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ASSESSMENT OF CHEMICAL AND RADIOLOGICAL VULNERABILITIES

Shivaji S. Seth
Senior Technical Advisor for Nuclear Safety
U.S. Department of Energy Richland Operations Office

ABSTRACT

Following the May 14, 1997 chemical explosion at Hanford's Plutonium Reclamation Facility, the Department of Energy Richland Operations Office and its prime contractor, Fluor Hanford, Inc., completed an extensive assessment to identify and address chemical and radiological safety vulnerabilities at all facilities under the Project Hanford Management Contract. This was a challenging undertaking because of the immense size of the problem, unique technical issues, and competing priorities. This paper focuses on the assessment process, including the criteria and methodology for data collection, evaluation, and risk-based scoring. It does not provide details on the facility-specific results and corrective actions, but discusses the approach taken to address the identified vulnerabilities.

1. INTRODUCTION

Various chemical occurrences, including the May 14, 1997 chemical explosion at the Hanford's Plutonium Reclamation Facility (PRF) and the December 8, 1999 accident at Oak Ridge's Y-12 Plant, indicate that significant chemical safety vulnerabilities may persist within the U.S. Department of Energy (DOE) defense nuclear complex. The Secretary of Energy's August 4, 1997 memorandum [DOE, 1997a] directed all DOE sites to reassess known chemical and radiological vulnerabilities and to evaluate for new vulnerabilities on a continuing basis. A subsequent memorandum [DOE, 1997b] provided additional direction and guidance to focus assessment efforts on waste storage tanks and ancillary equipment. The attainment of the goal to identify, characterize, and satisfactorily address all significant safety vulnerabilities is a challenging, ongoing process, especially at the larger DOE sites. The major roadblocks are the size of the problem (e.g., thousands of tanks and hundreds of miles of associated piping); technical issues (e.g., unique, complex, poorly known chemical mixtures stored in aging equipment); competing priorities; and limited resources.

Following the 1997 chemical explosion at PRF, all the DOE Richland Operations Office (DOE-RL) contractors urgently reviewed and evaluated their inventories to identify hazards associated with reactive chemicals and to ensure that appropriate hazard controls are in place. Extensive walk-down of facilities identified significant amounts of unneeded chemicals that were properly disposed, which resulted in a certain level of immediate risk reduction.

After the conclusion of the urgent effort mentioned above, DOE-RL and its prime contractor, Fluor Hanford, Inc. (previously, Fluor Daniel Hanford, Inc.), undertook a more systematic and comprehensive assessment of chemical and radiological vulnerabilities at the Project Hanford Management Contract (PHMC) facilities. The objectives and scope of the vulnerability assessment had to be carefully defined so that it did not unnecessarily duplicate the efforts that have gone into providing the basis for ongoing, well-defined risk elimination projects. For example, Hanford's cleanup mission is already addressing the interim and long-term hazards to the public and the environment through stabilization of diverse nuclear materials; deactivation and clean-out of reprocessing cells containing highly radioactive materials; and various other decommissioning, storage, and disposal projects. Also, it is noted that DOE-RL prime contractors responsible for the Environmental Restoration Contract and for the operation of the Pacific Northwest National Laboratory (work scope not encompassed by the PHMC) have ongoing risk characterization and cleanup efforts, which are commensurate with the nature of hazards associated with their facilities. Those efforts are separate from the vulnerability assessment discussed here.

The vulnerability assessment for PHMC facilities was specifically planned and designed to identify conditions not adequately understood and analyzed, or that do not have adequate controls, which could endanger the health and safety of workers and the public through injury or exposure to hazardous chemical or radiological material. The overall process was segregated into three phases. The first phase involved the development of a set of criteria and preliminary methodology for the assessment. The criteria and methodology explicitly took into account the generic complex-wide vulnerabilities that were identified in DOE's 1994 chemical vulnerability assessment [DOE, 1994]. The second phase consisted of a pilot test of the assessment criteria and methodology at five representative Hanford facilities. These two phases were instrumental in defining the scope and approach for a detailed, comprehensive assessment of all PHMC facilities. The third phase was that assessment, conducted according to the pre-defined objectives, scope, approach, and protocols.

The overall assessment, including all three phases, was performed over a period of about one year. It was a team effort, with Fluor Hanford taking the lead in terms of defining and directing the project, and PHMC subcontractors collecting data and evaluating vulnerabilities at their respective facilities.

This paper discusses the assessment with the objective of sharing the overall process and methodology. It does not present facility-specific results and corrective actions, except to characterize them in general terms so that the approach taken to address the identified vulnerabilities could be understood. Additional details are provided in [FDH, 1999].

2. OBJECTIVES AND SCOPE OF ASSESSMENT

The major objectives of the assessment were as follows:

- To identify and assess vulnerabilities, defined here as conditions that are not adequately understood, analyzed, or controlled, which could endanger the health and safety of workers or the public through injury or exposure to hazardous chemical or radiological material.
- To identify or develop appropriate corrective actions, applying a graded approach to addressing vulnerabilities.

The physical scope of the assessment basically included containment vessels of any kind and at any PHMC facility: containers, storage cabinets, tanks, piping, ancillary equipment, and miscellaneous structures, such as glove boxes, hot cells, and storage tunnels. However, the assessment scope and approach were developed to address credible vulnerability scenarios, so that available resources could be devoted to issues that may not have been adequately addressed through ongoing projects. In addition, the process allowed certain categorical exclusions.

Examples to illustrate these aspects are provided below.

Potential vulnerability scenarios:

- Explosion, ignition, or rapid over pressurization of the containment vessel (induced spontaneously, internally, or by external force, e.g., shock or heat)
- Release of materials due to containment vessel failure induced by contents or external source
- Release of materials due to incompatibility (reaction) between materials or between materials and the containment vessel

Storage vessels or containments that present a potential vulnerability:

- Portable storage vessels, ranging in size from small vials to large drums, including skid-mounted vessels (includes compressed inert, corrosive, poisonous, or toxic gases), rail cars, and tank trucks
- Above- and below-ground tank systems (including inactive miscellaneous underground storage tanks), ancillary piping, and equipment
- Sumps and piping that indirectly lead to tanks (i.e., do not completely drain to the tank)
- Distribution boxes leading to tanks or cribs, valve boxes, and pools
- Material/waste handling devices (e.g., glove boxes or other structures)
- Chemical Sewer Systems
- Storage tunnels

Chemicals and Containments that normally would not present a potential vulnerability:

- Any substance to the extent it is used also for personal, family, or household purposes or is present in the same form and concentration as a product packaged for distribution and use by the general public (e.g., bleach, motor oil, and gasoline) (DOE G 151.1-1, Volume II)
- Any commercial product in containers, without respect to volume, provided ALL of the following criteria are met —
  - Product must be stored in its original container, as packaged by the manufacturer. Bulk products, e.g., off-site owned and maintained containers such as rail cars, tank trucks, or compressed gas cylinders are considered to be original containers from the manufacturer or vendor.
  - Product must be stored in accordance with applicable recommendations or specifications (including shelf-life) set by the manufacturer.
  - Product must be stored in accordance with applicable site requirements, including DOE Orders and site procedures.
  - A Material Safety Data Sheet for the product must be available.

  - The product must be inventoried and tracked in a facility-based chemical management system.
  - The product container must be clearly labeled as to its contents.
- Ammunition and other munitions maintained for security operations provided they are stored, handled, and transported under approved Federal and State regulations, DOE Orders and site procedures
- Heating, ventilation, and air conditioning systems, including all materials contained within them, and their associated air distribution ductwork
- Fuel storage tanks (i.e., gasoline and diesel)
- Septic tanks, sanitary systems, Storm water drains, runoff tanks, and open storage pools
- Sumps and piping that directly lead to tanks (i.e., gravity drain completely to the tank)
- Ditches, ponds, trenches, soil drain fields, dry waste caissons, and burial grounds
- Fire water storage tanks and fire suppression systems
- Steam systems or pressurized air systems

Categorical exemptions:

Certain specific processes, facilities, or categories of containment vessels and materials were granted exemption from the vulnerability assessment. Exemptions were justified if substantial, documented information, which had been gathered through other efforts, was equivalent to information that would be gathered through the vulnerability assessment process. This information must have demonstrated that appropriate characterization and control of risk had been completed.

Exemptions were reviewed and approved by an Exemption Review Board through a formal process explicitly set up for this purpose. Facilities requesting exemptions were responsible for providing the supporting information and documentation. Insufficient knowledge about the material or containment vessel, nor the cost or timing of collecting the information, was allowed as basis for an exemption. Examples of facilities granted exemptions were the fully deactivated canyon processing facilities, PUREX and B-Plant, where achievement of appropriate pre-defined end-point criteria established by DOE and State regulatory authorities could be demonstrated.

3. ASSSESSMENT PROCESS

Besides the development of a proper scope and methodology, the key aspects of the overall assessment process included ensuring that adequate resources were devoted to the assessment through the formal request and approval of a change to the baseline work; training of the personnel involved in the assessment; and surveillance and verification by Fluor Hanford and DOE-RL.

The vulnerability assessment process involved the following major steps:

A. *Development of the assessment scope, methodology, and protocols*. Based on the results and information from Phases 1 and 2, a core team developed the detailed methodology, including the screening and scoping process for defining which items would be the subject of assessment (see illustration in Figure 1); lists of information and data to be gathered for facilities, containments, or vessels; requirements to be used in the assessment, electronic database format and content; data collection forms and checklists supporting the database; quality assurance requirements; qualification and training requirements; final deliverables; and the schedule. The core team had extensive qualifications and experience in safety, chemical management, radiological and environmental protection, conduct of operations, and performance assessment. The core team developed a management plan [FDH, 1998] and established protocols to implement the subsequent assessment process steps.

B. *Determination of impacts to current projects*. The subcontractors estimated the impact of conducting the facility assessments and developed formal Baseline Change Requests (BCRs). The impact of conducting the assessment took into consideration other priority work that would be either delayed or canceled, because additional funds for this assessment were not provided.

C. *Establishment of assessment of teams*. The subcontractors identified points of contact within their organizations and facilities, defined the roles and responsibilities, and established assessment teams comprised of qualified individuals to conduct the assessments at each facility.

D. *Training and performance of assessment*. Upon approval of the BCRs, subcontractors commenced assessments of their respective facilities. The assessment database format and instructions were transmitted to the teams, and training was provided to all personnel involved in the assessment. The teams were trained on the methodology for data collection, evaluation, and reporting to ensure thorough and consistent application at all facilities. The teams conducted the assessments, completed facility-level and containment vessel-level data collection forms, and entered the information into the assessment database. The nature of information required by the data collection forms is discussed later. The subcontractor organizations were responsible for verifying the accuracy of the information entered into the database. The database for each facility was then transmitted to the core team for consolidation and overall analysis.

E. *Surveillance of assessments*. A surveillance team comprising a few members drawn from the core team performed focused surveillance of the assessments to ensure that the information being gathered was acceptable and to allow for mid-course corrections. Surveillance was performed in at least one facility per subcontractor. Surveillance Report Summaries were prepared for each facility visited. Examples of inconsistencies that were found and corrected included incorrect classification of unknown contents, incorrect inclusion of out-of-scope items, and omission of items in scope. DOE-RL Facility Representatives performed surveillance and prepared independent reports.

F. *Overall analysis and results*. After the database was reviewed and verified, the core team identified appropriate groupings of vulnerabilities and expectations for management of the vulnerabilities.

G. *Follow-up and closure of corrective actions*. Actions that resulted from the assessment were managed within the framework of Fluor Hanford's Integrated Environment, Safety and Health Management System (ISMS).

4. ASSESSMENT METHODOLOGY

This section describes the data collected at the facility and containment vessel levels, the evaluations performed, and the manner in which this information was subsequently combined through an algorithm to score vulnerabilities based on the safety risk they present.

At the facility level, the data and information collected related to asset ownership and identification; and the adequacy of inspection, maintenance, and operation; configuration control; personnel training; and lessons learned program.

At the containment vessel level, the following categories of data and information were collected:

- Containment vessel ownership and identification
- Characteristics of vessel (e.g., capacity, construction material, and application)
- Characteristics of contents (e.g., name, concentration, volume, and compatibility)
- Quality of characterization data for level of confidence and need for additional data
- Hazard characteristics of containment vessel contents
- Relative risk ranking factors for consequence and likelihood of an occurrence
- Recommended additional controls
- Immediate and long-term corrective actions

Certain categories of data and information mentioned above; i.e., quality of data, reactivity hazard, and other risk ranking factors, were each defined further in terms of parameters that could be evaluated semi-quantitatively. These categories are further discussed next.

Quality of Characterization Data

The lack of adequate information about a material reflects increased risk because the requirements for its safe storage may not have been understood and implemented. The level of confidence in the available data to characterize the safety of the containment vessel and its contents was judged, based on the degree to which each of the following was available: (1) analytical data generated under an established quality assurance plan consistent with intended use; (2) process knowledge supported by controlled, peer-reviewed documentation; and (3) testimony from a person with primary knowledge.

Hazard Characteristics of Material

Material in a containment vessel was assigned to one or more of the following four groups, based on its reactivity hazard: (1) explosive, unstable reactive, unstable over time (e.g., due to aging in storage or contamination during use), and organic peroxides; (2) pyrophoric, water reactive, flammable gas, fissile materials; (3) corrosive and highly toxic materials; and (4) all other materials (generally not very reactive). Additional information helpful for classifying vessel contents into these groups, such as explanations of definitions and potentially adverse conditions, was provided to the assessment teams. Radioactive material was given an additional identifier. The contents, if unknown, were conservatively assigned to the first group.

Consequence Ranking Factors

The following factors, in addition to data quality and hazard characteristics of material, were considered to influence the severity of consequences resulting from the loss of control of material, such as through an uncontrolled reaction or a leak release:

(1) Potential for human injury. Considerations included accessibility to personnel, number of persons potentially affected, and expected severity.

(2) Potential for human exposure. Considerations included vessel location relative to people, number of persons potentially affected, and likely exposure scenarios.

(3) Potential and significance of secondary impact. Considerations included other systems, structures, and components that could magnify consequences, e.g., fixed radioactive contamination, safety-critical systems, and ventilation systems; and considerations, such as distances or barriers between systems, and hazard characteristics of materials impacted.

Likelihood Ranking Factors

The following factors, in addition to data quality and hazard characteristics of material, were considered to influence the likelihood of occurrences involving the loss of control of a material:

(1) Design. Considerations included safety features, as applicable; e.g., pressure relief, secondary containment, air filtration, hydrogen mitigation, shielding, and seismic capacity.

(2) Operation. Considerations included whether the vessel and any ancillary equipment are operated as designed, per manufacturer's specifications (including design life), and within the documented safety envelope.

(3) Containment vessel condition. Considerations included integrity testing, protection from corrosion, modifications that potentially degrade integrity, and visual condition.

(4) Maintenance and inspection. Consideration included whether preventive maintenance and inspections are regularly scheduled and implemented.

(5) Safety authorization basis, emergency planning, and other programmatic controls. Considerations included whether the configuration of the containment vessel and ancillary equipment is adequately documented, reviewed and approved; and whether it is subject to established programs, such as for inventory control, standards and requirements identification, authorization basis, fire protection, and emergency planning.

Risk-based Relative Ranking

The relative risk presented by a containment vessel was quantified by developing a vulnerability score, a numerical product of two quantities representing, respectively, the consequence and the likelihood of an occurrence. These two quantities, in turn, were obtained from the factors discussed above.

The data quality, the hazard group of material, and the consequence and likelihood factors were each parameterized and scored by assigning integer values, 1 through 5 (except for hazard group), where unity represented the best condition and the value five represented the worst. The parameter representing the hazard group of material was assigned the value 16, 9, 4, or 1, respectively, for the most reactive to the least reactive group. These values are each equal to the square of the hazard group in reverse order.

The quantity representing the consequence of an occurrence was the linear sum of parameter values for data quality (weighted twice), hazard group of material, and for each of the three consequence factors. The parameter value for data quality was doubly weighted so that the vulnerability score properly reflects conditions defined by poor quality data relative to those with good quality data. The quantity representing the likelihood of an occurrence was derived in the same manner, except that the linear sum of parameter values included each of the five likelihood factors instead of the three consequence factors.

The quantities representing the consequence and the likelihood were normalized so that their maximum value each was 10; and the maximum value of their product, the vulnerability score, was equal to 100. The algorithm for developing the vulnerability score was tested on selected containment vessels and materials, before its use by the assessment teams, to verify that it provides acceptable range of vulnerability scores for each hazard group.

5. OVERALL ANALYSIS AND RESULTS OF ASSESSMENT

There were a total of 1308 items for which data and information were collected. After the database of facility and containment vessel information, including the vulnerability scores, was reviewed and verified, the core team identified appropriate groupings of vulnerabilities and expectations for management of the vulnerabilities.

Ideally, the vulnerability scores would display a distribution centered near the bottom of the scale. This distribution would thin out as vulnerability scores increased because the number of items with relatively poor controls would be smaller. The scores generated by the assessment showed the expected pattern; however, it included an additional broad peak representing items that contain unknown materials. This is shown in Figure 2. A statistical analysis found that the data fit to a combination of two separate probability distributions: a gamma probability curve for the low-scoring group (i.e., a distribution that has only one tail), and a normal probability curve for the rest of the data. The division between the groups was identified as the point where the probability curve from one group was equal to the probability curve from the other group. This point, which occurred at a vulnerability score of 36, represented the boundary between the two groups.

The two groups of vulnerability scores were termed as the Activity-Level Group and the Facility-Level Group for the lower and the higher range of scores, respectively. These terms for the groups are based on how the identified vulnerabilities would be managed within the framework of ISMS. The characteristics and examples of the two groups are discussed below.

Activity-Level Group

This group is characterized by items whose properties and hazards were well understood and had adequate controls. Items in the Activity-Level Group could be addressed through existing processes, which include work planning and control, hazard identification and analysis, and conduct of operations. Work planning teams use the Automated Job Hazards Analysis process, applying a graded approach based on complexity and risk. Responsibility for resolving deficiencies at the activity level rests with the worker and the first-line supervisor.

Of the total number of items within the scope of the vulnerability assessment, 88% fell into this group. Fraction of the total identified as radioactive was 57%; and that identified as unknown was 0.2%. The group included waste containers, double-shell tanks, laboratory materials and waste streams, and receiving and shipping materials.

Facility-Level Group

This group is characterized by items whose properties and hazards were not sufficiently understood, and controls could be inadequate. Remediation and management of vulnerabilities at this level would require the consideration of facility workscope and project baselines, as well as the facility management's focused attention to ensure that adequate safety basis and proper hazard controls are in place. Safety basis changes could be required to resolve issues in this group. Actions taken to resolve deficiencies would include identifying the scope of work, ensuring adequate budgeting, recording actions through the Deficiency Tracking System, and tracking status through senior management meetings. Typically, these issues require significant resources to fix and need to be balanced against other facility priorities. Additionally, these issues should be specified as actions of remediation through the Multi-Year Work Planning process.

The Facility-Level Group accounted for 12% of the total number of items, with 87% identified as radioactive, and 85% of uncertain composition. These items include legacy waste or orphan containers, ion-exchange columns, single-shell tanks, inactive miscellaneous underground storage tanks, active and inactive radioactive waste transfer lines and associated valve pits and clean-out boxes.

6. CORRECTIVE ACTIONS AND FOLLOW-UP

A primary result of the vulnerability assessment was the identification of necessary corrective actions for the vulnerabilities identified. Identification of corrective actions was required for any material listed as unknown. The facility was also required to determine whether a corrective action should be implemented in the near-term or long-term. Many deficiencies and related corrective actions had been identified prior to the vulnerability assessment process.

The vulnerability grouping and nature of corrective actions were used to determine the priority and actions necessary to reduce the vulnerabilities to an acceptable risk. The corrective actions generally consisted of identifying the material through sampling and characterization, and determining the need for its continued storage. Examples of the identified corrective actions included the following:

- Sample and characterize material (one time or routinely).
- Review need for material and dispose or excess if not needed.
- Relocate or dispose of material.
- Implement a procedure for inspection.
- Reevaluate storage conditions/practices for material compatibility.
- Develop a surveillance procedure.
- Modify containment to add absorbent material.
- Label container.
- Isolate container from other systems.
- Properly vent containers to eliminate pressure buildup.
- Develop ways for detecting pressure buildups.
- Flush and clean containment.
- Determine potential for leakage.
- Verify status of container (e.g., whether it is empty).
- Install temperature controls.
- Perform an Unreviewed Safety Question (USQ) screening.
- Update the Authorization Basis.
- Close outstanding USQ.

During the course of the assessment, some situations were identified that required prompt corrective actions. For example, a few situations involved incompatible materials stored together, which were immediately corrected. In a couple of instances, more extensive actions were needed.

At the close of the assessment, the following recommendations were made:

- All open items in the Facility-Level Group should be entered into the Corrective Action Management System/Deficiency Tracking System for tracking completion of corrective actions. This process includes determining the priority of corrective actions. Items at the upper end of this group would generally receive priority in finalization of corrective actions.
- All items of unknown characteristics within the Facility-Level Group should be evaluated to determine the contents and to determine if the existing controls were adequate.
- Facility ownership should be clearly established for all items on the site.

7. SUMMARY AND CONCLUSION

The vulnerability assessment undertaken by DOE-RL and Fluor Hanford was an extensive effort that covered all PHMC facilities. The objectives, scope, and methodology for the assessment were carefully defined to focus on conditions that were not adequately understood or analyzed, or that did not have adequate controls, without duplicating previous and ongoing efforts. The assessment methodology incorporated the generic DOE complex-wide vulnerabilities previously identified, and went further in providing a semi-quantitative evaluation of the quality of data, hazard characteristics of material, and of several consequence and likelihood ranking factors. Based on this evaluation, each item subject to assessment received a relative vulnerability score to support the management of corrective actions. Vulnerabilities were split into two broad groups, the Facility-Level and Activity-Level Groups, so that the identified corrective actions could be readily managed within the framework of ISMS. The assessment provided a database of valuable information on facility and containment vessel conditions.

Overall, the vulnerability assessment showed that most of the items covered by the scope of the assessment were managed appropriately; and corrective actions, if necessary, could be addressed at the activity level through normal work planning and control processes. Some items required completion of existing programs to adequately identify their hazard characteristics and required controls. The assessment also identified opportunities for existing programs to reassess corrective actions and priorities.

8. REFERENCES

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Figure 1. Vulnerability Assessment Process

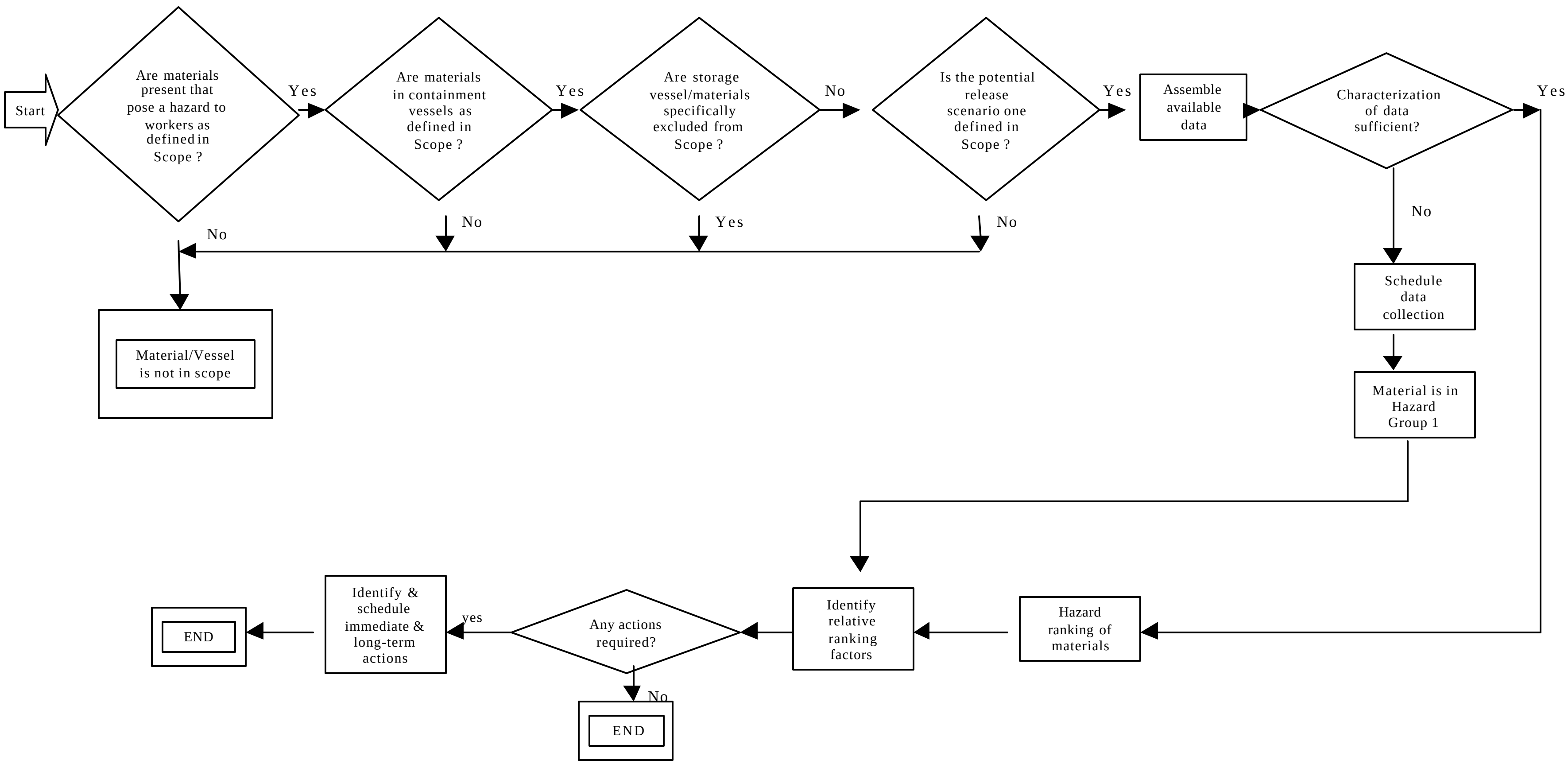

Figure 2. Results of Vulnerability Assessment