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DRC-2014-004741

MEMORANDUM

TO: File: 2013-5 year Renewal Request and Evaluation

THROUGH: John Hultquist, Licensing Manager

FROM: Charles Bishop, P.G., Hydrogeologist CEB

DATE: June 2, 2014

SUBJECT: Review of Energy*Solutions* Ground Water Quality Discharge Permit Compliance Analytical Parameters Request, Ground Water Quality Discharge Permit UGW450005.

Summary

The Utah Division of Radiation Control (DRC) oversees Energy*Solutions*' Ground Water Quality Discharge Permit (hereafter the Permit) for their Clive facility, and the Director of the DRC (hereafter Director) is responsible for ensuring that all applicable State regulations and objectives are met for radioactive materials and sources of radiation that constitute a significant health hazard, to provide for the safety of the citizens, and protect the environment of Utah. Groundwater protection at the Clive site is related to the hazards represented by the waste disposal operations, the hazards associated with the disposing of radioactive wastes come from the basic properties of theses wastes: the wastes are damaging to life (toxic), can be corrosive, release heat, can remain dangerous for long times, and are commonly associated with industrial process. Energy*Solutions* is required to install a groundwater monitoring system, with adequate detection parameters, capable of determining facility impact on groundwater, and any contaminant movement in the event of a release. Groundwater protection parameters and Ground Water Protection Levels (GWPLs) are used in the monitoring of site performance and to demonstrate regulatory compliance with requirements listed in Part I.C of the Permit. Parameters presently used at Clive are from Ground Water Quality Protection Rules (Utah Administrations Code (UAC) R317-6), or related to NRC rules. Ground Water Quality Standards, which basically reiterates U.S. EPA Primary Drinking Water Standards established under the Safe Drinking Water Act. Energy*Solutions* has proposed to remove certain compliance parameters from their Ground Water Quality Discharge Permit (hereafter the Permit) based on monitoring for these parameters are not required to ensure compliance with water quality regulations, and their monitoring no longer is adding useful information. The rationalization for the request relies on a Permit condition, and requirements contained in UAC R317-6 (Administrative Rules for Ground Water Quality Protection). The Permit defining groundwater in the vicinity of the site as, Class IV

groundwater; and the Administrative Rules for Ground Water Quality Protection, UAC R317-6-4.7, states that protection levels for Class IV groundwater will be established to protect human health and the environment. UAC R317-6-6.3, Application Requirements for a Ground Water Quality Discharge Permit, and UAC R317-6-6.3.I .7 requires the applicant to provide and justify monitored parameters to protect Class IV groundwater.

Groundwater is an important resource in the State of Utah that is protected in an environmentally sustainable and acceptable way to reduce any risk to public health. The State of Utah required that environmental impacts to groundwater be kept within tolerable risk levels at the Clive site and treats the shallow aquifer below the site as if it is vulnerable to contamination originating from the disposal embankments, protecting shallow groundwater below the Clive site. This encouraged waste containment engineering, and minimizes degradation of shallow groundwater below the site. The Clive facility is designed and operated to minimize the chance of any leakage to groundwater associated with waste. The parameters listed in the Permit for which samples are analyzed more than meets an objective of the detection of potential contamination, and some parameter are problematic. The extent of any groundwater contamination at the Clive Site will depend upon waste content and the subsurface hydrogeology. The Director is concerned with constituents that are reasonably expected to be in, or derived from waste disposed in an embankment. Previously, the Director set GWPLs as the State Ground Water Quality Standards or at an alternative concentration level, whichever was greatest. Because the shallow groundwater at the Clive site is saline and defined as Class IV groundwater an alternative GWPL was allowed, so long as the GWPLs are protective of public health and the environment. In assessing the impact of waste operation on groundwater quality individual elements or compounds in an analytical list can change or have their sampling schedule reduced based on the results of previous sampling events and/or their low probability of detection in groundwater.

Energy*Solutions* is proposing a strategy where radionuclides are sampled and analyzed on an annual basis, and inorganics (dissolved metals, including total uranium; cyanide; fluoride; and total nitrate/nitrite), and organic are sampled and analyzed less frequently (5 years). Energy*Solutions* is motivated by a multitude of analytical results that show little or no change in concentration over time, are below detection limits, and natural occurring parameters that have resulted in out-of-compliance monitoring at the Clive site. This strategy would minimize the occurrence of false detections by removing inorganics, and organics, while continuing to monitor radionuclides and compare these analytical results to the present GWPLs in the Permit. The inorganics, and organics would be compared to the descriptive statistic documented in the Comprehensive Groundwater Quality Evaluation Report and not to GWPLs in the Permit. The Director originally protected groundwater and choose parameters and concentration limits based on the Ground Water Quality Standards found in UAC R317-6-2, to allow the determination of background values at the Clive site, or based on NRC rules.

Unlike some inorganic metals, background levels of the radionuclides included as compliance parameters are essentially zero. Radionuclides are inorganic from a chemical and transport standpoint, and are more mobile than the inorganic compliance parameters. The Manifest Radioisotope Inventory Report provides documentation of the radiological content of the waste disposed in each embankment at the Clive site. Requiring the inorganic (metals) to meet drinking water standards at the Clive site seem to be problematic. Natural levels of metals have caused additional and unnecessary monitoring at the Clive site. These metal exceedencess have been demonstrated to be due to the background concentrations being greater than GWPLs. Over 20 years of inorganic data collection from Clive site monitoring wells has demonstrated that inorganics are not significant constituents and would be inadequate indicators of embankment leakage. Given the waste inventory, observed concentration of constituents in the evaporation ponds, potential mobility, and detectability of radiological constituents, radiological constituents are more reliable indicators of waste embankment leakage. Inorganics required in the Permit, at the LARW, Class A West and Evaporation; and 11e.(2) monitoring wells, with the exception of total uranium, can be removed from the parameter list. Monitoring of inorganics on a renewal bases (every 5 years) is acceptable.

When properly evaluated, non-natural occurring organic compounds are suitable indicators of contamination. As some organic compounds are not naturally occurring their detections in a monitoring well indicates contamination. Wells monitoring the 11e.(2) embankment are sampled and analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and the pesticide chlordane; and wells monitoring the LARW, and Class A West embankments and the ponds are sampled and analyzed for VOC's. Evaluating organic monitoring data at the Clive site indicate these compounds have not been detected at any compliance monitoring well in Clive groundwater. Most VOC's are not very mobile in groundwater, may be only slightly solubility in water, and their degradation can be substantial; the VOC's required in the Permit would seem to be rather weak indicators of groundwater contamination. Because of the non-detection of organic in 20 years, chemical nature of the VOC's, and slow movement of the groundwater at the Clive site, monitoring of VOC's on a renewal bases is acceptable. The Director has determined that VOCs required in the Permit, at the LARW, Class A West and Evaporation ponds; and 11e.(2) monitoring wells can be removed from the parameter list, SVOCs and the pesticide chlordane will remain for the11e.(2) monitoring wells. A much broader list of organic will continue to be sampled at the mixed waste embankment.

Energy*Solutions* also requested the elimination of total uranium analyses, while retaining total uranium GWPL in an August 4, 2014 letter (Energy*Solutions*, August 4, 2014), and addition of isotopic uranium(s) to the list of radiological compliance parameters for the 11e.(2) wells (isotopic uranium parameters are already included in the list of compliance parameters for the LARW, Class A West, and evaporation ponds GWPLs). Total uranium analyses are redundant to isotopic uranium, because total uranium concentrations can be calculated from isotopic data, and total uranium analysis provides less information than isotopic uranium analysis. A comparison of laboratory total uranium analytical results to total uranium values calculated from isotopic uranium data indicates that for almost all samples, the laboratory total uranium result is within the calculated total uranium range when the isotopic counting error is included. Total uranium mass concentration of any compliance sample will continue to be reported, but will be calculated from the isotopic uranium data and reported in accordance to Permit reporting requirements.

Background

To provide for the safety of the citizens, and to protect the environment of Utah, the Utah Division of Radiation Control (DRC) is responsible for ensuring that State regulations and objectives are met for radioactive materials and sources of radiation that constitute a significant health hazard. Energy*Solutions* LLC is a Utah-based company that operates a commercial radioactive treatment, storage, and disposal facility seventy-five miles west of Salt Lake City, located in a remote desert area near Interstate 80 in Tooele County, Utah, Section 32, Township 1 South, Range 11 West, Salt Lake Baseline and Meridian. The Energy*Solutions'* Clive site is permitted, licensed, and approved to receive, treat, and dispose of: (1) Class A Low-Level Radioactive Waste (LLRW); Naturally Occurring and Accelerator Produced Radioactive Material (NORM/NARM); Special Nuclear Material based on concentration limits under a Radioactive Material License (License #UT 2300249 as amended); (2) uranium and thorium mill tailings byproduct material as defined by section 11e.(2) of the Atomic Energy Act of 1954, as amended, 11e.(2) byproduct material is defined as the tailings or waste produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content (License #UT 2300478 as amended, referred to as 11e.(2) waste; and (3) hazardous waste that also contains low level, or NORM/NARM radioactive waste determined to be hazardous, Class A Mixed LLRW, Polychlorinated Biphenyl (PCB) Radioactive Waste. The Utah Division of Solid and Hazardous Waste (DSHW) has issued Energy*Solutions* a Resource Conservation and Recovery Act (RCRA) Part B Permit to treat and dispose of these wastes, (Permit #UT 982598898 as amended, referred to as Mixed waste). The Clive site provides a long-term disposal site for the isolation of low level radioactive wastes using above-ground engineered, designed, and operated disposal embankments. The DRC regulate the radioactive wastes, and the mixed wastes operations are regulated by both the DRC and the DSHW. DSHW regulates the hazardous waste portion and the DRC regulates the radioactive portion of the waste and administers a Ground Water Quality Discharge Permit (hereafter the Permit). The DRC ensures that all applicable regulatory requirements are met for the Permit.

Energy*Solutions*' Clive site has been providing a private disposal option for generators of radioactive waste materials in above ground disposal embankments from across the country. The Clive site is situated in a geographic setting that helps limit leachate generation and avoid contamination. The site is readily accessible by rail and truck and is designed to receive both bulk (e.g., intermodals, gondolas, etc.) and non-bulk (e.g., drums, boxes, etc.) wastes. The design of the embankments is patterned after State of Utah, and U.S. Department of Energy (DOE) specifications for a previously constructed disposal embankment. The Clive site has received waste from cleanup projects by the U.S. Environmental Protection Agency (EPA), U.S. DOE, U.S. Department of Defense (DOD), utilities, and other commercial entities.

In the late 1970s and early 1980s the U.S. DOE and the State of Utah began planning for the cleanup of an abandoned Salt Lake City uranium mill site. The Clive site was one of the sites investigated for the isolation of tailing from the central Salt Lake City Vitro site, and in June of 1980 the State of Utah chose it as the site where the tailing would be moved. The Vitro mill site was one of the first sites cleaned up under the DOE Uranium Mill Tailings Remediation Action (UMTRA) Program. Site features that were found favorable for the disposal of the tailing was the nonexistence population (with over 100 years of settlement in the state, no one had settled in this area); poor groundwater quality, low aquifer yields, lack of surface water, arid meteorology, and railroad access at the site. The Vitro embankment was constructed by the State of Utah from 1984 through 1988, with the first uranium tailing arriving in 1985. Because of the poor quality of the shallow groundwater at the Clive site there was only limited groundwater monitoring at the Vitro embankment, occurring from 1981 to 1987. After acquiring land adjacent to the Vitro disposal embankment and obtaining disposal licenses, waste disposal at the Envirocare (now EnergySolutions) Clive facility began in 1988 under a state license to dispose of NORM/NARM. In 1991 the license was modified to include the disposal of LLRW. The issuance of a preliminary Ground Water Quality Discharge Permit for the Clive facility was completed in 1991. Also in1991, Envirocare received a RCRA hazardous waste permit from the Bureau of Solid and

Hazardous Waste (now DSHW) to accept mixed waste. In 1993, Envirocare received a license from the U.S. Nuclear Regulatory Commission (NRC) to accept 11e.(2) wastes. Energy*Solutions* is now licensed by the Utah DRC to receive and dispose of 11e.(2) byproduct material as defined by the Atomic Energy Act, as amended.

Groundwater monitoring at the Clive site is a requirement of Federal or State of Utah regulation to protect groundwater, with State requirements being applied at the Clive site. The State of Utah provided guidelines for parameter selection and concentration limits in its Administrative Rules for Ground Water Quality, UAC R317-6-2, Table 1, and for groundwater classification, UCA R317-6-3, as part of a water protection strategy. UCA R317-6-3 requires the State to set water-quality standards, and establishes a regulatory program for enforcement. The rules established six classifications for groundwater[1], with the level of protection varying for each class, Class 1 being the most, and Class IV being the least protected. Ground water beneath the Clive site is Class IV, saline ground water (Class IV ground water has total dissolves solids (TDS) greater than 10,000 mg/L). Essentially, Class IV protection levels for groundwater are established to protect human health and the environment. At the time of initial licensing it was considered relatively unlikely that the groundwater in the shallow aquifer would be used for humans or livestock consumption, because of its' very high concentration of dissolved metals, making it not potable. The Permit sets some groundwater compliance parameters and protection levels according to groundwater quality protection regulations, contained in Utah Water Quality Protection Rules, Utah Administrations Code (UAC) R317-6, "Ground Water Quality Protection," to specify the protection of groundwater at the Clive facility that the DRC must adhere. The permit specifies groundwater quality requirements for field, inorganic (cyanide, fluoride, nitrate/nitrite, and dissolved metals), organic, and radiologic parameters. However, even the best laid plans have elements that make implementation more difficult than it first appears.

The Clive facility is designed and operated to minimize the chance of any leakage to groundwater associated with waste. Water was, and is considered a significant medium for the mobilization of radionuclides and other contaminants at the Clive site. Part of groundwater protection at the Clive site encompassed a strategy to prevent the spread of contaminants from operational facilities using water by controlling releases of contaminants to protect groundwater indirectly. Water used in operations, due to storm events, or infiltrating into the ground from embankments can move contaminants to groundwater, requiring operations be conducted in such a manner as to minimize these threats to groundwater. Waste handling and wash facilities are operated under Best Management Practices and Best Operation Practice standards to prevent the release of water. Because containment engineering and operations are used at the waste handling and wash operations, groundwater monitoring of waste handling and wash facilities was not required. Storm water is managed to prevent standing water, thus limiting infiltration. Another part of groundwater protection is in embankment construction that utilizes a multi-layered engineered cover system to limit infiltration, a clay liner to prevent seepage, and a well network for monitoring groundwater. Because disposal of waste in land embankments potentially allows precipitation to contact and infiltrate into buried waste, leaching chemical constituent of the waste, the groundwater around them is monitored. Without groundwater monitoring as an integrated activity to obtain and evaluate the chemical characteristics of groundwater at the Clive site,

[1] UCA R317-6-3 established six classifications for ground water: Class 1A for pristine ground water, Class 1B for irreplaceable groundwater, Class 1C for ecological important ground water, Class II for drinking water quality ground water, Class III for limited use ground water, and Class IV for saline ground water.

contamination may go undetected. Therefore, groundwater monitoring at a waste management facility is a significant component of public and environment protection. A network of groundwater monitoring wells was established for each embankment that continues to expand as more waste disposal embankments are added to the facility. The initial monitoring network consisted of 11 wells installed around the LARW embankment by 1991. At present, there are networks of monitoring wells placed around three waste disposal embankments: (1) Mixed Waste, (2) 11e.(2), (3) Class A, and the LARW embankment, which is closed. The Class A and Class A North embankments have been combined into a Class A West embankment. Monitoring wells and other sampling locations are described in Part I.F.1.(a), (b), and (c) of the Permit.

The selection of analytical parameters at Clive was based on a policy decision by the State, and Envirocare. The State determined to protect the shallow aquifer as if it were a drinking water resource, although groundwater at Clive is Class IV groundwater (saline). Ground Water Protection Rules set parameters and contaminant concentration limits in Table 1 of UAC R317-6-2 as the parameters and GWPLs for the Permit. Since the shallow groundwater was of poor quality and it was being protected as drinking water, minimum baseline groundwater quality monitoring was done at the Clive site in 1991 to accelerate the permitting process. The drinking water standards provide a target for groundwater treatment, if a contaminant were ever introduced into groundwater, and does not allow groundwater degradation. This was done to encourage waste containment engineering, protect public health and the environment, and to provide overall environmental protection to give the citizens of the State of Utah environment assurance at the disposal site from waste disposal that largely benefit waste generators outside of Utah. The Permit allows for the determination of alternate GWPLs. The State of Utah and Envirocare also agreed, in the early 1990s, that there would be monitoring of the shallow aquifer only; early hydrogeological characterization of the Clive site had established confining clay layers and an upward hydraulic gradient below the shallow aquifer (Bingham Environmental, Inc., 1991). Baseline groundwater quality was based on five monitoring wells from the Vitro embankment. To allow adjustments to the GWPL, because of the poor quality shallow groundwater below the Clive site, the Permit allowed flexibility in setting GWPL with the determination of alternate protection levels on a specific well and parameter basis, so long as the GWPLs were protective of the public health and the environment.

In a letter dated December 7, 2012 Energy*Solutions* requested the removal of metals, total uranium, cyanide, fluoride, total nitrate/nitrite (the inorganics), and organics as compliance parameters from the Permit (Energy*Solutions*, December 7, 2012). Given the waste inventory, concentrations, mobility, and detectability of radiological constituents, changes in radiological constituents would seem a likely indicator from an embankment, and it may be unreliable to anticipate the detection of non-radiological constituents associated with a release to groundwater, without detection of radiological constituents. Chemical and radiological constituents that are reasonable expected to be in or derived from the waste are potential monitoring parameters. The mobility of metals in groundwater has received considerable attention; metals can be toxic and even lethal at relatively low concentration. Sources of metals contamination include mining, and industrial solid wastes. Fluoride is widespread in nature, but usually in small amounts. Fluorides are used in various manufacturing processes. Cyanides readily dissolve in water to yield toxic cyanide ions or complexes of cyanides. Cyanides are present in waste from various industries. A common contaminant identified in groundwater is dissolved nitrogen in the form of nitrate/nitrite (NO_3^-/No_2^{-2}). This parameter is associated with agricultural activities and disposal of sewage, and its presence in concentrations is threatening aquifer systems around the world. Although these elements rarely occur at concentration large enough to comprise significant percentage of groundwater, there concentration can be above the specified limits. The concentrations are low because of constraints imposed by various chemical reactions. The mobility of these parameters in water at the Clive site is influenced by solution chemistry and surface properties of mineral phases in the sediments. Wells monitoring the 11e.(2) embankment are sampled and analyzed for VOCs, SVOCs, and the pesticide chlordane; and wells monitoring the LARW, Class A West and evaporation ponds are monitored for the VOC's. VOCs are infrequently detected at very low concentrations in Clive groundwater samples not related to waste disposal activities (typically one-time detections and not repeated in subsequent sampling). The source of these compounds may be sampling equipment, laboratory equipment, or airborne organics. The U.S. EPA Risk Assessment Guidance for Superfund lists acetone, 2-butanone, and methylene chloride as common laboratory contaminants detected in environmental samples (U.S. Environmental Protection Agency, 1989). Often, the same compound is detected in an associated trip blank sample, indicating introduction of sample contaminants at the laboratory, during shipment, or during sample handling. Bogus low-concentration detection of VOCs is common in environmental monitoring programs. VOCs have a high tendency to volatize and distribute preferentially into the air. VOCs are found in many industrial products including fuels, solvents, paints, and adhesives. SVOCs are fairly soluble, and have only a moderate tendency to volatize, and can be fairly persistent in groundwater. SVOCs are also present in many industrial products including plastics, dyes, disinfectants, and petroleum products. Energy*Solutions* believes that the data collected for the last 20 years provide evidence that organic parameters are not present; however, it could be that they have not arrived at a compliance monitoring well.

The Energy*Solutions* request references requirements contained in Utah Administrations Code (UAC) R317-6 (Administrative Rules for Ground Water Quality Protection) not specifying groundwater compliance parameters; Part I.A of the Permit defining groundwater in the vicinity of the site as Class IV; and UAC R317-6-4.7, Class IV Protection Levels, states that protection levels for Class IV groundwater will be established to protect human health and the environment (Energy*Solutions*, December 7, 2012). UAC R317-6-6.3, Application Requirements for a Ground Water Discharge Permit, and UAC R317-6-6.3.I.7 requires the applicant to provide a description and justification of monitored parameters. Energy*Solutions* believes it is reasonable that the monitoring program should be focused on known potential contaminants present in the disposal embankments, such as those documented in the Manifest Radionuclide Inventory Report.

Site Groundwater Hydrology

This section briefly describes the hydrogeologic environment at the Clive site, as it relates to Clive operations. Descriptions of the regional hydrogeology of the area are found in Stephen (1974) and Black and Others (1999), and more detailed descriptions of the aquifer system underlying the Clive site are found in hydrogeologic studies conducted for the facility, such as Bingham Environmental, Inc. (1991, 1993 and 1996), Mayo and Associates (1999), Pentacore Resources (2000), Envirocare of Utah, Inc. (2004), and Energy*Solutions* (2012).

In general, groundwater in the western Desert of Utah, in which the Clive site is located, is found in three aquifers systems, a principal basin-fill aquifer, alluvial-fan aquifer, and shallow surficial aquifer. The principal basin-fill aquifer is generally the largest, but the thickness of the basin-fill aquifer is unknown in the Clive area, it is generally considered to be composed of at least several hundred feet of fine-grained unconsolidated lacustrine sediments, and below a depth of about 50 feet at the Clive facility. Recharge to the principal basin-fill aquifer is derived from lateral subsurface flow from the surrounding mountains and alluvial-fan deposits. Groundwater quality of the basin-fill is considered poor and monitoring is not performed in the basin-fill aquifer at the Clive facility. The alluvial-fan aquifer is found along mountains fronts, and it can be a source of usable water. Recharge to the alluvial-fan aquifer is derived from precipitation in the surrounding mountains, and direct precipitation on the alluvial fans. The alluvial-fan aquifer is not found in the Clive area. The shallow aquifer is found in near-surface deposits consisting of unconsolidated interbedded clay, silt, and sand of Pleistocene and Holocene age (Stephens, 1974). Sources of recharge to the shallow aquifer include infiltration of precipitation on the surface (in area where water ponds), horizontal subsurface inflow, and upward leakage from underlying aquifers. Data collected from the shallow aquifer monitoring system has been used to understand the hydrogeology of the facility, determine the direction of ground-water flow, and rates of ground-water movement. The arid meteorology, with the low amount of precipitation, high evaporation rates, and no natural surface water at the Clive site tends to limit much direct surface recharge to the shallow aquifer.

Subsurface characterization at the Clive site has divided the shallow sediments into three hydrogeologic units with varying hydraulic conductivities, composed of thinly bedded to laminated lake and recent alluvium deposits of clay, silt, and sand (Solomon, 1993; Energy*Solutions*, March 16, 2010). In the area of the Clive facility up to 35 feet, but as little as 15 feet of unsaturated silt and clay lie above a 7 to 25 foot thick, averaging approximately 15 feet, silty sand unconfined aquifer, with embedded silt and clay sequences of the shallow aquifer. This shallow aquifer is unconfined, and ranges from 7 to 25 feet in thickness. The aquifer is considered shallow because the water table is generally within 30 feet below the ground surface and fluctuates in response to a variety of conditions, with ground-water levels rising and falling slightly with seasonal variations in precipitation or evaporation. A semipervious clay layer, at 35 to 45 feet depth, separates the shallow aquifer from lower saturated zones. The results of a large number of hydraulic conductive tests in the shallow aquifer throughout the Clive site have been used to determine groundwater under the Clive site, in the shallow aquifer, travel at 0.02 to 1.7 feet per year (Energy*Solutions*, November 28, 2012).

Shallow groundwater flow near and at Clive is influenced by natural and artificial factors. Regionally, groundwater flow in the shallow aquifer, beneath the Clive facility, flows generally towards the northeast. However, shallow groundwater flow is affected by infiltration of water from surface water retention facilities (ponds), and other water collection sites that have caused groundwater mounding and altered groundwater elevations, gradients, and flow directions locally in the vicinity of the recharge (Energy*Solutions*, November 28, 2012). Early hydrogeological characterization at the Clive site demonstrated that there was an upward gradient below the site (Bingham Environment, Inc., 1991); however, more recent characterization has showed this has changed in some area due to the groundwater mounding.

Groundwater in the shallow aquifer at the Clive site is saline, with TDS ranging for about 24,000 to 53,000 milligrams per liter (mg/L) (Energy*Solutions*, December 10, 2012). The high salinity of the shallow aquifer is likely a consequence of the decline of Pleistocene Lake Bonneville, which localized metals in the sediments of the area (chemical and physical processes occurring in closed basins significantly influence groundwater evolution), and the concentrating of metals through evapotranspiration. The Bonneville Salt Flats, just west of the Clive Site, subsequently became the natural terminus for Lake Bonneville, and large quantities of brine occur in the shallow aquifer under the Bonneville Salt Flats. Naturally occurring concentrations of many dissolved constituents at Clive exceed U.S. EPA drinking water standards (Mayo and Associates, 1999; Bingham Environmental Inc., 1996). The high salinity (poor quality) has caused problem in the chemical analysis of a number of parameters. Major dissolved constituents in Clive shallow groundwater are sodium and chloride, with calcium, magnesium, potassium, sulfate, and bicarbonate being other naturally occurring inorganics. These major constituents are typically present at concentration in the range of few tens of milligrams per liter (mg/L) to thousands of mg/L and constituent the bulk (approximately 99 percent) of the mineral matter contribution to the high TDSs groundwater. Some inorganic and dissolved metal constituents are present naturally in Clive groundwater in concentrations less than 10 mg/L and often much less than 1.0 mg/L (Energy*Solutions*, December 10, 2012). Metals such as arsenic, lead, cadmium, and chromium are present in amounts of only a few micrograms per liter, but are very important from a water quality standpoint. Natural occurring inorganic (metals) compliance parameters have resulted in continuous out-of-compliance monitoring of background conditions in a number of cases at the Clive site. Organic compounds are infrequently detected at very low concentrations (typically one-time detections and not repeated in subsequent sampling) and are not generally considered to be detected in Clive groundwater. These one-time detections have been attributed to laboratory contamination. Variability in groundwater quality measurements at the Clive site may be the result of the collection and analysis of a discrete sample from an individual compliance monitoring well, and the distribution of the chemical elements in the heterogeneity system being sampled. The intrinsic irregularity of groundwater measurements at the Clive site is a function of the system being sampled and therefore, cannot be reduced. Mayo and Associates (1999), and Bingham Environmental Inc., (1996) indicate that the TDS of the deep aquifer is less than that of the shallow aquifer, but is greater than 20,000 mg/L.

Nature of Waste

Radioactive waste comes from a variety of sources and the great care required in its disposal is related to hazard represented by the waste. Low-level radioactive wastes (radioactive materials in concentrations or quantities that exceed applicable Federal or State standards for unrestricted release) are considered suitable for disposal directly in surface or near-surface disposal sites under restricted environment conditions, following suitable treatment, or processing. Low-level radioactive waste can be toxic, corrosive, releases heat, long lasting, and commonly associated with industrial process. Historically, the greatest proportion of radioactive waste produced is low-level radioactive waste. Potential sources of radioactive material occur from throughout the nuclear fuel cycle; and mining and milling, and industry users of radioactive materials. Radioactive waste in engineered embankments is subject to leaching by water derived from precipitation; the liquid that is derived from this process is known as leachate. The various licenses and permits under which Energy*Solutions* operates govern the type, form, and quantity of LLRW, and 11e.(2) and Mixed wastes that can be receive for treatment, processing, and disposal.

Class A low-level radioactive waste is a result of the beneficial uses of radioactive materials, including electricity generation, medical diagnosis and treatment, biomedical and pharmaceutical research, and manufacturing. Because of the difficulty of monitoring for low radioactivity in many materials, any solid waste generated in suspect areas that potentially contacted radioactive materials is often treated as if it were contaminated; thus, low-level radioactive waste consists of radioactive materials and any solid materials that may have been in contact with radioactive materials. Energy*Solutions* receives radioactive waste including, but not limited to contaminated soils and building debris, soils with scrap metal, glass, wood, and masonry rubble; sludges, tailings, or residues form industrial waste streams; soils from decommissioning of reactor facilities; dry active waste from cleanup and maintenance of nuclear reactors, fuel processing, and decontamination and decommissioning operations; ion-exchange resins and solidified cleaning agent; large reactor components, concrete, discarded manufactured items, metal, plastic, and other radioactively contaminated debris. The contents of the waste will vary from source to source, but the radiological constituents that are reasonably expected in or derived from these wastes are potential constituent of concern. The composition of the waste will vary by location and placement time in an embankment. In 2006 the facility was permitted to dispose of waste containing shredded debris in the bulk waste lifts, this debris in general is either plastic or metal.

Class A LLRW classification at the Clive site encompasses the quantification of radionuclide concentration in the waste materials to comply with disposal site performance objectives (assignment depending entirely on the activity levels). Radioactive material concentrations can range from just above natural background levels to very high concentrations of radioactive materials, about 97 percent of the waste decays to safe level within 100 years. Determination of LLRW is done in accordance with the requirements of UAC R313-15-1009, Classification and Characteristics of Low-Level Radioactive Waste; were specific long-lived radionuclides listed in Table 1 (see below) of UAC R313-15-1009, and specific short-lived radionuclides listed in Table 2 (see below) of UAC R313-15-1009 are considered. Utah rule UAC R313-15-1009 is comparable to the NRC Waste Classification requirements in 10 CFR 61.55.

The waste is Class A if the radionuclides concentrations requirements listed in either Table 1 or Table 2 are not exceeded. For waste material that contains more than one radionuclide, the waste must be classified by applying a sum of fractions rule described in UAC R313-15-1009(1)(g). This rule states:

> For determining classification for waste that contains a mixture of radionuclides, it is necessary to determine the sum of fractions by dividing each radionuclide's concentration by the appropriate limit and adding the resulting values. The appropriate limits shall all be taken from the same column of the same table. The sum of fractions for the column shall be less than 1.0 if the waste class is to be determined by that column.

Classification Tables from UAC R313-15-1009

Long-lived radionuclides

Table 1

Radionuclide	Concentration	
	Ci/m^3	nCi/g
C-14	8	
C-14 (act)	80	
Ni-59 (act)	220	
Nb-94 (act)	0.2	

Radionuclide	Concentration	
	Ci/m^3	nCi/g
Tc-99	3	
I-129	0.08	
Alpha-emitting transuranics > 5 year half-life		100
Pu-241		3,500
Cm-242		20,000
Ra-226		100

Short-lived radionuclides

Table 2

Radionuclide	Concentration		
	Column 1 Ci/m^3	Column 2 Ci/m^3	Column 3 Ci/m^3
Total of all radionuclides < 5 year half-life	700	*	*
H-3	40	*	*
Co-60	700	*	*
Ni-63	3.5	70	700
Ni-63 (act)	35	700	7,000
Sr-90	0.04	150	7,000
Cs-137	1	44	4,600

* There are no limits established for these radionuclides in Class B or C wastes. Practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations for these wastes. These wastes shall be Class B unless the concentrations of other radionuclides in Table II determine the waste to be Class C independent of these radionuclides.

Energy*Solutions*' LLRW License also allows the disposal of NORM/NARM. NORM/NARM does not include byproduct, source, or special nuclear materials (generally contains radionuclides in the uranium and thorium decay series), and typically is produced by an industrial, mining, or manufacturing process. Since NORM/NARM waste is not considered LLRW by the U.S. NRC, waste classification regulations do not apply.

Energy*Solutions* accepts 11e.(2) waste, which are mining and milling residue (tailings or wastes produced from the extraction or concentration) of uranium or thorium in any ore processed primarily for its source material content. 11e.(2) waste contain low concentration of naturally occurring radioactive materials, and trace metals and any organics used in the processing. 11e.(2) byproduct material with an average concentration in any transport vehicle (truck or railcar) is not to exceed 4,000 Picocuries per gram (pCi/g) for natural uranium; 60,000 pCi/g, for any radionuclide in the Radium-226 series; or 6,000 pCi/g for any radionuclide in the thorium decay series. The nature of these wastes vary from mill to mill, but chemical and radiological constituents that are reasonably expected to be in or derived from the tailings are potential constituents of concern. 10 CFR Part 40, Appendix A, Criterion 13 provides a non-inclusive list of constituents of concern that are associated with 11e.(2) waste; provided in Table 3.

Some commercial low level waste contains chemically hazardous constituents and is classified as mixed waste. Mixed waste can be generated anywhere radioactive materials are used in processes that also involve the use of chemically hazardous materials. Energy*Solutions*' Clive facility is authorized to receive Class A Mixed Low-Level Radioactive Waste (Mixed Waste) for disposal, or treatment and disposal. Mixed low-level radioactive waste, besides being radioactive must also meet the condition of either being listed as a hazardous waste in Subpart D of 40 Code of Federal Regulations (CFR) 261, or exhibit any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261. Mixed waste typically includes organic liquids, metallic lead, cadmium, chromates, and waste oils along with the radioactive constituents. This waste is subject to leaching that could contain large numbers of inorganic, organ, and radioactive contaminants.

Table 3. Common mill and tailing chemical constituents

Parameter	Parameter
Inorganic Parameters (milligram per liter[mg/]l)	*Organic Parameters (mg/l)*
Arsenic	Acetone
Barium	2-Butanone
Beryllium	Carbon Disulfide
Cadmium	Chloroform
Cyanide	1,2-Dichloroethane
Chromium	Methylene Chloride
Copper	Naphthalene
Lead	Diethyl Phthalate
Mercury	2-Methylnaphthalene
Molybdenum	
Nickel	*Combined Radiologic Parameters (pCi/l)*
Selenium	Radium-226+radium-228
Silver	*Radiologic Parameters (pCi/l)*
Uranium – total	Thorium-230
Zinc	Thorium-232
Total Nitrate/Nitrite (as N)	

Energy*Solutions* received a Permit modification that authorized the receipt and disposal of PCB Radioactive and PCB Mixed wastes. Mixed Waste is defined by Energy*Solutions*'' State-Issued Part B Permit (# UTD982598898) as:

> Waste defined by the Low Level Radioactive Waste Policy Act, Public Law 96-573; this is radioactive waste not classified as high-level radioactive waste, transuranics waste, spent nuclear fuel, or byproduct material as defined by section 11e.(2) of the Atomic Energy Act, and contains hazardous waste that is either listed as a hazardous waste in Subpart D of 40 CFR 261 and/or exhibits any of the hazardous waste characteristics identified in Subpart C of 40 CFR 261, or hazardous waste which also contains naturally occurring radioactive materials.

In 2002, Energy*Solutions* received a Toxic Substances Control Act (TSCA) Coordinated Approval from the EPA to expand PCB receipt and disposal options. The TSCA Coordinated Approval has been subsequently expanded to include additional types of PCB radioactive and PCB mixed wastes. Hazardous waste constituents are regulated be the State issued Part B Permit, the groundwater discharge permit regulates one metal (total uranium) and radiologic parameters.

Regulatory Requirements

Groundwater monitoring requirements used at the Clive site evolve around compliance with State of Utah Water Quality Protection Rules, which largely incorporate U.S. EPA groundwater protection regulation of the Clean Water and Safe Drinking Water acts. The Federal Clean Water Act established the basic structure for regulating discharges of contaminants to the environment, and the Safe Drinking Water Act established groundwater protection standards. The Utah Water Quality Protection Rules are used to regulate activities that potentially pose a threat to waters of the State of Utah. As part of the overall regulations, groundwater is specifically addressed in the Ground Water Quality Protection Rules (UAC R317-6) that provides for the introduction of:

- A regulatory framework for the application of groundwater quality standards.
- Groundwater classes.
- Protection levels for each groundwater class.

The regulations recognize that not all groundwater is of the same value. The State defined protection levels as groundwater contaminant concentration limits and set groundwater classes for protection levels to apply to. The Water Quality Rules intent, as set forth by the State of Utah are:

> *"Whereas the pollution of the waters of this state constitute a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life, and impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of water, and whereas such pollution is contrary to the best interests of the state and its policy for the conservation of the water resources of the state, it is hereby declared to be the public policy of this state to conserve the waters of the state and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the state without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; to place first in priority those control measures directed toward elimination of pollution which creates hazards to the public health; to insure due consideration of financial problems imposed on water polluters through pursuit of these objectives; and to cooperate with other agencies of the state, agencies of other states and the federal government in carrying out these objectives."*

The term "beneficial uses" refers to an appreciable gain or benefit to a user; with the water making a substantial contribution as a source maintaining aquatic environments, being vital to urban and rural users, or providing a benefit to a wide range of uses to support a standard of living. The beneficial use classification depends upon the quality of water, the potential values of the water in the long term, and recognizes that not all water is of the same value. Therefore, the protection of groundwater is directly related to the value of the resource, and the chance of contamination of this resource.

Approaches to Parameter Selection and Groundwater Protection Levels
The selection of groundwater analytical monitoring parameters for detection of contamination is commonly based on criteria, such as:

- Prescribed by regulations
- Parameter is mobile (i.e., likely to reach groundwater quickly and unretarded)
- Parameter does not exhibit significant natural variability
- Parameter is correlative with constituents of the waste
- Parameter is easy to detect (not subject to significant sampling and analytical interferences)
- Parameter is not redundant with other chemical parameters
- Parameter does not create data interpretation problems
- Procedures and parameters of groundwater protection can be prescribed by regulatory requirements, and possible site monitoring, or ambient groundwater chemical quality needs.

As a monitoring endeavors goes from quantifying the general quality of groundwater and providing information on hydrogeological and groundwater conditions to only a detection monitoring effort, to identify the presence of any level of contamination of site groundwater, monitoring parameters or protection levels may change, as long as they are still protective. When groundwater contamination is related to waste constituents, parameters specific to the waste material, and history of the site can be used to determine chemicals of concern. If disposal records are available and waste constituents are well documented, the list of parameters can be relatively limited to waste constituents. The parameter list is more extensive if handling practices are poorly understood. Where policy allows, parameter lists may be narrowed as waste constituents and chemicals of concern become better defined. Individual chemical parameters used as compliance monitoring parameters may be adversely effected or changed through operations of the facility, removed by substitute or decomposes during transport through the subsurface, or there may be chemical and hydrological changes due to waste disposal operations that mobilizes groundwater constituents that were originally present in the aquifer. The chemical and hydrological changes caused by the operation of a waste disposal facility can mobilize groundwater constituents that were originally present in the aquifer.

Groundwater protection at the Clive site involves a shallow groundwater protection strategy designed to optimally maximize the detection of contaminants under pertinent uncertainties, measure chemical species to detect and determine background concentrations, and provide information about subsurface parameter distributions, to show if any contamination has occurred due to the waste operations. The selection of parameters was a subjective process, both for the questions of how many monitoring parameters are necessary, and how many parameters are needed to demonstrate that the system is capable of detecting groundwater contamination to a regulatory agency. Water quality parameters used at the Clive site are defined in UAC R317-6 based on groundwater as an acceptable drinking water source, based on NRC evaluations and rules (determined limits), or are a background concentrations. Groundwater protection regulations set groundwater quality standards in UAC R317-6-2, Table 1 that are used as contaminant concentration limits, essentially comparable to U.S. EPA Primary Drinking Water Standards for the purpose of protection the shallow groundwater. Criteria used in selection of a constituent for regulation under the Water Quality Standards were the analytical ability to detect, potential health risk, and occurrence or potential occurrence in groundwater.

Ground water quality in any compliance monitoring well at the LARW, and Class A West embankments were required to comply with the GWPLs found in Table 4, unless an alternative protection level (concentration based) is set on a well and contaminant-specific basis. Parameter concentrations in wells are compared to the GWPLs listed in Table 4 to evaluate the presence of contamination. GWPL were defined as the GWQS, a determined limit, or a background concentration, whichever is greater for the inorganic, organic, and radiologic parameters. Monitoring wells are sampled annually and analyzed for the chemical parameters listed in Table 4, these include field and inorganic (metals), organic, and radiologic parameters. Detection monitoring for the LLRW embankments and the evaporation ponds are designed to determine the presence of contamination in groundwater from the embankment. The detection of natural occurring listed parameters complicates the evaluation of contamination at the site.

Table 4: Ground water monitoring parameters and protection levels for the LLRW embankments and evaporation ponds monitoring wells.

Parameter	GWPL	Parameter	GWPL
Field and Inorganic Parameters (mg/l)		*Radiologic Parameters – Alpha Emitters (Picocurie per liter[pCi/]l)*	
Cyanide	0.2		
Fluoride	4.0	Neptunium-237	7
Total Nitrate/Nitrite (as N)	10.0	Strontium-90	42
pH (units)	6.5 – 8.5	Thorium-230	83
Dissolved Metals (mg/l)		Thorium-232	92
Antimony	0.006	Uranium-233	26
Arsenic	NA	Uranium-234	26
Barium	2.0	Uranium-235	27
Beryllium	0.004	Uranium-236	27
Cadmium	0.005	Uranium-238	26
Chromium	0.1		
Copper	1.3	*Radiologic Parameters – Beta/Gamma Emitters (pCi/l)*	
Lead	0.015	Carbon-14	3,200
Mercury	0.002	Iodine-129	21
Molybdenum	NA	Technetium-99	3,790
Nickel	0.10	Tritium	60,900
Selenium	0.05		
Silver	0.1	*Combined Radiologic Parameters (pCi/l)*	
Thallium	0.002		
Uranium – total	0.03	Radium-226 + Radium-228	5
Zinc	5.0		
Organic Parameters (mg/l)			

Parameter	GWPL	Parameter	GWPL
Acetone	0.7	1,2-Dichloroethane	0.005
2-Butanone	4.0	Methylene Chloride	0.005
Carbon Disulfide	0.7	1,1,2-Trichloroethane	0.005
Chloroform	0.08	Vinyl Chloride	0.002

Protection levels for inorganic (Cyanide, Fluoride, total Nitrate/Nitrite, and dissolved metals), organic, and radiologic parameters for the11e.(2) embankment are defined as the GWQS, determined limits, or the background concentration, whichever is greater. Groundwater quality in any compliance monitoring well at the 11e.(2) embankment complies with the GWPLs found in Table 5, unless an alternative concentration protection level has been cited on a well and contaminant-specific basis. Monitoring wells are sampled annually and analyzed for the chemical parameters listed in Table 5 that would likely indicate contamination. These include field and inorganic parameters, organic, and radiologic parameters. The detection of natural occurring listed parameters complicates the evaluation of contamination at the site.

Table 5: Groundwater monitoring parameters and protection levels for all 11e.(2) monitoring wells

Parameter	GWPL	Parameter	GWPL
Field and Inorganic Parameters (mg/l)		*Organic Parameters – Specific to 11e.(2) (mg/l)*	
Cyanide	0.2	Acetone	0.7
Fluoride	4.0	2-Butanone	4.0
Total Nitrate/Nitrite (as N)	10.0	Carbon Disulfide	0.7
pH (units)	6.5 – 8.5	Chloroform	0.08
Dissolved Metals (mg/l)		1,2-Dichloroethane	0.005
Antimony	0.006	Methylene Chloride	0.005
Arsenic	NA	Naphthalene	0.02
Barium	2.0	Diethyl Phthalate	5.0
Beryllium	0.004	2-Methylnaphthalene	0.004
Cadmium	0.005	Benzo(a)anthrancene	0.01
Chromium	0.1	Benzo(a)pyrene	0.01
Copper	1.3	Benzo(k)fluoranthene	0.01
Lead	0.015	Chlordane	0.002
Mercury	0.002	Chrysene	0.01
Molybdenum	NA		
Nickel	0.10		
Selenium	0.05		
Silver	0.1		
Thallium	0.002		
Uranium – total	0.03		
Zinc	5.0		
Combined Radiologic Parameters (pCi/l)			
Radium-226+radium-228	5		
Radiologic Parameters (pCi/l)			
Thorium-230	83		
Thorium-232	92		

In evaluating waste disposed in the Mixed Waste embankment, which includes both a low-level radioactive and hazardous waste component, the groundwater protection levels are defined as the GWQS for total uranium, determined limits for radiologic parameters, or the background concentration, whichever is greater. Non-radiologic parameters for the Mixed Waste embankment are regulated in the RCRA Part B Permit, so only radiologic parameters are specific in the Permit. Detection monitoring for the Mixed Waste embankment is designed to determine the presence of contamination in groundwater. Monitoring wells are sampled annually and analyzed for the chemical parameters listed in Table 6 that would likely indicate contamination; these include total uranium (metal), and radiologic parameters. At the Clive site Mixed Waste parameters concentration in wells are compared to the concentration listed in Table 6 to evaluate the presence of contamination. In all cases, ground water quality in any compliance monitoring well at the Mixed Waste cell shall comply with the GWPLs found in Table 6, unless other GWPLs have been cited on a well and radiologic parameter-specific basis.

Table 6: Groundwater monitoring parameters and protection levels for all Mixed Waste monitoring wells

Parameter	GWPL	Parameter	GWPL
Dissolved Metals (mg/l)			
Uranium – total	0.03		
Radiologic Parameters (pCi/l)			
Alpha Emitters		*Beta/Gamma Emitters*	
		Carbon-14	3,200
Neptunium-237	7	Iodine-129	21
Strontium-90	42	Technetium-99	3,790
Thorium-230	83	Tritium	60,900
Thorium-232	92		
Uranium-233	26		
Uranium-234	26	*Combined Radiologic Parameters (pCi/l)*	
Uranium-235	27	Radium-226 + Radium-228	5
Uranium-236	27		
Uranium-238	26		

The process of issuing a groundwater quality discharge permit under State of Utah Rules offers a certain degree of flexibility for stipulating monitoring analytical parameters for the water quality found at the Clive site, but a question remains for the DRC as to what are the most effective parameters in detecting contamination. Furthermore, naturally occurring inorganic compliance parameters found in the sediments of the Clive site have resulted in out-of-compliance monitoring of background conditions. Additionally, physical, hydrogeochemical, and biogeochemical subsurface processes may remove or modify an individual constituent, with various processes, such as adsorption, ion exchange, and biodegradation.

Groundwater monitoring at the Clive site needs to limit the exposure of radioactive and hazardous waste to the public, and to protect the environment; however, there is flexibility in how this is done. Energy*Solutions* proposes to use only radionuclides for annual monitoring at the Clive site, because some naturally occurring inorganic compliance parameters (a few dissolved metals) have resulted in out-of-compliance monitoring at the Clive site. Given the amount of existing data (both in time and space) and slow groundwater flow rates at the Clive facility, continued annual sampling and analysis to characterize background groundwater quality at existing wells is not be necessary.

Conclusions and Ground Water Quality Parameters

Analytical parameters for groundwater monitoring at the Clive site were chosen to protect, characterize, allow the determination of alternate concentration limits, and integrates operation issues (contaminant sources, indicator isotopes and their mobility) to provide safety assurance to the citizens of Utah, as the waste poses a potential long-term threat to the public health and environment. Even though groundwater at the Clive site does not meet drinking water standards this strategy provided a target to which groundwater should be treated if contaminants were found in the groundwater. An assessment of potential embankment impacts on groundwater quality at Clive requires consideration of the compositions of any leachate likely to cause an environmental impact as well as the source of, and concentration of those components (what is in the waste). Systematic changes in water constituent composition and concentrations occurs as water moves through waste materials, where it may leach radionuclides and other constituents, because water is an effective solvent and incorporates natural elements as well as any man made chemical constituents. Leachate can contain a large number of contaminants, with a wide range of concentrations depending on solubility, and chemical processes the waste is undergoing, and element abundance in the waste. Leachate characteristics evolve over time, as potential contaminants are flushed from the system, biodegraded occurs, or precipitate increase or decrease. During the operations of the Clive site the waste inventory will increase gradually as the disposal embankments are progressively filled, thus increasing potential groundwater source terms.

Energy*Solutions* wants the monitoring program to focused on identified radionuclides present in the waste received, and provided justification for the elimination of groundwater protection parameters for inorganic (metals, including total uranium; cyanide; fluoride; total nitrate/nitrite), and organics as compliance parameters. Energy*Solutions* contends:

- a more-specific approach of detection monitoring would be just as effective as the present approach and reduce the unnecessary monitoring of naturally occurring constituents.

- 20 years of data collection and evaluation has provides an understanding of background water quality at the Clive site, and any future comprehensive evaluations at that levels of detail will not provide additional information sufficient to justify the effort.

- the naturally poor water quality, due to high TDS, of the groundwater in the vicinity of the Clive site make it not suitable for most human uses and the regulatory requirements to protect groundwater requires a description and justification of the parameters to be monitored.

This would lead to an approach of using key indicator parameters (radionuclides) for frequent sampling and analysis, and a comprehensive list, most of the present compliance monitoring parameters, for less frequent measurement and less rigorous analysis. Maximizing the likelihood of detection of contaminants and minimizing the parameter list would limit the unnecessary monitoring of naturally occurring constituent at the Clive site. Parameters appropriate for groundwater detection monitoring should indicate if the waste operations are impairing the suitability of the groundwater. Given the waste inventory, potential mobility, and detectability of radiological constituents it is likely that detectable increases in a radiological constituent would arrive at a compliance monitoring well before non-radiological constituents, the inorganics and organics. Radioisotope analytical sensitivities are generally equal to that of inorganics compliance parameters at the site; and unlike some metals, background levels of some radioisotopes included as compliance parameters are essentially zero (Energy*Solutions*, December 7, 2012). Analytical methods used at the Clive site for detection and quantification of radiological constituents in water are standardized (U.S. EPA, U.S. DOE HASL-300, ASTM, etc.), and radioanalytical quality control is identical to non-radiological analytical quality control including analysis and reporting of method blanks, laboratory control samples, matrix spike samples, matrix spike duplicate samples, and laboratory duplicates. Radiological data collected at compliance monitoring wells at the Clive site have demonstrated the ability of radioanalytical laboratories to quantify concentration of radiological compliance monitoring parameters in the groundwater and to provide accurate, precise, and reproducible data (Energy*Solutions*, August 4, 2014). Radionuclides have been commonly used as surrogate parameters in embankment infiltration and transport modeling, because of their high mobility relative to metals and most organics, and the frequency of their presence in the waste (Whetstone Associates, Inc., July 19, 2000, November 22, 2000, August 1, 2000, November 18, 2011, and May 29, 2012). The Manifest Radioisotope Inventory Report provides documentation of the radiological content of the waste material disposed in each embankment at the Clive site (Energy*Solutions*, August 23, 2012).

With the issuance of the Permit in 1991, the State of Utah's policy was to protect the shallow groundwater by addressing potential contamination, although background conditions were not thoroughly characterized. The Director recognized groundwater monitoring is meaningful when the results of the individual analyses are compared to useful parameter protection limits, and set most GWPLs as the State Ground Water Quality Standards, but allowed the use of an alternate GWPL (background concentration), because the shallow groundwater at the Clive site is defined as Class IV groundwater and was not characterized adequately to set other GWPL. Background concentrations are based on statistical analysis of concentration data, and when they exceed the GWQS their protection levels are listed in the exception tables of the Permit, Tables 1B, 1D, and 1F. For various reasons detecting individual constituents in groundwater at the Clive site can be difficult due to the complex nature of the groundwater system (e.g. high concentrations of major dissolved solids causing interference problems for the analysis and quantification of minor and trace constituents), natural variability of constituent concentrations in an aquifer, and the problem of obtaining a representative groundwater sample. Naturally occurring inorganic compliance parameters found in Clive facility sediments and groundwater have affected the efficiency of compliance monitoring program and resulted in a number of the metals being listed for individual wells at various locations in the exception tables (in all cases these have been shown to be due to natural concentrations being greater than the GWPL). Background conditions at the Clive site are now well established, with over 20 years of data for inorganic, organic, and radiological parameters; the site is thoroughly characterized. Water Quality Rules indicate that groundwater protection should consider the beneficial use of water, which is generally dependent on the water quality and the potential value of the water, and allows flexibility in selecting compliance parameters and setting GWPLs is allowed, so long as they are protective of public health and the environment.

Chemical and physical changes can potentially mobilize or stabilize groundwater constituents that were originally present in, or introduced to the aquifer. Energy*Solutions* specially proposes to eliminate total uranium as a Permit compliance parameter, and to add isotopic uranium to the list of radiological compliance parameters for the 11e.(2) monitoring wells (isotopic uranium parameters are already included in the list of compliance parameters for the LARW, Class A West, evaporation ponds, and for Mixed Waste GWPLs). Total uranium concentrations can be calculated from isotopic data, and total uranium analysis provides less information than isotopic uranium analysis (Energy*Solutions*, December 7, 2012). Energy*Solutions* provided a comparison of laboratory total uranium analytical results to calculate isotopic uranium total uranium values that for almost all samples, the laboratory total uranium result is within the calculated total uranium range when the isotopic counting error is included. Total uranium will continuous to be reported, but will be a calculated concentration from the isotopic uranium. The total uranium GWPL would be retained as total uranium mass concentration will calculated and reported in accordance with reporting requirements

When properly evaluated, non-natural occurring organic compounds are suitable indicators of contamination. As some organic compounds are not naturally occurring, their presences in groundwater samples would likely indication that the facility has released contamination to the environment. Wells monitoring the 11e.(2) embankment are sampled and analyzed for VOCs, SVOCs, and the pesticide chlordane. Wells monitoring the LARW, Class A West and evaporation ponds are monitored for VOC's. The Mixed Waste monitoring wells are sampled for an extensive list of VOCs, and SVOCs requires under their Part B RCRA Permit. Evaluating organic monitoring parameters at the Clive site indicate these compounds have not been detected at any Clive compliance monitoring wells. Although VOCs are fairly soluble, the primary fate of most VOCs is difficult to understand, with biogeochemical processes occurring during subsurface transport making them particularly immobile in groundwater. SVOCs do not appear to have been detected in the shallow groundwater or related to waste disposal activities. The data collected for the last 20 years at the Clive site indicate that organic parameters do not appear to be present in, or at least have not reached any compliance monitoring wells. The VOCs required in the Permit may be somewhat feeble indicators of groundwater contamination. The organic compounds required in the current Permit would seem to meet this condition. Because of the non-detection of organics in 20 years, their complex nature, and slow movement of groundwater at the Clive site, monitoring of VOCs on a renewal bases is acceptable. A much broader list of organic will continue to be sampled at the mixed waste embankment. The Director has determined that VOCs required in the Permit, at the LARW, Class A West and Evaporation; and 11e.(2) monitoring wells, can be removed from the parameter list, SVOCs and the pesticide chlordane will remain for the11e.(2) monitoring wells.

Given public concerns the Director must decide how best to protect public health and the environment with such a mix of potential contaminants at a site, the question arises, what parameters should be monitored for, or should the system focus on a specific parameters list to minimize the impact of site introduced variability? Groundwater quality may be characterized by literally thousands of chemical constituents. Groundwater contamination at the Clive site could go undetected without adequate monitoring. It is important that the embankments be monitored to ensure that they do not, to any significant extent, create an unacceptable risk to groundwater. The purpose of monitoring is to maximizing the likelihood of detecting a contaminant release to groundwater. In any given monitoring program, there may be individual elements, groups of elements, or compounds in an analytical list that can be changed based upon the results of previous sampling events and/or their low probability of detection in groundwater. Parameter selection and GWPLs can be used to optimize the monitoring system, control false indications, eliminate unnecessary laboratory work, and minimize data management and regulatory responses. Analytical results that show little or no change in concentration overtime do not necessarily mean that the inorganic are not present, just that they have not reached a compliance monitoring well. The inorganic will no longer be compliance monitoring parameters. Although they will not be compliance parameters the inorganic would be retained as permit renewal parameters. At the time of Permit renewal, samples would be collected, analyzed, and reported. The results would be compared to a background dataset reported in the Comprehensive Groundwater Quality Evaluation Report.

The proposed groundwater parameters and protection levels universal to all LARW, Class A West and Evaporation Ponds wells:

Parameter	GWPL	Parameter	GWPL
Field Parameters		*Radiologic Parameters – Alpha Emitters (pCi/l)*	
pH (units)	6.5 – 8.5	Neptunium-237	7
		Strontium-90	42
		Thorium-230	83
		Thorium-232	92
Dissolved Metal (mg/l)		Uranium-233	26
Uranium - total	0.03	Uranium-234	26
		Uranium-235	27
		Uranium-236	27
		Uranium-238	26
		Radiologic Parameters – Beta/Gamma Emitters (pCi/l)	
		Carbon-14	3,200
		Iodine-129	21
		Technetium-99	3,790
		Tritium	60,900
		Combined Radiologic Parameters (pCi/l)	
		Radium-226 + Radium-228	5

The proposed groundwater parameters and protection levels universal for all 11e.(2) wells:

Parameter	GWPL	Parameter	GWPL
Field Parameters		*Organic Parameters – Specific to 11e.(2) (mg/l))*	
pH (units)	6.5 – 8.5	Naphthalene [(8)]	0.02
Dissolved Metal (mg/l)		Diethyl Phthalate	5.0
Uranium - total	0.03	2-Methylnaphthalene	0.004
		Benzo(a)anthrancene	0.01
Radiologic Parameters – Alpha Emitters (pCi/l)		Benzo(a)pyrene	0.01
Neptunium-237	7	Benzo(k)fluoranthene	0.01
Strontium-90	42	Chlordane	0.002
Thorium-230	83	Chrysene	0.01
Thorium-232	92	*Radiologic Parameters – Beta/Gamma Emitters (pCi/l)*	
Uranium-233	26	Carbon-14	3,200
Uranium-234	26	Iodine-129	21
Uranium-235	27	Technetium-99	3,790
Uranium-236	27	Tritium	60,900
Uranium-238	26		
		Combined Radiologic Parameters (pCi/l)	
		Radium-226 + Radium-228	5
		Radiologic Parameters (pCi/l)	
		Thorium-230	83
		Thorium-232	92

The proposed groundwater monitoring parameters and protection levels for all Mixed Waste monitoring wells:

Parameter	GWPL	Parameter	GWPL
Dissolved Metal (mg/l)			
Uranium - total	0.03		
Radiologic Parameters (pCi/l)		*Beta/Gamma Emitters*	
Alpha Emitters		Carbon-14	3,200
Neptunium-237	7	Iodine-129	21
Strontium-90	42	Technetium-99	3,790
Thorium-230	83	Tritium	60,900
Thorium-232	92		
Uranium-233	26		
Uranium-234	26	*Combined Radiologic Parameters (pCi/l)*	
Uranium-235	27	Radium-226 + Radium-228	5
Uranium-236	27		
Uranium-238	26		

Twenty years of inorganic data collection from monitoring wells at the Clive site has demonstrated that inorganics are not significant constituents, and would be inadequate indicators of embankment leakage. Energy*Solutions* has demonstrated that inorganic exceedances at a number of compliance monitoring wells are due to natural concentrations of metals in the shallow groundwater being greater than GWPLs. Inorganics required in the Permit, at the LARW, Class A West, and Evaporation Ponds; and 11e.(2) monitoring wells, with the exception of total uranium, can be removed from the parameter list and monitored on a renewal bases (every 5 years). VOCs required in the Permit, at the LARW, Class A West and Evaporation ponds; and 11e.(2) monitoring wells, can be removed from the parameter list as well, because of the non-detection of organics in 20 years, VOCs characteristics, and slow movement of the groundwater at the Clive site, monitoring of VOCs on a renewal bases (every 5 years) is acceptable. SVOCs and the pesticide chlordane will remain for the11e.(2) monitoring wells. Given the waste inventory, observed evaporation ponds constituents concentrations, potential mobility, and detectability of radiological constituents, radiological constituents are more reliable indicators of waste embankment leakage and radiologic parameters are added to the 11e.(2) embankment monitoring requirements.

Although the inorganics and organics are eliminated as compliance parameters, they will be retained as permit renewal parameters. At the time of Permit renewal, samples will be collected and analyzed for constituent concentrations and reported in the Comprehensive Groundwater Quality Evaluation Report, required for Permit renewal. The analytical results will be compared to statistical results for each parameter that is contained in the Comprehensive Groundwater Quality Evaluation Report. The comparison will evaluate potential changes in the groundwater inorganics and organic concentrations. If any Permit renewal parameters are found to be greater than the mean concentration plus two times the standard deviation concentration (background concentration) the Permittee will need to go into an accelerated monitoring program for that well and parameter. Additional, if any compliance monitoring well for the Mixed Waste embankment has a inorganic parameter that exceeds the GWPLs for the Mixed Waste Embankment, than wells along the east side of the LLRW embankment will immediately be sampled for that parameter. All embankments will continue to be monitored for radiological constituents. The proposed modification will not reduce protection of human health and the environment because potential impacts to groundwater from the Clive facility will be detected by continued monitoring of radiological compliance parameters in groundwater, which are better indicators of embankment leakage.

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