cr), lead (Pb), plutonium (Pu), radon (Rn), strontium (Sr), thorium (Th), tritium, and uranium (U).

2.1.2 Soil-Water Partition Equation for Organic Contaminants

$$C_t = RBGC \times DAF \left[(K_{oc}f_{oc}) + \frac{\theta_w + \theta_a H'}{\rho_b} \right] \quad \text{Equation 2}$$

For organic chemicals when f_{oc} is greater than 0.1% the distribution coefficient (K_d) is:

$$K_d = K_{oc}f_{oc} \quad \text{Equation 3}$$

If the f_{oc} is less than 0.1%, then sorption to mineral surfaces begins to be significant and it is not automatic that soil or aquifer organic carbon will be the primary surface onto which organic contaminants sorb (U.S. EPA, 1996b and Fetter, 1993). When f_{oc} is less than 0.1% and the soils contain a significant quantity of fine grained material, then Equation 3 will tend to over predict contaminant concentrations in soil leachate (U.S. EPA, 1996b).

Chemical specific values for K_{oc} are found in U.S. EPA Soil Screening Guidance and Technical Background Document (U.S. EPA, 1996a and 1996b).

Table 1: Definitions and Assumptions for the SWP Equation			
Parameter	Description	Units	Default
C_t	Screening level in soil	mg/kg	Chemical specific
RBGC	Groundwater quality criterion (MCLG, MCL, or BCL)	mg/L	Chemical specific
K_d	Distribution coefficient	L/kg	Chemical Specific
K_{oc}	Soil organic carbon-water partition coefficient	L/kg	Chemical specific
f_{oc}	Fraction organic carbon	Dimensionless	0.002
θ	soil porosity [$1-(\rho_b/\rho_s)$]	Dimensionless	0.43
θ_w	Water filled soil porosity	Dimensionless	0.30
θ_a	Air filled soil porosity	Dimensionless	0.13
H'	Henry's Law constant	Dimensionless	Chemical specific
ρ_b	Dry soil bulk density	kg/L	1.5
ρ_s	Soil particle density	kg/L	2.65
DAF	Dilution attenuation factor	Dimensionless	Site specific

2.1.3 Dilution Attenuation Factor

As soil leachate moves through soil to groundwater, contaminant concentrations are attenuated by physical, chemical, and biological processes that tend to reduce the eventual contaminant

concentration at the receptor point (U.S. EPA, 1996b). The SWP equation methodology, however, addresses only the physical process of contaminant leachate dilution in groundwater. The reduction in concentration is expressed by a dilution attenuation factor (DAF) which is the ratio of contaminant concentration in soil leachate to the concentration in ground water at the receptor point (U.S. EPA, 1996b). The DAF model derived from a water-balance relationship assumes an unconfined and unconsolidated aquifer (U.S. EPA, 1996b).

Because of the uncertainty resulting from the wide variability in subsurface conditions that affect contaminant migration in groundwater, the U.S. EPA does not provide default values for inputs to the dilution model equations (U.S. EPA, 1996a). The U.S. EPA used their Composite Model for Leachate Migration with Transformation Products (EPACMTP) during selection of the default DAF (U.S. EPA, 1996b). Implementation of the EPA CMTP modeling including Monte Carlo simulation is discussed in the Technical Background Document (U.S. EPA, 1996b). Based on the EPACMTP modeling and weight-of-evidence approach a default DAF of 20 was selected as protective for contaminated soil sources up to 0.5 acre in size (U.S. EPA, 1996b).

NDEP (2009) LBCLs use default values for the DAF of 1 and 20.

The DAF and aquifer mixing zone equations have five parameters (Table 2) that may be estimated to calculate site-specific values: (1) source length, (2) infiltration rate, (3) aquifer hydraulic conductivity, (4) aquifer hydraulic gradient, and (5) aquifer thickness. The calculated aquifer mixing zone thickness cannot exceed the aquifer thickness (U.S. EPA, 1996).

Source length (ft) is the length of the source parallel to the direction of groundwater flow.

For undeveloped areas infiltration (I) from precipitation has been evaluated by the U.S. Geological Survey (Eakin, et al, 1951, 1976 and U.S. Geological Survey, 2007) for the southwestern United States and the Great Basin. Reviewing these reports for areas adjacent to and comparable to the Las Vegas Valley indicates that no more than 2% of precipitation should infiltrate to groundwater at undeveloped locations in the vicinity of the BMI Complex and Common Areas. The mean annual precipitation for Las Vegas is about 4.1 inches (NCDC, 2004). Thus, the default infiltration rate (I) for Equations 3 and 4 in undeveloped areas is 0.08 inches per year.

For either industrial or municipal developed areas of the BMI Complex and Common Areas in Henderson Nevada, the Companies must develop a site-specific infiltration rate (I) factor. The infiltration rate (I) factors must be supported via specific references applicable to the site, analytical calculations, or numerical model simulations to show how the factors were developed. The NDEP must approve the factor(s) prior to use. The NDEP will not approve impermeable cover in the development of the infiltration rate, *e.g.*, paving.

Aquifer hydraulic conductivity (K) values should come from on-site measurements including aquifer pumping tests and/or slug tests. All tests must be conducted in accordance with an NDEP-approved work plan.

Hydraulic gradient (i) values must come from on-site groundwater level measurements.

Aquifer thickness (d_a) must be supported by on-site borehole lithologic logs.

Dilution Attenuation Factor Equation

$$DAF = 1 + \frac{Kid}{IL} \tag{Equation 3}$$

Aquifer mixing zone depth

$$d = 0.0112L^{0.8} + d_a \left[1 - \exp\left(-\frac{LI}{Kid_a}\right) \right] \tag{Equation 4}$$

Table 2: Definitions and Assumptions for the DAF Equation		
Parameter	Description	Units
K	Aquifer hydraulic conductivity	ft/yr
i	Hydraulic gradient	Dimensionless
d	Mixing zone depth ($d \leq d_a$)	ft
I	Infiltration rate	ft/yr
L	Length of area of concern parallel to groundwater flow direction	ft
d_a	Aquifer thickness	ft

2.2.1 Site Data Collection Requirements

Determination of comprehensive physical properties for vadose zone soils is needed for site-specific evaluations of soil leaching to groundwater. A minimum of five subsurface soil samples must be collected and analyzed for physical and chemical properties that are representative of the soil type in the area of contamination and leaching pathway. The recommended geotechnical laboratory methods include:

1. Grain size – ASTM D422 & C117 (sieve & hydrometer analysis for fines less than No. 200 sieve);
2. Grain density – ASTM D854;
3. Soil dry bulk density – ASTM D2937; and
4. Soil moisture content (volumetric) – ASTM D2216.

Total porosity is calculated from the soil bulk density and the grain density.

A minimum of five soil samples must be collected and analyzed for the following:

1. Soil pH – ASTM D4972;
2. Fraction organic carbon (f_{oc}) – ASTM D2974, Test Method C (or equivalent method); and
3. Cation exchange capacity (CEC) – U.S. EPA SW-846, Method 9081, Cation-Exchange Capacity of Soils (sodium acetate).

Soil pH values are used for the determination of K_d values for metals and K_{oc} values for ionizing organic compounds. Fraction organic carbon is used to calculate the K_d for organic compounds using Equation 3. The CEC is an input to SESOIL modeling for metals transport in the unsaturated zone. The CEC is highly dependent upon soil texture, color, and organic matter content. The latter samples must be collected from uncontaminated soils or background areas (U.S. EPA, 1998). All samples shall be collected using an NDEP-approved work plan.

3.0 Unsaturated Zone Leaching Modeling

The NDEP reviewed the U.S. EPA Soil Screening Guidance and Technical Background Document (U.S. EPA, 1996a and 1996b), guidance documents from five states as discussed above for determining soil cleanup levels for the leaching pathway, and unsaturated zone leaching models to evaluate their applicability for use at the BMI Complex and Common Areas in Henderson Nevada. Based on this review and considering the range of soil contaminants (*i.e.*, organic and inorganic), the NDEP recommends the use of the SESOIL model for semi-volatile organic compounds (SVOCs) and inorganic contaminants, and VLEACH for volatile organic compounds (VOCs) when supported by a site-specific conceptual site model (CSM). Both SESOIL and VLEACH should be used only when clean soil exists between the soil contamination and the seasonal high water table. Prior to implementing SESOIL and VLEACH modeling the Companies must submit a work plan that includes a CSM.

The NDEP recognizes that the CSMs for the BMI Industrial Complex and BMI Upper and Lower Ponds area likely have three distinct phases: 1) operational, 2) post-operational to current time, and 3) future development. For example, the operational period of the Upper and Lower Ponds actively received waste water from the plant area; water with SRCs recharged groundwater. During this period downward vapor diffusion was most likely *de minimis*. During the post-operational to current time soil saturation beneath the ponds gradually decreased to current conditions. Downward vapor diffusion may have occurred. For future development the potential recharge from development would again as in operational scenario more likely be dominant than downward vapor diffusion. In developing CSMs for the BMI Industrial Complex the three phases must be considered in light of the modeling objectives and sources of contamination.

The Summers model (Summers et al., 1980) may be used to process the SESOIL and VLEACH model results. Alternatively, the Companies may propose the use of other models to process SESOIL and VLEACH model output results; but, these models must be approved by the NDEP prior to use.

3.1 SESOIL

SESOIL is a one-dimensional vertical transport and fate model for the unsaturated (vadose) zone. Numerous state regulatory agencies have selected the SESOIL model for the development of soil cleanup objectives. The SESOIL model accounts for variable flow, as a function of the average moisture content, and advective transport of contaminants through soil affected by sorption, volatilization, degradation, cation exchange, hydrolysis, and metal complex formation. The total mass of contaminant within each cell is partitioned among three phases: liquid (dissolved in water), vapor, and sorbed to solid surfaces. SESOIL produces a leachate concentration not a groundwater concentration. Depending on the version of SESOIL employed, the output contaminant concentration can be specified for selected depths versus time and/or selected time versus depth.

3.2 VLEACH

VLEACH is a one-dimensional finite difference model that simulates fate and transport of volatile organic compounds (VOCs) in the unsaturated zone (U.S. EPA, 1997). The fate and transport processes are simulated in a vertical polygon that is represented by a stack of cells with constant thickness that reaches from the land surface to the groundwater table. The soil properties (e.g., dry bulk density, effective porosity, volumetric moisture content, and soil-water partition coefficient) and groundwater recharge rate are considered to be uniform within the vertical polygon. However, the initial VOC concentration may vary from cell to cell. Thus, *VLEACH* can account for lateral heterogeneity but not vertical heterogeneity.

Initially, the *VLEACH* model calculates the equilibrium partitioning within each cell among three phases: aqueous, vapor, and sorbed to solid surfaces. Distribution of the VOC between the phases occurs according to user defined, analyte-specific distribution coefficients. *VLEACH* then simulates the vertical transport of the analyte via advection in the aqueous phase and diffusion in the vapor phase. VOCs in the sorbed phase are considered to be immobile while analytes in the aqueous and vapor phases are considered to be mobile. Each cell is then re-equilibrated according to the distribution coefficients. Gas diffusion can take place at the top and bottom boundaries. Mass flux is calculated in the liquid phase across the bottom boundary. The model assumes a steady state downward water flow. The processes of *in-situ* degradation and dispersion are neglected.

3.3 Processing Unsaturated Zone Modeling Results

The Summers model may be used to calculate groundwater contaminant concentration employing SESOIL and VLEACH modeling results. The Summers model simulates dilution of soil leachate in groundwater based on flow-averaged concentration resulting from the mixing of soil leachate with the underlying groundwater. The predicted groundwater concentration may then be used to back-calculate the residual soil concentration that is protective of groundwater.

3.3.1 Processing SESOIL Model Results

The Summers model employs a simple mass balance assuming no attenuation of the contaminant in the aquifer and complete mixing (Summers et al., 1980):

$$C_f = \frac{Q_s C_s + Q_a C_a}{Q_s + Q_a} \quad \text{Equation 5}$$

where:

C_f = resulting concentration in groundwater ($\mu\text{g/L}$);
 Q_s = volumetric flow rate of leachate solute downward through the unsaturated zone (ft^3/yr);
 C_s = concentration of solute in unsaturated zone liquid ($\mu\text{g/L}$);
 Q_a = volumetric flow rate of groundwater laterally through the aquifer underlying the unsaturated zone (ft^3/yr); and
 C_a = initial concentration of solute in groundwater ($\mu\text{g/L}$).

Q_a may be calculated from Darcy's Law:

$$Q_a = K i A_a \quad \text{Equation 6}$$

where:

K = conductivity of the saturated zone (ft/yr);

i = hydraulic gradient through the saturated zone (dimensionless); and

A_a = cross-sectional area of aquifer (ft^2).

Q_s may be calculated from the area affected and infiltration rate by the equation:

$$Q_s = L W I \quad \text{Equation 7}$$

where:

L = length of area parallel to groundwater flow direction (ft);
W = length of area perpendicular to groundwater flow (ft); and
I = infiltration rate (ft/yr).

To calculate the resulting concentration (C_f) from the mixing of groundwater with leachate from the unsaturated zone C_a value is set to zero. The final form of the Summers model becomes:

$$C_f = \frac{LWI \times C_s}{LWI + KIA_d} \quad \text{Equation 8}$$

where the terms and units are as defined above.

The Summers model calculated concentration (C_f) can be used to back-calculate the LSSL value according to the following linear relationship, which holds true only if the Freundlich exponent is one (Ohio EPA, 1996):

$$LSSL = \frac{RBCG \times C_{soil}}{C_f} \quad \text{Equation 9}$$

where:

RBCG = groundwater quality criterion, *e.g.*, MCLG, MCL, or BCL ($\mu\text{g/L}$);
 C_{soil} = input contaminant concentration for Sesoil model (mg/kg); and
 C_f = Summers model resulting concentration in groundwater ($\mu\text{g/L}$).

3.3.2 Processing VLEACH Model Results

As described above for SESOIL model results, the Summers model (Equation 5) may be used to calculate groundwater contaminant concentration employing the VLEACH modeling results. Because, the VLEACH model calculates mass flux in leachate across the bottom boundary, Equation 8 can be modified as follows:

$$C_f = \frac{M_{VLEACH}}{Q_s + KIA_d} \quad \text{Equation 10}$$

where:

C_f = resulting concentration in groundwater ($\mu\text{g/L}$);
 M_{VLEACH} = mass flux from VLEACH (g/ft^3); and
 Q_s = volumetric flow rate of leachate solute downward through the unsaturated zone (ft^3/yr).

The LSSSL is calculated using Equation 9.

4.0 SPLP to Develop LSSLs

If the SWP equation with default values, the SWP equation with site-specific values, or the unsaturated zone modeling yield LSSLs that are lower than available site soil concentration data, SPLP leach testing may also be conducted to further refine LSSLs for soils when clean soil exists between the soil contamination and the seasonal high water table. The test procedure recommended for use in determining soil contaminant leaching potential is U.S. EPA Method 1312 the SPLP (U.S. EPA, 1998b). The partitioning of a contaminant between the solid and liquid phases is influenced by a number of factors including soil physical and chemical properties, groundwater chemical composition, and contaminant composition.

Leaching tests with acidic extraction solution were developed for cationic metals and should not be used for certain metallic ions with multiple valence states that behave as an anionic species. Common anionic metals include arsenic, chromium, and selenium (U.S. EPA, 1992). Leaching procedures that add acidic solutions may convert the anion to a cation and this would cause an incorrect measurement of the actual leaching potential of the contaminant. For example, hexavalent chromium will react with the acidic extracting fluid of some leaching tests to form trivalent chromium, a less mobile form of chromium. Therefore, that leaching test may underestimate the amount of chromium that would leach from soils contaminated with chromium (U.S. EPA, 1992 and WDNR, 2003).

As noted earlier, the K_d values for contaminants and metals in particular are affected by a variety of soil and groundwater conditions including, but not limited to: pH, oxidation-reduction conditions, iron oxide content, soil organic matter content, cation exchange capacity, and major ion chemistry. Leach tests such as the SPLP that employ either acidic or pH neutral solutions do not replicate conditions that occur *in-situ* in the aquifer. Thus, the use of site-specific materials in a standard leach test, such as the SPLP, does not necessarily assure that representative values are obtained for the desorption of contaminants. Therefore, the NDEP recommends that without significant documentation site-specific sorption values calculated using leaching test results should not be used in other contaminant and fate models.

4.1 Soil Sampling and Batch Extraction Analysis

1. Collect a minimum of three soil samples for each area of concern. The total number of soil samples will be determined based on the size of the area being evaluated.
2. The SPLP test requires 100 grams of soil and 5 to 25 grams for soil contaminant analysis.
3. Measure the pH of the soil sample using ASTM D4972.
4. Analyze soil samples for the same constituents as being determined in the SPLP tests.

5. One sub-sample must be supplied for leaching via SPLP Method 1312. The NDEP recommends that two extractions be conducted employing:
 - i. Extraction fluid #2 – pH 5.00 ± 0.05; and
 - ii. Extraction fluid #3 – pH neutral, reagent grade water (ASTM Type II)
6. Measure pH of the leachate at the conclusion of the SPLP extraction.
7. Analyze the leachate for the list of site-related chemicals (SRCs) or the list as developed by previous screening using the LBCLs and LSSLs.

4.2 Processing SPLP Results

The SPLP test inherently has a 20:1 dilution factor (EPA, 1998b). This dilution factor is the only dilution that should be used, *i.e.*, a DAF factor should not be applied to the SPLP results (WDNR, 2003). The SPLP leachate concentration (C_{SPLP}) can be used to back-calculate the LSSL value according to the following linear relationship:

$$LSSL = \frac{RBCG \times C_{soil}}{C_{SPLP}} \quad \text{Equation 10}$$

where:

RBCG = groundwater quality criterion, *e.g.*, MCLG, MCL, or BCL ($\mu\text{g/L}$);
 C_{soil} = contaminant concentration in soil used for SPLP test (mg/kg); and
 C_{SPLP} = resulting concentration in leachate solution ($\mu\text{g/L}$).

References

Eakin, T.E. and Maxey, G.B., 1951. Ground Water in Ruby Valley, Elko and White Pine Counties, Nevada, Office of the State Engineer and U.S. Geological Survey. pg 80.

Eakin, T.E., Price, D., and Harrill, J.R., 1976. Summary Appraisals, of the Nation's Ground-Water Resources – Great Basin Region, Geological Survey Professional Paper 813 – G, U.S. Government Printing Office, Washington.

Hawai'i Department of Health. 2007. Use of Laboratory Batch Tests to Evaluate Potential Leaching of Containments from Soil. Hazard Evaluation and Emergency Response. April.

Minnesota Pollution Control Agency, 1998. Draft Guidelines, Risk-Based Guidance for the Soil Leaching Pathway, User's Guide; Working Draft. MPCA Site Response Section. May.

Michigan Department of Environmental Quality, 2004. RRP Operational Memorandum No. 2, Sampling and Analysis – Attachment 2, Soil Leaching Methods. Remediation and Redevelopment Division. October.

New Jersey Department of Environmental Protection, 2008a. Guidance Document, Development of Site-Specific Impact to Ground Water Soil Remediation Standards Using the Soil-Water Partition Equation; Revised. December.

New Jersey Department of Environmental Protection, 2008b. Guidance Document, Using the SESOIL Transport Model to Assess the Impact to Groundwater Pathway; Revised. December.

New Jersey Department of Environmental Protection, 2008c. Guidance for the Use of the Synthetic Precipitation Leaching Procedure to Develop Site-Specific Ground Water Remediation Standards. June.

NDEP, 2009. User's Guide and Background Technical Document for Nevada Division of Environmental Protection (NDEP) Basic Comparison Levels (BCLs) for Human Health for the BMI Complex and Common Areas, Revision 3. Bureau of Corrective Actions Special Projects Branch, Las Vegas, NV. June.

National Climate Data Center (NCDC), 2004. National Climatic Data Center. Available Online at: <http://www4.ncdc.noaa.gov>.

Ohio Environmental Protection Agency, 2002. Ohio EPA Derived Leach-Based Soil Values, Appendix Technical Support Document; 2nd Revision. Division of Emergency and Remedial Response. February.

Summers, K., S. Gherini, and C. Chen. 1980. Methodology to Evaluate the Potential for Ground Water Contamination from Geothermal Fluid Releases. EPA-600/7-80-117, U.S. EPA/IERL, Cincinnati, Ohio.

U.S. EPA, 1992. Ground Water Issue, Behavior of Metals in Soils. Office of Research and Development and Office of Solid Waste and Emergency Response, EPA/540/S-92/018. October.

U.S. EPA, 1996a. Soil Screening Guidance: User's Guide, April 1996. Office of Solid Waste and Emergency Response: Washington, DC, EPA/540/R-96/018.

U.S. EPA, 1996b. Soil Screening Guidance: Technical Background Document, May 1996. U.S. Environmental Protection Agency, Office of Emergency Response: Washington, DC, EPA/540/R-95/128.

U.S. EPA, 1997. VLEACH, A One-Dimensional Finite Difference Vadose Zone Leaching Model, Version 2.2 – 1997. Office of Research and Development, Center for Subsurface Modeling Support: Ada, OK.

U.S. EPA, 1998a. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, Office of Research and Development; EPA/600/R-98/128. September.

U.S. EPA, 1998b. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) 3rd ed., draft, U.S. Environmental Protection Agency, Office of Solid Waste: Washington, DC. <http://www.epa.gov/epawaste/hazard/testmethods/index.htm>.

U.S. EPA, 1999a. Understanding Variation in Partition Coefficient, K_d , Values, Volume I: The K_d Model, Methods of Measurement, and Application of Reaction Codes. Office of Air and Radiation, EPA402-R_99-004A. August.

U.S. EPA, 1999b. Understanding Variation in Partition Coefficient, K_d , Values, Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (^3H), and Uranium. Office of Air and Radiation, EPA402-R_99-004A. August.

U.S. Geological Survey, 2007, Ground-Water Recharge in the Arid and Semiarid Southwestern United States, Professional Paper 1703. Ground-Water Resources Program. July.

Wisconsin Department of Natural Resources, 2003, Guidance on the Use of Leaching Testing for Unsaturated Contaminated Soils to Determine Groundwater Contamination Potential. Bureau for Remediation and Redevelopment, PUBL RP-523-03. October.