Collecting, Analyzing, and Visualizing Environmental Data Using Innovative GIS Techniques at Camp Sibert

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***Abstract*—Former Camp Sibert was a large-scale chemical warfare materials (CWM) training site in the United States from late 1942 through early 1945. In addition to chemical training, several types and calibers of conventional weapons were also fired there. At the end of World War II, this formerly used defense site (FUDS) was closed. CWM, unexploded ordnance (UXO), and munitions and explosives of concern (MEC) are safety hazards that may constitute an imminent and substantial danger to the public and the environment. Since 1997, Parsons, awarded by the U.S. Army Corps of Engineers, has conducted numerous phased engineering evaluation/cost analysis (EE/CA), remedial investigation/feasibility study (RI/FS), and removal action (RA) on the CWM and conventional MEC sites inside former Camp Sibert. This paper discusses how we utilized innovative GIS techniques during these environmental investigations to collect, store, process, analyze, and visualize the large amount of the projects data. They have been proven to be useful, efficient, reliable, and cost-effective.**

***Index Terms*—Geographic information system (GIS), environmental remedial investigation, munitions and explosives of concern (MEC), chemical warfare materials (CWM), munitions debris (MD), munitions constituents (MC).**

I. Introduction

Former Camp Sibert is located in north-central Alabama in the Canoe Creek Valley between Chandler Mountain and Red Mountain to the northwest, and Dunaway Mountain and Canoe Creek Mountain to the southeast (Fig. 1). It was the first large-scale chemical agent training area in the United States. In 1942, the Army acquired 37,035 acres of land there to develop a Replacement Training Center for the Army Chemical Warfare Service. Units and individual replacements received basic military training and training in the use of chemical weapons, decontamination procedures, and smoke operations from late 1942 to early 1945 (Fig. 2).

Several types and calibers of weapons were fired at Camp Sibert, with the 4.2-inch mortar being the heavy weapon used in most training. The most commonly used chemical agents at Camp Sibert are phosgene (a choking agent), mustard/ nitrogen mustard (a blistering agent), and lewisite (a blistering agent). In addition to chemical training, several types of conventional weapons, such as machine guns, flamethrowers, grenades, automatic rifles, pistols, artillery, bazookas, anti-aircraft/anti-tank rockets, and mortars were fired at the former Camp Sibert too (Fig. 3).

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At the end of World War II, the training activities were not needed any more and the camp was closed. Some unwanted chemical warfare materials (CWM) were buried there. CWM and other unexploded ordnance (UXO), discarded munitions and explosives of concern (MEC), munitions constituents (MC), and munitions debris (MD) are safety hazards that may constitute an imminent and substantial danger to the public, project personnel, and the environment.

Since 1997, Parsons Corporation, awarded by the U.S. Army Corps of Engineers (USACE), has conducted numerous phased engineering evaluation/cost analysis (EE/CA), remedial investigation/feasibility study (RI/FS), and removal action (RA) projects on these formerly used defense sites.

So far, hundreds of thousands metallic anomalies have been investigated, and many tons of metallic debris were disposed of in accordance with local, state, and federal regulations. More than thirty intact 4.2-in. mortars were also recovered (Fig. 4). All intact munitions recovered were safely packaged, transported, and processed for neutralization. A large number of soil, sediment, surface water, and groundwater samples were collected and analyzed for chemical agents, agent breakdown products, and hazardous, toxic and radioactive waste (HTRW) constituents.

Innovative GIS (Geographic Information System) techniques have been used during the environmental remedial investigations to collect, store, process, analyze, and visualize the huge amount of data, such as historical aerial photos/drawings, sample locations and their analytical results, field observations, reconnaissance tracks, geophysical and geological data, water wells, census data, etc.

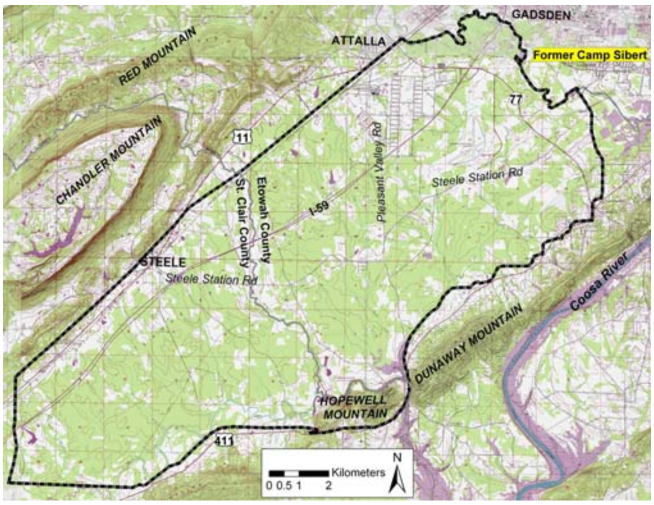

Fig. 1. General location of former Camp Sibert.

Fig. 2. Training at former Camp Sibert from 1942 through 1945.

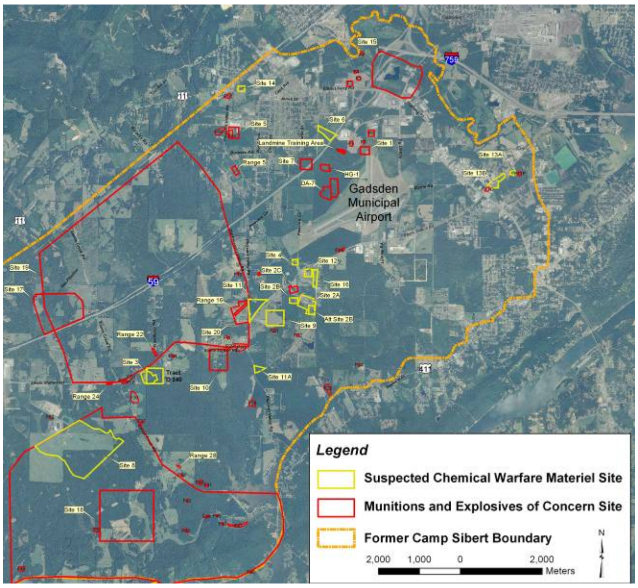

Fig. 3. CWM sites (yellow polygons) and conventional munitions and explosive of concern (MEC) sites (red polygons) within former Camp Sibert boundaries.

Fig. 4. CWM, UXO, discarded military munitions and munitions constituents were discovered in various CWM and conventional MEC sites within former Camp Sibert, and safely removed and disposed from them.

II. Innovative GIS Approaches to Field Data Collection

For each environmental investigation project, its field activities could last quite a few months and an extensive amount of data could be collected, such as field observations, samples, reconnaissance tracks, geophysical meandering paths/towed arrays, anomaly points and polygons, survey/intrusive grids, bush cleaning status, right of entry (ROE) status, groundwater elevations, and geological surveys, etc. Efficient, reliable, and high quality field data collection process is crucial to the success of the project in terms of meeting or exceeding the project objectives and ensuring that the project is executed and completed on schedule and within budget.

After carefully evaluated the needs of the projects, we selected the most appropriate mobile GIS software and customized/enhanced it to automate field data collection as much as possible and ensure data quality and integrity, following the relevant spatial data and metadata standards and guidelines. Field GIS data and geophysical survey results are synchronized to the centralized database through secured wireless network. Processed, analyzed, and updated GIS data, such as daily field work status, new sampling and geophysical survey plans, and updated ROE status are synchronized/uploaded back into the field mobile GIS devices and geophysical equipment automatically. Each day, all the interested parties, such as the project team, field crews, GIS team, the client, regulators, and other related stakeholders, looked at the same most updated data and maps in real time (Fig. 5).

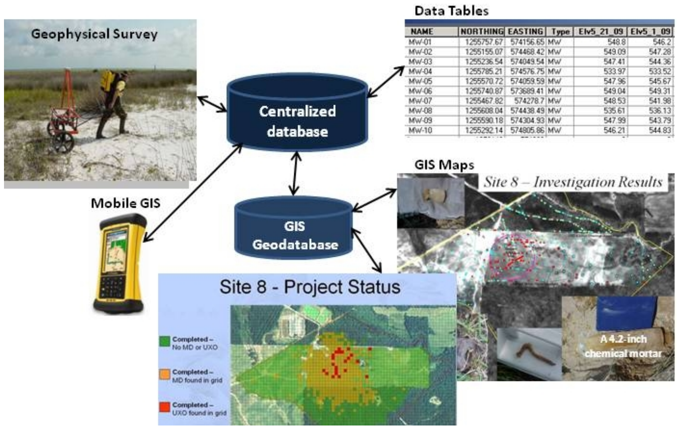

Fig. 5. Field data are collected efficiently, synchronized to the centralized database through secured wireless network, and viewed by project team, field crews, and other relevant stakeholders in real time. Detailed data tables and summary tables can be queried from the central database and maps/graphics can be generated from it. Updated data can be synchronized/uploaded back onto field mobile GIS devices and geophysical equipment automatically. Procedures are built into the process to ensure data quality, integrity, and security.

From the centralized database, the project managers and their staff can query out detailed data tables and/or summary tables, create graphs, and generate reports. From the Geodatabase, our GIS team can extract, process, and analyze the geospatial data to generate GIS maps to be included in project reports and presentations [12], and prepare final GIS deliverables to the clients.

On Fig. 5, the GIS map on the lower right corner displays the geophysical investigation results at Site 8, a large CWM site inside former Camp Sibert. The lines are the geophysical meandering paths. The color coded dots are geophysical anomalies. The photos show the findings of the UXO (4.2-inch chemical mortars), MD/MEC items, and cultural debris on the site during the field investigation. The GIS map on the bottom is the Site 8 Removal Action daily project status map. It was updated with new field investigation data automatically each day. The green squares on the map represent completed grids with no MD or UXO, the golden squares being completed grids with MD found in them, and the red squares being completed grids with UXO found in them. The size of each grid is 100 ft by 100 ft. About three thousand grids were investigated during the 24-month RA field investigation, from which a large amount of data were collected and many GIS maps were generated.

Some of the GIS maps were published through the internet so that people without GIS knowledge or software are able to view the maps and data, download them, and edit them, depending on their access privilege levels we granted to them [1]. With these innovative and high-tech GIS approaches, all the interested parties could view the project data and maps at the same time and make the most informed, updated, and appropriate decisions in real time.

III. Analyzing Data to Extract Useful and Meaningful Information

A tremendous amount of efforts have been spent to collect data before and during the projects. These data have to be carefully processed and analyzed to reveal useful and meaningful information, based on which the most accurate decisions are to be made. Dealing with the dangerous CWM, UXO, and other MEC on the site, there could be serious consequences if a wrong decision is made based on the inaccurate information interpreted from the data.

A. Using GIS Tools to Analyze Historical Aerial Photos and Drawing to Indentify Impacted Areas

Former Camp Sibert is a 37,035-acre large FUDS. As Fig. 3 shows, there are many CWM and conventional MEC sites within its boundaries. Due to budget and schedule constraints, it is virtually impossible to investigate the whole FUDS area. Also, it is not easy to get ROE from some of the property owners. So, the project team and their field crews have to identify and focus their investigation and sampling strategy on targeted areas, which were most likely impacted by the former training and related activities.

In 2009, the chemical agent contaminated media Removal Action (RA) and the Remedial Investigation/Feasibility

Study (RI/FS) projects were conducted on Site 2A within former Camp Sibert. Site 2A was used for chemical agent decontamination training on an airplane fuselage, building walls/floors, shell holes, trucks, and different road types. The site also included a mustard soakage pit, chemical agent storage area, a supply building, and a shower/dressing building. CWM and equipment left over from the training at Camp Sibert were buried at this site in three pits. Excess chemical agents were poured into a soakage pit.

The GIS team obtained, processed, and analyzed the historical drawings and aerial photos to identify the former chemical training areas, the CWM burial pits, and the mustard soakage pit on the site (Fig. 6 and Fig. 7). These kinds of information were very useful for the project team and their field crews to plan their soil, surface water, sediment, groundwater, and water well sampling locations, geophysical survey areas, and intrusive investigation (trenches and grids) layouts, as shown on Fig. 7.

B. From Existing Geophyscially Surveyed Data to Predict Possible Anomaly Locations in the Adjacent Unknown Areas

Before the Removal Action (RA) investigation was conducted at Site 8 in 2004, we retrieved and reviewed all the previous geophysical and intrusive investigations data (red dots on Fig. 8). Project records show that during an EE/CA investigation in 2000, the central portion of Site 8 was geophysically surveyed using meandering paths, and 532 anomalies were identified. Another phased EE/CA investigation was conducted at Site 8, in 2002. The site was geophysically mapped using towed arrays, with 8,673 more anomalies identified.

We statistically analyzed these anomalies identified from these previous investigations and predicted the possible anomaly distribution patterns in the adjacent unknown/un-surveyed areas (yellow dots on Fig. 8) [2,6,8,9,10]. Since the southern portion of the site was not included in the RA at that stage of the project, the predicted anomaly points in the south were manually cleaned out from the map. Later on, RA was conducted in the southern portion to cover the whole site (see Fig. 5).

This geophysical anomaly distribution map was used by the RA project team and the field crews to acquire ROE, plan bush clearing areas, additional geophysical survey areas, intrusive-investigation areas/grids, vapor containment structure (VCS) positioning, and safety exclusion zones.

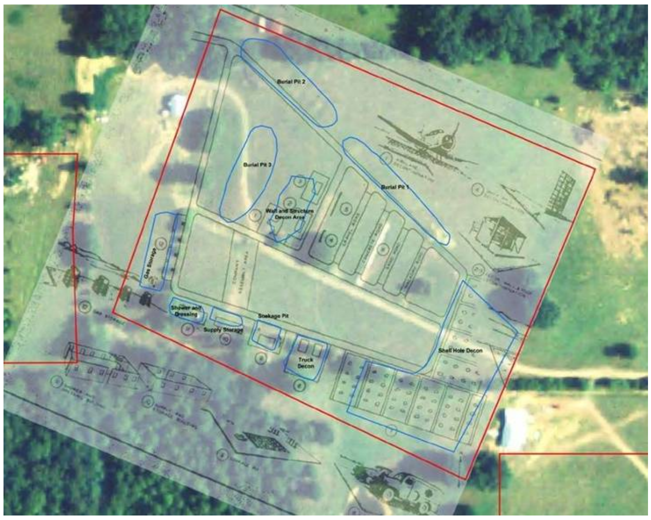

Fig. 6. A 1944 training document showing the layout of the CWM decontamination training areas at Site 2A. This historical drawing was scanned, georeferenced, and overlaid onto a recent aerial photo to locate the areas of concern (AOC) on the site.

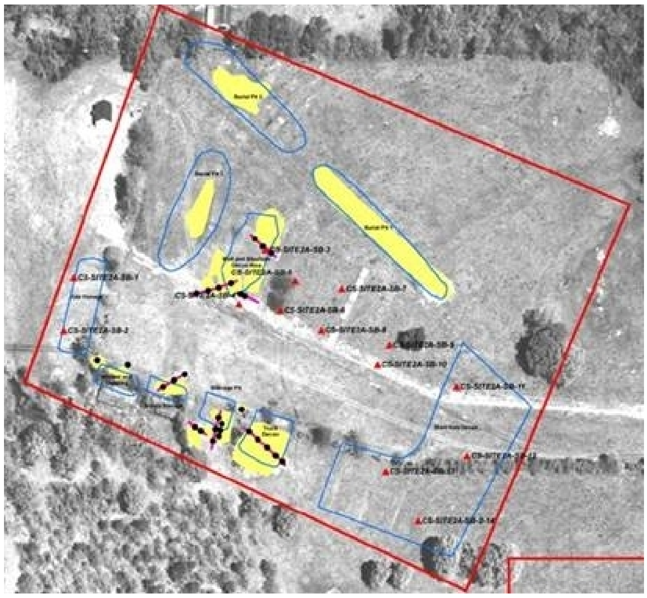

Fig. 7. A 1944 historical aerial photo of Site 2, showing the features related to the CWM training and the burial pits of the unwanted chemicals, live agents, training equipments, and munitions debris. Samples (red dots), trenches (pink lines), and geophysical survey (yellow areas) were planned on these identified and targeted impact areas, instead of the whole site.

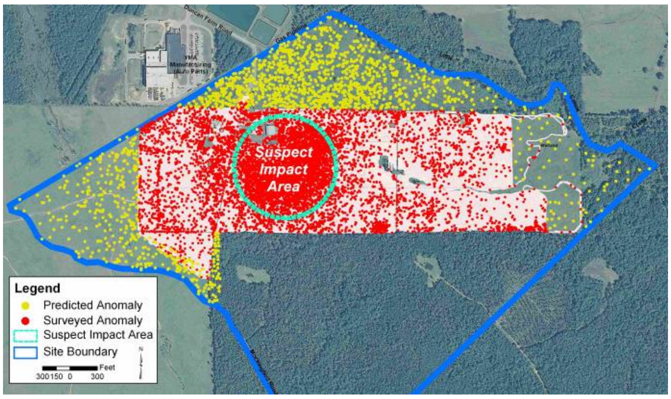

Fig. 8. Geophysically surveyed anomaly locations (red dots) from the previous EE/CA investigations, and the statistically predicted anomaly locations (yellow dots) in the adjacent areas to be investigated (RA) at Site 8, a Toxic Munitions Impact Area, within former Camp Sibert.

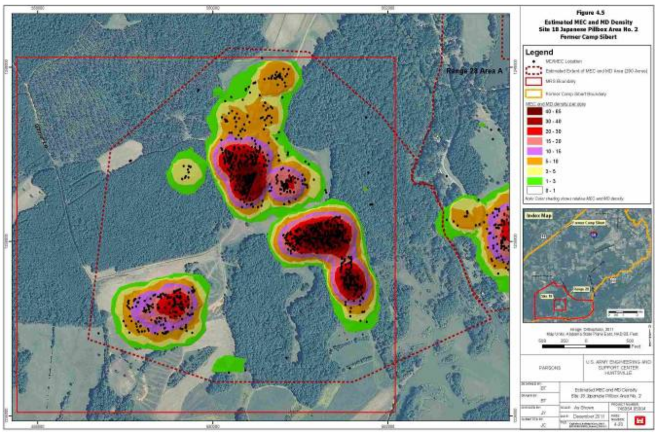

Fig. 9. MEC and MD density analysis at Site 18, a conventional MEC site inside former Camp Sibert. The relative density values increase from green to dark red, as the colored scale bar on the map legend shows.

C. Using GIS to Calculate MEC/MD Density

A Remedial Investigation and Feasibility Study (RI/FS) was conducted at some selected CWM and conventional MEC sites, inside former Camp Sibert in 2010 and 2011. The RI used a combination of digital geophysical mapping (DGM), intrusive investigation of geophysical anomalies, and mag-and-dig investigation methods to determine the nature and extent of munitions-related (MD, MC, MEC, UXO, CWM) contamination at the conventional MEC sites and suspect CWM sites. Samples were collected at the locations most likely to contain MC contamination. The major purpose of the RI was to develop and evaluate effective remedial alternatives. Based on the results and conclusions of the RI, the Feasibility Study (FS) was started on these sites in early 2011. The FS developed and assessed seven different alternatives for managing risks associated with potential MEC and MC. Its main purpose is to provide decision makers with the necessary data to select the final remedies for the sites. The density of MEC and MD is one of the most important factors in developing and evaluating the remedial alternatives for a site.

We compiled and statistically analyzed the huge amount of the data from various previous investigations and the current RI/FS project, and generated the MEC/MD density maps for the whole former Camp Sibert and the individual sites selected for this RI/FS project (Fig. 9) [3,8,9]. The MEC/MD density information was used in developing and screening of the seven remedial alternatives, listed below.

1. No Further Action (NFA)
2. Educational Awareness
3. Surface MEC Removal with MC-Contaminated Soil Removal
4. MEC Removal to 1-foot Depth with MC-Contaminated Soil Removal
5. MEC Removal to Detection Depth with MC-Contaminated Soil Removal
6. Fencing and Signage
7. Excavation, Sifting, and Restoration

IV. Modeling and Visualizing Data to Reveal Useful and Meaningful Information

During the past 15 years, numerous investigations have been conducted at various CWM and conventional MEC sites within former Camp Sibert, and an extensive amount of geophysical, hydrological, and analytical data have been collected, processed, and analyzed. Some of the data are complicated and hard to understand by simply looking at the data tables. GIS and other modeling and visualization techniques were used to manipulate the data and display them in the formats and ways that are easier for the decision makers to better understand and interpret the data. Cost savings were achieved by maximizing the use of existing data while minimizing the need to collect additional data unnecessarily.

During the RA and RI/FS investigations at Site 2A in 2009, the soil was sampled for the presence and level of contamination from chemical agent (CA) and agent breakdown products. 64 soil samples were taken from the Mustard Soakage Pit. Arsenic was detected in all of these samples at concentrations ranging from 640J µg/kg to 140,000 µg/kg. Arsenic in 20 of those samples exceeded the established background level of 7,659 µg/kg (~8 mg/kg). The highest detected arsenic concentration was in a floor sample (SB-35) collected at a depth of four feet (Table I).

This table contains valuable information about arsenic contamination of the Mustard Soakage Pit. However, simply looking at the numbers in the table alone, it is hard to understand the whole contamination situation of the site above and below the ground. To help the decision makers to better understand the data and visualize site conditions in a three-dimensional space, we created color shaded arsenic concentration maps at each depth interval (Fig. 10).

To visualize the data even better, we exported this GIS dataset to a 3D modeling application (EVS) and generated a three-dimensional arsenic concentration model (Fig. 11). This 3D model can be rotated so that it can be viewed from any angle and elevation. It can also be displayed at any arsenic concentration levels, such as 5 mg/kg level (top model of Fig. 11), 200 mg/kg level (bottom model of Fig. 11), etc. The volume of the contaminated soil can be calculated from these 3D models too [3,7,11].

TABLE I: MUSTARD SOAKAGE PIT PRELIMINARY ARSENIC RESULTS IN MG/KG

Mustard Soakage Pit Preliminary Arsenic Results in mg/kg															
Depth	SB 31	SB 32	SB 33	SB 34	SB 35	SB 36	SB 37	SB 38	SB 45	SB 46	SB 47	SB 48	SB 49	SB 50	SB 51
0-2	1000	16	4.3	3.4	380	67	2.8	60	3.2	140	3.7	5.1	4.2		16
2-4	n/a	n/a	n/a	n/a	750	80	2.3	6.1	2.7	154	3.4	5.6	4.9		15
3-5	720	2.8	2	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4-6	n/a	n/a	n/a	n/a	1500	1.9	3.1	10	1.4		3.3	16.1	5.1		73
5-7	n/a	n/a	n/a	3.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6-8	n/a	n/a	n/a	n/a	150	2.7	2.1	50	1.5	2.3	4.9	2.8	37.6		9.5
8-10	n/a	n/a	n/a	n/a	77	2.2	2.1	9.2	3.9		3.8	2.7	5		7.6
10-12	n/a	n/a	n/a	n/a	93	1.9	1.5	4.1	1.9	2.5	3.6	3.3	3.4	2.9	5
12-14	n/a	n/a	n/a	n/a	95	2.1	2.4	3.4	3	4.6	3	3.7	21.6	2.6	320
14-16	n/a	n/a	n/a	n/a	33	2.6	2.5	18	1.8		2.2	33.8	2	6.3	7.7
16-18	n/a	n/a	n/a	n/a	51	2	1.6	160	1.5	67	2.5	7.2	ND	3.4	3.2
18-20	n/a	n/a	n/a	n/a	3.2	n/a	2.3	8.2	1.7	11	1.545	2	2.6	3.8	1.3
Notes															
1. Background is 7.8 mg/kg															
2. Bold concentrations are above background.															

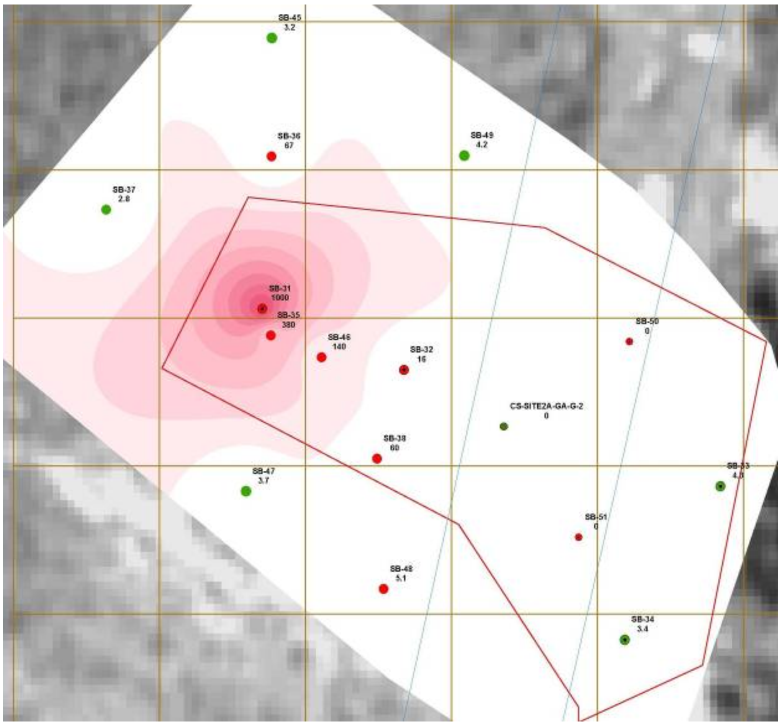

Fig. 10. Mustard Soakage Pit arsenic concentration at 0-2 feet depth interval.

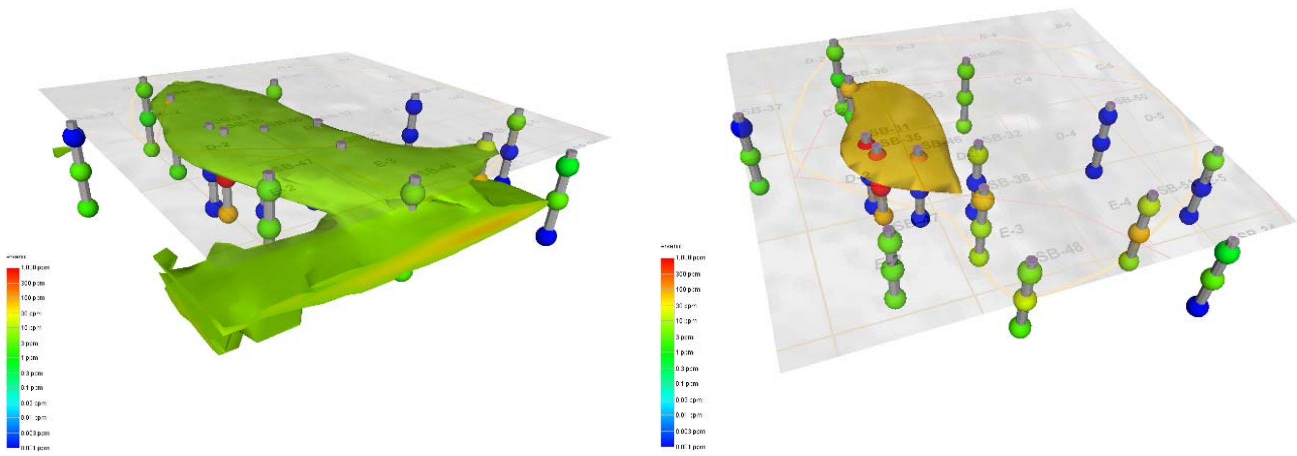

Fig. 11. Mustard Soakage Pit arsenic concentration 3D (0-20 feet depth) models. The bars represent soil borings, The colors correspond to the arsenic concentration levels. The top model shows the 3D extent of arsenic concentration above 5 mg/kg. The bottom model indicates the 3D extent of arsenic concentration above 200 mg/kg, mainly in the soil borings of SB-31, SB-35, and 3B-46 area.

With these 2D concentration maps and the 3D models, it is now much easier to visualize the extents of the arsenic contamination in a three-dimensional space. These visualization techniques added values to the existing data and revealed the useful and meaningful information hidden in the data and hard to see and understand otherwise.

V. Conclusion

In the past 15 years, Parsons have conducted many phased environmental investigations, such as sites reconnaissance, EE/CA, RI/FS, and RA, on over 35 CWM and conventional MEC sites/areas within the boundary of former Camp Sibert. Our GIS programmers developed/customized GIS applications to make field data collection, transfer, and distribution more efficient, secure, reliable, cost-effective, and compliant to the relevant spatial data and metadata standards. With these innovative and high-tech GIS systems, all the interested parties could view, upload/download, edit the data, and make decisions in real time.

Various GIS and database techniques were utilized to process, store, analyze, visualize, and display the large quantity of projects data. By analyzing historical and recent aerial photos, we identified the locations and precisely delineated the boundaries of the environmentally impacted areas due to the past training and other related activities. This important information helped the project teams and field crews to focus their limited resources to the right areas, which saved money and possible issues. While ensuring sufficient amount of data were collected for each project, we maximized the values of the existing data collected from previous investigations through data mining. For example, we statistically analyzed the anomaly data from the previous EE/CA investigation at Site 8, and predicted the possible anomaly distribution patterns into the adjacent areas (Fig. 8) for the RA project. It guided the ROE requesting process, bush cleaning, geophysical survey, intrusive investigations, and other activities of the RA. For the current RI/FS project, we compiled and analyzed the MEC and MD data from all previous and current onging investigations, and calculated the MEC/MD density patterns throughout Camp Sibert (Fig. 9). Cost saving was achieved by using existing data instead of re-collecting data unnecessarily. The objectives and quality of the project were also met or exceeded by identifying data gaps and collect the needed data to make technically sound decisions.

Although data are needed for an environment investigation, a large volume of data can be challenging to understand and make correct decisions. We have used GIS and other modeling and visualization techniques to extract meaningful information from the data and display it in the formats, such as 3D topographic maps of the sites, bedrock depth maps, groundwater elevation maps, surface water flow paths, geophysical anomaly distributions, shaded contaminants concentration contours, 3D models of the contaminants, ROE status map, daily field work status maps, etc. They are much easier to visualize and understand than large data tables.

In summary, utilizing innovative GIS techniques, such as mobile and web-based GIS applications, enterprise-level Geodatabases, and various data processing, analyzing, modeling, simulating, and visualizing tools, we supplied the projects and our clients with high quality, compliant, cost-effective, and low/non-risk GIS services and products.

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