Radiological Data Consolidation and 3D Modeling of a Building – 15473

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ABSTRACT

A portion of a building at an industrial facility that conducted monazite sands-processing operations in the 1950s under contract to the Atomic Energy Commission (AEC) became contaminated. Subsequently the U.S. Department of Energy designated the facility for remedial action under the Formerly Used Sites Remedial Action Program (FUSRAP). Remedial investigation, remedial actions and post-remediation surveys have been conducted in portions of the building. Radiological data for the interior of the building were compiled, evaluated and presented in a three dimensional (3-D) model (the model) created by AMEC Foster Wheeler in order to identify areas that meet the Record of Decision (ROD) cleanup criteria, and identity areas that may require remedial action or may require additional investigation due to data gaps.

The data from different phases of investigation and remediation cover different portions of the building and in some cases overlap. In addition, the data were collected over a period of more than ten years, for different objectives, and thus the instruments and methods for establishing efficiency were not necessarily consistent. The data consolidation process included determining the relative quality of data points to include in the model and the development of rationale associated with assigning a quality level (i.e. ranking) to each data point. The rationale for ranking data quality included, as the primary determining factors, chronological order of the data (most recent was ranked as more reliable), certainty of the sample locations within the building, and analytical data quality. A 3-D model of the building was created using a laser point cloud scan which was then converted into a 3-D design model. Sample locations were then entered into the model and linked with the analytical database to allow display of the radiological results in the model. The visual model allows both strategic and tactical decisions to be made, depending on the level of detail examined.

The evaluation process allowed maximum use of the historical data set, rather than requiring older data to be disregarded, and provided at a minimum a qualitative sense of data quality/confidence in the data. The

process also highlights the importance of collecting high quality data from the very beginning with a consistent locational coordinate system, and the need for a good visualization model in order to assess contaminant locations during remedial action or post-remediation surveys.

INTRODUCTION

As part of the US Army Corps of Engineers (USACE) Formerly Utilized Sites Remedial Action Program (FUSRAP), a data compilation and 3-D modeling of historical radiological survey data for a radiologically contaminated building was performed. The effort was conducted so that radiological data for the interior of the building could be evaluated in order to identify areas that meet the Record of Decision (ROD) cleanup criteria and identify areas that may require remedial action or may need additional investigation due to data gaps. To complete the effort, a 3-D model (model) of the building created by completing a 3-D laser Point Cloud Scan of the building to document and inventory the current building and its structure, and utilizing Autodesk Revit software to incorporate the scan results and information obtained from the existing CAD drawings to create a model that reflects the current conditions of the building. The historical data was consolidated and entered into a relational project database housed in a Microsoft SQLServer Enterprise 2008 server. The database and model were integrated by means of an Open Database Connectivity (ODBC) connection to display the sampling locations and specified data attributes in 3-D within the building allowing the users of the model to view and virtually “walk thru” the building while viewing the specified data attributes.

The processing of monazite sand at the facility occurred in a processing plant located within the building. Processing of the monazite sand began in May 1956. The products of the monazite processing were reported to be crude thorium hydroxide and rare earth sodium sulfate. Isotopic components of the raw monazite sand include Uranium-238 (U-238) and Thorium-232 (Th-232) and their decay progeny. Processing operations ceased sometime in the spring of 1957.

The U.S. Department of Energy (DOE) identified the site for inclusion in FUSRAP in 1984. In 1986, Oak Ridge National Laboratory (ORNL), at the request of DOE, conducted a limited radiological survey to evaluate present or potential health risks (ORNL, 1989). Thorium was reported as the most prominent radionuclide present. A Remedial Investigation (RI) was conducted in 2000, under contract to USACE. Residual radiological activity was identified during the RI. Thorium and uranium and their decay progeny were identified as Radionuclides of Concern (ROCs) at levels above background on each of the five floors of the building.

A total of 11 areas of concern (AOCs) were identified within the building during the RI based on surveys of accessible areas[1]. These AOCs included the floors, walls, and ceilings of the fourth and fifth floor, together with smaller isolated areas of the first, second and third floors. The soil under the first floor was also identified as an AOC. Abandoned-in-place piping and equipment on the fourth and fifth floors were also noted as being potentially impacted with residual radioactivity. A Feasibility Study (FS) was then prepared to identify and evaluate potential remedial alternatives to address residual activity identified during the RI. The RI/FS process was conducted consistent with FUSRAP, the Comprehensive Environmental Response, Compensation, and Liability Act and the National Contingency Plan. A ROD identifying the Remedial Action (RA) for the building was finalized in April of 2005 (USACE, 2005). The RA selected for the site was "decontamination with removal to industrial use levels."

Specific remedial goals (RGs) were defined in the ROD for building components in the building as: to reduce surface activity on building component surfaces to below the Derived Concentration Guideline Level Average ($DCGL_W$) of 1,234 disintegrations per minute (dpm)/100 centimeters squared (cm^2) (740 dpm/100 cm^2 for alpha activity and 494 dpm/100 cm^2 for beta activity) above component background levels for each type of material in accordance with the guidance provided in Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), or other appropriate guidance, as needed. RGs for localized areas of elevated surface activity - Derived Concentration Guideline Level Elevated Measurement Comparison, ($DCGL_{EMC}$) - must also be met in order to achieve the remedial action objective. RGs shall be developed in accordance with MARSSIM, or other appropriate guidance, for localized areas of elevated radionuclide concentrations on various materials. RGs include cleanup to the appropriate $DCGL_W$ with a maximum removable fraction of 20%.

Remedial actions previously conducted at the Site include, but are not limited to, the following:

- Removal and replacement of a portion of the ground floor concrete slab and underlying soil;

[1] Additional areas with radiological impact potentially above cleanup criteria defined in the ROD have been identified since the RI was completed (such as through surveys conducted during subsequent remedial actions).

- Removal of abandoned equipment and unused utilities on the third, fourth and fifth floors and relocation of certain heating, ventilation, and air conditioning (HVAC) utilities on the third floor;
- Removal of the concrete deck, and replacement by a steel deck, at a portion of the high roof;
- Removal of the concrete slab and steel plate/grate from the fourth and fifth floors;
- Removal of a switch gear room and abutting break room on the third floor (concrete floor and cinder block walls);
- Removal of the second floor laboratory cinder block walls and decontamination of the laboratory floor;
- Removal of a structurally degraded ground floor interior brick wall and degraded wooden and brick AOC-10 structures from the second floor elevation upwards;
- Removal of miscellaneous steel members, primarily at the fourth and fifth floor elevations and within the area of AOC-10; and
- Decontamination of structural steel, generally from the fourth floor elevation up, using abrasive blasting and hand power tool techniques with subsequent coating.

In progress and post-remedial surveys were conducted by the RA contractors and independent interim final status surveys (FSS) of areas of the building were also completed in 2013, and included certain areas at the second, third, fourth and fifth level of the building.

METHODS

As noted above, remedial actions have been performed in some areas of the building resulting in the removal of significant portions of the RI defined AOC (for example the concrete floor on the fourth and fifth floors and much of the AOC-10 structure). In those areas, post remedial action surveys were ranked as higher quality data. Data from earlier investigations are included if areas sampled were not subsequently removed or decontaminated during the remediation efforts, but they are ranked as lower quality data. In addition, the existing data for areas outside these AOCs are included in the database if they meet the data assessment requirements.

Direct reading (static or stationary measurement) results, building material sample results, sub-slab soil results and smear results are included in the database. Dose measurements with specific locations are also included. However, scan results are not included in the database as they are not generally location specific and provide little additional value to the radiological assessment of the facility where substantial static measurements exist.

Overall, the data were compared to the established DCGLs for the building as summarized in Table I. Initially data were compared to the $DCGL_W$ and if the alpha or beta levels are exceeded then the data were compared to $DCGL_{EMC}$ values for various area factors to identify which $DCGL_{EMC}$ area factor would allow the point to meet the cleanup criteria.

Table I Building DCGLs

ROC	**Total (fixed plus removable) dpm/100cm^2**	**Removable dpm 100/cm^2**
$DCGL_W$ Th-232 and progeny	1,234	247
$DCGL_W$ Alpha	740	148
$DCGL_W$ Beta	494	99
$DCGL_{EMC}$ Alpha (100 m^2)	740	148
$DCGL_{EMC}$ Beta (100 m^2)	494	99
$DCGL_{EMC}$ Alpha (36 m^2)	2,014	403
$DCGL_{EMC}$ Beta (36 m^2)	1,343	269
$DCGL_{EMC}$ Alpha (25 m^2)	2,873	575
$DCGL_{EMC}$ Beta (25 m^2)	1,915	383
$DCGL_{EMC}$ Alpha (16 m^2)	4,428	886
$DCGL_{EMC}$ Beta (16 m^2)	2,952	590
$DCGL_{EMC}$ Alpha (9 m^2)	7,752	1,550
$DCGL_{EMC}$ Beta (9 m^2)	5,168	1,034
$DCGL_{EMC}$ Alpha (4 m^2)	17,014	3,403
$DCGL_{EMC}$ Beta (4 m^2)	11,343	2,269
$DCGL_{EMC}$ Alpha (1 m^2)	65,725	13,145
$DCGL_{EMC}$ Beta (1 m^2)	43,817	8,763

Radiological surveys were performed utilizing different methodologies, so each methodology and the resultant data obtained was evaluated to determine the level of confidence and quality. In some cases, multiple surveys and sampling events were conducted in the same area of the building. The most current data was selected to represent each area unless the data quality was such that older data provides a better representation. In locations where data from multiple datasets and sources existed for a given area, the availability of additional data was identified. If a situation was encountered where the most current dataset was not used to represent current conditions and an older dataset was used, justification for its use was provided. Data assessment began with the most current data and worked backwards chronologically so that areas of overlap were identified for comparison.

As the ultimate goal of remedial actions at the building is to achieve radiological release criteria established in the ROD, MARSSIM was the primary basis for evaluation of the data. Several data quality indicators (DQI) were utilized that establish the criteria for evaluation of each data set to evaluate data set quality as shown in Table II.

Table II DQIs

Data Quality Indicator	Significance	Action/Remark
Completeness	Less than complete data set could decrease confidence in supporting information.	Objective of 90-percent completeness for survey units or designed investigations.
Comparability	Affects ability to combine analytical results.	Confirm data collected from randomly selected locations within a survey area are unbiased and comparable by design and can be combined. Also will evaluate surveys of the same areas performed at different times. Primary parameters for field measurements include instrument type, efficiency, background and MDC following the MARSSIM. Laboratory samples will utilize QC provided.
Representativeness	Non-representativeness increases or decreases Type I error (false negative) depending on the bias.	Confirm sample allocation included a minimum number of unbiased, randomly distributed sample locations based on survey design. Identify biased samples.
Precision	Measurement variability, due to techniques and/or technology, may increase uncertainty.	Evaluate each of the data sets for replicate measurements, background measurements, and source response check measurements to gauge reproducibility. Then compare all to determine compatibility/bias.
Accuracy	Sampling and data handling can introduce bias and affect Type I and Type II (false positive) errors.	Evaluate each of the data sets for field measurement procedures and instrument calibration. Then compare all five to determine bias.

Measurement uncertainty associated with radiation measurements and samples in a building arose from two principal sources – field sampling variation and instrument measurement variation. Of these two, field sampling variation was likely the greatest contributor to overall uncertainty because of the inherent logistics of sample collection activities (process of making measurements).

Data verification compares the collected data to the objectives in each report. Data verification included:

- assessment of activities performed during implementation by means such as inspections, QC checks, or surveillance;
- documentation of deficiencies or problems encountered during implementation; and
- review of corrective actions to ensure adequacy and appropriateness.

The data analysis framework incorporated data quality assessment (DQA) components discussed in MARSSIM to assess the overall usability of the data for its intended use. This included review of QA/QC performed during collection of the data, basic statistics (mean, median, standard deviation, minimum, maximum), and posting plot as part of the data rationale.

Missing data may reduce the precision of estimates or introduce bias, thus lowering the confidence level of the conclusions. The importance of lost or suspect data was evaluated in terms of the sample location, analytical parameter, nature of the problem, decision to be made, and the consequence of an erroneous decision. Critical locations or parameters for which data are determined to be inadequate were identified.

This process begins with the chronological order of the radiological surveys, beginning with the most recent. This approach was taken since the most recent surveys were performed for interim FSS, following the MARSSIM, while the older investigations that had different objectives (for example, in progress remedial surveys may be biased to provide the contractor confidence that remedial goals had been met in its area of work) did not follow that approach in terms of data quality for measurements.

The next step in the data rationale sequence was evaluating the sample location information. Numerous surveys were conducted in the same areas within the building and remedial actions had removed major sections of the building. This establishes the logic to determine the precedence of the data beginning with the most recent. The first determination was whether the location still exists (or was removed due to remediation). If the location was still in place, then the data was compared to the already processed data (reverse chronological order) and added to the model if not a duplicate. Then the location accuracy was assessed (for both duplicate and non-duplicate locations). This process was repeated until all the data sets were evaluated for location information.

The final step in the rationale process was evaluating the data quality. This entailed comparing the provided information to the MARSSIM with respect to reported values/parameters, instrument efficiency, minimum detectable concentrations, instrument type and measurement technique. This step led to the most variability due to different contractors performing measurements and the period of time covered.

The overall quality ranking was a combination of the data quality and location accuracy assessments. For data with high data quality and location accuracy, an overall high quality ranking was assigned. For data with high data quality but low location accuracy, an overall medium quality ranking was assigned. For data with low quality and either location accuracy (low or high), an overall low quality ranking was assigned.

A 3-D laser Point Cloud Scan of the building was performed to document and inventory the current building and its structure. 3-D laser scanning is a non-contact, non-destructive technology that digitally captures the shape of physical objects using a line of laser light. 3-D laser scanners create “point clouds” of data from the surface of an object and map an object’s exact size and shape into the computer as a digital 3-D representation. The Point Cloud Scan process identifies the dimensions and locations of the interior building structure, utilities and appurtenances, and also provides a 3-D photographic representation of the building.

Upon completion of the Point Cloud Scan, a 3-D model was created of the existing building utilizing Autodesk Revit software by incorporating the scan results and information obtained from the existing CAD drawings of the building to provide a model that reflects the current conditions of the building. While the Point Cloud Scan provides a very accurate depiction of the building, considerable effort is required to convert this data into building elements in the model. Upon completion of the model, two dimensional (2-D) base maps were created that include floor plans, building elevations, building sections, and enlarged elevations. The maps are a necessary supplement to the 3-D model, for example for annotation and use in the field.

The 3-D model was integrated with the database by means of ODBC connection to display the sampling locations and specified data attributes in 3-D within the building. Using Navisworks software that is available for free download, the model can be used to view and virtually "walk thru" the building while viewing the specified data attributes.

Approximately 10,000 records were entered into the model to provide a physical location in the model space. In the model, each record has a specified symbol that contains a unique identifier correlating to an identical unique identifier in the database. This allowed the data to be transferred between the model and the database. In addition each symbol has labels and data attributes that can be read in and printed to the 2-D drawing sheets.

DISCUSSION

As expected, there were numerous variations within the reported datasets. This included not only the survey methods and instrument efficiency methodology but also the level of detail recorded for radiological surveys. The laser Point Cloud Scan also presented some challenges as well since most of the floors in the upper levels have been removed. Scans were generated from accessible locations and the point cloud was utilized to create a 3-D model and updated drawings of the facility. Placement of radiological data within the 3-D model also had some issues as some survey documentation did not provide clear reference to the location of the radiological survey within the facility, while others had no specific location provided. The approach taken and impact of these challenges to the overall model is presented in this section.

The generation of a 3-D model is the foundation for allowing visualization of the radiological data. The missing floors in the upper levels of the facility posed a limitation due to access but also allow for scans from the lower floors looking up that would not have been available otherwise. Sufficient data was collected for complete generation of a 3-D model that supported the level of details necessary for locating radiological data. The scanning process and an example of the scan output are shown in Figures 1 and 2. An example of the 3-D model is provided in Figure 3.

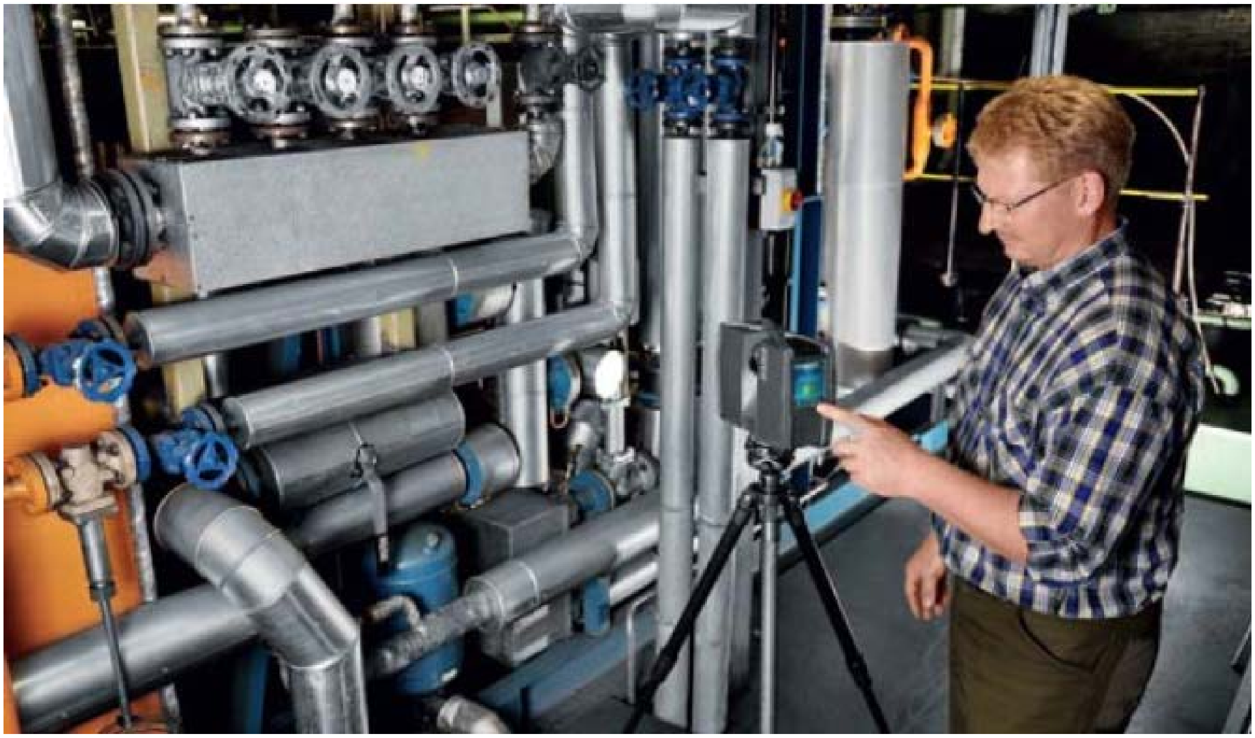

Figure 1 – Point Cloud Scanner

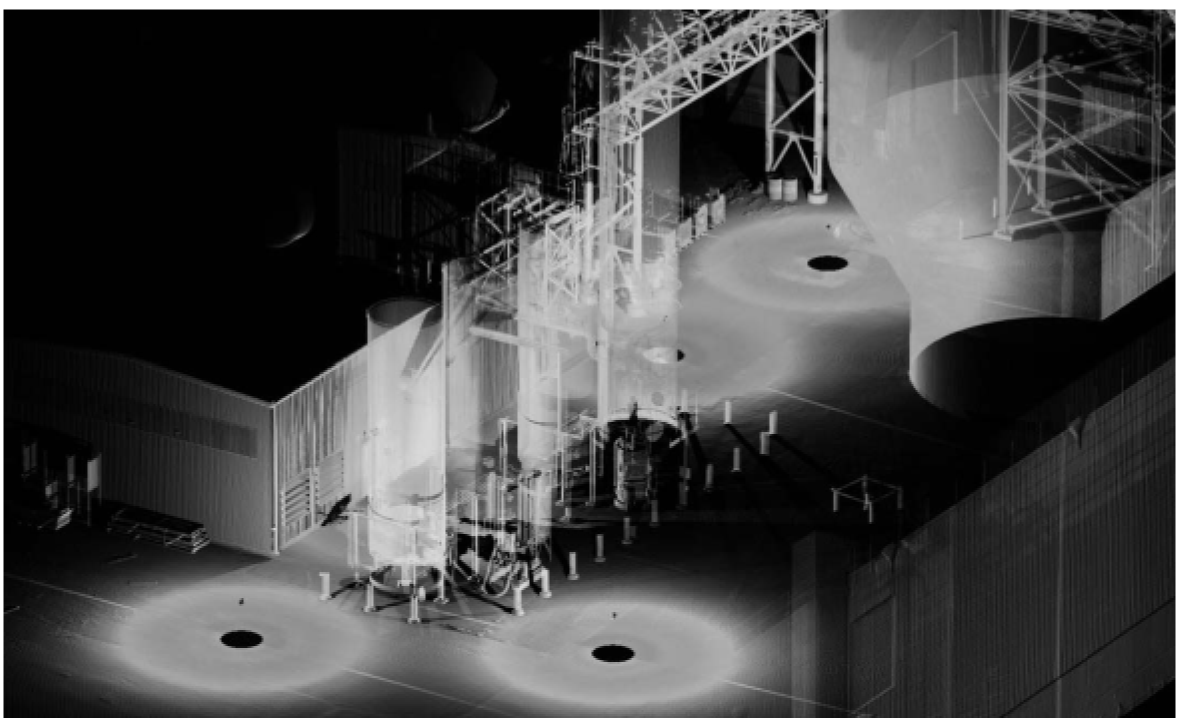

Figure 2 – Point cloud Scan output. Each Scan captures over 48 million points and overlapping scans

ensures full coverage of features hidden form a single scan location

Locating points within the 3-D model was not always straightforward. In some cases the location maps within the survey data packages were well marked, and included clear orientation and position within the building. Others had poor orientation or the position within the building was not provided. Part of the early data had measurements collected randomly with no specific locations provided. Locating data on the structural steel beams and columns (including I beams, C-Channels, built up box columns) was difficult at times if the reference/orientation information was not documented with the location map. Another unique factor was the Surface Contamination Monitor (SCM) reported data included in the RI. The SCM collected millions of data points that were utilized to create detailed color shaded location maps. The raw data was not available and only the data included in summary tables for each survey area, with no location specific data, was available. For locations that were not accurately provided, the location quality was flagged low.

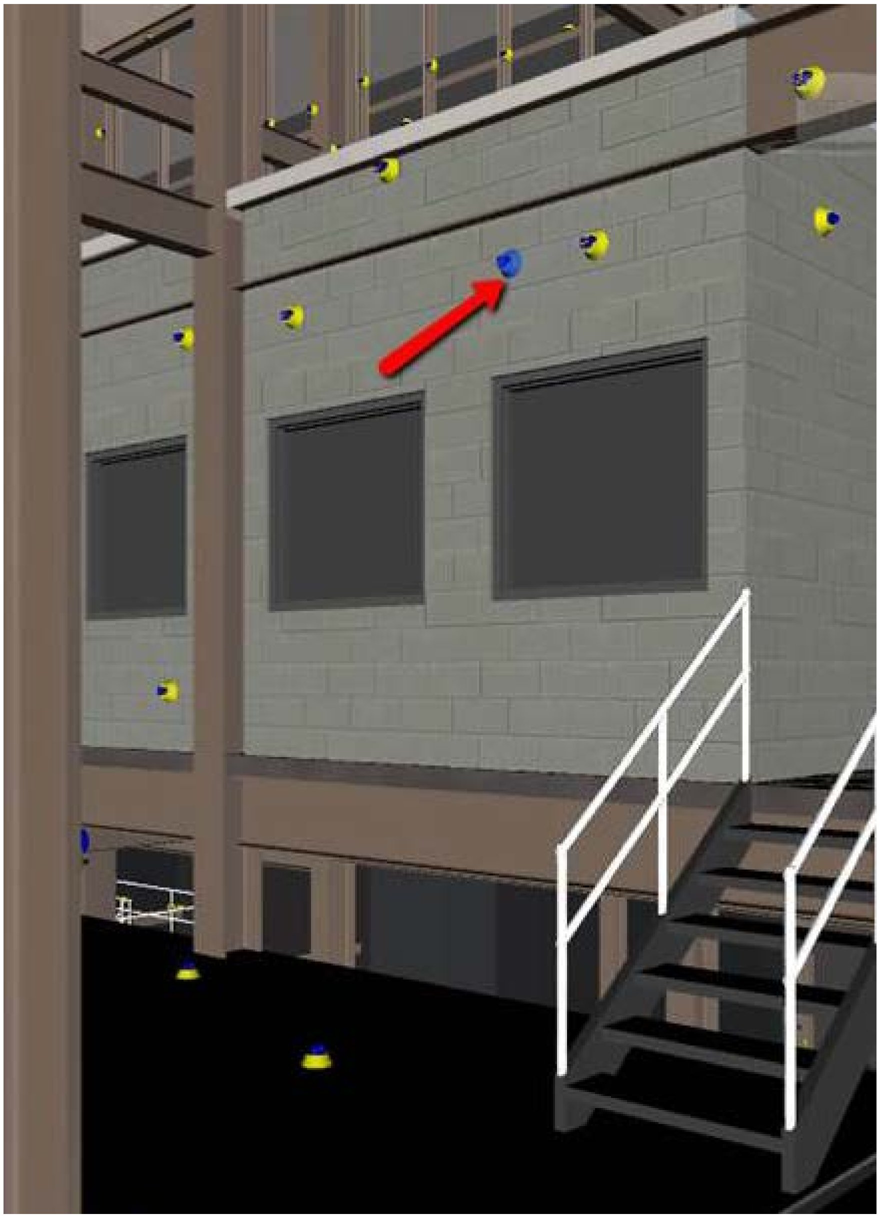

Figure 3 – 3D Model Example

Radiological data had a number of challenges associated with assessment and loading into the database as well. There were differences in the types of instruments utilized, method/radionuclide for determining efficiency, minimum detectable concentration and uncertainty. In some cases portions of this information were missing/not provided or the methods/calculations not specified. Another challenge was the manner in which the data was recorded/reported. Total and removable data was provided separately in some reports and combined in others and the differing formats used complicated data entry. Also, some numbers were difficult to read (hand written or poor quality document scans) reducing the efficiency of the data entry. As noted above, the RI included a SCM to collect millions of data points that were utilized to create detailed color shaded location maps. The RI report did not include the SCM raw data and only provided summary tables (minimum, maximum and average) for each survey area with limited calibration or measurement quality information provided (likely a consequence of summarizing the SCM report into the larger RI report).

Most of the older radiological data was determined to have low quality (MARSSIM standards), primarily due to lack of information provided. Once the data was input to the database it was compared to the DCGLs, which provided a quick assessment of potential areas of concern. Having a complete database of radiological results for the building will allow for additional statistical evaluations of the data in preparation/support of remedial action decision making, potentially including FSS.

CONCLUSIONS

The project is not 100 percent complete as of the writing of this paper. However, the following conclusions are apparent from this work: The process of compiling various data sets into a single database is significant challenge. Adding data evaluation to this process complicates some steps, but in the end provides much greater functionality and assessment capabilities. This is especially true when the radiological surveys have been performed by various groups over a number of years. The addition of a 3-D model not only provides an accurate depiction of the current facility, but also serves as the base for locating radiological data. The combination of the two creates a very powerful tool for visualization and assessment beyond those typically utilized following the MARSSIM. While the process was challenging at times, the end result was well worth the effort. Going through this process highlighted the true value of detailed accurate radiological survey data. One of the lessons learned from this process was that if the details are not included in the original records or captured in the report, do not expect to be able to retrieve them at a later date. Nevertheless, the absence of such detail does not negate the usefulness of the remaining information, provided the data quality is understood. The database and 3-D model provide a tool not otherwise available for strategic and tactical evaluation of potential options in order to complete the remedial action process and achieve unrestricted use for the building.

REFERENCES

AMEC, 2014, *Rationale Report Building 23*, Final, November.

USACE, 2005. *Record of Decision*, Final, April.