IMPLEMENTATION OF A COMBINED RISK- AND DOSE-BASE END STATE APPROACH TO DECOMMISSION A DEPLETED URANIUM SITE

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ABSTRACT

The Watertown General Services Administration (GSA) Site, formerly a part of the Watertown Arsenal in Watertown, Massachusetts, was contaminated with depleted uranium, heavy metals, and petroleum and, due to the presence of mixed waste, was jointly regulated by the Nuclear Regulatory Commission (NRC), the Massachusetts Department of Public Health (MADPH), and the Massachusetts Department of Environmental Protection (MADEP). The NRC and MADPH regulated the residual radioactivity on the site resulting from former operations involving depleted uranium, and the MADEP regulated hazardous wastes at the Site, which by MADEP-definition included depleted uranium. To address the closure requirements of the three regulatory agencies, a single process that would satisfy the performance standards of each regulation and be agreed upon by all three regulatory agencies was developed by identifying similarities in the performance standards and goals of NRC/MADPH and MADEP site investigation and risk characterization processes. A project steering group comprised of representatives from MADEP, MADPH, NRC, and the current and proposed future Site owners was then formed to create a forum for discussion of stakeholder concerns, regulatory requirements, presentation of technical issues, and identification of the future land use conditions that the cleanup criteria would be developed to meet (i.e., the risk-based end state), with the overall objective of creating a technical and regulatory approach that all stakeholders were amenable to. This paper describes the successful implementation of the risk-based end states approach to achieve decommissioning and regulatory release of the Watertown GSA Site.

INTRODUCTION

The Watertown Arsenal, located in Watertown Massachusetts, operated from 1818 to 1968 to produce munitions and to support munitions research and development, in support of the U.S. Army. The property known as the GSA Site is an 11.9 acre parcel of land adjacent to the Watertown Arsenal that was owned by the Commonwealth of Massachusetts until it was withdrawn by the federal government in 1920 for use in support of Watertown Arsenal operations.

Beginning in the late 1950's and continuing through the 1960's, activities at the Watertown Arsenal included research and development, and light manufacturing, of munitions made with depleted uranium metal (DU). Specific activities performed at the Arsenal included grinding, milling, heat treating and melting, cutting, drilling, and polishing of DU. The scrap DU, consisting of slag, small pieces of metal, and machining filings and turnings, required off-site disposal. To reduce the volume of material requiring off-site disposal and to remove the pyrophoric properties of DU, the DU scrap was stabilized through a burning process which converted the DU to depleted-uranium oxide. This activity was performed at an area in the northern third of the GSA Property which subsequently became known as the ‘burn area’. The burning (i.e., stabilizing) of the DU scrap was performed on a concrete pad in metal canisters which were then shipped off-site for disposal.

In 1967, the Army, having discontinued operations at the Arsenal and having no further need for the property, transferred the 11.9-acre parcel to the GSA (hence, the name Watertown GSA Site). The GSA made several uses of the property since taking title but by the mid-1990’s had determined that the property was excess to the needs of the federal government. As a condition of the original federal land withdrawal in 1920, a “reverter clause” was established. The reverter clause specified that in the event that the land was no longer required for use by the federal government, the title rights to the property would be reverted to the original owner, the Commonwealth of Massachusetts. The reverter clause specifically designated the Commonwealth’s Metropolitan District Commission (MAMDC) as the title recipient.

Although several investigations pertaining to radionuclide contamination at the GSA Property, as well as remediation of contaminated soils, were performed in support of the transfer to GSA stewardship, the GSA Property was not addressed under the overall investigation and closure of the Watertown Arsenal, and was never formally closed in accordance with applicable state and federal regulations. This paper describes the technical and regulatory approach that was used to facilitate closure of the Watertown GSA Property, and enable transfer of the property to the MAMDC for a new land use.

PROBLEM STATEMENT

Past use of the Watertown GSA property by the U.S. Army involved the use and disposal of hazardous and potentially hazardous materials, most notably the stabilization of DU scrap. It was hypothesized that the burning of DU scrap was facilitated by use of flammable materials such as petroleum. Other releases of chemical constituents, including those from underground and above ground storage tanks, and miscellaneous disposal of wastes from Arsenal operations, likely occurred at the GSA property over the course of federal ownership. Consequently, DU and chemical contamination existed in soil at the property at the time that Arsenal operations ceased in 1967.

Initially, concerns regarding possible DU contamination in soil at the GSA property were investigated and addressed when operations at the Arsenal ceased in 1967. Numerous radiological investigation activities, and several small remediation activities, occurred between 1967 and 1995, resulting in the collection of more than three hundred soil, groundwater, surface water, and sediment samples, as well as in-situ and walk-over surveys over most of the property. However, at the conclusion of each of these investigation and/or remediation activities, it was determined that the Site could not meet the criteria for unrestricted release because previously uncharacterized contamination was identified, standards for release criteria that were previously unavailable had been developed, or standards for release had changed. The NRC placed the Watertown GSA property on the Site Decommissioning Management Plan (SDMP), and in 1999 the NRC notified GSA of an official time-line for removing the Watertown GSA property from the SDMP.

In 1988, under M.G.L. c. 21E, the state of Massachusetts assigned the MADEP authority to promulgate the Massachusetts Contingency Plan (MCP), which constitutes the regulations governing the evaluation and closure of hazardous waste sites in Massachusetts. In 1990, petroleum contamination was discovered at the Watertown GSA property during an investigation related to DU. The contamination was reported to the MADEP in accordance with the requirements of the MCP, and the site was subsequently classified by the MADEP as a Tier 1A Disposal Site, indicating that it was a high priority Site that required direct oversight by the MADEP.

Five major site investigation activities relating to chemical contamination were conducted at the Site between 1990 and 1999, resulting in the collection of more than two hundred soil, sediment, surface water, and groundwater samples that were subsequently analyzed for various chemical parameters. In 1999, MADEP indicated that radiological contamination, which previously had not been characterized in accordance with MCP requirements, was subject to the closure requirements under the MCP. Therefore, in circumstances similar to those encountered in the radiological investigations, it was determined at the conclusion of each of these investigation activities that the Site could not meet the MCP closure requirements because previously uncharacterized contamination was identified, standards for closure that were previously unavailable had been developed, or standards for closure had changed. In 1999 the MADEP issued a final extension of the deadline for achieving closure under the MCP.

Consequently, by 2000, numerous site investigation activities for DU and chemicals had been completed, large numbers of environmental samples had been analyzed for uranium and various chemical parameters, soil with the highest activities of uranium had been removed for off-site disposal, and two regulatory entities (NRC and MADEP) had provided timelines for achieving closure of the Site under the purview of each agency. However, closure and release of the Site could not be accomplished because the roles of the specific regulatory entities in the site closure process, and the closure requirements applicable to each of the regulatory entities, were not well defined. Moreover, the closure requirements of these entities in some cases appeared to contradict each other, and it was unclear which regulatory requirement took precedence in circumstances of ambiguity.

MACTEC Engineering and Consulting was contracted through the U.S. Army Corps of Engineers to develop and execute a closure plan for the Watertown GSA property, with the ultimate objectives of 1) removing the Site from State and Federal regulatory oversight, and 2) permitting transfer of the property to a future owner.

RISK-BASED END-STATE APPROACH

Risk-based end states (RBES) are representations of site conditions and associated information that reflect the planned future use of a property and are appropriately protective of human health and the environment consistent with that use. The objective of RBES, articulated in the Department of Energy (DOE) Policy 455.1 "Use of Risk-Based End States", is to improve the effectiveness of cleanup programs by focusing remedial efforts on clearly articulated and technically defensible and achievable goals that are grounded in the vision for the site at the end of the cleanup effort (the "end state"), which should be driven by the expected future land use. The policy states that a risk-based end state vision should be formulated in cooperation with regulators, and in consultation with affected governments, Tribal nations, and stakeholders, as appropriate, and that the end states developed through this process should be the basis for exposure scenarios developed in baseline risk assessments that help establish acceptable exposure levels for use in developing remedial alternatives.

Regulatory Requirements

To transfer the GSA property from the federal government to the MAMDC, the potential hazards to human health associated with exposure to hazardous materials originating at the site had be evaluated and demonstrated to be within acceptable limits. The demonstration of compliance with, and establishment of, acceptable limits had to consider three regulatory entities:

1) Nuclear Regulatory Commission (NRC).
   The NRC had the regulatory authority and responsibility to determine that the radiological criteria for release of this federally owned and operated site had been achieved. The regulatory criteria for license termination and release of property with residual radioactive material under NRC jurisdiction are contained in the U.S. Code of Federal Regulations, Title 10, "Energy," Parts 20, 30, 40, 50, 51, 70, and 72, *Radiological Criteria for License Termination*. There were essentially two options available to address the disposition of the Watertown GSA property: A) Remove all residual radioactivity exceeding the generic (or screening level) radioactivity in soil concentration guidelines; and, B) Derive and apply site-specific soil concentration guidelines based on the health hazard (dose) posed by any residual radioactivity present on the site.

   The latter option was the chosen path for the GSA site. This option required the evaluation of the potential for producing a radiation dose to individuals that might be exposed in the future to the residual radioactivity that might be left in place on the site. A property specific concentration guideline (termed a Derived Concentration Guideline Level [DCGL]) would be established, corresponding to an acceptable and safe level of public exposure in lieu of applying the generic (or default) guidelines. The applicable NRC regulation is a performance-based standard that requires the responsible party (licensee) to demonstrate to a satisfactory degree that a member of the public potentially exposed to residual radioactivity at the site will not receive an annual dose in excess of 25 millirem (mrem) in any one year, having considered all credible sources and pathways for exposure.

2) Massachusetts Department of Public Health (MADPH).
   The MADPH did not explicitly have regulatory authority or responsibility at the Watertown GSA site; however, state regulations comparable to those promulgated and enforced by the NRC and under the charge of the MADPH are in place within the State of Massachusetts. As an NRC agreement state, the Commonwealth of Massachusetts publishes regulations governing the licensure, control, and use of radioactive materials within the State. The MADPH administers the State's regulation, which includes a provision along with the

criteria for license termination and release of a site. The MADPH administered regulation is parallel to the NRC regulation. MADPH differs from the NRC only in the annual dose criterion for unrestricted release: 10 mrem/yr instead of 25 mrem/yr.

3) Massachusetts Department of Environmental Protection (MADEP).
The Watertown GSA site has been identified and listed as a Tier 1A site under the MCP. The MADEP also had regulatory authority and responsibility to determine that the site met the MCP requirements for a Response Action Outcome (RAO). The regulatory framework for achieving an RAO under the MCP criteria is fundamentally consistent with the NRC and MADPH regulatory framework, as all three regulatory entities base “acceptable limits” on the protection of human health. The principle conceptual difference between the NRC (and MADPH) and MADEP frameworks is found in the basic measure of human health detriment. Rather than using an annual radiation dose criterion as the benchmark for evaluating risk to human health, the MCP uses an estimate of excess lifetime cancer risk (ELCR) and non-cancer hazard (or chemical toxicity) as the benchmark for evaluating risk of harm to human health. The MCP stipulates that a Condition of No Significant Risk is achieved when the ELCR does not exceed a cumulative receptor risk of 1 in 100,000 ($1x10^{-5}$, or 1E-05) and the non-cancer hazard index (HI) does not exceed 1.

In addition, the MADEP requires evaluation of risks to public welfare, safety, and the environment, and the MADEP risk threshold criteria apply to both radionuclides and to chemical contaminants. These represent requirements that are unique to the MADEP regulatory framework, as compared to the NRC and MADPH regulatory frameworks.

Reconciling Competing Regulatory Frameworks

There were three regulatory agencies using essentially two separate regulatory frameworks and several separate compliance limits, aimed at the same fundamental objective of protecting public health and the environment, which had to be accounted for in the closure of the Site:

- 25 mrem/yr—NRC
- 10 mrem/yr—MADPH
- 1E-05 ELCR for radionuclides (cumulative among all radionuclides and media) —MADEP
- 1E-05 ELCR for chemicals (cumulative among all chemicals and media) – MADEP
- HI of 1 for chemicals and radionuclides (cumulative among all chemicals, radionuclides, and media) – MADEP
- No Significant Risk to Safety, Public Welfare, and Environment - MADEP

The NRC, MADPH, and MADEP had to approve the DCGL and closure process for radionuclides, whereas only the MADEP had to approve the characterization and closure process for chemicals. As indicated in Figure 1, the NRC and MADPH use a common site evaluation process that is grounded in a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) framework, whereas the MADEP has options for two different site characterization processes, neither of which explicitly follows MARSSIM, but which share some common fundamentals with MARSSIM. An approach for integrating the critical attributes of each regulatory framework into an efficient site evaluation and closure process was conceived. The approach entailed evaluation of the Site using two parallel tracks:

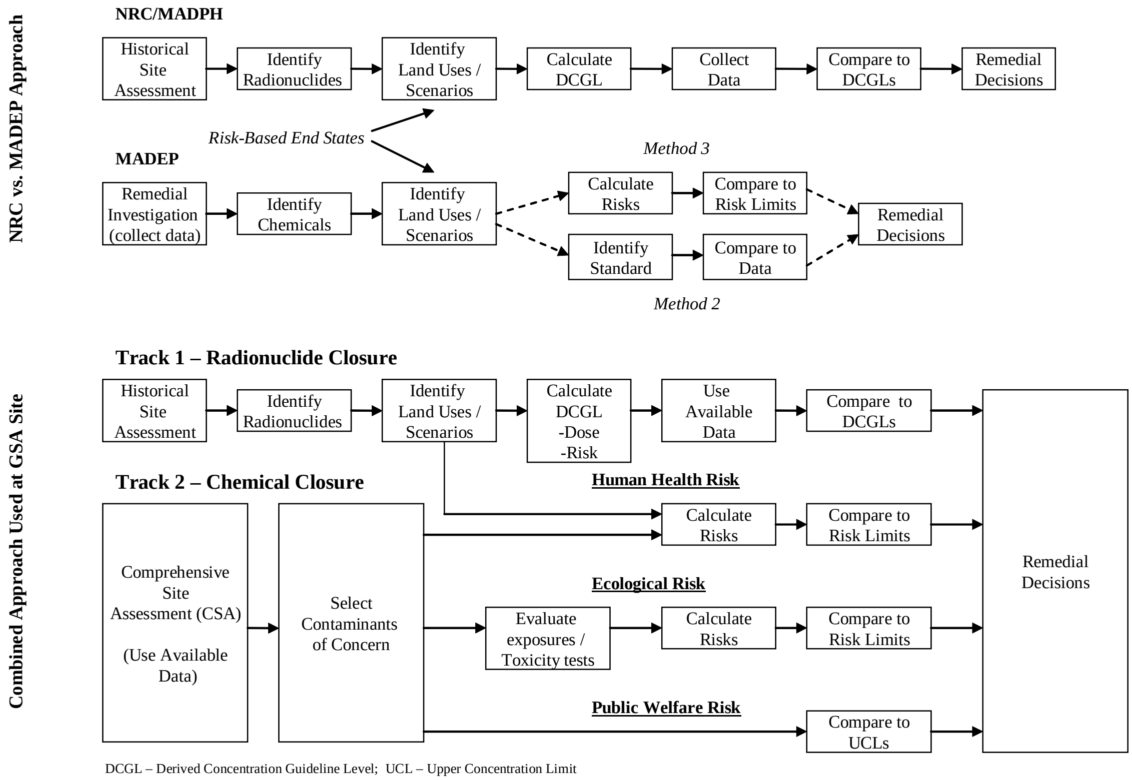

Figure 1: Integrated Regulatory Approach used to Evaluate and Close Watertown GSA Site

Fig. 1. Integrated Regulatory Approach used to Evaluate and Close Watertown GSA Site.

Track 1: Radiological contamination at the Site would be addressed following MARSSIM guidance through the submission of a Historical Site Assessment (HSA), preparation of Site-specific DCGLs, and completion of a sampling and survey report, which would document compliance with the DCGLs. This process, conceptually, was similar to the MADEP Method 2 characterization process (Figure 1) and, consequently, had familiarity within the MADEP. Because the DCGLs would need to comply with NRC dose-based release criteria, MADPH dose-based release criteria, and MADEP risk-based criteria, the DCGL would be derived in consideration of each of these criteria, and the lowest of the values among all risk-based land use scenarios, based on an annual radiation dose of 25 mrem/yr, an annual radiation dose of 10 mrem/yr, an ELCR of 1E-05, or a HI of 1, would be identified as the DCGL. A key component of the derivation of the DCGL would be selection of receptor exposure scenarios and assignment of quantitative exposure parameters that could meet the performance standards and requirements of all three regulatory agencies.

Track 2: Chemical contamination would be characterized in a Comprehensive Site Assessment (CSA) in accordance with the MCP performance standards for completing site characterizations. The CSA would include characterization of risks to human health, safety, public welfare, and the environment associated with chemical constituents at the Site. The human health risk assessment would use the same land use exposure scenarios that were developed to derive the DCGL, to ensure that risk-based evaluations for chemicals and radionuclides were grounded on the same receptor land use and exposure assumptions. The CSA would refer to the HSA, DCGL document, and sampling and survey report for characterization of radionuclides, and the RAO would refer to these documents to support closure of DU issues under the MCP. However, evaluation of chemical hazards would include evaluation of the chemical toxicity of uranium, to ensure that additive hazards for chemicals and uranium were accounted for. Since risks and hazards associated with chemical contamination, and risks to the environment, only needed to comply with MADEP regulatory criteria, the process used to evaluate these attributes could follow a standardized MADEP approach, as shown in Figure 1.

The outcomes of the two tracks would be used to identify remedial actions required at the Site, if any, and remediation, if required, would proceed under a single remedial event. The balance of this paper emphasizes the process used to complete Track 1.

Steering Group

Because the process described above would require both technical understanding and procedural compromise among the regulatory entities, it was decided that the formation of a steering group comprised of technically competent individuals representing the site regulators and identified stakeholders would be beneficial. The steering group had representatives from the U.S. Army Corps of Engineers, Army Research Laboratory (ARL), NRC (Region I and Headquarters), GSA, the Commonwealth of Massachusetts (MADPH, MADEP, MAMDC), and the Town of Watertown, Massachusetts.

The steering group was charged with representing the interests of the regulating agencies and identified stakeholders in the process to derive a dose-based soil concentration guideline value specific to the Watertown GSA site property. The steering group members were public health professionals and health physicists who were well versed in the details necessary to derive a site-specific concentration guideline, or responsible individuals appointed to represent the interests of their constituency. While the NRC retained the federal regulatory authority and responsibility to approve the criteria for the radiological release of the property, it was clear that the U.S. Army and the NRC desired the cooperative input from the identified stakeholders and state regulators so that the decision was acceptable not only to NRC but also to the Commonwealth of Massachusetts and the impacted community. Federal members were charged with ensuring that federal expenditures were responsible and commensurate with the hazards presented, and that the site would be safe for the envisioned future uses.

The steering group met five times throughout the site closure process. In the fist meeting, the process and regulatory framework for achieving site closure was presented and discussed. Agreement was reached on the two-track conceptual framework that would be used to achieve site closure, and the process that would be used to develop a site-specific DCGL that could meet the dose-based endpoints of the NRC and MADPH and risk-based endpoints of the MADEP. The steering group also discussed the various risk-based end states for the property. The second and third meetings focused on finalizing the suite of proposed exposure scenarios, the design of the conceptual site models, and the appropriateness and acceptability of values selected for key parameters to modeling calculations, to support the risk-based end states discussed in the first meeting. A fourth meeting was held following the submittal of the draft version of the DCGL document to the regulating agencies. Written comments were received from the NRC, MADEP, and MADPH. Each comment or question on the Draft DCGL document was discussed and resolved at that meeting. A fifth meeting was held to discuss and reach agreement on the approach that would be used to evaluate data for the Site and demonstrate compliance with the DCGL.

In addition to the steering group's key role in facilitating the development of the site-specific DCGLs, the process was communicated with, and input received from, the affected public. A number of public outreach efforts were employed to communicate the activities and decisions involving the Watertown GSA site, including special presentations given to a local citizen's restoration advisory board (RAB) on the scientific basis, regulatory framework, and decision logic used at the GSA site to derive the site-specific radionuclide DCGLs and demonstrate site closure.

The steering group discussions and associated public outreach were considered key to the process and the overall acceptance of the derived concentration guideline value.

Risk-Based Land Use Scenarios

The GSA Property is presently a fenced, vacant lot, and has four vacant warehouse-style buildings. The property is covered with sandy fill soils and sparse to heavy vegetation, and is bordered by wetland areas on all sides that drain to the Charles River. Land in the vicinity of the property is urban, consisting of commercial retail establishments, urban green-space recreational parks, and luxury condominiums. Consequently, the current condition of the site made it practically unusable and any use in the current condition would be limited to very short exposure duration. Therefore, current land uses were not considered in the development of the RBES.

The land title transfer process provided for ownership to revert to the Commonwealth of Massachusetts under the oversight of the MAMDC. The MAMDC had published a long-range plan calling for the development of the site into a recreational facility for public use. The municipality of Watertown had also expressed interest in the property for like use, but indicated that the municipality was interested in obtaining space for vegetable garden plots that could be used by members of the community for gardening. A number of potential future use scenarios were proposed and entertained by the site steering group, and were evaluated to assess their plausibility. Scenarios considered included the rural family farm, commercial agricultural uses, urban residential uses, open public space, community gardening, and a proposed future use as a community sporting and recreation complex hosting ball fields and an aquatic/ice rink facility. It was acknowledged among members of the steering group that the most likely potential future uses of the site were those associated with some form of public or recreational use. Therefore, the end-state for the property was collectively agreed to as being a public recreational complex that would feature outdoor ball-playing fields, an indoor ice rink, and community gardens. In the event that the envisioned development did not occur, it was agreed that the property would become open green space.

The same process that was used to develop the envisioned end-state for the property was also used to exclude several potential land uses and exposure media from evaluation. Specifically, residential farming (subsistence farming) and commercial agricultural use were considered to be inconsistent with the urban land use surrounding the site and, therefore, were not considered credible as future Site uses. Urban residential use was considered to be inconsistent with the envisioned future use of the property. Use of groundwater and installation of private supply wells were restricted in Watertown, and the groundwater was not classified by the Commonwealth of Massachusetts as an aquifer that required protection as a potable water source. No uranium had been detected in groundwater, surface water, or sediment in previous investigations at the Site. In addition, structures at the site had already been shown to have no measurable residual radioactivity. Therefore, the DCGL was derived to be protective for potential exposures to soil.

A suite of four exposure scenarios emerged as plausible and credible for the end-state land use. These included:

- Workers exposed while working at the site's recreation facilities (occupational worker)
- Users of the recreational facility (recreational visitors/participants)
- Urban community gardeners (community gardeners)
- Workers exposed while constructing/redeveloping the Site (construction workers)

The end-state land uses, exposure scenarios, and specific exposure parameter values that were assigned to each of these scenarios, for use in quantifying exposure, were presented to the Steering Group in an End-State Vision document, and modified as appropriate through discussion and negotiation with the Steering Group.

DCGL

The DCGL is the concentration, which, if left in place, would be adequately protective of human health in reasonably foreseeable future uses of the GSA site. As discussed previously, the NRC, MADPH, and MADEP agreed to a process in which a single DCGL would be derived and used to support closure of the Site with respect to DU. However, the technical aspects of the dual regulatory framework were not specifically consistent, as shown in Table I.

To reconcile these differences, rather than using two different and discreet approaches to the derivation of the DCGL, a more holistic approach was used. Specifically, for each parameter, values were identified for RESRAD default, MADEP default, and site-specific. The site-specific values were derived through discussion with the steering group, in consideration of the end-state land uses. Then, the parameter values were selected in consideration of the site-specific land uses, and the flexibilities within the regulatory frameworks. Table II shows this process, using the Occupational Worker scenario as an example. The exposure parameter values were then used to derive DCGLs for each receptor scenario, based on a deterministic analysis and dose-limits of 10 mrem/yr, 25 mrem/yr, an ELCR of 1E-05, and a HI of 1. A probabilistic analysis was also presented using the range and distribution of values expected for the site-specific exposure conditions considered to satisfy the NRC/MADPH requirements and to provide an estimate of the degree of conservatism in the set of deterministic values employed to derive the DCGL. While yielding slightly more conservative DCGLs, this approach met the performance standards of each regulatory framework, and ensured that the scenarios and parameters used to measure human health risk were consistent between the derivation of the DCGL and the chemical risk assessment.

Table I. Comparison of NRC/MADPH and MADEP Methodologies

	NRC / MADPH	MADEP
Measure of Health Detriment	Radiation Dose measured in millirem per year	Excess Lifetime Cancer Risk measured as the probability of cancer mortality, and chemical toxicity (Hazard Index)
Health Detriment Compliance Standard	Peak annual dose among years 0 to 1000; compared to: • NRC dose limit of 25 mrem/yr • MADPH dose limit of 10 mrem/yr	Cumulative risk among all years exposed (typically 25 to 30 years); compared to: • MADEP cumulative cancer risk limit of 1E-05; • MADEP cumulative hazard index limit of 1
Health Risk Methodology	Probabilistic	Deterministic
Parameter Value Basis	Mean value for critical group	Reasonable Maximum Value picked from accepted default values or derived for site-specific conditions
Calculation Method	Computer Modeling Code	Algebraic summation using spreadsheet

Table II. Summary of Key Exposure Parameters – Occupational Worker

Parameter	MADEP Default	RESRAD Default	Site-Specific	Value Selected	Rationale for Selected Value
Exposure Period (Duration) [yrs]	25	30	3 to 10	25	Factor used to establish the period over which risk is summed. Twenty-five years exposure duration is the default value specified by MADEP and represents a worst-case scenario value for occupational setting. Workplace statistics support a much lower expected exposure duration corresponding to the average length of time a person stays employed at the same job.
Exposure Frequency [days/yr]	250	NA	125 (most employees are part-time)	250	Assumes full-time year around employment period (50 weeks) with two weeks allowance for sickness and vacation.
Exposure Time [hrs/day]	8	NA	4 to 8	8	Assumes 8-hour workday. Exposure time is divided between time spent indoors (8 hours during winter months, 7 hours during summer months) and time spent outdoors (1 hr during summer months).
Indoor Time Fraction [unitless]	NA	0.5	4 to 8 (most employees are part-time)	0.2117	The fraction of a total year (8760 hr) that is spent indoors on site. In addition, this parameter is used to determine the application of the inhalation and external gamma shielding factors. Equals 1855 hrs indoors on site divided by 8760 hours.
Parameter	**MADEP**	**RESRAD**	**Site-**	**Value**	**Rationale for Selected Value**

	Default	Default	Specific	Selected	
Outdoor Time Fraction [unitless]	NA	0.25	Not more than 1 hour outdoors	0.0166	The fraction of a total year (8760 hr) that is spent outdoors on site. Equals 145 hrs outdoors on site divided by 8760 hours.
Shielding Factor, External Gamma [unitless]	NA	0.7	0.05	0.05	The structure itself provides an attenuating effect during indoor exposure periods. Value calculated with MicroShield gamma attenuation software. Based on regional construction practices and requirements, a structure housing a recreation complex supporting a hockey rink is likely to have at least 12” of compacted fill underlying a 4 to 8” thick concrete slab.
Inhalation Rate [m^3/yr]	Receptor-specific	8400	5500	5500	Annual inhalation rate based on geometric mean rate for long-term exposure to adult males (EPA Exposure Factors Handbook).
Mass Loading for Inhalation [ug/m^3]	0.000032	0.0001	NA	0.000032	Mass loading in air describes the airborne dust loading conditions on the site. Value selected is the median mass loading measured in Massachusetts. Specified value (32 µg/m^3) for typical receptors in open field.
Soil Ingestion Rate [g/yr]	18.3	36.5	0.6	18.3	MADEP default value for older children and adults engaged in non-contact intensive activities (50 mg/day).

NA – not applicable

RESULTS

DCGL

The DCGL was identified by: 1) deriving separate DCGLs for each of the receptor exposure scenarios; 2) for each receptor scenario, identifying the DCGL based on the lesser of an ELCR of 1E-05, and HI of 1, an annual radiation dose of 10 mrem, and an annual radiation dose of 25 mrem; and 3) selecting the lowest DCGL among all receptor scenarios and regulatory limits as the recommended DCGL for the GSA Site.

As shown in Table III, the most sensitive receptor scenario/compliance limit was the occupational worker scenario at an ELCR of 1E-05. Therefore, the recommended DCGL for the GSA Site of 340 picocuries per gram (pCi/g) total uranium was based on an ELCR of 1E-05 for the occupational worker scenario. For all other receptor exposure scenarios, the radionuclide concentration associated with 1E-05 or 10 mrem were higher than the radionuclide concentration associated with the occupational worker scenario. Therefore, the recommended DCGL was associated with ELCR values below 1E-05 for all receptors. In addition, the DGCL value was associated with annual radiation doses of less than 10 mrem/yr for all receptor scenarios.

Table III. Derivation of DCGL

Scenario	**Average Residual Radioactivity Concentration in Soil Total Uranium** (pCi/g)		
	Annual Dose (10 mrem/y)	Cancer Risk (ELCR = 1 x 10^{-5})	Chemical Toxicity (HI = 1.0)
Construction Worker	560	1330	1130
Occupational Worker	2150	**340**	6800
Recreational Visitor	3350	725	3400
Recreational Gardener	5175	635	4250

Demonstrating Compliance

Because there was a wealth of previously collected data from the Site, NRC, MADEP, and MADPH agreed to utilize the existing radiological site data to the maximum extent possible in determining whether the Site met the approved release criterion. The available data had been compiled over several sampling events and included many different types of analytical measures of the uranium activity present in soils on the Site. There were three principle sources of data available, representing site conditions from 1981 through 1996, both prior to and after remediation of soil.

Statistical limitations on the combining of data prevented the use of a classic statistical evaluation of the data as a single data set. Subsets of the data were, in some cases, insufficient when taken alone to provide risk managers with an adequate assessment of the concentration of residual radioactivity in soil needed to arrive at a confident and defensible decision.

A reasonable alternative to the classic statistical approach and one which made the fullest use of the extensive existing radiological data previously collected from the Site was a comprehensive “weight-of-evidence” evaluation. This technique considered each subset of data independently (since it would have been inappropriate to combine or pool these data subsets) and focused on the relevant descriptive statistics from each subset (e.g., median, 95% upper confidence limit [UCL_{95}] for the median, maximum, etc.) in comparison with the approved DCGL. Individual data subsets, when appropriately parsed into survey units, may not have contained enough samples or measurements to provide a robust assessment of the residual radioactivity in soil when considered alone. However, when several of these subsets of the data from a given survey unit were independently evaluated in the context of the approved soil DCGL, the totality of the available evidence could be considered in a quantitative, if not statistically rigorous, manner.

Adding to the conservatism embodied in this evaluation approach was:

1. The fact that much of the data collected at the Site was biased toward identifying and characterizing the locations on the Site having the highest concentrations of residual radioactivity; and

2. The fact that much of the data collected at the Site was obtained prior to extensive remediation efforts undertaken at the Site. Such data naturally biased the assessment of the radiological conditions at the Site to conditions that once existed at the Site rather than those that were present following remediation.

The site was segregated into six survey units (Figure 2) in order to: A) ensure that the number of survey data points was relatively uniformly distributed over areas with similar contamination potential, history, and concentration distribution; B) account for features of the Site having naturally distinguishable sections (e.g., the 'burn area' which had unique deposition mechanisms and the highest expected concentration of residual radioactivity); and C) group areas of the Site with like histories and contamination potentials into single survey units.

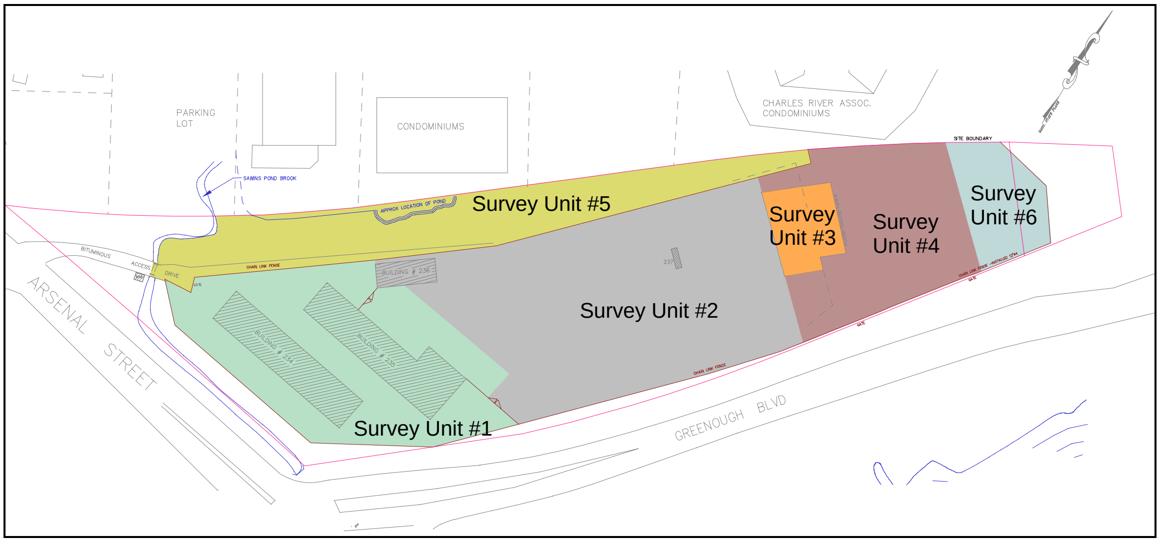

Fig. 2. Survey Units, Watertown GSA Site

Table IV shows the weight-of-evidence approach that was used to evaluate conditions at the Site relative to the DCGL, using survey unit 3, the 'burn area' (and most contaminated area at the Site) as an example.

The summary statistics presented in Table IV show that the earliest sampling (prior to any remediation in the burn area) yielded central tendency estimates (median and geometric mean) for uranium activity in surface soil near the 340 pCi/g total uranium soil DCGL with a maximum value of 7,100 pCi/g. That sampling was biased toward the assessment of the highest detected activity in the area. Significant soil excavation had occurred in Survey Unit 3 in an effort to remediate the burn area. That these efforts were effective was evidenced by the summary statistics for data subsets collected following remediation. Data collected after remediation yielded central tendency estimates (median and geometric mean), upper confidence intervals, and maximum values that are significantly below the applicable soil DCGL.

From the summary descriptive statistics for each of the data subsets, for each of the survey units, it was evident that the weight of the analytical evidence clearly indicated that the residual radioactivity associated with activities involving depleted uranium was below the soil DCGL of 340 pCi/g total uranium.

Table IV. Summary Statistics and Weight-of-Evidence Approach

Data Subset		Survey Unit GSA-03					
		Statistic[1]					
		Number of Measurements	LCL_{95} (median)	Median	UCL_{95} (median)	Geometric Mean	Maximum
ANL Coring Samples (Pre-remediation)	(All Depths)	22	88.3	192	308	213.2	7100
	(Surface Soil)	16	163	269.5	348	356	7100
	(Subsurface Soil)	6	18.7	46.6	258	54.3	258
ANL Boring Samples (Pre-remediation)	(All Depths)	34	6.8	15.2	55.1	22.4	588
	(Surface Soil)	6	48.2	131.5	288	121.3	288
	(Subsurface Soil)	28	4.4	12.3	22	15.6	588
CNSI Boring Samples (Post-remediation)	(All Depths)	18	0.3	0.5	2.7	0.9	14
	(Surface Soil)	4	(2)	3.3	(2)	1.7	14
	(Subsurface Soil)	14	0.3	0.5	2.7	0.8	4.9
MK Gamma Exposure Rate Measurements (Post-remediation)		5	(2)	13.8	(2)	13.7	14.7
MK Grid Soil Samples (Post-remediation)	Random, All Depths	2	(2)	9.6	(2)	6	17
	Random, Surface Soil	1	(2)	17	(2)	17	17
	Random, Subsurface Soil	1	(2)	2.1	(2)	2.1	2.1
MK Surface Soil Grab Samples (Post-remediation)		2	(2)	17	(2)	17	17.3
MK In-Situ Gamma Spec on Grid (Post remediation)		13	7	14	20	11.9	35
MK In-Situ Gamma Spec, Biased Locations (Post-remediation)		2	(2)	11.4	(2)	11.4	12.3
MK Bulk Soil Samples (Post-remediation)		6	0	0.1	12	0.3	12
MK Soil Boring Samples (Post-remediation)	Gamma Spec, All Depths	152	2.1	2.1	3.8	7.6	253.1
	Gamma Spec, Surface Soil	24	3.7	9.3	81.8	18.7	253.1
	Gamma Spec, Subsurface Soil	128	2.1	2.1	2.2	6.3	223.2
	Fluoroscopy, All Depths	18	3	7.6	17.4	7.6	109
	Fluoroscopy, Surface Soil	7	3.9	17.4	109	14.8	109
	Fluoroscopy, Subsurface Soil	11	1.6	5.3	9.8	5	29

1. All values in units of pCi/g, Total U except for Gamma exposure Rate Measurements which are in units of μR/h.
2. Insufficient number of data points to calculate the statistic.

MCP Risk Assessment

The MCP risk assessment used chemical data collected during the various chemical investigation activities performed throughout the 1990’s, in conjunction with the exposure scenarios developed in support of the DCGL derivation, using the Method 3 approach (Figure 1). To calculate a hazard index for combined exposures to chemicals and uranium, for each exposure scenario the hazard index for chemicals was calculated and summed with the hazard index that corresponded to the DCGL of 340 pCi/g (as a mass equivalent of 861 mg/kg uranium). This approach was based on the premise that the uranium concentrations at the Site would need to be at or below the DCGL in order for the site to be released from NRC and MADPH regulation.

The results of the MCP risk characterization indicated that no ELCR values for chemicals or HI values for chemicals and uranium, for any of the exposure scenarios evaluated, exceeded the MCP cancer risk limit of 1E-05 and HI of 1. The results of the public health risk characterization indicated that no concentrations of chemicals or uranium (at the DCGL) exceeded the MCP upper concentration limits (UCLs). In addition the results of the environmental risk assessment showed that the Site did not pose significant risks to the environment. Consequently, the Site was eligible for release from MADEP regulation.

CONCLUSIONS

The regulatory and technical approach used for evaluating radiological and non-radiological substances at the Watertown GSA Site has had the distinct advantage of allowing evaluation of radiological and non-radiological substances to proceed under a single technical framework that has reduced the cost and timeframe of the site investigation and remedial process. Use of the steering group process ensured that the cleanup criteria were developed based on a realistic future land use which stakeholders were agreeable to, and ensured that stakeholders were “on the same page” with respect to regulatory and technical issues. Despite the fact that the Watertown GSA Site was MADEP’s first experience with radionuclides in relation to the NRC’s dose-based regulatory approach, the use of the steering group resulted in a synthesis of the two applicable regulatory frameworks and approval of a single radionuclide DCGL by MADEP, NRC, and MADPH within an 18-month time frame. The NRC de-listed the Watertown GSA Site in 2003, and the MADEP accepted and approved the RAO for the Watertown GSA Site in 2004.

Had this process not been used, two separate site investigation and risk characterization processes would have been required to meet the performance standards of the MADEP and NRC/MADPH regulations. This would have resulted in a substantial increase in cost, extension of the site investigation/remediation timeline and, likely, two differing sets of remedial alternatives.