# Risk-based Prioritization of Facility Decommissioning and Environmental Restoration Projects in the National Nuclear Legacy Liabilities Program at the Chalk River Laboratory – 13564

Jerel G. Nelson*, Michael Kruzic*, Carlos Castillo**,
Todd Pavey***, Tamer Alexan ****, Ian Bainbridge*****
*WorleyParsons, Mississauga, ON, L4W 4H2, **WorleyParsons, Las Vegas, NV 89128,
***WorleyParsons, Idaho Falls, ID 83402, **** WorleyParsons, Burnaby, BC, V5C 6S7
*****Atomic Energy Canada Limited, Chalk River Laboratories, Chalk River, ON, K0J1J0

## ABSTRACT

Chalk River Laboratory (CRL), located in Ontario Canada, has a large number of remediation projects currently in the Nuclear Legacy Liabilities Program (NLLP), including hundreds of facility decommissioning projects and over one hundred environmental remediation projects, all to be executed over the next 70 years. Atomic Energy of Canada Limited (AECL) utilized WorleyParsons to prioritize the NLLP projects at the CRL through a risk-based prioritization and ranking process, using the WorleyParsons Sequencing Unit Prioritization and Estimating Risk Model (SUPERmodel). The prioritization project made use of the SUPERmodel which has been previously used for other large-scale site prioritization and sequencing of facilities at nuclear laboratories in the United States. The process included development and vetting of risk parameter matrices as well as confirmation/validation of project risks. Detailed sensitivity studies were also conducted to understand the impacts that risk parameter weighting and scoring had on prioritization. The repeatable prioritization process yielded an objective, risk-based and technically defendable process for prioritization that gained concurrence from all stakeholders, including Natural Resources Canada (NRCan) who is responsible for the oversight of the NLLP.

## BACKGROUND / INTRODUCTION

The Nuclear Legacy Liabilities Program (NLLP) contains hundreds of projects at seven Atomic Energy of Canada Ltd. (AECL) sites, in three Canadian provinces (Ontario, Manitoba and Quebec). The NLLP contains over 443 remediation projects located at the Chalk River Laboratory (CRL), including hundreds of facility decommissioning projects and numerous environmental remediation projects, to be remediated over the next 70 years. In order to achieve the NLLP objective of effectively reducing the nuclear legacy liabilities (projects) in a safe and cost effective manner, the NLLP projects need to be prioritized in a risk-based manner. In order to demonstrate this commitment to all stakeholders, WorleyParsons worked with AECL to facilitate a prioritization process that effectively risk-ranked all of the NLLP initiatives to be undertaken.

The NLLP prioritization project was executed using the proprietary WorleyParsons Sequencing Unit Prioritization Estimating Risk model (SUPERmodel) process and application. The SUPERmodel was used by WorleyParsons to prioritize the NLLP projects at CRL and produce corresponding risk-ranking and project comparison reports to address NLLP Strategic Planning commitments.

## SUPERMODEL APPLICATION AND PROCESS OVERVIEW

The SUPERmodel is a relational database that utilizes a multi-attribute ranking/scoring system to model the relative priority of each project based on its overall risk to the public, environment, and the applicable strategic planning program. The SUPERmodel process used by WorleyParsons to meet the needs of the NLLP and AECL is illustrated in Fig. 1. The term projects is used to refer to the decommissioning of buildings/structures and/or environmental remediation of Waste Management Areas (WMAs) and affected lands.

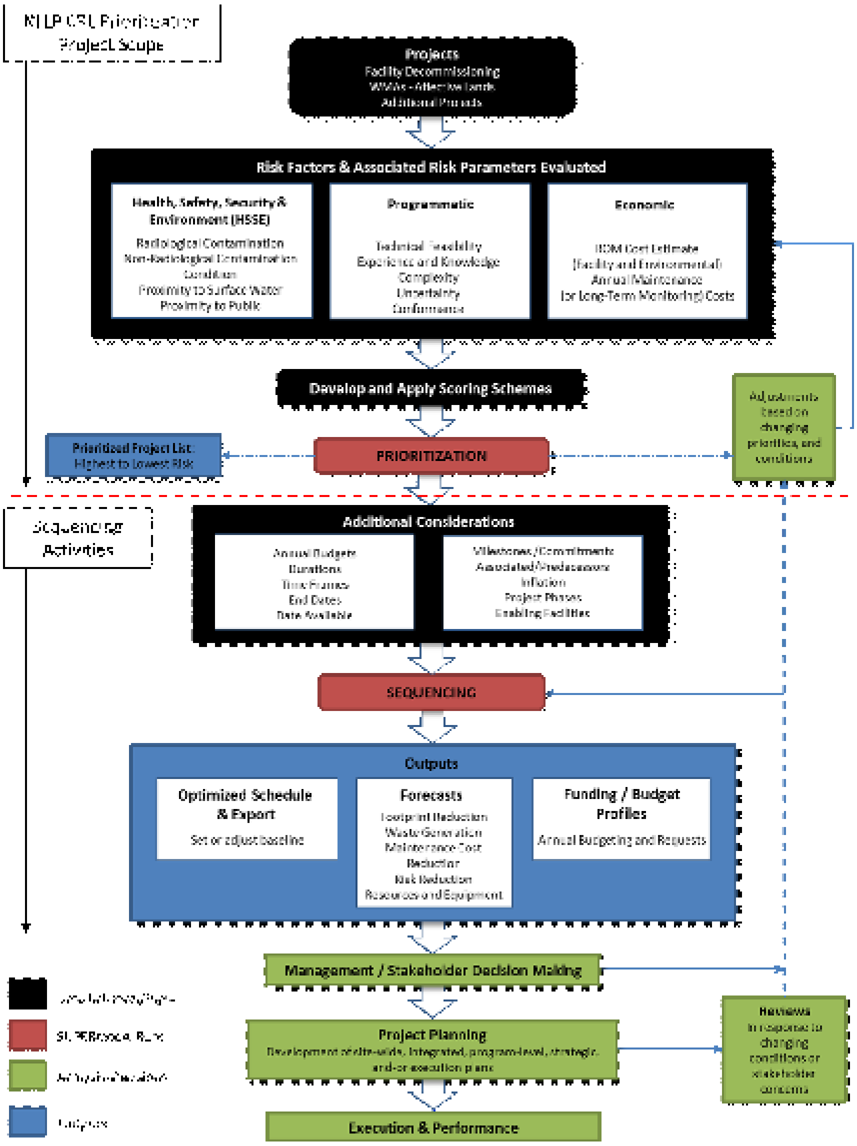


**Fig. 1 SUPERmodel Prioritization Process**

Only the first half of the SUPERmodel process, prioritization, was implemented for the NLLP prioritization project, as represented by the activities above the dotted red line in Figure 1. The prioritization process within the SUPERmodel process was comprised of the following: (a) identification of the projects included in the NLLP CRL prioritization effort and data collection and entry; (b) evaluation of each project against certain risk-based aspects, referred to as risk parameters, that impacted prioritization ; (c) development and application of scoring schemes; and (d) prioritization using risk ranking.

## IDENTIFICATION OF THE PROJECTS AND DATA COLLECTION

Project data were an essential input to the SUPERmodel process to facilitate the prioritization process. The collected data were used to evaluate each project against certain risk parameters, which were likely to impact prioritization.

When the requested data were not available or unfeasible to obtain in the short duration, available data, such as facility type, year, location, etc. were used, along with risk-based criteria developed jointly with AECL, to determine a default risk level for each project until additional data became available. This enabled prioritization to continue with key assumptions until additional data becomes available. However, actual project specific data were used whenever possible, because the accuracy of the risk-rankings increased with the use of validated project-specific data. Table I contains the data elements required from each project to perform prioritization.

**Table I. Data Required to Support Prioritization**

| | | |
|---|---|---|
| Site name | Contamination type | Technical Feasibility[a] |
| Project number | Technology type | Experience and Knowledge[a] |
| Project name | Waste volume | Complexity[a] |
| Status | Construction Composition | Uncertainty[a] |
| Project type | Radiological Contamination[a] | Conformance[a] |
| Project classification | Non-Radiological Contamination[a] | Rough Order of Magnitude (ROM) cost[a] |
| Age | Proximity to Public[a] | Annual maintenance Costs[a] |
| Area/Zone | Proximity to Surface Water[a] | |
| Size | Condition[a] | |

[a] Prioritization risk parameters

## RISK EVALUATION CRITERIA AND PROCESS

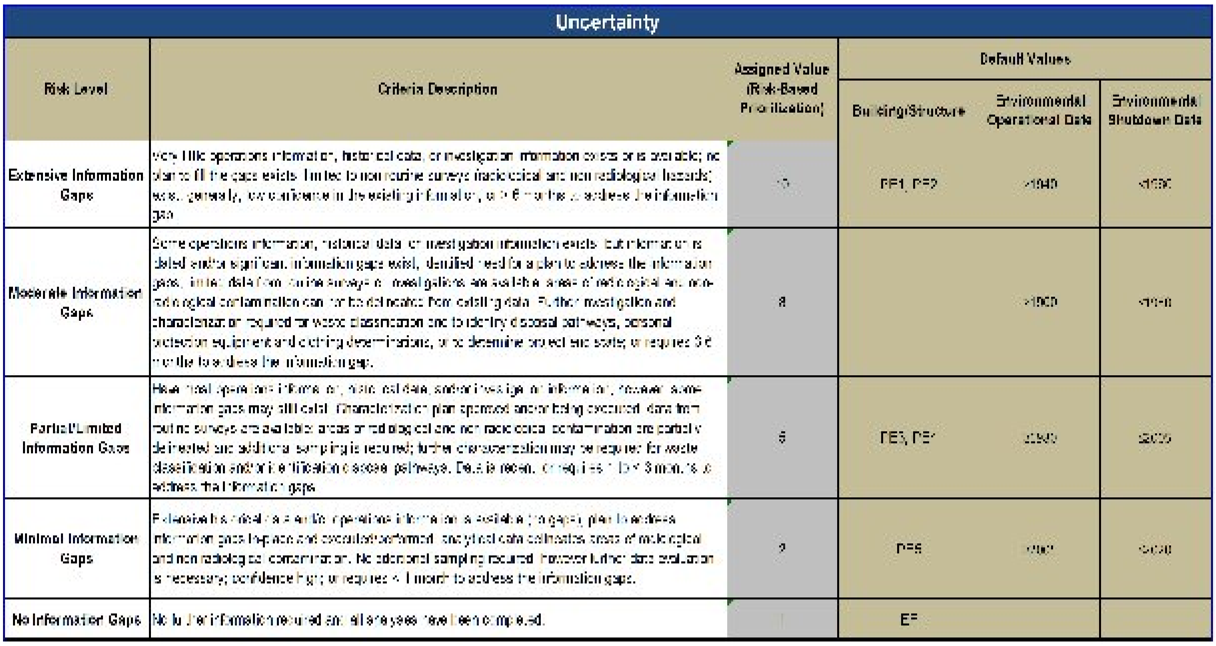
Concurrent with data collection, a list of risk parameters that could affect project prioritization was developed. Risk parameters included certain physical, resource, and economic-based aspects that could be used to evaluate the relative-risk of any project. A total of twelve risk parameters were identified for the NLLP Prioritization project. Each of the twelve risk parameters fell into one of three risk factors that were developed as a means to classify and sort the identified risk parameters. The three risk factors were developed for AECL after reviewing AECL CRL specific documentation [1] and speaking with AECL CRL site representatives and project sponsors. Table II identifies the three risk factors and the risk parameters contained within each. Each risk factor and risk parameter are discussed in subsequent sections.

**Table II. Risk Factors and Risk Parameters**

| HSSE | Programmatic | Economic |
|---|---|---|
| Radiological | Uncertainty | Annual maintenance costs |
| Non-Radiological | Conformance | ROM cost estimate |
| Condition | Technical feasibility | |
| Proximity to surface | Complexity | |
| Proximity to public | Experience and knowledge | |

Risk parameter matrices were developed as a means to evaluate each project against a set of established criteria that would be used to identify each project's relative risk ranking. A matrix was developed for each risk parameter and clearly identified the evaluation criteria for each risk parameter, the risk levels (e.g., extensive, low), assigned risk values (e.g., 1, 10) that corresponded to the identified evaluation criteria for each project, and the default values that were used when project data was not available to support the evaluation. An example risk parameter matrix, developed for the uncertainty risk parameter, is identified in Table III.

**Table III Example Risk Parameter Matrix**



Uncertainty

| Risk Level | Criteria Description | Assigned Value (Risk-Based Prioritization) | Default Values | | |
|---|---|---|---|---|---|
| | | | Building/Structure | Environmental Operational Data | Environmental Shutdown Data |
| Extensive Information Gaps | Very little operations information, historical data, or investigation information exists or is available; no plan to fill the gaps exists; limited to non routine surveys (radiological and non radiological hazards) exist; generally, low confidence in the existing information; or > 6 months to address the information gap. | 10 | PE1, PE2 | >1940 | <1980 |
| Moderate Information Gaps | Some operations information, historical data, or investigation information exists, but information is dated and/or significant information gaps exist; identified need for a plan to address the information gaps; limited data from routine surveys or investigations are available; areas of radiological and non-radiological contamination can not be delineated from existing data. Further investigation and characterization required for waste classification and to identify disposal pathways, personal protection equipment and clothing determinations, or to determine project end state; or requires 3-6 months to address the information gap. | 8 | | >1960 | <1990 |
| Partial/Limited Information Gaps | Have most operations information, historical data, and/or investigation information; however, some information gaps may still exist. Characterization plan approved and/or being executed; data from routine surveys are available; areas of radiological and non radiological contamination are partially delineated and additional sampling is required; further characterization may be required for waste classification and/or identification disposal pathways. Data is recent. Or requires 1 to 3 months to address the information gaps. | 5 | PE3, PE4 | ≥1980 | ≤2005 |
| Minimal Information Gaps | Extensive historical data and/or operations information is available (no gaps); plan to address information gaps in place and executed/performed; analytical data delineates areas of radiological and non radiological contamination. No additional sampling required; however further data evaluation is necessary; confidence high; or requires < 1 month to address the information gaps. | 2 | PE5 | [illegible] | <2010 |
| No Information Gaps | No further information required and all analyses have been completed. | 1 | EF | | |

The example risk parameter matrix identifies a series of columns and rows that have a variety of purposes as part of the risk-ranking process. The first and second columns from the left, risk level and criteria description, respectively, were developed at the same time. For each risk parameter, AECL and WorleyParsons developed distinct criteria descriptions that aligned with the different types of projects within the NLLP at CRL. In the example matrix, the uncertainty risk criteria sought to differentiate projects based on the level of data available on the project and the amount of effort (estimated duration) required to fill any data gaps before the project can be successfully executed. The risk criteria located at the top of the matrix was provided for projects that had extensive information gaps, while the criteria descriptions toward the bottom of the matrix represented projects with very few data gaps. Risk levels in the first column were then developed that summarized each of the corresponding risk criteria in the second column. In the example risk matrix, a risk value titled extensive information gaps was created to align with the top most criteria description that indicated that very little project information was available and extensive data gathering would be required. Risk levels were developed for each criteria description in this manner. Risk levels and criteria descriptions at the top of the matrices described projects that carried more risk to the NLLP than those located toward the bottom; likewise, criteria descriptions at the bottom of the table corresponded to projects with lower risk.

The assigned (risk) value column identified a value that was selected that most closely aligned with the criteria description, on a scale from one to ten. WorleyParsons and AECL assigned risk values to each project based on the project's current condition, with the lowest risk projects receiving the lowest scores and the highest risk projects receiving the highest scores. When reviewing the risk criteria and assigning risk levels/values, it was necessary to make selections based on the current project conditions because the timeframe when each project would be executed was unknown. In addition, the amount of changes that would take place at the project location between the time of prioritization and actual decommissioning or remediation was also unknown. In the example risk parameter matrix, projects identified with a risk level of extensive information gaps were assigned a risk value of ten. This process was repeated for all risk parameters. The assigned values were then directly input into the SUPERmodel to assign a risk-ranking to each project for each risk parameter. Additional weighting of the assigned values were applied during a later stage of the prioritization process.

Default values identified in the right hand columns of the example risk parameter matrix were included in each risk parameter matrix in order to assign a risk value to each project when little to no data existed for the project. This activity was necessary because the SUPERmodel required that a risk value be assigned to each project for every risk parameter in order to accurately perform prioritization.

AECL was able to select different default values for each risk parameter matrix because the selected default values weren't characteristic of all projects for the particular risk parameter. For example, Planning Envelopes (PEs), a CRL specific method of categorizing their seven different types of remediation projects, were selected as default values for buildings/structures because most of the CRL NLLP projects were either assigned a PE or one could be assumed based on project descriptions. Also, certain types of hazards (e.g., radiological contamination) were associated with specific PEs. Operational and shutdown dates were often used for the environmental remediation projects because they were more indicative of the site conditions than the PE. In the Table II example, default values for PE1 buildings/structures were assigned a risk value of 10 because a large effort, with respect to duration, would typically be required to gather additional information to support project execution, even though there may be large quantities of incomplete, outdated, or insufficient data.

## HSSE Risk Factor and Associated Risk Parameters

The HSSE risk factor is the composite of health, safety, and security risks posed by the project, in its current condition, to the public and the environment. The risk parameters included within the HSSE risk factor are:

*Radiological contamination*: This risk parameter evaluated the level of radiological contamination for projects associated with buildings/structures and the quantity of radioactive material present at environmental remediation projects. Radiological contamination was included as a project risk parameter because it has the potential to complicate the decommissioning/remediation projects. In addition, this risk parameter recognizes that worker protection, environmental protection, execution efficiency, and waste management issues become increasingly more complex as radiological contamination levels increase for buildings/structures and as the quantity of radioactive material increases for WMAs.

*Non-radiological contamination*: This risk parameter evaluated the quantity of non-radiological contamination for projects associated with buildings/structures and the presence of non-radioactive material above acceptable criteria at environmental remediation projects. Non-radiological contamination was included as a risk parameter because it also complicates decommissioning/remediation activities. In addition, the risk associated with protecting the CRL workers, public, and environment during remediation activities increases as the quantity of non-radioactive contamination increases.

*Proximity to public*: This risk parameter evaluated the distance of the project location to the CRL site boundary, which dictated the risk level of the project for this risk parameter. A primary assumption for this risk parameter was that the public was always located at any of the site boundaries of the CRL, even though the site as a whole is located in a relatively remote area and is adjacent to other government owned property and the Ottawa River. This risk was evaluated due to the potential exposure that could occur from hazardous or radioactive materials released from any of the project locations at any point in time.

*Proximity to surface water*: This risk parameter was developed to identify the distance of the project location to the nearest surface water body in order to assign the risk level of the project. The proximity of a project to surface water represented a risk to the public, employees at the CRL and the environment. Surface water included lakes, rivers, streams and wetlands that could be impacted from a project with an identified source of contamination and/or groundwater plume. The risk criteria were not based upon the proximity of the source of contamination or a groundwater plume to surface water, rather the proximity of the discharge point of the groundwater plume to surface water. The closer the proximity to a surface water body, the greater the risk to the public and environment, thus the particular project should be ranked higher in terms of prioritization.

*Condition:* This risk parameter was developed to evaluate the physical state of buildings/structures and the state of containment at environmental remediation projects (i.e., have plumes been created). The condition of a facility reflected its physical state in terms of structural integrity, uncontrolled releases to the environment, necessary permits required to enter the building/structure (hazards to personnel entering), and breaches to the containment system, if any. The criterion descriptions within the condition risk parameter addressed two general types of projects, buildings/structures and WMAs/affected lands. The criterion also recognized that a structurally poor facility poses a greater risk to personnel at the CRL, the public, and the environment while it remains in place awaiting decommissioning/remediation. It was also recognized that a project of newer construction or one that is currently occupied can remain intact for a longer period of time without structural degradation or contamination migration.

## Programmatic Risk Factors and Associated Risk Parameters

The programmatic risk factor addressed risks to the project that could impact the ability for work to be performed as planned while maintaining cost and schedule projections. The risk parameters within the programmatic risk factor included:

*Technical Feasibility*: This risk parameter evaluated the availability and cost effectiveness of currently available technologies anticipated to be used for each project. It was identified that proven technologies, methodologies, and resources must be sufficiently available to support smooth, predictable job performance and execute projects with a high degree of confidence. When any of these three are less than fully available to the project, the risk of not being able to efficiently implement the project increases.

*Experience and Knowledge*: This risk parameter evaluated the availability of personnel to support the execution of the project that had project-specific operational experience or knowledge. It was identified that an experienced and knowledgeable planning and execution work force is necessary for highly predictable decommissioning and remediation project performance. Therefore, a lack of available personnel with project-specific expertise and knowledge of the project's operating history would increase risk to the NLLP. This risk would be realized in the form of reduced efficiency, increased project costs, increased schedule and safety issues.

*Complexity*: This risk parameter evaluated the building structures and/or waste containment structures with respect to their physical complexity. The complexity of the physical structure of the project, or the systems contained within the project structure, affect the planning and execution of demolition and remediation projects. Historically, complex projects have had higher degrees of risk, and are therefore more likely to incur project delays and increased durations/cost. Because there was a wide range of project types within the NLLP CRL prioritization project, such as removal of underground storage tanks to demolition of a nuclear facility, the recognition of the complexity of each project was critical to the overall portfolio risk profile.

*Uncertainty*: This risk parameter evaluated the availability of historical, operational, and/or information retrieved through investigative characterization methods (e.g., surveys, sampling). The quantity of gaps for each project provided an indication of the effort required to complete planning for execution of decommissioning/remediation and the risk to the NLLP. Risk could be realized in many forms with respect to uncertainty, such as project delays, compromises to worker safety, and increased waste management/disposal costs if the project's hazards/conditions were not adequately understood.

*Conformance*: This risk parameter evaluated the status of each project with respect to building codes and fire inspections for buildings/structures and licensing status for WMAs/affected lands. The risk parameter was developed under the assumption that projects that were up to date with applicable building codes or licensing requirements represented a relatively low risk to the NLLP. However, if a building/structure did not conform to current building codes and fire prevention regulations, there existed an increased risk to CRL and the NLLP until decommissioning is completed.

## Economic Risk Factors and Associated Risk Parameters

*Annual Maintenance Costs:* The annual cost maintenance risk parameter was developed to reflect the anticipated costs necessary to maintain each project from the time they were turned over to the NLLP until the project is executed. Annual maintenance costs were calculated by the SUPERmodel as a percentage of the overall ROM cost (3%) for each project. Costs in-lieu of annual maintenance costs (e.g., well monitoring) were manually input into the model when provided by AECL for some of the environmental remediation projects.

*ROM Cost Estimate:* The ROM cost estimate risk parameter was a reflection of the overall cost of the decommissioning or remediation of each project. The ROM cost estimate covered the full range of demolition project activities, including waste characterization, planning, mobilization, verification sampling and analysis, asbestos removal (a limited amount that would remain after operations turnover to the NLLP), demolition, project management, demobilization, and preparation of final reports; however, it did not include deactivation, hazardous materials removal, safe shutdown, ongoing maintenance/monitoring, or other annual fixed costs because these were addressed under other programs outside of the NLLP. Project ROM cost estimates, identified to the nearest ten thousandth dollar, were used to assign a risk ranking value relative to the other NLLP projects. The project ROM cost risk values were then normalized on a 1-10 range. By following this process, a risk parameter matrix was not required for this risk parameter.

Two types of ROM cost estimating models were used as part of the prioritization process within the SUPERmodel, a facility (building/structures) decommissioning ROM cost estimating model and an environmental remediation ROM cost estimating model.

Building/structure decommissioning ROM cost estimates were calculated for each project in the SUPERmodel using a ROM cost estimating model that was originally developed by the Idaho National Laboratory, formerly the Idaho National Engineering and Environmental Laboratory (INEEL) [2]. The cost model was updated in 2003 using actual decommissioning costs for completed facility decommissioning projects at the US Department of Energy Savannah River Site and escalated at 3% per year to the current year (2012) and calibrated to align with AECL NLLP site-specific conditions. In summary, the facility ROM estimates were calculated using the following process:

a) Identified base facility decommissioning unit rates;
b) Identified cost adjustment factors that reflect the project's end state, construction type, radiological contamination, non-radiological contamination, complexity and uncertainty;
c) Calculated the initial ROM cost by multiplying the project area against each of the cost adjustment factors; and
d) Applied an AECL NLLP site correction factor (SCF) to the ROM cost; use of an SCF was necessary because actual decommissioning costs could not be provided to WorleyParsons for contractual purposes.

Similar to the ROM cost estimate risk parameter for buildings/structures, the ROM cost estimate was used to determine the relative risk level for each environmental remediation project. This was completed by calculating the ROM costs for each project and identifying the range of all ROM cost estimates. Then the ROM cost estimates were normalized on a 1-10 range and assigned risk score relative to the other projects. The environmental remediation ROM costs were calculated using the following process:

a) Identified a list of remediation methodologies applicable to the NLLP projects and assigned a specific methodology to each project;
b) Identified unit rate cost estimates for the selected remediation technologies based on published remediation rates or rates jointly determined with AECL based on recent remediation activities;
c) Identified estimated waste volumes for each project; and
d) Calculated the environmental ROM cost estimate for each applicable project by multiplying the selected unit costs by the volume of contaminated media.

## WEIGHTING AND SCORING

### Risk Parameter Weighting

Weighting was used as part of the SUPERmodel process to place additional emphasis on certain risk parameters that were identified as higher concerns to the NLLP than other risk parameters. This weighting increased the risk-ranking of projects that were assigned high risk values within the particular weighted risk parameter and lowered those projects within the risk parameters that received lower weightings. This provided stakeholders the opportunity to ensure that the appropriate weightings are applied to those risk parameters of higher importance at the initial level, without influence specific project prioritizations and prevented arbitrary prioritization because the selected risk parameter weightings were applied to all projects.

Risk parameter weightings were developed jointly between WorleyParsons and AECL; stakeholders included representatives from Strategic Planning, Environmental Restoration, Facility Decommissioning, and NRCan in a workshop setting. The weighting process was performed by reviewing each of the risk parameters with respect to the other risk parameters within each risk factor. Each of the twelve risk parameters were reviewed by each of the attending groups. The representatives identified a percentage from 0 – 100% for each risk parameter within one of the risk factors. Risk parameters that were deemed more important to prioritization, with respect to the represented organization, were assigned higher percentages. Therefore, the risk parameters within the three risk factors each added to 100%, as shown in Table IV. This process was also applied to the risk parameters within the programmatic and economic risk factors. This method of weighting forced the representatives to identify and document which risk parameters should have more of an influence over prioritization with respect to one another. The results were tabulated and averaged with each group's assigned percentages being considered equally. The final risk parameter weightings after all the assigned percentages were averaged.

Weightings were applied to each risk parameter to determine the weighted risk parameter score by multiplying the project's risk value times the agreed upon average weighting percentage, as shown in Equation 1. This equation was applied to all of the NLLP projects included in the prioritization.

$$[\text{Condition(w)}] = \text{Project 1 assigned risk value} \times \text{weighting\%} \qquad \text{(Eq. 1)}$$

Where,
(w) = weighted risk parameter
weighting% = final weighting for condition risk parameter

## Risk Factor Scores

After each project received a weighted risk parameter score for each risk parameter, risk factor values were calculated. Risk factor values for each project were calculated by adding each of the weighted risk parameter scores for the particular project, with the exception of the HSSE risk factor which multiplied the sum of two risk parameter scores against the sum of the remaining three risk parameters. These calculations reflect the additive effect of the risks within the programmatic and economic risk factors and the compounding effect of radiological contamination and non-radiological contamination on the HSSE risk factor. The equations used in the SUPERmodel to determine the three risk factor values are identified below.

$$\text{HSSE} = (\text{radiological contamination(w)} + \text{non-radiological contamination(w)}) \times (\text{proximity to the public(w)} + \text{proximity to water(w)} + \text{condition(w)}) \qquad \text{(Eq. 2)}$$

$$\text{Programmatic} = (\text{technical feasibility(w)} + \text{experience and knowledge(w)} + \text{complexity(w)} + \text{uncertainty(w)} + \text{conformance(w)}) \qquad \text{(Eq. 3)}$$

$$\text{Economic} = (\text{ROM cost estimate(w)} + \text{annual maintenance cost(w)}) \qquad \text{(Eq. 4)}$$

*NOTE: In subsequent prioritization modeling, the size of the facility or environmental restoration project will also weigh into the HSSE risk factor value so that small projects with contaminated areas do not rank higher than large projects with more extensive contamination with the same radiological and non-radiological risk value.*

## Scoring Schemes and Composite Risk Scores

Scoring schemes (SS) involved the application of additional weightings to each of the three risk factor values for each project in order to place additional emphasis, with regard to risk-ranking, on any of the three risk factors. SS were used to address NLLP concerns that certain risk factors may be more important to prioritization than others.

A base set of four SS were developed by jointly between WorleyParsons and the AECL Strategic Planning group and concurred by the Key AECL decisionmakers and external stakeholders, including representatives from AECL and NRCan. The set of four SSs that were presented are identified in Table V. The SS were developed as a means to apply more weight to a single risk factor than the other two risk factors combined, with the exception of SS1, where all risk factors were equally weighted. This second layer of weighting forced AECL to determine if any of the three risk factors were more important than the other two with respect to prioritization. AECL and WorleyParsons ultimately decided that SS1, which had an equal distribution of weighting with no net change to the prioritization results, was the best fit for the CRL NLLP prioritization projects. However, the other three SS were applied, prioritization reports developed, and the results reviewed. In addition, comparison reports were generated that compared the results of

SS1 against each of the other three SS, with respect to changes in the risk-rankings, so that AECL could see the effects and/or impacts of the weightings and any sensitivities in order to make any necessary adjustments to the risk factor weightings as appropriate.

**Table V. Base Set of Four Scoring Schemes**

| Scoring Scheme | HSSE Weighting | Programmatic Weighting | Economic Weighting |
|---|---|---|---|
| SS1: All Things Being Equal (base case) | 33% | 33% | 33% |
| SS2: Safety First | 60% | 30% | 10% |
| SS3: Program Objectives | 10% | 60% | 30% |
| SS4: Economic | 10% | 30% | 60% |

A Composite Risk Score (CRS) was calculated for each project by applying the selected scoring scheme to the three risk factors for each project. The following equation shows how the CRS was calculated within the SUPERmodel for all projects, applying SS1.

$$\text{CRS } (\textit{Example Project 1 using SS1}) = (\text{HSSE}*0.33 + \text{Programmatic } *0.33 + \text{Economic}*0.33) \qquad \text{(Eq. 5)}$$

## SENSITIVITY STUDY

A sensitivity study was performed as part of the prioritization process to determine which risk parameters had the greatest impact on risk-ranking (prioritization). The sensitivity study process involved the manipulation of risk parameter assigned values and SS weightings in order to document deviations from a baseline. The risk parameters, risk factors, and scoring schemes that resulted in larger variations during the study were shown to have a greater impact on the prioritization of the projects.

The sensitivity study was performed as part of the SUPERmodel process, after all project data was received and prior to the final risk ranking and prioritization. Performing the study prior to risk ranking helped ensure that AECL understood the impact that their selections (e.g., weightings applied to risk parameters, use of default values) had on prioritization. This presented an opportunity for AECL to gather additional data and reduce the use of defaults for risk parameters that were shown to have a greater degree of impact.

The following conclusions and findings were observed from the sensitivity study:

a) The highest weighted risk parameter for any given risk factor had the greatest impact to the CRS, likewise, the lowest weighted risk parameter for a given risk factor had the lowest impact to the CRS;
b) Annual maintenance costs, radiological contamination, ROM cost, and non-radiological contamination were the most sensitive risk parameters;
c) The sensitivity study showed that project rankings changed when the risk parameter scores and SSs changed;

d) As expected, regardless of the SS applied, projects in PE1- nuclear facilities, were among the top risk--ranked projects based on the default values, which was primarily caused by the high assigned risk parameter values for most of the projects; and
e) When the economic and programmatic SS were applied, the programmatic SS weightings influenced the CRS more that the economic SS weightings to the overall CRS.

## PRIORITIZATION OUTPUTS

Risk ranking reports (i.e. prioritization lists) from highest to lowest risk for the selected group of NLLP projects were generated at the end of the project. For each project, this report identified the risk factor scores for each risk parameter, the normalized CRS, and the project ranking, from one to the total number of projects in the report. The top of the report also identified which SS was applied and what group of projects (e.g. only facilities that would be within NLLP control) were included in the report. Risk-ranking reports were generated for each of the four SS.

In addition, comparison reports that compared the prioritization rankings of two SS were also generated. For the NLLP prioritization project, four comparison reports were generated, with the baseline SS (SS1) compared against each of the other SS (SS2 to SS4). The reports identified the difference between the risk factor values and the associated percent changes of the two SS being compared. In addition, this report identified the position change (e.g., 2nd to 12th – a drop of 10 places) for each project when comparing SS2, SS3, or SS4 against the baseline SS1.

## PRIORITIZATION RESULTS

At the conclusion of the NLLP prioritization project, several outcomes were identified with respect to the CRL projects:

a) PE1 projects (nuclear facilities) and PE2 projects (radiochemical laboratories) generally trended toward the top of the priority/ranking list. PE1 and PE2 projects typically had greater than average assigned risk values and default values for the twelve risk parameters that were evaluated;
b) PE7 projects (WMAs) and PE6 projects (affected lands) with large waste volumes requiring remediation, were present within the top 20 highest risk projects. Other PE6 and PE7 projects with smaller waste quantities requiring remediation were present lower on the lists. Waste volumes dramatically increased the project ROM cost estimate, which was one of the risk parameters that resulted in the greatest impact to the risk rankings;
c) Projects associated with low levels of radiological and non-radiological contamination as well as low hazard contaminated and non-contaminated structures typically fell in the mid-to-low range of the risk-ranking list due to the project's elevated programmatic and economic risks and higher ROM costs associated with waste volumes or building size;
d) Projects with small footprints or waste volumes and low hazards such as support structures, utilities, and administrative buildings trended toward the bottom of the risk-rankings lists. This also included contamination plumes where monitored natural attenuation would likely be selected as an end-state, since these projects were deemed relatively low risk and low cost to address;
e) The use of default risk values resulted in blocks of similarly ranked projects. Groups of projects that relied on the use of default data each received the same risk factor scores and subsequently the same CRS when project data was not available. This resulted in the

projects being grouped together on the risk-rankings list. In most cases, default values were based on what PE the project belonged to, therefore blocks of projects with the same risk factor scores and CRS were present in various locations of the risk-rankings list. However, as these were generally mid-to-low in the overall priority ranking, we will have time in subsequent planning cycles to gather and use more exact data to provide further differentiation of projects in the future.

## CONCLUSIONS AND PATH FORWARD

WorleyParsons worked directly with the AECL to produce a risk-based rankings list of the CRL projects to address NLLP strategic planning requirements. To accomplish this, WorleyParsons evaluated the NLLP portfolio of remediation projects at CRL, their inputs, physical attributes and other observable factors to identify their respective overall risk to AECL and NLLP stakeholders. A by-product of this process included the consolidation of project data into a central database and the development of independent facility and environmental remediation project ROM cost estimates.

In order to support this process, AECL, supplied the best available project-specific data and provided input into the prioritization process during the various analysis activities. The key AECL decisionmakers and external stakeholders were engaged twice during the prioritization process to ensure their involvement and to ensure stakeholder expectations would be met. It was identified during the findings presentation with the key AECL decisionmakers and external stakeholders that several improvements could be made that would provide greater resolution of the prioritization results. This included reviewing the use of default values, improving waste volume estimates and waste management unit rates, and the general refinement of the project-specific data for the risk parameters with the greatest impact to prioritization. These changes are currently being addressed jointly with AECL.

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## REFERENCES

1. AECL. 2011. Comprehensive Preliminary Decommissioning Plan, CPDP-508300-PDP-001 Revision 1.
2. INEEL. 1999. Environmental Management Integrated Plan (EMIP) D&D Parametric Model, Excel spreadsheet of the D&D Operations Department.