DOE/FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

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Decision Support Tool for Prioritization of Surveillance and Maintenance Funds across all Excess Facilities

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ABSTRACT

The Department of Energy (DOE) currently faces a difficult task in the disposition of the numerous excess or to-be excessed facilities owned by the Department. Many of these facilities are in various physical conditions and contain potentially hazardous nuclear, chemical, radiological or industrial materials left behind as a byproduct of nuclear weapons production, nuclear powered naval vessels and commercial nuclear energy production (DOE, 2008). During the last period of a facility's life cycle, it is important that surveillance and maintenance (S&M) be adequate to maintain the facility within an appropriate safety envelope. Inadequate investment in maintenance can cause facilities to deteriorate to the point they are unsafe for human entry. Too often this can mean tremendous increases to cost during deactivation and decommissioning (D&D). However, experiences often show that once buildings have been declared excess and enter the transition phase (as defined in DOE G 430.1-5 *Transition Implementation Guide*), maintenance budgets are drastically reduced. This is justified by the desire to not spend money "on a building that is being torn down." The objective of this study was to provide the U.S. Department of Energy (DOE) Environmental Management (EM) federal project directors and their contractors with a decision support tool to aid in prioritizing S&M investment across a site's excess facilities so that the limited budget available can be used most effectively. The analytical hierarchy process (AHP), a multi-criteria decision making method developed by Dr. Thomas Saaty in the 1970's, was used to derive the weight of importance of a defined list of risk-based criteria and typical S&M activities. A total of 10 facilities at the Oak Ridge National Laboratory (ORNL) varying in perceived hazards and conditions were chosen to test the tool by evaluating them with respect to each risk criterion and combining these results with the weight of importance of the S&M they require. The final result was a rank of S&M activities to be performed on all the facilities based on the relative weight of importance of the activity coupled with the risk posed by the facility. This method addressed the needs of all of the facilities without ignoring the S&M activities of the lower risk facilities. In doing so, the site can prevent the lower-risk facilities from becoming a higher risk in the future. The result of this study was analyzed for consistency and reflected the overall technical judgment of subject matter experts, based on the facilities used in the test. This tool can be a starting point to determine how to distribute S&M budgets, to help make consistent and risk-based decisions and to provide documentation for future reference and review. In addition, the tool is flexible enough to be modified and used at other DOE sites. Several factors which include the weights assigned to each criterion, the final rank of the facilities and the S&M actions, are subject to the judgment of the decision maker. For this reason, a sensitivity analysis will be the next step to improve the decision tool.

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1. INTRODUCTION

The Department of Energy (DOE) currently faces a difficult task in the disposition of the numerous excess or to-be excessed facilities owned by the Department. Many of these facilities are large, complex and contain potentially hazardous nuclear, chemical, radiological or industrial materials left behind as a byproduct of nuclear weapons production, nuclear powered naval vessels and commercial nuclear energy production (DOE, 2008). As DOE facilities complete mission operations and are declared excess, they pass into a transition phase that ultimately prepares them for disposition. The disposition phase of a facility's life cycle usually includes deactivation, decommissioning (D&D), and surveillance and maintenance (S&M) activities. S&M activities are conducted throughout the facility life cycle, including those times when the facility is not operating and is not expected to operate again. During these last periods, it is important that S&M be adequate to maintain the facility within an appropriate safety envelope through a seamless transition to the final disposition. S&M is adjusted as transition D&D activities are completed.

Experience often shows that once buildings have been declared excess and transferred to S&M, maintenance budgets are drastically reduced and the facilities are taken "cold and dark" as quickly as possible. However, the result can be the eventual deterioration of a building to the point that it is unsafe for human entry. Thus, when D&D activities are ready to commence, risk and safety concerns posed by the unstable structure must be addressed. This can create additional cost to D&D including shoring up floors, installing netting, fall protection, and additional personal protective equipment (PPE), etc.

Structural deterioration of some Oak Ridge National Laboratory (ORNL) facilities such as 3026 C&D and the 2000 Complex are proof of the long term consequences of inadequate S&M investment. The absence of maintenance, continuing roof leaks and the absence of air circulation within the buildings have contributed to their continuing deterioration.

2. EXECUTIVE SUMMARY

This summer internship research work has been supported by the DOE/FIU Science & Technology Workforce Initiative, an innovative program developed by the U.S. Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2008, an FIU-ARC intern spent 10 weeks doing a summer internship at the ORNL's Nuclear Operations Directorate under the supervision and guidance of Mr. Thomas B. Conley.

The analytical hierarchy process (AHP) was used to evaluate a number of facilities against a defined list of risk-based criteria and typical S&M activities. This method uses pair-wise comparisons to derive the weights of importance of the criteria. Once the facilities are evaluated against each criterion, the final scores are used to prioritize them. The final outcome of this tool is a final ranking of all the S&M required by the facilities based on the risk posed by the facility and the weight of each of the S&M activities. A total of 10 facilities from ORNL were chosen to test the tool against each risk-based criterion. The result of this study was analyzed for consistency and reflected the overall technical judgment of subject matter experts, based on the facilities used in the test. The decision tool is flexible enough to be used in other DOE sites. A sensitivity analysis will be the next step to improve the decision tool.

3. RESEARCH DESCRIPTIONS

Multi-criteria decision methods (MCDM) are used to help make complex decisions given a set of alternatives and a list of criteria; they can improve the quality of decisions by making choices more explicit, rational, and efficient (Hobbs, 2000). The AHP is a type of MCDM developed by Dr. Thomas L. Saaty in the 1970's. This method uses a structured framework that allows for the comparison of qualitative data by means of a pair-wise comparison technique.

A set of facilities varying in perceived hazards and conditions were prioritized based on risk using the following criteria:

- Extent of contamination
- Facility nuclear categorization
- Environmental Safety & Health (ES&H)
- Time until D&D
- Accumulated delayed maintenance estimates
- Time since declared excess
- Status of legacy materials cleanout

In addition to the risk criteria, a list of general S&M activities was also used in the initial tool development:

- Contamination control
- Roof repair
- Safety basis surveillance
- Ventilation
- Fire system maintenance
- Heating, ventilation, and air conditioning (HVAC)
- Steam repair
- Grounds keeping
- Structural repair
- Legacy waste removal
- Liquid waste systems

The risk criteria and the general S&M activities were defined in order to make it easier for subject matter experts to interpret them accordingly (Appendices A and B). Once the criteria and the S&M activities were identified and defined, a group of subject matter experts from ORNL met to do a pair-wise assessment. A nine-point scale developed by Dr. Thomas L. Saaty, shown in Table 1, was used during this process (Triantaphyllou, 2000).

Table 1: Saaty 9 Point Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two criteria are judged to be equally important.
3	Weak importance of one over another	Experience and judgment slightly favor one criterion over another.
5	Moderate importance of one over another	Experience and judgment moderately favor one criterion over another.
7	Strong importance	Experience and judgment strongly favor one criterion over another.
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments.	When compromise is needed.
Reciprocals of above nonzero	If criterion *i* has one of the nonzero numbers assigned to it when compared to activity *j*, then *j* has the reciprocal value when compared to *i*.	

Both sets of criteria were set up in a matrix format and the weight of importance of the criteria was normalized to add up to 100% (Appendix C).

The AHP is also used to evaluate the alternatives with respect to each criterion. However, since this problem involves a large number of alternatives and criteria, it would not be practical to do pair-wise comparison of all the alternatives at this point because the procedure can become long and tedious. For this reason, a new scale was developed to measure each facility with respect to each risk criterion (Appendix C).

Ten facilities from ORNL, varying in perceived hazards and conditions, were chosen to test the tool:

- 3026 C/D – CAT 3 facility
- 3517 – CAT 2 facility
- 2000 Complex – Radiological facility
- 2026 - Radiological facility
- 4501/4505 - Radiological facility
- 3503 - Industrial facility
- 3550 - Radiological facility
- 7710 -Radiological facility
- 2011 - Radiological facility
- 2009 - Radiological facility

The final score for each facility was calculated using the following formula (Triantaphyllou, 2000):

$$FinalScore = \sum_{j=1}^{n} a_{ij} w_j \text{ , for i =1,2,3,…m}$$

Where, n = number of decision criteria, a_{ij} is the actual value of the i-th alternative in terms of the j-th criterion, and w_j is the weight of importance of the j-th criterion.

4. RESULTS AND ANALYSIS

A group of subject matter experts familiar with the ORNL facilities met to evaluate each risk criterion and S&M activity based on their expertise. The results from the pair-wise comparison are shown below as a percentage (Figure 1). The extent of contamination criterion is composed of two sub-criteria, radiological and chemical. ES&H is also composed of three sub-criteria: environment, safety and health. These sub-criteria were evaluated in the same format using pair-wise comparison.

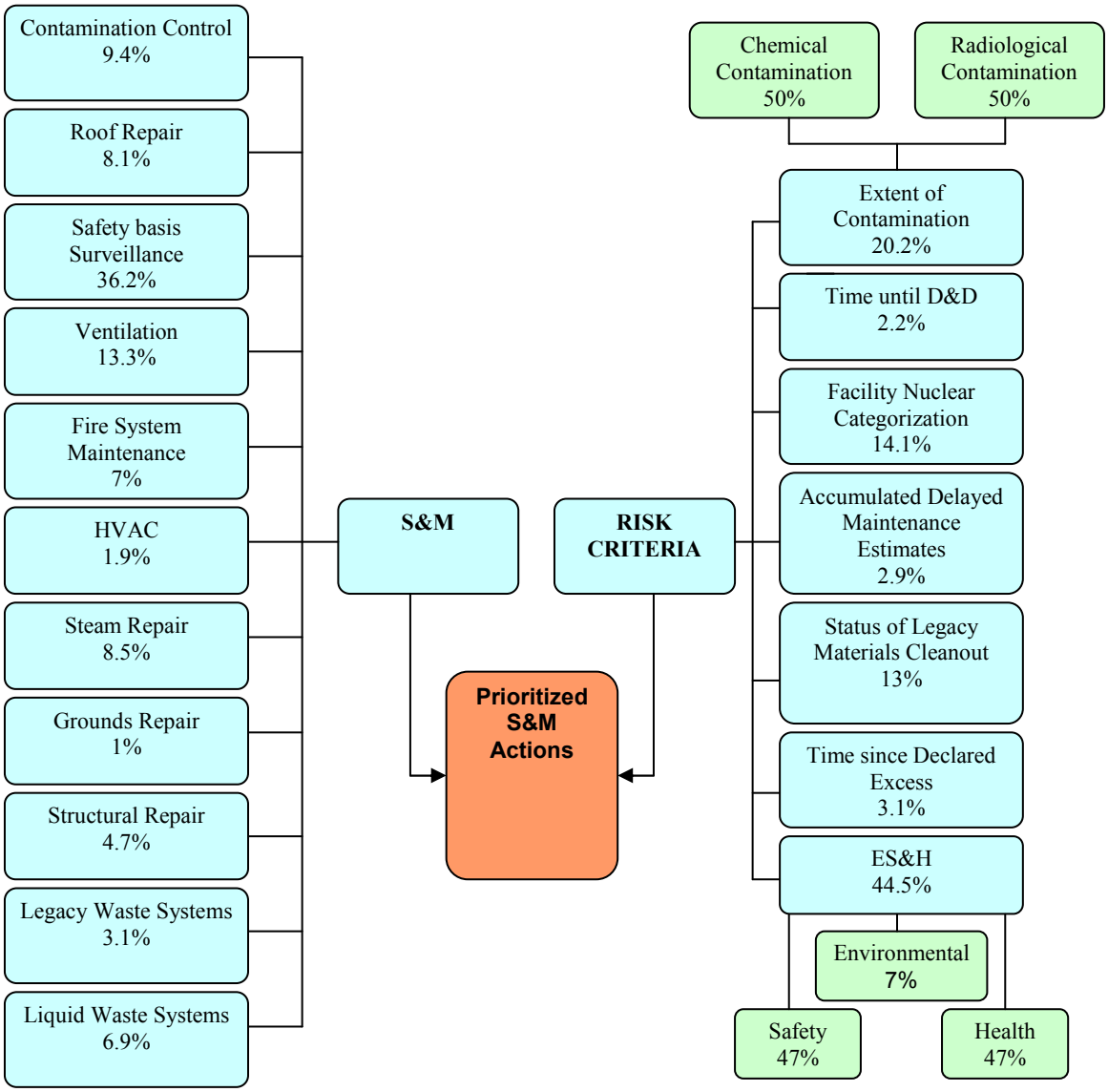

Figure 1. Percent Weight of Importance

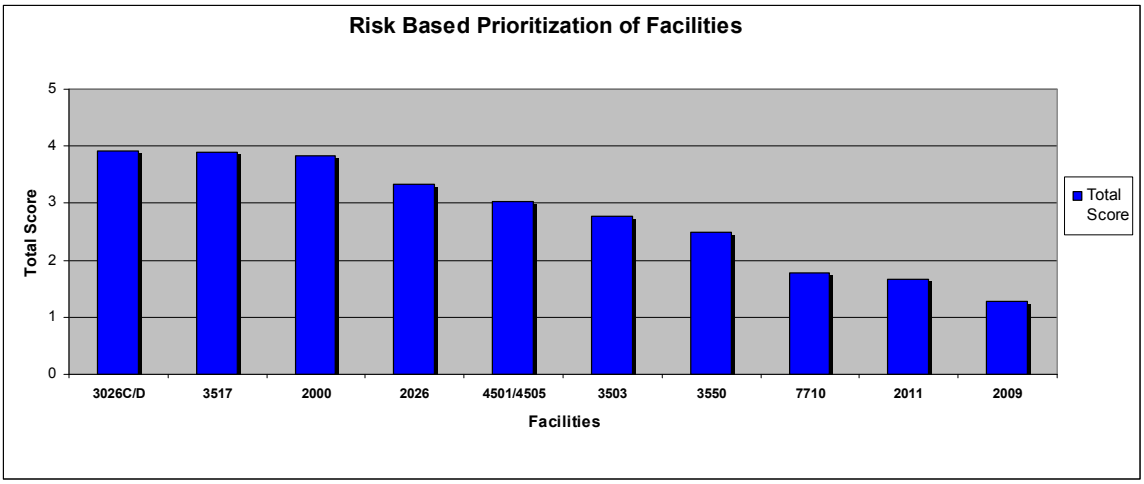

Figure 2. Risk Based Prioritization of ORNL Facilities

The results from the facility ranking were combined with the weight of importance of the S&M activity they require. A table was created so that the subject matter experts could identify the S&M for each facility, the final overall S&M activities rank was automatically calculated in the excel sheet.

S&M Check List

Facility	Safety Basis Surveillaince	Ventilation	Contamination Control	Steam Repair	Roof Repair	Fire System Maintenance	Liquid Waste Systems	Structural Repair	Legacy Waste Removal	HVAC	Grounds Keeping
3026C/D	x	x	x		x			x	x		
3517	x	x	x	x		x	x		x	x	
2000		x	x		x	x		x			x
2026	x	x	x			x	x		x	x	x
4501/4505		x	x			x			x	x	
3503			x	x	x	x			x		
3550						x		x			x
7710		x				x				x	x
2011											x
2009		x									

Table 2. S&M Check List

The final result after evaluating the facilities against each criterion and identifying their S&M was a rank of S&M activities to be performed on all the facilities based on the weight of importance of the activity and the risk posed by the facility. This method addressed the needs of all of the facilities without ignoring the S&M activities of the lower risk facilities. Doing so can prevent lower risk facilities from becoming a higher risk in the future. The results of this study showed consistency and reflected the overall judgment of subject matter experts, based on the facilities used in the test (Figure 3).

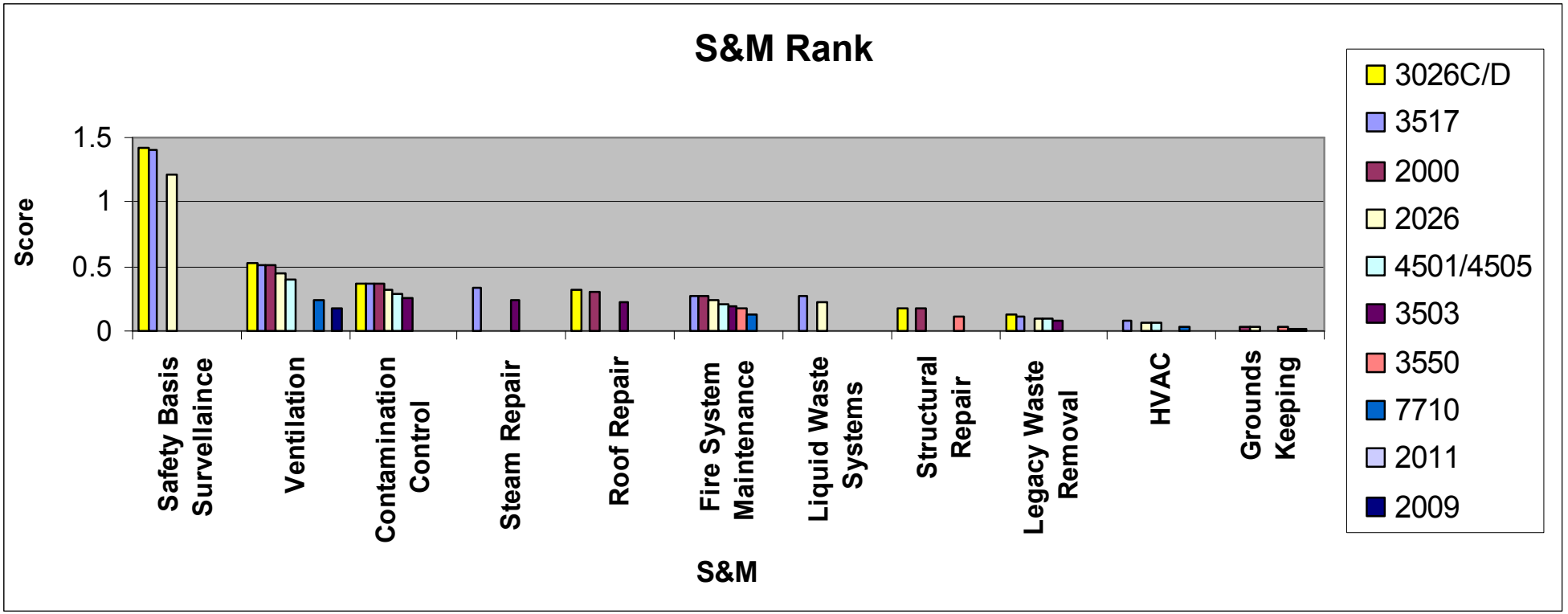

Figure 3, Final Test Results

5. OVERALL PROJECT CONCLUSIONS

The Decision Support Tool can be a starting point to determine how to distribute S&M budgets, to help make consistent and risk-based decisions and to provide documentation for future reference and review. In addition, the tool is flexible enough to be modified and used at other DOE sites such as the Savannah River Site where the tool was introduced and received positive feedback. A team of S&M experts from the Savannah River Site have been introduced to the tool and are planning to test it with some of their facilities. The experts will be able to add or edit the criteria, revise the pair-wise assessment or insert a larger number of facilities based on any unique needs at their site.

Several factors which include the weights assigned to each criterion, the final rank of the facilities and the S&M actions are subject to the judgment of the decision maker. For this reason, a sensitivity analysis will be the next step to improve the decision tool. Further research on the applicability of this tool will lead to the development of a model to determine how much money should be spent in S&M and the possible consequences of delaying a maintenance action on the final cost of D&D.

6. REFERENCES

Hobbs B. F., 2000. *Energy Decisions and the Environment: A Guide to the Use of Multicriteria Methods.* Boston: Kluwer Academic Publishers. 6-8.

Triantaphyllou, E., 2000. *Multi-Criteria Decision Making Methods: A Comparative Study.* The Netherlands: Kluwer Academic Publishers.

U.S. Department of Energy, Retrieved August 01, 2008 from http://www.doe.gov/environment/index.htm.

APPENDIX A. Risk Criteria Definitions

Criteria	Sub-criteria	Definition
Extent of Contamination	**Radiological Contamination**	Addresses extent of radiological contamination of facility and its impact on S&M. Includes the existence of facility-specific regulatory agreements related to radiological contamination.
	Chemical Contamination	Addresses extent of chemical contamination of facility and its impact on S&M. Includes measure for facility-specific environmental regulatory agreements or requirements.
Facility Nuclear Categorization		Addresses Nuclear Categorization of Facility with assumption that impact of problems at nuclear facilities create greater potential for risk.
ES&H	**Environmental**	Addresses the likelihood of and the extent/damage possible to the environment in the event of a release of contamination because of inadequate S&M. Examples of factors to be taken into consideration include contamination of soil, groundwater, streams, or other natural resources, as well as airborne contamination.
	Safety	Addresses the physical safety impacts on personnel created by the failure of the facility structure or infrastructure due to the lack of performance of S&M activities. These impacts are to be focused around facility personnel and those in the area and could consider materials of construction and failures of systems such as ventilation and fire detection/ suppression.
	Health	Addresses the impact on the health of workers and/ or the general population (when considering the facility location/ proximity to other operating facilities and general population centers due to the lack of proper S&M.) The considerations here are to be focused more on the body's physiological responses to exposure to the hazards rather than the more physical damage aspects to be considered in "Safety".
Time Until D&D		Addresses time between S&M and D&D at the time of the prioritization. Like the other criteria discussed, this criteria will change from year-to-year.
Accumulated Delayed Maintenance Estimates		Estimates the total cost of all facility maintenance that has been delayed/unperformed since facility became non-operational.
Time since declared excess		Addresses the time since the facility has been declared excess.
Status of Legacy Materials Cleanout		Addresses the extent of the efforts to remove legacy materials in preparation for either facility transfer to EM, the start of D&D or both.

APPENDIX B. S&M Definitions

Maintenance Action	Definition
Contamination Control	Actions required to prevent the spread of contamination. It includes decontamination and contamination fixing efforts.
Roof Repair	Maintenance and repair of the roof.
Safety Basis Surveillance	The surveillances required by documented safety analysis or equivalent documents.
Ventilation	Maintenance of systems designed to maintain air flow to prevent the uncontrolled release of contamination. This will include duct work, filters, and blowers.
Fire System Maintenance	Maintenance of systems designed to mitigate a fire event.
HVAC	Maintenance of heating, ventilation and air conditioning.
Steam Repair	Maintenance of systems designed to move and control steam through out the facility.
Grounds Keeping	Mowing grass, filling in animal holes, controlling weeds and other maintenances related to grounds keeping.
Structural Repair	Any maintenance related to structural repairs. Not including the roof.
Legacy Waste Removal	Efforts associated with the disposition of legacy waste in anticipation of D&D activities. Includes those items that are easily removed or require minimal effort to disconnect.
Liquid Waste Systems	Maintenance of piping, sumps and associated equipment designed to remove liquid waste from a facility.

APPENDIX C. Pair-wise Comparison Matrices

Risk Criteria	Extent of Contamination	Facility Nuclear Categorization	ES&H	Time Until D&D	Delayed Maint. Estimates	Declared Excess	Legacy Materials	Normalized Weight
Extent of Contamination	1.0	7.0	0.1	8.0	9.0	8.0	2.0	**0.202**
Facility Nuclear Categorization	0.1	1.0	0.1	9.0	9.0	9.0	2.0	**0.141**
ES&H	7.0	7.0	1.0	9.0	9.0	9.0	9.0	**0.445**
Time Until D&D	0.1	0.1	0.1	1.0	0.3	1.0	0.1	**0.022**
Accumulated Delayed Maint.	0.1	0.1	0.1	3.0	1.0	0.3	0.1	**0.029**
Time Since Declared Excess	0.1	0.1	0.1	1.0	3.0	1.0	0.1	**0.031**
Status of Legacy Materials Cleanout	0.5	0.5	0.1	9.0	9.0	9.0	1.0	**0.130**

Extent of Contamination	Radiological Contamination	Chemical Contamination	Normalized Weight
Radiological Contamination	1.0	1.0	**0.50**
Chemical Contamination	1.0	1.0	**0.50**

ES&H	Environment	Safety	Health	Normalized Weight
Environment	1.0	0.1	0.1	**0.07**
Safety	7.0	1.0	1.0	**0.47**
Health	7.0	1.0	1.0	**0.47**

S&M	Contamination Control	Roof Repair	Safety Basis Surveillance	Ventilation	Fire System Maintenance	HVAC	Steam Repair	Liquid Waste systems	Normalized Weight
Contamination Control	1.00	3.00	0.11	1.00	1.00	9.00	3.00	3.00	**0.094**
Roof Repair	0.33	1.00	0.11	0.20	1.00	9.00	0.13	4.00	**0.081**
Safety Basis Surveillance	9.00	9.00	1.00	9.00	9.00	9.00	9.00	9.00	**0.362**
Ventilation	1.00	5.00	0.11	1.00	5.00	9.00	5.00	4.00	**0.133**
Fire System Maintenance	1.00	1.00	0.11	0.20	1.00	7.00	1.00	5.00	**0.070**
HVAC	0.11	0.11	0.11	0.11	0.14	1.00	0.11	0.13	**0.019**
Steam Repair	0.33	8.00	0.11	0.20	1.00	9.00	1.00	0.20	**0.085**
Grounds Keeping	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	**0.010**
Structural Repair	0.33	0.14	0.11	0.25	1.00	9.00	0.20	0.20	**0.047**
Legacy Waste Removal	0.14	0.14	0.11	0.14	0.20	8.00	0.20	0.33	**0.031**
Liquid Waste systems	0.33	0.25	0.11	0.25	0.20	8.00	5.00	1.00	**0.069**

APPENDIX D. 5 Point Scale

Criteria	5 - Very High	4 - High	3 - Moderate	2 - Low	1 - None
Radiological Contamination	Facility has known or suspected radiological contamination to the degree that significant contamination control efforts must be considered during S&M .	Facility has known or suspected radiological contamination to the degree that moderate contamination control efforts must be considered during S&M.	Facility has a limited extent of known radiological contamination or there is reason to suspect the presence of radiological contamination based on known building processes (e.g. spill records or building postings indicate isolated portions of the facility would require special measures due to radiological contamination during S&M, or known building processes included some minor wet chemistry functions). Moderate to low contamination control efforts must be considered during S&M	Facility has no known radiological contamination based on building history.	Facility characterization confidence is high that no radiological contamination is present.
Chemical Contamination	Facility has known or suspected chemical contamination to the degree that significant contamination control must be considered during S&M	Facility has known or suspected chemical contamination to the degree that moderate contamination control efforts must be considered during S&M or is subject to site-specific regulatory agreement due to presence of chemical contamination.	Facility has a limited extent of known chemical contamination or there is reason to suspect the presence of chemical contamination based on known building processes (e.g. spill records or building postings indicate isolated portions of the facility would require special measures due to chemical contamination during S&M, or known building processes included some minor wet chemistry functions).	Facility has not been characterized, but has no known chemical contamination based on building history.	Facility characterization confidence is high that no chemical contamination is present.
Facility Nuclear categorization	CAT-2	CAT-3	Radiological High Risk	Radiological Low Risk	This Facility is not RAD facility
Environmental	Extensive contamination **or** facility deterioration could cause a very high negative impact on the environment.	Extensive contamination **or** facility deterioration could cause a moderate to high negative impact on the environment.	Limited contamination **or** facility deterioration that could cause a moderate impact on the environment	Some contamination **or** facility deterioration with low potential impact on environment	No unusual environmental concerns.
Safety	Extensive facility deterioration with very high potential impact on the safety of personnel.	Extensive facility deterioration with moderate to high potential impact on the safety of personnel.	Limited facility deterioration with some moderate potential impact on the safety of personnel.	Some facility deterioration with limited potential impact on the safety of personnel.	No unusual safety concerns.
Health	Extensive contamination with very high potential impact on the health of workers and/or general population.	Extensive contamination with moderate to high potential impact on the health of workers and/or general population.	Limited contamination with moderate potential impact on the health of workers and/or general population.	Some contamination with limited potential impact on the health of workers and/or general population.	No unusual health concerns.
Time Until D&D	16 years or more	11 - 15 years	6 - 10 years	2- 5 years	<= 1 year
Accumulated Delayed Maintenance Estimates (ADME)	ADME > $1.5M	$1M <= ADME < $1 .5M	$500 K <= ADME < $1 M	$100 K <= ADME < $500K	ADME < $100 K
Time Since Declared Excess	16 years or more	11 - 15 years	6 - 10 years	2- 5 years	<= 1 year or has not been declared excess
Status of Legacy Materials Cleanout	Large inventory of legacy waste with significant effort required to remove.	Large inventory of legacy waste with moderate effort required to remove	Medium to low inventory of legacy waste with moderate effort required to remove.	Small inventory of legacy waste with little effort required to remove	There is currently no legacy waste in the facility.