Draft Statement of Work Plan
Revision 3

REQUEST FOR PROPOSAL (RFP)
BACKGROUND DOCUMENTATION

Drilling, substrate recovery and sampling, and installation of groundwater monitoring wells on Runit Island, Enewetak Atoll, Republic of the Marshall Islands

2021-2023

This work was performed under the auspices of the
U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

LLNL-MI-817635

Project Driver

This work plan will be performed under the auspices of the U.S. Department of Energy (DOE) by Lawrence Livermore National Laboratory (LLNL) in support of Public Law (P.L.) 112-149, Insular Areas Act 2011. The P.L. establishes a mandate for the U.S. DOE to perform visual inspections of a nuclear waste containment structure (commonly known as *Runit Dome*) located on Runit Island at Enewetak Atoll in the northern Marshall Islands, and develop a long-term groundwater monitoring program at the site. Visual inspections of the containment structure were completed in 2013 and 2018. To implement a groundwater monitoring program, it will be necessary to drill, recovery and sample subsurface materials, and install a series of hydrologically aligned groundwater monitoring wells both on and off *Runit Dome*. This document was prepared as background information for potential subcontractors interested in bidding on the borehole drilling and substrate recovery and/or groundwater installation phases of the project. The drilling and groundwater installation phase of the project is scheduled to take place late summer of 2021 with pump testing and initial groundwater sampling operations to be performed synchronously.

Project Location and Logistics

The Republic of the Marshall Islands lies in the north-western equatorial Pacific Ocean between Hawaii and Australia. Enewetak Atoll is former U.S. nuclear test site. The project calls for the drilling and establishment of groundwater monitoring wells placed on and off a low-level radioactive waste containment structure built on Runit Island during 1980 (Fig. 1). The containment structure is located on the northern end of Runit Island – a small, uninhabited islet located on the eastern fringe of the atoll. During 1979-80, a mixture of soil-cement and radioactive debris were buried inside an unlined nuclear test crater formed during the Cactus test, and then covered over with a concrete cap to help reduce effects of weathering on the waste pile below (Hamilton, 2013). The Lacrosse crater of similar dimensions is easily recognizable on the ocean reef NE of *Runit Dome* (Fig. 1).

Personnel engaged in this project traveling from the U.S. Mainland will overnight in Hawaii, and then fly onto Kwajalein or Majuro Atolls the following morning. From there the support team will board a *Donier* twin propeller aircraft operated by Air Marshall Islands (AMI) and take a 2 to 3-hour flight to Enewetak Atoll. The weather is hot and humid but tempered by trade winds that prevail throughout most of the year. The temperature averages around 27 degree Celsius (80 degrees Fahrenheit) and rarely fluctuates. Although Runit Island is covered with low-lying tropical vegetation there are few trees to provide shade. Lodging for the support team will be provided at site aboard ship or in dorm-style facility located on Enewetak Island (about 8 miles away by small boat). All local travel arrangements, along with food and lodging, will be provided by LLNS on behalf of the subcontractors.

Fig 1. Aerial view of *Runit Dome* on Runit Island, Enewetak Atoll (credit - *Google Earth*).

Background Information

The U.S. conducted 43 atmospheric nuclear weapons tests at Enewetak Atoll between 1947 and 1958. Enewetak Atoll was resettled in 1980. Prior to resettlement, contaminated surface soil and radioactive debris from various islands were selectively removed, mixed with cement, and buried inside Cactus crater above and below sea level. The waste pile was then covered over with an array of 45 cm (18 in) thick concrete panels to form an erosion resistant dome shaped structure. The Cactus crater waste containment structure formally consists of five major structural elements:

1. A non-load bearing, erosion resistant concrete cap.
2. A concrete key wall located around the perimeter of the dome.
3. A soil-cement zone above ground-level.
4. A *tremie layer* of soil-cement placed underwater inside Cactus crater.
5. A fallout zone of pulverized coral resulting from the original nuclear blast.

The dimensions of *Runit Dome* are approximately 100 m (340 ft) in diameter, and about 10.5 m (35 ft) above sea level. The waste pile contains 83,000 cubic meters of contaminated surface soil (as soil-cement) and about 4,700 cubic meters of contaminated debris (Hamilton, 2013). A generalized schematic showing the layout and design features of the *Runit Dome* containment structure is shown in Figure 2 of the Hamilton (2013) report. The cleanup program focused on reducing levels of Transuranium (TRU) elements (^{238}Pu,

^{239}Pu, ^{240}Pu, and ^{241}Am) in surface soil to prescribed cleanup standards. The entombed soil and debris also contained a range of activation and fission products.

The last two nuclear test events on Runit Island, code named Quince and Fig, were detonated in 1958 at ground level near the middle of Runit Island (DOE, 2000). Radiological surveys later revealed that particles recovered from the vicinity of the Quince and Fig sites contained relatively high concentrations of unfissioned nuclear fuel, including fragment size particles of plutonium (DOE, 1982). This higher-level debris was subsequently recovered, immobilized inside concrete blocks, and the concrete blocks placed under the apex of the dome in an area described as the 'donut hole'. It should be noted that established locations for drilling boreholes on the containment structure are located away from the 'donut hole'.

Previous Investigations

The National Academy of Sciences (NAS) funded an investigation to evaluate the efficacy of the *Runit Dome* containment structure during the early 1980s. Although the NAS study concluded that the containment structure contents posed no credible hazard to the Enewetak Atoll inhabitants, at least part of the radioactivity contained in the structure was thought to be available for transport to the groundwater and subsequently to the lagoon (Noshkin and Robinson, 1997). The NAS investigation included analysis of soil and groundwater on Runit Island. The work is detailed in Ristvet (1980) and summarized below as part of this background document.

In March 1980, a drill crew consisting of one driller and two helpers with use of a portable, skid mounted Boart Longyear 53 rig on a truck was mobilized to Runit Island. The drilling equipment included 35 five-inch diamond core bits, five-inch and 6 7/8-inch rock bits, 1.5-inch by 18-inch and three-inch by 18-inch split spoons with a 140-lb hammer, 26 m (85 feet) of NX drill rods, 10.6 m (35 feet) of six-inch steel casing, and a separate closed circulation system with pump. The drill rig and circulation system were powered using a four-cylinder gas engine. Eighteen boreholes were drilled and sampled within and adjacent to *Runit Dome* over a period of 17 days. Three of the 18 boreholes (CD-1, CD-12 and CD-17) were continuously cored through the concrete cap to the bottom of the containment structure to depths ranging from 12 to 17 m (36.5 to 52 ft). Nine of the boreholes were drilled through the depth of the concrete cap (about 45 cm or 18 inches in thickness), 4 boreholes (CD-2, CD-10, CD-13 and CD-14) were drilled down through the key wall to depths ranging from 3.4 to 4.2 m (11 to 13.5 ft), and 2 boreholes (CD-15 and CD-16) were drilled into natural geologic materials adjacent to the dome to depths ranging from 23.8 to 25 m (78.5 to 80.5 ft) below ground level. A diamond core bit with seawater or mud circulation was used to drill through the concrete cap, key wall structures and underlying radiological debris within the dome, and through the geologic materials off the dome. Concrete and highly consolidated materials were sampled by continuous coring. Loosely consolidated soil, debris, and geologic materials were generally sampled using a split spoon sampler. Due to loosely consolidated material within and off *Runit Dome*, a bentonite drilling mud was required to stabilize the borehole due to extensive sloughing and caving. Six-inch steel casing was also temporarily installed as needed to maintain borehole stability.

The boreholes located on *Runit Dome* on average encountered about a 4-m layer of soil-cement beneath the concrete cap. The soil-cement zone was found to be variably consolidated with intervals requiring over 100 blow counts per foot to drive a split spoon sampler, especially near the bottom of this zone at about 4 m (13 ft) depth. Oversize debris consisting of cobbles, decaying wood and other organic matter, concrete, wire, and metal debris was occasionally encountered in the soil-cement zone from 4 to 5.5 meters (13 to 17 ft) depth. Below the oversize material, the CD-1 borehole encountered an approximately 6.5 m (20 ft) thick sequence of alternating, poor-to-moderately cemented layers with un-cemented soil and various types of debris from about 5.5 to 12 m (17 to 37 ft) depth. This zone was continuously cored using seawater for circulation with poor to fair recovery ranging from 0 to 50%. The crater fallback zone was encountered from 12 to 16 m (37 to 52 ft). The fallback zone consisted of un-cemented fine to medium-grained coralline sand and fractured gravel. It was successfully sampled using a split spoon sampler with blow counts varying from 13 to 32 blows per foot. Samples removed from the borehole were routinely scanned for alpha, beta, and gamma radiation, and exhibited near background levels of contamination. The CD-17 well was cased with 5 cm (2 inch) diameter, continuously slotted PVC casing to 11 m (36.5 ft) for groundwater sampling. The geologic material beneath the crater fallback zone is expected to be fractured beachrock.

The two boreholes located adjacent to *Runit Dome* encountered un-cemented coralline sand and gravel to about 2 m (6 ft). From 2 to 25 m (6 to 80 ft) depth, the boreholes encountered alternating moderate to well-cemented coralline grainstone, boundstone, and fractured beachrock with layers of un-cemented coralline sand and gravel. No core, debris or soil samples were recovered from these boreholes, which were logged using only drill cuttings. Both boreholes were completed to a depth of about 24 meters (80 ft) with 4-inch, continuously slotted PVC casing for groundwater sampling.

Depending on tide level, groundwater was encountered at depths of 4.5 to 6 m (15 to 20 ft) beneath *Runit Dome*, and at 3 to 4 meters (10 to 13 ft) beneath the island at the off-dome locations. Seawater was encountered at 15 to 20 m (50 to 60 ft) on the island.

Project Objective

The overall objective of this project is to develop and implement a technically defensible, long-term groundwater monitoring program on and around the Cactus crater contaminant structure on Runit Island. Under the drilling phase of the project, it is expected the drilling subcontractor will work with LLNS and a Drilling Geologist (DG) - Subject Matter Expert (SME) in hydrogeology to determine needs to drill a minimum of seven (7) boreholes located on and off the containment structure in anticipation installing groundwater sampling wells. The drilling operation must allow for optimum recovery of subsurface substrate materials. Representative subsurface materials will be packaged and shipped back to LLNL for radionuclide analysis. The remaining material will be packaged on-site and managed as radioactive waste for subsequent disposal in the United States (*yet to be determined*). The original workplan called for the use of an Fraste XL Multidrilll with hammer and rotary capability previously acquired by the program. While this drilling rig can still be made available as needed or in a backup capacity, *it has since been determined that the most effective drilling method in this type of environment that allows for more optimum recovery of substrate material is likely to be that associated with use of a sonic drilling apparatus.*

Waste characterization and handling will be managed outside of the drilling contractor award but will necessarily require driller feedback on the expected amount of waste to be generated. The subcontractor is also expected to provide a listing of required hand tools, gas powered equipment and/or other supplies and equipment needed to maintain operations and perform on-site repairs under a fully self-contained field operation without the need for outside services or suppliers. All logistical operations involving the shipment of materials along with local (in-county) personal travel will be managed by LLNS. As previously discussed, the services of a DG SME in hydrogeology will be sought to work closely with the drilling subcontractor to determine needs for operation of a sonic drilling rig(s) or equivalent and help define procurement needs for tooling, on-site service vehicles and/or other equipment or consumable supplies as needed.

The overall aim of the *Runit Dome* Project is to evaluate potential adverse health and ecological impacts of leakage of radioactive contamination from *Runit Dome* into the surrounding marine environment. To accomplish this goal, LLNL scientists plan to monitor groundwater quality and water levels in a minimum of six (6) borehole locations using multi-depth sampling techniques. The data and information developed from this study will be used to assess and model the impacts of significant hydrologic events, including tropical storms, on the fate and transport of radionuclides contained in the waste pile and underlying groundwater.

Proposed Scope

Three (3) boreholes will be drilled into the waste pile on the containment structure, 2 boreholes off the containment structure, and 1 borehole at a control site on Runit Island at some distance away from the containment structure (Table 1; Fig. 2). The 3 boreholes on the containment structure will be located at the corners of a triangle with orientation across and along forcing lines predicted by the direction of prevailing winds and the ocean reef break (Fig 2). This arrangement will allow for an estimate of water table shape, gradient, and direction. The proposed borehole locations shown in Figure 2 are approximate with boreholes placed on the C row above the base of the dome on segment C9, C25 and C33. The compression strength of concrete (as per ASTM C42) across a path that the drilling rig would take to access these locations averaged 6,704 psi with a Coefficient of Variation (COV) of 16.4% (Hamilton, 2020).

Table 1. Summary of Borehole and Well Specification Details for Groundwater Sampling Wells.

ID code	Depth	Drill Method	Screen Depths (based on an 80 ft borehole)
On-containment Structure Boreholes			
21RD-01	max 25 m (80 ft)	Sonic	Tremie (18-24 ft; 47-53 ft), Fallback (55-61 ft); Factured Geologic Below Crater (72-78 ft)
21RD-02	max 25 m (80 ft)	Sonic	Tremie (18-24 ft; 47-53 ft), Fallback (55-61 ft); Factured Geologic Below Crater (72-78 ft)
21RD-03	max 25 m (80 ft)	Sonic	Tremie (18-24 ft; 47-53 ftft), Fallback (55-61 ft); Factured Geologic Below Crater (72-78 ft)
Off-containment Structure Boreholes			
21OD-01	Max 22 m (72 ft)	Sonic	Loosely consolidated sand and gravel (10-16 ft; 39-45 ft); Alternating cemented corraline grainstone and boundstone (47-53 ft; 64-70 ft)
21OD-02	Max 22 m (72 ft)	Sonic	Loosely consolidated sand and gravel (10-16 ft; 39-45 ft); Alternating cemented corraline grainstone and boundstone (47-53 ft; 64-70 ft)
Background Control Site Borehole			
21BG-01	Max 22 m (72 ft)	Sonic	Loosely consolidated sand and gravel (10-16 ft; 39-45 ft); Alternating cemented corraline grainstone and boundstone (47-53 ft; 64-70 ft)

Note. Well screen depths are estimates. Actual screen depths will be determined by the drilling geologist based on observations made during drilling operations.

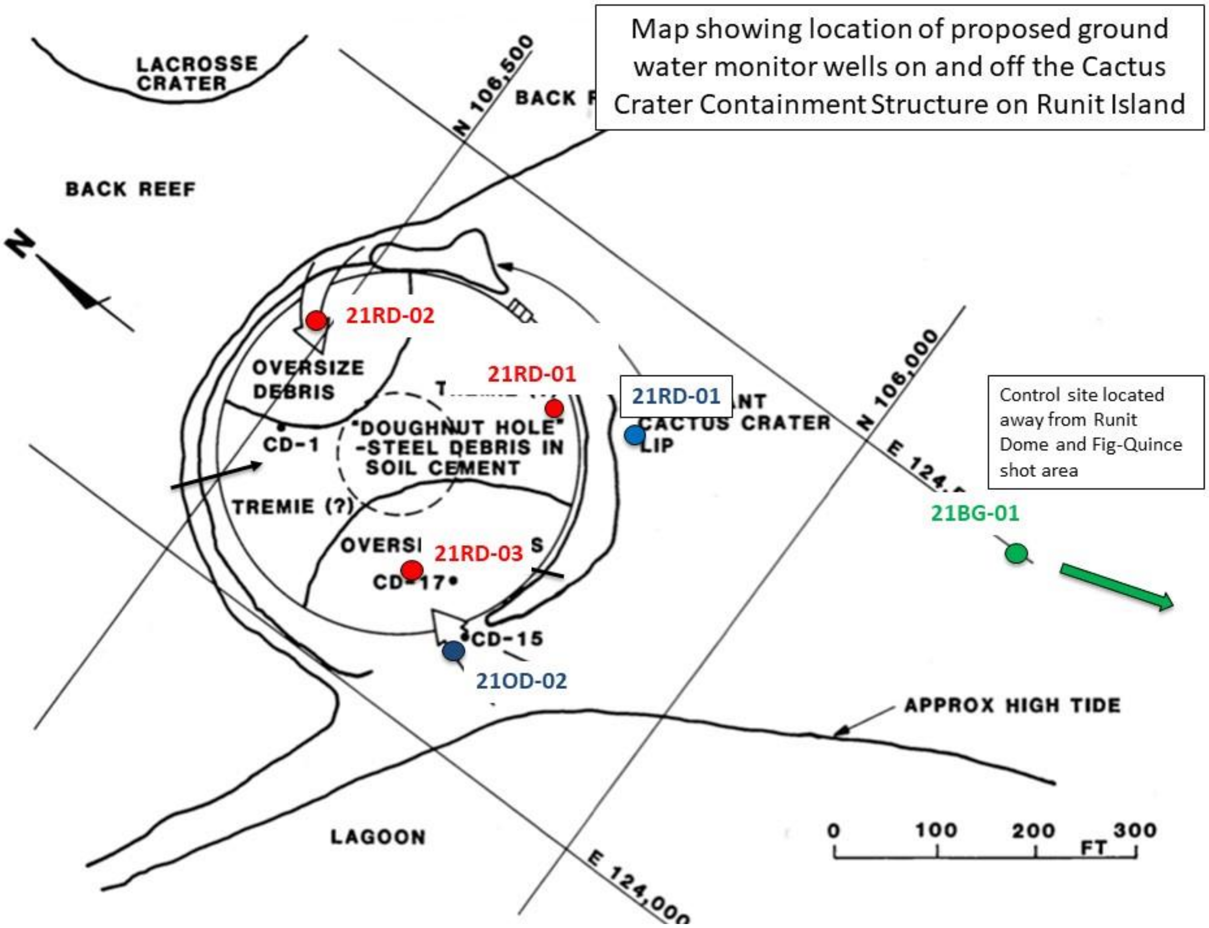

Fig 2. Schematic cross-section showing proposed locations of groundwater monitoring wells on and off *Runit Dome* (modified after Ristvet, 1980).

A final decision on borehole locations will not be made until the start of drilling activities. All boreholes will be completed as groundwater sampling wells by the DG SME in hydrogeology. Borehole drilling requirements should be based on drilling approximately 480 linear feet of borehole on a timeline of approximately 10 full workdays. Consideration will be given to a 24-h drilling operation at site using two separate crews on 10 to 12-hour shifts. Pricing should include a contingency budget line to allow for drilling up to an additional 120 ft of borehole and spending 3 additional days at site to allow flexibility in making real-time adjustments to drill depths consistent with placing groundwater monitoring wells within different media or geologic horizons and/or drilling one or more additional boreholes or addressing unanticipated findings.

The three boreholes in the on-containment structure position will be identified as 21RD-01, 21RD-02, and 21RD-03. The two boreholes in the off-containment structure position will be identified as 21OD-01 and 21OD-02. The remaining borehole located at the control site will be identified as 21BG-01 (Table 1).

The supplemental information given below is expected to aid subcontractors in making more informed decisions about how best to meet the requirements of the drilling and groundwater well installation phases of the project.

For on-containment structure borehole wells, the subcontractor should anticipate the need to drill and continuously sample the soil-cement substrate above sea level (between 0.5 to 6 m), from within the 3 to 8 m layer of tremie concrete placed below sea level, from within the 3 to 8 m (10 to 25 ft) layer of fine sediment contained within crater fallback zone, and from the geologic materials below the crater to a maximum depth of approximately 25 meters (80 ft) (Table 1; Fig 3). The range of material encountered will likely include loosely consolidated soil, debris, geologic materials, hardened Portland cement and moderate to well-cemented sediments, including materials prone to sloughing and/or caving. Due to the shape of the concrete cap and dome structure, measures will need to be taken to safely position and operate the drill rig on the surface of the dome.

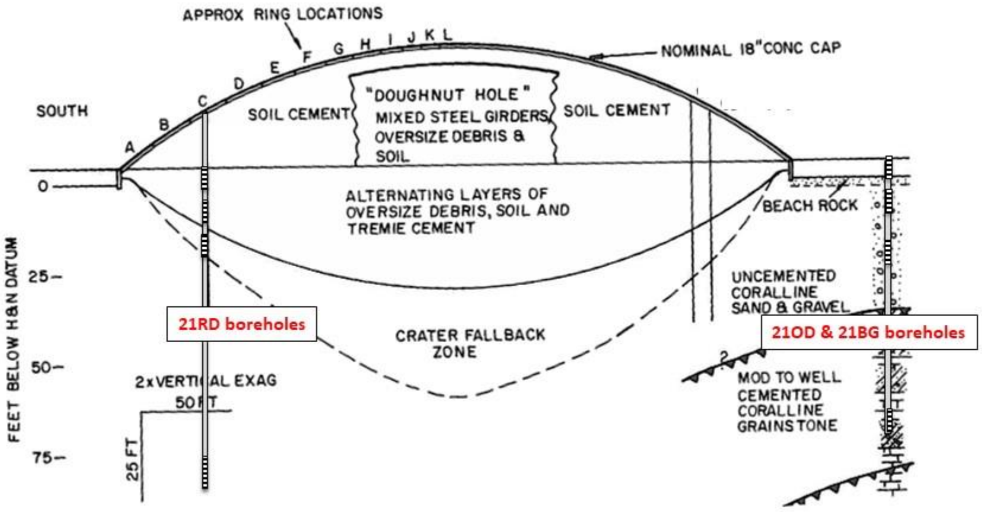

Fig 3. Idealized map showing placement of discrete depth groundwater monitor wells on and off *Runit Dome* (modified after Ristvet, 1980).

For off-containment boreholes wells, there will be a need to drill and continuously sample loosely consolidated coralline sand and gravel from the ground surface to about 10-12 meters (33-39 ft), and interbedded layers of cemented grainstone and boundstone layer between 10 to 25 meters (33 to 80 ft) with some alternating coralline sand and gravel (Table 1; Fig. 3). Where appropriate, all drill cuttings, drilling fluids and groundwater will require a closed circulation system to prevent spillage or minimize releases to the environment. The DG SME hydrogeologist will review data collected during drilling and sampling operation, and then specify a well completion design for each borehole with necessary well installation requirements (screen depths, plug back depths, other).

As shown in Fig. 2, normalizing to an 80 ft maximum depth borehole, we anticipate need to screen each 21RD *borehole to allow multi-depth groundwater sampling in the tremie layer (minimum of 2 depths centered around* 6.5 m (or 21 ft) and 13 m (or 40 ft), in the Crater fallback zone (minimum 1 depth centered 18 m or 58 ft), and in the fractured geologic material below the crater (1 depth centered around 23 m or 75 ft).

Similarly, the 21OD and 21BG boreholes wells should be screened in the loosely consolidated coralline sand and gravel [2 depths centered around 4 m or 13 ft and 10 m or 32 ft], and in the deeper alternating un-cemented coralline sand/gravel and cemented grainstone and boundstone layers [2 depths centered around 15.5 m or 50 ft) and 20.5 m or 67 ft]. The DG SME in consultation with the drill operator team shift lead will record whether fresh water or seawater is used during drilling operation, and at what depth groundwater is encountered in each borehole. This information will be used for well design to include the depths of intervals of annular materials and placement of well screen. Depending on tide level, fresh groundwater is anticipated at 4 to 6 meters (13 to 20 ft) beneath *Runit Dome* and at 3 to 4 meters (10 to 12 ft) beneath the island in the off-containment structure locations. Previous investigations noted that tides influence the level of groundwater within the *Runit Dome* containment structure. Well completion design should allow for groundwater sampling and placement of water quality sensor equipment.

Sampling and Monitoring Protocol

The drilling subcontractor in coordination with the CSSO/DG SME in geohydrology will need to continuously sample the subsurface borehole materials recovered from each borehole. All core samples will be screened with handheld radiation detectors, and temporarily placed in containment troughs to prevent any contamination of the dome surface or surface soil on the island.

The DG SME is expected to aid efforts to document drilling and sampling activities and lead the subsequent well installation phase of the project. The well log should include descriptions of all anthropogenic and natural geologic materials encountered in each borehole. In consultation with CSSO, the GD SME will also describe and label and prepare all representative borehole materials for shipment to LLNL for radiological analysis. For example, analytical subsamples obtained from the site 2 off-containment borehole (21OD-02) at 10 meters would be identified as 21OD02-ID (10 meters) where ID is a unique field log tracking number. The containment bag will be similarly labelled and include the date, location notes and sample interval. All analytical subsamples and waste containment shipments will be managed under a formal Chain-of-Custody (COC) process. Any radiation measurements (counts rates) conducted in the field on core or recovered materials should be noted in the drilling log with an indication of whether samples exhibit background or elevated radiation count rates. After log descriptions are completed, all subsurface borehole materials will be placed in metal drums with a copy of the COC documentation (with sample listings, dates, depth, and any measured radiation count rates).

After the well is installed, DG SME in consultation with the CSSO will conduct pump and well development testing. Potential chemical and physical will include water conductivity, pH, RO and clarity. Once the well has been satisfactorily completed, baseline groundwater samples will be collected and stored until they are ready for shipment to LLNL for analysis. Groundwater samples will be managed in the same way as borehole materials with sample tracking using unique identifiers and COC documentation.

Job Hazards Analysis (JHA)

The drilling and bore installation subcontractors will be responsible for submitting a drilling operations Job Hazards Analysis (JHA) as formal part of the response to this call. The JHA will be reviewed and approved by LLNS prior to award of contract.

Additional personnel monitoring procedures, any specific Personal Protective Equipment (PPE) requirements and other recommended LLNS safety measures for conducting services at site under this project will be outlined in separate safety documentation. All subcontractors and field labor support personnel will be afforded the opportunity to participant as volunteers in the Marshall Islands Radiological Protection Monitoring Program based on Whole Body Counting and Pu urinalysis bioassay monitoring.

LLNS safety documents will also outline specific radiological monitoring protocols for all personnel working on Runit Island. PPE such work boots, gloves, coveralls, and respirators will remain on island during drilling operations. Personnel will be scanned with a hand-held radiation meter prior to leaving the island to ensure that no measurable radiological material is present. Any radiation discovered will be removed and verified with handheld radiation meters prior to leaving the island. The LLNS safety documentation also addresses non-radiological hazards, such as heat exhaustion, and specifies monitoring and control measures, e.g., use of heat stress monitors positioned on and around the work site, shading, hydration, electrolyte replacement and rest periods, to minimize any adverse effects of work activities on personnel.

Schedule

The Runit Project is expected to extend over calendar year 2021-2023. Under the drilling contract award, the following list of phased deliverables are expected to be completed 01/01/21 through 9/30/21.

(i) Provide consulting services to LLNS in cooperation with Drilling Geologists Subject Matter Expert (DG SME) in geohydrology, to identify and provide procurement bids for tooling, accessories, consumables and spare parts needed to drill up to 465 linear feet of bore hole over 6 different sites on and off the Cactus Crater containment structure on Runit Island.

(ii) In consultation with LLNS and the assigned DG SME in geohydrology, identify procurement needs and acquire separate bids to purchase tooling and consumable supplies needed to drill an additional 120 linear feet of borehole.

(iii) Provide a 3-month rental with a 1-month extension option for a Fraste style drilling rig or equivalent fitted with sonic head.

(iv) Provide a 3-month rental with a 1-month extension option (or purchase on second-hand market) for a multi-purpose tracked loader support vehicle with bucket, folk-lift, and drum loader and grapple or equivalent to support drilling operations on and off the Cactus Crater containment structure on Runit Island.

(v) Provide a 3-month rental with a 1-month extension option (or purchase as new or on the second-hand market) any additional major items of equipment needed to support a fully self-contained drilling operation on and off the Cactus Crater containment structure on Runit Island.

(vi) Take delivery of tooling, accessories, consumable materials, and spare parts procured by LLNS for the drilling operation and verify delivery of all equipment and supplies.

(vii) Ready the drill rig, support vehicle(s), tooling and all related materials and supplies for shipment to the Marshall Islands inside 20 ft. shipping transportainers.

(viii) Provide drill helpers and a lead driller to participate in a 10-day drilling operation on and off the Cactus Crater containment structure on Runit Island with a 3-day contingency option to be applied and funded on an as needed basis.

Notes:

1. To ensure timely completion of the drilling operation on Runit Island within the allotted timeframe (10-13 days), it is anticipated that the drilling contractor will base the cost of providing Services based on continuous operation of the drill rig using separate drilling teams working 10 to 12-hour shifts.

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